Pediatric Trauma

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Conflict of Interest

I have no financial disclosures related to this presentation

The views expressed in the presentation are my own and do not reflect any official position or policy

Objectives

Introduction to Pediatric Trauma

Trauma Injury Classification

Initial Management

- ABCDEs

Non-accidental Injury

Injury Prevention

Questions/Discussion

Background

Trauma is #1 cause of death in children and adolescents

- 10,000 fatalities yearly in US
- #1 cause of death in the world for < 40yo

Pediatric Trauma Mechanism

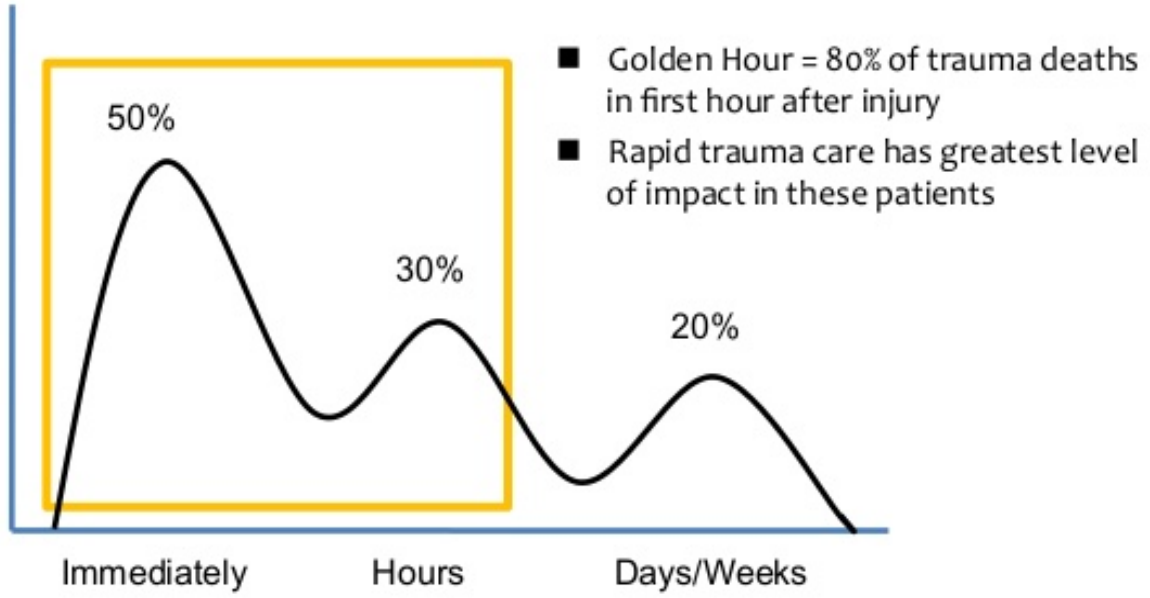
- 90% Blunt
- Multisystem (small bodies with large surface area)
- Anatomy different than adults!

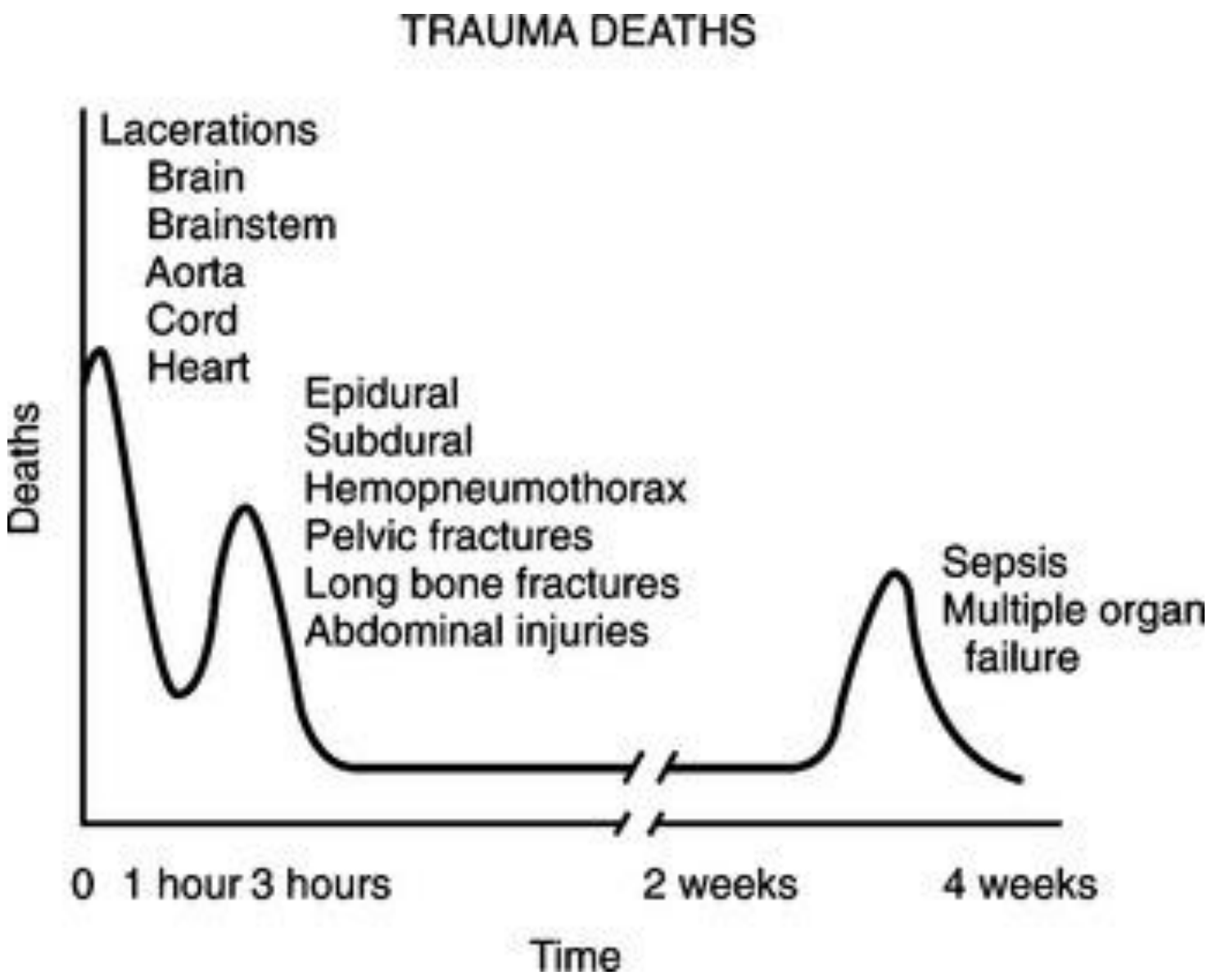
Background

- Prehospital Care Similar in Adults and Pediatrics
- Trimodal Distribution
- Golden Hour
- Identify and Stabilize Life Threatening Injuries
- Rapid transport to definitive care!

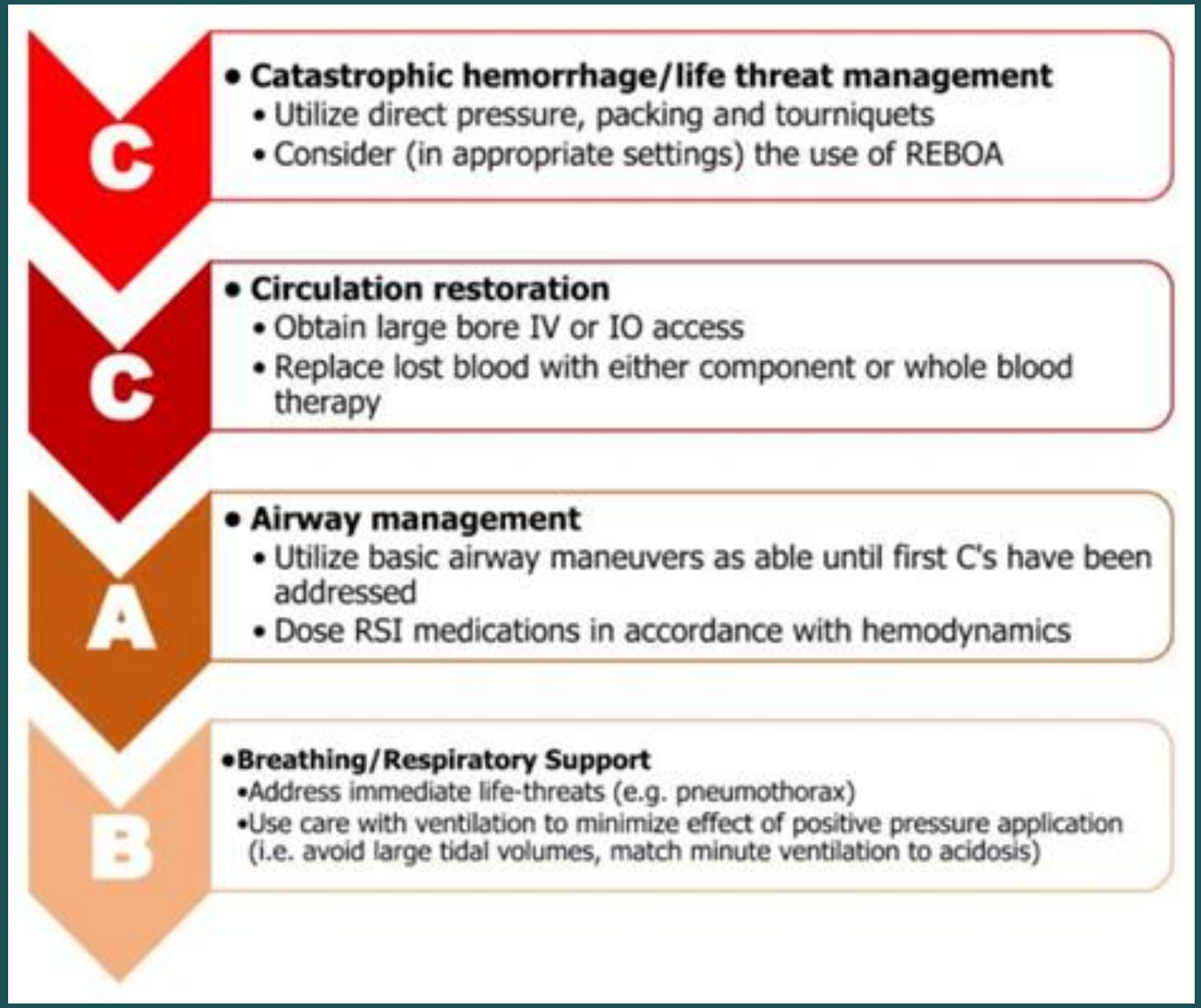
Epidemiology

Trimodal Distribution of Trauma Deaths




TRAUMA DEATHS
Lacerations
Brain
Brainstem
Aorta
Cord
Heart
Epidural
Subdural
Hemopneumothorax
Pelvic fractures
Long bone fractures
Abdominal injuries
Sepsis
Multiple organ failure
Deaths
0
1 hour
3 hours
2 weeks
4 weeks
Time

- **A**irway/**A**lign (c-spine precautions)
  - Patent Airway
  - Protect Airway
- **B**reathing
  - Breath sounds present, equal bilaterally
- **C**irculation
  - Blood Pressure
  - IV (and/or IO) access
- **D**isability
  - Mental Status: GCS
- **E**xposure/**E**nvironment
  - Patient history (found in freezing temperatures outside)
  - Current patient condition (don't be the cause of exposure: air conditioning, no blankets)


C
• Catastrophic hemorrhage/life threat management
• Utilize direct pressure, packing and tourniquets
• Consider (in appropriate settings) the use of REBOA
C
• Circulation restoration
• Obtain large bore IV or IO access
• Replace lost blood with either component or whole blood therapy
A
• Airway management
• Utilize basic airway maneuvers as able until first C's have been addressed
• Dose RSI medications in accordance with hemodynamics
B
•Breathing/Respiratory Support
•Address immediate life-threats (e.g. pneumothorax)
•Use care with ventilation to minimize effect of positive pressure application (i.e. avoid large tidal volumes, match minute ventilation to acidosis)

Trauma Injury Classification

Extent

- Localized Trauma: 1 anatomic region
  - head, neck, chest, back, abdomen, extremities
- Multiple Trauma: ≥ 2 anatomic regions or body systems

Type

- Blunt (Fall, MVC, assault)
- Penetrating (GSW, stabbing, explosion shrapnel)
- Burn (thermal, chemical, inhalation)

Severity

- Stability (VS, clinical exam, high risk mechanism of injury)

High Risk Mechanisms of Injury

Examples of injury severity

Anatomic region	Mild	Moderate	Severe
Head	Fall <3 feet or from standing height Blow to head with no LOC and small hematoma	Blow to head with brief LOC Superficial penetrating injury to the scalp (BB gunshot wound)	Blunt head trauma with GCS ≤12 Intracranial penetrating head trauma
Neck	Restrained passenger of MVC with <20 mph (32 kph) force	Pedestrian hit by a car Bicyclist hit by a car Fall >10 feet or 3x standing height Penetrating injury not deep to the platysma muscle	Blunt neck trauma with palpable stepoff or neurologic deficit Diving injury with neck pain and paresthesias down both arms Penetrating neck trauma deep to the platysma muscle
Thorax	Punch to chest wall with superficial bruise and normal respirations	Pleuritic pain or significant bony tenderness after blunt trauma	Blunt trauma with hypoxemia or dyspnea Penetrating chest trauma with shock
Abdomen	Hit in the stomach by a soccer ball kicked by a playmate	Blunt trauma with abdominal tenderness or hematuria Restrained MVC passenger with a contusion from the seat belt Penetrating wound superficial to the peritoneum	Blunt trauma with shock Penetrating trauma deep to the peritoneum
Extremities	Fall on outstretched hand with no deformity Inverted ankle with lateral malleolar swelling but no deformity	Extremity injury with obvious deformity	Crush injury with pallor and pain Penetrating injury with vascular compromise

LOC: loss of consciousness; GCS: Glasgow coma scale; MVC: motor vehicle collision.

