Malaysian Society of Paediatric Anaesthesiologists (MSPA)

PAEDIATRIC ANAESTHESIA HANDBOOK

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PREFACE FROM THE EDITORS

Paediatric anaesthesia in Malaysia is a relatively young subspecialty. Paediatric anaesthesiologists and children's hospitals are few and far between. Yet many anaesthesiologists and registrars are required to anaesthetise children in their daily practice. Most registrars and general anaesthesiologists find anaesthetising children very challenging. Realising this, the Malaysian Society of Paediatric Anaesthesiologists (MSPA) has taken the initiative to come out with this handbook.

Written by a group of practising Malaysian paediatric anaesthesiologists, this handbook is not meant to be a textbook of anaesthesia but a guide and a source quick reference of the commonly encountered problems in paediatric anaesthesia. It offers a practical approach to paediatric anaesthesia with a concise account of the topic which are essential for the safe practice of anaesthesia. The topics range from basic anatomy, physiology and pharmacology of infants to perioperative, intraoperative and postoperative care of paediatric patients. Also included are management of common preoperative problems in paediatric anaesthesia, resuscitation guidelines, algorithms, treatment protocols and a list of drug dosages. Each chapter includes an introduction to the topic, and learning objectives, followed by a concise presentation of the salient points. Each chapter also provides references and suggestions for further reading to facilitate in-depth study of topic.

We hope that this book will be valuable to residents and trainees as well as practicing anaesthesiologists who do not manage paediatric cases on a regular basis.

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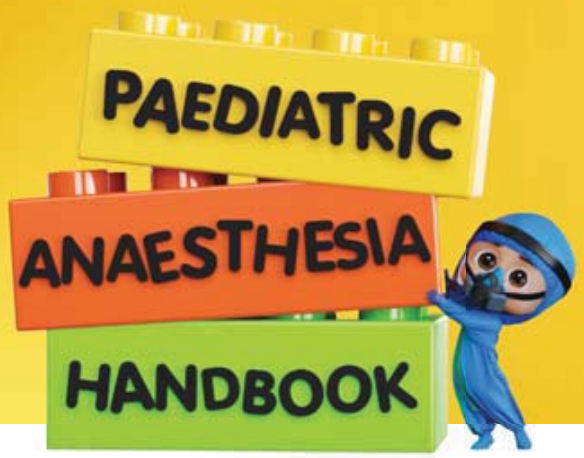
Prof Dr Felicia Lim
Prof Dr Lucy Chan



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BASIC PAEDIATRIC ANATOMY, PHYSIOLOGY & PHARMACOLOGY

Yoga Bhavani Shanmuganathan

By the end of this chapter you should be able to:

1. *Appreciate the differences in the anatomy, physiology and pharmacology pertaining to the paediatric population.*
2. *Anticipate the difference in children in order to prepare the anaesthesia for them.*
3. *Understand the central nervous system is sufficiently developed to process nociception in utero, hence children regardless of age feel pain.*

INTRODUCTION

Infants and young children ARE NOT SMALL ADULTS.
"One size fits all" DOES NOT APPLY.
Common terms
Definition

Preterm	:	born before 37 weeks of gestation
Term Neonates	:	born 37 to 40 weeks, up to age 1 month
Newborn	:	first 24 hours of life:
Infant	:	1 to 12 months
Toddler	:	1 to 3 years
Preschooler	:	3 to 5 years
School Age	:	6 to 12 years
Adolescent	:	13 to 18 years

Airway and Respiratory System in Neonates & Infants

Head is large in relative to torso.

Large tongue contributes to airway obstruction during anaesthesia.

Larynx is high and anterior at level C3 to C4.
Epiglottis is long, stiff, U-shaped, flops posteriorly. Head needs to be in a neutral position.
'Sniffing the morning air' position will not help bag mask ventilation or to visualise glottis

Obligate nasal breathers. Hence narrow nasal passages contribute to 50% of airway resistance, easily blocked by secretions, may be damaged by a nasogastric tube or a nasal endotracheal tube (ETT).

Airway is funnel shaped and narrowest at the level of the cricoid cartilage in the pre-pubertal child and at the level of the vocal cords after puberty.

Tracheal diameter in the newborn is 4 to 5 mm. Airway trauma easily results in oedema. Just 1 mm of oedema can narrow a baby's airway by 60%. Children before puberty should have an uncuffed tube and there should be a slight air leak with positive pressure ventilation. If resistance occurs during intubation, no force to be applied and downsizing the tube is advocated. It is suggested that minimal leak be present around the endotracheal tube to prevent trauma, resulting in subglottic oedema and subsequent post-extubation stridor.

Term neonate 3 mm to 3.5mm I.D

1 year old	3.5 to 4.0 mm I.D
2 year old	4.5 to 5.0 mm ID.

More than 2 years of age, estimate by the formula: 4 + age (years)/4.

ETT at least one size smaller and larger must be available.
ETT positioned to sit at least 1 cm above the carina and taped securely to prevent tube dislodgement or an endobronchial intubation with head movement.

Ventilation is primarily diaphragmatic. Bulky abdominal organs or a stomach filled with gases from poor bag mask ventilation can splint the diaphragm,impairing ventilation.

Infants have reduced functional residual capacity (FRC), increased respiratory rate(RR) and work of breathing(WOB). They fatigue faster due to low percentage of Type I muscle fibres in the diaphragm which increases to adult levels over the first year of life. WOB may be 15% of oxygen consumption. Infants have higher oxygen consumption per kg body weight

Minute ventilation is more dependent on respiratory rate than on tidal volume (TV).

Functional residual capacity (FRC) decreases with apnoea and anaesthesia causing lung collapse. The closing volume is larger than the FRC until 6 to 8 years of age. Increased tendency for airway closure at end expiration. Thus, neonates and infants generally need IPPV during anaesthesia and benefit from a higher RR and the use of PEEP. CPAP during spontaneous ventilation improves oxygenation and decreases the WOB.

Intubation attempts must not exceed 30 seconds. Increased oxygen consumption leads to increase in CO2, requiring increased ventilation to eliminate it. Thereby a higher RR is needed. The rate in the newborn is 35 to 40 breaths/minute. Tidal volume (mls/kg) is similar for adults and children.
The alveoli are thick walled at birth and only 10% of the total number of alveoli found in adults. Alveoli clusters develop over the first 8 years of life.

Physiological dead space accounts for 30% and is increased by anaesthetic equipment.

All opioids and CNS depressants must be given with caution in neonates unless the patient is ventilated and closely monitored as they can depress the ventilatory response to a rise in PaC02.
Extubation laryngospasm tends to occur less frequently if the child is fully awake at the time of extubation. You may need to be with a child in recovery until fully awake if the recovery staff are inexperienced with children.

Postoperative apnoea after anaesthesia is common in very young infants (particularly premature infants). Significant apnoea lasting more than 15 seconds are associated with desaturation or bradycardia . Premature and ex-premature babies up to 50 weeks post conceptual age are at risk of apnoea after general anaesthesia. Close observation for at least 24 hours mandatory.

Cardiovascular System

Myocardium being less contractile in neonates, reduces ventricular compliance. Therefore stroke volume is limited and cardiac output is rate dependent. Hence, bradycardia causes reduced cardiac output.

Vagal parasympathetic tone is dominant making them more prone to bradycardias.

Bradycardia associated with hypoxia should be treated with oxygen and ventilation initially. External cardiac compression will be required in the neonate with a heart rate of less than 60bpm, or 60 to 80 bpm with adequate ventilation.
PDA contracts in the first few days of life and will fibrose within 2 to 4 weeks.

Closure of the foramen ovale is pressure dependent and closes in the first day of life but it may reopen within the next 5 years. The neonatal pulmonary vasculature reacts to the rise in PaO2 and pH, and the fall in PaCO2 at birth. However, with alterations in pressure and in response to hypoxia and acidosis, reversion to the transitional circulation may occur in the first few weeks after birth.

Blood Volume

Age	Blood Volumes
Newborn	85 to 90 ml/kg
6 weeks to 2 yrs	85 ml/kg
2 yrs to puberty	80 ml/kg

Renal System

Renal blood flow and GFR is low in the first 2 years of life due to high renal vascular resistance. Low tubular concentrating ability leads to higher obligatory fluid loss.

Tubular function is immature until 8months, so infants are unable to excrete a large sodium load. Urine output should be at least 0.5 ml/kg/h. Dehydration is poorly tolerated. Premature infants have increased insensible losses as they have a large surface area relative to weight. There is a larger proportion of extra cellular fluid in children (40% body weight as compared to 20% in the adult).

Hepatic System

Liver in the newborn contains 20% of the hepatocytes found in adults and continues to grow until early adulthood. Drug effects are prolonged in neonates, therefore should be titrated to effect, given by bolus rather than infusion. Barbiturates and opioids have a longer duration of action due to the slower metabolism.

Morphine clearance in neonates is a quarter that of adults so that the elimination half time will be 4 times that of adults. The immature respiratory centre makes the neonate more sensitive to the respiratory depressive effects of morphine.

Glucose Metabolism

Hypoglycaemia is common in the stressed neonate and glucose levels should be monitored regularly. Glycogen storage is in the liver and myocardium. An infusion of 10% glucose may be used to prevent neurological damage from hypoglycaemia. Infants and older children maintain blood glucose better and rarely need glucose infusions. Hyperglycaemia is usually iatrogenic.

Haematology

At birth, 70 to 90% are HbF. By 3 months, HbA predominates, HbF levels drop to

around 5%. Newborn Hb is around 18-20 g/dl.

Over 3 to 6 months,it drops to 9 to12 g/dl as the increase in circulating volume increases more rapidly the bone marrow function. Hb of less than 13 g/dl in the newborn and less than 10 g/dl in the first 6 months of life may be significant.

Vitamin K dependent clotting factors (II, VII, IX, X) and platelet function are deficient in the first few months. Vitamin K is given at birth to prevent haemorrhagic disease of the newborn. Transfusion is generally recommended when 15% of the circulating blood volume has been lost.

Temperature Regulation

Large surface area to weight ratio, minimal subcutaneous fat. Shivering, sweating and vasoconstriction mechanisms poorly developed. Non-shivering thermogenesis uses brown fat (comprises 2 to 6% of neonatal body weight located around the scapulae, mediastinum, kidneys and adrenal glands)

Heat loss up to 2°C during the first hour of anaesthesia mostly via radiation besides conduction, convection and evaporation. Active measure such as forced air warming and warm IV fluids. Optimal ambient temperature to prevent heat loss is 34°C for the premature infant, 32°C for neonates and 28°C in adolescents and adults.

Reduction in body temperature causes: -

- respiratory depression,
- acidosis,
- decreased cardiac output,
- reduced platelet function,
- prolonged duration of action of drugs.
- increased risk of infection.

Central Nervous System

The poorly formed blood brain barrier enables drugs such as barbiturates, opioids, antibiotics and bilirubin to cross easily causing a prolonged and variable duration of action.

Preterm infants have thin walled, fragile cerebral vessels that are prone to intraventricular haemorrhages(IVH). The risk is increased with:-

- hypoxia
- hypercarbia
- hypernatraemia
- low haematocrit
- awake airway manipulations
- rapid bicarbonate administration
- fluctuations in blood pressure and cerebral blood flow. Cerebral autoregulation is present and functional from birth.

The sympathetic nervous system is not well developed. Infants can easily become bradycardic. Atropine premedication will reduce the incidence of bradycardia and

reduce secretions. (IV/IM dose 0.01 to 0.02 mg/kg).

Psychosocial

Infants below 9 months old tolerate parental separation and suffer less stranger anxiety.

Older Infants and children up to school age can get very upset and stressed by the separation from their parents and exposure to new unfamiliar people and surroundings. It is challenging to rationalize with children of this age. Hence, premedication along with parental presence helps.

Older children and adolescents can get very apprehensive about the surgical procedure, its possible mutilating effects on their body, and the obvious possibility of pain. Concerned about loss of self-control and the unknown. Fear of not waking up after surgery can be very real and extremely disturbing for some.

Parental anxiety is readily perceived and reacted on by the child. The ability and the need to build trust quickly with the child and his/her parent is extremely important skill-set for a paediatric anaesthesiologist.

Developmental aspects of pain

Neonates, including the premature, show well developed responses to painful stimuli. This is associated with increase in heart rate, blood pressure and a neuro-endocrine response. The foetus shows a stress response (and behavioural changes) to painful stimulation from 18 to 20 weeks gestation, which can be attenuated by the administration of fentanyl. Attenuation of the stress response to surgery improves postoperative morbidity and mortality in neonates.

Recommendations for surgery to be avoided in neonates if possible due to the long-term effects of exogenous opioids and painful experiences in the neonatal period.

Pain in neonates should be treated using multimodal analgesia, but opiates should be used judiciously, for both pharmacokinetic (reduced drug metabolism) and pharmacodynamic reasons (increased opiate sensitivity).

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PREOPERATIVE EVALUATION AND FASTING GUIDELINES

Usha Nair

By the end of this chapter you should be able to:
a. Assess all children before elective and emergency surgery.
b. Explain risk before taking consent.

INTRODUCTION

The preoperative preparation and evaluation of a child require good communication with parents and care givers. The information provided and rapport established aim to provide a less traumatic experience.

Preoperative evaluation of the child

Always examine the child in the presence of parents or care givers. In the case of a distressed child do not separate the child from care givers

A. History

1. Birth history and any events occurring since then. Prematurity requires calculation of corrected gestational age and progress since birth.
2. Complications of prematurity like NICU admission, ventilatory support, feeding problems and current respiratory and cardiac function.
3. Associated congenital anomalies.
4. History of noisy breathing, snoring, observed apnoea in cases of enlarged tonsils and adenoids and obese children.
5. Previous anaesthetic history, surgery and recovery
6. Family history of anaesthesia related events
7. Family history of motion sickness
8. Drug history
9. Allergies to drugs, food, environment.
10 Exclude a URTI
11. Special needs, learning disabilities, behavioural issues

B. Physical examination

1. Thorough general examination of all systems
2. Anatomical defects and congenital deformities (look out for any associated syndromes)
3. Airway and dentition
4. Nutritional & hydration status
5. Checking on venous access
6. Height & weight

C. Laboratory investigations

1. For day care surgery no laboratory investigations are necessary unless history and examination warrant it.
2. For major surgery-
   The mandatory test: FBC, blood urea electrolytes
   The optional test: Coagulation profile, ABG, group save and hold blood, ECG, Chest X-ray
3 Sleep study is ordered on a case by case basis
4 Echo, ultrasound and other imaging studies should be discussed with surgeon and done if helpful in the surgery and outcome.

D. Premedication

It is rarely used for children except in special cases and it must be discussed with specialist earlier. Some of the sedative agents recommended for premedication are oral midazolam and intranasal dexmedetomidine.

Once the child has been served premedication, the child should not be left alone and should be nursed in a cot bed with monitoring until called to theater.

Fasting guidelines

For elective surgery in healthy patients

1. Clear fluids up to 2 hours before anaesthesia. May give 3 mls/kg up to a maximum of 200 mls. (in a child age 12 years old and above)
2. Breast milk - last feed should be 4 hours before anaesthesia
3. Formula milk and meal - should be 6 hours before anaesthesia.
4. Intravenous fluids should be started when needed to tide over the fasting time.
5. Consult anaesthetist in-charge of list as timing and order of list may change.

