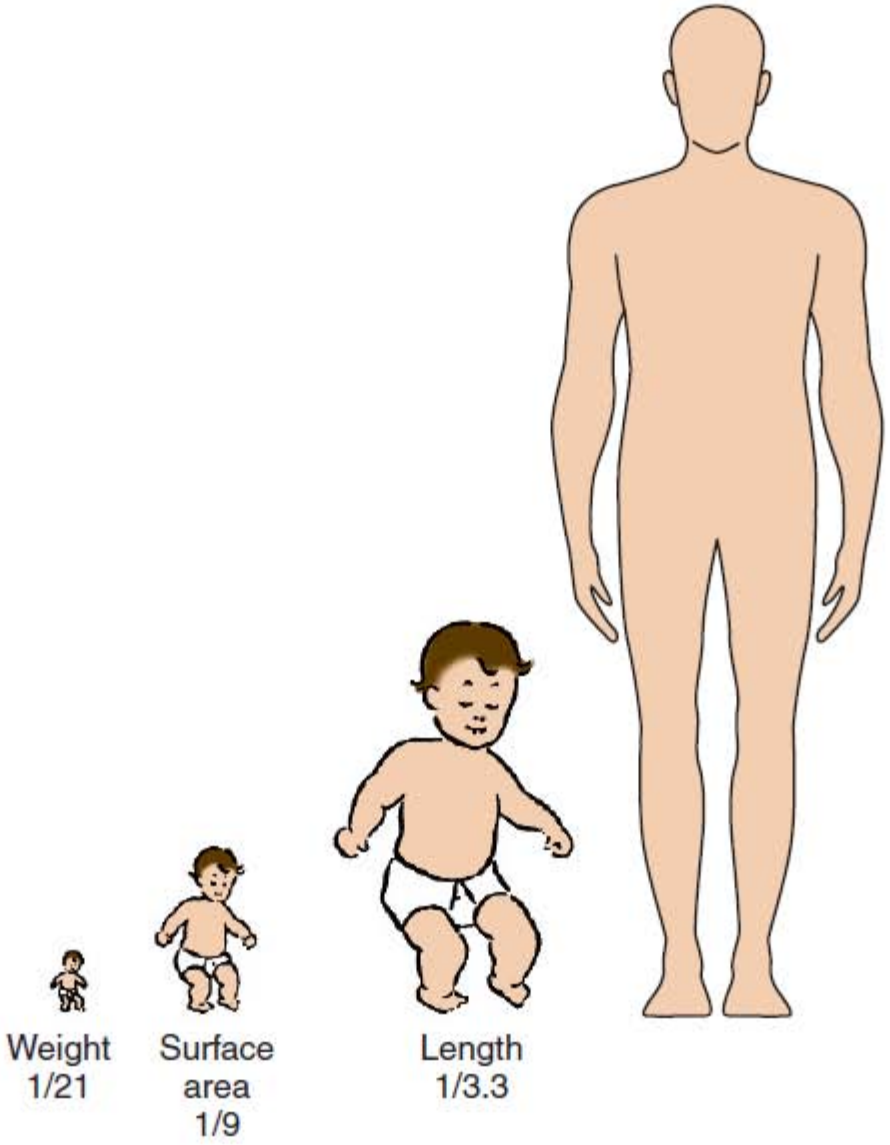
PEDIATRICS ANESTHESIA

DR.SIRILUK CHUMNANVEJ
ANESTHESIOLOGIST

The "little" patients
should not be considered
"miniature adults".

Proportions of newborn to adult



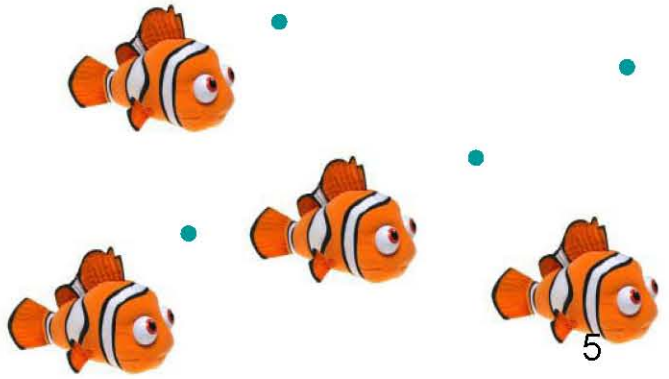
Smith's Anesthesia for Infants and Children, 8th ed., 2011.

PEDIATRICS ANESTHESIA

1. Developmental Physiology of the Infant
2. Common Neonatal Problems
3. Anesthetic Equipment
4. Fasting Time
5. Preoperation & Premedication
6. Management of Anesthesia
7. Fluid Management
8. Postoperative Care
9. Special Problems

1.Developmental Physiology of the Infant

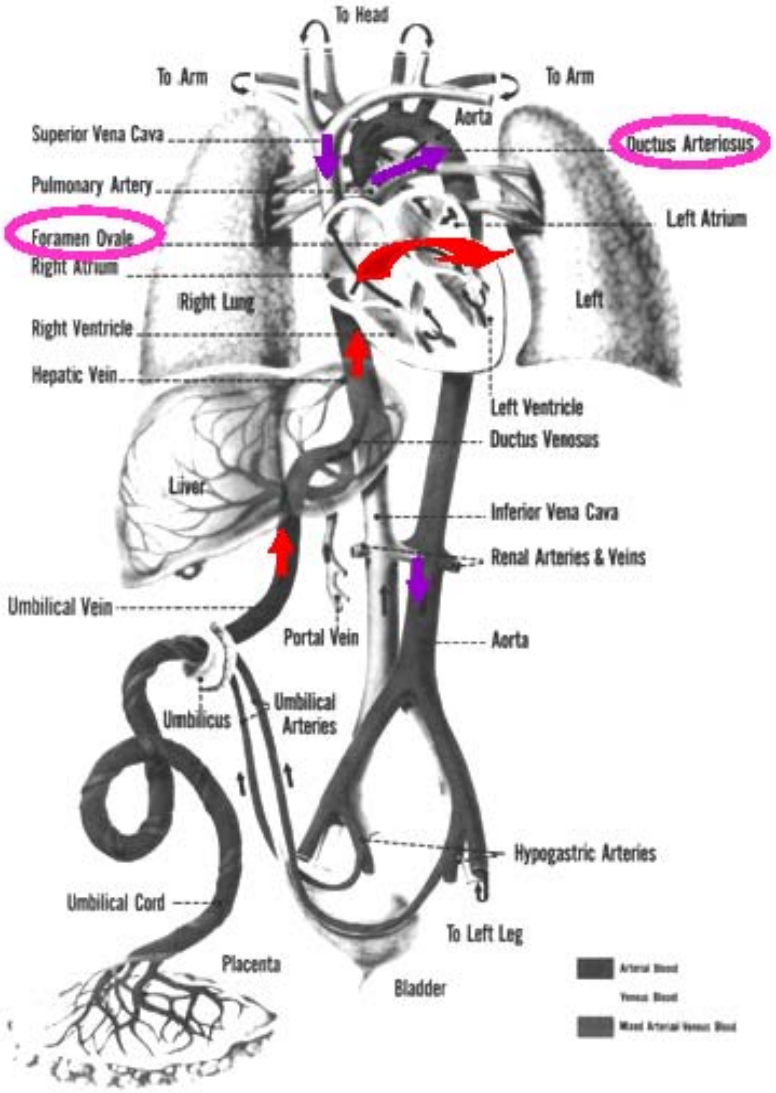
- Cardiovascular System
  - Fetal and Adult Circulations
- Respiratory system
  - Airway of the infant
- Central nervous System
- Kidneys
- Liver
- Gastrointestinal System
- Thermoregulation
- Metabolism

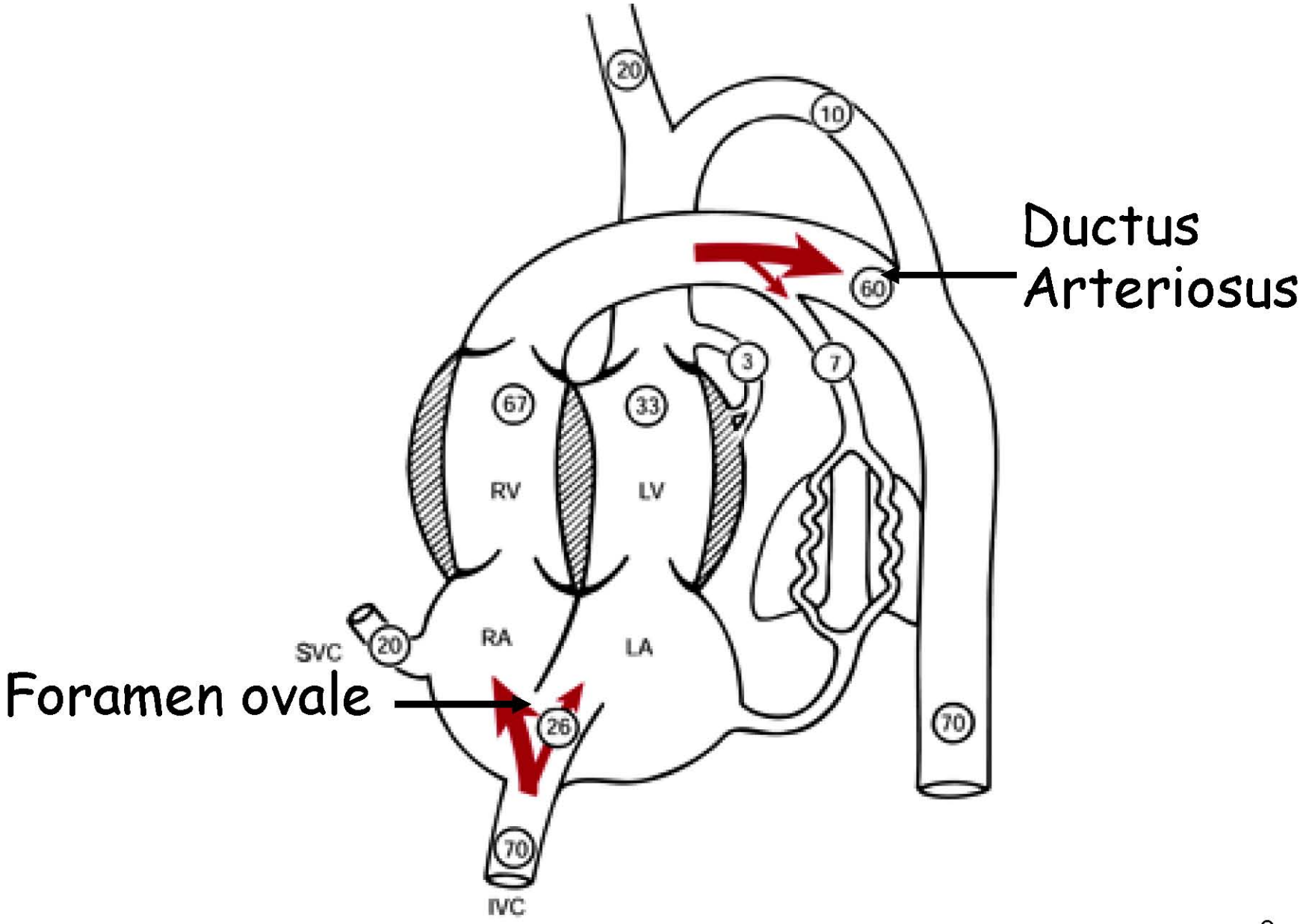


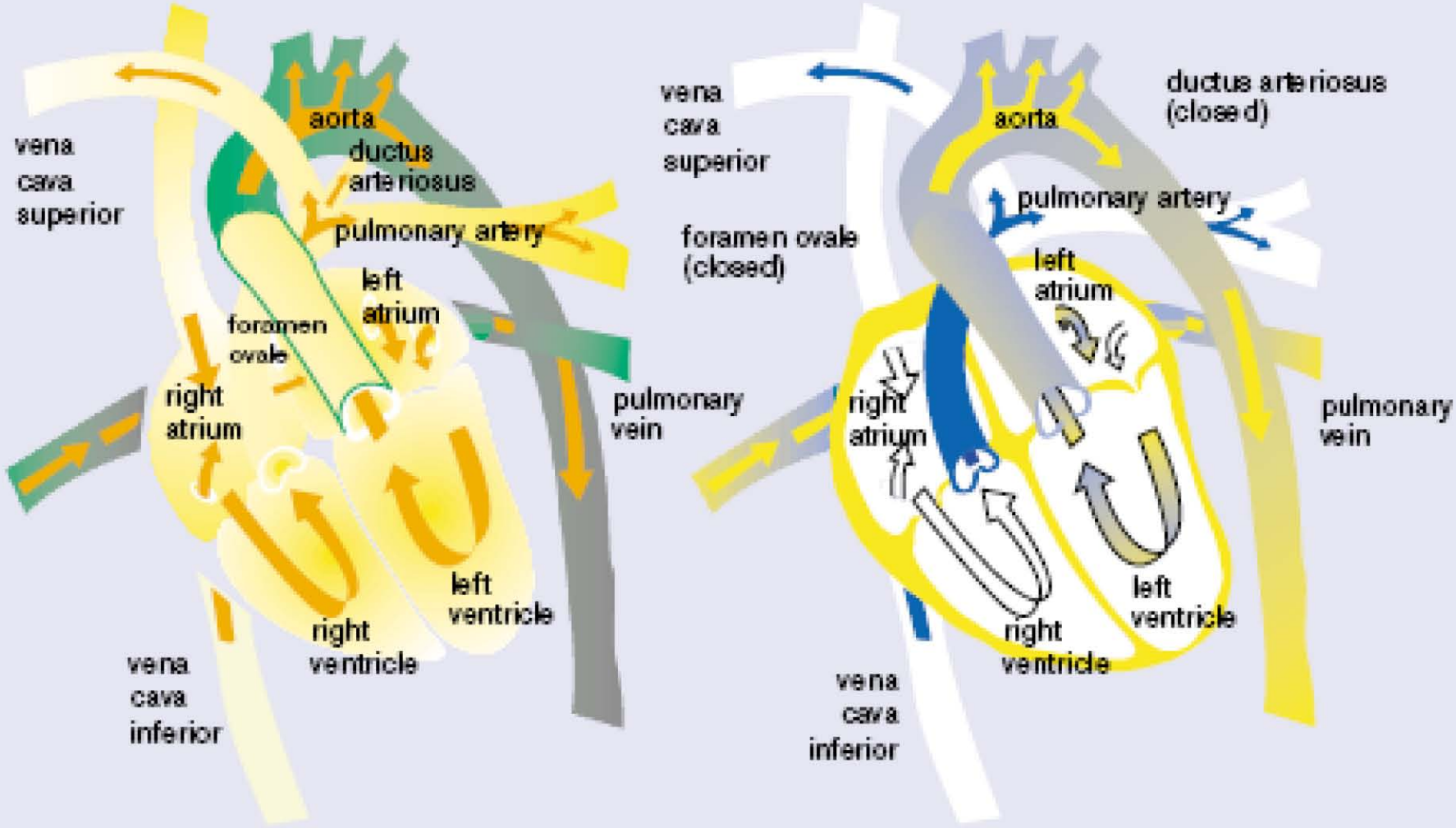
Cardiovascular System

- Fetal circulation to adult circulation
- Immature myocardium
  - sensitive to volume loading
  - poor tolerance to increased afterload
  - heart rate-dependent cardiac output

Fetal and Adult Circulations




Ductus Arteriosus
Foramen ovale
20
10
60
3
7
67
33
RV
LV
SVC
20
RA
LA
26
70
70
IVC


vena
cava
superior
aorta
ductus
arteriosus
pulmonary artery
left
atrium
foramen
ovale
right
atrium
pulmonary
vein
left
ventricle
right
ventricle
vena
cava
inferior
vena
cava
superior
foramen ovale
(closed)
aorta
ductus arteriosus
(closed)
pulmonary artery
left
atrium
right
atrium
pulmonary
vein
left
ventricle
right
ventricle
vena
cava
inferior

Heart Rate in Children

	Awake	Asleep	Exercise/Fever
Newborn	100–180	80–160	<220
1 week–3 months	100–220	80–200	<220
3 months–2 years	80–150	70–120	<200
2–10 years	70–110	60–90	<200
>10 years	55–90	50–90	<200

Smith's Anesthesia for Infants and Children, 9th ed., 2017.

BP & HR in Children

Age	HR	BP
NB	120	70/45
1 yr	120	80/60
2 yr	110	80/60
4 yr	100	85/60
6 yr	100	90/60
8 yr	90	95/62
10 yr	90	100/65

Mean SBP

Age > 1 year can be calculated from the formula:

- Upper limit (5th centile) is:

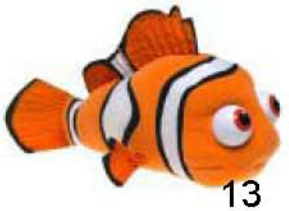
$$\text{SBP} = 90 + (\text{Age in years} \times 2)$$

- Lower limit (5th centile) is:

$$\text{SBP} = 70 + (\text{Age in years} \times 2)$$

Respiratory system

- Anatomy of Airway
- Oxygen consumption
- Respiratory muscles



Airway of the infant

- Obligate nose breather
- Large head, short neck, large tongue
- High and Anterior larynx
- Short epiglottis & angled over laryngeal inlet
- Vocal cords are angled
- Funnel-shaped larynx
- Narrowest portion = subglottic region at the level of the cricoid cartilage

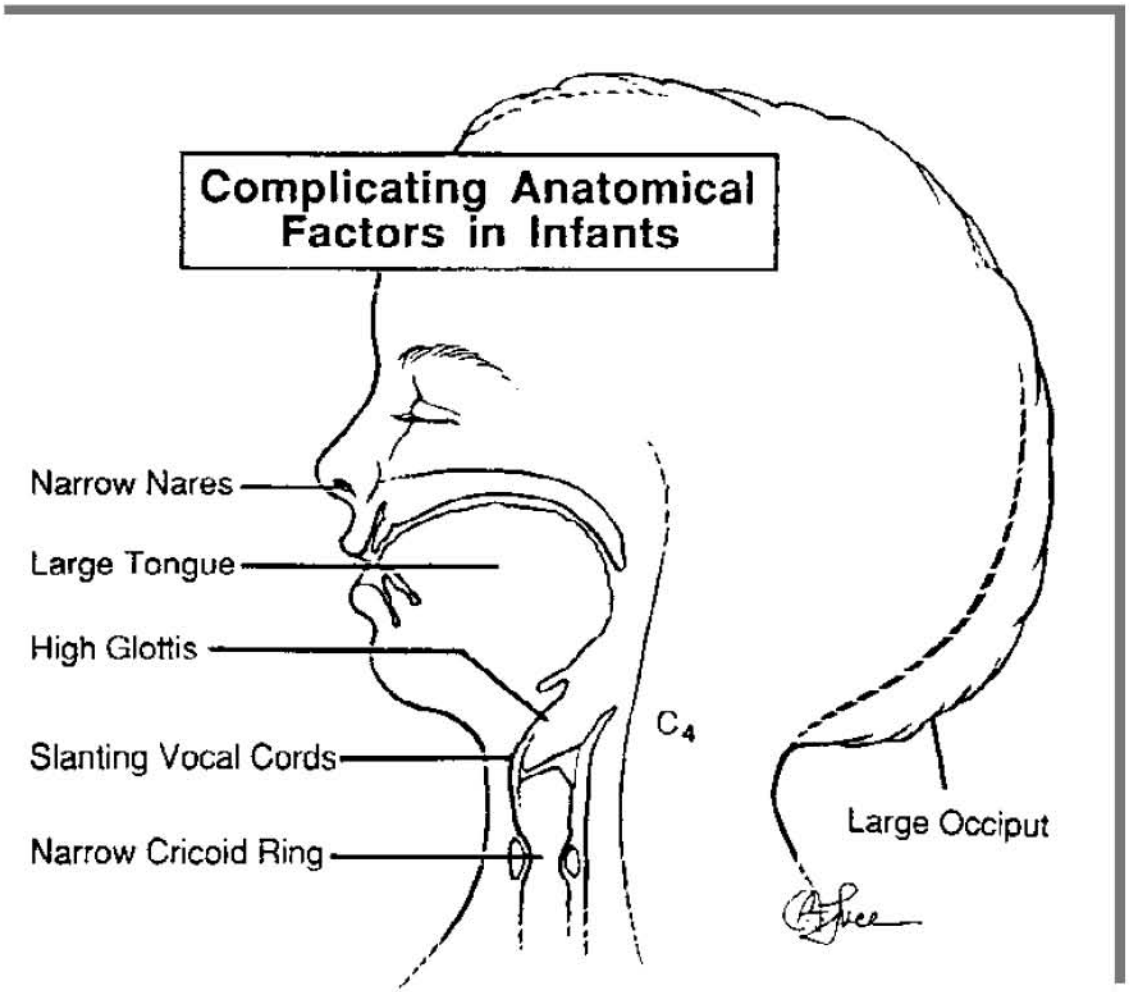
Dalal and colleagues (2009)

Based on bronchoscopic images,

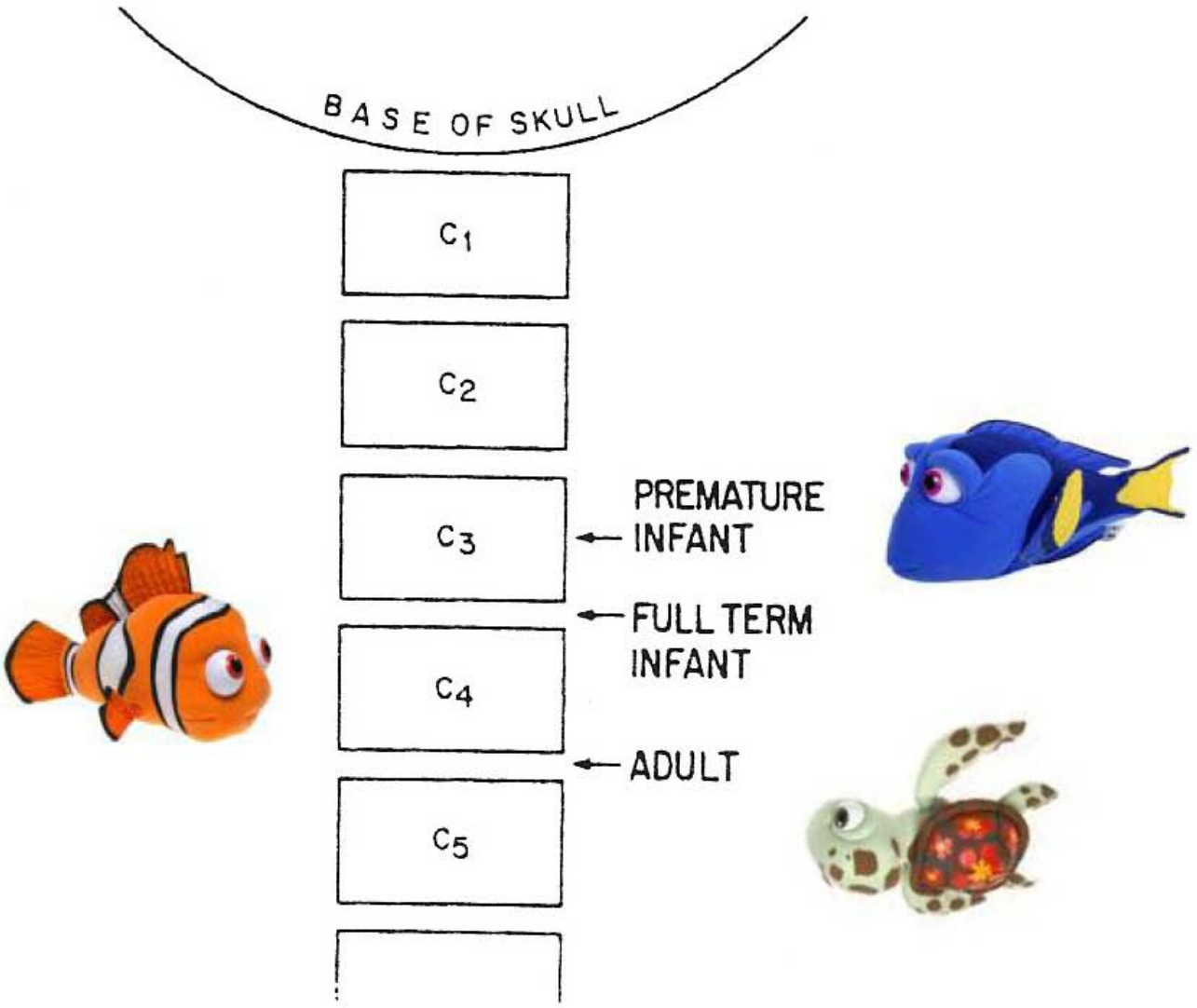
for infants & children → the glottis may be the narrowest portion (not the cricoid)

Smith's Anesthesia for Infants and Children, 8th ed., 2011.

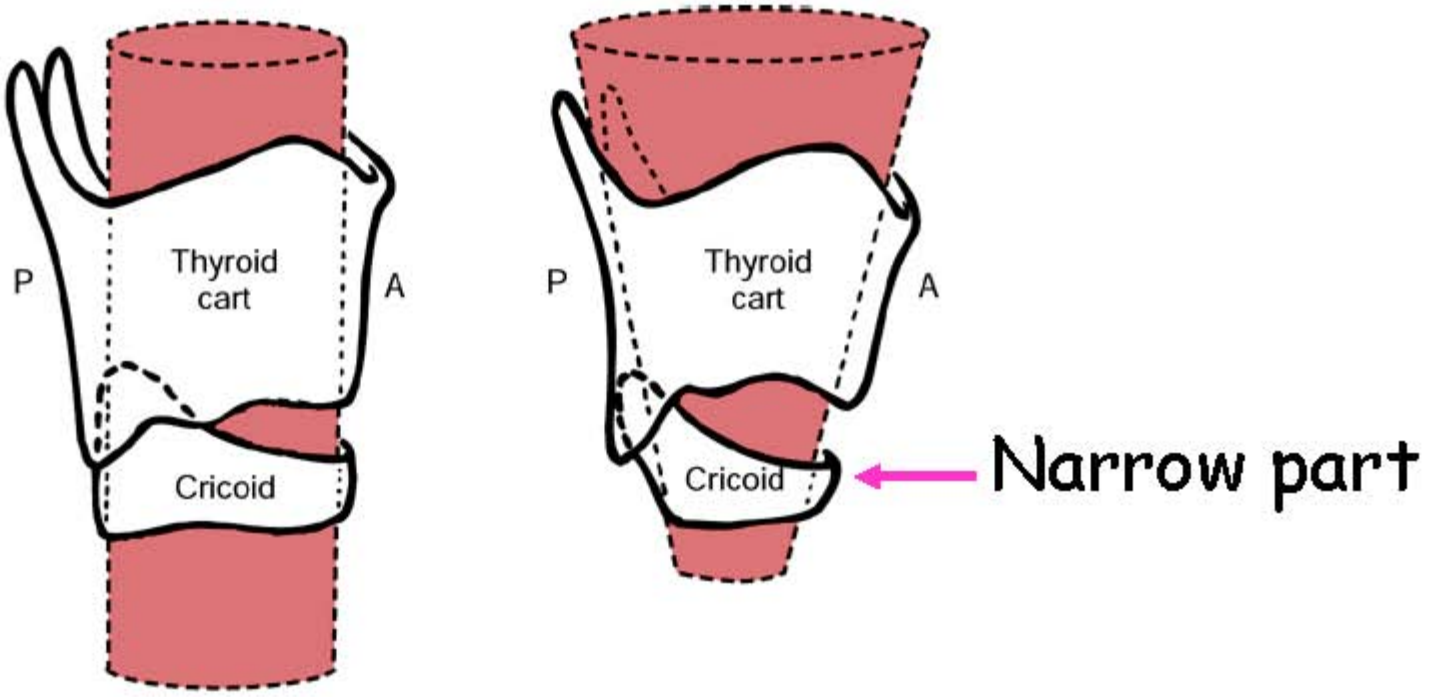
Complicating Anatomical Factors in Infants