Initial Management

Identify and Stabilize Life Threatening Injuries First

Trauma patients change status quickly so

- **MUST monitor closely**
- **MUST have plan for if/when patient who is initially stable deteriorates**
- **MUST be able to act quickly to implement plan**
- **Must be familiar with NORMAL vital signs in children (differs by age)**

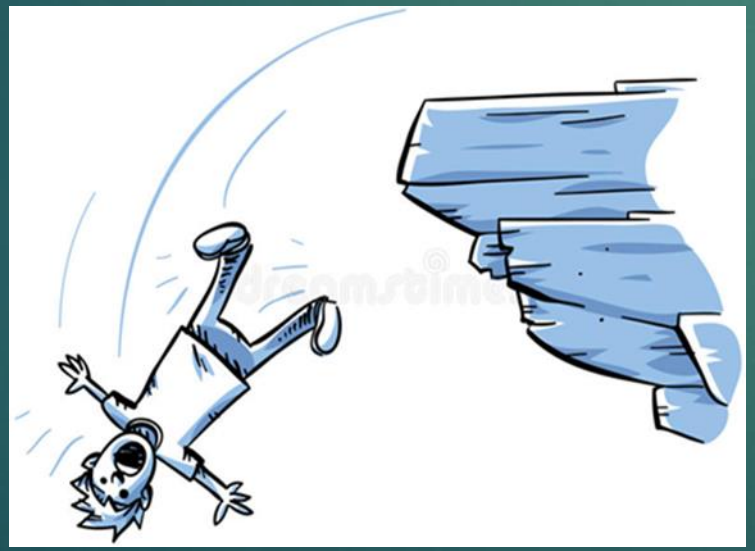
PEDIATRIC VITAL SIGNS

Age	HEART RATE		RESP	BLOOD PRESSURE			
	Awake HR (beats/min)	Sleeping HR (beats/min)	Resp Rate (breaths/min)	Minimal Systolic Pressure (mmHg)	Systolic Pressure (mmHg)	Diastolic Pressure (mmHg)	Mean Arterial Pressure (mmHg)
Neonate (0-30 days)	100-205	90-160	40-60	60	60-84	31-53	48-60
Infant (1-12 months)	100-180	90-160	30-53	70	72-104	37-56	50-62
Toddler (1-2 years)	98-140	80-120	22-37	74	86-106	42-63	49-62
Preschooler (3-5 years)	80-120	65-100	20-28	78	89-112	46-72	58-69
School aged (6-9 years)	75-118	58-90	18-25	86	97-115	57-76	66-72
10+ years	60-100	50-90	12- 20	90	102-131	61-83	71-79

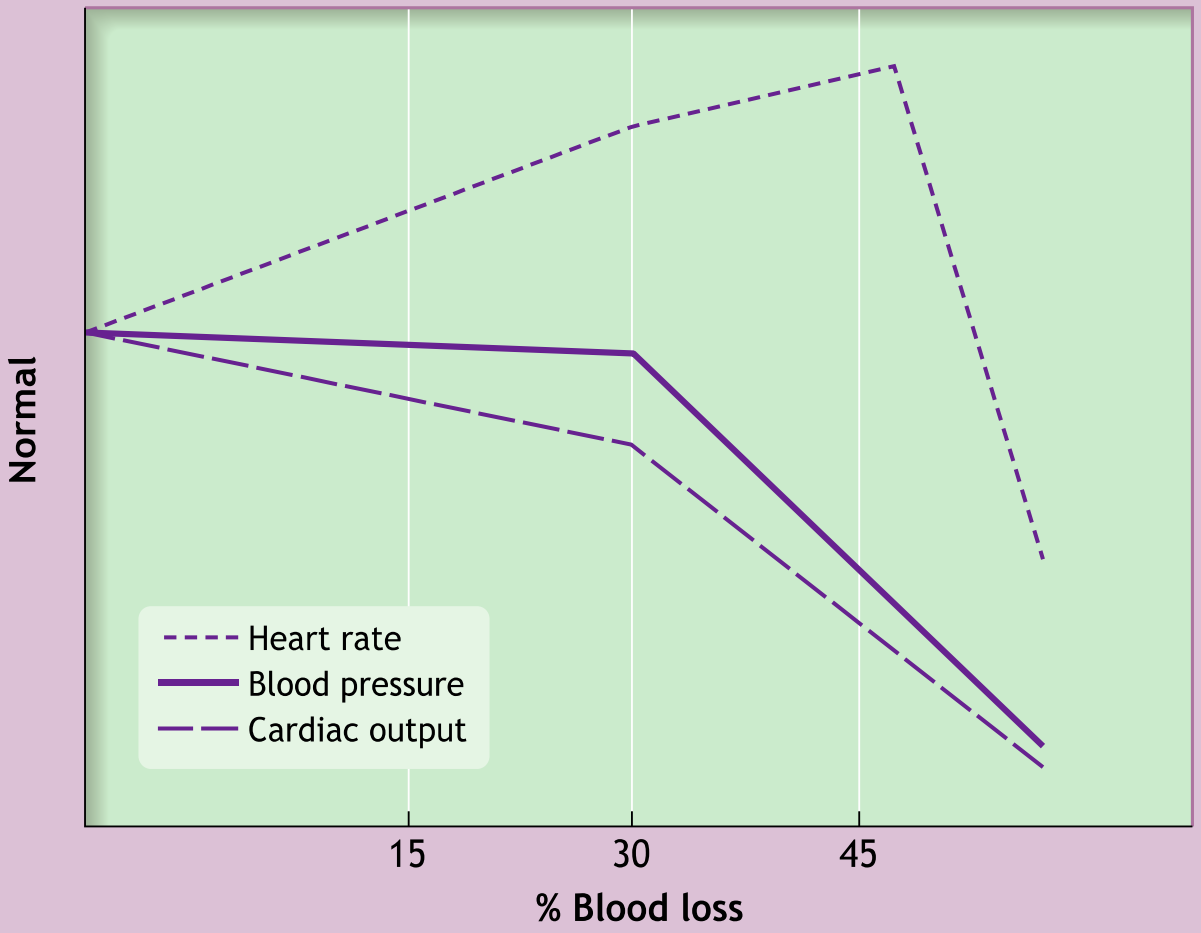
Initial Management

A child's body HIDES injuries and derangements

- Phenomenal physiologic compensation
- Compensate, compensate, compensate…then suddenly fall off cliff
  - BE HIGHLY CONCERNED if tachycardia in young children, even if normotensive… think of tachycardia in child the way you would hypotension in an adult



Physiologic Impact: Hemodynamic Changes

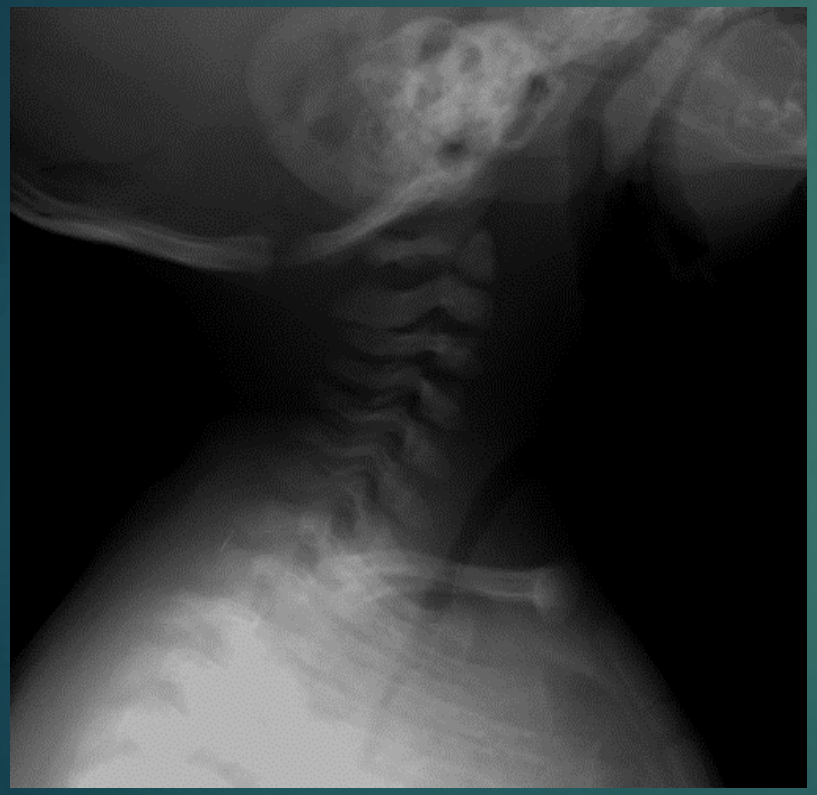


Airway/Align

What is MOST COMMON cause of pediatric cardiopulmonary arrest?

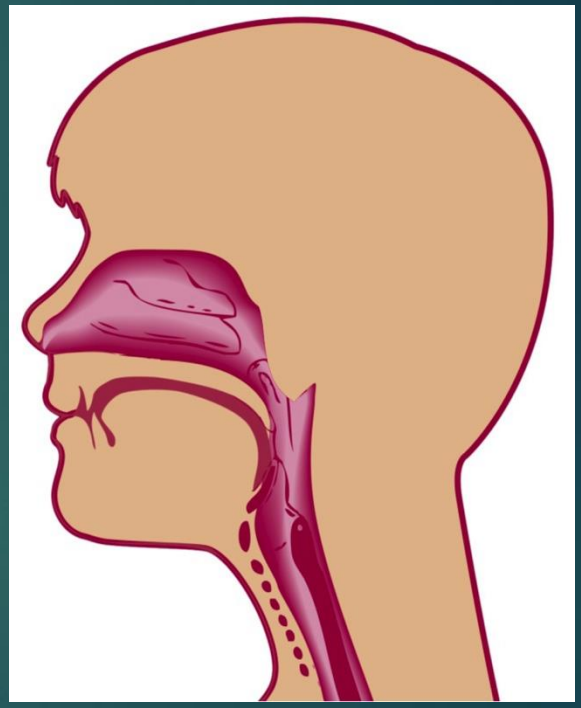
Hypoxia and Inadequate Ventilation

Airway/Align



Anatomic Considerations:

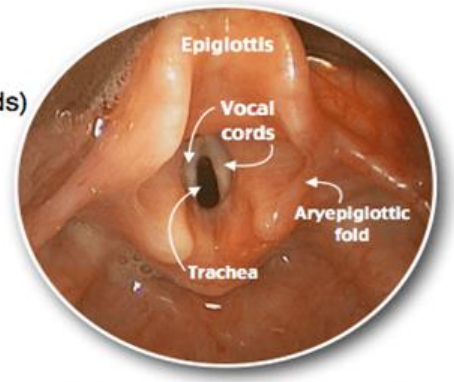
-Larger tongue
-Smaller jaw
-Shorter, narrower, funnel-shaped airway
-Anterior larynx
-Flexible, loose cervical spine ligaments
-Large heavy skulls