* clear fluids - water, plain tea, non-particulate fruit juice like apple juice. When in doubt only offer water!
* In the case of emergency surgery, fasting guidelines should be the same as elective unless surgery is urgent.
  - Document the last meal and that situation was urgent
  - All precautions must be taken for a patient with full stomach

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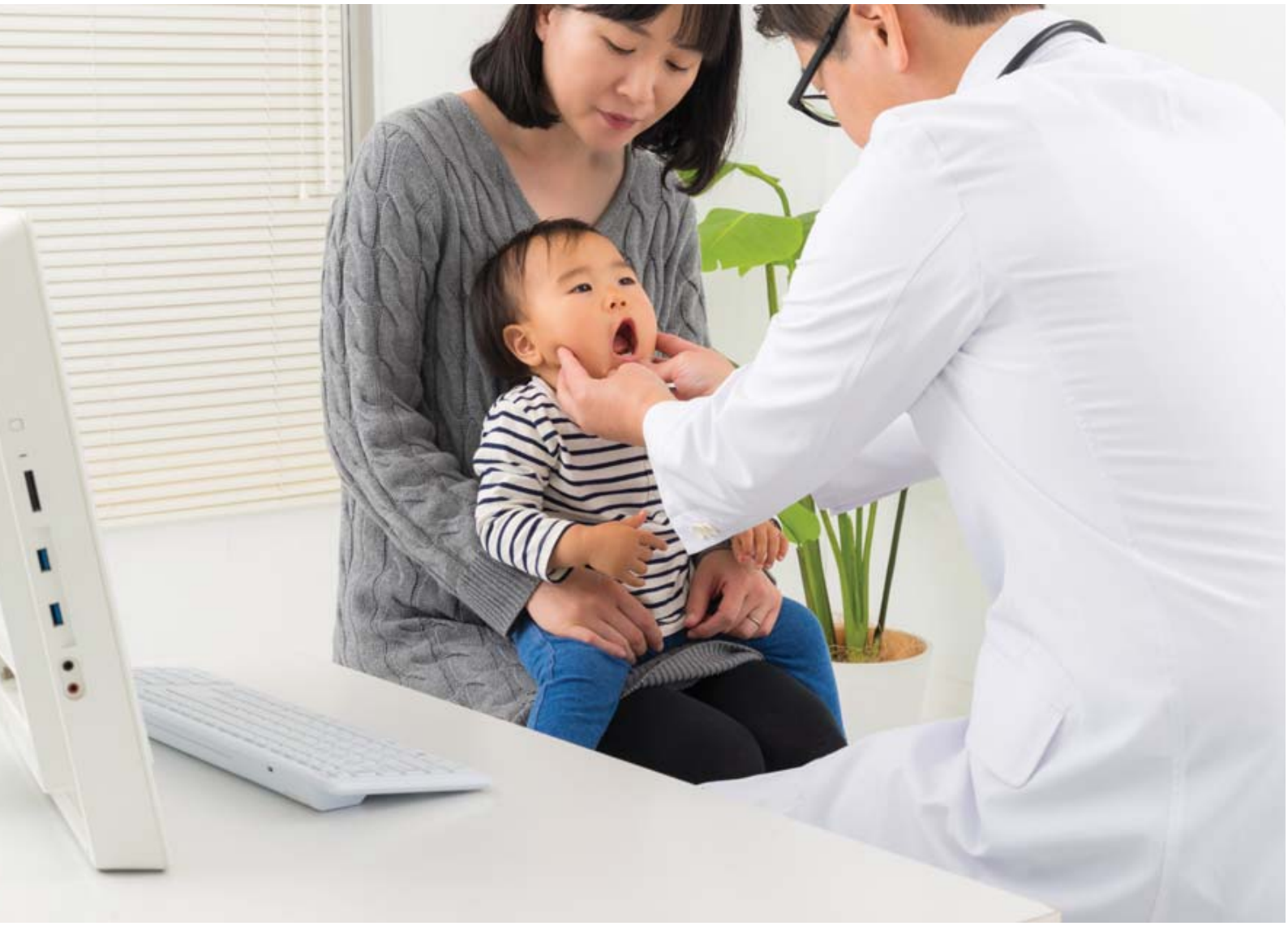


COMMON CONGENITAL SYNDROMES AND IMPLICATIONS TO ANAESTHESIA

Intan Zarina bt. Fakir Mohamed

By the end of this chapter you should be able to:
Recognize general clinical presentation of common congenital syndromes and their implications to anaesthesia.

INTRODUCTION

An understanding of common congenital syndromes is vital to safely administer anaesthesia with emphasis on the specific anomalies involved.

This requires a systematic approach during pre-operative assessment to identify relevant issues:

1. Occult, serious abnormalities that have not been identified
2. The link with malignant hyperthermia
3. The difficult airway
4. Difficult venous access
5. Psychological problems/mental retardation

Preoperative assessment (history, physical examination, investigations)

Perinatal progress
Previous anaesthetic record

i. Airway

Assessment of nasal passages, mouth opening, tongue, mandible, temporomandibular joint and cervical spine

Disorders that distort normal anatomy include:

- maxillary hypoplasia - Apert syndrome
- mandibular hypoplasia - Pierre Robin
- mandibular and maxillary hypoplasia - Treacher Collins syndrome
- Hemifacial microsomia - Goldenhar syndrome
- Mucopolysaccharidosis (MPS) - thickened, stiff abnormal tissues
- Macroglossia - Beckwith-Wiedemann and Down syndromes

As a consequence of distorted anatomy:

- Facemasks may be difficult to fit
- Upper airway may be crowded
- Laryngoscopy and intubation may be difficult

Supraglottic airway device (SGA)– is useful for airway maintenance and as a conduit for fibre-optic intubation.

ii. Breathing

Respiratory muscle and bulbar weakness are features of myopathic conditions.

iii. Cardiovascular

Many congenital syndromes have an associated cardiac lesion.

iv. CNS, Spine

A meticulous neurological evaluation relevant to intracranial pressure (craniosynostosis) and abnormalities in the spine (Down syndrome, Hurler syndrome)

v. Endocrine, metabolic and renal system.
Careful management of glucose in glycogen storage disorder such as in von Gierke and Pompe disease.
Ensure minimum fasting time.

vi. Skin, Bone and joint disorders
Care during positioning of patients.

SPECIFIC CONGENITAL SYNDROMES

(A) SYNDROMES AFFECTING AIRWAY MANAGEMENT

Down's Syndrome

Down syndrome is associated with major congenital abnormalities including cardiac lesion, craniofacial abnormalities and intellectual impairment.

- occipito-atlanto axial instability - care during intubation and positioning
- large tongue and a narrow nasopharynx - upper airway obstruction
- larynx is often slightly small- need ETT 0.5mm smaller
- intravenous access may be difficult

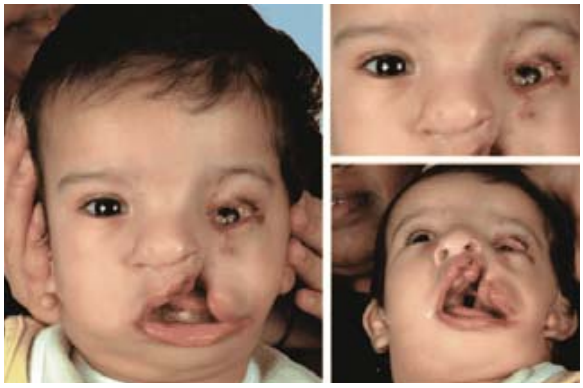
Pierre Robin Syndrome

Migronathia, glossoptosis, cleft palate and associated with CHD

- Upper airway obstruction occurs after induction of anaesthesia
- Need to use airway adjuncts or SGA
- Direct laryngoscopy can be very difficult

** With age and growth of the mandible usually become easier to manage*

Goldenhar syndrome



Hemifacial microsomia (asymmetrical hypoplasia of malar, maxillary and mandible)

- Preoperative cardiac evaluation (CHD/VSD/TOF)
- Check renal function (Renal anomalies)
- Challenging face mask ventilation
- Intubation may be difficult

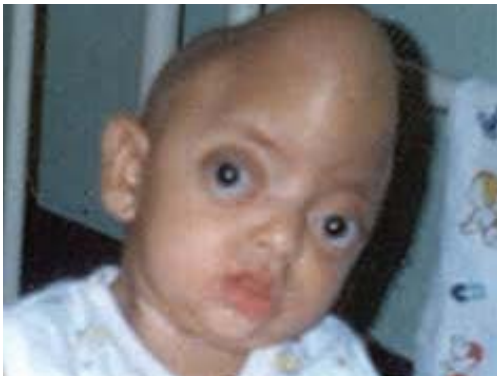
(Facial asymmetry worsens as the child grows)

Treacher Collins syndrome

Characterized by bilateral malar, maxillary/mandibular hypoplasia, small mouth, temporo-mandibular joint abormalities, defect of the lower eyelid and malformation of external ear.

- cleft palate and cardiac anomalies
- Direct laryngoscopy and intubation can be very difficult

Syndromic craniosynostosis



Apert, Crouzon, Pfeiffer

Characterized by prematurely fused skull-bone sutures and involvement of the facial skeleton (upper airway obstruction and raised intracranial pressure)

- Multidisciplinary team management
- Almost 50% have OSA
- Risk of airway obstruction on induction of anaesthesia

Mucopolysaccharidoses

Lysosomal storage disorders: enzyme defects that result in accumulation of glycosaminoglycans in cellular lysosomes throughout the body

Sub-types classification:

I Hurler syndrome
II Hunter syndrome
III Sanfilippo syndrome
IV Morquio syndrome
V Scheie syndrome
VI Maroteaux-Lamy syndrome
VII Glucoronidase deficiency

- For these patients, the anaesthesia risk is very high.
- Hence, the clinical evaluation of the cardiac and respiratory systems is crucial
- They will need close postoperative monitoring.

Airway management

Overall incidence of airway difficulties is 25% with failure to intubate in 8%. This is due to:

- Airway tissue deposition of glycosaminoglycans
- Short neck
- Poor joint mobility
- Macroglossia
- Cervical spine instability (Hurler, Morquio)

Therefore, careful preparation and planning with full range of difficult airway adjuncts is paramount.

Arthrogryposis

Multiple congenital contractures affecting two or more parts of body.

- Potential difficult airway due to small mouth, micrognathia, limited temporomandibular joint motion and atlanto-occipital instability.
- Difficult venous access.

(B) SYNDROMES ASSOCIATED WITH VENTILATORY PROBLEMS

Muscular dystrophy

A group of X linked genetic disorders in which there is absent or abnormal dystrophin leading to muscle weakness and atrophy. Duchenne muscular dystrophy (DMD) is the most common form.

- restrictive lung disease due to respiratory muscle weakness and scoliosis
- dilated cardiomyopathy
- risk of rhabdomyolysis and hyperkalaemia
- fibrosis of the conduction system - rhythm disturbances

Requires multidisciplinary assessment

Evaluate lung function tests, sleep studies and echocardiograms

(C) OTHERS

Osteogenesis imperfecta

- fractures may occur with any manipulation
- care during intubation and positioning

Conclusion

It is useful for the anaesthetist to actively search for specific anomalies that might potentially impact on the provision of anaesthesia.

Careful planning includes selecting an appropriate location for the procedure and postoperative care has to be individualized.

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PERIOPERATIVE FLUID MANAGEMENT

Sushila Sivasubramaniam

By the end of this chapter you should be able to:
a. Assess fluid requirement in children.
b. Prescribe fluids in children.

INTRODUCTION

Perioperative fluid therapy is a medical prescription:

- Volume and composition adapted to patient status, type of operation, postoperative events.
- Dose, fluids and electrolytes are calculated on child's weight
- Adjust for co-morbid (neurology, burns, CHD, sepsis, chronic illness).

Indications for IV fluids

1. Resuscitation as a bolus fluid in hypovolaemia/shock.
2. Maintenance fluid to replace urine output and insensible losses
3. Replacement fluid to replace abnormal losses from GI/other body cavities/fasting deficit

Principles and protocols for intravenous fluid therapy

1. Fluid prescription and the 5 Rs: Resuscitation, Routine maintenance, Replacement, Redistribution, Reassessment.
2. Offer IV fluid therapy as part of a protocol.

Resuscitation	• Bolus • Normal Saline/Ringer's Lactate • Alternatively and ONLY under direction of specialist - other crystalloids (plasmalyte, sterofundin) - colloids (gelafundin, 5% albumin) - blood products, blood components • No starch base solutions • Glucose Free
Routine Maintenance	• 4-2-1 rule • Isotonic crystalloids (sodium 131-154 mmol/l)
Replacement & Redistribution	• Dehydration/ ongoing losses/ fasting deficit • Normal saline/ Ringer's Lactate

Resuscitation

- Bolus 20ml/kg < 10min.
- Cardiac/ kidney disease, aliquots of 5ml/kg. Intracranial pathology, bolus 10ml/kg.
- Term neonates, bolus 10-20ml/kg < 10 minutes (Ringer's Lactate/ Normal Saline/ 5% Albumin)
- Reassess and repeat if required.

Maintenance Fluid:

1957, Holliday & Segar: 4-2-1 formula

Weight	Infusion dose
First 10 kgs	4mls/kg
Second 10 kgs	2ml/kg
Subsequent kgs	1ml/kg

2004, Holliday & Segar

Superhydration reduces PONV after squint surgery, tonsillectomy, adenoidectomy, daycare. Caution for long surgeries, CHD, renal insufficiency.

Perioperative infusion rates: 20-40ml/kg/h over 2-4 hours
Postoperative inpatient infusion rates: 2/1/0.5 ml/kg/h for the first and second 10kg and >20kg respectively

Replacement & Redistribution

Estimation of fluid deficit:

- Preoperative losses: fasting deficit, haemorrhage, third space losses (ECF losses from surgical trauma, tissue exposure).

- Estimate dehydration from history, physical examination and laboratory parameters.

Clinical assessment for degree of dehydration

Signs & Symptoms	Mild	Moderate	Severe
Weight loss	3-5%	6-9%	>10%
Fluid Deficit	30-50 ml/kg	60-90 ml/kg	>100 ml/kg
General appearance	Alert, restless, thirsty	Thirsty, restless, lethargic	Drowsy to comatose, sweaty, cold
Pulse	Normal rate & volume	Increased rate, weak	Rapid, feeble
Blood Pressure	Normal	Normal/ low	Low/ unrecordable
Respiration	Normal	Deep	Deep/ rapid
Anterior Fontanel	Normal	Sunken	Markedly depressed
Skin turgor	Normal	Decreased	Greatly decreased
Eyes	Normal	Sunken, dry	Markedly sunken/ very dry
Mucous Membrane	Moist	Dry	Very dry
Capillary Refill	Normal	<2 sec	>3 sec
Urine Output	1-2 ml/kg	Decrease	Oliguria/ Anuria

Calculate Child's Water Deficit

Water deficit (mls) = Degree of dehydration expressed as % of body weight. 10ml/kg of fluids required for every 1% dehydration correction

E.g. 10kg child who has a 5% dehydration has a water deficit of 500ml		
Maintenance		
Infusion rate/ hour	4ml x 10 kg	= 40ml/hour
Deficit		
5 % Dehydration (5% of body water)	5 x 10ml x 10kg Correction per 1%= 10ml/kg	= 500ml over 24 hr (21ml/hr)

- Replace over a period of time.
- Rate adjusted with ongoing clinical assessment.
- Use isotonic solution.
- Reassess clinical status and weight every 4-6 hours. Adjust fluid rate.
- Replacement may be rapid in gastroenteritis, slower in diabetic ketoacidosis and meningitis, and much slower in hypernatraemic states (rehydrate over 48-72 hours, serum Na should not fall by >0.5 mmol /l /hr).

Ongoing losses

- Calculate base on each previous hour, or each 4 hour period depending on situation.
- Replace with Normal Saline/ Ringer's Lactate
- Fluid losses with high protein content e.g. burns, replace with 5% Albumin
- Match replacement fluid with content of losses *(refer Diagram)*

Fasting Deficit

- Fluid deficit= hourly maintenance requirement X Number of fasting hours
  - ½ of deficit replaced in 1st hour
  - ¼ of deficit replaced in 2nd hour and 3rd hour

* For short surgeries < one hour, 10-15ml/ kg can be given as deficit, maintenance and replacement.

Fluid administration according to severity of tissue trauma

1 Maintenance + trauma= basic hourly fluid (plus item 2 below)
Maintenance volume= 4ml/kg/hour
Maintenance + mild trauma = 6ml/kg/hour
Maintenance + moderate trauma = 8ml/kg/hour
Maintenance + severe trauma = 10 ml/kg/hour

2 Blood replacement 1:1 with blood and colloid or 3:1 with crystalloids

* Use Ringer's Lactate for both maintenance and replacement of fluid loss intraoperatively.

Intraoperative Dextrose

- Risk of perioperative hypoglycaemia is low
- Children at risk :
  - Neonates first 48 hours of life
  - Preterm and term neonates receiving dextrose containing solutions
  - Infants and children on TPN
  - Low Birth Weigh children, prolong surgery and with regional anaesthesia: maintenance fluid with 1-2.5% Dextrose or monitor blood glucose during surgery

Diagram of ongoing losses

(refer Diagram next page)

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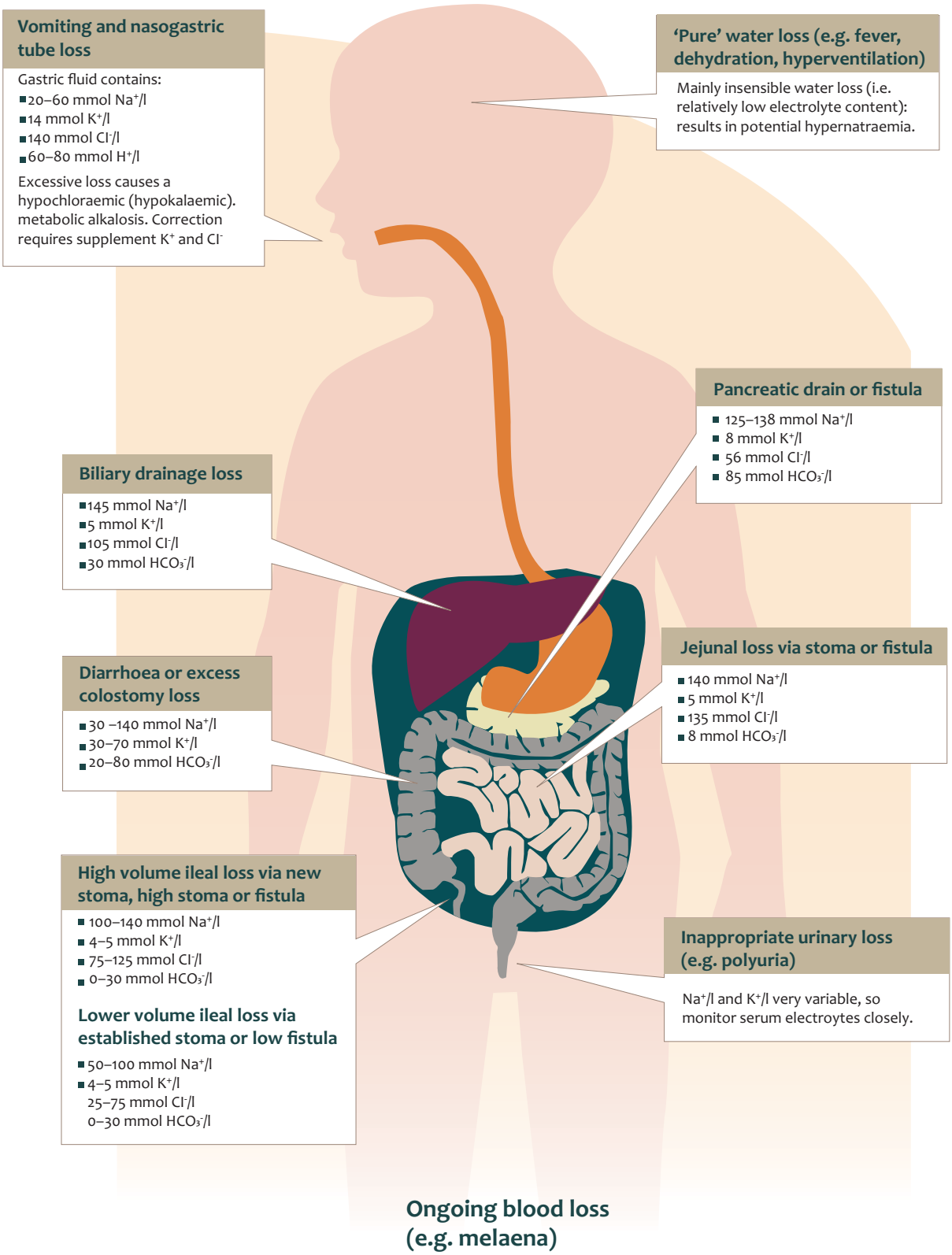
Diagram of ongoing losses



DIFFICULT AIRWAY MANAGEMENT

Teo Shu Ching

By the end of this chapter you should be able to:

1. *Outline the basic principles of paediatric airway assessment*
2. *Discuss the management of unexpected and expected difficult paediatric airways.*

INTRODUCTION

Paediatric airway is generally straight forward provided that the anaesthetist appreciates the differences between adult and paediatric airway. Therefore, it is important to identify one's limit and failure to call for help for fear of negative reputation may lead to death of a child.