Glottic opening relative to cervical vertebra



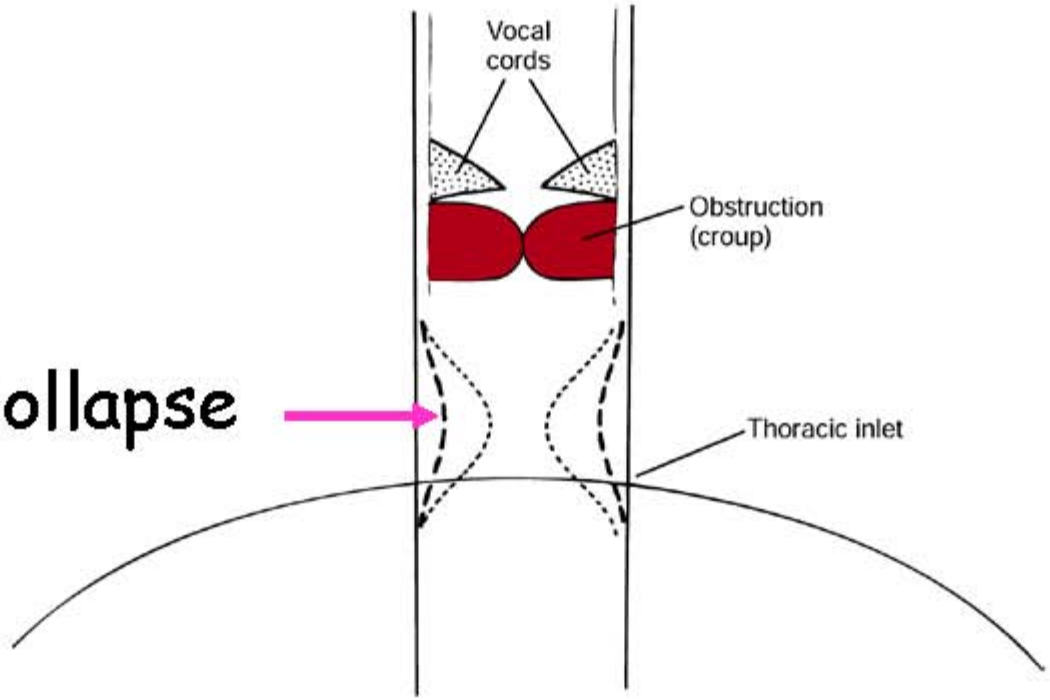
Adult and Infant Larynx



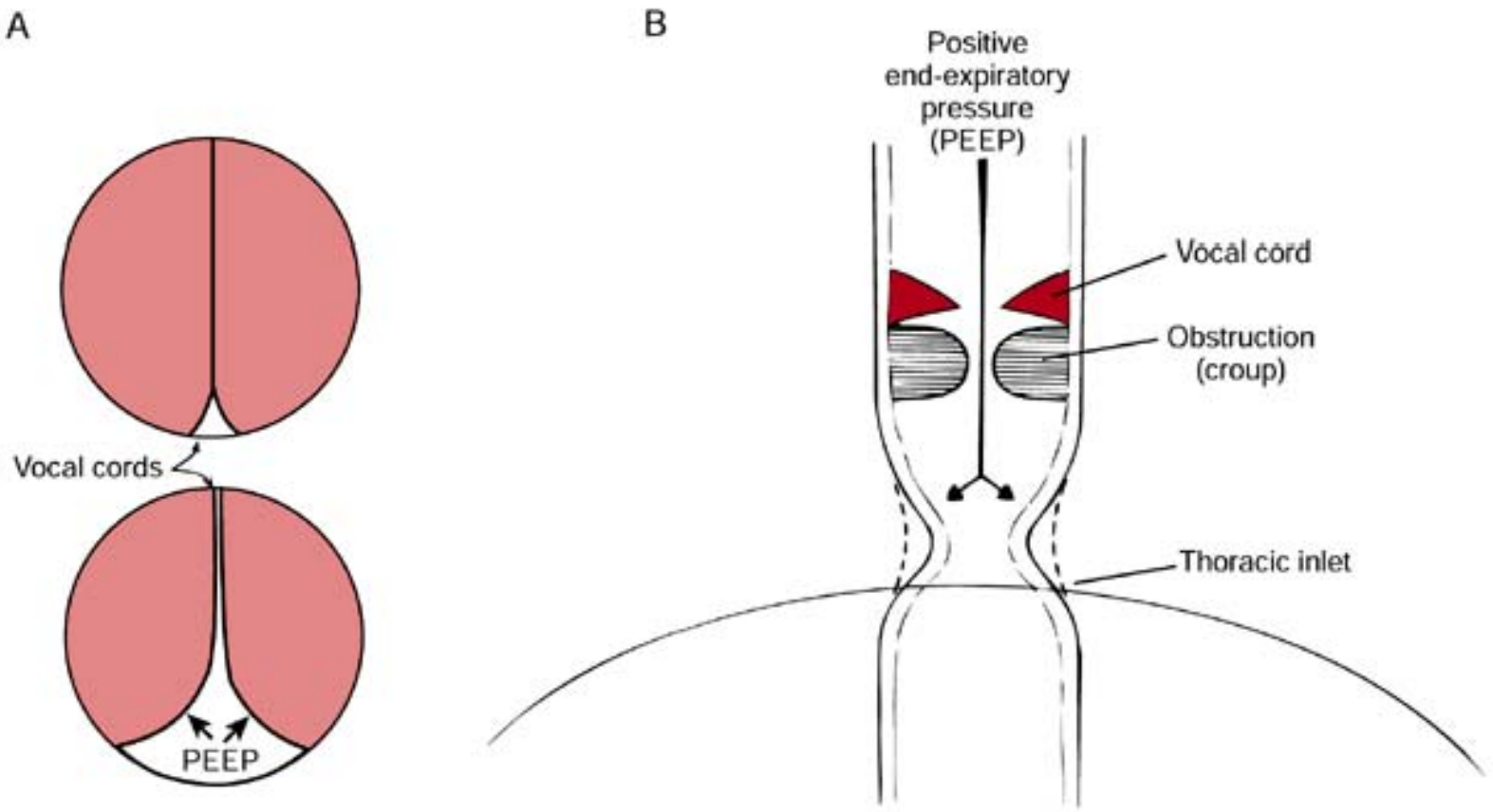
Narrow part is Glottic opening

Compliant airway structures

Dynamic collapse



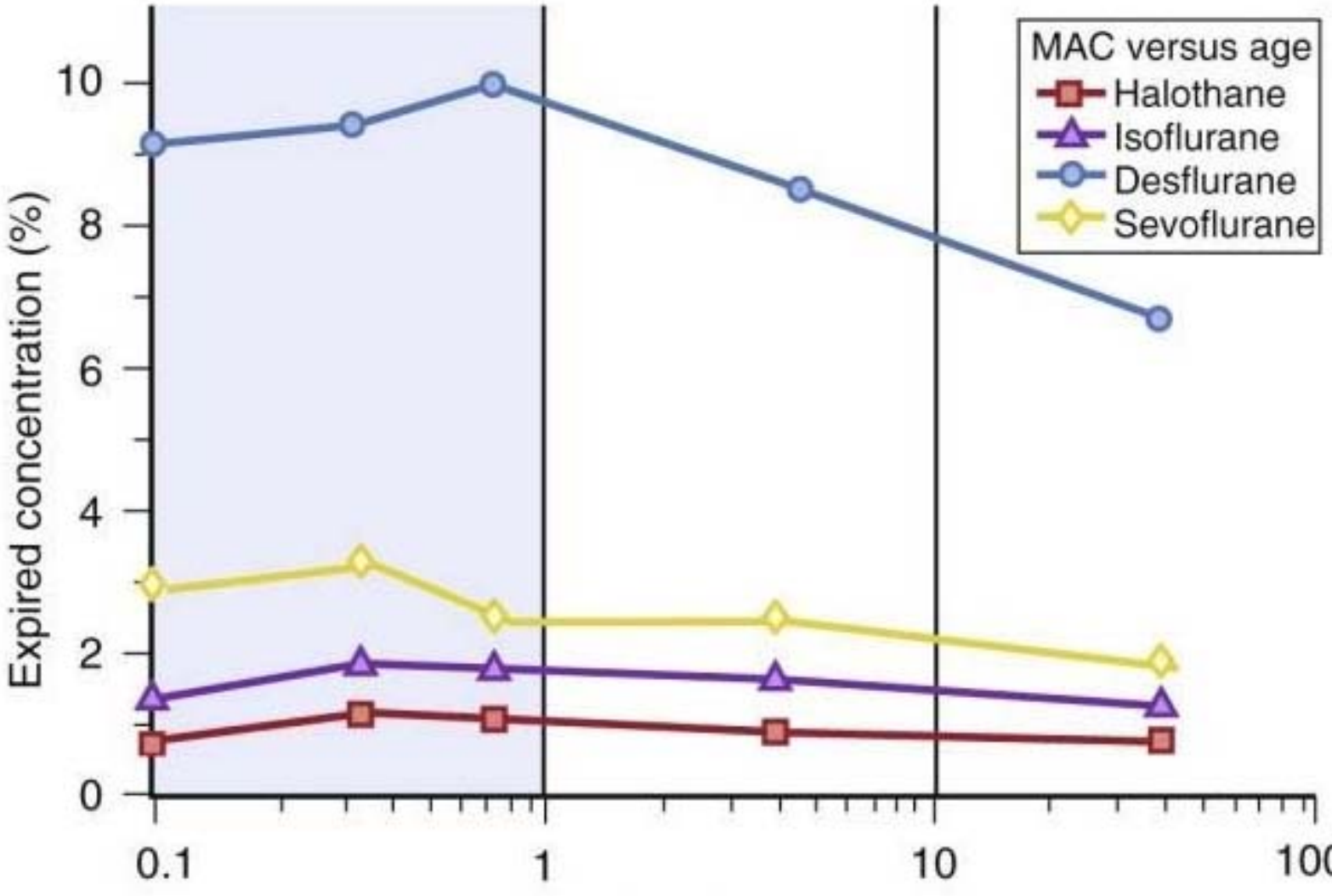
Rx Laryngospasm with PEEP



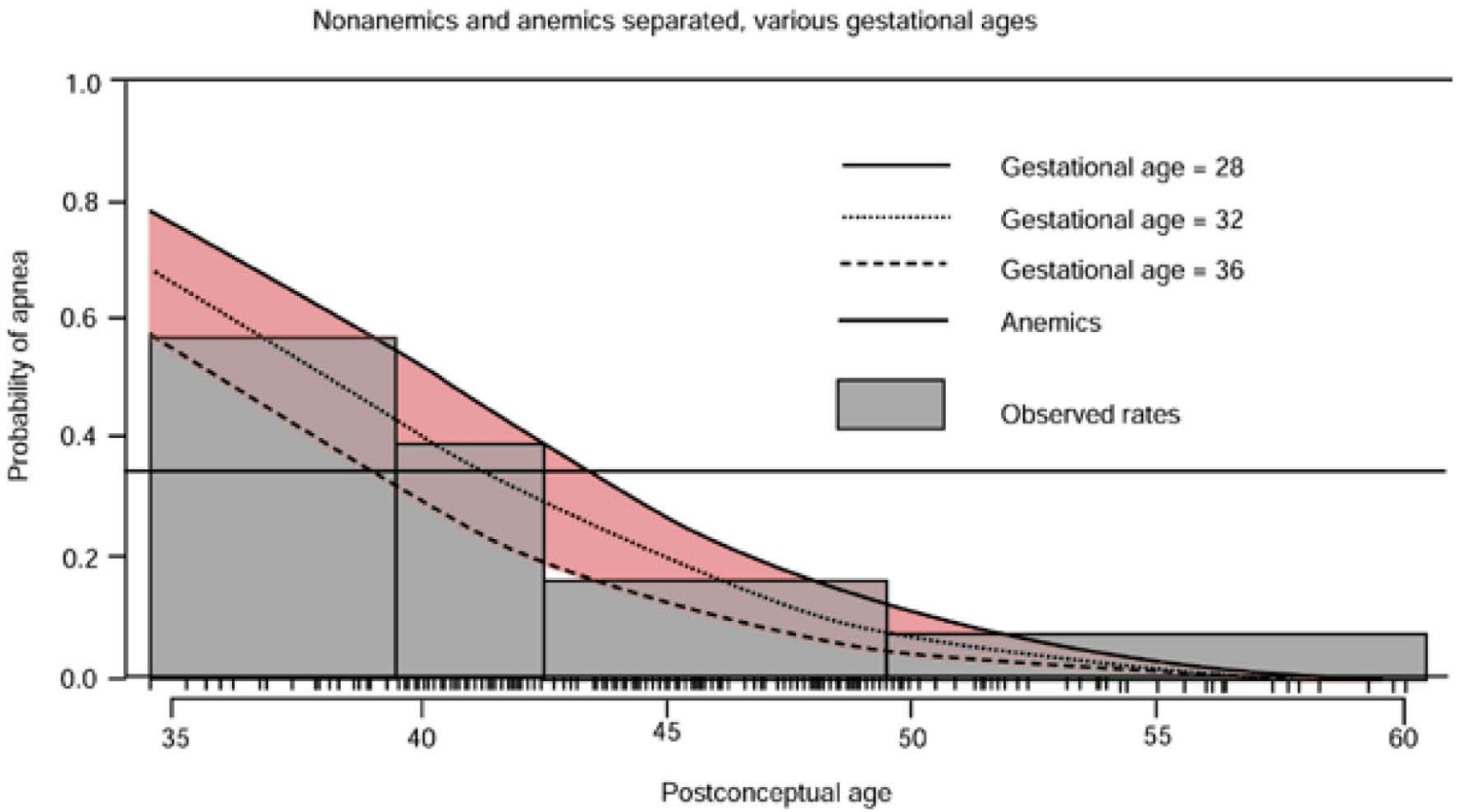
Respiratory System

- increase WOB
  - compliant chest wall
  - noncompliant lung
  - fewer type I diaphragmatic m. fibers
- prone to hypoxia
  - high oxygen consumption
  - high CC/FRC ratio
- periodic breathing

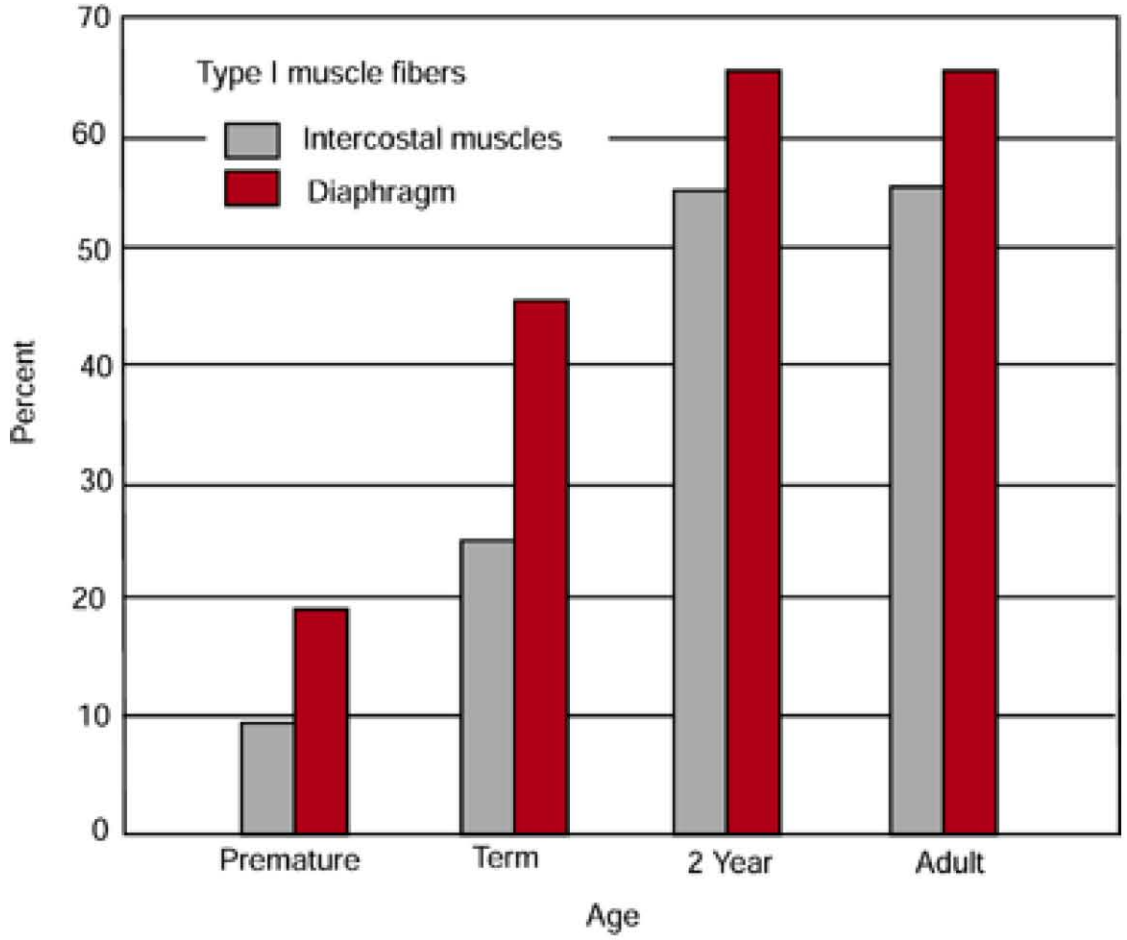
MAC of Inhalation Agents



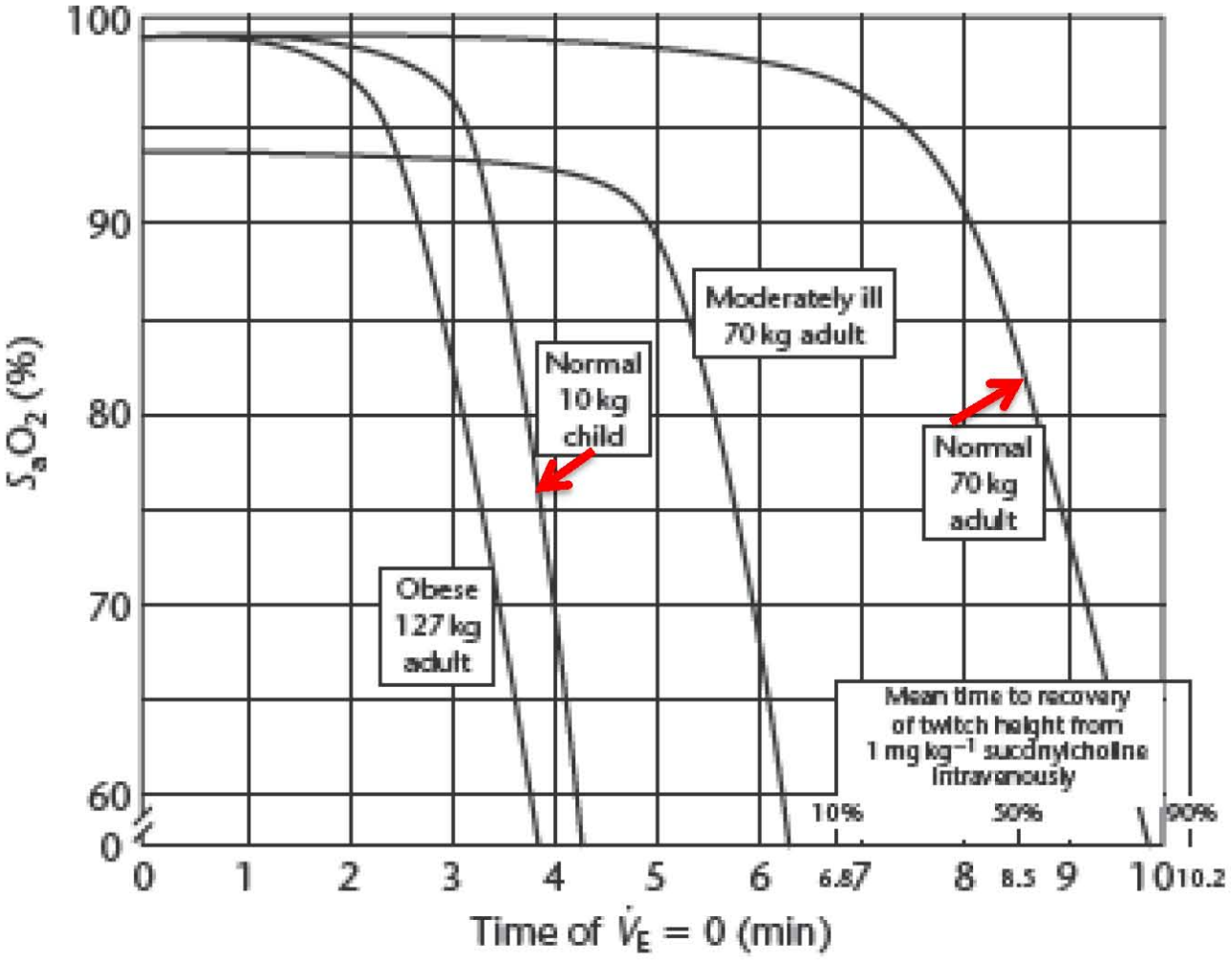
Predicted probability of Apnea



Diaphragm & Intercostal muscles changes during the first 2 yrs of life



Time to Hb desaturation with initial FAO_2 0.87



Ian Calder, Core topics in airway management, 1 st ed, 2005.

Respiratory rates in Children

Age	Respiratory Rate (min^{-1})
Birth to 6 weeks	45–60
6 weeks to 2 years	40
2 years to 6 years	30
6 years to 10 years	25
>10 years	20

Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Normal Respiratory Values

Parameter	Infant	Adult
RR	30-50	12-16
TV	7	7
Dead space	2-2.5	2.2
Alv vent	100-150	60
VO_2	7-9	3

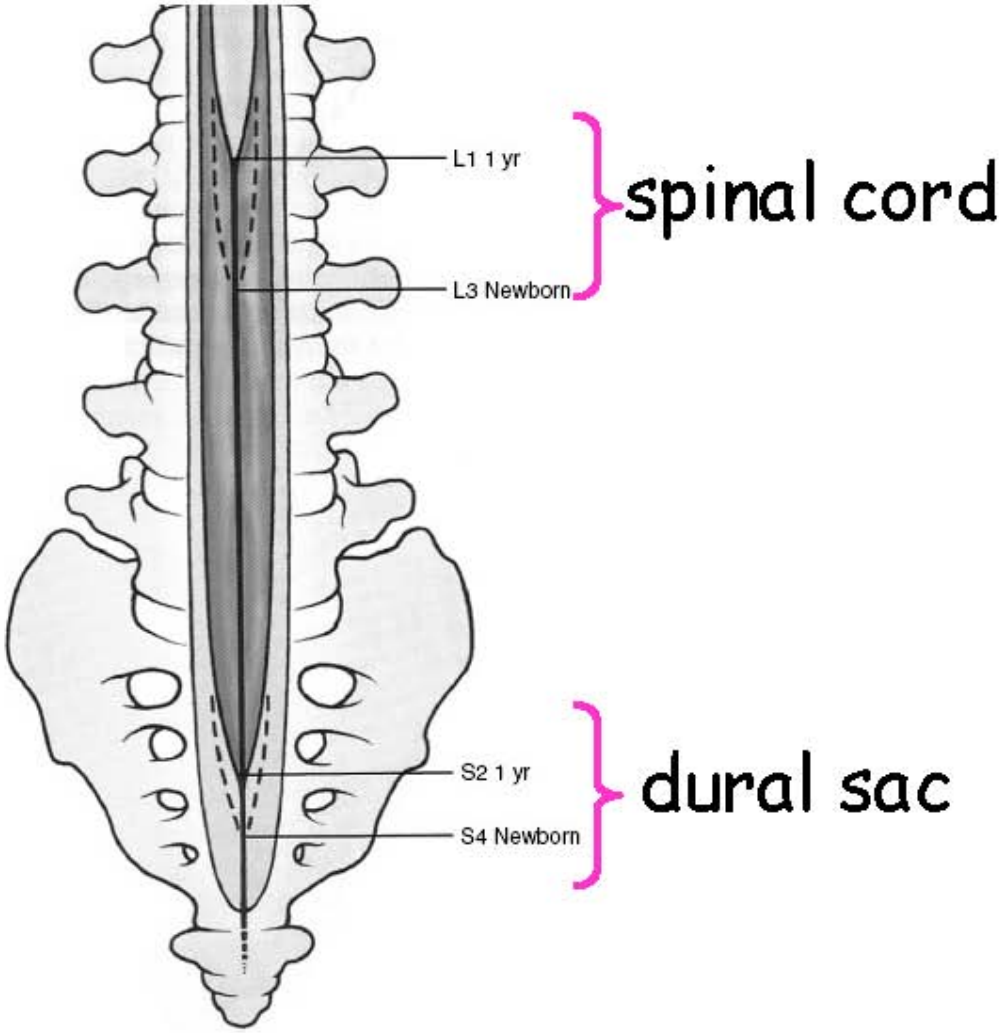
Central nervous System

- **Spinal cord**
  - At birth = L3 vertebra
  - 1 year = L1 vertebra

- **ANS**
  - parasympathetic fully functional at birth
  - sympathetic fully developed until 4 - 6 mths

Smith's Anesthesia for Infants and Children, 8th ed., 2011.

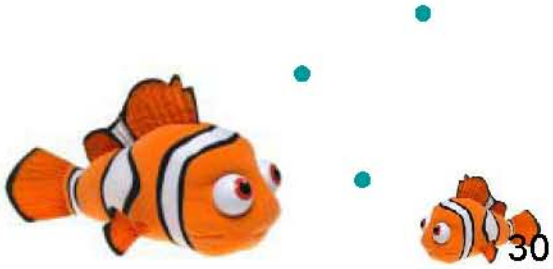
Termination of the dural sac & spinal cord



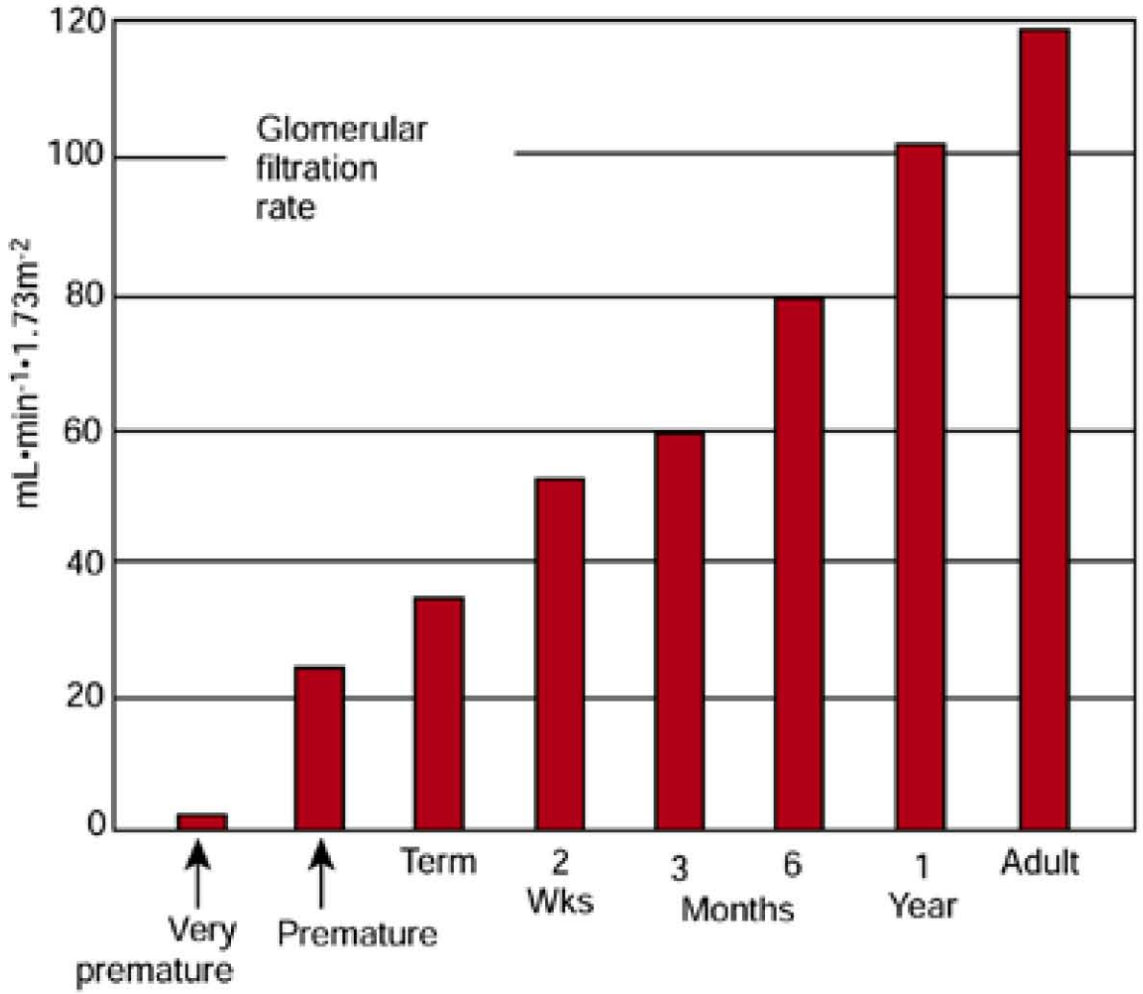
Robert S. Holzman, A Practical Approach to Pediatric Anesthesia, Chapter 8, 1st Ed. 2008.

Kidneys

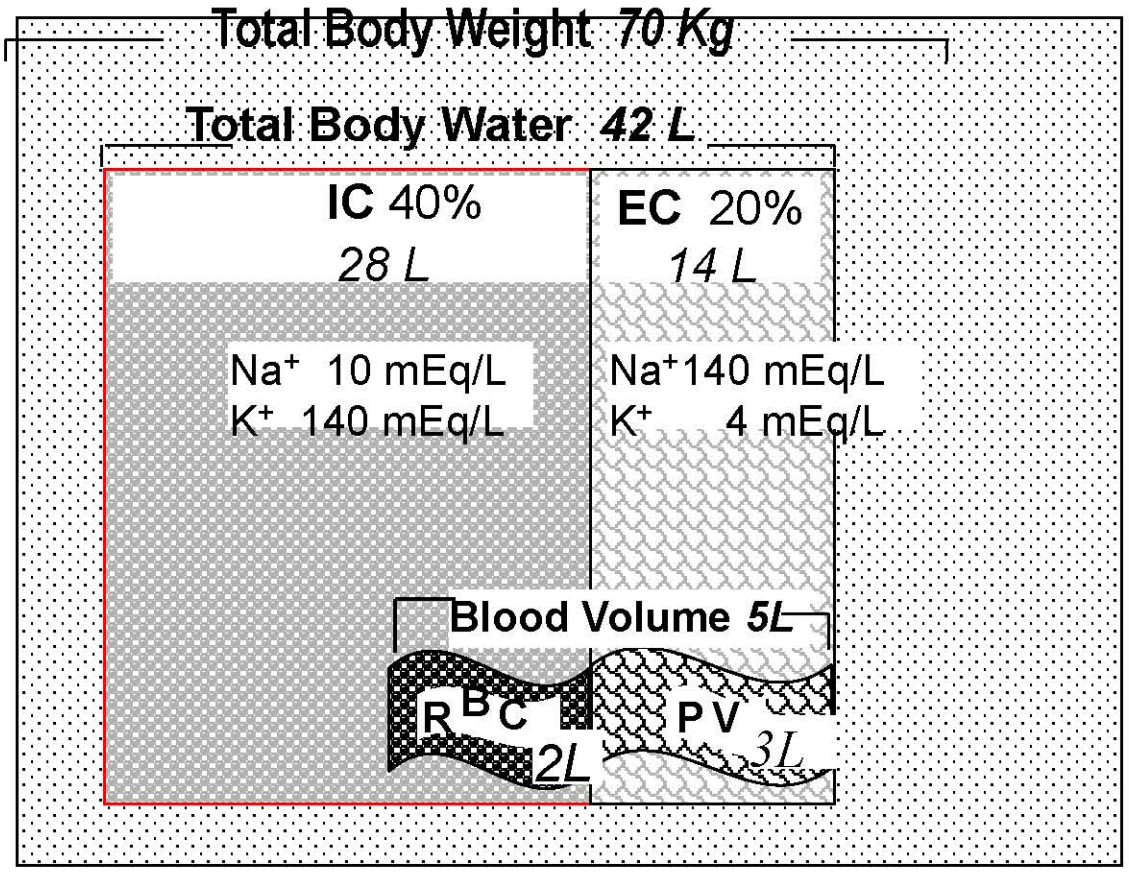
- impaired ability of handle free water and solute loads
- prolonged half-life of drugs



GFR in all ages



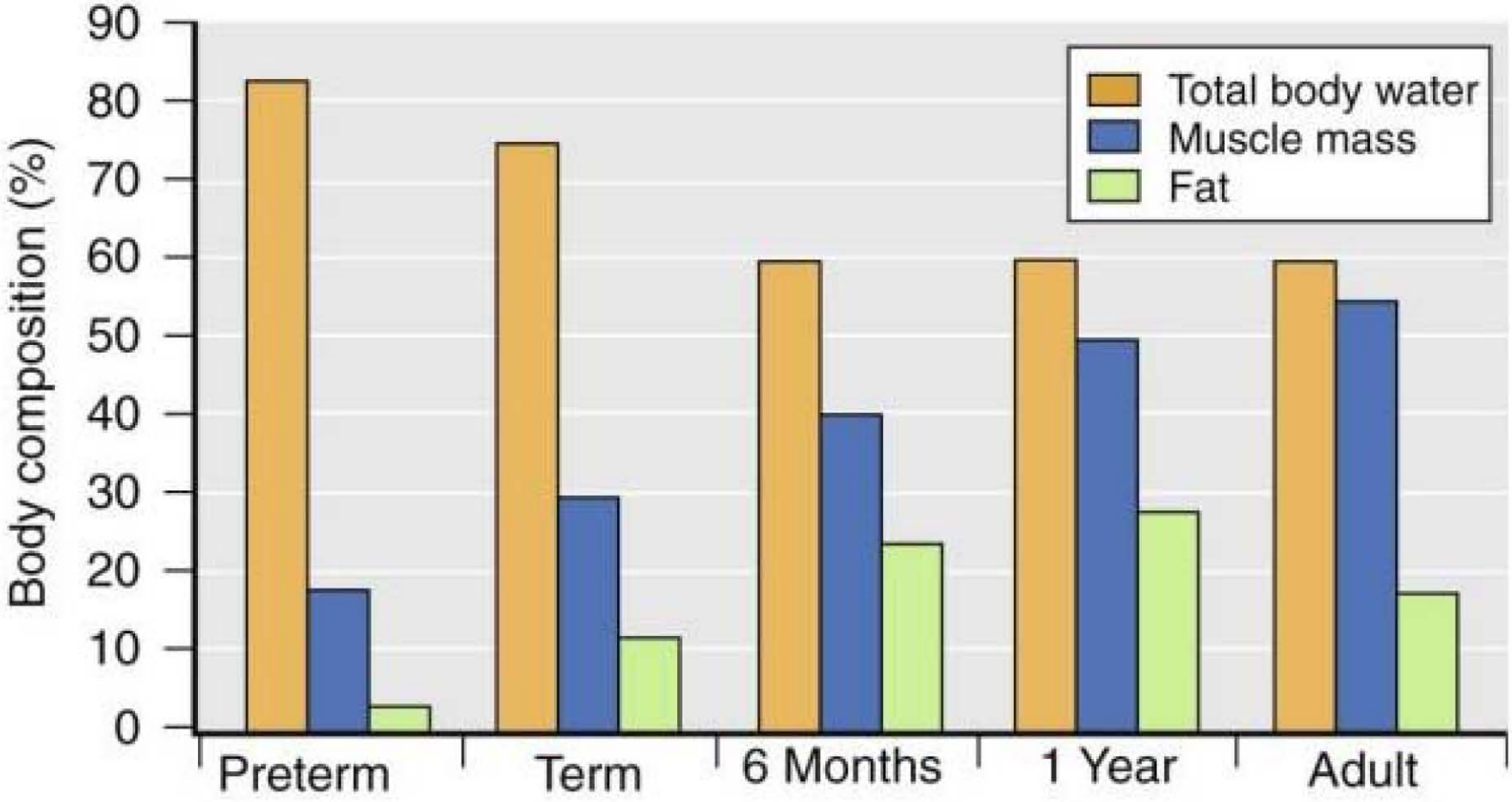
การกระจายของน้ำในร่างกาย



Total Body Water (TBW)

Fluid	NB (%BW)	Adult (%BW)
1.ECF	40	20
-Interstitial	35	15
-Plasma	5	5
2. ICF	35	40
TBWรวม	75	60

Body composition



Variation of Body Fluid Distribution by Age Group

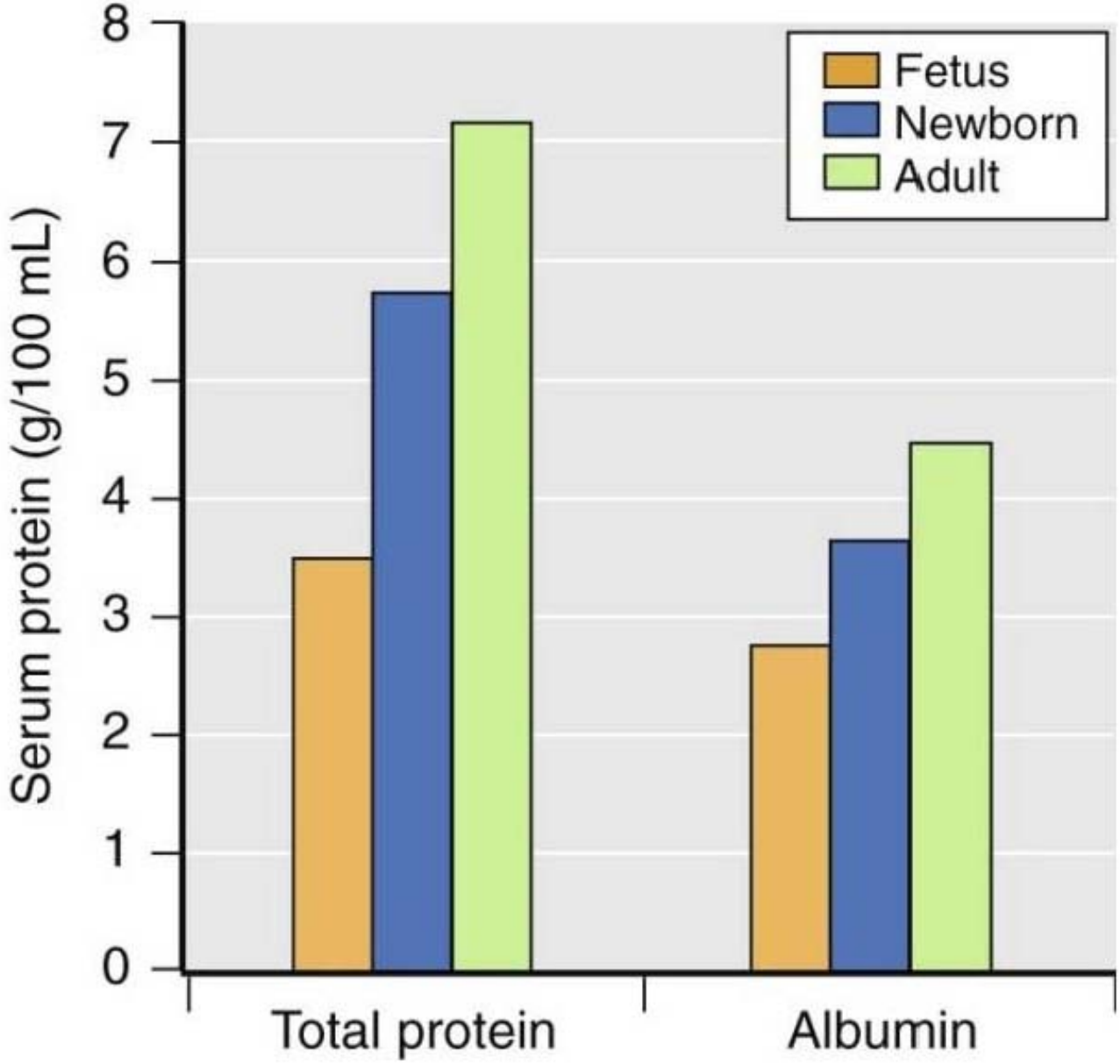
Distribution of Body Fluids	Preterm Neonates	Full-Term Neonates	Infants	Children	Adults
Total body fluids	80-85%	70-75%	65%	55-60%	50-55%
Intracellular	20-25%	30-35%	35%	35-40%	40-45%
Extracellular	55-60%	45%	30%	20-25%	20%

Ronald D. Miller, Chapter81:Regional Anesthesia in Children, Anesthesia, 7 th ed, 2009.