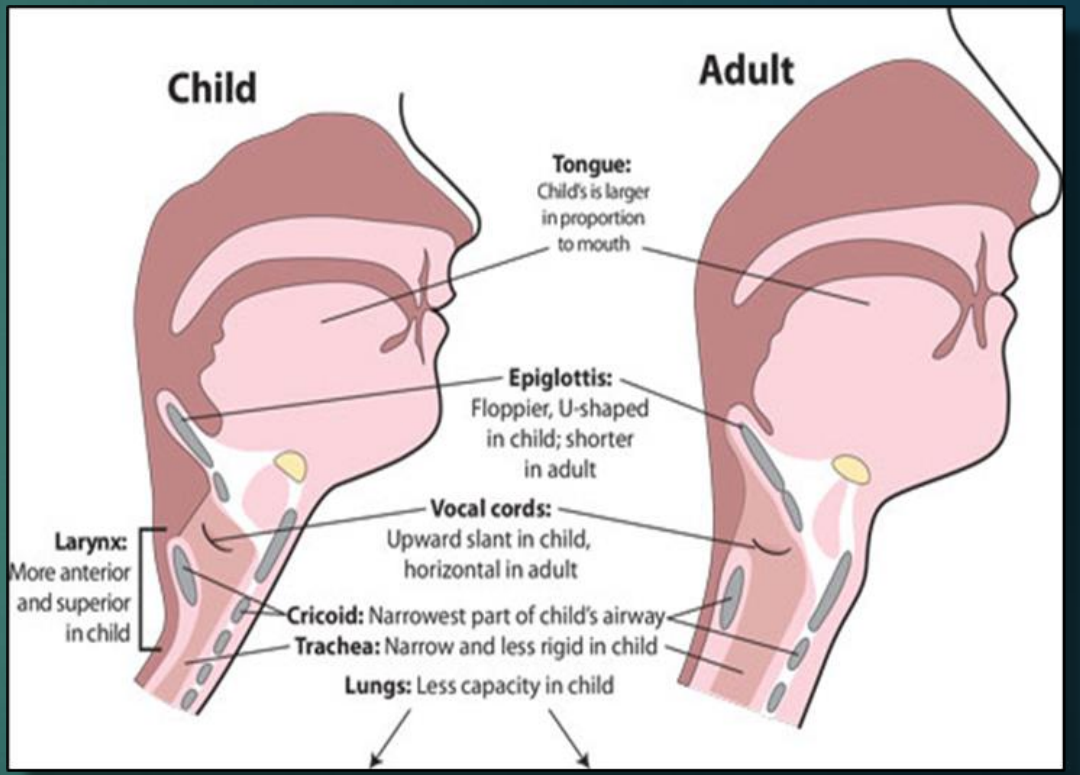


Anatomical Differences Between Pediatric and Adult Airways

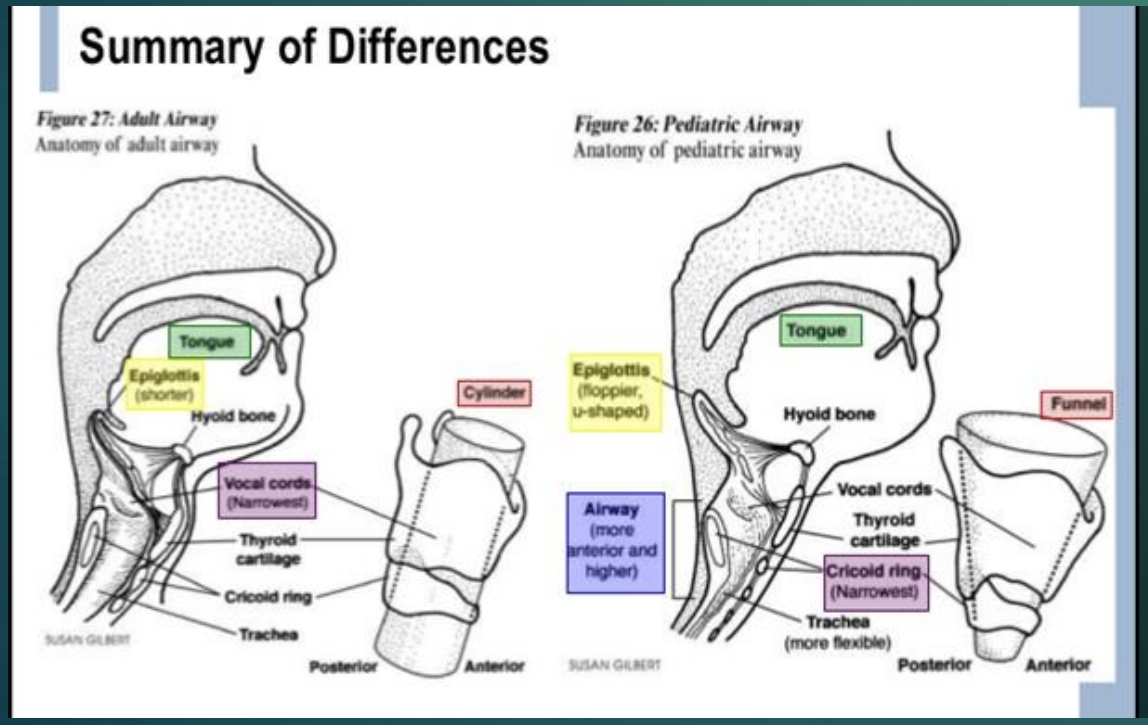
Pediatric airway

- Proportionally **smaller larynx**
- **Narrowest** portion is the **cricoid cartilage** (below vocal cords)
- **Epiglottis** is **longer** and **narrower**
- **Head** and **occiput** are proportionally **larger**
- **Tongue** is proportionally **larger**
- **Neck** is much **shorter**
- **Larynx** is more **anterior** and **cephalad**
- **Adenoids** are are **larger**
- Risk of **mainstem intubation** is much **higher** in pediatrics due to short trachea and bronchus





Summary of Differences



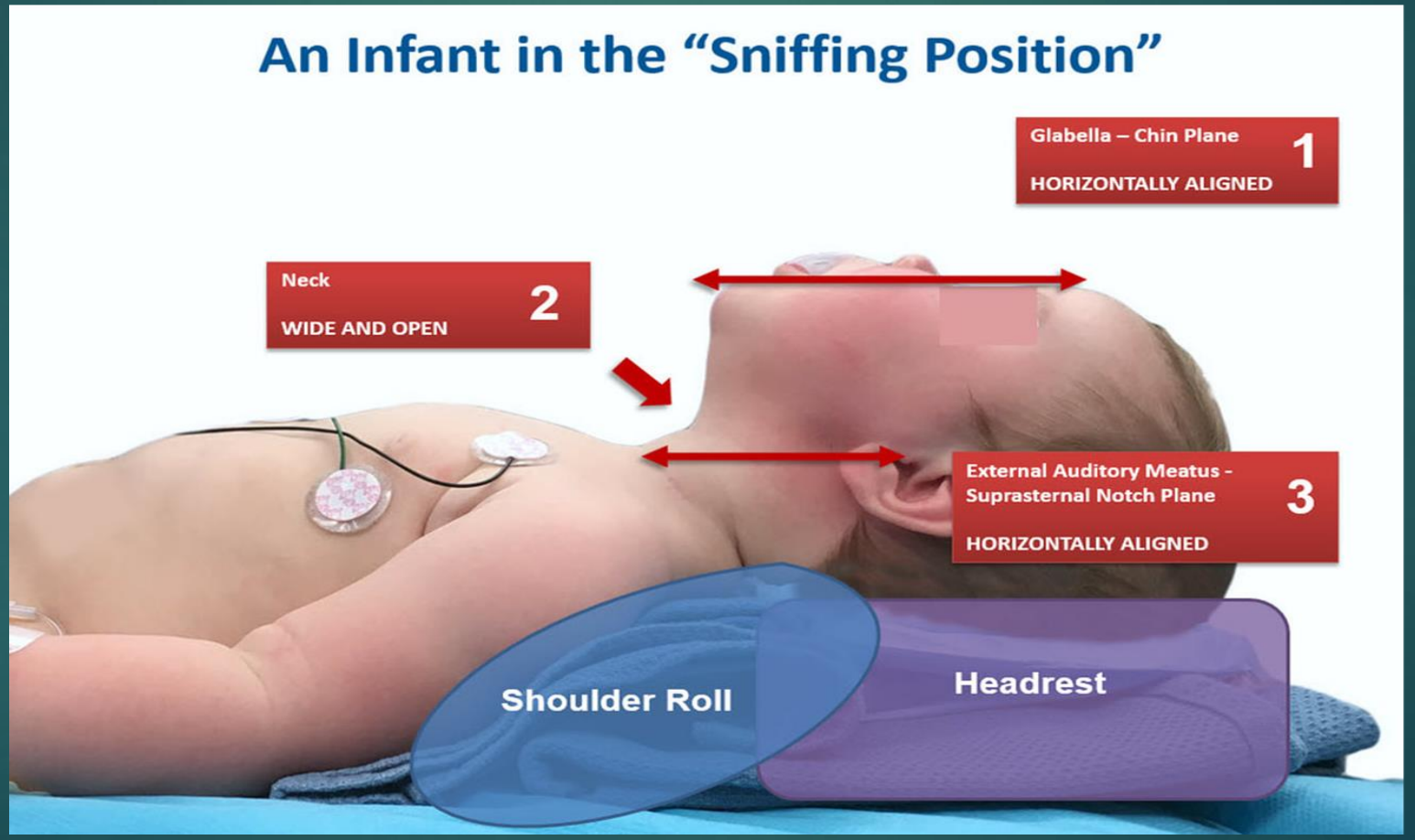
Airway/Align

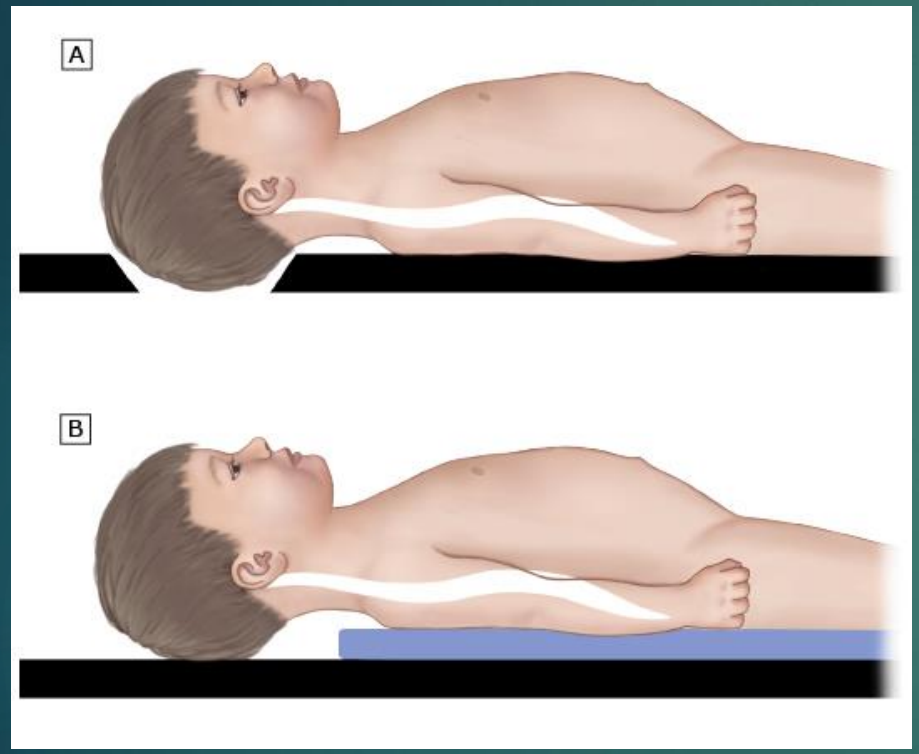
- Airway Patency
  - Foreign body
  - Injury to trachea/larynx
  - Facial/mandible fractures

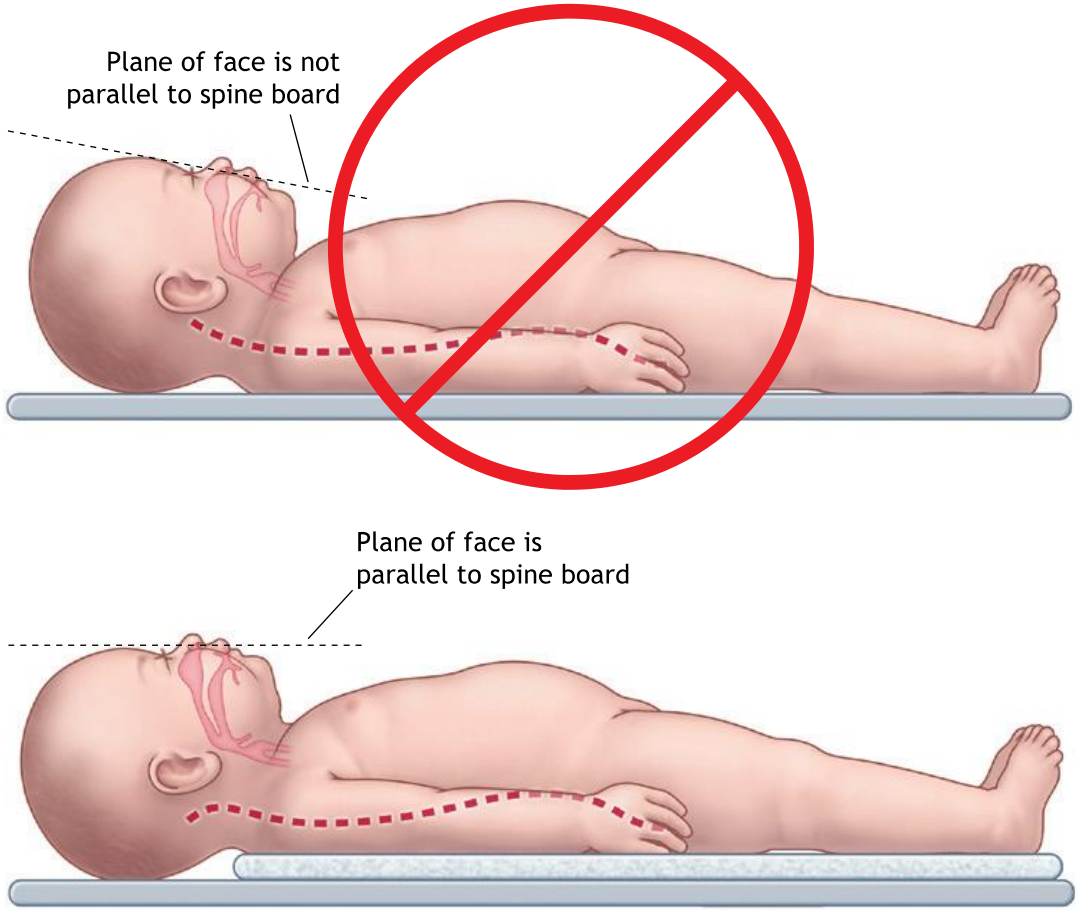
- Crying loudly is actually a GOOD sign (airway patent, able to generate breath, mental status appropriate)
  - Don't rely exclusively on crying
  - Look for other findings, stridor, coughing, gagging, central/acro-cyanosis

Airway/Align

What exactly IS the "Sniffing Position" Anyhow?