Some of the features of difficult airway related to paediatric syndromes / diseases (not exclusive) are listed in Table 1.

Table 1

Hypoplastic Mandible / Small Chins	Pierre Robin (improve with age), Treacher Collins, Goldenhar, Apert, Turner, Crouzon
Other syndromes associated with potential difficult airways	Freeman-Sheldon, Beckwith-Wiedemann
Other diseases commonly encountered potential difficult airways	Choanal atresia, encephalocele, mucopolysaccharidosis, cystic hygroma, jaw or neck contracture from trauma or burn, vallecular cysts, inflammatory causes (epiglottitis), neoplasm

Management Principles

- General principles in adult difficult intubation and extubation of such patients can be applied. New equipment or technique should be attempted alongside experienced personnel.
- Proper history taking and physical assessment, anticipate difficulty, plan and prepare ahead
- Cooperative child – awake fibreoptic intubation with mild sedation / anxiolysis
- Frightful child, infants, neonates – anaesthetize maintaining spontaneous ventilation to further assess airway
    - Assess possibility of successful intubation, with videolaryngoscope / direct laryngoscope
    - Assess ease of mask ventilation
    - Consider topical local anaesthetics in spontaneous ventilation
    - May consider paralysis with rocuronium if both conditions are fulfilled without other contraindication to paralysis (eg. collapsing airway), with sugammadex standby.

The choice of anaesthetic technique in managing paediatric difficult airway depends on the anaesthetist's familiarity. The pro and cons are as listed in Table 2

Table 2

Volatile Anaesthesia	Total Intravenous Anaesthesia (TIVA)
Pros - High familiarity - Easily available	Pros - Reduce risk of airway activation - Able to maintain depth of anaesthesia
Cons - Prolonged induction in partially obstructed airway (e.g. vallecular cyst) - Difficulty maintaining depth of anaesthesia due to interruption of ventilation and prolonged intubation. Inadequate depth predisposes to airway activation (e.g. laryngospasm)	Cons - Need IV access to begin with - High initial bolus may lead to apnoea - Restricted by age and weight (TCI model limit) - Limited resources (e.g. unavailable pumps) - Unfamiliarity

Some of Airway adjuncts and techniques that are useful in managing paediatric airway.

- OELM (Optimal External Laryngeal Manipulation)
  - Useful in infants and children with short immobile neck

- LMA
  - Can be used for spontaneous or to assist ventilation
  - Can be used as route for fiberoptic intubation while maintaining oxygenation
  - Can be used as per DAS (Difficult Airway Society) algorithm
  - May not sit well especially in infants and neonates, multiple insertion can lead to airway trauma and bleeding

- Videolaryngoscope with styletted ETT
  - Excellent alternative to FOB
  - Use angulated blades of each device (e.g. D-blade in C-Mac, S3/4 in GlideScope)
  - Adult size blades can be used in neonates with appropriate care

- FOB intubation
  - Awake FOB intubation is only for cooperative child
  - Asleep FOB intubation is more utilized in children
  - Smaller size scope has no or poor suctioning capacity, easily obscured by blood or secretion
  - Bigger scope limits the size of ETT that can be used, alternatively:
  - Use with guidewire through working channel and left guidewire as guide to railroad ETT (with or without stiffer catheter)
  - Use to visualise glottis via oral or one nostril, and intubate via another nostril or orally (side)

After airway assessment and discussion with surgeons, a structured plan for airway management is required before induction of anaesthesia. In the event of unexpected difficult airway, the anaesthetist can proceed to manage the airway using existing guideline, such as Algorithm from DAS (Difficult Airway Society) for child aged 1-8 years. This algorithm provide guideline for:

- Difficult Mask Ventilation
- Unanticipated difficult intubation
- CICV (Cannot intubate and cannot ventilate)

  Refer: https://das.uk.com/guidelines/paediatric-difficult-airway-guidelines

The extubation process of a child with difficult airway is as crucial as intubation itself. It should be performed in the following manner:

- In a controlled environment, OT or ICU
- Ensure child is fully awake, with good breathing effort
- May need IV dexamathasone for multiple attempts

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NEONATAL ANAESTHESIA

Ruwaida Isa

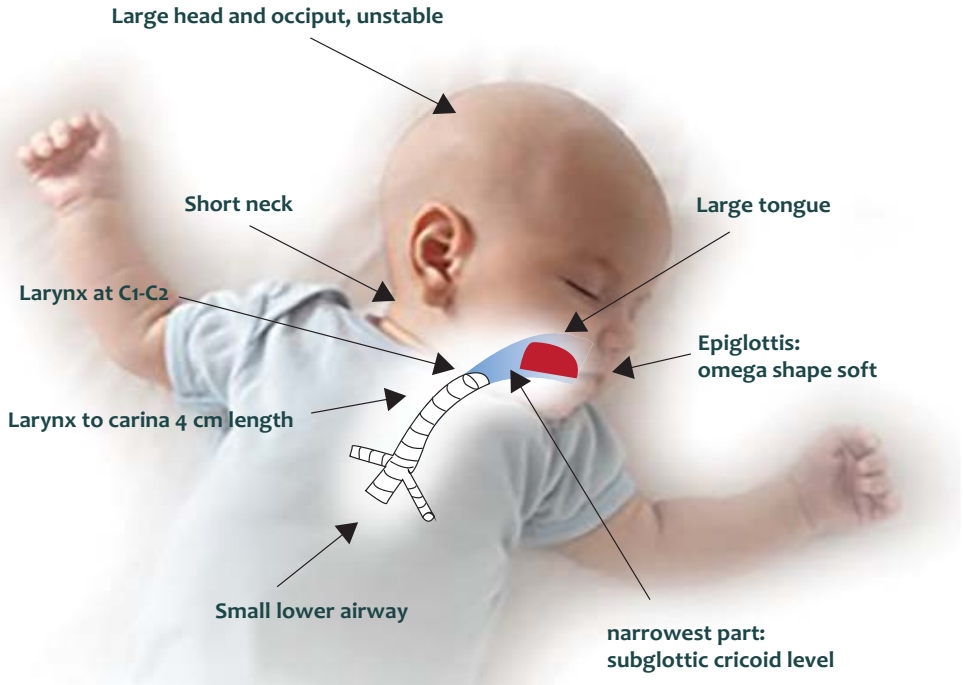
By the end of this chapter you should be able to:

a. *Understand neonatal physiology and its anaesthetic implication*
b. *Manage anaesthesia-related adverse events in a neonate during perioperative period*
c. *Apply strategies and special care throughout anaesthetizing neonates*

The following risks are associated with neonatal anaesthesia:

a. Prematurity
b. Presence of congenital lesions or syndromes
c. Disease processes peculiar to neonates including necrotizing enterocolitis (NEC), bowel atresia and patent ductus arteriosus (PDA)
d. Narrow margin for error regarding drug administration and dilution, difficulty of correct placement of endotracheal tube

Neonatal airway



Differences between adult and neonatal airway

Table 1

	INFANT	ADULT
Head	Large, prominent occiput	Flat occiput
Tongue	Relatively larger	Relatively smaller
Larynx	Cephalad position opposite to C1-C2	Opposite to C4-C6
Epiglotttis	Omega shape and soft	Flat and flexible
Vocal cords	Short and concave	Horizontal
Narrowest portion	Cricoid ring, below cords	Vocal cords
Cartilage	Soft	Firm
Lower airways	Smaller, less developed	Larger. More cartilage

Preterm neonates are classified as

- borderline preterm (36-37 weeks' gestation)
- moderate preterm (31-36 weeks' gestation)
- severe preterm (24-30 weeks' gestation)

Full term is considered to be 37 to 42 weeks' gestation.

SGA neonates have different pathophysiologic problems from preterm infants (<37 weeks' gestation) of the same weight (further reading required).

Post conceptual age is gestational age + postnatal age.

- Premature infants < 60 weeks' post conceptual age have the greatest risk of postanaesthetic complications.

Common complication related to prematurity

- anaemia
- intraventricular haemorrhage
- periodic apnoea accompanied by bradycardia
- chronic respiratory dysfunction
- jaundice
- infection

Postoperative apnoea

It is of major concern in neonatal surgery.

Definition: -Absent breathing for ≥ 15 seconds
-Absent breathing < 15 seconds if associated with bradycardia (<100 bpm) or oxygen saturation < 90%

Factors contributing to postoperative apnoea

Table 2

Central contributors	Inadequate development of respiratory centers Incomplete myelination of central nervous system
Metabolic contributors	Hypothermia Hypoglycemia Hypocalcemia Acidosis
Anaesthetic contributors	Residual inhalation anaesthesia Residual opioid plasma concentrations Residual neuromuscular blockade

Neonatal physiology and anaesthetic implications

Table 3

System	Characteristics	Anaesthetic implication
CNS	Incomplete myelination	Judicious use of muscle relaxant
	Lack of cerebral autoregulation	CPP control Immature
	Cortical activity well developed	Risk of intraventricular haemorrhage
	High risk to developed ROP	Pain relief and adequate level of anaesthesia are essential
		Maintain O2 Saturation 94 – 98%
RESPIRATORY		
MECHANICAL	Reduced Lung compliance low lung elastic recoil Decrease rigidity of chest wall Decrease V/Q caused by lung fluid Diaphragm: Type I muscles (fatigue resistant) are only 10-25%, mainly type II muscle Obligatory nasal breather	Assist or control ventilation during GA
	Minute Ventilation: FRC = 5:1 FRC (30 ml/kg) maintained dynamically Closing Capacity are more than FRC	Clear nasal passage if sign of difficult breathing Rapid desaturation during attempt of intubation
ANATOMY	Large tongue position of larynx, epiglottis, vocal cord and subglottic region are anterior and superior	Airway management and intubation difficult Potential upper airway obstruction
BIOCHEMICAL	Respond to hypercapnia not potentiate by hypoxia Immature Hering Breuer reflex Periodic breathing with transcient apnea	Avoid hypoxia Maintain normothermia Apnea with no desaturation responded to stimulation Desaturation require stimulation and airway support

STRATEGIES AND SPECIAL CARE DURING ANAESTHETISING NEONATES

Neonatal anaesthetic care begins with a detailed birth and maternal history in pre-operative evaluation. A poor post-natal history raises a red flag if there is:

- History of significant neurological or cardiovascular impairment.
- History of respiratory problems such as recurrent apnoea, bradycardia or oxygen dependence

Most drugs used during anaesthesia lead to depressant effects. Therefore, dosages should be titrated.

- Consider a regional anaesthetic technique to general anaesthesia
- Volatile Agents
  Reduce MAC in most agents, increase depressant effects on heart, respiratory mechanics, neuronal apoptosis in animal study
- Opioids
  MORPHINE – decrease clearance and increase Respiratory depression
  FENTANYL – decrease clearance with variability, increase chest wall rigidity, increase vagal tone, decrease baroceptor reflex
  REMIFENTANIL- same or increase clearance by tissue and plasma esterases, safest drug during anaesthesia
- Propofol
  Decrease clearance with variability, increase risk of hypotension (can be profound)
- Midazolam
  Decrease clearance, increase risk of hypotension
- Neuromuscular blocking agents
  Pharmacokinetics & dynamics affected by larger volume of distribution with low clearance, immature myoneural junction and low muscle mass
- Maintain normothermia more than 36°C in perioperative period
- Requirements for postoperative monitoring must be clearly documented in patient's notes

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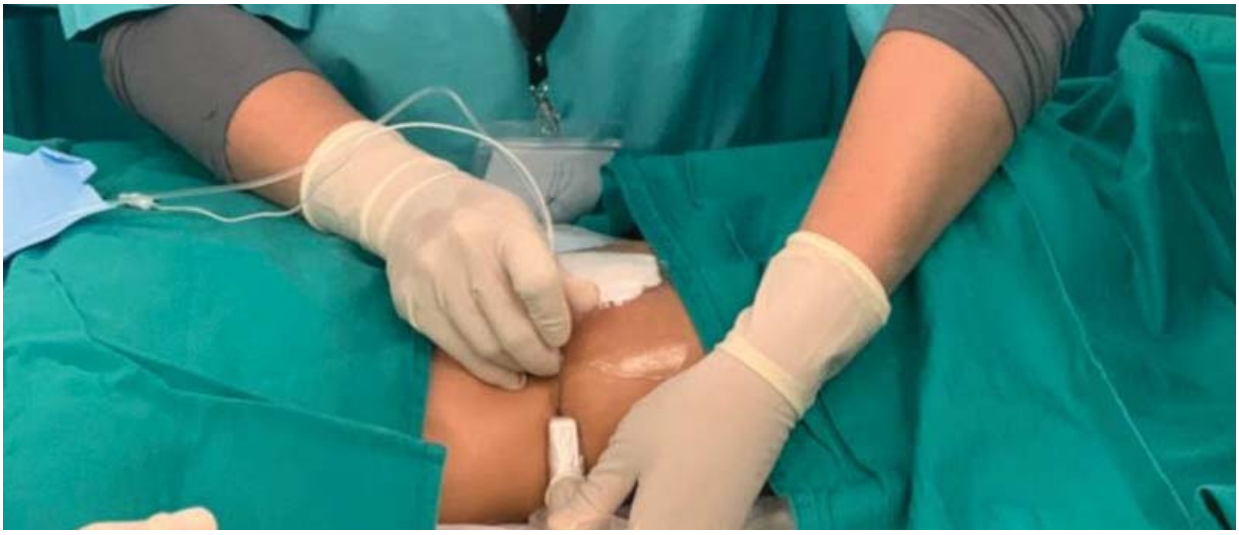
PAEDIATRIC REGIONAL ANAESTHESIA

Nur Hafiizhoh binti Abdul Hamid

Paediatric Regional Anaesthesia (PRAN) is commonly combined with general anaesthesia (GA), enabling opioid sparing analgesia and promotes early recovery in paediatric patients.



Learning Objectives:

1. *Understand the safety in PRAN*
2. *Know how to perform common blocks in children*
   a. *Peripheral Nerve Block*
   b. *Central Neuraxial Block*

SAFETY IN PRAN

- It is considered safe to perform PRAN under GA or sedation.
- It should be conducted under aseptic technique. Standard monitoring (pulse rate, pulse oximeter, respiratory rate, and electrocardiograph) are mandatory during performance.
- Nerve stimulation and ultrasound guidance (USG) are encouraged to increase success and reduce complication.
- A small gauge short-bevel needle is preferred.
- Maximum local anaesthetic (LA) dose, volume, and concentration should be precalculated. The volume could be reduced when the block is performed under ultrasound guided. Injection should be given slowly in 0.1 ml/kg aliquot.

1. COMMON PERIPHERAL NERVE BLOCK

1.1 INTERFASCIAL PLANE BLOCKS.

• Provides intraoperative and postoperative analgesia (myotome and dermatome) for anterior abdominal incisions but not visceral organs. Therefore, systemic analgesia should be co-administered.