Liver

- Impaired drug metabolism
- Minimal glycogen store and unable to handle large protein loads, tendency to hypoglycemia and acidemia
- Coagulopathy

Changes in total serum protein & albumin values with maturation

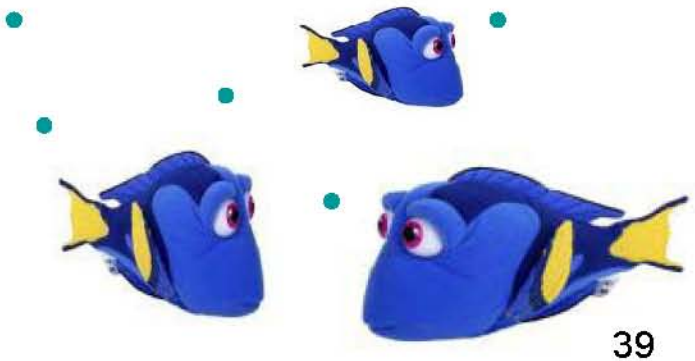


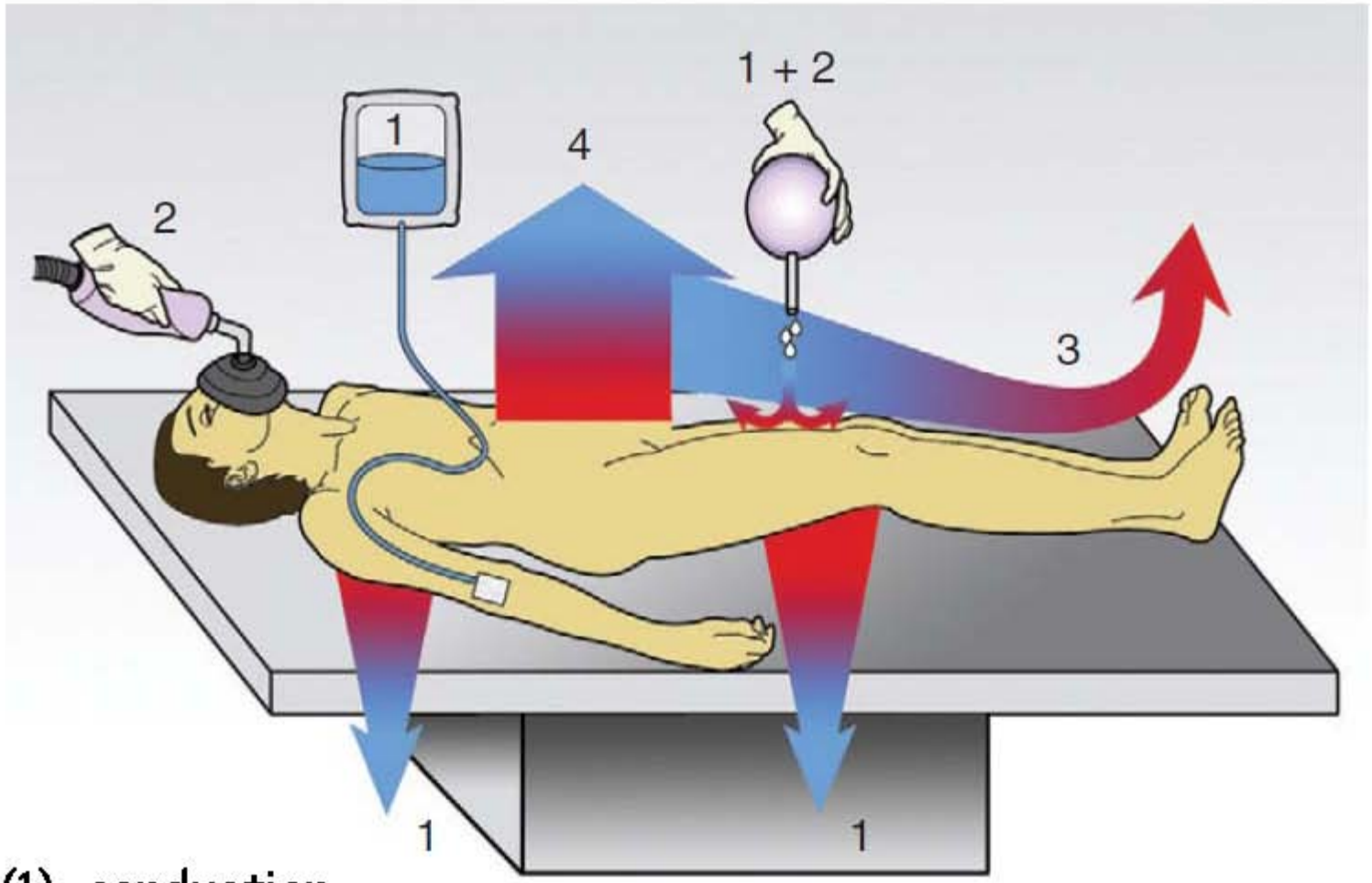
Gastrointestinal system

- At birth, gastric pH is alkalotic; by the second day of life, pH is in the normal physiologic range
- The ability to coordinate swallowing with respiration does not fully mature until infants are 4-5 mths → gastroesophageal reflux
- developmental problem occurs within the GI system →symptoms within 24-36 hours of life;
  - upper intestinal abnormalities → vomiting & regurgitation
  - lower intestinal abnormalities → abdominal distention & failure to pass meconium

Thermoregulation

- heat loss
  - large body surface-to-weight ratio
  - lack of subcutaneous fat
- Vulnerable to hypothermia

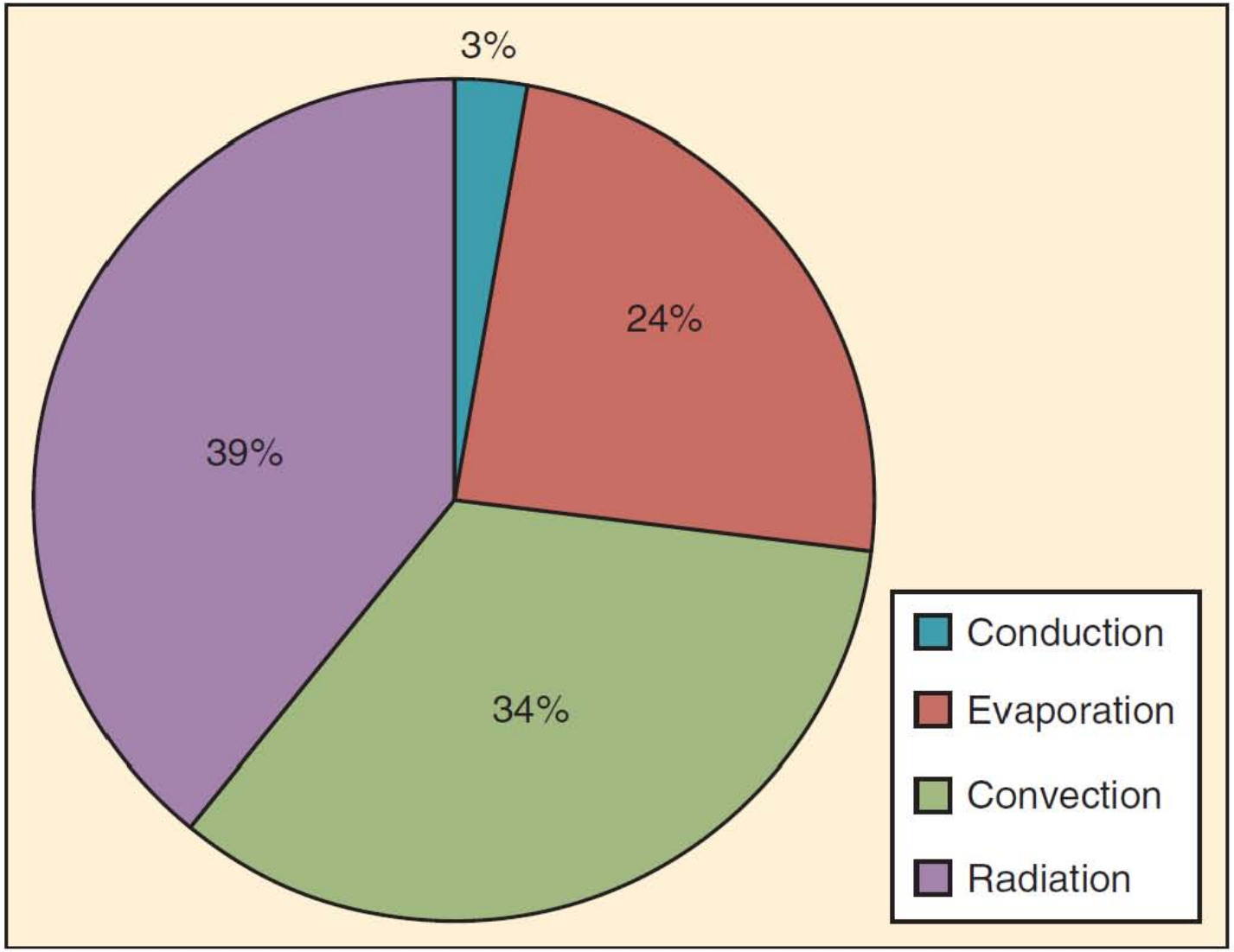




(1) conduction
(2) evaporation
(3) convection
(4) radiation

Smith's Anesthesia for Infants and Children, 8th ed., 2011.

Contributions of Each Mechanism to Total Heat Loss



Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Prevent hypothermia

- **phase I** (initial rapid decline in body temperature) →

Prewarming for half an hour with convective forced-air warming blankets effectively prevents hypothermia by eliminating the central-peripheral temperature gradient.

- Methods to minimize **phase II** hypothermia (slower decrease in body temperature) from heat loss include
  - use of forced-air warming blankets and warm-water blankets,
  - heated humidification of inspired gases,
  - warming of intravenous fluids,
  - raising ambient operating room temperature.

Prevention for hypothermia

reduce heat lost from

- conduction by placing the baby on a warming mattress and warming the operating room (≥ 26.7◦C)
- convection by keeping the infant in an incubator, covered with blankets
- radiation by use of a double-shelled Isolette during transport
- evaporation by humidification of inspired gases, the use of plastic wrap to decrease water loss through the skin, and warming of skin disinfectant solutions.
- Hot air blankets are the most effective means of warming children

Pharmacodynamics

The body compartments (fat, muscle, water) change with age

- water soluble drug has a larger volume of distribution → larger initial dose (mg/kg) to achieve the desired blood level ; most antibiotics, succinylcholine
- drug that depends on redistribution into fat for termination of its action ö less fat → longer clinical effect ; thiopental
- drug that redistributes into muscle may have a longer clinical effect ; fentanyl

Pharmacodynamics

Factors effect in the neonate's response to medications;

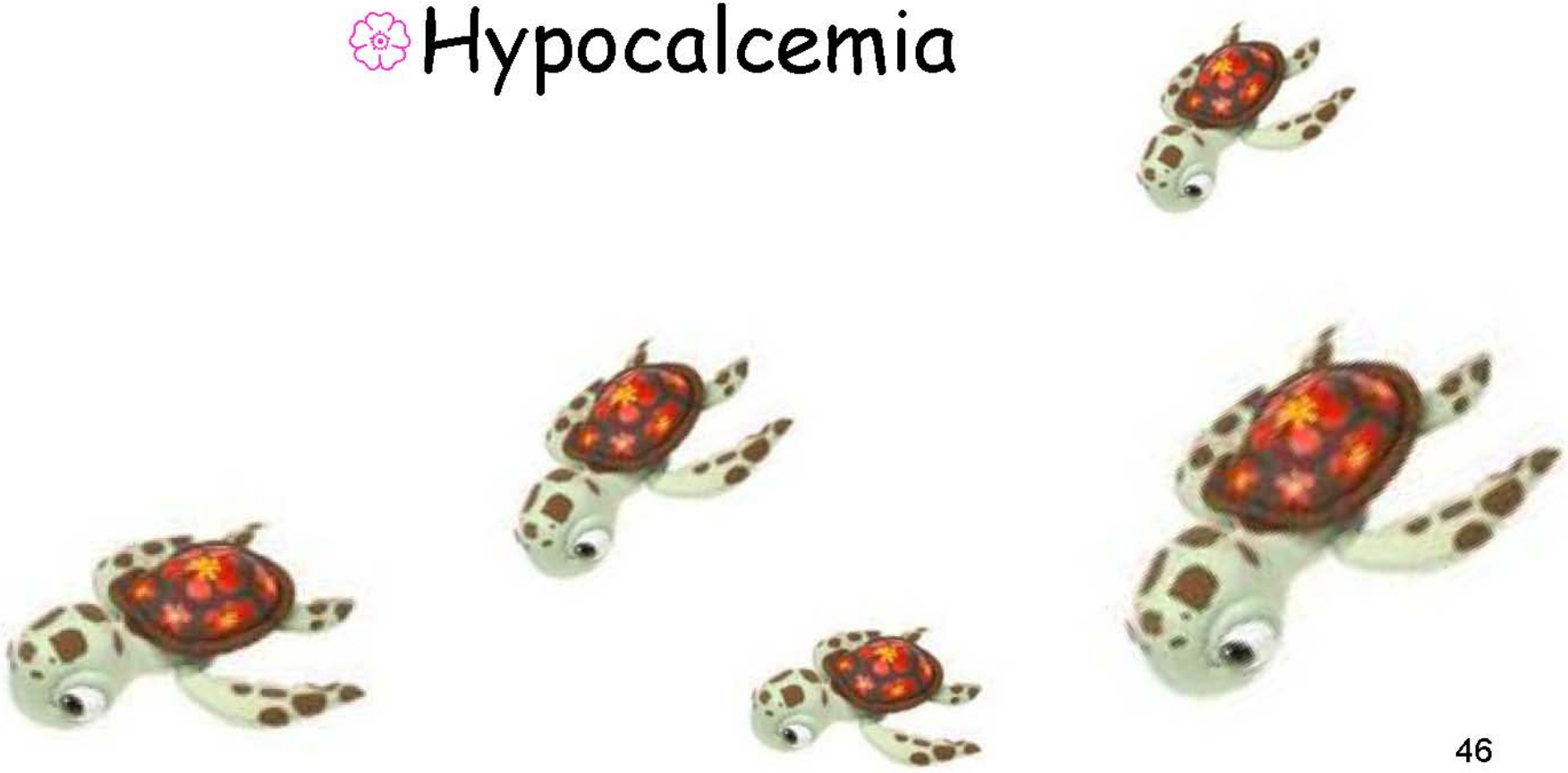
(1) delayed excretion secondary to the larger volume of distribution,

(2) immature hepatic and renal function,

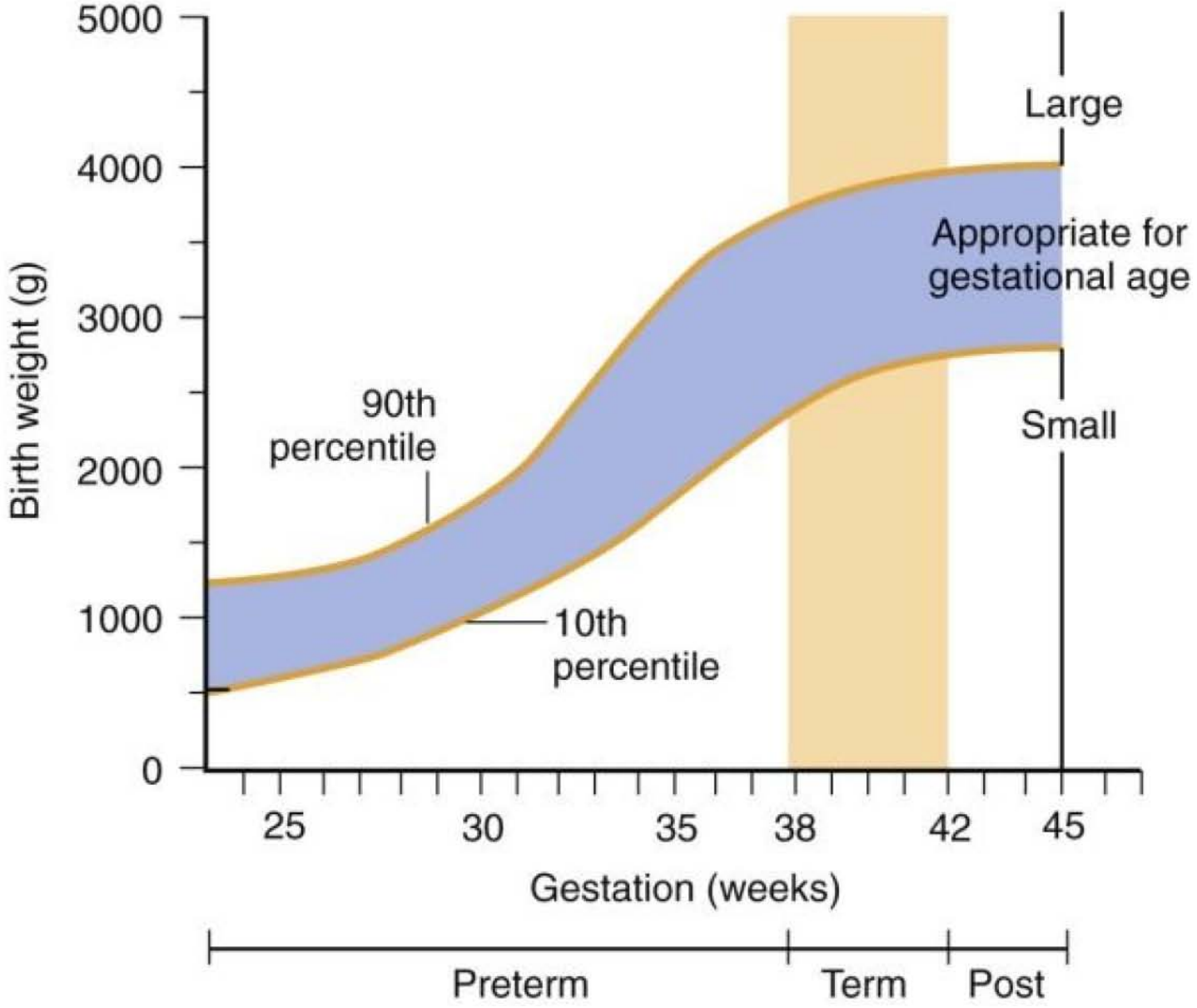
(3) altered drug excretion caused by lower protein binding

Metabolism

- Hypoglycemia
- Hypocalcemia



Plotting weight against gestational age



2. Common Neonatal Problems Associated With Weight & GA

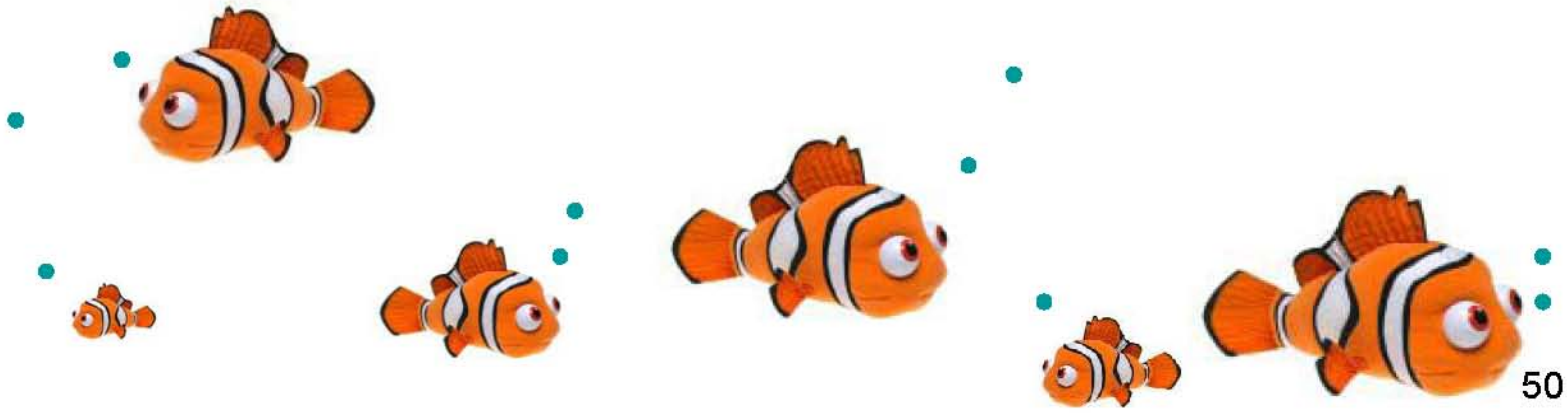
GA	BODY SIZE	INCIDENCE OF NEONATAL PROBLEMS
Premature	Small	Respiratory distress syndrome
		Apnea
		Hypoglycemia
		Hypomagnesemia
		Hypocalcemia
		Fetal alcohol syndrome
		Viral infection
		Thrombocytopenia
		Congenital anomalies
		Maternal drug addiction
		Neonatal asphyxia
		Aspiration pneumonia

GA	BODY SIZE	INCIDENCE OF NEONATAL PROBLEMS
Term Postmature	Small	Congenital anomalies Viral infection Thrombocytopenia Maternal drug addiction Neonatal asphyxia Hypoglycemia Fetal alcohol syndrome
Any GA	Large	Birth trauma Hyperbilirubinemia Hypoglycemia: infant of diabetic mother Transposition of great arteries

3.Anesthetic Equipment

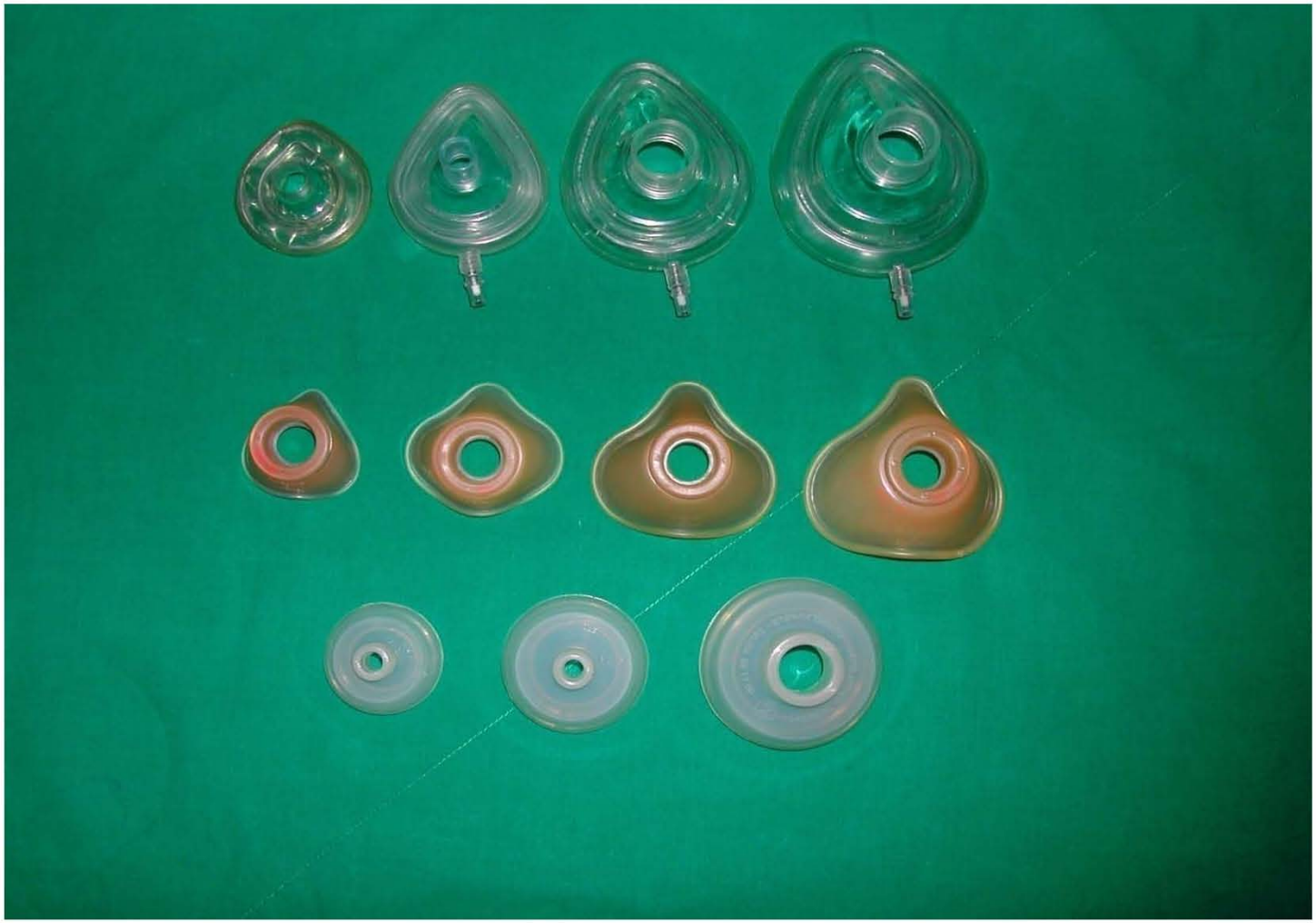
Appropiate for ages & sizes

- Face Masks
- Breathing Circuits
- Endotracheal tubes
- Laryngeal Mask Airway

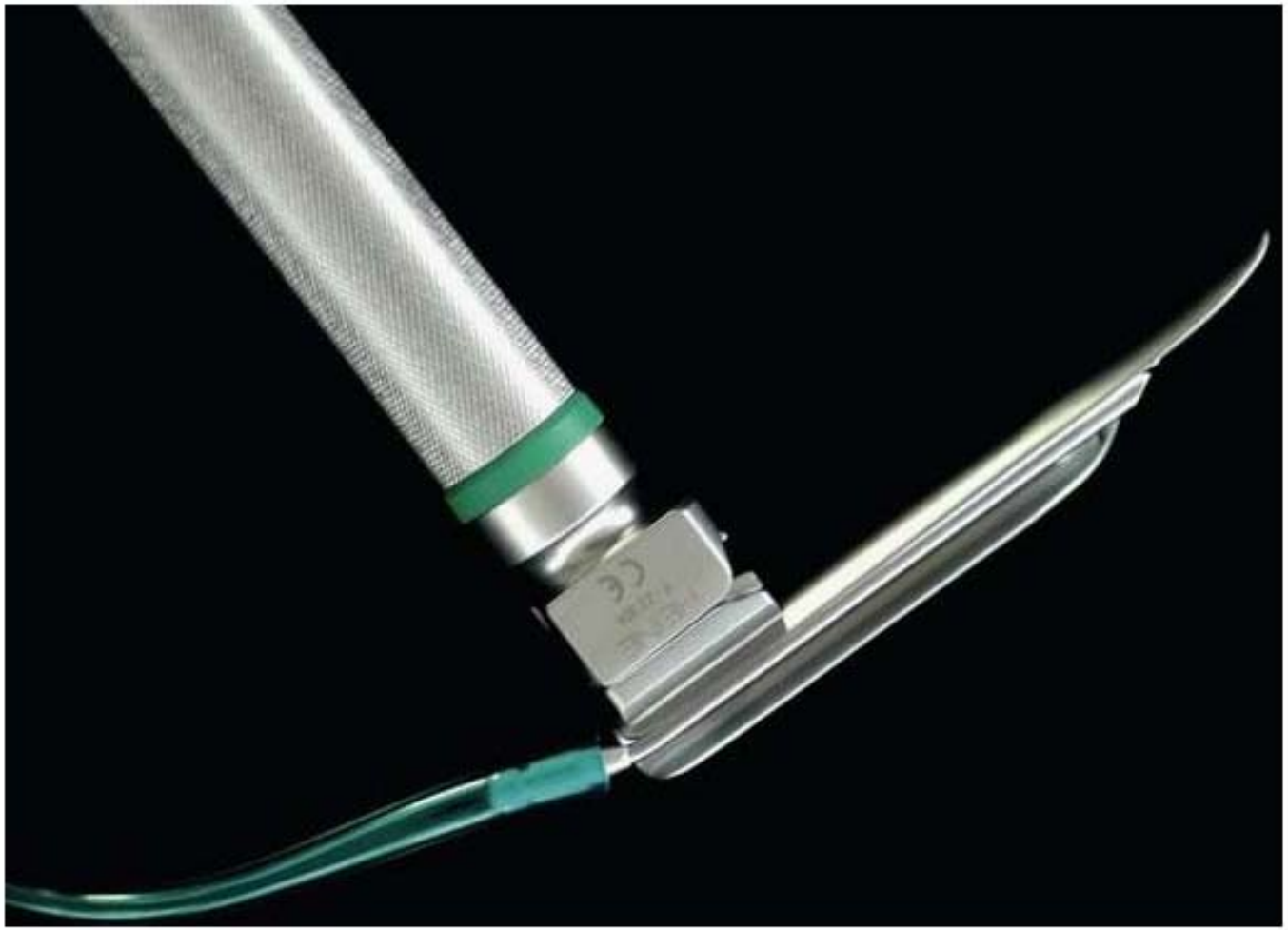


A suitable choice of anesthetic agents
is adapted especially for little patients.