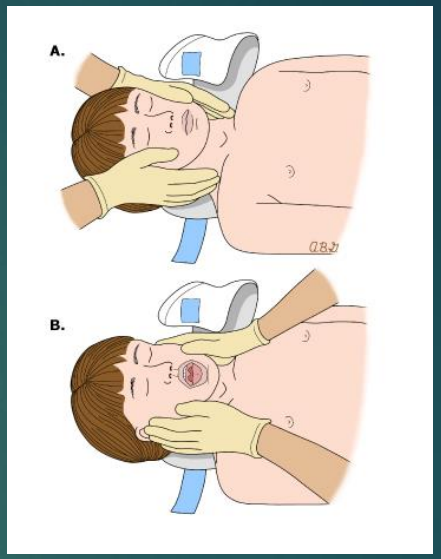


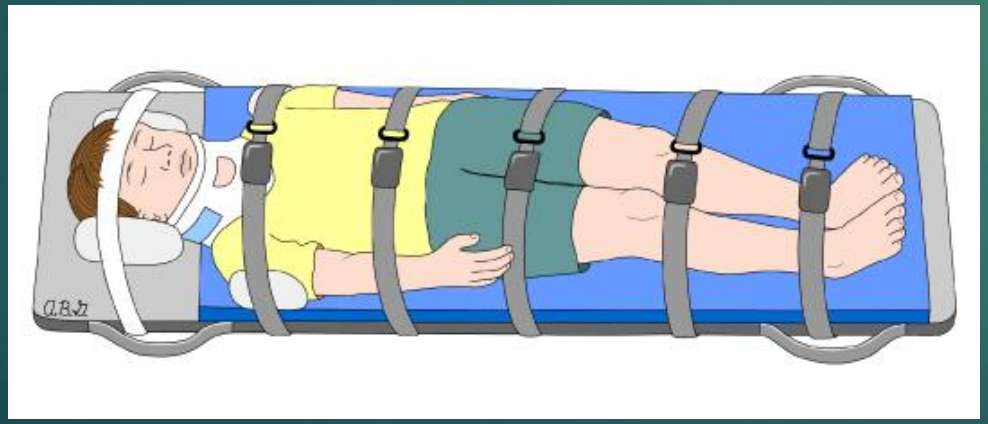

A
B


Plane of face is not
parallel to spine board
Plane of face is
parallel to spine board

Airway/Align

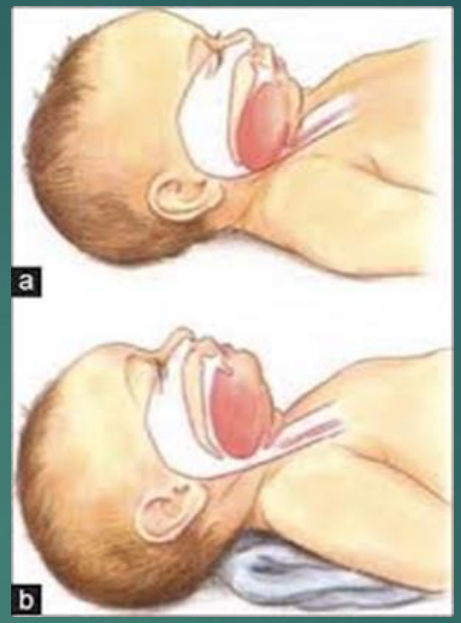
- Manual stabilization during airway manipulation
- Padding or folded blanket/towels (not pillow)
- Fully immobilize on backboard… kids are squirmy by nature!!!

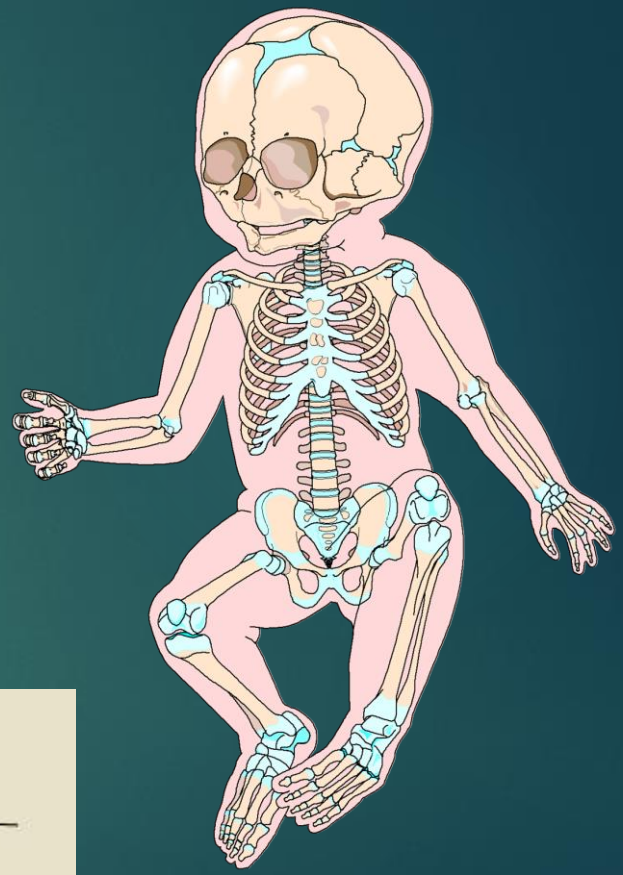


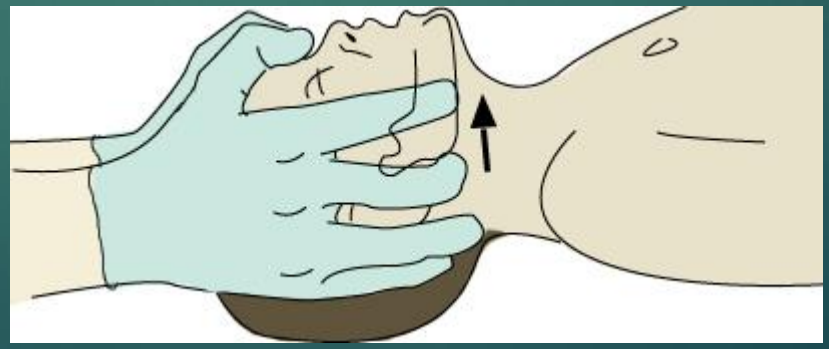


Airway/Align

- ASSUME C-Spine injury and maintain stabilization
  - Children have big floppy head on neck with relatively weak muscles
  - No head tilt-chin lift…
  - Jaw thrust often effective







Airway/Align

PEARLS

- Endotracheal Tube Size
  - [16 + age (years)] ÷ 4 = Internal Diameter
  - Circumference of child's 5th phalanx (pinky finger) = Outside Diameter
  - ETT depth = 3x size of endotracheal tube used (internal diameter) = cm depth

- Practice:
  - 4yo

    Size = 5mm (ID); Depth = 15cm
  - 8yo

    Size = 6mm (ID); Depth = 18cm

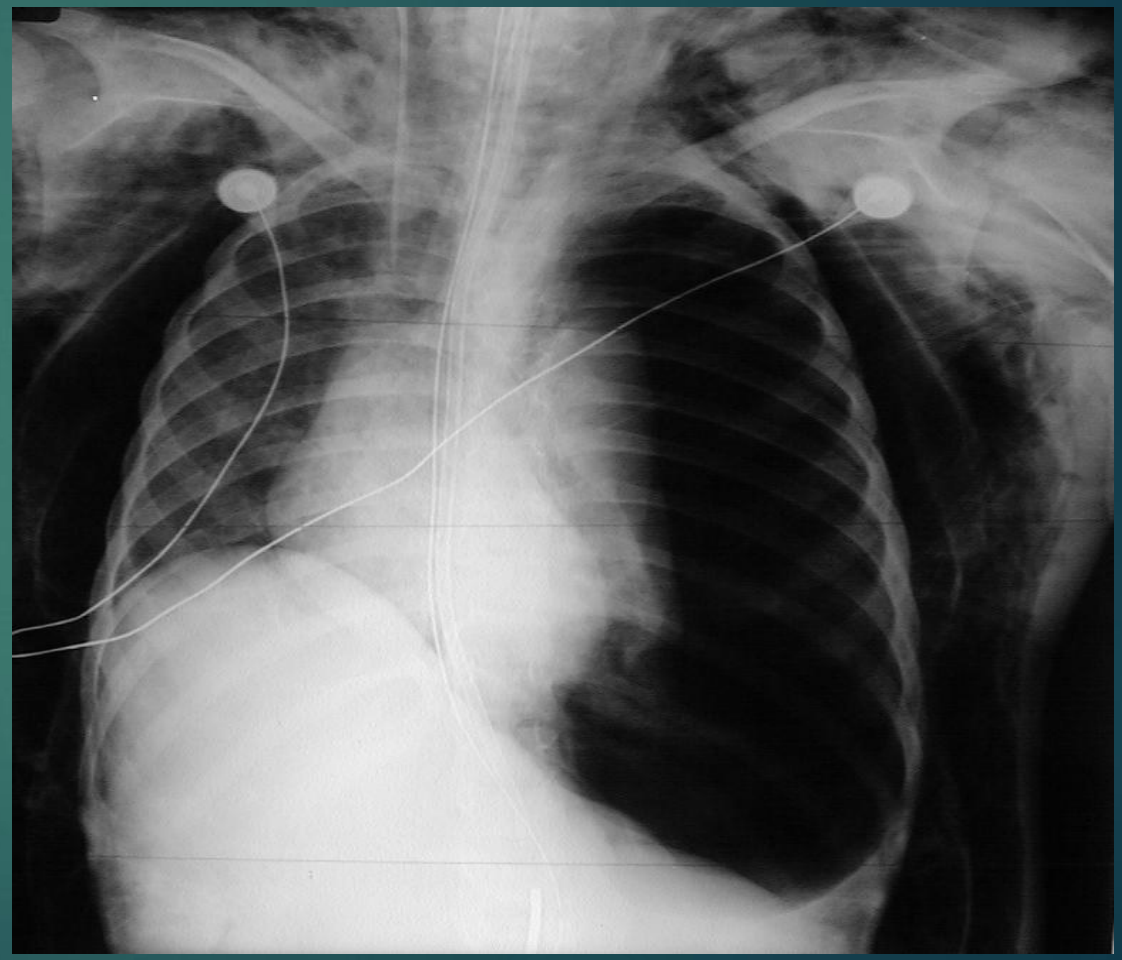
Airway/Align

- Rigid Cervical Collar
  - Appropriate size of utmost importance!
- Many cervical collars are commercially available that provide sizing from infancy to adulthood:
  - Stifneck (Laerdal)
  - Aspen Pediatric Collar (Aspen Medical Products)
  - Philadelphia (DeRoyal)
  - Miami J (Ossur Americas)
- Alternatives if not available
  - A well-placed alternative better than poorly fitting c-collar
  - Rolled towel can be placed around the neck, crossed in front of the neck over the chest and secured with tape
  - If transporting child still in car seat… towel rolls to stabilize c-spine