• **Anatomy:**
  - Anterior abdominal wall innervation
    i. Ventral rami of T6-T12 thoracic nerves
      - Laterally, travels within Transverse Abdominis Plane (TAP)- between transversus abdominis muscle (TAM) and internal oblique muscle (IOM).
      - Anteriorly, penetrate rectus sheath (RS) at posterolateral border of rectus abdominis muscle (RAM), subsequently pierces RAM and anterior RS to innervate the skin.

    ii. Iliohypogastric (IH) nerve (T12, L1)
      - Run superior to ilioinguinal nerve, divides into lateral and medial cutaneous branches at iliac crest level. The medial cutaneous branch penetrates IOM and external oblique muscle (EOM) ventrally to supply suprapubic region.

    iii. Ilioinguinal (II) nerve (L1)
      - Run deeper and inferior to IH nerve, perforates TAM at iliac crest level, and continues within the TAP. Gradually, pierces IOM and EOM

• **Drug & Equipment:**
  - Ideally, use the high frequency linear array US probe.
  - Table 1 shows LA dose and volume for interfascial blocks. Maximal LA dose of 0.75mg/kg/side is advocated due to presence of a large well-vascularized surface promoting faster LA absorption.
  - Maximum cumulative LA for multiple interfascial blocks should not exceed 1.5mg/kg.

• **Complications:**
  - Peritoneal and visceral organ puncture
  - Vessel puncture and haematoma

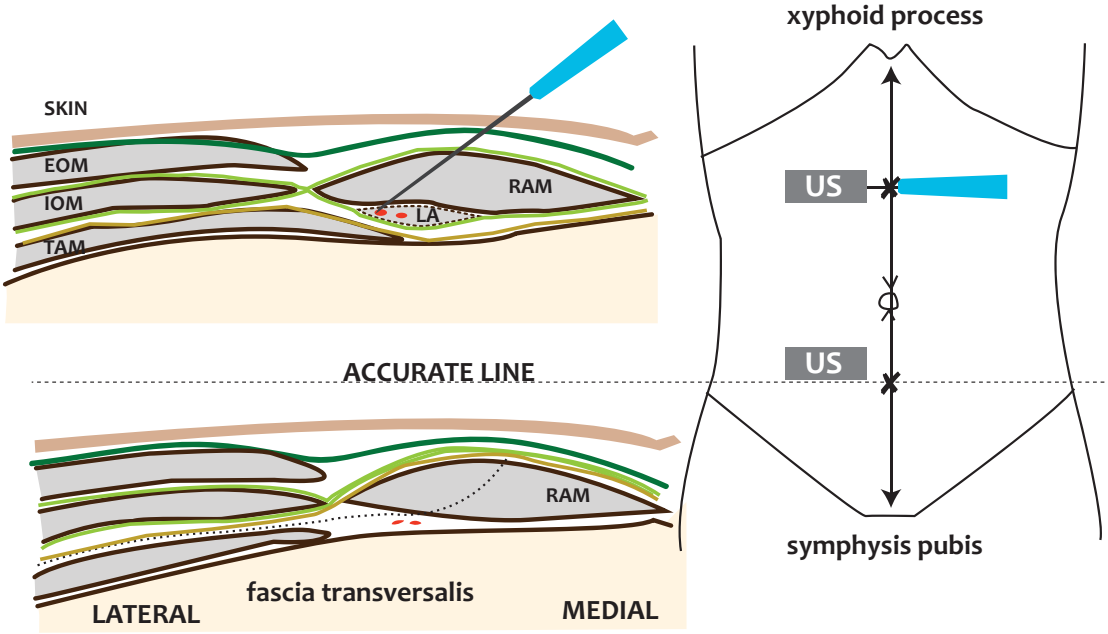
Table 1

INTERFASCIAL BLOCK	BUPIVACAINE/ LEVOBUPVACAINE	ROPIVACAINE
Single shot	0.1 – 0.3ml/kg of 0.25%	0.125 – 0.375ml/kg of 0.2%
Continous infusion	0.1 – 0.3ml/kg/hour of 0.2%	

1.1.1 RECTUS SHEATH BLOCK

- Indications: pyloromyotomy, umbilical and paraumbilical hernia repair and midline incision.
- RAM is bordered by linea alba medially, linea semilunaris laterally, anteriorly and posteriorly by RS.
- USG technique:

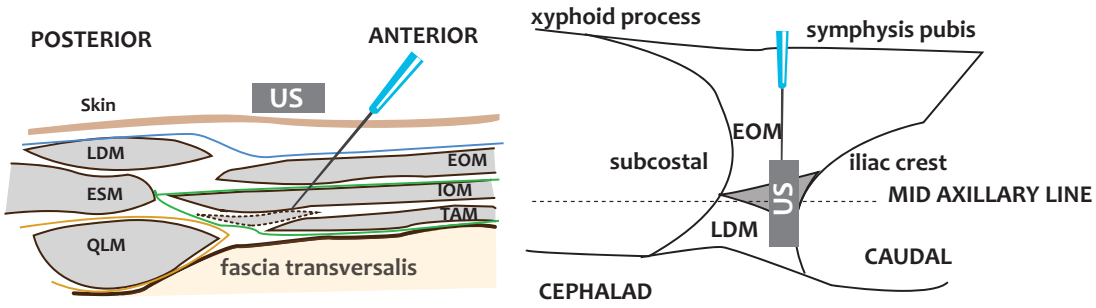
- Perform in supine position.
- Place the probe transverse to the abdomen; between xyphoid process and umbilicus for upper midline surgery and between umbilicus and symphysis pubis for lower midline surgery.
- Slide laterally to visualize linea semilunaris and the beginning of 3 lateral muscles (EOM, IOM and TAM). TAM usually begins underneath the posterior RS, acting as protective layer preventing accidental peritoneal penetration.
- Insert needle in In-Plane (IP) approach, lateral to medial trajectory targeting lateral belly of RAM. Place the needle tip between RAM and posterior RS. Observe elevation of RAM during LA injection. Turn the probe sagitally to assess the LA spread.
- Below arcuate line, posterior RS and TAM is lacking causing RAM to lie directly above fascia transversalis (FTV). Proceed with extreme caution.



Picture 1: Diagramatic view of USG rectus sheath block

1.1.2 TRANSVERSE ABDOMINIS PLANE BLOCK

- Indications: Open appendicectomy, stoma creation, iliac crest bone harvest and laparoscopic surgeries
- **USG technique.** (picture 2)
  - Perform in supine position.
  - Place the probe transverse over the linea alba at umbilical level. Slide laterally until the probe is positioned between subcostal margin and iliac crest at mid-axillary line (MAL). Identify from deep to superficial structures –peritoneum, FTV, TAM, IOM, EOM, subcutaneous tissue and skin.
  - Needle insertion point should be paralleled with probe to generate optimal needle visualization. Insert the needle in IP approach, targeting towards posterior-most of the TAP, preferably beyond MAL.



Picture 2: Diagramatic view of USG TAP block.

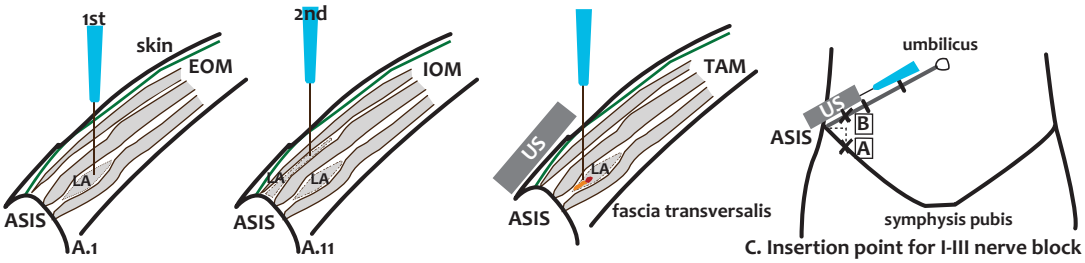
1.1.3 ILIOINGUINAL AND ILIOHYPOGASTRIC NERVE (II-IH) BLOCK

- Indications : Herniotomy, hydrocele and varicocele repair and orchidopexy.
- Landmark technique. *(Picture 3: A.i & A.ii)*
- It is perform in supine position.
- Insertion point is medial and inferior to ASIS, but the distance varies with age as shown in Table 2.

Table 2

AGE	Neonate	Infant	Toddler	Young children	Older children, Adolescence and Adults
INFEROMEDIAL DISTANCE FROM ASIS (cm)	0.3	0.5	1.0	1.5	2.0

- Insert needle at point A, perpendicular to skin. A 'pop' will be felt when EOM aponeurosis is pierced.
- Continue needle advancement until a second 'pop' is felt indicating IOM penetration. Deposit half of LA volume to block II nerve
- Retract the needle until subcutaneous layer; and re-elicit the first 'pop' again. Deposit the remaining LA between EOM and IOM to block IH nerve



Picture 3: Diagrammatic view of landmark and USG technique of II-IH nerve block.

- **USG technique** (Picture 3: B & C)
- Place the probe immediately medial to ASIS and parallel to spinoumbilical line (between ASIS and umbilicus). ASIS should be visible laterally with EOM, IOM, TAM. At point B, II and IH nerves lies in close proximity, majority within TAP.
- Insert the needle via IP approach, in lateral to medial trajectory. Iliacus muscle and iliac bone act as protective layers preventing peritoneal and bowel puncture
- Inadvertent femoral nerve block is preventable by limiting the LA volume and avoiding compression over the injection site.

1.2. PENILE BLOCK

Anatomy:

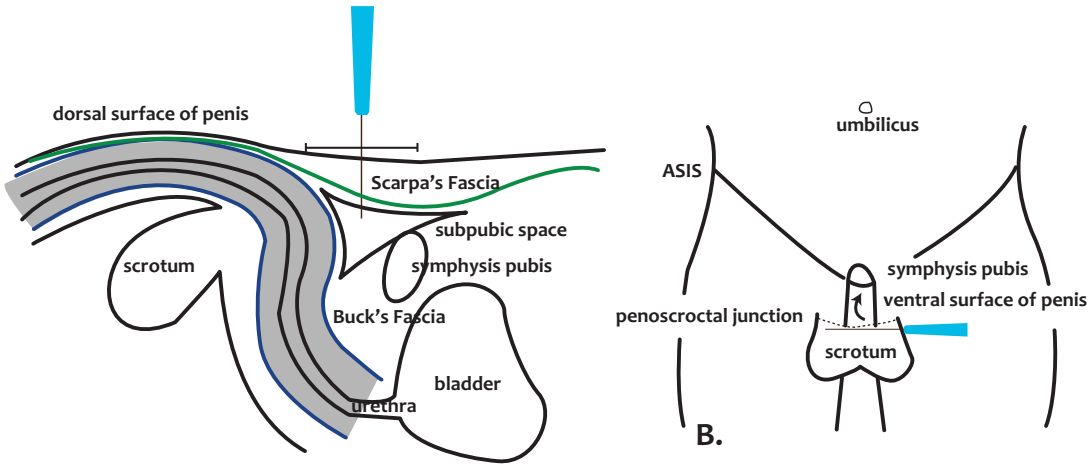
- Penis is innervated by

i. Dorsal nerve of penis in the dorsal aspect:

ii. Ventral branch of dorsal nerve of penis, genitofemoral and ilioinguinal nerve in the ventral aspect:

- Subpubic approach of dorsal nerve penile block (DNPB) is commonly practiced among anaesthetist.
- Successful penile block should cover both dorsal and ventral aspect of penis.

- **Drug & Equipment:**
  - LA : 0.2ml/kg (0.1ml/kg/dorsal side) + 1-2ml for ventral. LA with adrenaline is contraindicated.
  - In children; maximum volume is 5 ml/each side of subpubic space (SPS). (total maximum = 10ml)



Picture 4: Diagramatic view of subpubic approach DNPB(A) and penoscrotal infiltration(B).

- **Landmark technique.** (Picture 4)
  - The block is performed in supine position.
  - Pull the penis caudally to put the Scarpa's fascia under tension.
  - Needle insertion is midway between symphysis pubis and base of penis.
  - Insert needle perpendicular to the skin and angulate 15° laterally during needle advancement. A distinct 'pop' will be felt during Scarpa's fascia penetration. With negative aspiration, give half of LA volume. Appreciate upward and forward movement of the penis during LA injection, indicating successful expansion of SPS.
  - Retract the needle until subcutaneous layer and redirect toward the opposite side. Inject the remaining LA once Scarpa's fascia is penetrated.
  - Complete the penile block by local anaesthetic infiltration along the penoscrotal junction.
  - Complications
    - Block failure
    - 'Macainoma'

2. CENTRAL NEURAXIAL BLOCK

2.1 SINGLE SHOT CAUDAL BLOCK

- Caudal analgesia (CA) is achieved by injecting local anaesthetic into caudal epidural space. CA provides adequate analgesia for thoracic, abdominal, perianal, perineal and lower limb surgery.
- Anatomy:
- Table 3 shows anatomical and physiological differences, relevant to epidural and CA.

Table 3

	TERM NEONATE	6 MONTH OLD	>1 YEAR OLD
INTERCRESTAL LINE	L5-S1	L4-L5	L4
SPINAL CORD	L3-L4	L2-L3	L1-L2
DURAL SAC	S3-S4	S2-S3	S1-S2
LARGEST INTERVERTEBRAL SPACE	L5-S1		T12-L1
LUMBAR LORDOSIS	NO	NO	YES
CSE VOLUME (ml/kg)	10	4	2
EPIDURAL CONTENT	- Softer ligamentum flavum - looser connective tissue - looser edidural fat		
RESPONSE TO SYMPATHETIC BLOCK	- reduces resting sympathetic tone - hypotension is uncommon in <8 years old		

- **Pharmacology**
- Table 4 shows dose, volume and concentration of LA for single shot CA based on Armitage formula. Maximum LA volume should not exceed 1.25ml/kg or 20-25ml; to avoid excessive intracranial pressure increment.

Table 4

DISTRIBUTION OF SINGLE SHOT CAUDAL	DOSE AND CONCENTRATION	
	BUPIVACAINE/ LEVOBUPVACAINE (not exceed 2.5mg/kg)	ROPIVACAINE (not exceed 2.5mg/kg)
sacral region (Perianal, perineal surgery)	0.5ml/kg of 0.25%	0.5ml/kg of 0.25%
sacral up to T10 level (lower abdominal, lower limb sugery)	1.0ml/kg of 0.25%	1.0ml/kg of 0.25%
sacral up to T6 level (lower thoracic, abdominal surgery)	1.25ml/kg of 0.2%	1.25ml/kg of 0.16%

- **Landmark technique**
- CA is performed in lateral 'knee to chest' position.
- Identify bilateral posterior superior iliac spine, palpate at midline and walk finger caudally, appreciate the flattened surface of median crest. Sacral hiatus (SH) is immediately at the edge of the flattened structure. At SH, feel for bilateral sacral cornuae.
- Insert needle at apex of SH with 45° - 60° needle advancement towards caphalad,

until a 'give' is felt indicating SCL penetration; entering caudal epidural space. Needle reangulation and further advancement is unnecessary.

- Wait 30 - 60 seconds for passive blood and CSF flow before testing for negative aspiration. Needle position is confirmed with loss of resistance prior to LA injection.

3 ADDITIVE AND ADJUVANT IN NEURAXIAL AND PERIPHERAL NERVE BLOCK

- Single shot PRAN has limited duration of action 4 – 12 hours, with peripheral block offers a longer period of analgesia.
- Prolongation of block could be achieved by
- Inserting a catheter for a continuous infusion or intermittent boluses.
- Mixing LA with adjuvant drugs for single shot block.
- Adjuvant can prolong block duration and analgesic effect up to 12 - 18 hours, reduces anaesthetics requirement and smoothen emergence and recovery.
- Table 5 show the list of adjuvants that could be added for neuraxial and peripheral nerve block.

Table 5

ADJUVANTS (preservative free)	DOSE	
	CENTRAL NEURAXIAL BLOCK	PERIPHERAL NERVE BLOCK
FENTANYL	Infusion : 0.3-2 mcg/kg/h	–
CLONIDINE	Single shot : 1.0-2.0 mcg/kg Infusion : 0.1-0.5 mcg/kg/h	0.5 – 1.0 mcg/kg
DEXMEDETOMIDINE	–	0.5 – 1.0 mcg/kg
S-KETAMINE	Single shot : 0.5-1.0 mg/kg	–

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NON-OPERATING ROOM ANAESTHESIA

Rufinah Teo

By the end of this chapter you should be able to:

- *Identify the challenges associated with anaesthesia and sedation in remote locations.*
- *Understand the principle on the conduct of safe anaesthesia outside the operating theatre.*

INTRODUCTION

- Non-operating room anaesthesia(NORA)is the provision of anaesthesia and sedation outside the operating theatre.
- Common procedures done in remote locations include:
  - Radiology department (MRI, CT scan & interventional radiography).
  - Oncology (radiotherapy, bone marrow aspiration and/or intrathecal injections).

Challenges

Personnel

- Lack of trained assistance to assist anaesthetist.
- The anaesthetist may not be familiar with the environment or the equipment provided.

The patient

- Patients are often admitted as day case or as in-patients in ward.
- Frequently associated with multiple co-morbids that necessitates diagnostic imaging or therapeutic procedures.

The work environment

- Unfamiliar working environment.
- Limited resuscitative and monitoring facilities.
- Cramped and congested work area.
- Low ambient temperature with risk of hypothermia in small babies.
- Inadequate space, monitoring facilities and trained staff at recovery bay.

The procedure

- Many procedures require screening in a darkened room, making clinical monitoring difficult.
- Accessibility to patient is limited, giving rise to problems of using long breathing circuits (kinking, disconnection, increased dead space) and long extensions for intravenous access.
- Patient my need to be positioned in the lateral (CT guided biopsies) or prone (nephrostomy tube insertion). Complications related to positioning are: pressure sore, nerve entrapment and eye injury.
- Risk of anaphylaxis or allergic reaction following contrast agents.
- Radiation hazard to patient and personnel.