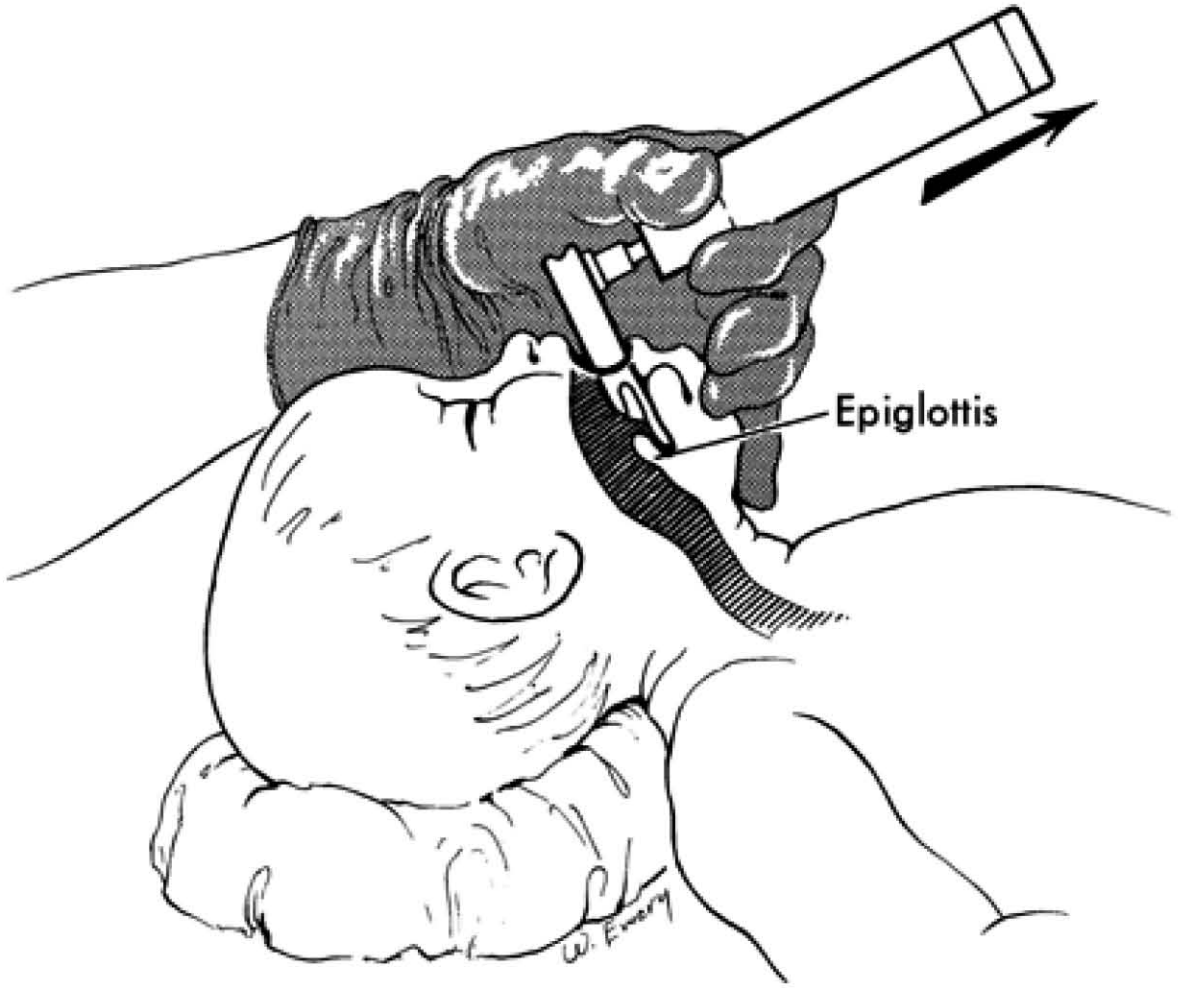
Face Masks



Oxyscope



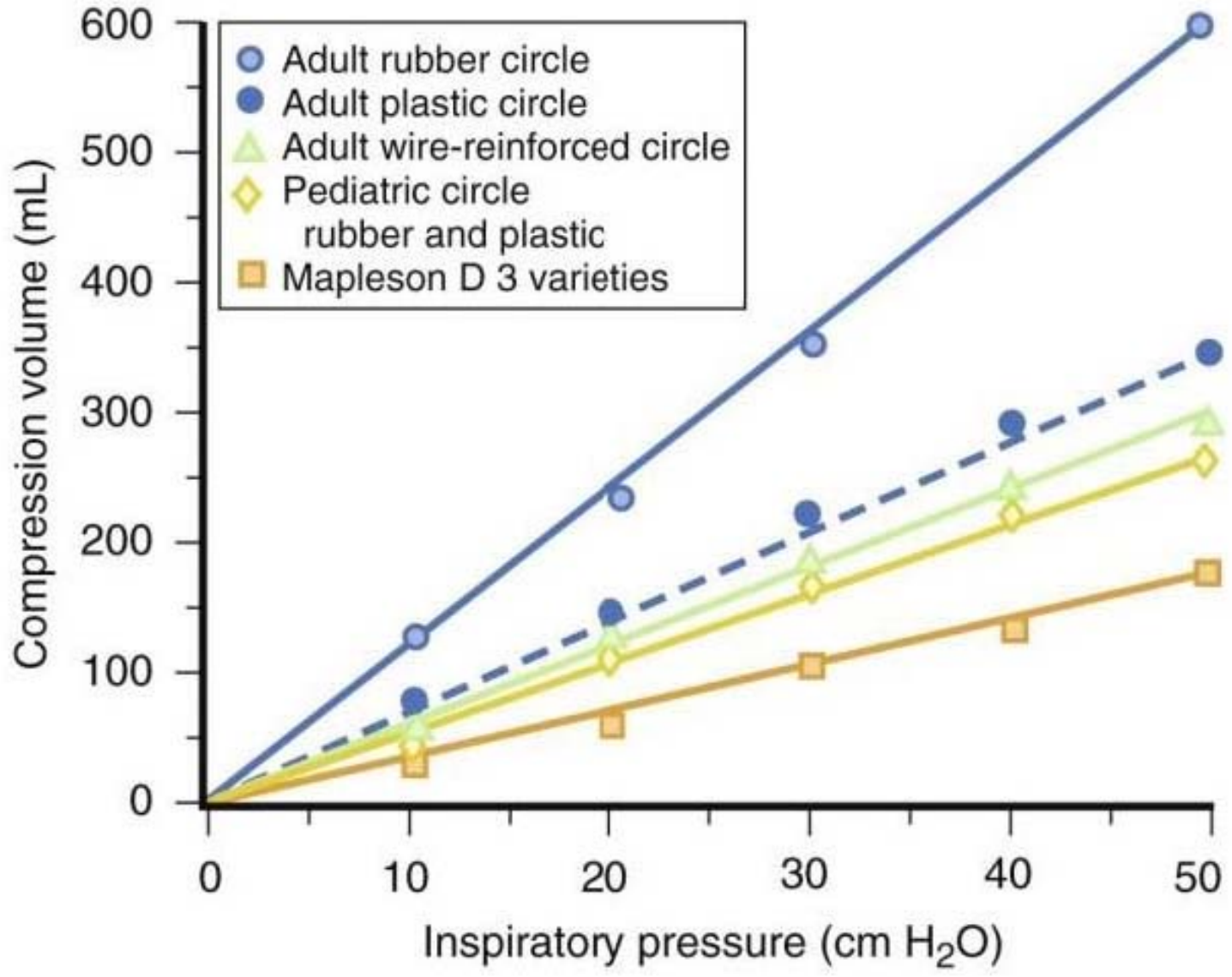
Intubation



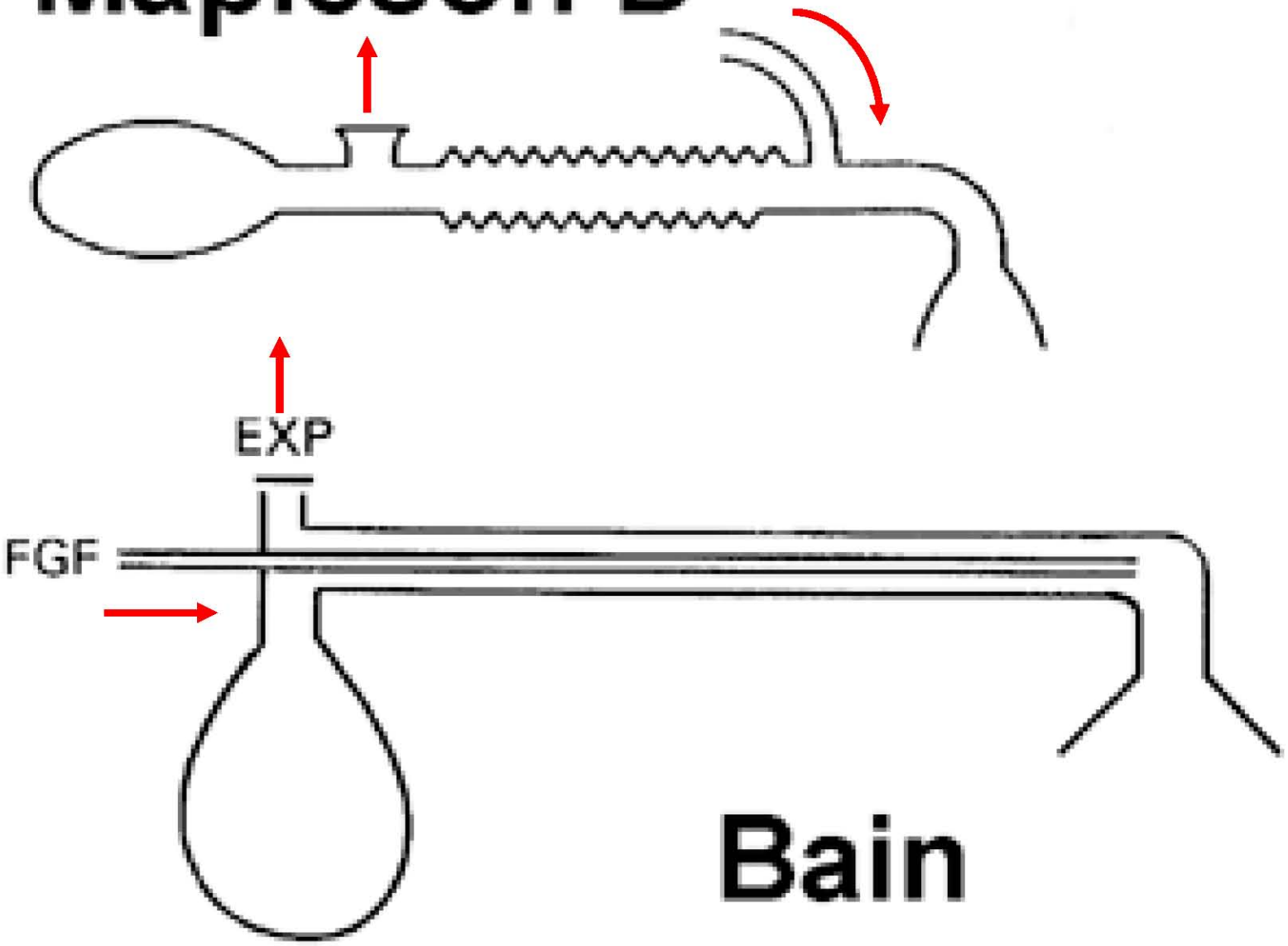
Breathing Circuits

- Jackson Rees modified T- piece
- Bain circuit
- Pediatric circle system

Anesthesia Circuits



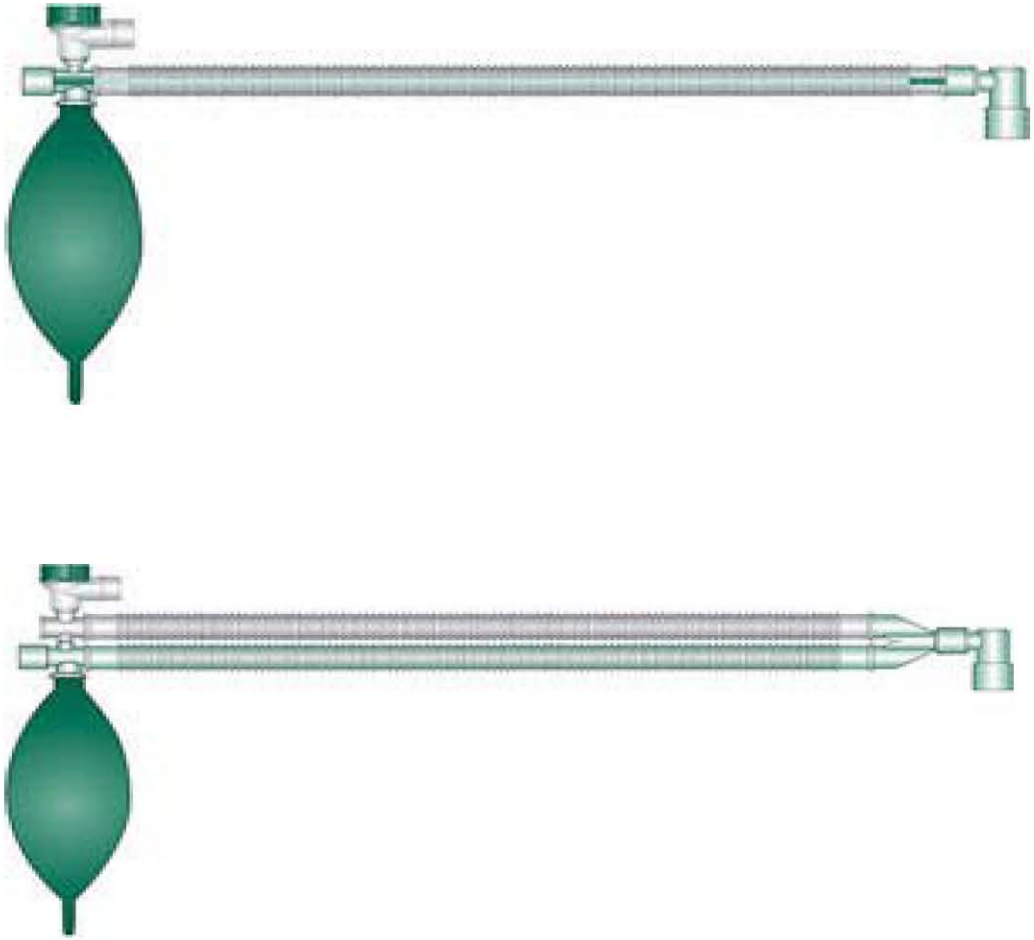
Mapleson D



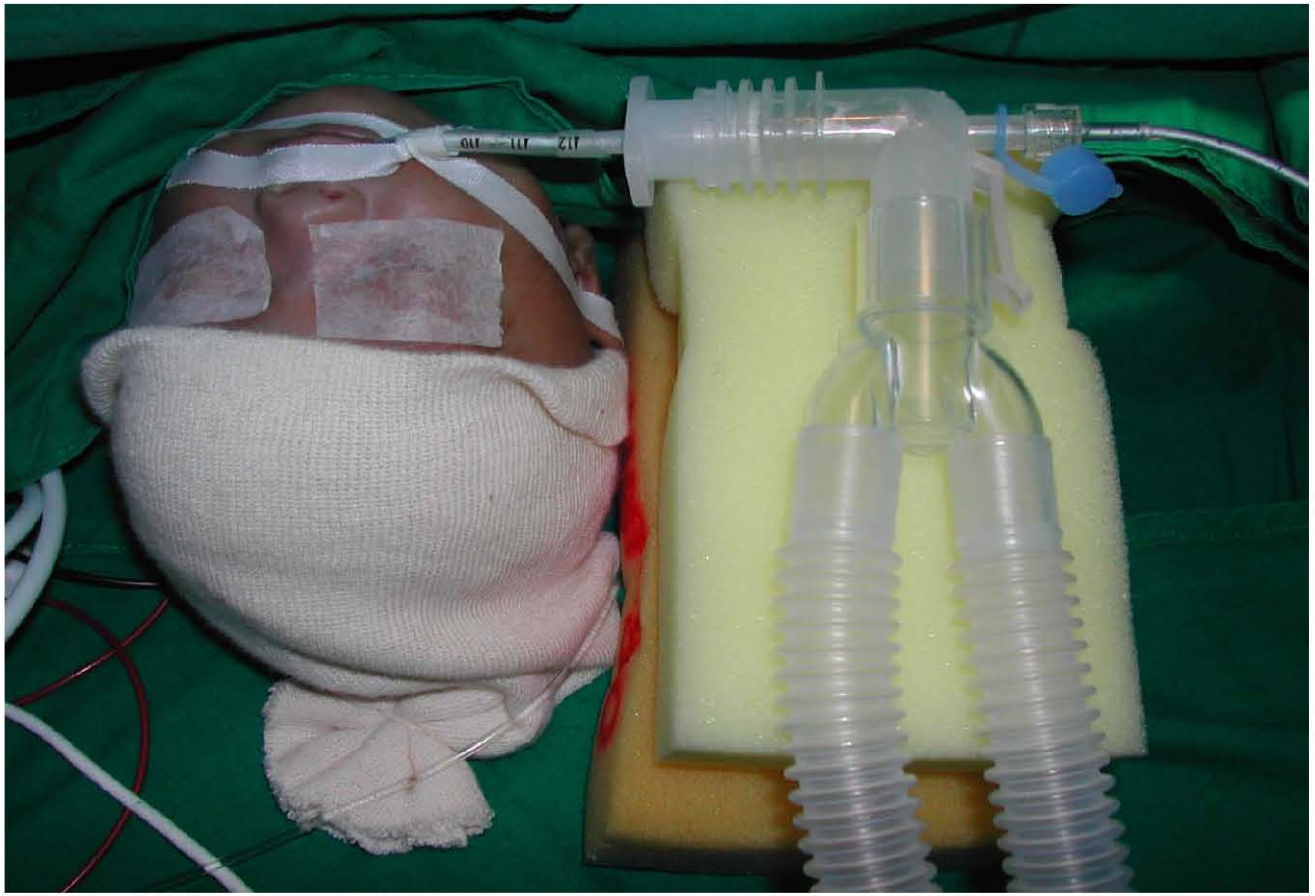
Bain

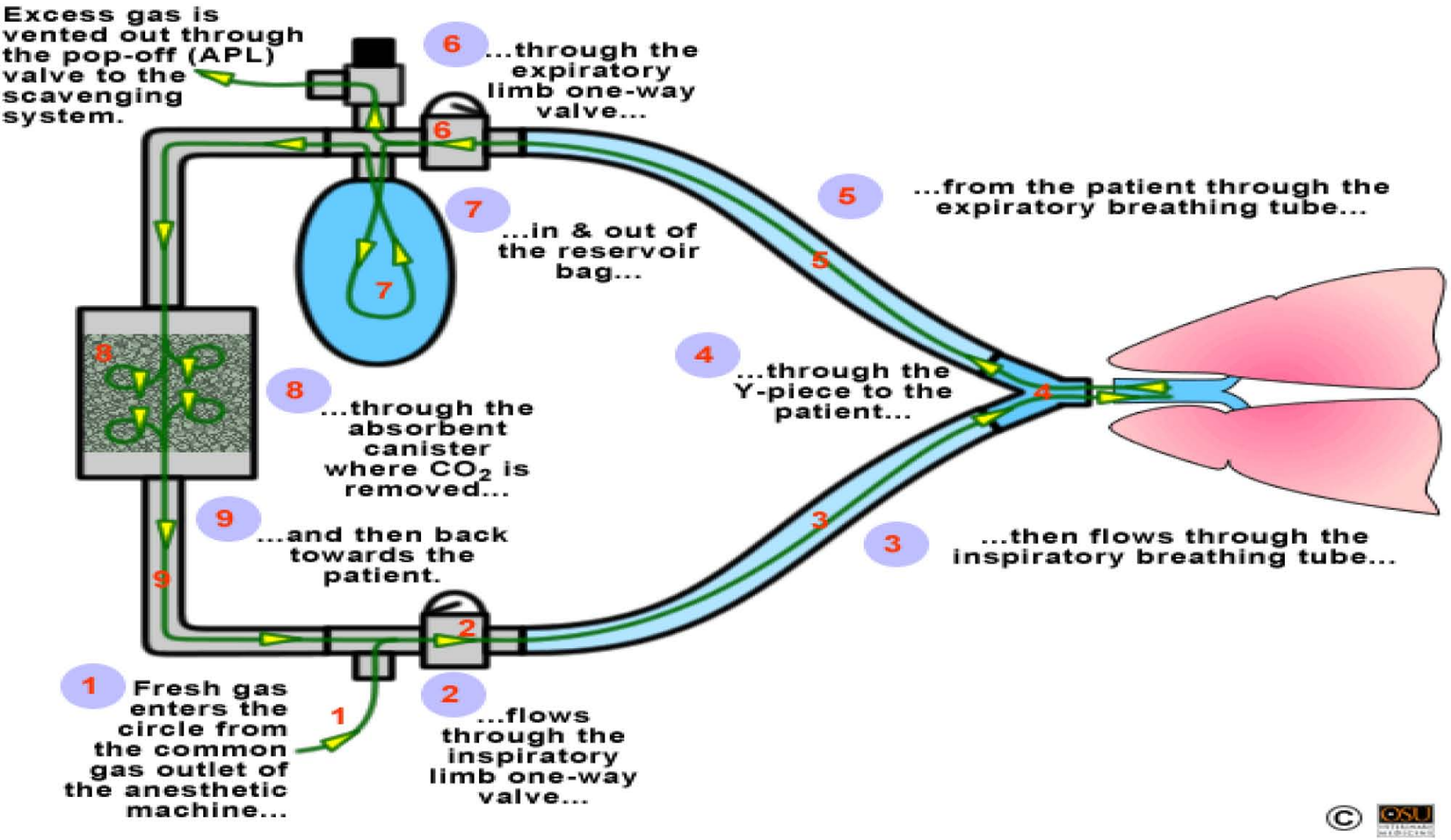
Jackson Rees modified T- piece

Bain circuit



Circle Circuit

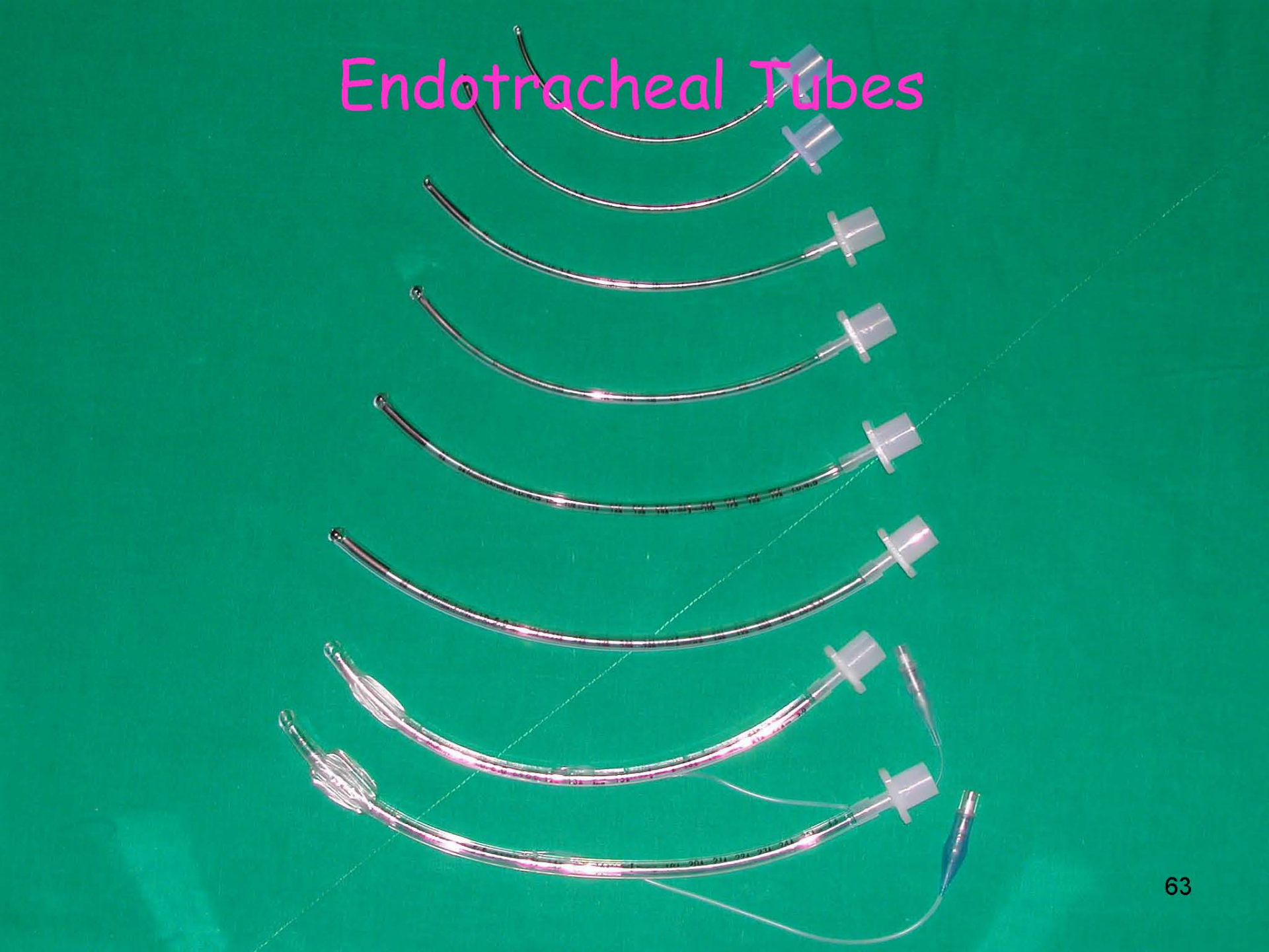



Excess gas is vented out through the pop-off (APL) valve to the scavenging system.
6 ...through the expiratory limb one-way valve...
7 ...in & out of the reservoir bag...
5 ...from the patient through the expiratory breathing tube...
4 ...through the Y-piece to the patient...
8 ...through the absorbent canister where CO_2 is removed...
9 ...and then back towards the patient.
3 ...then flows through the inspiratory breathing tube...
1 Fresh gas enters the circle from the common gas outlet of the anesthetic machine...
2 ...flows through the inspiratory limb one-way valve...

Endotracheal Tubes

- Internal diameter (I.D.) = $\frac{\text{age (yr)}}{4} + 4$
  - Leak at 20-30 cmH_2O
  - Uncuffed endotracheal tubes at age < 8 yrs
- NG tube size (Fr) = $\frac{\text{age (yr)} + 16}{2}$

Endotracheal Tubes



Recommended Sizes & Distance of ETTubes and Laryngoscope Blades for Use in Pediatric Patients

Age of Patient	Internal Diameter of Endotracheal Tube (mm)	Recommended Size of Laryngoscope Straight Blade	Distance of Insertion* (cm)
Preterm (<1250 g)	2.5 uncuffed	0	6-7
Full term	3.0 uncuffed	0-1	8-10
1 yr	3.5-4.0 cuffed	1	11
2 yr	4.5-5.0 cuffed	1-1.5	12
6 yr	5.0-5.5 cuffed	1.5-2	15
10 yr	6.0-6.5 cuffed	2-3	17
18 yr	7-8 cuffed	3	19

Weiss and colleagues (2009)

A multicenter, randomized prospective study of 2246 children (birth to 5 years) undergoing general anesthesia

→ cuffed ETTs VS uncuffed ETTs did not increase the risk of postextubation stridor (4.4% vs. 4.7%)

→ reduce the need for ETT exchanges (2.1% vs. 30.8%)

- No role of cuffed ETTs in neonates & infants who require prolonged ventilation

Smith's Anesthesia for Infants and Children, 8th ed., 2011.

Advantages of Cuffed versus Uncuffed Endotracheal Tubes

Cuffed	Uncuffed
Advantages	
Not important for subglottic stenosis	Larger tube, so less resistance for spontaneous breathing and mechanical ventilation
Fewer repeat laryngoscopies and reintubations	Lower risk of occlusion
Less contamination	No cuff = no ridges
Lower fresh-gas flow	No concern about tip-to-cuff border distance
Better protection against aspiration	No requirement for pressure monitoring

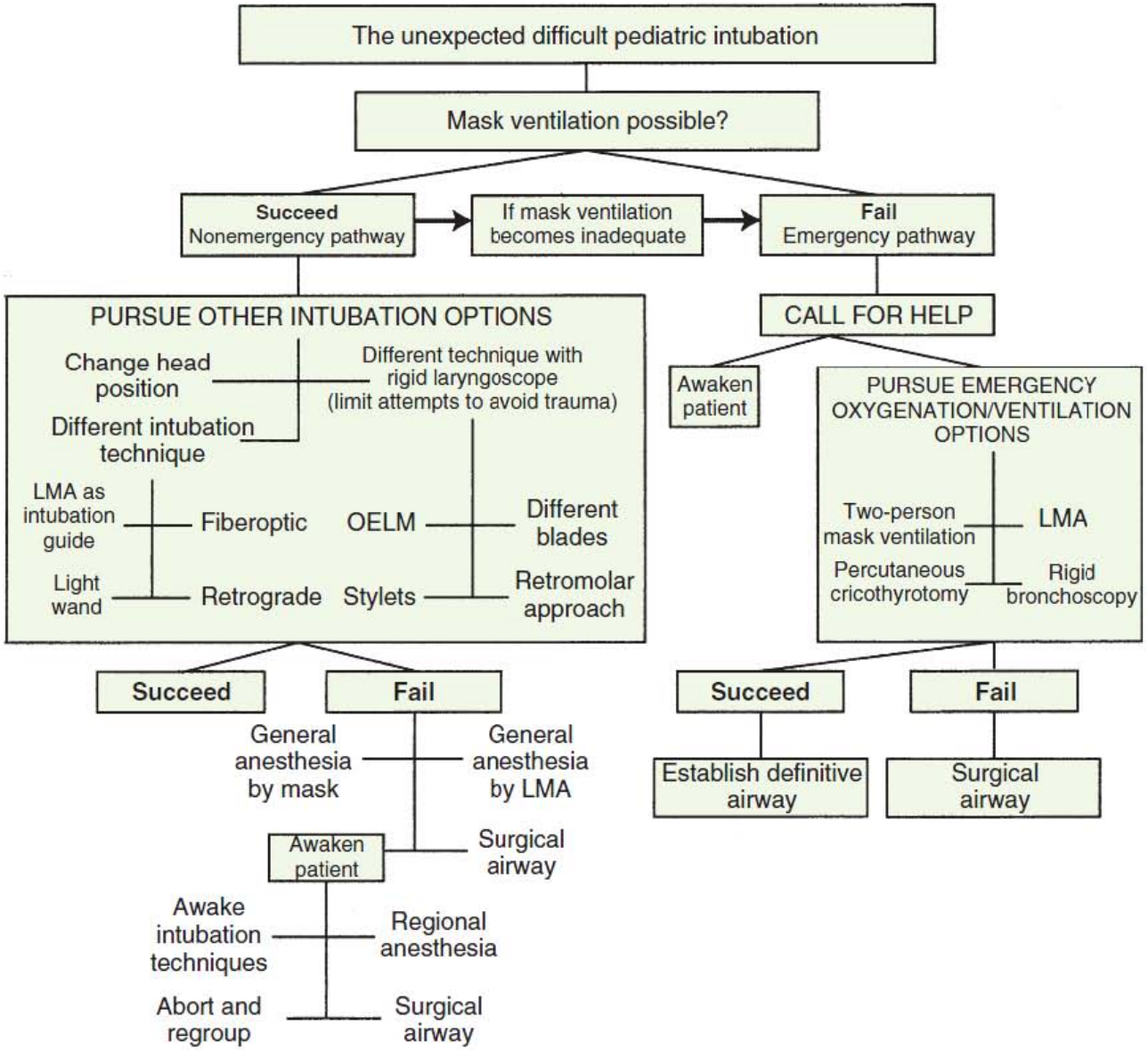
Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Advantages of Cuffed versus Uncuffed Endotracheal Tubes

Cuffed	Uncuffed
Indications	
High risk of aspiration	Minus the concerns on the left, most likely does not matter much
Preexisting or impending impaired pulmonary compliance	
Patient with poor lung compliance undergoing minimally invasive abdominal or chest surgery	
Cardiopulmonary bypass	
Requirement for precisely controlled mechanical ventilation	

Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Decision Pathway for Difficult Pediatric Airway



Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Recommended Length of Central Venous Catheter (CVC) Insertion

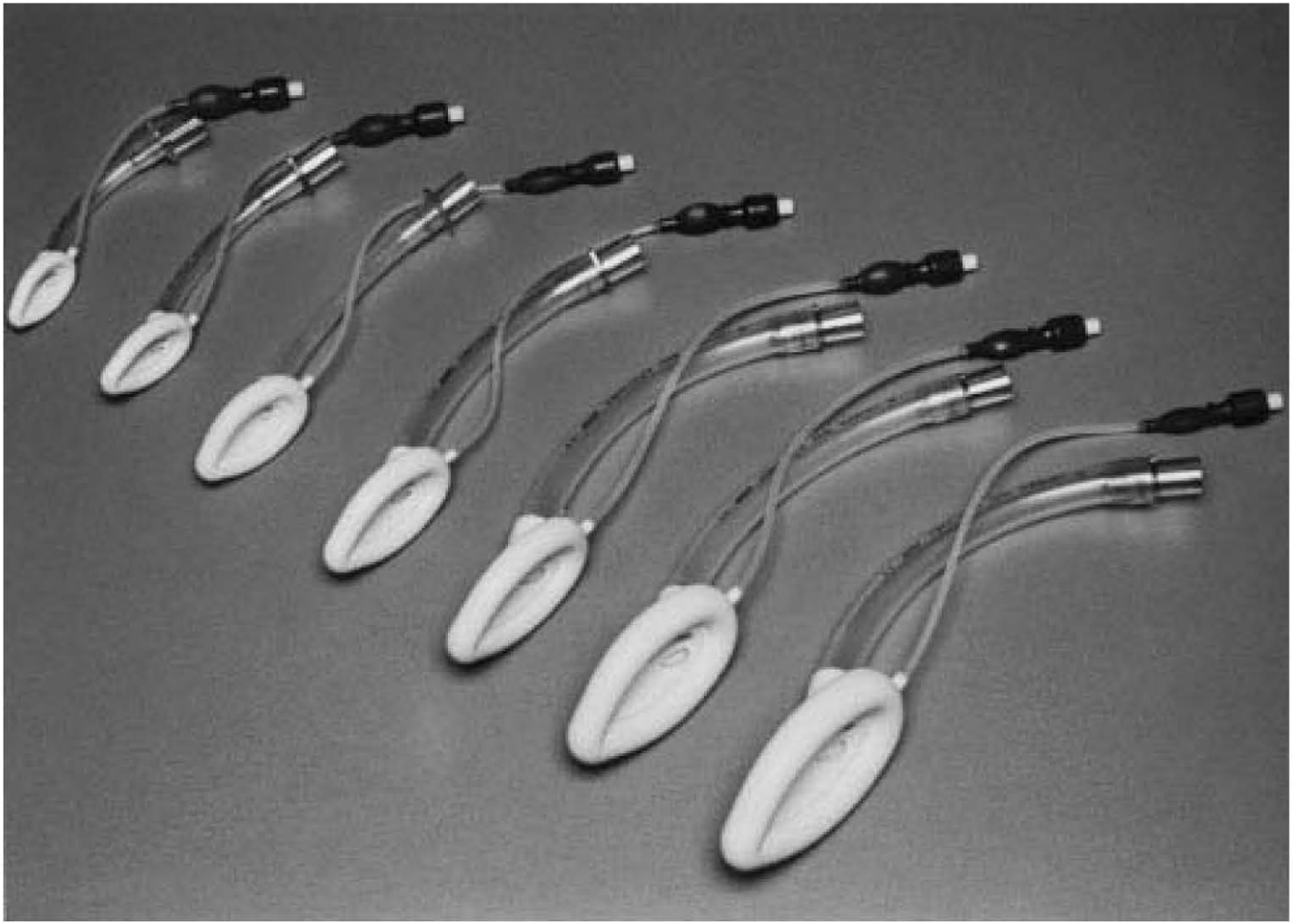
Patient Weight (kg)	Length of CVC Insertion (cm)
2–2.9	4
3–4.9	5
5–6.9	6
7–9.9	7
10–12.9	8
13–19.9	9
20–29.9	10
30–39.9	11
40–49.9	12
50–59.9	13
60–69.9	14
70–79.9	15
≥80	16

Fleisher, Chapter 3: Anesthesia and Uncommon Diseases, 5th ed. 2005.