Breathing

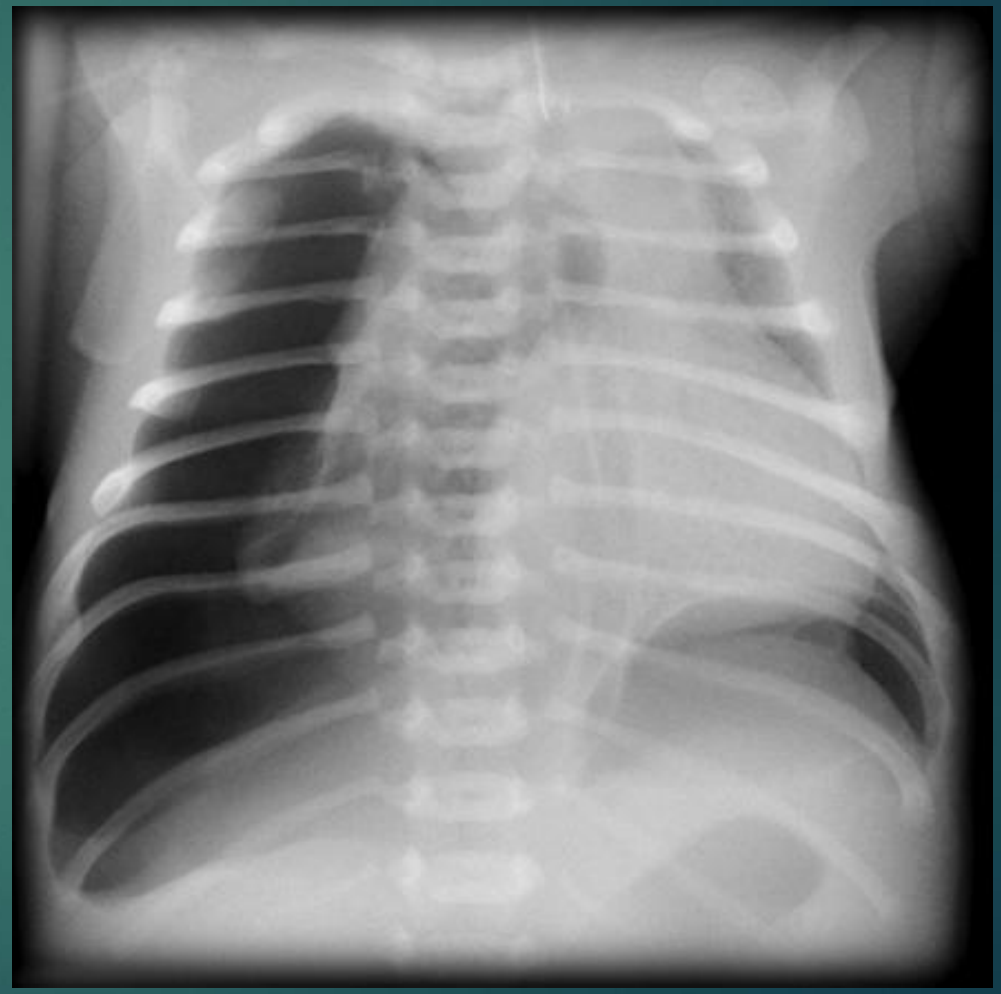
Anatomic Considerations:

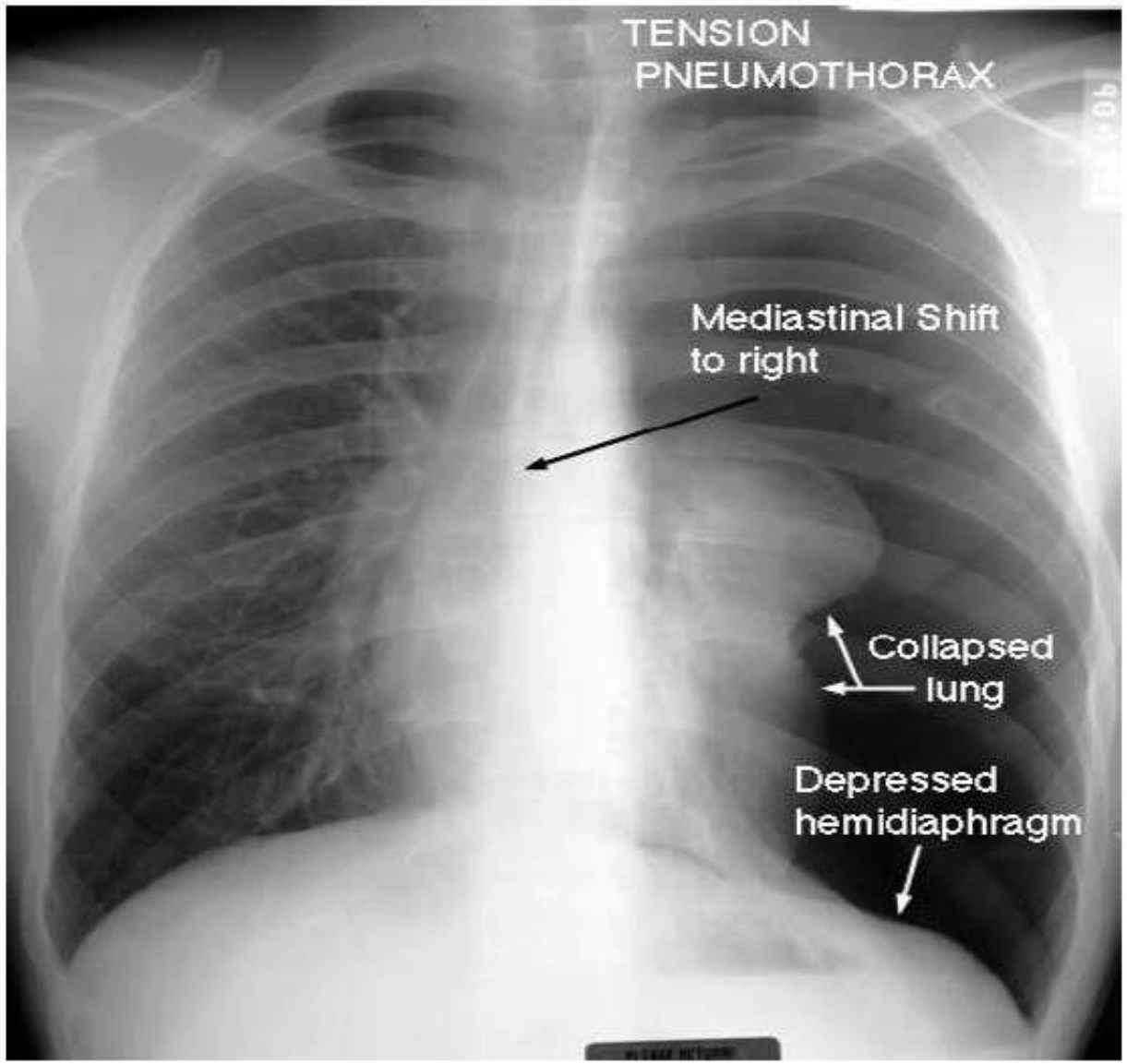
- Soft, pliable chest wall – pulmonary contusion
- Horizontally aligned ribs, weak intercostal muscles
- Rib fractures indicate significant force
- Tension pneumothorax more likely due to mobile mediastinum
- Smaller lungs = smaller volumes!
  - Barotrauma
  - Iatrogenic Pneumothorax if bag too aggressively or with too large volume in ambu bag!



Breathing

- Tension Pneumothorax
  - Needle Decompression
  - Which side?
    - RIGHT



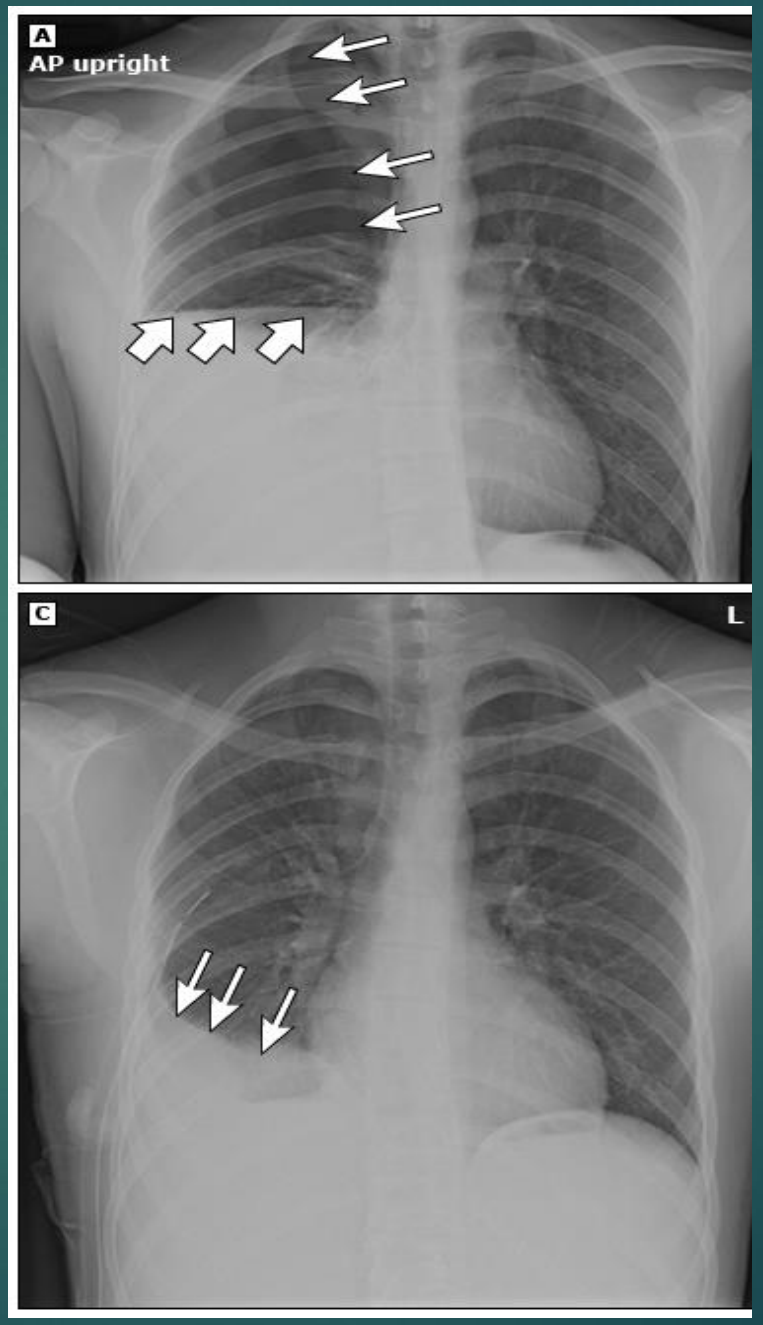

TENSION
PNEUMOTHORAX
Mediastinal Shift
to right
Collapsed
lung
Depressed
hemidiaphragm

Breathing

- Pulmonary Contusions
- Pliable chest wall so rib fractures unlikely
- Energy transferred directly into lung tissue → pulmonary "bruising"

Breathing

- Hemothorax

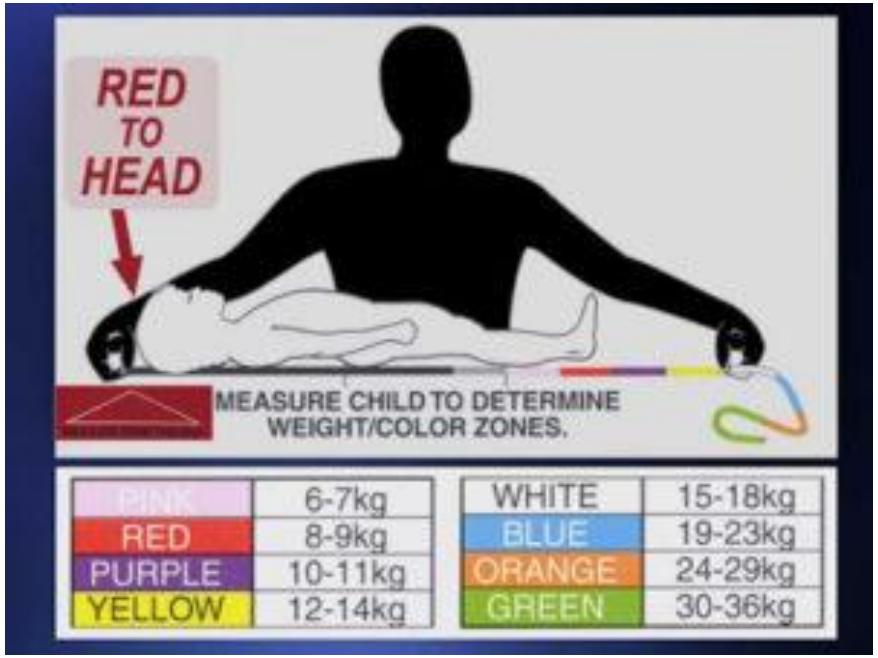


Circulation

- Resuscitation
  - Bolus: Isotonic solution at 20 mL/kg

    ***** BLOOD FIRST AT INOVA AND MOST TRAUMA CENTERS!**

  - Use Whole Blood for children of all ages
  - Early use of plasma and platelets if giving PRBCs
  - We have Peds MTP (Massive Transfusion Protocol) at Inova!