Conduct of general anaesthesia: (options include inhalational / intravenous induction with spontaneous or controlled ventilation)

Assessment

- Primary diagnosis and indication for procedure.
- Associated syndromes and comorbidities and current medications
- History of allergies to contrast medium.
- Relevant anaesthethic history.
- Focused examination on airways, respiratory, cardiovascular and neurological system.
- Adequate information to parents or

guardian regarding risks and benefits of procedure under anaesthesia.
- Patients should be fasted according to local guidelines.

Special precautions in those with:

- Ex-premature who are < 60 weeks postconception (risk of apnoea)
- Raised intracranial pressure.
- Risk of aspiration eg gastroesophageal reflux disease (GERD).
- Difficult airway eg syndromic or obese child.
- American Society of Anesthesiologists Classification (ASA III) or greater.
- Autism spectrum disorder.

Anaesthetic and equipment check (same as in the operating theatre)

- All machine and equipment check are as per protocols in the operating theatre.
- Resuscitaion drugs and devices must be available within reach.
- Monitors include: pulse oximetry, electrocardiogram (ECG), non-invasive blood pressure (NIBP) and capnography.

Recovery

- Supplemental oxygen.
- Standard monitoring as per recovery guidelines in operating theatre.

Conduct of sedation

- Assessment, anaesthetic machine, equipment check and post sedation care should be the same as general anaesthesia.
- There are 3 targeted sedation states:
  - Minimal: Child is calm and responds to verbal commands. Ventilatory and CVS functions are maintained.
  - Moderate: Depression of consciousness, responds to light tactile stimulus. Spontaneous ventilation is adequate. CVS functions are maintained.
  - Deep: Patient is not easily arousable. Require assistance to maintain patent airway. CVS functions are preserved.
- Monitoring of patients should include clinical signs of depth of sedation, respiratory rate, heart rate, signs of pain and distress.
- The recommended monitoring for moderate and deep sedation is shown in Table 1.

Table 1

Level of sedation	Moderate	Deep
Monitoring	Pulse oximetry	Pulse Oximetry
	Heart rate	Heart rate
	Respiratory rate	ECG
	Strongly recommended:	Respiratory rate
	ECG	Blood Pressure
	Capnography	Capnography

[Adapted from NICE. Sedation in Children and Young People. London, UK: NICE 2010.]

Table 2: Commonly used drugs for sedation

Table 2

Drug	Dosage	Indication	Special consideration
Midazolam	**IV:** 0.1mg/kg **Oral:** 0.4-0.5mg/kg (max 15mg) **Intranasal:** 0.2-0.3mg/kg **Rectal:** 0.3-0.5mg/kg (max 15mg)	Minimal sedation	Paradoxical CNS stimulant
Propofol	**IV:** 1-2mg/kg iv **TCI:** 0.5-2 mcg/ml **Infusion:** 6-10mg/kg/hr	Moderate or deep sedation	Injection pain, apnoea
Ketamine	**IV:** 0.5-2mg/kg iv bolus then 0.25-1mg/kg prn **Intranasal:** 2-4mg/kg	Dissociative sedation and analgesia	Combination with midazolam or propofol (ketofol) for reduction of psychomimetic side effects
Clonidine	**IV/Intranasal:** 1-2mcg/kg **Oral:** 2-3mcg/kg	Anxiolysis	Slow onset
Dexmed-etomidine	**Infusion:** 0.2-0.7µg/kg/hr **Oral/intranasal/buccal:** 2-3 µg/kg	Moderate and deep sedation, small analgesic effect	Slow onset, spontaneous respiration
Remifentanil	**Infusion:** 0.1-0.3 µg/kg/min	Analgesia	Apnoea
Fentanyl	**IV:** 1-2 µg/kg	Analgesia	Apnoea

Special considerations for MRI

- MRI magnet (up to 3.0 Tesla magnetic field) may cause malfunction to certain devices such as cochlear implants.
- Ferromagnetic implants (eg prosthetic heart valves, intraocular implants) may get dislodged.
- Loose ferromagnetic objects (oxygen tank, drip stand) can pulled at high speed, risking injuries to patient.
- Use of anaesthetic machine, monitoring devices for patients and infusion pumps MUST be MRI compatible / safe.

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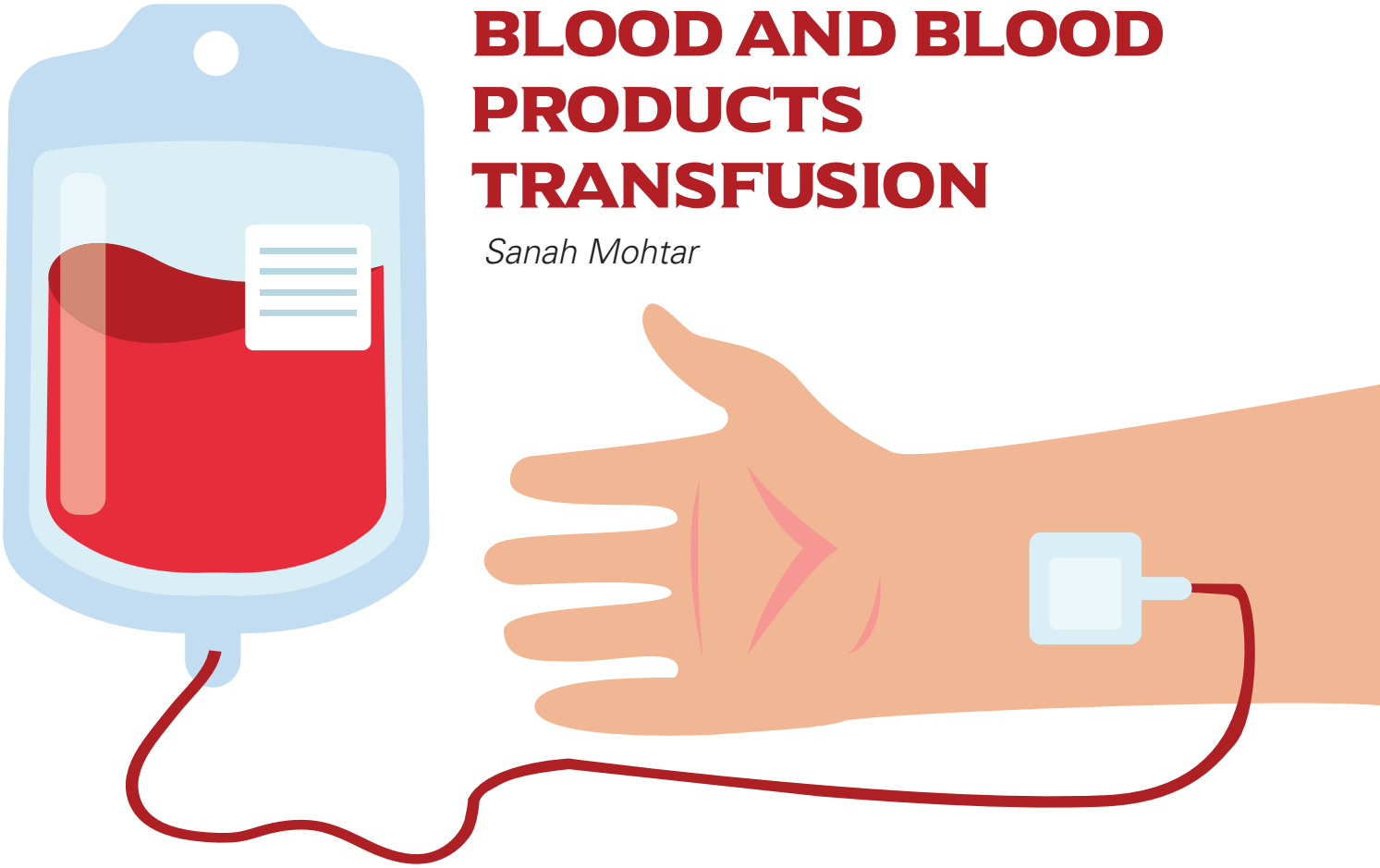

BLOOD AND BLOOD PRODUCTS TRANSFUSION

Sanah Mohtar

By the end of this chapter you should be able to:

1. *Recognise that neonate and children have a different normal range for haematological parameters.*
2. *Identify the thresholds for transfusion in neonate and children vary from those in adults.*
3. *Manage transfusion based on clinical assessment and outweigh the benefits against the risks.*

NORMAL VALUES

Normal haemoglobin values are highest at birth and gradually decreases over the first few months of life due to reduce red cell production (Table 1). Preterm neonates show a more significant decrease. By 12 years old, the haemoglobin level is the same as adulthood.

Table 1: Normal haematological ranges

	Full term	*Premature
Haemoglobin (g/dL)		
At birth	14-24	Slightly less than full term
1 month	13.9	11.5
3 months	12.2	11.7
6 months to 6 years	10-14	12.4
7-12 years	11-16	
Platelets (x 10^9/L)	150-450	150-450
PT (s)	10-16	11-22
aPTT	31-55	28-101
INR	0.80-1.20	0.9-1.60
Fibrinogen (g/L)	1.7-4.0	1.5-3.7
Total Blood volume, TBV (ml/kg)	80-85 (75-80)#	90-100

**Normal value for preterm infants will depend on gestational age.*
 # Blood volume by 6 months of age.

RED BLOOD CELL (RBCs) TRANSFUSION

a. Neonate and infants

The threshold for RBCs transfusion in neonates differs from children and adults, for several considerations, which include;

- Infant's blood volume
- Physiologic anaemia of infancy
- The infant's inability to tolerate minimal physiological stress

Current evidence of the optimum level of acceptable haemoglobin in neonate is controversial and evolving. However, for practicality, the PRBC transfusion guide in neonate is as table 2

Table 2: Practical guide for PRBC transfusion in neonates/ infants less 4 months of age

Indication for transfusion	Suggested Hb (g/dL)
Acute blood loss > 10% of blood volume or Anaemia immediately after birth	**12**
Ventilated **Postnatal age;** **< 1 week** **> 1 week**	 **< 12** **< 10**
Oxygen therapy/ CPAP **Postnatal age;** **< 1 week** **> 1 week**	 **< 10** **< 9**
No respiratory support, stable	**< 7**

b. Children

In general, the principles of PRBCs transfusion in older infants and children are the same as for adults. However, young infants may less able to tolerate acute blood loss due to their limited capability to respond to hypovolemia by increasing myocardial contractility and also due to higher oxygen consumption as compared as adult.

Table 3: Guidelines for transfusion of PRBCs in children older than 4-month (as children younger than 4 months have different physiologic processes hence the triggers are *different*)

1.	**An emergency surgical procedure in a patient with *symptomatic anaemia* preoperatively**
2.	**Preoperative anaemia when another corrective therapy (e.g. iron supplement) is not available**
3.	**Acute intraoperative blood loss > 15% of total blood volume or hypovolaemia not responding to other fluid therapy**
4.	**Haematocrit < 24% with signs and symptoms of anaemia**
5.	**Haematocrit < 40%; With severe pulmonary disease With extracorporeal membrane oxygenation (ECMO)**

Dose and calculation

The volume of PRBCs required to raise the Hb at a given level is calculated based on patient's body weight as the formula below:

Volume of PRBCs(ml) = required rise in Hb (g/dL) X Weight (kg) X 4 (Constant)

In cases of anticipated massive blood loss, it is essential to calculate the patient's estimated blood volume (EBV). The estimated maximal allowable blood loss (MABL) and the volume of blood required to raise the Hb at a given level should also be calculated.

$$\text{MABL (ml)} = \frac{\text{Initial Hb} - \text{Target Hb}}{\text{Average Hb}} \times \text{EBV}$$

PLATELET TRANSFUSIONS

Platelet transfusions are indicated to prevent or decrease bleeding associated with qualitative or quantitative platelet deficiencies. Neonates may require a higher platelets threshold due to impaired platelet function and its associated risk of intracranial haemorrhage.

Table 4: Guidelines for platelet transfusion support

Clinical condition	Acceptable Platelets count (x 10^9/L)
Neonate with bleeding	**50**
Sick neonate, not bleeding	**30-50**
Stable neonate, not bleeding	**20**
Stable infant/child ICU	**20**
Any infant/child for an invasive procedure or surgery or active bleeding	**50-100**

**A volume of 5-10ml/kg of platelet transfusion is expected to increase the platelets count by 50-100x10^9/L.*

PLASMA TRANSFUSION

The indication is to correct bleeding due to coagulation disorder and should be based on point of care testing or laboratory test. In neonate or smaller infants, it may be reasonable to transfuse earlier than older child due to the decreased levels of vitamin-K dependent coagulation factors. It should not be used as a primary purpose to correct hypovolaemia.

The dose is 10-20 ml/kg, which is expected to increase factor activity by 20% in a child without ongoing consumption of coagulation factors.

MASSIVE TRANSFUSION

Massive blood transfusion in paediatrics is defined as:

1. Transfusion of more than one total blood volume (TBV) within 24 hours or
2. Transfusion of more than 50% TBV in 3 hours or 2-3ml/kg/min.

Consumptive coagulopathy is common following resuscitation; therefore, permissive hypotension should be considered until bleeding is secured. Early used of blood products (e.g. 2:1:1 ratio of PRBC, FFP and platelets) have shown to improve outcome.

Table 5: Recommended blood products transfusion in massive blood loss

Platelet	**15-20 ml/kg aliquots to be considered after every 40ml/kg of PRBCs transfusion.**
FFP **1 unit = 200ml**	**20 ml/kg aliquots (ratio of at least 1 FFP: 2 PRBCs).**
Cryoprecipitate **1 unit = 20-50ml**	**10ml/kg**

Blood products transfusion should be altered accordingly once laboratory parameter are accessible; with therapeutic goal of Hb 8 g/dl, fibrinogen > 1.5 g/L, PT ratio < 1.5 and platelet count > 75 x 10^9/L.

SUMMARY

- The risks and benefits should always be considered in initiating blood and blood product transfusion in neonate and children.
- The volumes and rates for transfusion in children should be carefully calculated and prescribed in mL, not component units, in order to minimise dosing errors and reduce the risk of circulatory overload.
- A restrictive red cell transfusion policy is safe for clinically stable children.

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ANAESTHESIA FOR THE CHILD WITH UPPER RESPIRATORY TRACT INFECTION (URTI)

Muhammad Habibullah Zakaria

By the end of this chapter you should be able to:

a. *Identify the risk factors for perioperative respiratory adverse events (PRAEs)*
b. *Evaluate preoperatively the child with URTI*
c. *Manage the child with URTI coming for surgery*

INTRODUCTION

URTI is the most common infection that occurs 6-8 times per year in children. 95% of URTI are secondary to viral causes, with rhinoviruses accounting for 30-40% of infection. Airway hyper-reactivity is common after URTI and has important clinical implications in anaesthesia.

RISKS OF ANAESTHESIA FOR THE CHILD WITH URTI

Children who undergo general anesthesia with a current or recent URTI are at increased risk of perioperative respiratory adverse events. PRAEs include laryngo-spasm, bronchospasm, atelectasis, coughing, airway obstruction, hypoxia, stridor and breath holding.

RISK FACTORS FOR PERIOPERATIVE RESPIRATORY ADVERSE EVENTS (PRAE)

PATIENT FACTORS
Age • The younger the greater the risk • Infant <6 months have a higher risk of bronchospasm • Children <2 years have a higher risk for oxygen desaturation
Co-morbid conditions • ASTHMA • CONGENITAL HEART DISEASE • BRONCHOPULMONARY DYSPLASIA, • CYSTIC FIBROSIS • OBSTRUCTIVE SLEEP APNEA
Passive smoker
Obesity
Syndromes associated with airway obstruction (Down Syndrome)
SURGICAL FACTORS
Shared airway procedures (eg; ear, nose and throat, dental, respiratory) Upper abdominal surgery
ANAESTHESIA-RELATED FACTORS
Induction of anaesthesia • Thiopentone > halothane> sevoflurane > propofol
Airway management • endotracheal tube > LMA > facemask (most important is sufficient anaesthetic depth)
Less experience with airway management

The risk of perioperative complications is greatest in the presence of acute infection but remains increased for 2-6 weeks after URTI. Airway reactivity is increased for up to 6-8 weeks following an URTI.

Overall 2-7 times increased risk PRAE in URTI
Intubated URTI has 11 times increased risk versus without URTI.
Most adverse perioperative events are easily manageable and have no lasting effect.

PREOPERATIVE EVALUATION

i) Detailed history

- Signs and symptoms that should be elicited include fever, clear or green nasal secretions, wet or dry cough, wheezing, changes in respiratory pattern, shortness of breath, anorexia, malaise and/or changes in playfulness and physical activity.
- Simply asking the parents whether a child is sick, is an important part of preoperative evaluation.

ii) Physical examination

- Patient should be examined for obvious signs of a URTI such as nasal discharge, repeated coughing, a sick appearance, and/or fever. The chest should be auscultated for wheezing, crackles, or rhonchi as signs of lower respiratory tract infection. Inspection of the throat may help.