Laryngeal Mask Airway

Laryngeal Mask Size	Patient Weight
1	≤5 kg
1.5	5-10 kg
2	10-20 kg
2.5	20-30 kg
3	30-50 kg
4	50-70 kg
5	70-100 kg
6	>100 kg

LMA



4.Fasting Time

Meal Type	NPO Time
Clear Liquids	2 hours
Breast Milk	4 hours
Formula	6 hours
Light Meal	6 hours
Heavy Meal	8 hours

Smith's Anesthesia for Infants and Children, 9th ed., 2017.

5. Preoperation & Premedication

- routine hemoglobin measurement in
  - infants younger than 6 months to assess the severity of the physiologic hemoglobin nadir (especially former preterm infants with a potential risk for apnea)
  - older children expected to significant blood loss
- preoperative echocardiogram in
  - chemotherapy with anthracyclines
  - children with congenital heart disease
  - neonates at risk for associated cardiac anomalies
- antiseizure medications will generally benefit from preoperative assessment to ensure therapeutic levels.

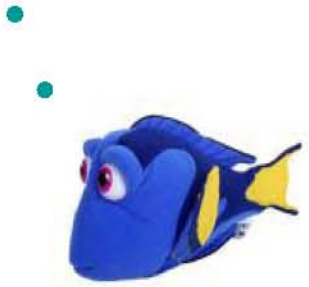
Ronald D. Miller, Chapter82:Pediatric Anesthesia, Anesthesia, 7 th ed, 2009.

The Child with an Upper Respiratory Tract Infection

- If the child is acutely ill and obviously getting worse → cancel for 4 wks
- If the child has rhonchi and a productive cough → cancel for 4 wks
- If the child is stable and afebrile and has had the URI for several days → proceed, avoid ET intubation, not prolong procedure
- The best way of avoiding last-minute cancellations is a phone call by nursing staff the day before to inquire about the child's health

Premedication

Medication	Oral	Intravenous	Transmucosal	Intramuscular
Midazolam (mg/kg)	0.25–1	0.05–0.1	0.2–0.3 (nasal)	0.1–0.15
Fentanyl (mcg/kg)		0.5–1	10 (oral transmucosal)	
Ketamine (mg/kg)	6–10	1–2	5–10	3–7
Clonidine (mcg/kg)	2.5–5	1–2		
Dexmedetomidine (mcg/kg)		0.25–1	1–2 (nasal)	1–2



Smith's Anesthesia for Infants and Children, 9th ed., 2017.

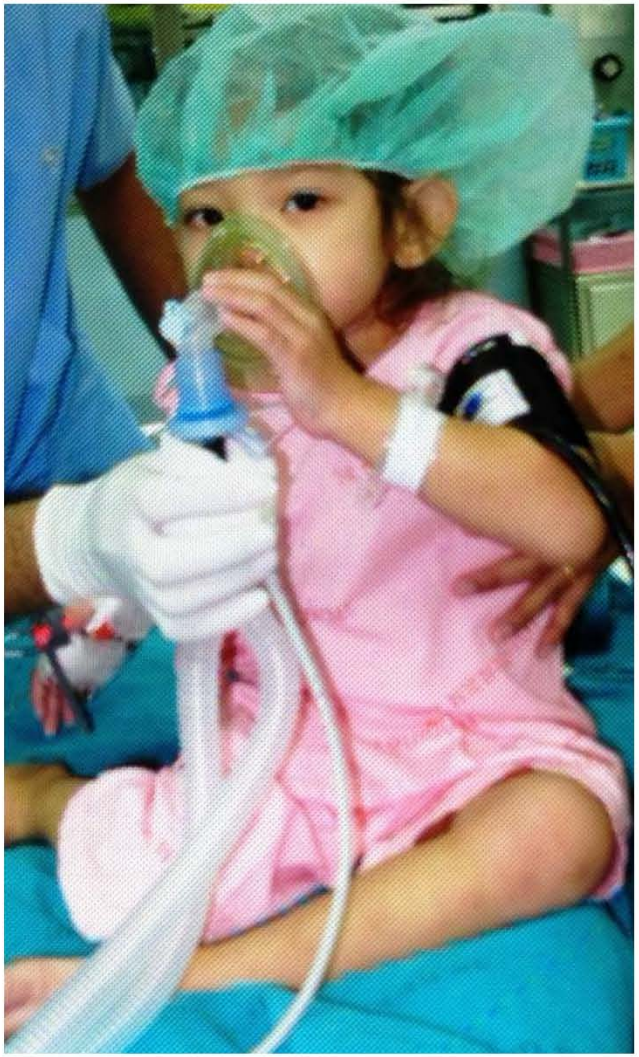
6.Management of Anesthesia

- Induction of Anesthesia
- Types of General Anesthesia
- Monitoring
- Maintenance
- Regional anesthesia
- Reversed & Extubation

Induction of Anesthesia

Parental presence during induction of anesthesia

- Mask → infants < 10-12 months
- Intravenous
- Intramuscular
- Rectal



Intravenous induction

- **Propofol**
- higher in younger (2.9 mg/kg for age < 2 years) than in older children (2.2 mg/kg for age 6 - 12 yrs)
- **Thiopental**
- 5 - 6 mg/kg in healthy
- 2 - 4 mg/kg in low fat stores children ; neonates, malnourished infants
- **Ketamine**
- rectally (10 mg/kg)
- orally (6 - 10 mg/kg)
- intravenous (1 - 2 mg/kg)
- **Etomidate**
- 0.2 to 0.3 mg/kg good for head injury, unstable cardiovascular status; cardiomyopathy

Types of General Anesthesia

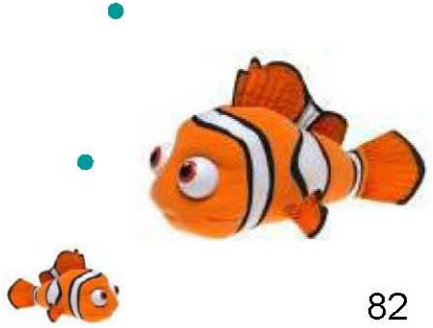
- GA with mask
- GA with LMA
- GA with endotracheal tube

Monitoring

- Precordial or Esophageal stethoscope
- Electrocardiography
- NIBP
- Pulse oximetry
- Temperature
- Capnography

Maintenance

- N_2O : O_2 or O_2 : Air
- Inhalation
  - isoflurane
  - sevoflurane
  - desflurane
- Muscle relaxants ; Sch
- Narcotics ; Fentanyl



Recommended Guidelines for Doses of NDMR (mg/Kg)

	Intubation Dose*	Maintenance
Succinylcholine	1–2	—
Cisatracurium	0.1–0.2	0.02–0.05
Vecuronium	0.05–0.1	0.02
Rocuronium	0.3–1.0†	0.1
Pancuronium	0.08–0.1	0.02

Smith's Anesthesia for Infants and Children, 9th ed., 2017.

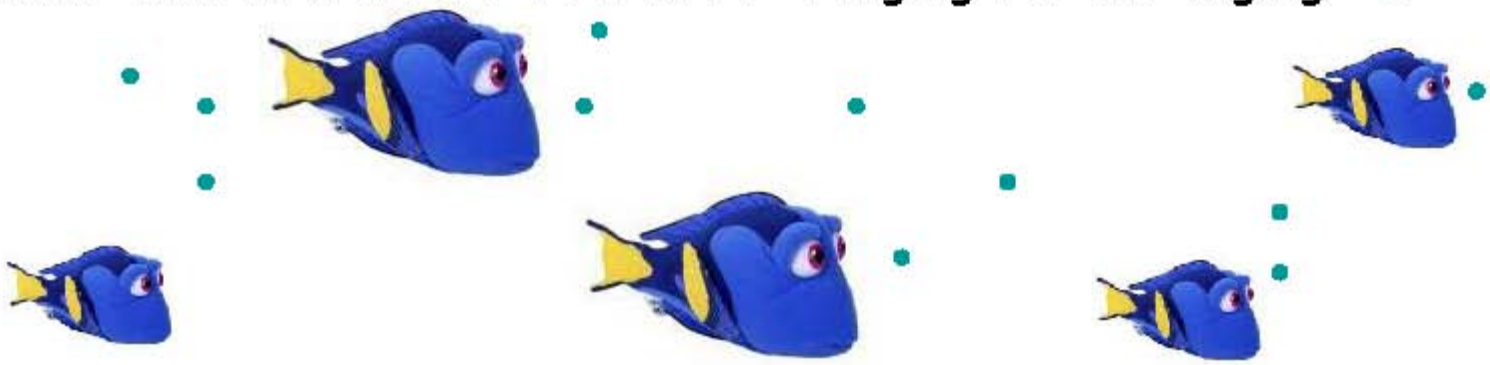
Reversed by

Atropine 0.02 mg/kg

Prostigmine 0.02 -0.06mg/kg

Sugammadex (antagonize the effects of rocuronium)

increasina dose from 2-4 mg/kg to 16 mg/kg



Ronald D. Miller, Chapter29:Pharmacology of Muscle Relaxants and Their Antagonists , Anesthesia, 7 th ed, 2009.

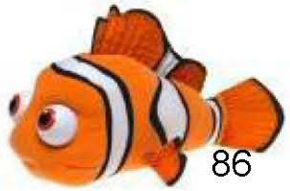
Extubation

- Awake
- Moving actively
- Good Respiratory efforts
  - Maintaining adequate, nonparadoxical breathing
  - Generating a negative inspiratory pressure greater than 30 cm H_2O
- Flexing limbs [Sustaining hip flexion with leg elevation for 10 seconds]
- Lifting the head and/or coughing forcefully

Smith's Anesthesia for Infants and Children, 8th ed., 2011.

Common Problems in the PACU

- Apnea of Prematurity
- Airway Obstruction
- Obstructive Sleep Apnea
- Postobstructive Pulmonary Edema
- Postintubation Croup
- Cardiovascular Instability
- Nausea and Vomiting
- Temperature Instability
- Emergence Delirium
- Pain and Discomfort



Smith's Anesthesia for Infants and Children, 8th ed., 2011.

7.Fluid Management

- Maintenance fluid
- Deficit fluid
- Replacement fluid
- Blood Transfusion

Maintenance Fluid

Weight (kg)	Hourly fluid (ml)
< 10	4 ml/kg
11-20	40 ml + 2 ml/kg >10
>20	60 ml + 1 ml/kg >20

Average fluid need of low-birth-weight infants (mL/kg / 24 hr) during first week of life

		Body weight (gm)			
Age (days)	**Component**	***751 to 1000***	***1001 to 1250***	***1251 to 1500***	***1501 to 2000***
1	IWL [†]	65	55	40	30
	Urine [‡]	20	20	30	30
	Stool	0	0	0	0
	Total	85	75	70	60
2 to 3	IWL	65	55	40	30
	Urine	40	40	40	40
	Stool	0	0	0	5
	Total	105	95	80	75
4 to 7	IWL	65	55	40	30
	Urine	60	60	60	60
	Stool	5	5	5	5
	Total	130	120	105	95

Smith's Anesthesia for Infants and Children, 7th ed., 2005.

Guidelines for Fluids for Newborn & Children During the Perioperative Period

Isotonic (Non glucose) ➡

Age (yr)	Hydrating Solution During First Hour (mL/kg)	Hydrating Solution During Following Hours
Neonates		Maintenance fluid: 4 mL/kg/hr 5% to 10% dextrose in 0.75 normal saline plus 20 mEq sodium bicarbonate/L
		Trauma: 6 to 10 mL/kg/hr for intraabdominal or 4 to 7 mL/kg/hr for intrathoracic surgery replaced with Ringer's lactate
<3	25	Maintenance fluid: 4 mL/kg/hr 5% dextrose in normal saline
3 to 4	20	Maintenance and trauma: basic hourly fluid 4 mL/kg 5% dextrose in normal saline + If mild trauma 2 mL/kg = 6 mL/kg/hr + If moderate trauma 4 mL/kg = 8 mL/kg/hr + If maximal trauma 6 mL/kg = 10 mL/kg/hr
>4	15	

Smith's Anesthesia for Infants and Children, 9th ed., 2017.

- Deficit fluid

= maintenance fluid x hr of fluid restriction

- 50% in the 1st hr
- 25% in the 2nd hr
- 25% in the 3rd hr

Replacement Fluid

- mild tissue trauma = 2-4
- mod tissue trauma = 4-6
- severe tissue trauma = 6-8

(ml/kg/hr)

Method to predict metabolic rates during critical illness

AVERAGE HOSPITAL ENERGY REQUIREMENTS

Body Weight (kg)	kcal/kg/day
0 to 10	100
10 to 20	1000 + 50/kg
>20	1500 + 20/kg

Increases in Energy Expenditure with Stress	
Fever	12% per °C
Cardiac failure	>37° C
Major surgery	15% to 25%
Burns	20% to 30%
Severe sepsis	Up to 100%
	40% to 50%

Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Clinical & laboratory assessment of severity of dehydration

Signs and Symptoms	Mild Dehydration	Moderate Dehydration	Severe Dehydration
Weight loss (%)	5	10	15
Fluid deficit (mL/kg)	50	100	150
Vital Signs			
Pulse	Normal	Increased; weak	Greatly increased; feeble
Blood pressure	Normal	Normal to low	Reduced and orthostatic
Respiration	Normal	Deep	Deep and rapid
General Appearance			
Infants	Thirsty, restless, alert	Thirsty, restless, or lethargic, but arousable	Drowsy to comatose; limp, cold, sweaty; gray color
Older children	Thirsty, restless, alert	Thirsty, alert, postural hypotension	Usually comatose; apprehensive, cyanotic, cold
Skin turgor[†]	Normal	Decreased	Greatly decreased
Anterior fontanel	Normal	Sunken	Markedly depressed
Eyes	Normal	Sunken	Markedly sunken
Mucous membranes	Moist	Dry	Very dry
Urine			
Flow (mL/kg/hr)	<2	<1	<0.5
Specific gravity	1.02	1.020–1.030	>1.030

Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Maximal allowable blood loss

$$MABL = EBV \times \frac{(\text{starting Hct} - \text{target Hct})}{\text{starting Hct}}$$

Normal EBV in (ml/Kg)

- Preterm = 100 - 120
- Full Term = 90
- Age 3-12 mths = 80
- Age > 1 yr = 70

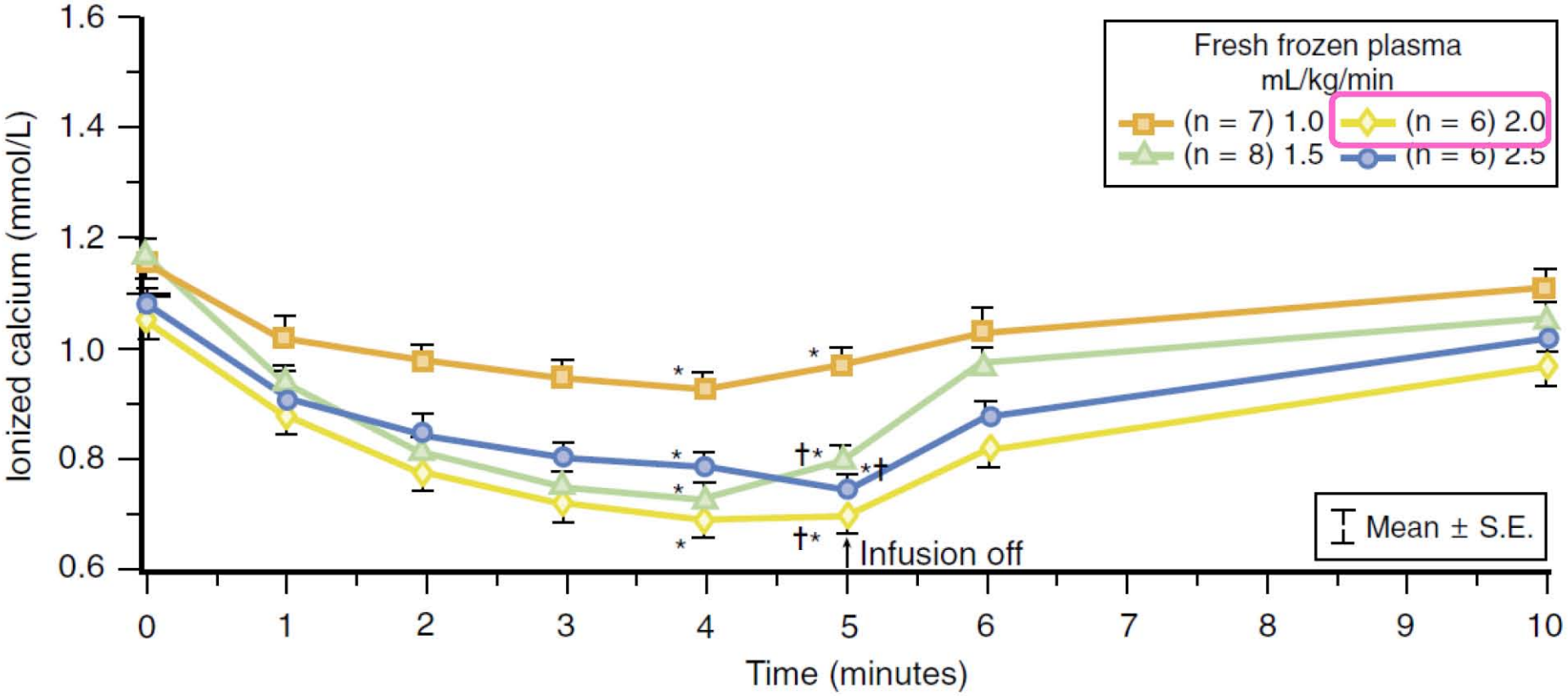
Blood Transfusion

ตัวอย่างการคำนวณ ในเด็กหนัก 15 Kgs และ Hct 20 %

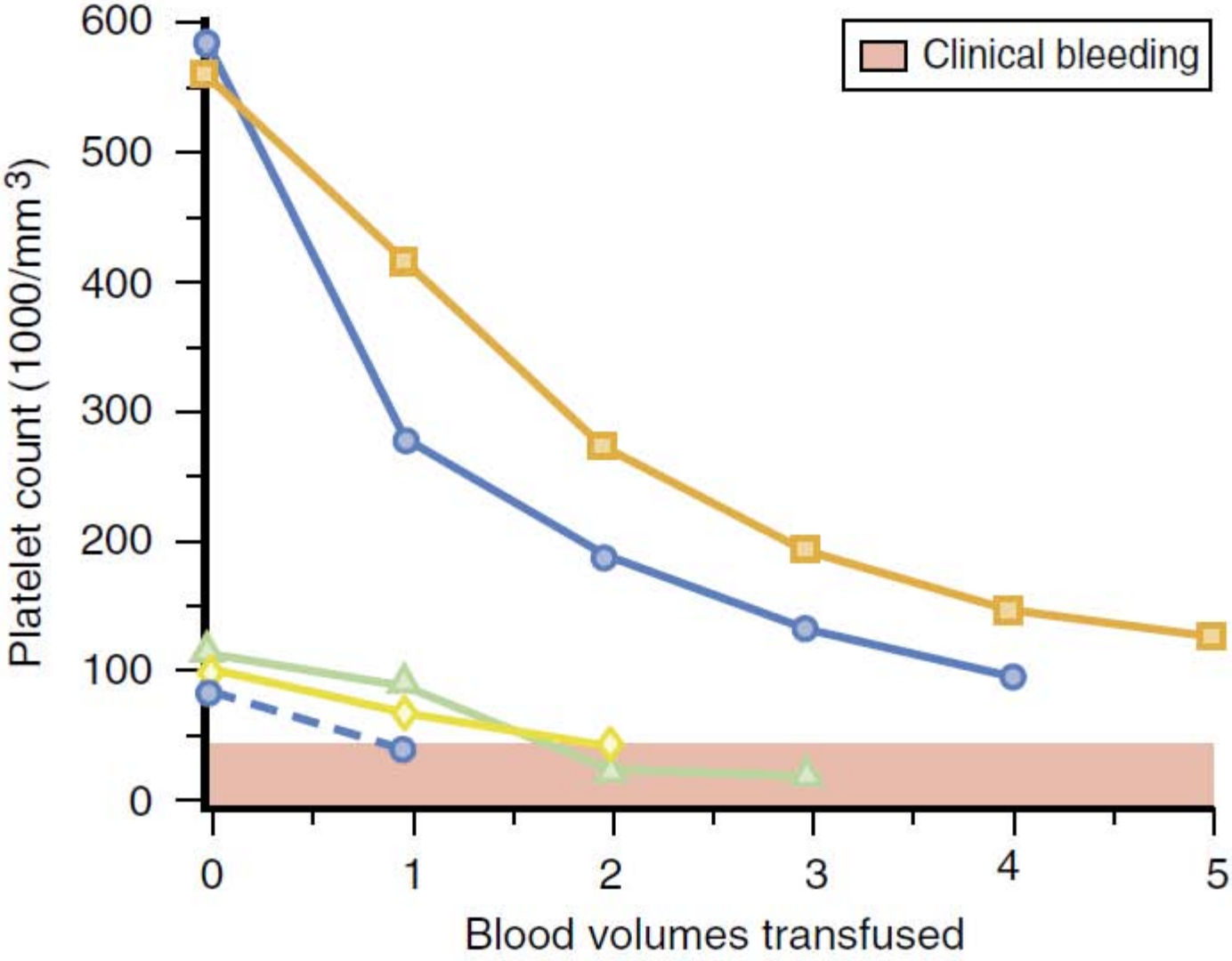
$$\text{Volume of PRBCs to be transfused} = \frac{\left[\text{Desired Hct (35)} - \text{Present Hct (20)} \times \text{EBV}\left(70\ \text{mL/kg} \times 15\ \text{kg}\right)\right]}{\text{Hematocrit of PRBCs}\left(\sim 60\%\right)}$$

Blood component → Hypocalcemia

FFP



Dilutional Thrombocytopenia



8.Postoperative Care

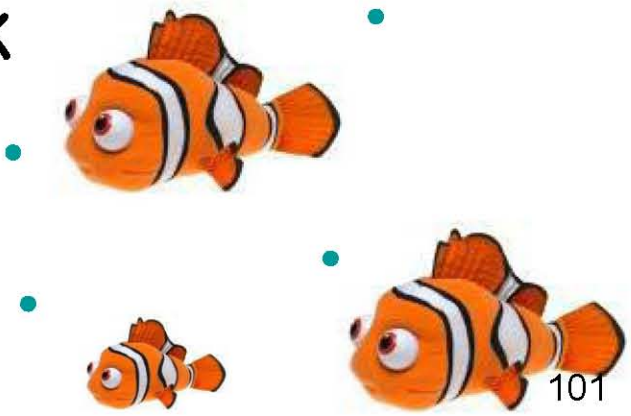
- Correct abnormal finding
  - Anemia
  - Hypothermia
- Monitoring
- Oxygen therapy
- Analgesia
- Subglottic edema (postintubation croup)

Postoperative Analgesia

- **Acetaminophen** 60 mg/kg/day
- **Codeine + Acetaminophen**
- **Narcotics**
  - fentanyl 1-2 mcg/kg, iv, q 1 hr
  - pethidine 0.5-1 mg/kg, im, q 4 hr
  - morphine 0.02-0.05 mg/kg, im, q 4 hr
  - codeine 1-1.5 mg/kg, im, q 4 hr

Postoperative Analgesia

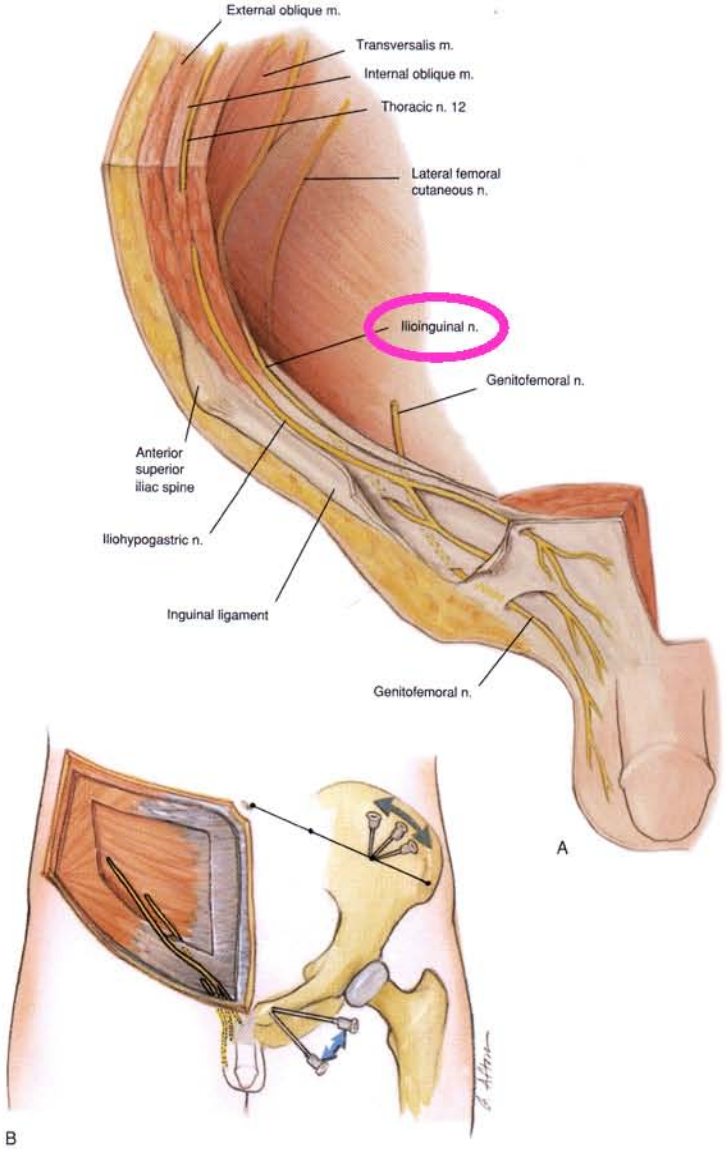
- continuous narcotic infusion
- PCA
- regional anesthesia
  - caudal block, epidural block
  - peripheral nerve block
  - local infiltration



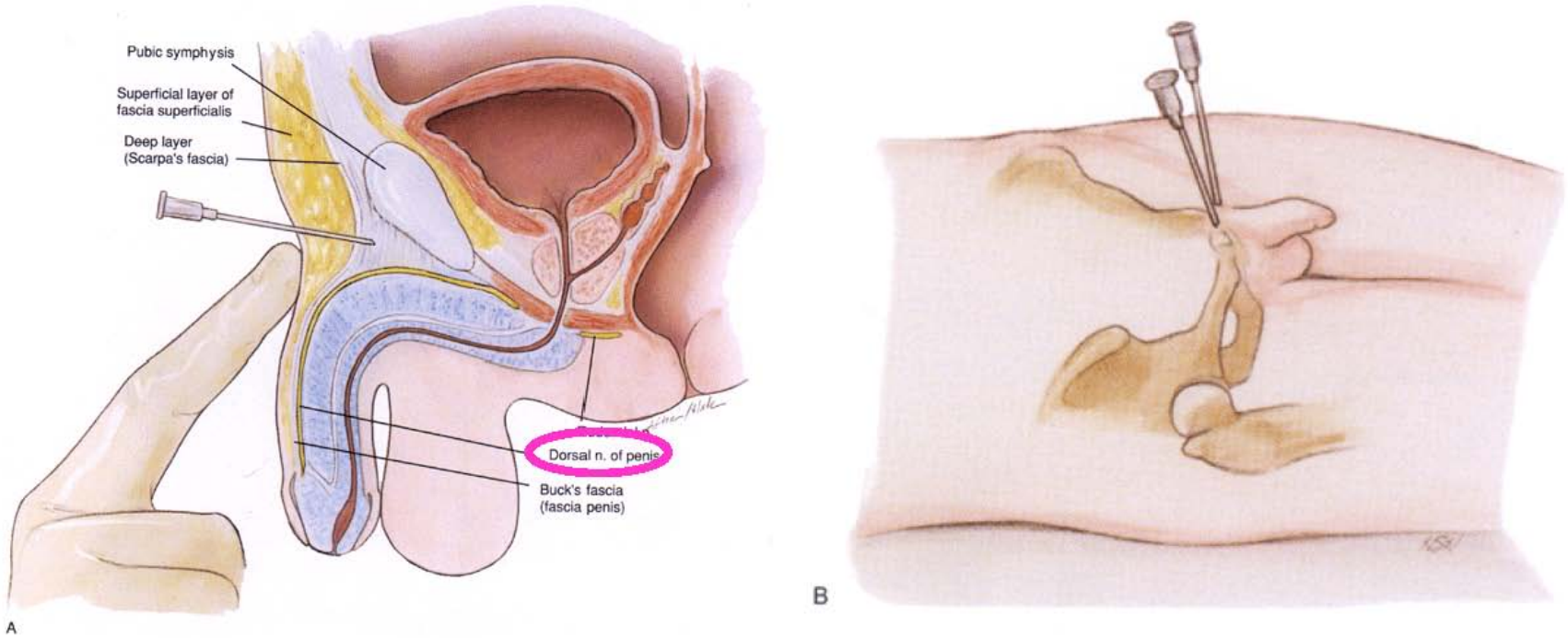
Regional anesthesia in Pediatrics

- Peripheral nerve block
  - Ilioinguinal NB
  - Iliohypogastric NB
  - Penile NB
- Caudal block (Epidural block)
  - Dosage prescription scheme of Armitage
    - 0.5 mL/kg, all sacral dermatomes are blocked
    - 1.0 mL/kg, all sacral and lumbar dermatomes are blocked
    - 1.25 mL/kg, the upper limit of anesthesia is at least midthoracic