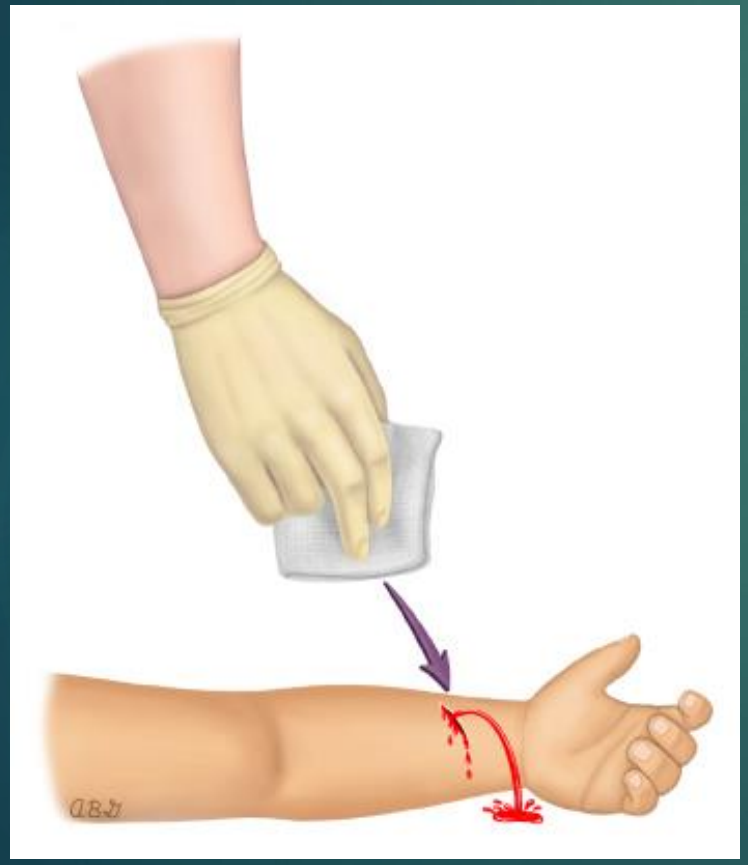
Circulation

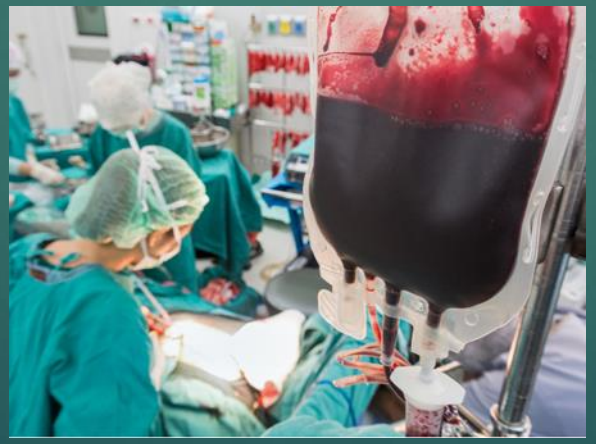
Classification of hemorrhagic shock in children

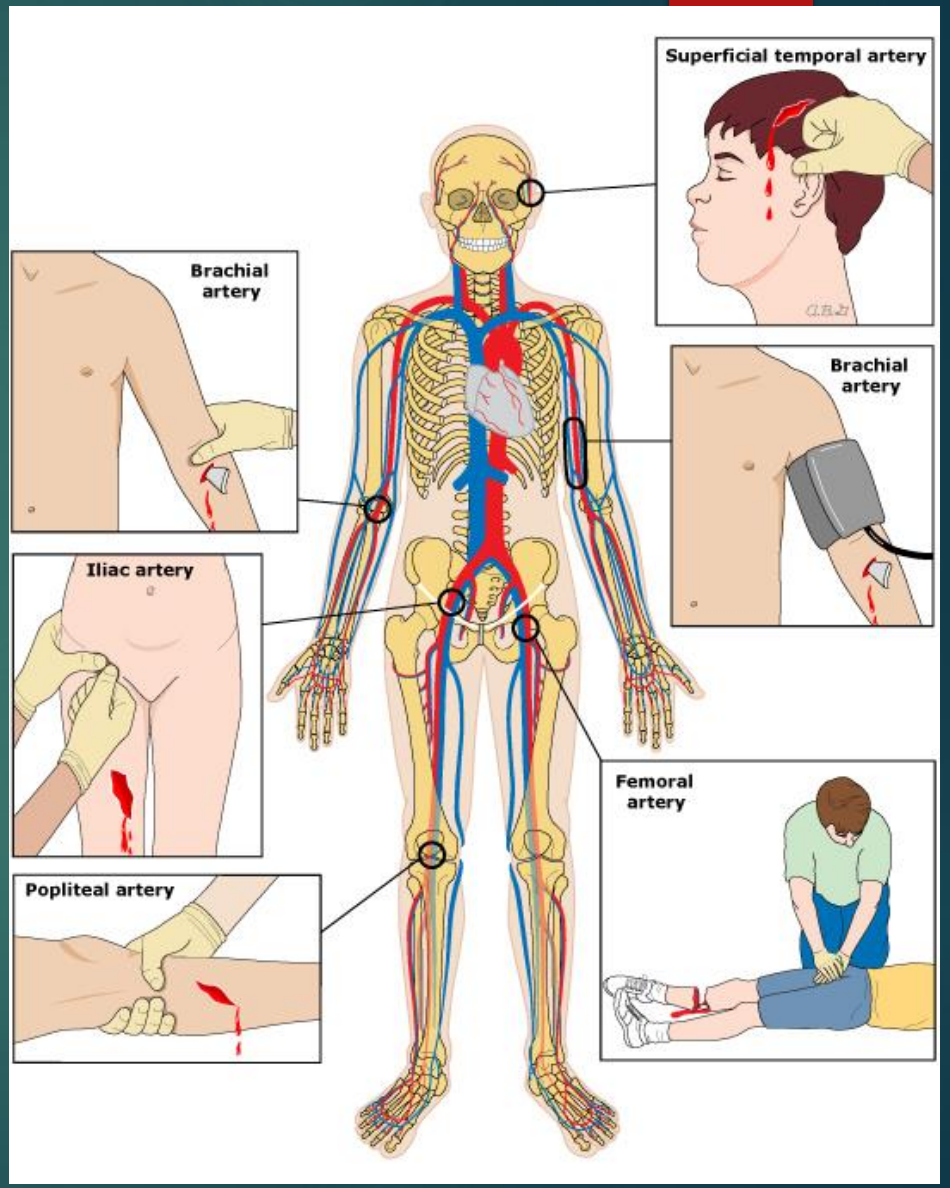
	Class I, very mild	Class II, mild	Class III, moderate	Class IV, severe
Percent blood volume loss	<15%	15-30%	30-40%	>40%
Heart rate	Normal	Slightly increased	Moderately increased	Markedly increased
Respiratory rate	Normal	Slightly increased	Moderately increased	Markedly increased, markedly decreased, or absent
Blood pressure	Normal or slightly increased	Normal or slightly decreased	Decreased	Decreased
Pulses	Normal	Normal or decreased peripheral	Weak or absent peripheral	Absent peripheral, weak or absent central
Skin	Warm and pink	Cool extremities, mottled	Cool mottling extremities, or pallor	Cold extremities with pallor or cyanosis
Capillary refill	Normal	Prolonged	Markedly prolonged	Markedly prolonged
Mental status	Slightly anxious	Mildly anxious, confused, combative	Very anxious, confused, or lethargic	Very confused, lethargic, or comatose
Urine output	Normal	Slightly decreased	Moderately decreased	Markedly decreased or anuria

Data from: Hazinski, MF, Barkin, RM. Shock. In: Pediatric emergency medicine: Concepts and clinical practice, Barkin, RM (Ed), Mosby-Yearbook Inc, St. Louis, MO 1997. p. 118; and Waltzman, ML, Mooney, DP. Major trauma. In: Textbook of Pediatric Emergency Medicine, Fleisher, GR, Ludwig, S, Henretig, FM (Eds), Lippincott Williams & Wilkins, Philadelphia 2006. p. 1354.

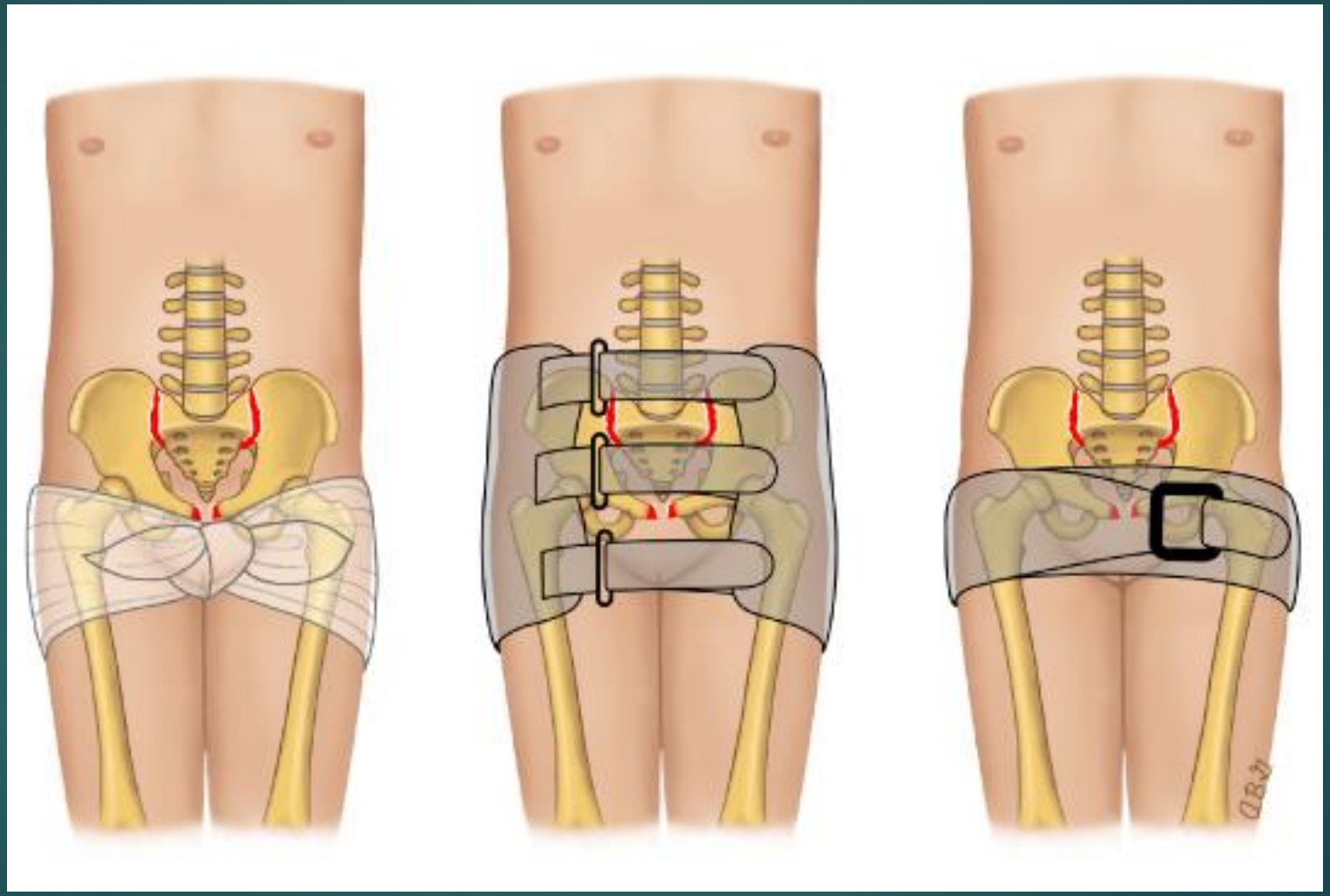
Circulation
Hemorrhage Control







Hemorrhage Control: Pelvic Binder



Circulation

Tibial Intraosseous Insertion in Pediatric Emergency Care: A Review Based upon Postmortem Computed Tomography

H. Theodore Harcke, MD, Riley N. Curtin, M. Patricia Harty, MD, Sharon W. Gould, MD, Jennie Vershvovsky, MD, Gary L. Collins, MD, Stephen Murphy, MD

Forensic review of 42 needles in 31cases

- 40% unsuccessful
  - 14% tibial perforation
  - 14% cortical placement
  - 11% missed