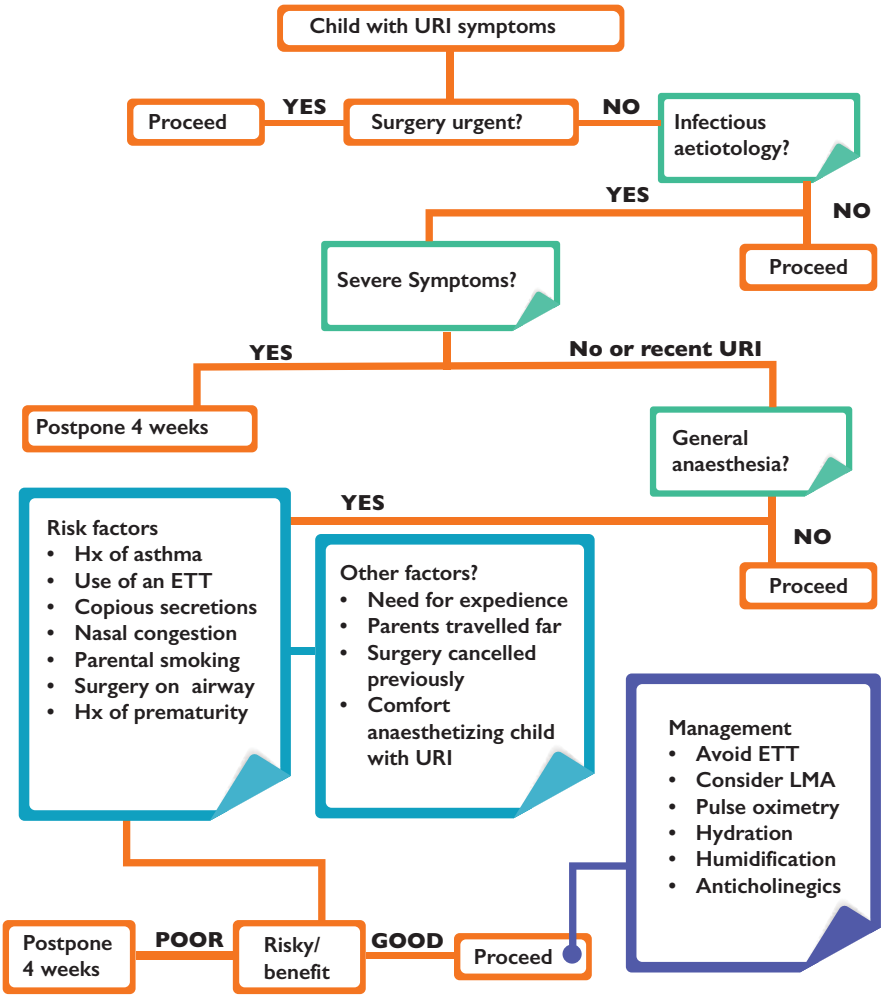
iii) Laboratory and radiologic examination

- Preoperative laboratory and radiologic evaluation are rarely necessary or helpful for otherwise healthy children with a URTI.

iv) Assess risk / benefit

- Consider age, presenting symptoms, urgency, co-morbid conditions, type of surgery and anaesthetist's comfort.
- Easy to postpone if child overtly sick. Decision to cancel on a case by case basis.
- General consensus for reschedule is 2-4 weeks

SUGGESTED ALGORITHM FOR THE ASSESSMENT AND ANAESTHETIC MANAGEMENT OF THE CHILD WITH AN UPPER RESPIRATORY INFECTION



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DRUG DOSAGES IN PAEDIATRIC ANAESTHESIA

Hamidah Ismail

1. RESUSCITATION DRUGS

Adrenaline	:	0.01 mg/kg IV/IO (0.1 mL/kg 1:10,000) Max : 1 mg/dose (10 mL 1:10,000) ET = 0.1mg/kg (0.1ml/kg of 1:1,000) Max ET: 2.5 mg/dose
Atropine	:	0.01- 0.02 mg/kg IV; use 0.04 mg/kg IM/ET IV, Max: 1 mg IV
Amiodarone	:	5 mg/kg IV/IO (Max dose 300 mg) bolus for VF / pulseless VT or infuse over 20 min for SVT
Bicarbonate	:	1-2mEq/kg (0.3 x kg x BE) IV, IO
Calcium	:	Calcium Chloride 10% (27mg Ca++/ml) : 0.1-0.3ml/kg IV slowly, max 1gm Calcium Gluconate 10% (9mg Ca++/ml) : 0.6-1 ml/kg IV slowly, max 2gm/dose
Dextrose	:	0.5-1gm/kg IV (1-2ml/kg D50, 2-4ml/kg D25, 5-10ml/kg D10)
Ephedrine	:	0.2-0.3mg/kg/dose
Lignocaine	:	1 mg/kg bolus IV/IO

2. CARDIOVERSION/DEFIBRILLATION

(use lower energy dose initially and increase if needed)

Atrial Arrhythmias	:	0.5 - 1 joules/kg; synchronized
Ventricular Tachycardia with Pulse	:	0.5 - 2 joules/kg; synchronized
Ventricular Fibrillation or Pulseless Ventricular Tachycardia	:	2 – 4 joules/kg
Adenosine	:	0.1mg/kg (max 6 mg); repeat dose 0.2mg/kg (max 12mg)=

3. INOTROPES AND VASOACTIVE DRUGS

Adrenaline : 0.01 - 1 mcg/kg/min, (BW x 0.3)mg in 50ml ; 1ml/hr= 0.1mcg/kg/min
Dopamine : 2 - 20 mcg/kg/min , (BW x 15)mg in 50ml ; 1ml/hr= 5mcg/kg/min
Dobutamine : 2 - 20 mcg/kg/min, (BW x 15)mg in 50ml ; 1ml/hr = 5mcg/kg/min
Isoprenaline : 0.01 - 1mcg/kg/min
(BW x 0.3)mg in 50ml ; 1ml/hr=0.1mcg/kg/min
Milrinone : May load with 25 - 50 mcg/kg over 30 - 60 min, 0.375 - 0.75mcg/kg/min
(BW x 3)mg in 50ml D5 ,1ml/hr= 1mcg/kg/min
Noradrenaline : 0.01 -2 mcg/kg/min (BW x 0.3)mg in 50ml ; 1ml/hr= 0.1mcg/kg/min
Nitroprusside : 0.5 - 10 mcg/kg/min; (BW x 3)mg in 50ml D5 ; 1ml/hr= 1mcg/kg/min
Nitroglycerin : 0.5 - 5 mcg/kg/min; (BW x 3)mg in 50ml D5, 1ml/hr=1mcg/kg/min
Phenylephrine : 0.5-10mcg/kg/min titrate to effect, 0.5-10mcg/kg bolus
Prostaglandin E1: 0.01-0.1mcg/kg/min
Vasopressin : 0.0001-0.001units/kg/min (mix 1.5 U/kg in 50ml so 1 ml/h = 0.0005U/kg/min (adult dose 4 U/h)
Levosimendan : 0.2 mcg/kg/min for 24 hours

4. PREMEDICATION /SEDATIVE DRUGS

Chloral Hydrate : 50-100mg/kg PO/PR (max 2 gm in divided doses)
Clonidine : 0.004mg/kg PO (max 0.1mg)
Dexmedetomidine : 0.1-2 mcg/kg loading dose infused over 10 minutes followed by 0.7-1 mcg/kg/h
Ketamine : 3-6mg/kg PO, 6-10mg/kg PR , 3mg/kg intranasal
Midazolam : 0.05 – 0.3mg/kg IV,IM, 0.2mg/kg intranasal, 0.5mg/kg PO, 0.5-1mg/kg PR
Promethazine : 1mg/kg PO

5. INDUCTION AGENTS

Etomidate : 0.3mg/kg IV
Ketamine : 1-2mg/kg IV
Midazolam : 0.05 – 0.3mg/kg IV,IM, 0.2mg/kg intranasal, 0.5mg/kg PO, 0.5-1mg/kg PR
Methohexital : 1-2mg/kg/dose IV , 30-40mg/kg PR
Propofol : 2-3mg/kg IV, infusion 50-300mcg/kg/min
Thiopenthone : 3-7mg/kg IV, 20-40mg/kg PR

6. MUSCLE RELAXANTS

Atracurium : 0.5mg/kg IV
Cisatracurium : 0.1-0.2mg/kg/dose IV , lasts 15-45 minutes)
Mivacurium : 0.2-0.3mg/kg/dose lasts 15 – 20 minutes
Pancuronium : 0.1mg/kg/dose IV ; lasts 1-2h
Rocuronium : 0.6mg/kg (3 minutes to intubate) , 0.9mg/kg
Suxamethonium : 2-3mg IV for <1 year, 1-2mg/kg IV , 4mg/kg IM
Vecuronium : 0.1mg/kg/dose IV ; lasts 30 minutes

7. REVERSAL AGENTS

Atropine : 0.01-0.02mg/kg IV

Glycopyrrolate : 0.005-0.01mg/kg IV
Neostigmine : 0.05-0.07mg/kg IV
Physostigmine : 0.01mg/kg slow IV
Edrophonium : 1mg/kg IV for muscle relaxation ; 0.2mg/kg IV for myasthenia
Sugammadex : 2mg/kg when TOF ratio 0.7 , 4mg/kg for PTC 1-2, 12mg/kg for urgent reversal.
Flumazenil : (sedation reversal) , 0.01mg/kg IV (Overdose), 0.01 mg/kg then 0.005 – 0.01mg/kg/h
Naloxone : 0.01 – 0.1mg/kg/dose IV ,ET (last for 20 min)

8. ANALGESIA - OPIOIDS

Fentanyl : 1-2mcg/kg/dose
Alfentanil : 30-50mcg/kg at induction, 0.5-1.5mcg/ kg/min
Pethidine : 1mg/kg/dose IV (Rigors 0.1mg/kg/dose once)
Morphine : 0.05 – 0.2mg/kg/dose IV , 0.2 – 0.3mg/ kg/dose PO
Oxycodone : 0.1 – 0.2mg/kg 4 – 6h
Oxycontin SR : 0.1 – 0.2mg/kg 12h
Tramadol : 1-2mg/kg q6h (max 100mg) children 4-16 year old

9. ANALGESIA - NON- OPIOIDS

Acetaminophen : IV routes : 15mg/kg q6h (7.5mg/kg in neonates and infant < 10kg) PO 10-15mg/kg 4-6h, PR 30-40mg/kg loading ,then 20mg/kg q6h (maximum 75mg/kg/24h)
Ibuprofen : 5-10mg/kg PO (max 800mg)
Ketorolac : 0.5mg/kg up to 15mg<50kg, 0.5mg/kg up to 30mg > 50kg
Celecoxib (Celebrex) : > 12 yrs 100-200mg BD
Amytriptyline : 0.5mg/kg titrate to effect
Gabapentin : 5 – 15 mg/kg/day in 3 divided doses for 3 -12 years of age 300mg 8Hly for more than 12 year-old

10. MISCELLANEOUS

Dexamethasone : 0.2 – 1 mg/kg/dose
Dantrolene : 2.4mg/kg load , if no response 4.8mg/kg until symptoms are controlled.
Maintenance : 1.2mg/kg IV 6H as needed.
Esmolol : 100-500 mcg/kg IV over 1-5 minutes, 50-300 mcg/kg/min infusion
Furosemide : 0.5 – 1 mg/kg/dose PO, IM , IV
Granisetron : 10 mcg/kg/dose IV/PO 12 Hly
Heparin : 50-100 U/kg IV bolus then 10-20U/kg/h, cardiopulmonary bypass 300 U/kg IV
Hydrocortisone : anti-inflammatory 0.2 – 1 mg/kg/dose 6Hly status asthmaticus 4 – 8 mg/kg loading, then 2 – 4 mg/kg/dose 4 – 6 Hly
Insulin : 0.02 – 0.1 U/kg/h

Methylprednisolone : anti-inflammatory 0.04-0.2 mg/kg 6H
: status asthmaticus 2mg/kg loading , 0.5-1 mg/kg/dose 6Hly
: spinal shock 30mg/kg IV over 1H then 5.4mg/kg/H x 23H
: liver transplantation 20mg/kg
Magnesium sulphate : 25-50mg/kg over 10-20 minutes IV
Maintenance 16mg/kg/h to achieve plasma level of 0.8-1.2 mmol/L
Metoclopramide : 0.1-0.2 mg/kg/dose PO, IV q6h
Mannitol : 0.25 – 1 gm/kg/dose IV
Omeprazole : 0.6 – 0.7 mg/kg/dose PO (daily or BD)
Ondansetron : 0.15mg/kg IV, SL, PO q8h (max 8mg/dose)

ENDOTRACHEAL TUBES (mm ID)

	Uncuffed	Cuffed
Preterm (<1.5kg)	2.5	
Preterm (1.5-3kg)	3	
Full-term Neonate	3	
1 Year	4	3-3.5
2 Years	5	4-4.5
>2 Years	Age/4 + 4	0.5-1.0mm smaller then Uncuffed ETT

Cuffed ETT :Assure leak with deflated cuff at 20-40cm H2o PIP

SINGLE LUNG VENTILATION

AGE(yr)	ETT (ID in mm)	BB	UNIVENT	DLT
0.5-1	3.5-4.0	5		
1-2	4.0-4.5	5		
2-4	4.5-5.0	5		
4-6	5.0-5.5	5		
6-8	5.5-6.0	5	3.5	
8-10	6.0 cuffed	5	3.5	26
10-12	6.5 cuffed	5	4.5	26-28
12-14	6.5-7.0 cuffed	5	4.5	32
14-16	7.0 cuffed	5	6	35
16-18	7.0-8.0 cuffed	9	7	35

LMA CLASSIC

MASK SIZE	PATIENT SIZE	MAX CUFF VOL Air (ml)	LARGEST ETT (ID mm)
1	Infant up to 5 kg	4	3.5
1.5	Infant 5-10kg	7	4
2	Children 10-20kg	10	4.5
2.5	Children 20-30kg	14	5
3	Children 30-50kg	20	6
4	Adult 50-70kg	30	6
5	Adult 70-100kg	40	7
	Adult > 100kg	50	7

LOCAL ANAESTHETIC (Volume adjusted for nerve block)

Maximum Doses	Plain mg/kg	With Adrenaline (1: 200,000) mg/kg
Lignocaine	5	7
Bupivacaine	2.5	3
Levobupivacaine	2.5	3
Ropivacaine	2.5	3

TRANSFUSION SHORT CUTS

Whole Blood	6 ml/kg	Increases Hb by 1 g/dL
PRBCs	4 ml/kg	Increases Hb by 1 g/dL
Platelets	5-10 ml/kg	Increases platelet count by 50,000-100,000/mm3
Fresh Frozen Plasma	10-15 ml/kg	Factor levels increase by 15-20%
Cryoprecipitate	1 – 2 units/kg	Increases fibrinogen by 60-100 mg/dL

PACKED RED BLOOD CELL (PRBC)TRANSFUSION

$$\text{Volume of PRBC to be transfuse} = \frac{(\text{desired Hct} - \text{present Hct}) \times \text{EBV}}{\text{Haematocrit of PRBC (60)}}$$

MAXIMUM ALLOWABLE BLOOD LOSS (MABL)

$$\text{MABL} = \text{EBV} \times \frac{(\text{present Hct} - \text{minimum accepted Hct})}{\text{Present Hct}}$$

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PERIOPERATIVE PAEDIATRIC RESUSCITATION

Sivaraj Chandran

By the end of this chapter you should be able to:

1. *Recognize the need for resuscitation*
2. *Manage paediatric resuscitation*
3. *Perform resuscitation in prone position*
4. *Monitor the effectiveness of CPR*
5. *Administer Post resuscitation Care*

1. Recognizing the Need for Resuscitation

Early detection of problems and prompt action is the key for successful resuscitation. Intraoperative indication for resuscitation includes hypoxaemia, hypotension, bradycardia, arrythmias, abrupt decrease in ETCO2 and asystole.

Early resuscitation responses:

1. Inform the surgical and nursing team
2. Call for help and a crash cart
3. Stop the administration of potentially deleterious substance
4. Stop surgical stimulation.

5. Place the patient on 100% oxygen (unless fire in airway).
6. Consider Trendelenburg position and wide-open (isotonic) fluids if the patient is hypo-tensive.
7. Start chest compressions if vital organ blood flow is compromised.
8. Assign leader and roles and start resuscitation record.

2. Airway Management

1. Consider early tracheal intubation to secure the airway during CPR. However, do not forget that patient dies because of failure to oxygenate rather than failure to intubate.
2. If unable to intubate, oxygenate the patients first either with bag-valve-mask or with supraglottic airway while waiting for expert help.
3. Do not cause undue interruption of oxygenation or chest compression
4. Consider cuffed ET tube in
   - poor lung compliance
   - high airway resistance or
   - a large glottic gas leak (uncuffed ETT)
5. Use 100% oxygen during CPR
   Wean oxygen down to 94-99% after ROSC (return of spontaneous circulation) in the post resuscitation period
6. Avoid excessive ventilation

Advantages of tracheal tubes

- Prevents need for interruption during compression
- Obviates need for a team member to hold continuous cricoid pressure during ventilation to reduce risk of aspiration
- Reduce risk of stomach distension and splinting of diaphragm

3. Circulation

Effective chest compression

- Maintain good hand position, lower half of sternum
- Push hard at least > 1/3 AP chest diameter
- Push fast at least 100-120/minute allowing complete chest recoil
- BVM: 15 compressions: 2 ventilations
- Advanced airway (ETT or supraglottic airway): continuous compression and 1 breathe every 2-3 sec (20-30 breaths/min)
- Minimize interruption between compressions
- Switch rescuer at 2-minute interval or earlier to prevent fatigue
- On return of spontaneous circulation (ROSC), ventilate 12-24/minute depending on age normal values
- Always consider and treat the reversible 6H & 5T'S during CPR

- For more effective chest compression, use 2 thumbs encircling method to deliver compression for infant.
- Allow full chest recoil and avoid leaning on the child's chest during relaxation phase.