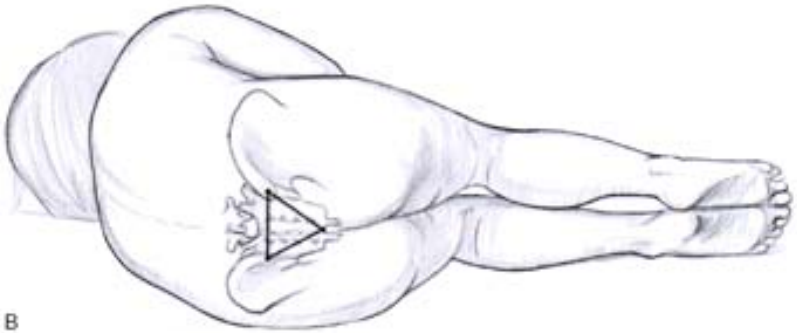
Ilioinguinal NB



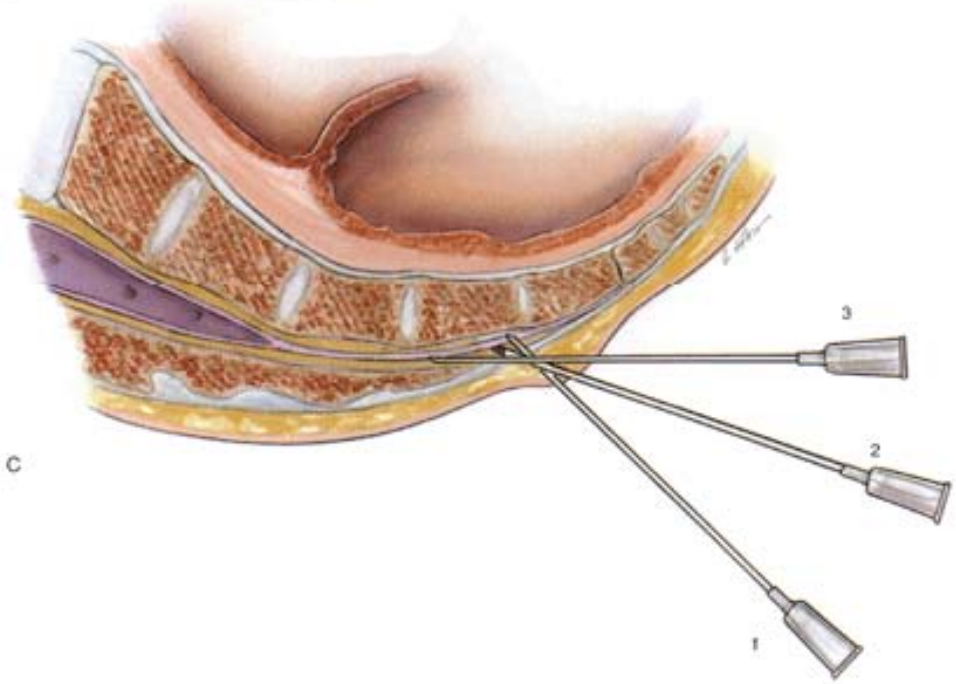
Penile NB


Pubic symphysis
Superficial layer of fascia superficialis
Deep layer (Scarpa's fascia)
Dorsal n. of penis
Buck's fascia (fascia penis)
A
B

Caudal block



B



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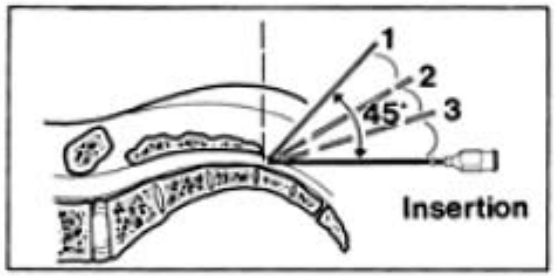
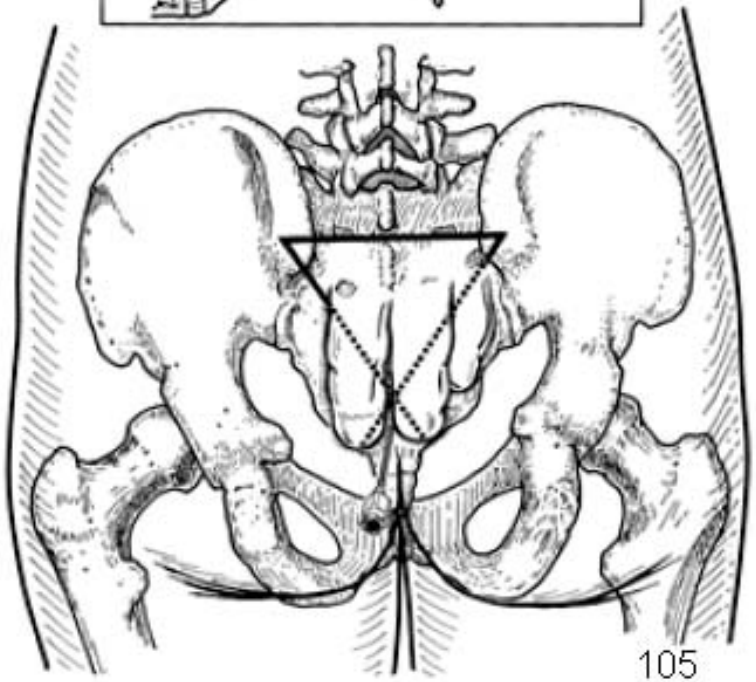
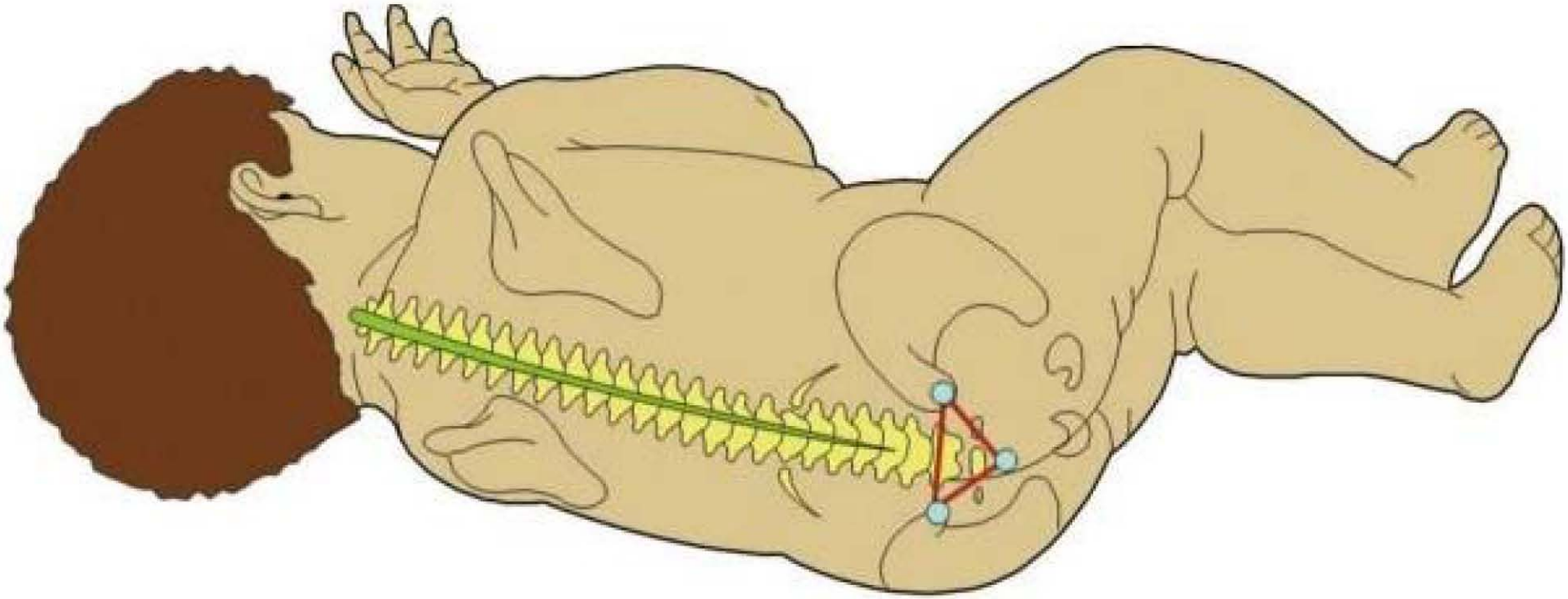
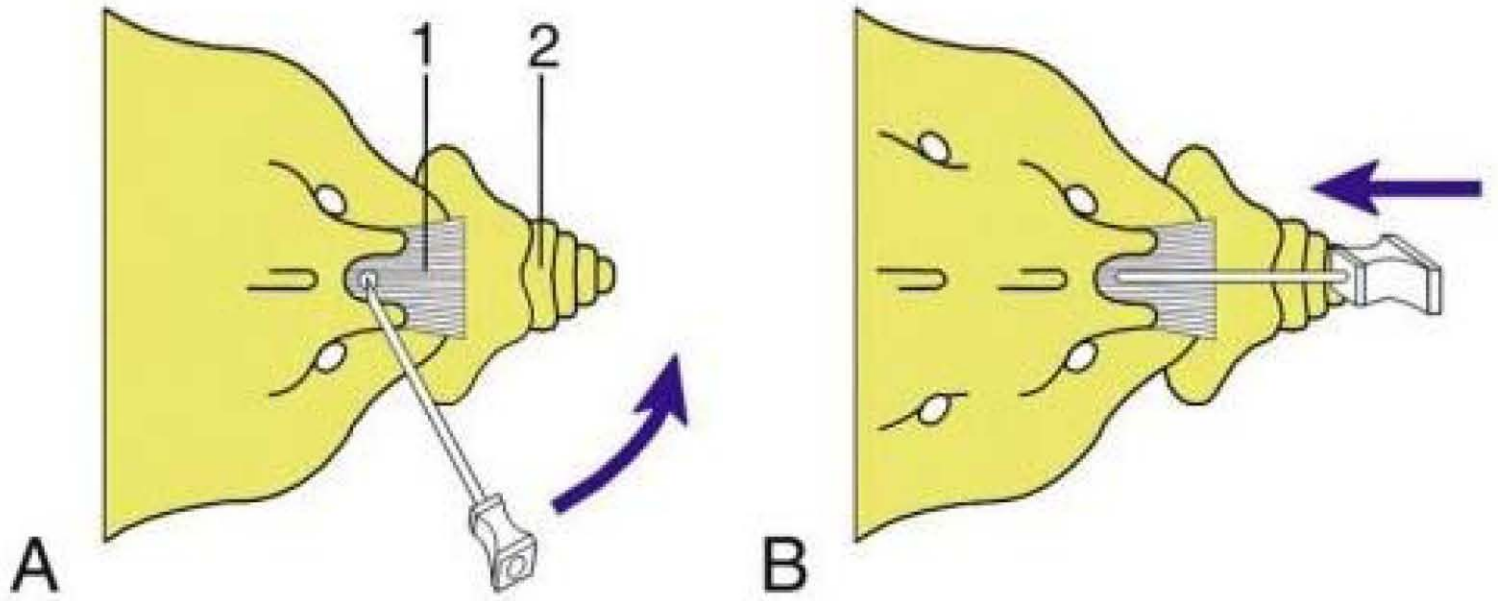
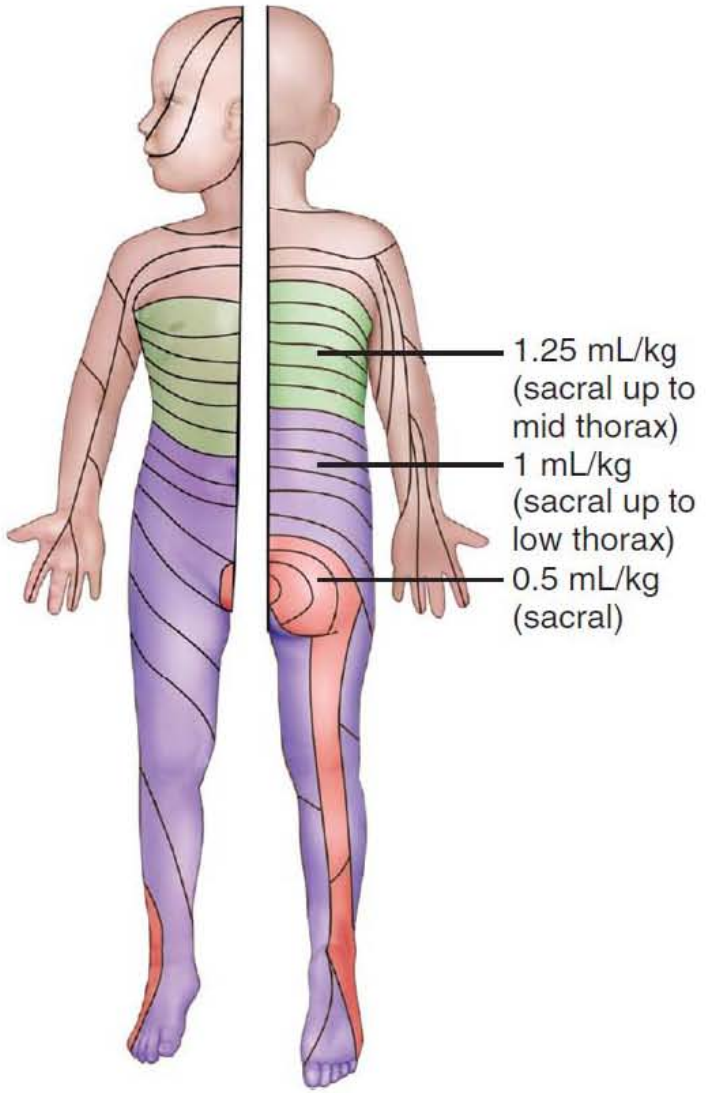







1
2
A
B

Dermatomal Distribution of Local Anesthetic for a Single-Shot Caudal Block



Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Commonly Used Additives and Recommended Doses in Pediatric Regional Anesthesia

Additive	Recommended Doses	Maximum Doses
Morphine		
Epidural	30 µg/kg	50 µg/kg
Intrathecal	10 µg/kg	20 µg/kg
Fentanyl (epidural)	1-1.5 µg/kg	2.5 µg/kg

Ronald D. Miller, Chapter81:Regional Anesthesia in Children, Anesthesia, 7 th ed, 2009.

Usual & Maximum Recommended Doses of Local Anesthetic

Local Anesthetic	Single Dose	Continuous Infusion Rate	Continuous Infusion Rate in Infants (<6 mo)*
Bupivacaine	3 mg/kg	0.4–0.5 mg/kg/hr	0.2–0.25 mg/kg/hr
Levobupivacaine	3 mg/kg†	0.4–0.5 mg/kg/hr	0.2–0.25 mg/kg/hr
Ropivacaine	3 mg/kg†	0.4–0.5 mg/kg/hr	0.2–0.25 mg/kg/hr
Lidocaine	5 mg/kg	1.6 mg/kg/hr	0.8 mg/kg/hr
Lidocaine with epinephrine‡	7 mg/kg	NA	NA

Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Test Dose of local anesthetic

- test dose of LA containing 5 μg per mL of epinephrine (0.1 mL/kg, maximum of 3 mL) to detect inadvertent intravascular injections
- awake patient → HR ≥ 10 bpm = positive sign
- $\frac{1}{4}$ of anesthetized children → HR not increase
- Increased BP ≥ 15 mmHg

- more sensitive indicator → ↑ T-wave amplitude on ECG (> 25%)
- T-wave height will increase within 20 secs. and disappear within 60 secs.

Robert S. Holzman, A Practical Approach to Pediatric Anesthesia, Chapter 8,1st Ed. 2008.

Local Anesthetic Toxicity Rx

1. Airway management, FiO_2 100%
2. Seizure suppression
3. Cardioplumonary resuscitation (limit epinephrine to 1 mcg/kg per dose)
4. Alert the nearest institution that has cardiopulmonary bypass capabilities
5. Administer 20% lipid emulsion

   Bolus 1.5 cc/kg IV 1 minute

   Start a continuous infusion of 0.25 cc/kg/min

   Repeat the bolus every 5 minutes for persistent cardiovascular collapse

   Double infusion rate if the blood pressure returns but remains low

   Continue the infusion for a minimum of 30 minutes

   The recommend upper limit of lipid emulsion is 10 cc/kg in the first 30 minutes.

Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Local Anesthetic Toxicity Rx

- 20% intravenous lipid emulsion
- By lipid scavenges, extracts, & binds lipophilic local anesthetics from tissue and plasma
- recommended dose = 1 mL/kg over 3 mins
  - repeated up to 3 mL/kg
  - followed by infusion of 0.25 mL/kg/min until hemodynamic recovery is achieved
  - rate ≥ 8 mL/kg is not likely to be effective

Robert S. Holzman, A Practical Approach to Pediatric Anesthesia, Chapter 8,1st Ed. 2008.

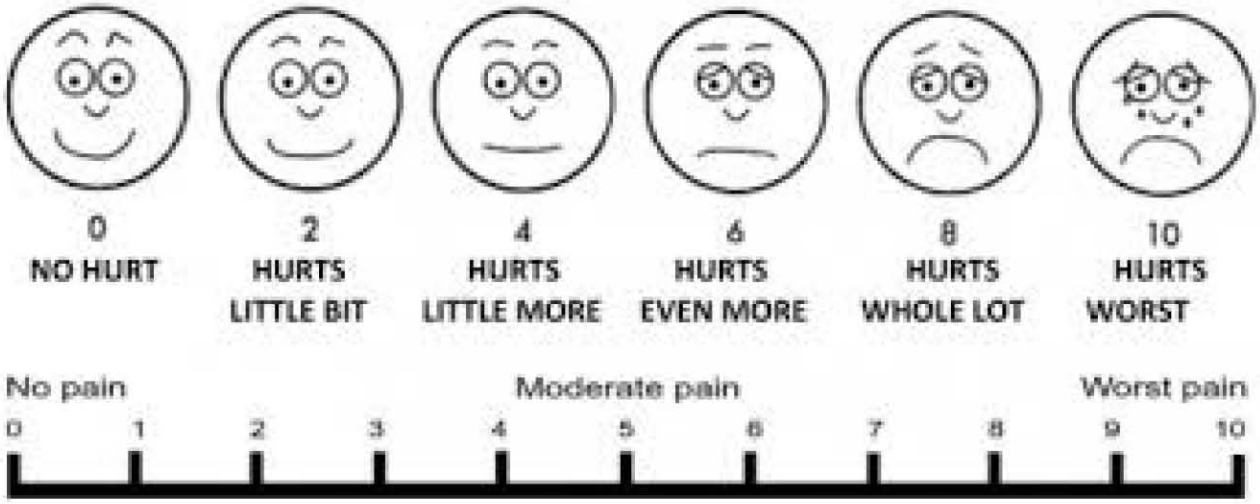
Pain Measurement Scales

Facial Expression-Leg Movement-Activity-Cry-Consolability (FLACC) Scale

Categories	Scoring		
	0	1	2
Face	No particular expression or smile	Occasional grimace or frown, withdrawn, disinterested	Frequent to constant frown, clenched jaw, quivering chin
Legs	Normal position or relaxed	Uneasy, restless, tensed	Kicking, or legs drawn up
Activity	Lying quietly, normal position, moves easily	Squirming, shifting back and forth, tensed	Arched, rigid, or jerking
Cry	No cry (awake or asleep)	Moans or whimpers, occasional complaint	Crying steadily, screams or sobs, frequent complaints
Consolability	Content, relaxed	Reassured by occasional touching, hugging, or being talked to, distractable	Difficult to console or comfort

Pain Measurement Scales

Wong-Baker FACES Pain Rating Scale



Common Problems in the PACU

- Apnea of Prematurity
- Airway Obstruction
- Obstructive Sleep Apnea
- Postobstructive Pulmonary Edema
- Postintubation Croup
- Cardiovascular Instability
- Nausea and Vomiting
- Temperature Instability
- Emergence Delirium
- Pain and Discomfort

Smith's Anesthesia for Infants and Children, 8th ed., 2011.

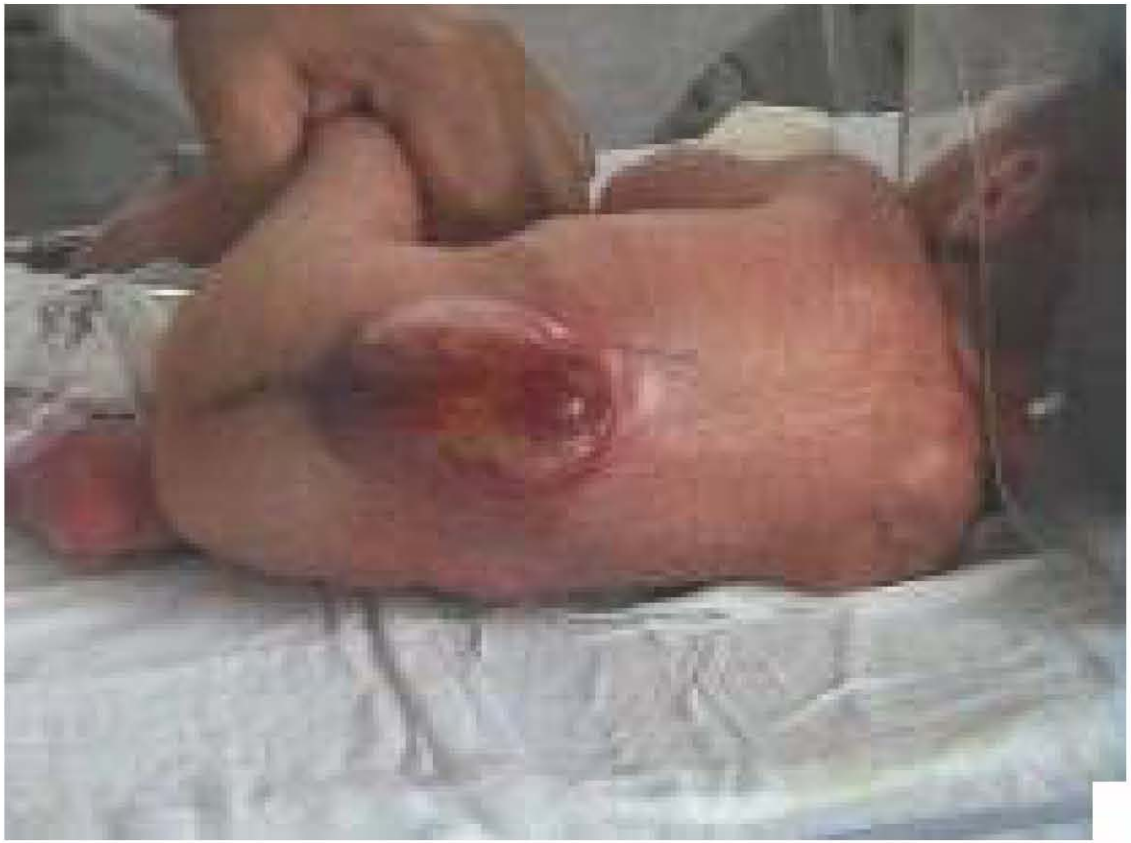
9.Special Problems

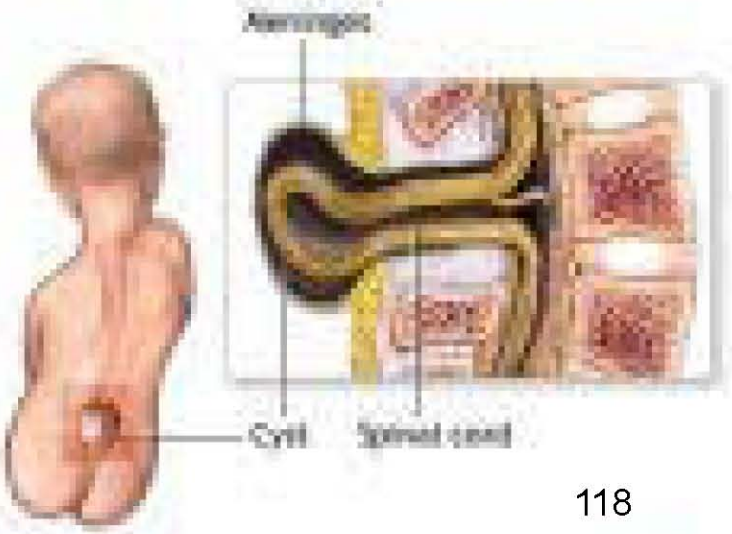
- Meningomyelocele
- Pyloric Stenosis
- Omphalocele & Gastroschisis
- Tracheoesophageal Fistula
- Diaphragmatic Hernia
- Preterm Infant
- Necrotizing Enterocolitis
- Intussusception
- Children with Obstructive Sleep Apnea
- URI
- Hirschsprung's disease

Meningomyelocele

Problems

- Associated with Hydrocephalus
- Fluid & Blood loss from defect
- Cranial nerve palsy → inspiratory stridor
- Potential Brainstem herniation
- Latex allergy precaution




Meninges
Cyst
Spinal cord

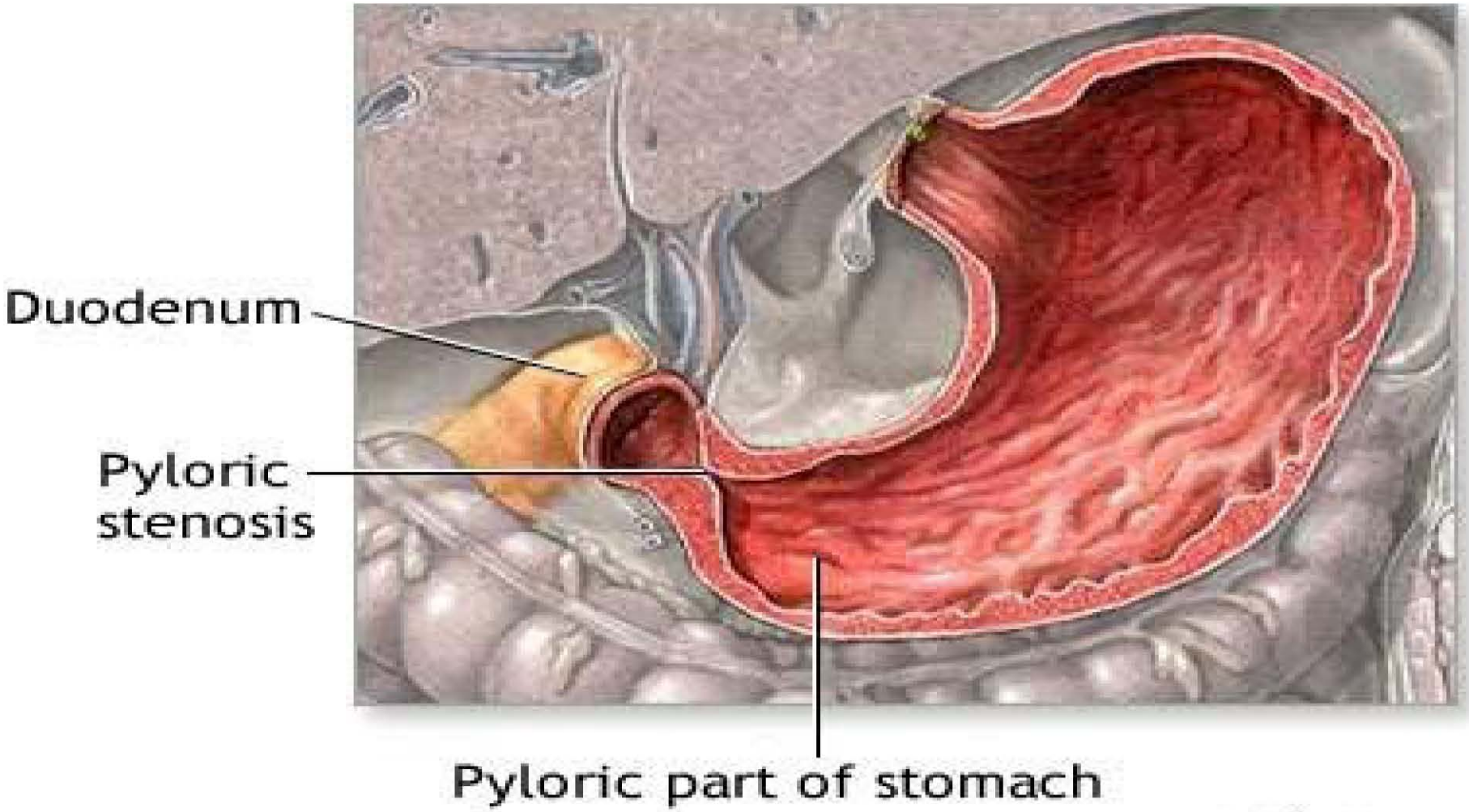
Pyloric stenosis

- **Incidence** 1 in every 300 live births
- Males > Female 4 times

- **Signs and Symptoms**
  - nonbilious projectile vomiting at 2 - 5 wks of age
  - symptoms may develop - 1st week to 5th month of life
  - vomiting occurs within 30 - 60 mins after feeding
  - hypokalemic, hypochloremic primary metabolic alkalosis with a secondary respiratory acidosis
  - Hypovolemia, Hypokalemia, Hypocalcemia
  - Compensatory respiratory acidosis → resulting from hypoventilation & periodic apnea

Smith's, Anesthesia for Infant and Children, 9th ed.,2017.

Roberta L. Hines, Stoelting's Anesthesia and Co-Existing Disease, Chapter 24:Pediatric Diseases, 5th ed.2008.



A.D.A.M.