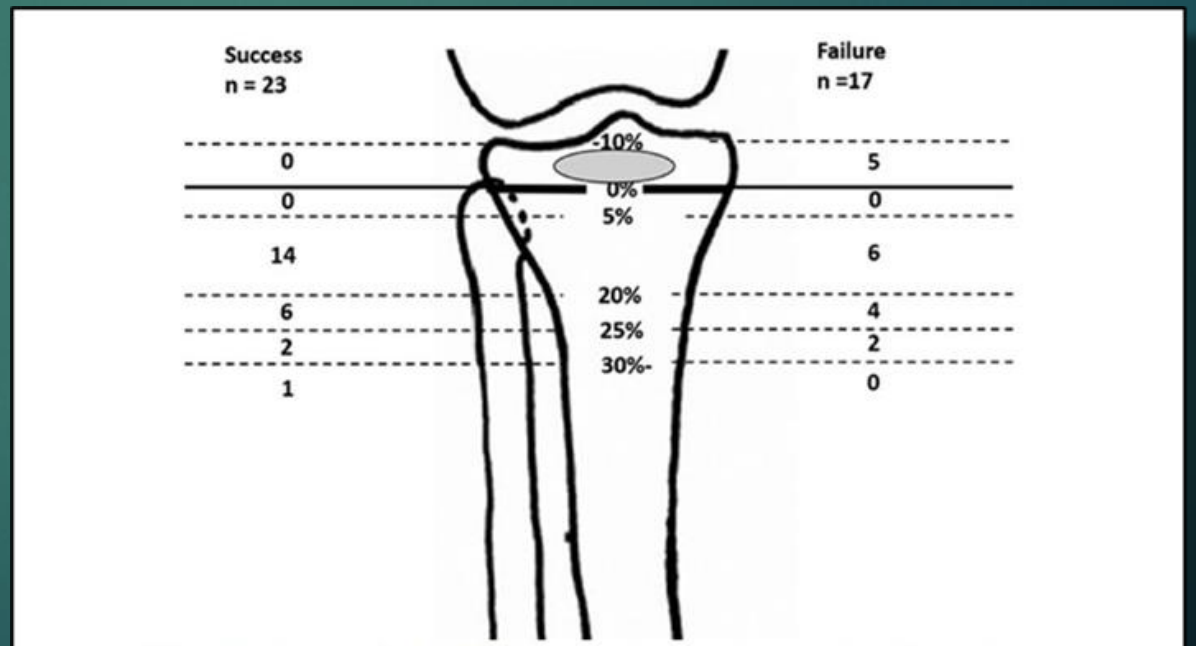


Figure 1. Needle location level for successful and failed intraosseous needle placements with respect to tibia length. Range for satisfactory placement is 5% - 30% of the tibia length.

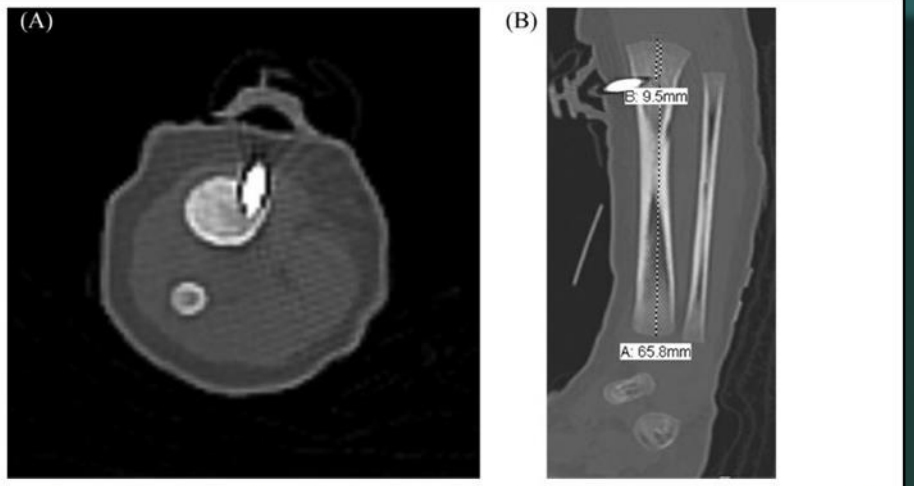


FIGURE 2. Successful needle placement in a 2-week-old male. (A) Axial CT of the proximal right tibia (larger of the two cross-sections) shows the needle tip to be in the medullary portion of the bone. Because of the needle angulation, the needle length was measured as 15 mm on a reconstructed coronal image. (B) Placement level of an intraosseous needle in the tibia as measured on a coronal CT image. Needle distance from the proximal growth plate (B = 9.5 mm) divided by the bony tibia between the growth plates (A = 65.8 mm) and expressed as a percent (X 100) shows needle 14.4% distal to the plate. This corresponds to the metaphysis (0 to 20%) by our criteria.

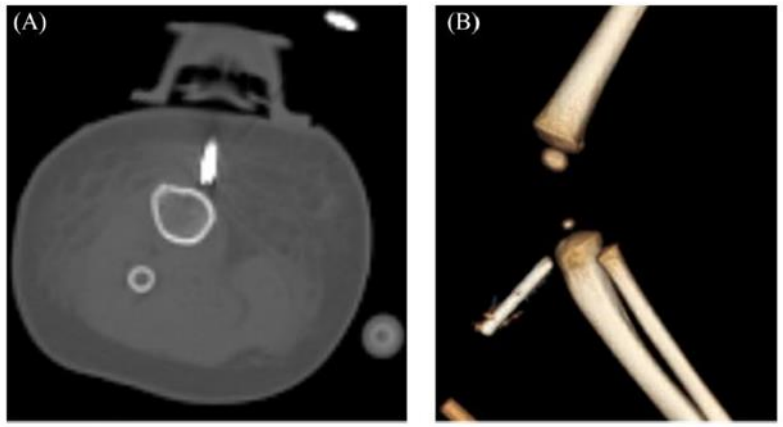


FIGURE 3. Unsuccessful needle placement in a 2-month-old female. (A) Axial CT of the proximal right tibia shows the needle tip to be in soft tissue medial to the bone. The needle length measured as 15 mm. (B) 3D reconstruction shows the level and direction of the needle.

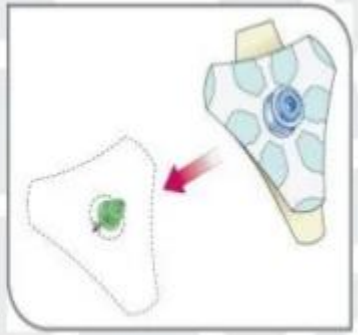
FIGURE 4. 3D reconstruction of the right lower leg in a 4-month-old female. The intraosseous needle has perforated the tibia. Measurement showed the needle length to be 25 mm.

Circulation

Pediatric EZ-IO Insertion

- Pediatric insertion requires a gentle grip and a soft touch
- One size does not fit all
  - Consider tissue depth in needle selection

- Be cautious of driver recoil
  - Release the trigger when you feel the lack of resistance
- The EZ-Stabilizer is highly recommended on newborns and infants



Disability

Sign	Glasgow Coma Scale[1]	Pediatric Glasgow Coma Scale[2]	Score
Eye opening	Spontaneous	Spontaneous	4
	To command	To sound	3
	To pain	To pain	2
	None	None	1
Verbal response	Oriented	Age-appropriate vocalization, smile, or orientation to sound, interacts (coos, babbles), follows objects	5
	Confused, disoriented	Cries, irritable	4
	Inappropriate words	Cries to pain	3
	Incomprehensible sounds	Moans to pain	2
	None	None	1
Motor response	Obeys commands	Spontaneous movements (obeys verbal command)	6
	Localizes pain	Withdraws to touch (localizes pain)	5
	Withdraws	Withdraws to pain	4
	Abnormal flexion to pain	Abnormal flexion to pain (decorticate posture)	3
	Abnormal extension to pain	Abnormal extension to pain (decerebrate posture)	2
	None	None	1
Best total score			15

Calculate Pediatric GCS

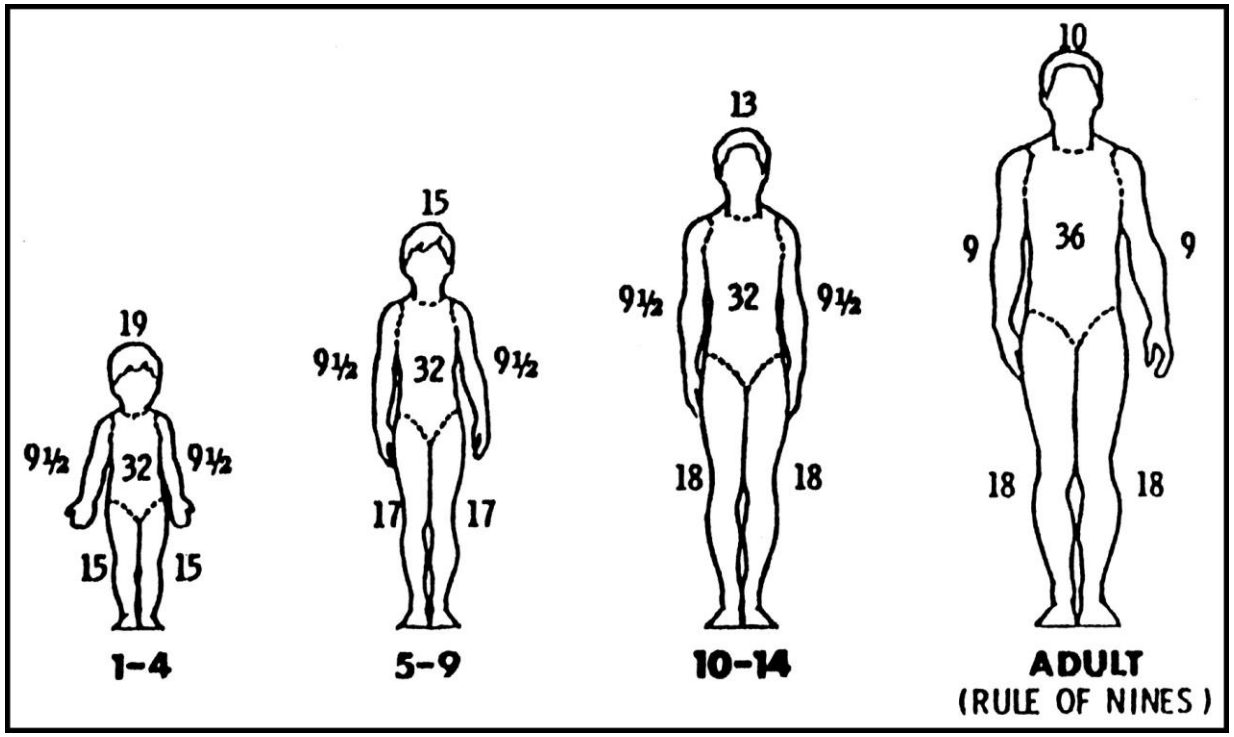
- 11mo male infant
- Eyes = squeezed closed
- Verbal = Crying loudly, irritable
- Motor = Spontaneously, vigorously moving all extremities

- GCS = ???
  - 1 + 4 + 6 = 11

- Intubate?

Environment/Exposure

- Higher body surface area to volume ratio
  - Less muscle mass (volume) to produce heat
  - More area to lose heat through
  - Larger head area
    - Wrap head!
- Thinner skin
- Less insulation by subcutaneous tissue



Non-Accidental Injuries

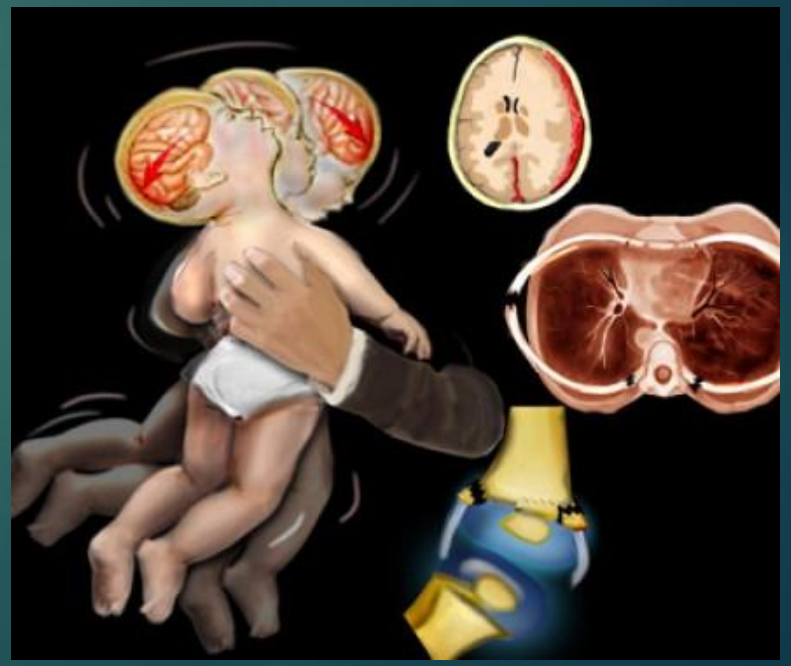
Clues from History:

- Story Discrepancies
- Delay in care
- Repetitive injuries
- Inappropriate responses
  - Caregiver emotion doesn't fit situation
- Medical neglect
- Developmentally improbable mechanism
  - 2mo infant falling down stairs… cannot accomplish on their own

Non-Accidental Injuries

Clues from Physical Exam:

- Multicolored bruises
- Bilateral subdural hematomas
- Retinal hemorrhages
- Femur fracture(s)
- Rib fracture(s)
- Unusual scald / contact burns



Non-Accidental Injuries

What to do with information?