4. Medication Administration

- Good venous access is needed for medication administration;
- IV or IO access is better than ETT route.
- During CPR, any medication given via peripheral / central line with the tip below di-aphragm should be flushed with at least 0.25ml/kg Normal Saline.

5. Defibrillation & Cardioversion

- Use a biphasic defibrillator at an initial dose of 2 joules/kg.
- Second attempt at 4 joules/kg, and subsequent shock doses may be increased to a maximum of 10 joules/kg.
- Biphasic shock waveform is more effective and requires less energy to terminate fi-brillation in the heart.
- Use of biphasic energy results in increased success with fewer complications and the need for only 1 shock at a time, thus reducing the interruption of chest compressions and reducing no-flow time during defibrillation attempts.
- Synchronised cardioversion is used for arrhythmias with unstable haemodynamic in the presence of a pulse and requires less energy delivery than does defibrillation.
- Starting dose is 0.5 to 1.0 joule/kg. If it is ineffective, the dose can be increased to 2 joules/kg.

6. Prone Resuscitation

- Initiate CPR in prone position to minimize the no-flow interval till patient is placed supine
- Posterior compression can be done by heel of one hand on spine and second hand on top if there is no midline incision
- Place a fist or sandbag under sternum for more effective counter pressure
- Prone CPR should be performed for 2 minutes, and then adequacy of CPR is evaluated by looking at the capnograph and reposition back to supine
- For Prone CPR in presence of midline incision, using the heel of each hand placed on the ribs on each side of incision under scapula.
- For infant, the compression can be done by using encircling technique and thumb in midline if no incision and thumbs in lateral if there is an incision .

7. Monitoring the Effectiveness of CPR

1. Quantitive ETCO2

Keep ETCO2 > 10 mmHg

- Confirms placement of ETT
- A sudden increase in ETCO2 suggests ROSC
- Adrenaline and vasoconstrictors may transiently decrease ETCO2
- Sodium Bicarbonate transiently increases ETCO2

2. Arterial diastolic Blood Pressure

Keep Diastolic Pressure > 15 mmHg

Correlates with myocardial blood flow and likelihood of ROSC

3. Central Venous Oxygen Saturation (ScVO2)

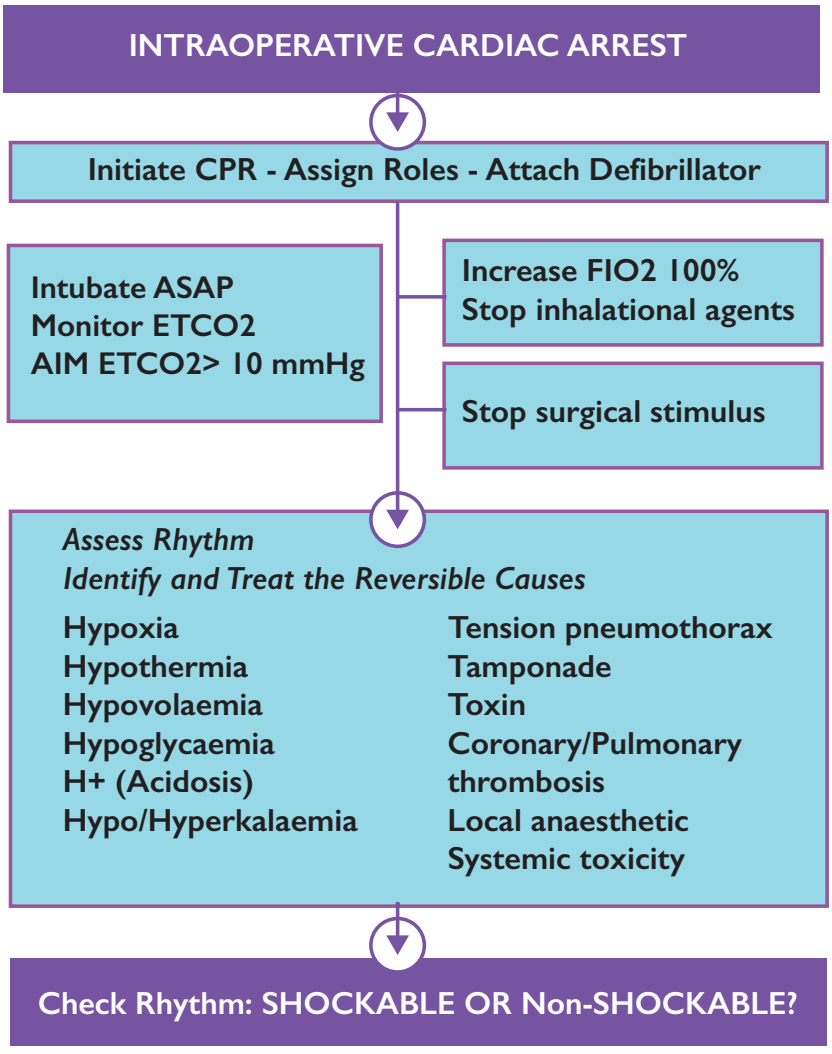
Aim ScVO2 > 30%

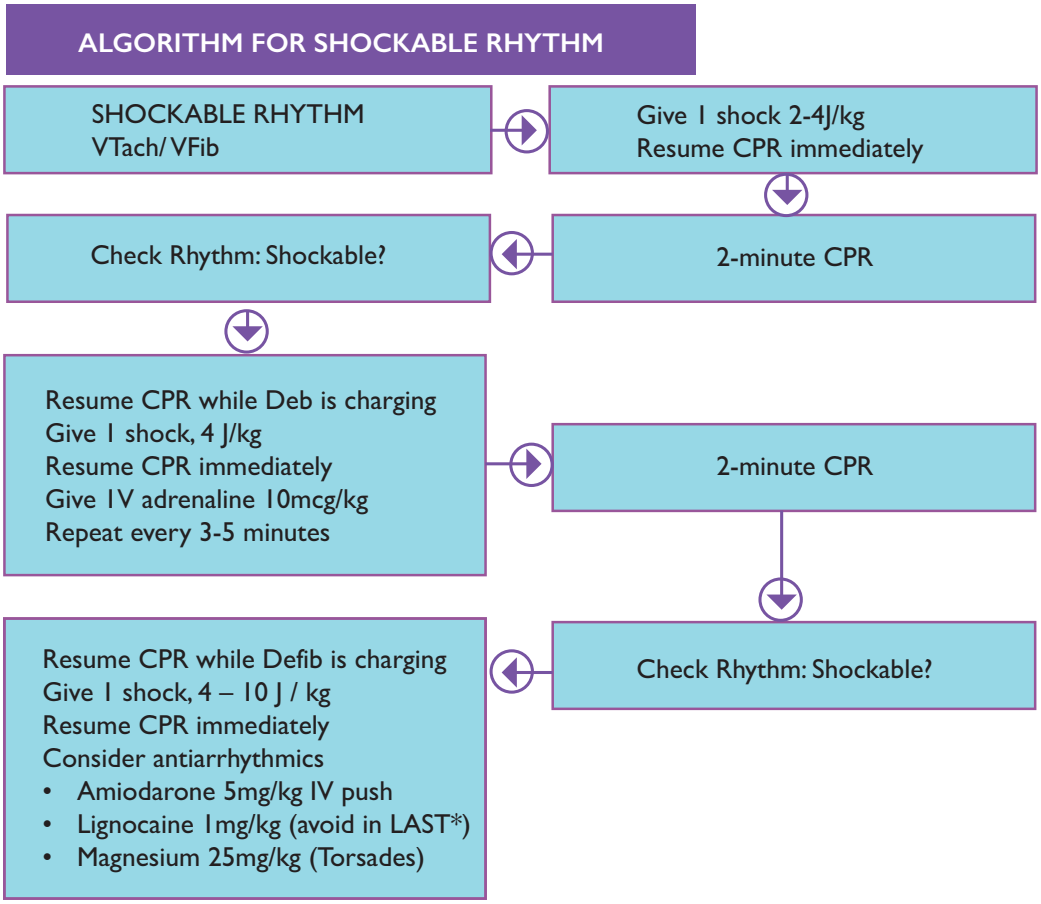
4. Palpation of pulse

May lead to the misinterpretation of retrograde venous pulsation as arterial flow because of adjacent vascular structures

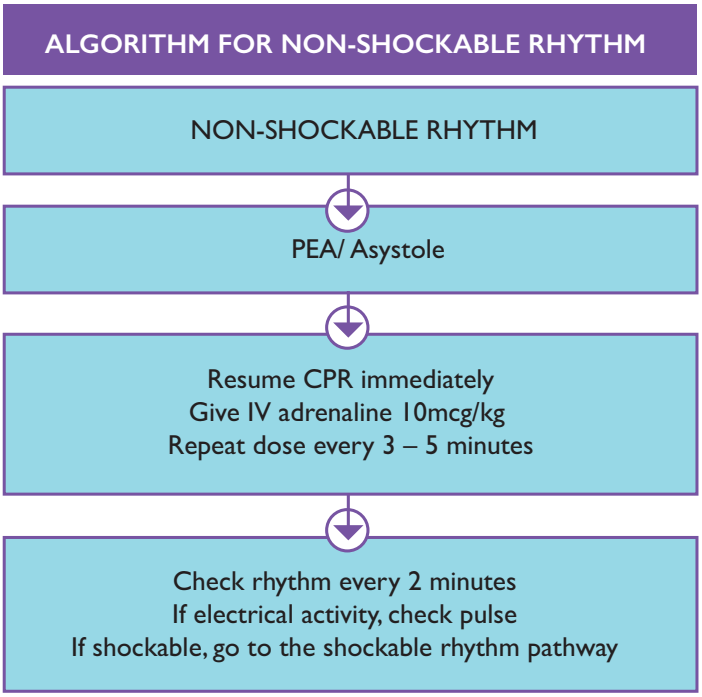
8. Post Resuscitation Care

- Maintain normotension
- Temperature Maintenance (Avoid fever, consider therapeutic hypothermia 32-34°C)
- Maintain oxygen saturation 94-99%
- Avoid hyperventilation
- Maintain normoglycaemia
- Break bad news to parents & family
- Team Debriefing





**LAST – Local Anaesthetic Systemic Toxicity*



PEA – Pulseless Electrical Activity

Hypoxia during intraoperative period

1. Give 100% oxygen
2. If on ventilator, switch to hand-bag ventilation and check lung compliance
3. If patient is still hypoxic, call for help and declare an emergency

Determine Airway Patency

- Obstruction / Leak Present?
- Kinked / Disconnection airway device?

If no signs of obstruction or leak

AUSCULTATE FOR BREATH SOUNDS

- Look for wheezing / rhonchi
- If clear breath sounds, good chest expansion – check for BP / Perfusion

If there is obstruction / poor compliance

- Check for kinked airway device / tubing
- Check ETT depth; endobronchial intubation
- Suction ETT

If no improvement with all above , remove airway device , establish bag mask ventilation, get help and re-secure the airway

If Circuit Leak, bag does not fill

- Check for disconnection
- Chest soda lime canister for leak
- Possible ETT / LMA cuff not sealing trachea

If no improvement with all above, switch to self-inflating ventilation bag used for emergencies and get help

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PERIOPERATIVE PAEDIATRIC LARYNGOSPASM

Sivaraj Chandran

By the end of this chapter you should be able to:

1. *Identify risk factors for laryngospasm*
2. *Recognize and manage laryngospasm*

Laryngospasm:

- **Is a reflex closure of the upper airway as a result of the glottic musculature spasm.**
- **is an anaesthetic emergency.**
- **Can be complete or partial.**
- **Can lead to hypoxia, bradycardia and eventually cardiac arrest.**

1. Prevention

Identify Risk Factors

>Anaesthesia Related factors

1. Insufficient depth of anaesthesia
2. Airway iritation caused by:
   - Volatile Agents (desflurane > isoflurance > sevoflurane)
   - Mucous
   - Blood
   - Manipulation (laryngoscopy , suction catheter)
3. Airway Device
   - Use of SGA predisposed patient to greater risk of laryngospasm than ETT.

IV induction agents

- Thiopentone predisposed patient to greater risk of laryngospasm than propofol

Experience of anaesthetist

- Inexperienced anaesthetist are more likely to cause laryngospasm

>Patient Related factors

1.Age

- Inverse correlation with age, in which younger patients are at greatest risk.

2. Airway Hyperactivity
   - Asthma (10 times increased risk , if active asthma)
   - URTI (10 -fold risk, up to 6 weeks). Therefore it is advisable to delay elective cases for at least 2 weeks from recovery of URTI.
   - Passive exposure of Tobacco smoke (10 times increased risk in children)
3. Obese patients with OSA
4. Patients with airway anomaly (Subglotic stenosis, cleft palate, vocal cord paralysis, laryngomalacia, tracheal stenosis, Pierre Robin Syndrome)
5. Patients with GERD due to primary aspiration or chronic inflammation of upper airway.

>Surgical Related Factors

Shared airway surgery eg Tonsillectomy / Adenoidectomy carry greatest risk

2. Recognition of Laryngospasm

Clinical Features

- Inspiratory stridor which may progress to complete obstruction
- Signs of airway obstruction - Increase respiratory effort, tracheal tug, paradoxical respiratory effort
- Obstruction not relieved by Guedel airway
- Oxygen desaturation with or without bradycardia

Signs of complete airway obstruction:

- No chest wall movement with no breath sounds on auscultation
- No stridor
- TIGHT BAG CANNOT VENTILATE

3. Treatment of Laryngospasm

- Maintain airway (chin lift, jaw thrust)
- Give CPAP, 100% Oxygen
- Clear the secretions / blood

Assess air entry and bag movement

If air entry and bag movement **PRESENT**

- Deepen Anaesthesia with boluses of IV propofol 0.5 to 1.0 mg/kg or with sevoflu-rane
- Reassess air entry with CPAP
- If improve, maintain the airway until the child is fully awake
- If no improvement, intubate

If air entry and bag movement **ABSENT**

- Get help for intubation
- Consider IV suxamethonium 0.5 to 2 mg /kg after IV atropine 0.02mg/kg

Or IV propofol 1mg/kg

- Intubation with positive pressure ventilation

CPAP = continuous positive airway pressure

Larson' s Notch – "Laryngospasm Notch"

Apply pressure firmly, bilaterally, inwardly and anteriorly at the the laryngospasm notch while performing jaw thrust
(Contraindicated in mastoid surgery, base of skull surgery)

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ANAPHYLAXIS

Ina Ismiarti Shariffuddin

By the end of this chapter you should be able to:

a. Identify the cause of perioperative anaphylaxis

b. Manage perioperative anaphylaxis

INTRODUCTION

Perioperative allergic reaction is rare but can be fatal. It can be classified according to the modified Ring and Messmer scale, Grade I-IV as shown below. (Table 1) Grades I and II reactions are not life-threatening and more likely to be non-allergic , whilst Grades III and IV reactions are life-threatening, fulfil the criteria for anaphylaxis, and is usually IgE- mediated.

Table 1. Grading of suspected perioperative allergic reactions according to the modified Ring and Messmer scale.

Grade	Clinical signs
I	Skin, mucosal signs, or both: generalised erythema, extensive urticaria, or both with or without angioedema
II	Moderate multi-organ involvement: skin, mucosal signs, or both with or without moderate hypotension, tachycardia, moderate bronchospasm or gastrointestinal symptoms
III	Life-threatening mono- or multi-organ involvement: life-threatening hypotension, tachycardia, or bradycardia with or without cardiac arrhythmia, severe bronchospasm, skin, mucosal signs, or both, or gastrointestinal symptoms
IV	Cardiac or respiratory arrest

Possible causes for anaphylaxis:

Common allergens in perioperative period are NMBA, antibiotics and latex.1

Management for life threatening anaphylaxis (grade III and IV)

Early diagnosis of anaphylaxis is crucial. Other cause of hypotension, bronchospasm cardiac arrest need to be excluded.

Other differential diagnosis to exclude:

1. too deep anaesthesia leading to hypotension
2. too light anaesthesia leading to bronchospasm
3. drug induced histamine release leading to vasodilation
4. septic shock

Immediate management

1. Use the ABC approach (Airway, Breathing, and Circulation).
2. Remove all potential causative agents and maintain anaesthesia, if necessary, with an inhalational agent.
3. CALL FOR HELP and note the time.
4. Maintain the airway and administer oxygen 100%. Intubate the trachea if necessary and ventilate the lungs with oxygen.
5. Elevate the patient's legs if there is hypotension.
6. If appropriate, start cardiopulmonary resuscitation immediately according to Advanced Life Support Guidelines.
7. Give IV Adrenaline at 1.0 mcg.kg-1 (0.1ml.kg-1 1:100 000 solution)
8. Several doses may be required if there is severe hypotension or bronchospasm. If several doses of adrenaline are required, consider starting an intravenous infusion of adrenaline.
9. Give saline 0.9% or lactated Ringer's solution at a high rate via an intravenous cannula of an appropriate gauge at 20 ml.kg-1
10. For persistent bronchospasm/high airway pressures after 10 min, can administer inhaled bronchodilators (e.g. salbutamol). If persistent bronchospasm despite of this, consider IV bronchodilators (e.g. ketamine, salbutamol, aminophylline or magnesium sulphate).