Pyloric Stenosis

Problems

- Hypochloremic -Hypokalemic Metabolic Alkalosis
- Aspiration (gastric content)
- Hypotension
- Dysrhythmia
- Inadequate respiration
- manifested in the first 3 - 6 weeks of life

- **Diagnosis**
  - olive-like mass → palpated in the epigastrium
  - upper GI contrast studies (barium swallow)
  - Ultrasonography sensitivity 95% & specificity 100%
- **Treatment**
  - Pyloromyotomy → definitive treatment
  - not a surgical emergency
  - Fluid resuscitation guided by serum electrolyte →
    - serum chloride > 100 mEq/dL
    - serum bicarbonate < 28 mEq/dL
  - Metabolic alkalosis must be corrected prior to surgery to prevent postoperative apnea

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- **Prognosis**
  - Surgical treatment is curative
  - Feedings within 4 - 6 hrs following surgery

- **Management of Anesthesia**
  - full stomach → risk of aspiration; upper GI contrast studies
  - Prevent by
    - premedication with atropine
    - large-bore orogastric catheter

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General Anesthesia Guidelines for Pyloric Stenosis

Premedication: not generally indicated
Monitors: standard anesthesia monitoring, gastric decompression
Anesthetic induction: intravenous rapid sequence
Propofol 2 mg/kg and rocuronium 0.5 mg/kg
or
Atropine 20 mcg/kg, propofol 2 mg/kg, and succinylcholine 2 mg/kg
or
Atropine 20 mcg/kg, propofol 3 mg/kg, and remifentanil 1 to 2 mcg/kg
Airway: endotracheal tube
Anesthetic maintenance: air/oxygen/sevoflurane or isoflurane
Anesthetic adjuncts: ondansetron
Intraoperative and postoperative pain management:
- Acetaminophen: intravenous 15 mg/kg or rectal 30 to 40 mg/kg initial dose
- Wound infiltration with local anesthetic agent

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- **Postoperative Management**
  - Postoperative depression of ventilation by
    - CSF alkalosis
    - intraoperative hyperventilation
  - Apnea monitoring for the first 12 hours after surgery
  - hypoglycemia may occur 2 - 3 hrs after surgery due to inadequate liver glycogen stores & cessation of intravenous dextrose infusions

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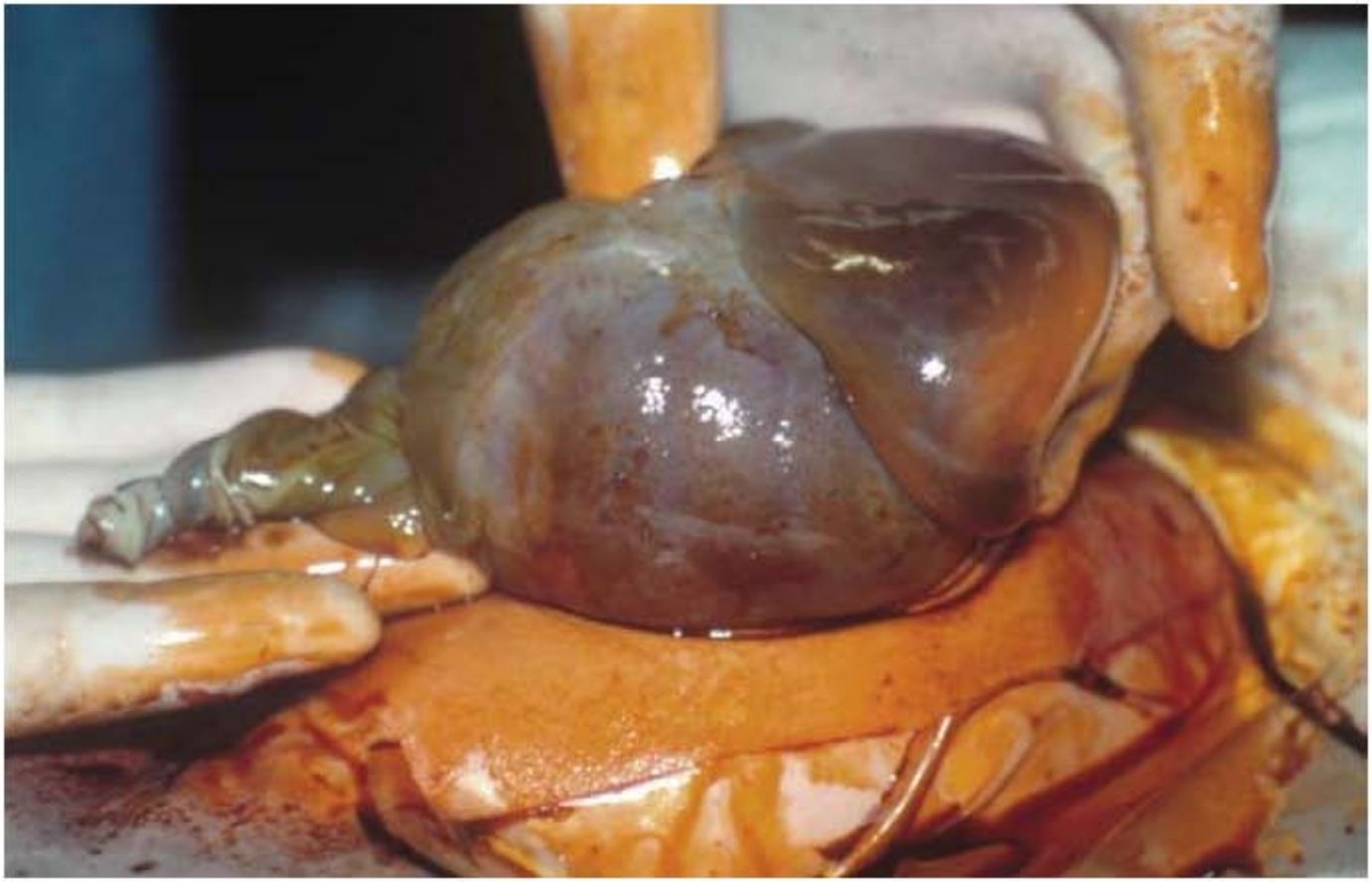
Omphalocele & Gastroschisis

Problems

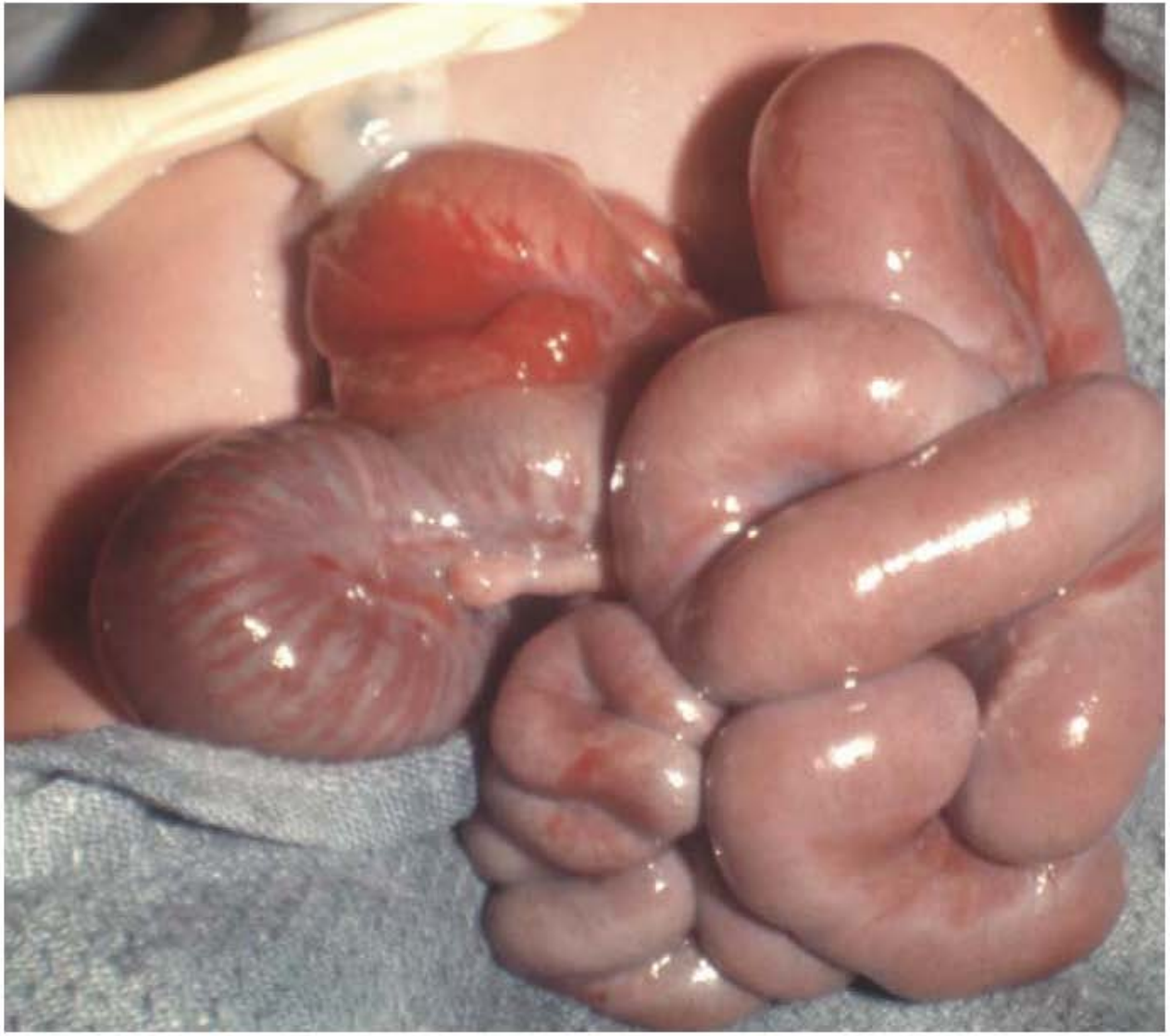
- Hypovolemia → Severe dehydration
- Heat loss → Hypothermia
- Prone to infection
- Increase intra-abdominal pressure
  - Cardio-respiratory compromise
  - Edema of lower extremities
  - Organ ischemia
- Prolong bowel dysfunction

♥ High association with prematurity and other congenital defects

Omphalocele



Gastroschisis



Comparison of Gastroschisis & Omphalocele

	Gastroschisis	Omphalocele
Incidence	1: 10,000	1: 4,000–7,000
	Intact umbilical cord and evisceration of bowel through a defect in the abdominal wall right of the cord	Herniation of bowel and liver thorough umbilical wall covered by membranes unless ruptured liver and other organs
Sac	No membrane covering (sac absent)	Present
Associated Organs	No	
Associated Anomalies	Intestinal atresia 25%	Chromosomal anomalies
	Cryptorchidism 31%	Trisomy 18, 13, 15, and 21
		Beckwith-Wiedemann syndrome
		Pentalogy of Cantrell
		Prune belly syndrome
Maternal Age	< 25 yr	Older
Smoking and Alcohol Use	Yes	No
Teratogens	Acetaminophen, aspirin, pseudoephedrine use in pregnancy: Yes	No
Congenital Heart Disease	12%	24%
Prematurity	40%-67%	10%-23%

	Gastroschisis	Omphalocele
Pathophysiology	Occlusion of the omphalomesenteric artery	Failure of gut migration from the yolk sac into the abdomen
Incidence	~1 in 15,000 births	~1 in 6000 births
Incidence of associated anomalies	~10%-15%	~40%-60%
Location of defect	Periumbilical	Within the umbilical cord
Problems associated with the defect	Inflammation of exposed gut Edema Dilated and foreshortened gut (chemical peritonitis)	Congenital heart disease (~20%) Exstrophy of the bladder Beckwith-Wiedemann syndrome (macroglossia, gigantism, hypoglycemia, hyperviscosity)

- Primary closure → cause
  - respiratory compromise
  - decreased venous return
  - circulatory dysfunction
  - Lower extremity congestion & cyanosis
- Primary closure is not recommended if
  - inspiratory pressures > 25 - 30 cm.H_2O
  - Intravesical/Intragastric pressures > 20 cm.H_2O

- **Prognosis**
  - survival rate for gastroschisis ≥ 90%
  - survival rates for omphalocele 70% - 95%

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- **Preoperative Management**
  - prevention of infections
  - minimization of fluid & heat loss
    - Covering exposed viscera with moist dressings & plastic bowel bag & maintaining neutral thermal environment
  - decompressed stomach with orogastric tube
  - Fluid;
    - Volume 2-4 times of daily maintenance requirement (≥8–16 mL/kg/hour)
    - 5% albumin = 25% of replacement fluids
  - Hypovolemia is indicated by hemoconcentration & metabolic acidosis

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- **Management of Anesthesia**
  - preservation of body temperature & continuation of fluid replacement
  - decompression of the stomach and preoxygenation
  - N_2O is avoided
  - Monitoring airway pressure
  - Direct monitoring of ABG & pH is helpful for guiding fluid therapy
  - Need mechanical ventilation for 24-48 hours

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Preoperative

Adequate hydration
Maintenance of temperature, prevention of heat loss
Evaluation for congenital heart disease and other associated abnormalities
Broad-spectrum antibiotics
Measure electrolytes

Intraoperative

Rapid-sequence induction
Avoid mask ventilation and abdominal distension
Muscle relaxation (nondepolarizing muscle relaxants)
Inhalational agents as hemodynamically tolerable
Opioids for analgesic
Consider regional anesthesia for intraoperative and postoperative care.
Monitors: standard monitors, arterial catheter if hemodynamically unstable
Consider central venous catheter for both intraoperative monitoring and post-operative nutrition
Monitor inspiratory pressures during defect closing
Right upper-extremity pulse oximeter (preductal)
Pulse oximetry on lower extremity. Used for postductal saturation and perfusion of lower extremity during abdominal closure.
Prevent hypothermia; forced air warmer

Postoperative

Mechanical ventilation unless defect small
Regional anesthesia encouraged unless prolonged intubation expected

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Esophageal atresia / Tracheoesophageal fistula

- **Incidence** of EA/TEF = 1 : 3,000-4,500 neonates
- 50% of EA associated with
  - VATER (vertebral defects, imperforate anus, tracheoesophageal fistula, cardiac, radial & renal dysplasia)
  - VACTERL (VATER + cardiac & limb anomalies)
- 20% of EA → co-existing CVS anomalies (VSD, TOF, coarctation of the aorta, ASD)
- 30% - 40% → Preterm

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- **Signs and Symptoms**
  - presents with respiratory distress associated with
    - episodes of coughing
    - Cyanosis
    - frothing at the mouth and nose
  - Feeding exacerbates these symptoms
  - Pulmonary aspiration
  - Infants with isolated TEF in the absence of EA may elude diagnosis until later in life → recurrent pneumonias & refractory bronchospasm

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- **Diagnosis**
  - Prenatally; suspected EA if polyhydramnios
  - After birth;
    - oral catheter cannot passed into the stomach
    - cyanosis, coughing, choking during feedings
  - Plain radiographs of the chest&abdomen → coiling of a NG tube in the esophageal pouch
  - pure EA → airless, scaphoid abdomen

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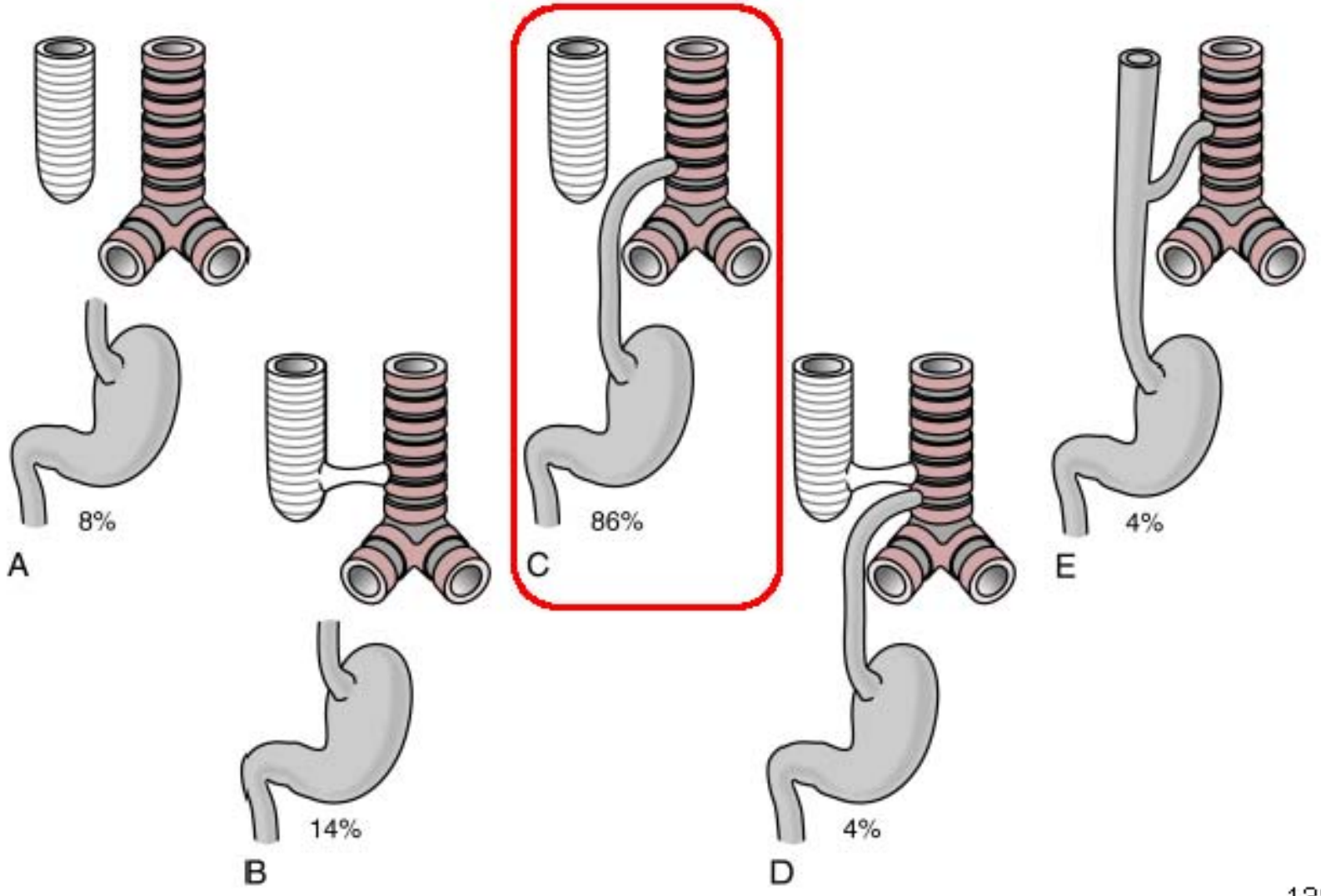
Types of EA/TEF



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Tracheoesophageal Fistula

Problems

- Prematurity ċ associated congenital anomaly
- Dehydration
- Pneumonitis
- Inadequate ventilation
  - Gastric distension
  - Air leak through gastrostomy
- Problems at ET tube
- Tracheomalacia

Preoperative management : protect the lungs from aspiration pneumonia

- Avoiding feeding
- Upright, semiprone positioning of the infant to minimize gastroesophageal reflux
- Intermittent suctioning of the upper pouch
- Administration of antibiotics

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- **Treatment**
  - maintain patent airway & prevent aspiration
    - Stopped feedings
    - head-up position to minimize regurgitation
    - Continuous suctioning of the proximal esophageal segment
  - avoided ET intubation
  - Type C→ Primary repair without gastrostomy
  - Delayed Sx (3-6 mths)→ Ligated fistula with inserted gastrostomy
  - Significant associated anomalies → staged surgical approach with initial gastrostomy

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- evaluation for associated anomalies; Rt-sided aortic arch (require Lt thoracotomy approach)
- Repair may be transpleural or extrapleural

- **Prognosis**
  - pathologic finding in EA is decreased tracheal cartilage→ tracheal collapse after tracheal extubation
  - esophageal stricture → require dilatation
  - Chronic gastroesophageal reflux & dysphagia

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- **Management of Anesthesia**
  - awake intubation with spontaneous ventilation

  or fentanyl (0.2-0.5 mcg/kg)
  - inhalation induction → intubated without muscle relaxants
  - intravenous induction → ventilation to minimize PIP
  - Proper placement of ET tube is critical;

    above the carina but below the TEF

ET tube advanced into Rt main bronchus then withdrawn until bilateral breath sounds are present

  - avoid excessive airway pressures
  - anesthetic technique depends on physiologic status → Low-dose volatile + air/O_2/opiate

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- Intraoperative fluid losses replaced with crystalloid 6 - 8 mL/kg/hr
- Blood loss replaced with 5% albumin & blood → Hct ≥ 35%
- Avoid hypothermia
- During surgery, lung retraction may impair ventilation & surgical manipulation of the trachea → airway obstruction
- Frequent tracheal suctioning
- Excessive neck extension & reintubation → compromised new anastomosis

- Tracheomalacia is common (up to 78%), clinically significant in only about 10% of patients

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Interventions to protect the lungs from aspiration in TEF

- Avoidance of feedings
- Upright positioning of the infant to decrease the likelihood of gastroesophageal reflux (30-degree elevation)
- Antibiotic therapy & physiotherapy if pneumonia is diagnosed
- Intermittent suctioning of the upper blind esophageal pouch

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Anesthetic Management for TEF

Monitor

- Standard monitoring
- Upper- & lower-extremity pulse oximeter
- Arterial access if hemodynamically unstable, congenital heart disease, or significant lung disease preoperatively

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Anesthetic Management for TEF

Inhaled induction with sevoflurane

Establish intravenous access

Maintain spontaneous ventilation

If bronchoscopy is performed prior to surgical repair:

- Glycopyrrolate
- Topicalize vocal cords and trachea with lidocaine
- Titrate inspired anesthetic concentration
- Proporol or ketamine PRN

If fistula is 1 cm or more above carina, intubate (bevel ETT anterior) (inflate cuff if cuffed tube)

- If fistula below carina, then left mainstream intubation

Neuromuscular blockade after lung isolation

Position left lateral decubitus for right thoracotomy (no right aortic arch)

Fentanyl for analgesia

Consider regional anesthesia

Temperature: forced-air warmer

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Anesthetic Management for TEF

Postoperative

- Postoperative ventilation, minimize neck extension

- Regional anesthesia for pain

- Multimodal analgesia including regional anesthesia

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Monitors

Standard monitoring

Upper- and lower-extremity pulse oximeter

Arterial access if hemodynamically unstable, congenital heart disease, or significant lung disease preoperatively

Anesthestic

Inhaled induction with sevoflurane

Establish intravenous access

Maintain spontaneous ventilation

If bronchoscopy is performed prior to surgical repair:

- Glycopyrrolate
- Topicalize vocal cords and trachea with lidocaine
- Titrate inspired anesthetic concentration
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Fentanyl for analgesia

Consider regional anesthesia

Temperature: forced-air warmer

Postoperative

Postoperative ventilation minimize neck extension

Regional anesthesia for pain

Multimodal analgesia including regional anesthesia

Congenital diaphragmatic hernia

- **Incidence** of CDH = 1:2,500-3,000 live births
- Male to Female ratio = 1:1.8
- The most common & largest diaphragmatic defect (75-80%) → left posterolateral pleuroperitoneal canal (foramen of Bochdalek)

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CDH is associated with the following:

- Varying degrees of bilateral lung hypoplasia
- Pulmonary hypertension & arteriolar reactivity
- Congenital anomalies ;
  - Cardiac
  - Gastrointestinal (intestinal malrotation)
  - Genitourinary
  - Skeletal
  - Neural
  - Trisomic

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- **Signs and symptoms** (soon after birth)
  - scaphoid abdomen,
  - barrel-shaped chest,
  - detection of bowel sounds during auscultation of the chest,
  - profound arterial hypoxemia

- Classic triad of CDH consists of
  - Cyanosis
  - Dyspnea
  - Apparent dextrocardia

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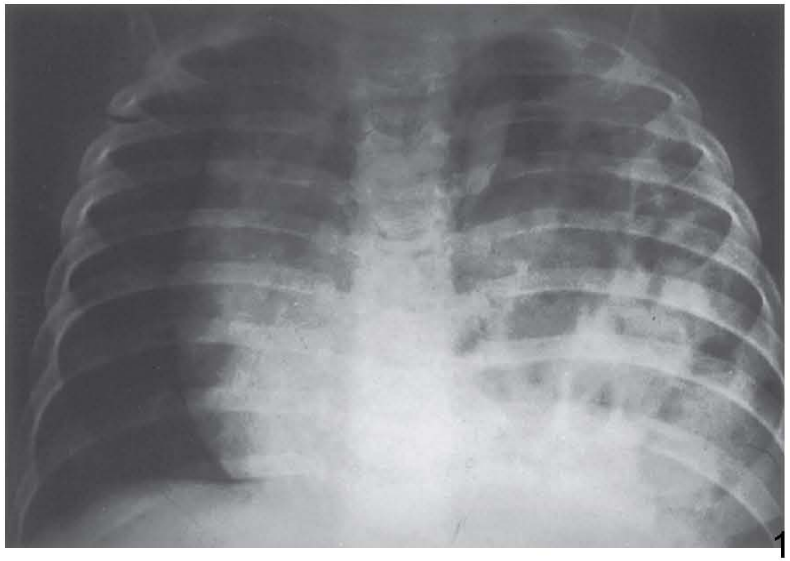
- **Diagnosis**
  - Prenatal (20 GA);

    ultrasonography→ findings that correlate with poor prognosis include polyhydramnios, displacement of the stomach above the diaphragm

  - CXR showing loops of bowel or bowel gas pattern in the chest along with mediastinal shift



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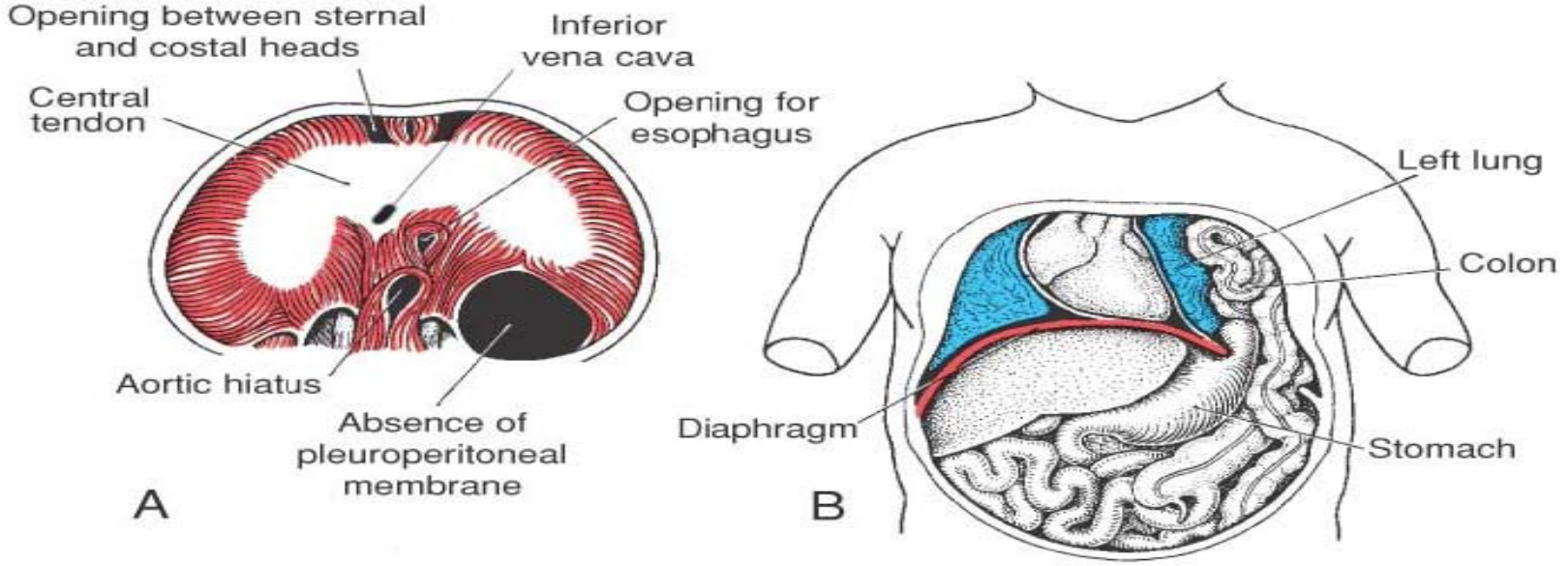
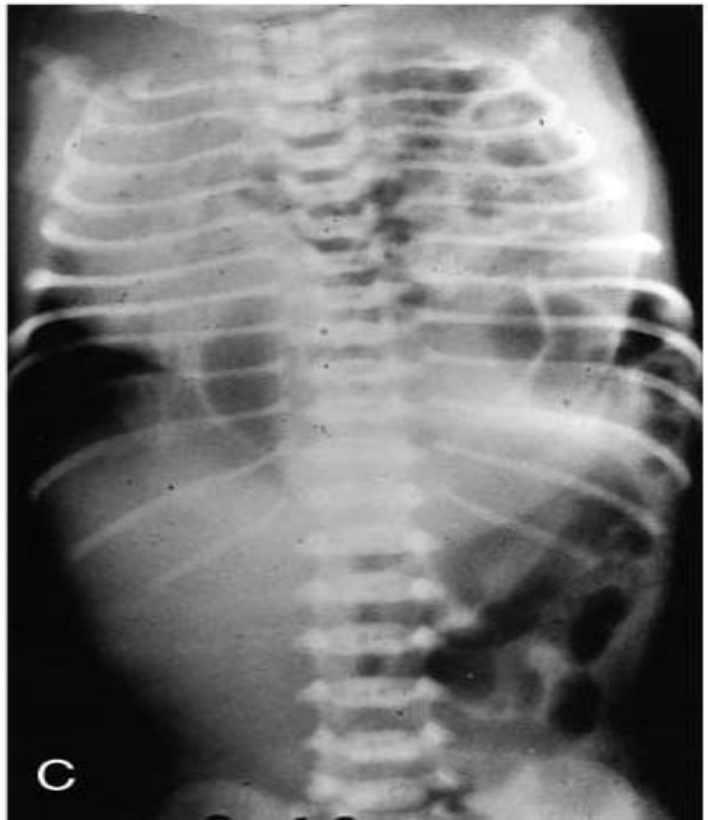

Opening between sternal and costal heads
Inferior vena cava
Central tendon
Opening for esophagus
Aortic hiatus
Absence of pleuroperitoneal membrane
A
Left lung
Colon
Diaphragm
Stomach
B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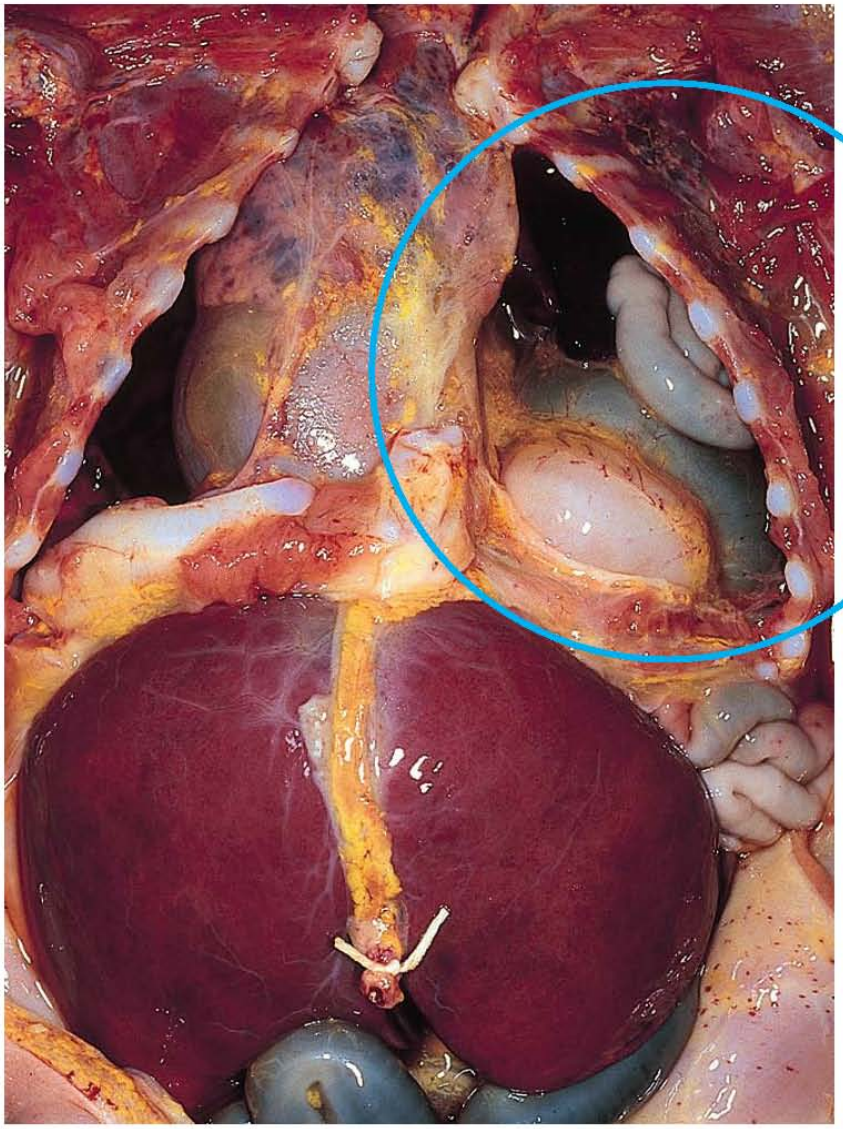

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Diaphragmatic Hernia

Problems

- Hypoplastic lung
- Gastric distension
- Acidosis
- Pneumothorax
- Mediastinum shift
- Pulmonary hypertension

- **Treatment**

a) Immediate treatment

- decompression of the stomach with an orogastric or nasogastric tube
- administration of supplemental O_2
- Early tracheal intubation
- PPV < 25 - 30 cm H_2O
- NO (10-20 mcg/Kg) as a bridge to ECMO

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- **Treatment**

b) do not require immediate surgery

- Must correct pulmonary hypoplasia 5-15 days

→ until decreased PVR & maintained ventilation with a low PIP (<25 cm H_2O) and FiO_2 =0.5

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Surgical intervention should be done when optimized cardiorespiratory status ;

- Arterial pressure normal for gestational age & stable for specific patient for 12 - 24 hours
- Preductal SaO2 at least 85%, preferably 90-95%, with an FiO_2 <0.50
- No acidosis ; lactate < 3 mmol/L
- Urine output 1 - 2 mL/kg/hour

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- **Prognosis**
  - Survival 42% - 75% → restrictive lung dz & reactive airways
  - related to the degree of pulmonary hypoplasia & associated anomalies

  - **Factors associated with a poor prognosis** ;
    - severe pulmonary hypoplasia
    - herniation to the contralateral hemithorax
    - onset of symptoms in the first 24 hours of life
    - severe Rt-to-Lt shunt that requires ECMO
    - associated major developmental anomalies
    - delivery in a nontertiary center

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Improved operative survival rate of CDH

- strategy of delaying surgery to ensure stabilization of the transitional circulation
- adopting a lung-protective or "gentle ventilatory" strategy by using
  - small tidal volumes
  - as low as possible PEEP
  - accepting higher PCO_2 (permissive hypercapnea)
- The lung-protective approach aims to avoid barotrauma & volutrauma