Mandatory Reporting

Social Work

Physical examination components for physical abuse

- Any injury to a preambulatory infant, including bruises, mouth injury, fracture, and intracranial or abdominal injury
- Injuries to multiple organ systems
- Multiple injuries in different stages of healing
- Patterned injuries
- Injuries to nonbony locations, such as the torso, ears, face, neck, or upper arms
- Significant injuries that are unexplained
- Additional evidence of child neglect or failure to thrive
- Different forms of injury present (eg, burns, fractures)

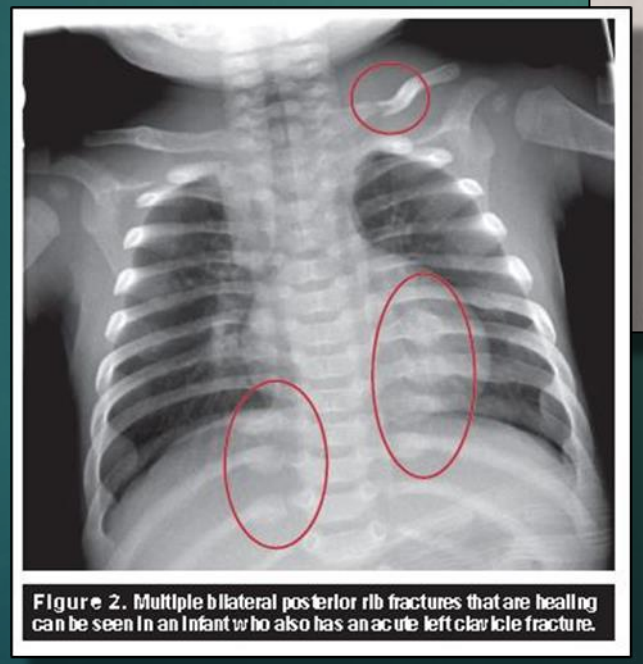


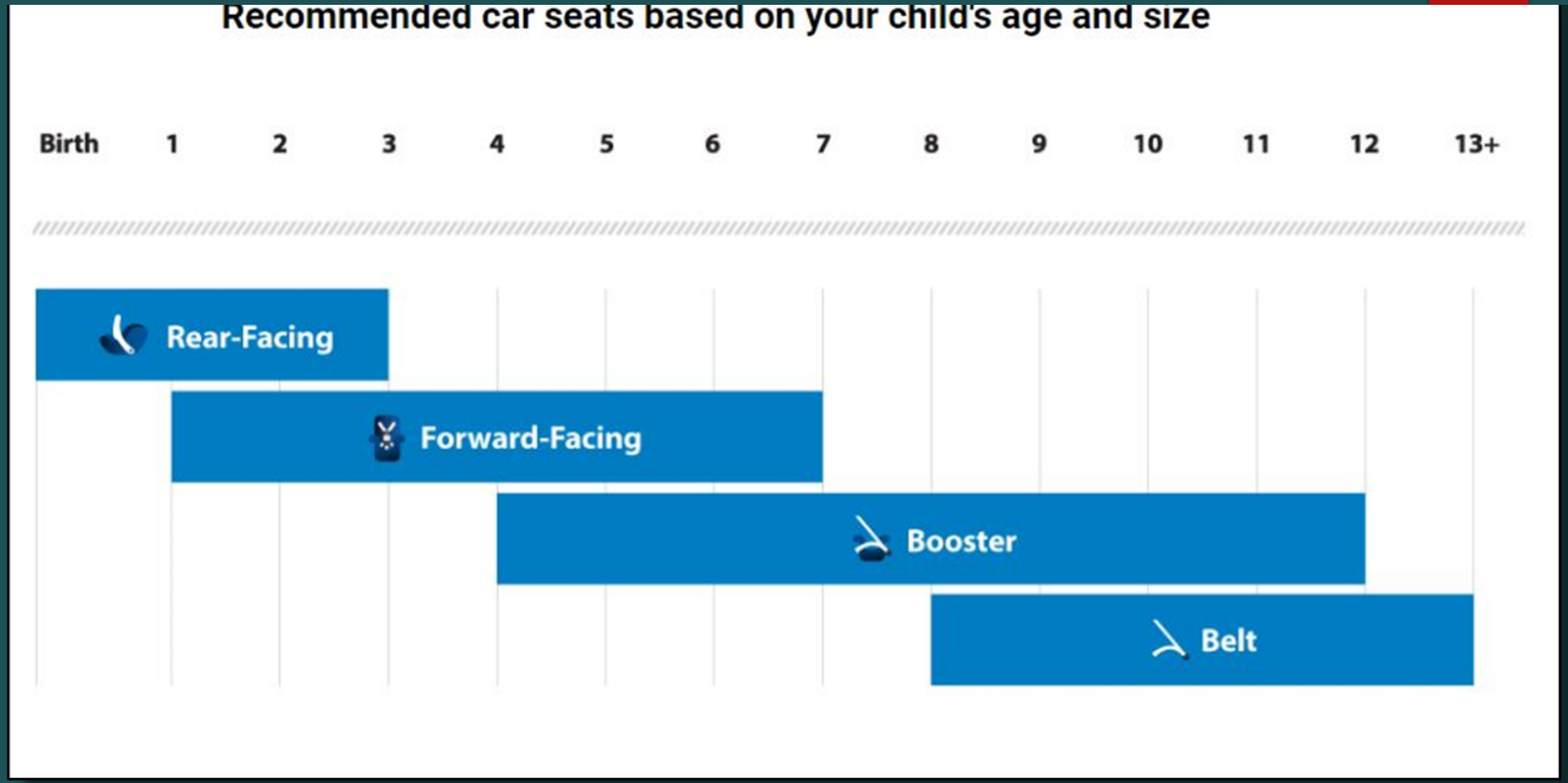
Figure 2. Multiple bilateral posterior rib fractures that are healing can be seen in an infant who also has an acute left clavicle fracture.

Injury Prevention: Restraints


KXLY NIGHTSIDE
BABY SURVIVES FATAL CRASH
EJECTED FROM VEHICLE IN CAR SEAT

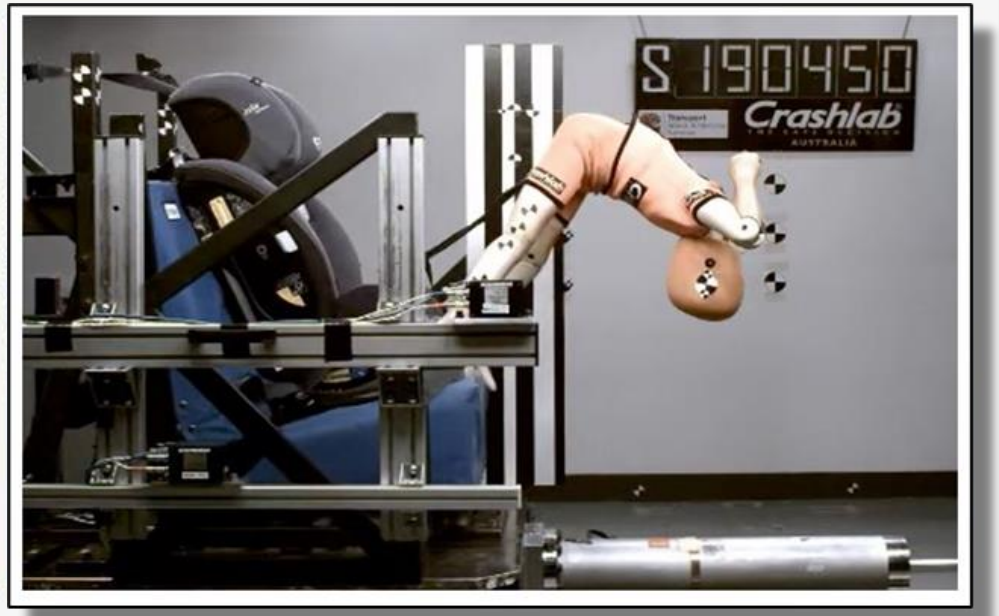

KXLY NIGHTSIDE
BABY SURVIVES FATAL CRASH
EJECTED FROM VEHICLE IN CAR SEAT
11:02 PM
1:31 / 2:28


KXLY NIGHTSIDE
31°
BABY SURVIVES FATAL CRASH
EJECTED FROM VEHICLE IN CAR SEAT
11:01 PM
39°


Recommended car seats based on your child's age and size
Birth
1
2
3
4
5
6
7
8
9
10
11
12
13+
Rear-Facing
Forward-Facing
Booster
Belt

Injury Prevention: Restraints

WHAT DO THE CHILD CAR SEAT STATISTICS SHOW?



- More black (45%) and Hispanic (46%) children were not buckled up compared with white (26%) children (2009-2010).
- More of the older children (48% of 8-12 year olds) were not buckled up compared with younger children (33% of 4-7 year olds; 21% of children under age 4) in 2016
- Restraint use among young children often depends upon the driver's seat belt use. Almost 40% of children riding with unbelted drivers were themselves unrestrained.
- More than two-thirds of fatally injured children were killed while riding with a drinking driver.

One CDC study found that, in one year, more than 618,000 children ages newborn to 12 rode in vehicles at least some of the time without the use of a restraint be it car seat, booster seat or seat belt.

Questions and Discussion

Case Study #1

A 7-year-old boy is struck by a moving car while riding his bicycle (unhelmeted). He is unresponsive on arrival, breathing rapidly, and is pale with mottled extremities.

Vital signs: HR 144, RR 38, BP 80/57, GCS score 5 (E = 1, V = 2, M = 2)

What is your initial assessment?

What are your priorities for initial resuscitation?

Case Study #2

You arrive to a home where a 9 month old female infant is reported to have fallen down a flight of stairs. You find her lying at the bottom of the stairs. Her eyes are closed and she is not moving.

Two adults are nearby laughing and joking. They say she is just "playing possum" and does this frequently.

Airway is patent. Respirations appear rapid and shallow. Breath sounds are equal and present bilaterally. She is tachycardic but normotensive for her age. She localizes to painful stimuli but does not make a sound or open her eyes.

What are your initial thoughts?

How do you proceed?

Pediatric FAST

Blood = Positive FAST
No blood = Non-diagnostic
(NOT Negative!!!)

CIRCULATION

A
B
C
D
E

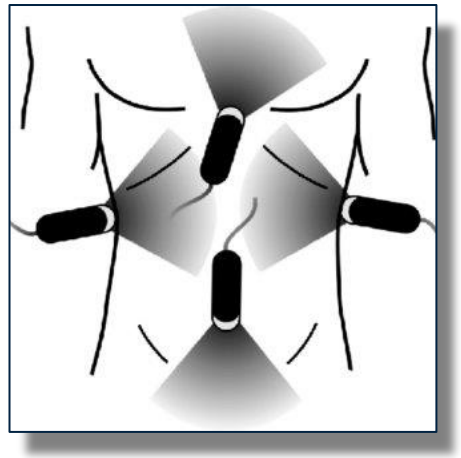
The Utility of the Focused Assessment With Sonography in Trauma Examination in Pediatric Blunt Abdominal Trauma
A Systematic Review and Meta-Analysis

Tian Liang, MD,† Eric Roseman, MD,*† Melanie Gao, BA,*† and Richard Sinert, DO*†*

- Pediatric Emergency Care 2018- SUNY & Kings County

- FAST US useful for HD unstable pts

- Meta-analysis of 8 prospective studies (2135pts)
  - Hemodynamically stable patients (14% IAI)
  - (+) FAST US - 63% predictive
  - (-) FAST US – 9% false negative
- Recommend CT with iv contrast with (+)
  - lifetime risk of radiation-induced cancer 0.00023 (single abdominal CT scan in a 5yo)
- Risk of nontherapeutic laparotomy



A
B
C
D
E

TABLE 2. Intraosseous needle placement by age and length

Needle Length	Age ≤ 6 mos	> 6 mos – 2 years	> 2 years	Total*
15-mm				
Success	14	4	2	20 (65%, 48–81)
Failure	11	0	0	11 (35%, 19–52)
25-mm				
Success	0	1	4	5 (46%, 16–75)
Failure	5	1	0	6 (54%, 6–65)
15 mm and 25 mm Combined				
Success*	14 (47%, 28–66)**	11 (92%, 76–100)**		
Failure*	16 (53%, 35–72)**	1 (8%, 0–24)**		

*n (percent, 95% confidence interval).
**$p < 0.05$.

TABLE 3. Intraosseous needle placement by location

Provider/Location	Success*	Failure*	Total
First Responder	7 (54%, 27–81)	6 (46%, 19–73)	13
Emergency Room	14 (70%, 50–90)	6 (30%, 10–50)	20
Total	21	12	33

*n (percent, 95% confidence interval).