Secondary management

After adequate epinephrine and fluid resuscitation, these drugs can be administered:

1. IV Hydrocortisone
   - Child 6 - 12 years: 100 mg
   - Child 6 months - 6 years: 50mg
   - Child <6 months: 25mg

2. IV Chlorphenamine
   - Child 6 - 12 years: 5 mg
   - Child 6 months - 6 years: 2.5 mg
   - Child <6 months: 250 mcg. kg-1

Investigation

1. Take blood samples for mast cell tryptase:
   - Initial sample as soon as feasible after resuscitation has started - do not delay resuscitation to take the sample.
   - Second sample 1 - 2 h after the start of symptoms.
   - Third sample either at 24 h or in convalescence (for example in a follow-up allergy clinic).

Investigations to identify the causative agent

1. The anaesthetist who gave the anaesthetic or the supervising consultant anaesthetist is responsible for ensuring that the reaction is investigated in a special allergic clinic.
2. The patient should be informed on the reaction and is given a written and verbal recommendations for subsequent anaesthesia.

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DESATURATION

Ina Ismiarti Shariffuddin

By the end of this chapter you should be able to:

a. Identify the cause of desaturation in anaesthesia

b. Manage desaturation

INTRODUCTION

Desaturation under anaesthesia can potentially be life threatening and if the cause of desaturation is not address in a rapid manner, the patient may suffer grave prognosis. Therefore, the cause for desaturation in paediatric patient should be managed promptly. A patient with SpO2 of less than 94% is assume hypoxia until proven otherwise.

Possible causes for desaturation:

Desaturation in a patient perioperatively should be approached in a rapid and logical manner. The easiest way to exclude the cause of desaturation or hypoxia is to use "**ABCDE**":

Airway: Is the airway clear?
Breathing: Is the breathing adequate?
Circulation: Is the circulation working normally?
Drugs: Any drug causing a problem?
Equipment: Is the equipment working properly?

Management

Hand ventilate the patient via a facemask, LMA or endotracheal tube if the respiration is inadequate.

Use with 100% Oxygen (if needed use Oxygen from a tank).

Check the SPO2 Probe and waveform, reposition if needed.
Call for HELP.

Rule out causes using ABCDE (as below) and treat accordingly.

Source of problem	Common Problem	Management
AIRWAY	a. Laryngospasm b. One lung ventilation due to endobronchial intubation c. Excessive secretion blocking the airway d. Aspiration	Administer high flow 100% oxygen Rule out any airway obstruction: - Use chin lift / jaw thrust if using a mask - rule out laryngospasm (partial: presents of inspiratory stridor, Complete: silent chest). Treat laryngospasm if present. - Suction the airway to clear secretions Check position of tracheal tube/ LMA; Reposition LMA if necessary and if in doubt take LMA or tracheal tube out
BREATHING	a. Bronchospasm b. Hypoventilation c. Pneumothorax d. Pulmonary embolism	Check adequate rate and check adequate tidal volume. Check ET CO2. Rule out any ETT blockage/kinked. Listen to both lungs Bronchospasm? - consider bronchodilators. Pneumothorax? - consider chest drain.
CIRCULATION	a. Hypotension b. Bradycardia c. Hypovolaemia	Check pulse Check blood pressure Check ECG Check for blood loss / dehydration / fluid loss? If no pulse/BP/ signs of life, Start CPR and consider reversible causes (4H's, 4T's **H**ypotension, **H**ypovolaemia, **H**ypoxia, **H**ypothermia; **T**ension pneumothorax, **T**amponade (cardiac), **T**oxic effects (deep anaesthesia, sepsis, drugs), **T**hromboemboli (pulmonary embolism).
DRUGS	a. Anaphylaxis b. Hypotension c. Paralysed muscle	If anaphylaxis is suspected; stop administration of the drug and manage anaphylaxis accordingly.
EQUIPMENT	a. Check for disconnection or obstruction of the breathing circuit b. oxygen supply not working c. monitoring equipment failure	Faulty anaesthesia equipment: Use a self-inflating bag to ventilate the patient with air while new equipment or oxygen supplies are obtained. If equipment is missing, mouth to tracheal tube, or mouth-to-mouth ventilation, may be lifesaving.

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RESTLESS CHILD IN RECOVERY

Phang Ye Yun

By the end of this chapter you should be able to:

a) Identify the cause of restlessness

b) Recognize emergence delirium (ED) and identify risk factors

c) Prevent and manage ED

INTRODUCTION

- Restless child in the recovery room is distressing, not only for the staff, but also for the parents. More so when it results in physical harm and dislodging intravenous access, drains, catheter etc.
- This often creates a false impression of the "quality" of the anaesthesia.
- Before attributing restlessness to ED, other serious causes should be excluded.

Possible causes for restlessness or agitation in recovery:

- Pain
- Hypoxia and Hypercarbia

- Airway obstruction
- Hypoglycemia
- Central nervous system illness e.g. seizures, raised intracranial pressure
- Electrolyte imbalance especially hyponatremia
- Temperature abnormalities
- Drugs - Extrapyramidal effects, especially from some antiemetics
  – Inadequate reversal of muscle relaxants
- Full bladder, urinary retention
- Fear/anxiety
- Thirst, hunger
- Underlying behavioral disorder e.g. austism, ADHD
- **Emergence delirium**
  d) a state of postoperative confusion and disorientation associated with restlessness, involuntary movements and inconsolability.
  e) Symptoms include agitation, hyperactivity with flailing movements, confusion, and failure to recognise/engage with people and the surroundings.
  f) can be accompanied by behavioural changes such as thrashing, screaming, prolonged crying and combativeness.
  g) usually self-limiting and short-lived. It occurs within the first 30 min after anaesthesia, lasts for a few minutes to hours but may take up to 2 days to resolve.
  h) incidence: varies from 20%-80% in paediatrics

Risk factors for ED

- Age: pre-schoolers (2-5 years) - psychological immaturity
- Preoperative anxiety, previous surgery
- Parental anxiety
- Sevoflurane/desflurane anaesthesia - rapid washout and emergence from anaesthesia
- Surgery in head and neck areas especially tonsils, thyroid, teeth, ears and eyes.
- Child temperament

Treatment for ED

1. Paediatric Anaesthesia Emergence Delirium (PAED) scale as showed in Table 1 can be used in identifying and monitoring the severity of ED once the alternative pathological causes have been eliminated.

Table 1. Paediatric Anaesthesia Emergence Delirium (PAED) scale

Behaviour	Not at all	Just a little	Quite a bit	Very much	Extremely
Make eye contact	4	3	2	1	0
Purposeful actions	4	3	2	1	0
Aware of the surroundings	4	3	2	1	0
Restless	0	1	2	3	4
Inconsolable	0	1	2	3	4

PAED scale: Maximum score = 20. Higher score indicates increased severity

2. Ensure patient safety, excluding physical discomfort and reassurance. Reunite patient with parents.
3. Pharmacological treatment should be undertaken if there is a potential risk of selfinjury, such as:
   - IV fentanyl 1-2 µg/kg
   - IV propofol 0.5-1.0 mg/kg
   - IV midazolam 0.02-0.1 mg/kg

Prevention of ED

1. Identify those with high risk of ED and modify anaesthetic technique.
2. Reduce parental and child preoperative anxiety by giving pre-emptive preparation and also premedication to anxious children if necessary.
3. Ensure adequate analgesia and apply regional technique whenever possible.
4. TIVA with propofol been shown to reduce the risk of ED.
5. Drugs given below have been reported to be useful for prevention and treatment of ED. Note that these preventive strategies increase sedation and may delay discharge from post anaesthetic care unit.

Table 2. Drugs useful for prevention of ED.

Agent	Route/time of administration
Propofol	I.V.TIVA/ I.V. at end of surgery (1mg/kg)
Midazolam*	P.O. premedication (0.5 mg/kg) / I.V. at end of surgery (0.03mg/kg)
Clonidine	Caudal (1µg/kg)/ I.N. preoperative (4 µg/kg)/ I.V. (intra-/postoperative) (1-3 µg/kg over 10 min)
Dexmedetomidine	I.N. preoperative (2-3µg/kg)/ I.V. intraoperative infusion (0.2-1.0 µg/kg/h)/ I.V. at end of surgery (0.3 µg/kg)
Fentanyl	I.V. intraoperative (2 µg/kg) or at end of surgery (1 µg/kg)
Alfentanil	I.V. intraoperative (10 µg/kg)
Dexamethasone	I.V. preoperative (0.2 mg/kg)
Ketamine	P.O. premedication (6mg/kg)/ I.N. preoperative (2mg/kg) /I.V. at end of surgery (0.25mg/kg)

*May cause paradoxical agitation. I.V.= intravenous, TIVA= total intravenous anaesthesia, P.O.= per oral, I.N.= intranasal

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POST-OPERATIVE NAUSEA AND VOMITING IN CHILDREN

Phang Ye Yun

By the end of this chapter you should be able to:

a. Identify the risk factors of post-operative vomiting

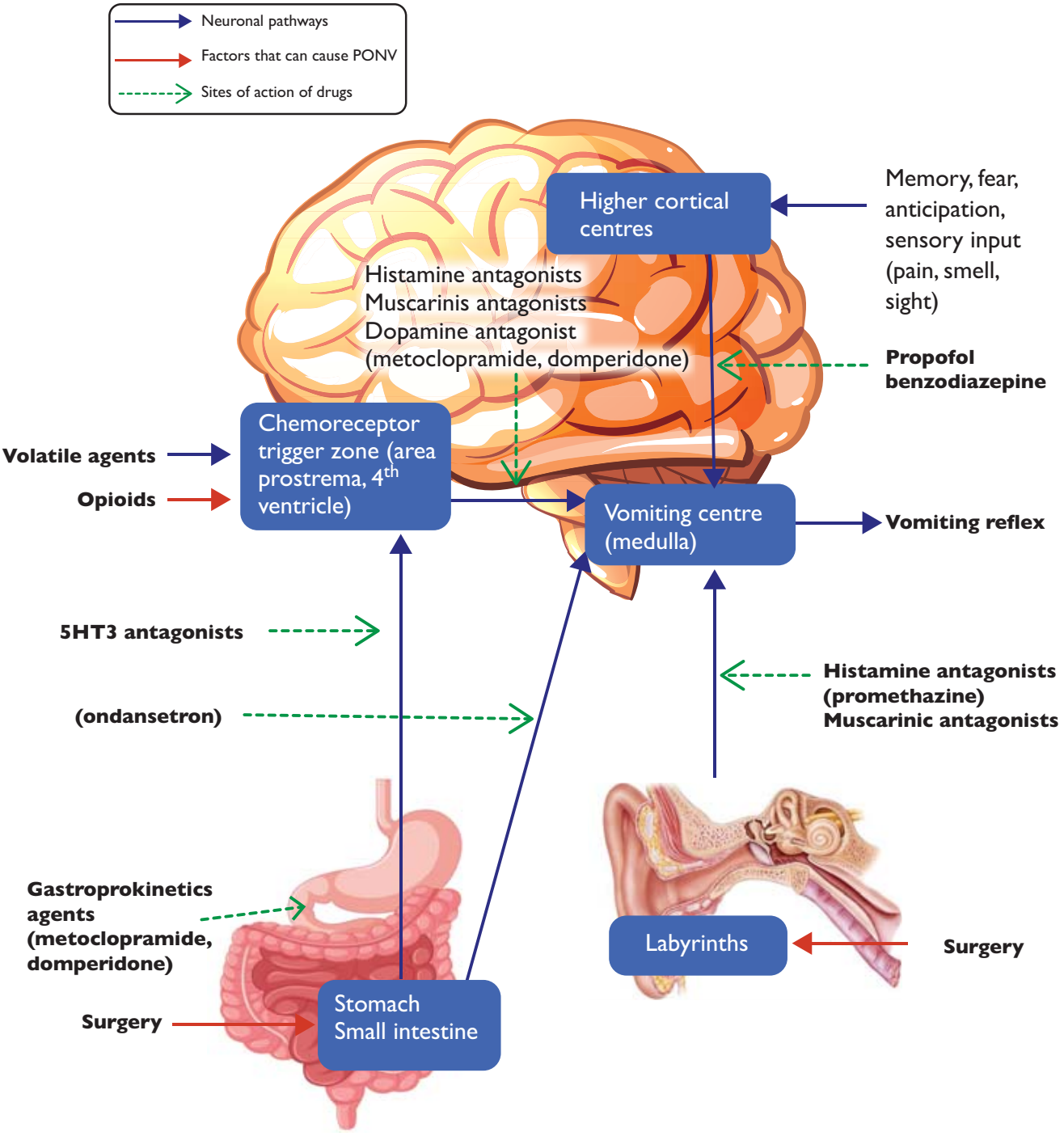
b. Prevent and manage PONV

INTRODUCTION

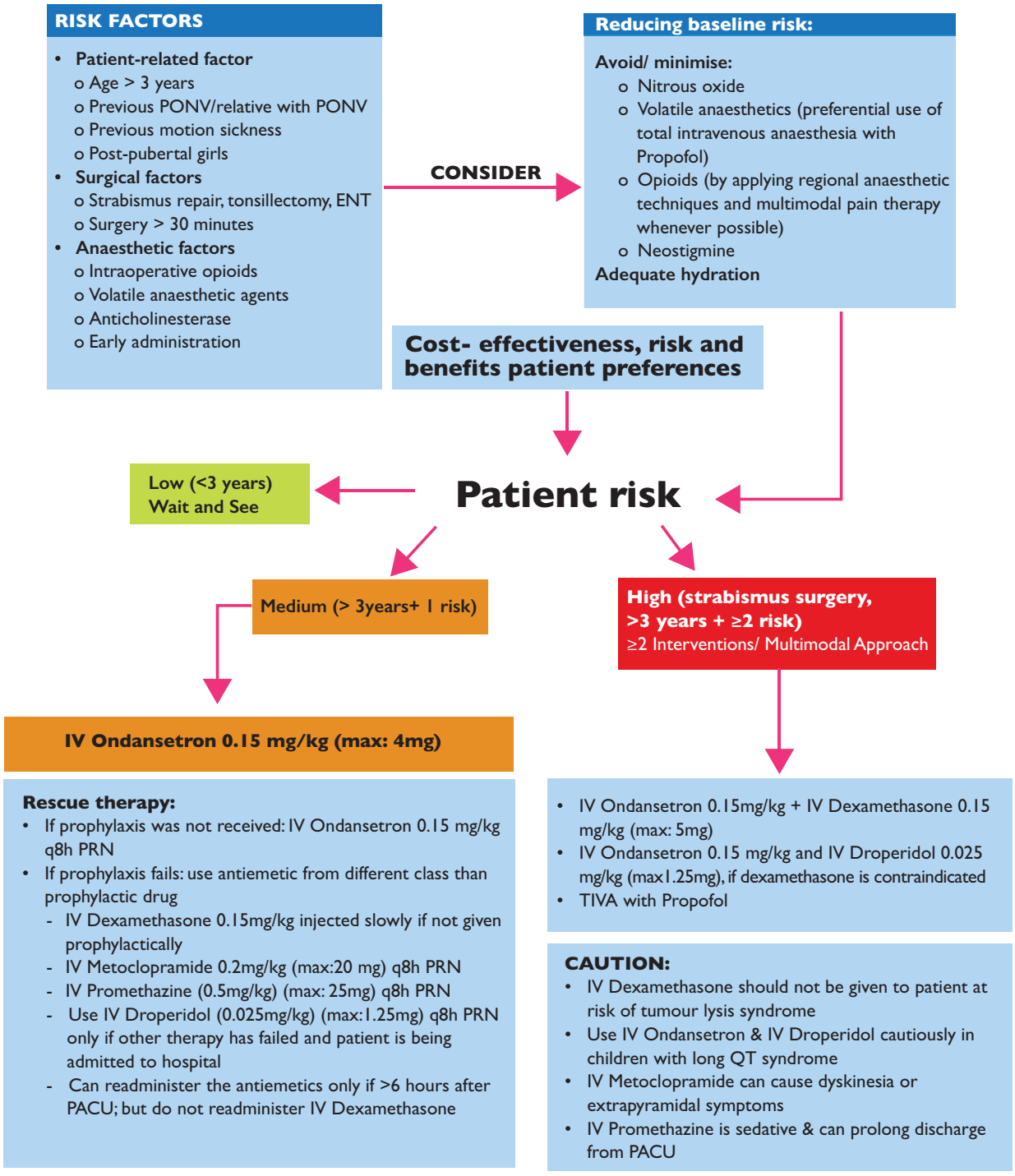
Nausea is the uncomfortable sensation of an impending episode of vomiting whereas vomiting is complex and is mediated by vomiting centre, thought to reside in the brainstem. Postoperative vomiting (POV) is more commonly studied in children than postoperative nausea because of a child's inability to effectively express distress after experiencing nausea. Severe post-operative vomiting can lead to pulmonary aspiration, hypovolaemia and electrolyte imbalance (hyponatraemia), fatigue, wound dehiscence, esophageal tears, delay in hospital discharge and last but not least, anxiety among patients.

Incidence:

- Overall incidence: 13 – 42%, 2x as in adults
- Inversely related to age, less than 3 years old : 22–40%; more than 3 years old 42 – 51% (increase 0.2-0.8% / year)
- No difference between boys and girls before puberty (after puberty females have 2 to 3 times the incidence of PONV as males)



Treatment strategies for postoperative nausea and vomiting
Recommendation for the Management of PONV in children



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