- **Management of Anesthesia**
  - awake tracheal intubation following preoxygenation
  - preductal arterial cannulation (Rt radial)

for monitoring SBP, blood gases, pH

  - N_2O should be avoided
  - PPV < 25 - 30 cm H_2O to minimize the risk of pneumothorax
  - Hypothermia must be avoided
  - After CDH reduction, an attempt to inflate the hypoplastic lung is not recommended

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Goals of ventilation and oxygen delivery in OR

- small tidal volume
- minimal PEEP (2 - 4 cm H_2O) to avoid atelectasis & trauma from shear stress (low-volume injury)
- adequate oxygenation without hyperoxia (SpO_2 90% to 95%)
- permissive hypercapnea
- maintaining adequate pH >7.25

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- **Postoperative Management**
  - no effective treatment for pulmonary hypoplasia
  - postoperative course characterized by
    - rapid improvement
    - followed by sudden deterioration with profound arterial hypoxemia, hypercapnia, acidosis → death
    - mechanism for this deterioration is the reappearance of fetal circulation patterns

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Preoperative

Intubation and ventilation with permissive hypercapnia
Avoid bag-and-mask ventilation
Nasogastric tube for stomach decompression
Broad-spectrum antibiotics
Sedation/anesthesia

Intraoperative

Standard monitoring
Right upper-extremity pulse oximeter (preductal sat 90 to 95)
Lower-extremity pulse oximeter
Arterial catheter
Central venous pressure catheter
Anesthetic agents
High-dose opioids (50 mcg/kg fentanyl)
or
Low-dose inhaled agents with moderate doses of opioids (10 to 20 mcg/kg)
Nondepolarizing muscle relaxant
Ventilation
Permissive hypercapnia; peak pressures <25 cm/H_2O. Use PEEP 2 to 4 cm/H_2O
Temperature
Forced-air warmer

Postoperative

Consider regional anesthesia for postoperative pain
Continue postoperative ventilation

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Preterm Infant

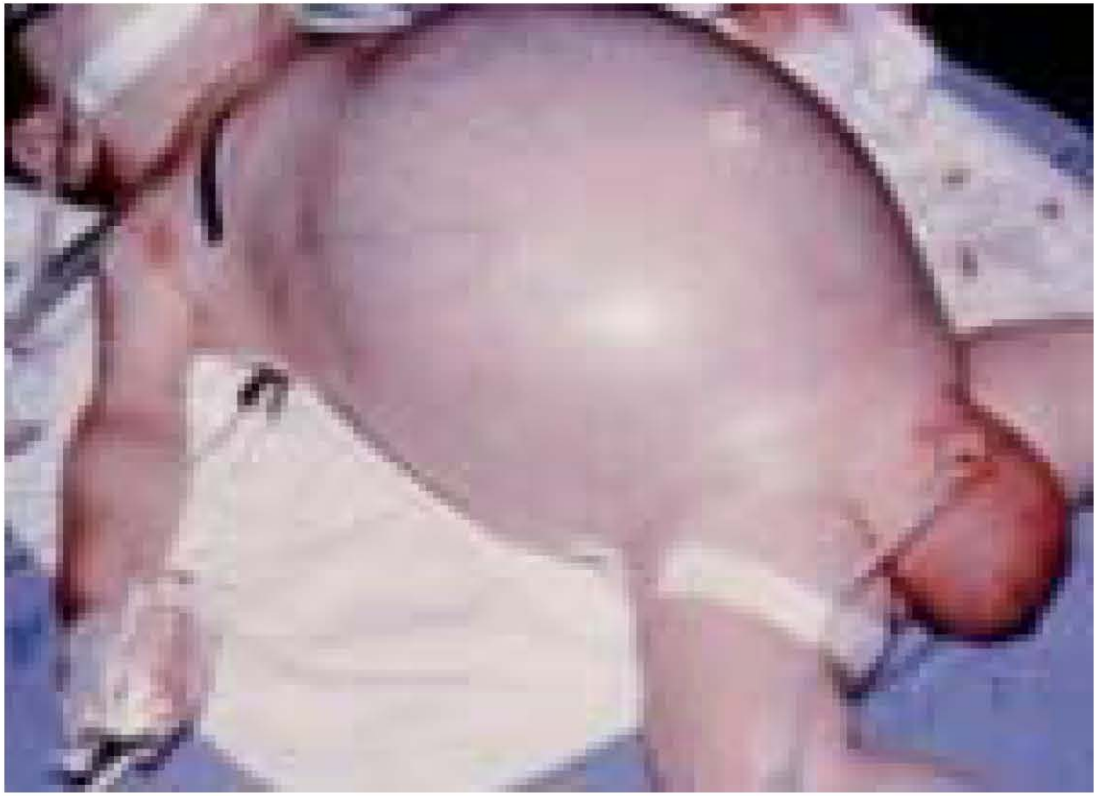
Problems

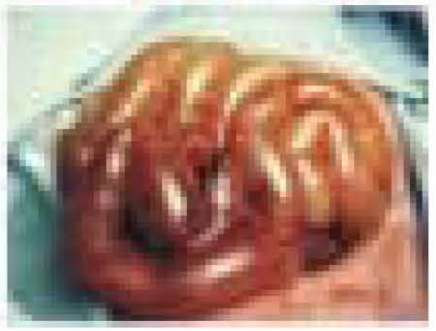
- CVS ; PDA , CHF , LV เจริญไม่เต็มที่
- RS ; Birth asphyxia , RDS , Apneic spell , BPD , Decrease O2 transportation
- Retinal vessel → ROP
- Decrease temperature control
- Hypocalcemia
- Hypoglycemia
- Hyperbilirubinemia
- Infection
- Cerebral hemorrhage

Necrotizing Enterocolitis

Problems

- Prematurity with LBW
- Dehydration
- Inadequate respiration
- Coagulopathy
- Increase HbF





Indications for Abdominal Surgery in NEC

Absolute Indications

Pneumoperitoneum
Intestinal gangrene (positive results of paracentesis)

Relative Indications

Clinical deterioration
Metabolic acidosis
Ventilatory failure
Oliguria, hypovolemia
Thrombocytopenia
Leukopenia, leukocytosis
Portal vein gas
Erythema of abdominal wall
Fixed abdominal mass
Persistently dilated loop

Nonindications

Severe gastrointestinal hemorrhage
Abdominal tenderness
Intestinal obstruction
Gasless abdomen with ascites

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Preoperative

Optimize hemodynamic and coagulation status

Check blood product availability

Check placement of endotracheal tube and catheters

Know acceptable hemodynamic parameters (BP, PSO_2, FiO_2)

Adequate venous access

Intraoperative

Standard monitoring and arterial catheter

Maintain hemodynamic stability

Consider vasoactive support (dopamine or epinephrine gtt)

Opioids or low-dose inhaled anesthetic agent with neuromuscular paralysis

Check glucose levels and electrolytes

Fluid resuscitation: fresh-frozen plasma, cryoprecipitate, and pooled red blood cells

Careful attention to temperature homeostasis – Forced air warmer

Postoperative

Mechanical ventilation

Sedation and analgesia

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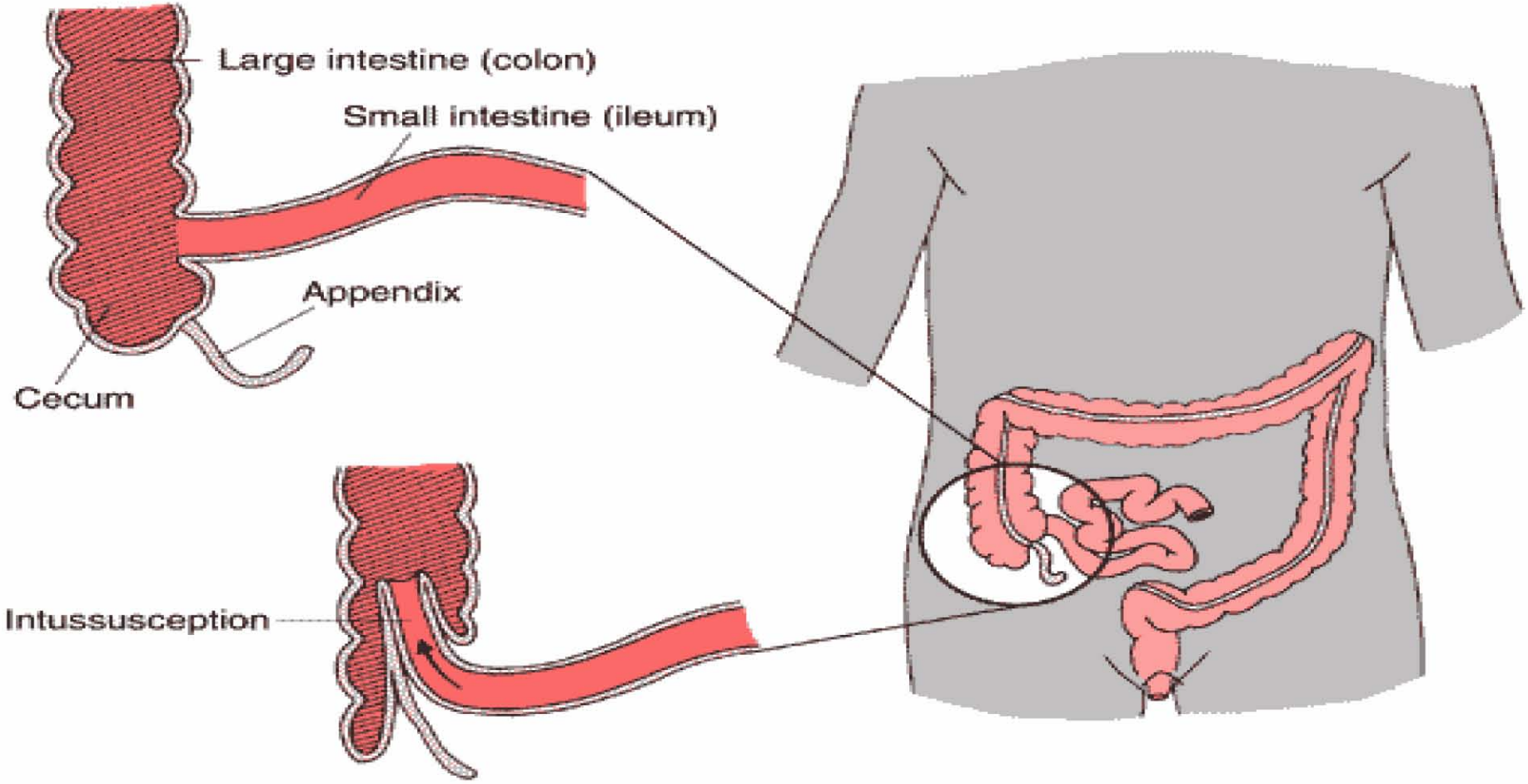
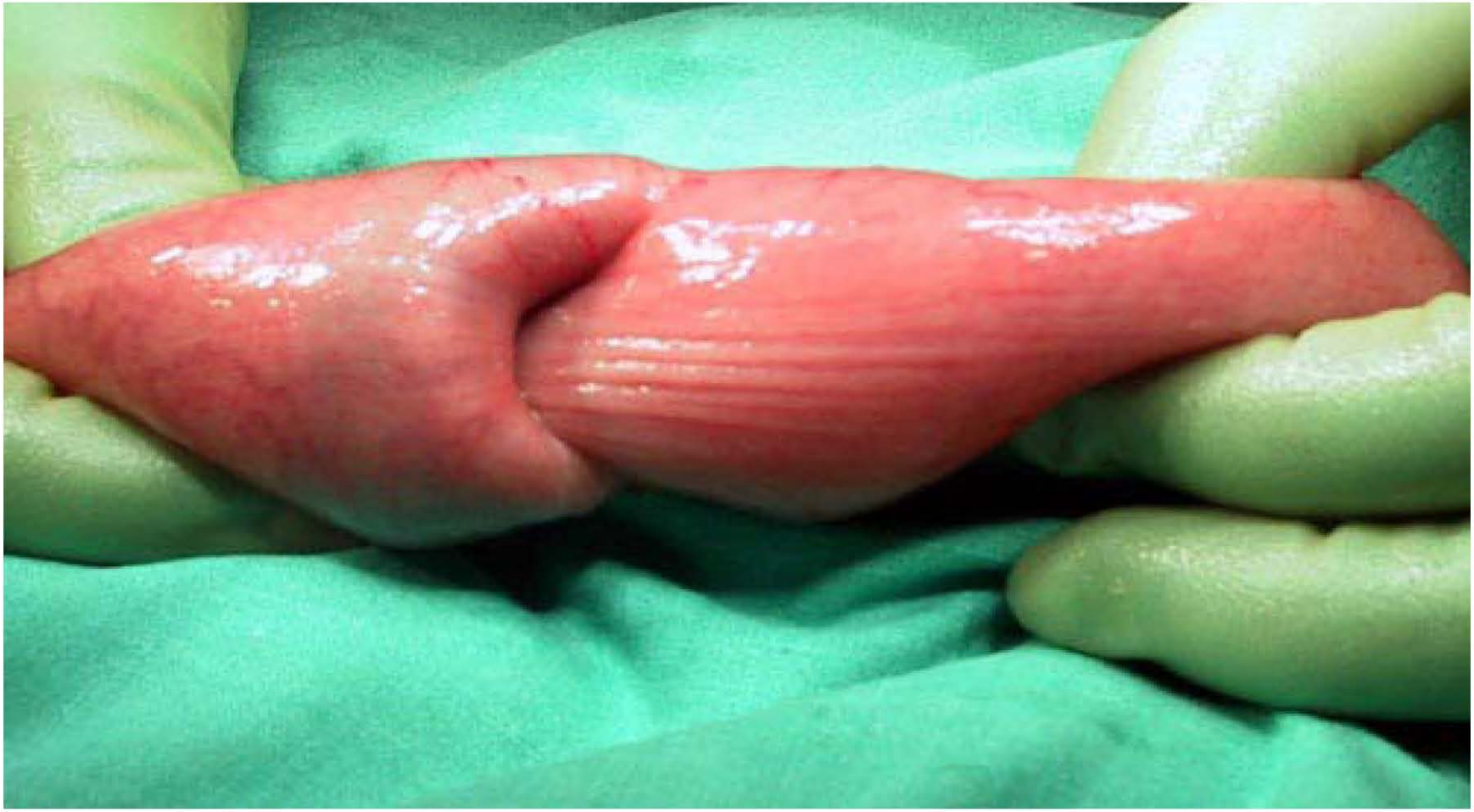
Intussusception

Problems

- Aspiration (gastric content)
- Hypotension
- Anemia
- Distended abdomen

Intussusception





Recommended General Anesthesia Guidelines for Intussusception

Premedication: as clinically indicated
Monitors: standard anesthesia monitoring
Vascular access: 1–2 large-bore catheters, arterial and central venous catheters if hemodynamically unstable
Anesthetic induction: intravenous propofol 2 mg/kg (if unstable ketamine 1 to 2 mg/kg) and rocuronium 1 mg/kg
Airway: endotracheal tube
Anesthetic maintenance: air/oxygen/sevoflurane or isoflurane. Avoid nitrous oxide
Anesthetic adjuncts: ondansetron
Intraoperative and postoperative pain management:
- Acetaminophen: intravenous 15 mg/kg
- Opioids: morphine 0.05 to 0.1 mg/kg or fentanyl 1 to 2 mcg/kg
- Dexmedetomidine 0.5 to 1 mcg/kg upon emergence
- Regional anesthesia depending on the surgical approach and clinical condition (tap block, rectus sheath block, epidural block, paravertebral block)

Smith's, Anesthesia for Infant and Children, 9th ed.,2017.

Factors affecting decision for elective surgery in a child with URI

Pros

- Presence of runny nose alone
- Active, happy child
- Older child
- Clear lungs

Cons

- Recent development of symptoms within 1 to 2 days
- Fever
- Lethargic child
- Purulent nasal discharge
- Wheezing, rhonchi
- Child <1 year, ex-premature
- Major surgery

	1	2	5
C: Current signs and symptoms	None	Mild - Parent confirms URI and/or congestion, rhinorrhea, sore throat, sneezing, low fever, dry cough	Moderate/ Severe - Purulence, wet cough, abnormal lung sounds, lethargy, toxic appearance, high fever
O: Onset	>4 weeks ago	2-4 weeks ago	<2 weeks ago
L: Lung Disease	None	Mild - RSV, mild intermittent asthma, CLD if >1 year old, loud snoring, passive smoking	Moderate/ Severe - Moderate persistent asthma, infant with CLD, OSA, pulmonary HTN
D: Airway Device	None or facemask	LMA or supraglottic	Endotracheal tube
S: Surgery	Other (including ear tubes)	Minor airway - T/A, NLD probe, flexible bronch, dental extractions	Major airway - Cleft palate, rigid bronch, maxillofacial

Table 1. The COLDS Score, from Lee, B. J. and August, D. A. (2014), COLDS: A heuristic preanesthetic risk score for children with upper respiratory tract infection. Pediatric Anesthesia, 24: 349–350.

The Child with an URI

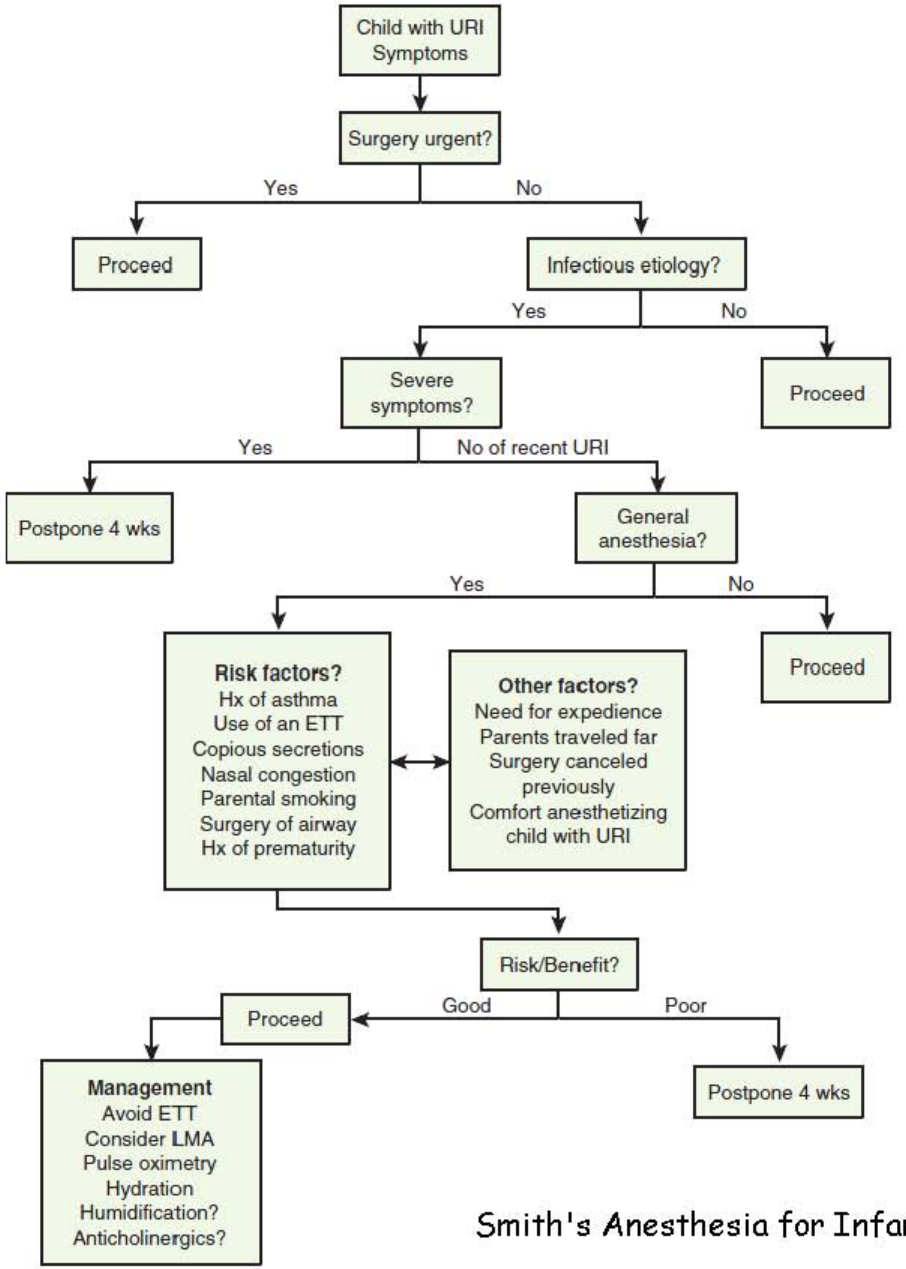
- If the child is acutely ill and obviously getting worse → cancel for 4 wks
- If the child has rhonchi and a productive cough → cancel for 4 wks
- If the child is stable & afebrile & had URI for several days → proceed, avoid ET intubation, not prolong procedure
- The best way of avoiding last-minute cancellations is a phone call by nursing staff the day before to inquire about the child's health

Independent risk factors for perioperative respiratory complications

- intubation in children < 5 years old
- reactive airway disease
- paternal smoking
- prematurity
- airway surgery
- presence of copious secretions along with nasal congestion

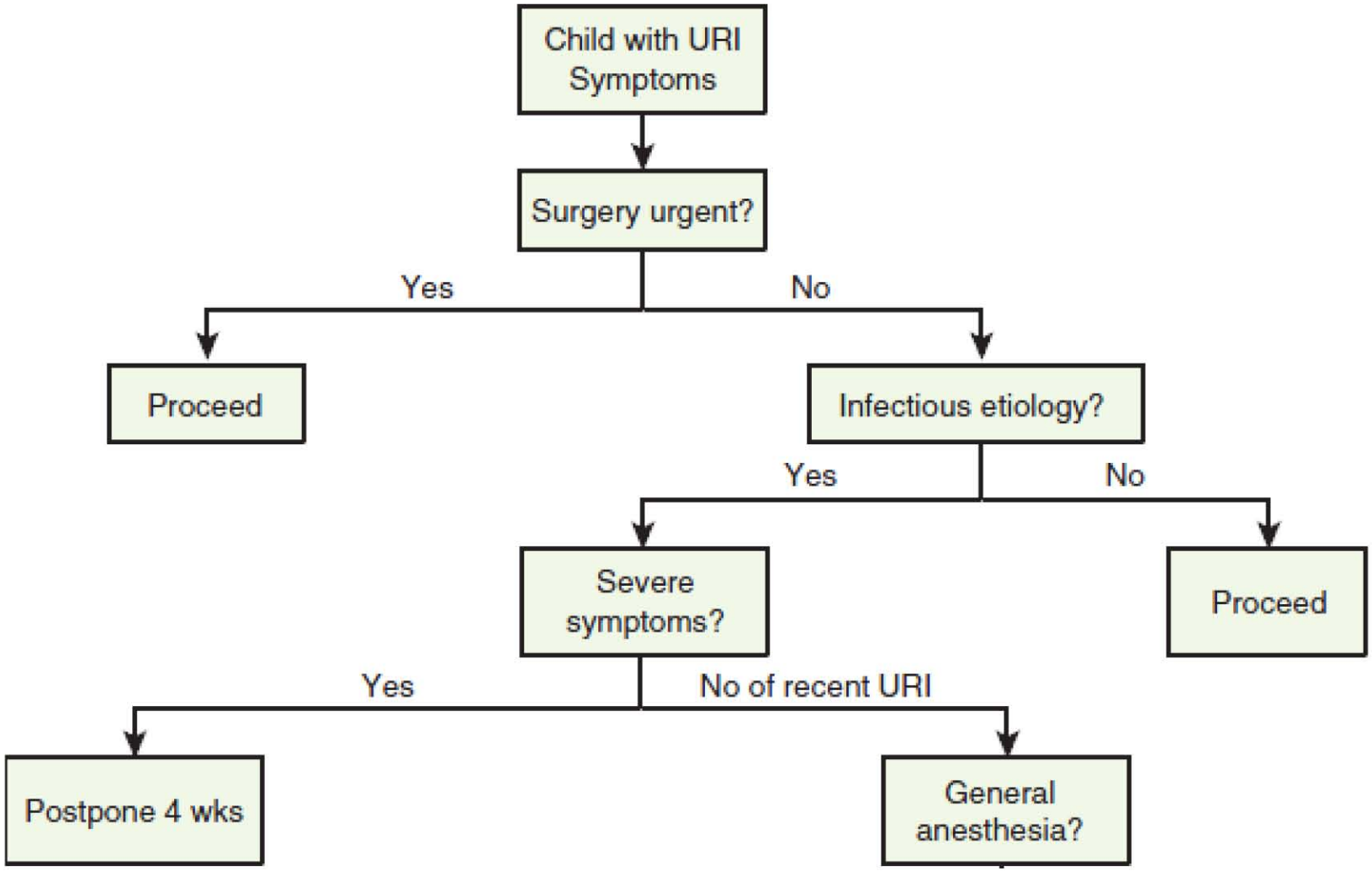
Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Clinical Decision Algorithm for URI



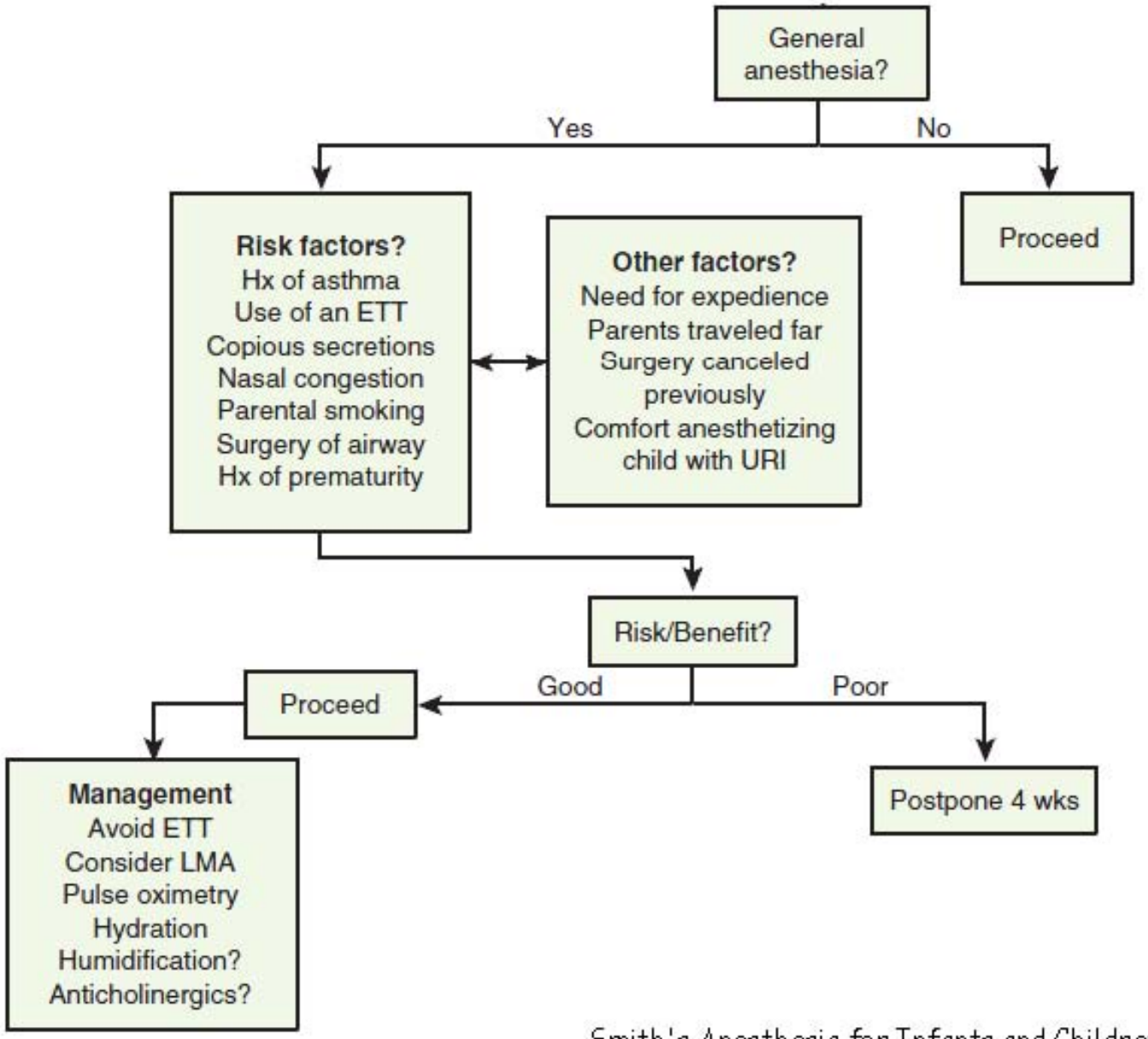
Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Clinical Decision Algorithm for URI



Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Clinical Decision Algorithm for URI



Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Anesthesia for emergency surgery in the setting of URI

- Preoperative administration of nebulized albuterol

- Minimize airway resistance & maximize bronchodilation ; propofol , sevoflurane

- No empiric administration of glycopyrrolate
  (laryngospasm , RR = 3.7)

Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Obstructive sleep apnea (OSA)

- Peak incidence 2 - 6 years of age
- Cause → Tonsillar hypertrophy
  Craniofacial anomalies
- Severe OSA → risk for systemic hypertension & pulmonary hypertension

(preoperative echocardiogram)

- Increased mu opioid receptors → sensitivity to opioids ⬆

Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Questions to Identify OSA in Pediatric Patients

1. Does your child snore?
2. Does your child pause when he/she snores? How long are the pauses?
3. Are you concerned about your child's snoring?
4. Is your child sleepy during the day?
5. Does your child have behavioral problems?

Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Children with Obstructive Sleep Apnea

Problems

- risk factors for postoperative complications
  - age younger than 3 years
  - abnormal coagulation values
  - evidence of OSA
  - systemic disorders ; cor pulmonale, metabolic diseases
  - presence of craniofacial or airway abnormalities
  - procedure for peritonsillar abscess
  - living a long distance from an adequate health care facility

Perioperative management for OSA

- moderate - severe OSA not be appropriate for outpatient surgery if the surgery involves the airway or Age ≤ 3 yrs.
- severe OSA who use CPAP or BiPAP → available in recovery & ward
- ⬇ Opioids analgesia
- ⬆ Nonopioid analgesia ; regional anesthesia

Smith's Anesthesia for Infants and Children, 9th ed., 2017.

Hirschsprung's disease

(congenital aganglionic megacolon)

- **Incidence** 1 in 5000 live births
- male predominance
- characterized by → absence of parasympathetic ganglion cells in the large bowel
  - aganglionosis extends proximally from anus usually limited to rectum & sigmoid colon

Roberta L. Hines, Stoelting's Anesthesia and Co-Existing Disease, Chapter 24:Pediatric Diseases, 5th ed.2008.

- **Signs and Symptoms**
  - Constipation → dilatation of the proximal bowel & abdominal distention
  - enterocolitis with associated signs of bowel obstruction
  - explosive diarrhea following a rectal examination

Roberta L. Hines, Stoelting's Anesthesia and Co-Existing Disease, Chapter 24:Pediatric Diseases, 5th ed.2008.

- **Diagnosis**
  - suspected in any full-term neonate with delayed passage of stool
  - classic radiographic finding → presence of transition zone between normal dilated proximal colon & narrow, spastic distal colon segment
  - Rectal biopsy is the diagnostic gold standard → absence of ganglion cells and the presence of hypertrophied nerve bundles that stain positively for acetylcholinesterase

Roberta L. Hines, Stoelting's Anesthesia and Co-Existing Disease, Chapter 24:Pediatric Diseases, 5th ed.2008.

- **Treatment**
  - Surgical treatment aimed at bringing ganglionated bowel down to the anus
  - primary endorectal pull-through procedure
  - decompressive colostomy is indicated in infants presenting with severe enterocolitis

Roberta L. Hines, Stoelting's Anesthesia and Co-Existing Disease, Chapter 24:Pediatric Diseases, 5th ed.2008.

- **Prognosis**
  - require reoperation in
    - retained or acquired aganglionosis
    - severe strictures
    - dysfunctional bowel
    - intestinal neuronal dysplasia

Roberta L. Hines, Stoelting's Anesthesia and Co-Existing Disease, Chapter 24:Pediatric Diseases, 5th ed.2008.

- **Management of Anesthesia**
  - IV catheters should be placed in upper extremities
  - Epidural anesthesia provides excellent intraoperative & postoperative analgesia
  - Extubation at the end of surgery

Roberta L. Hines, Stoelting's Anesthesia and Co-Existing Disease, Chapter 24:Pediatric Diseases, 5th ed.2008.

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