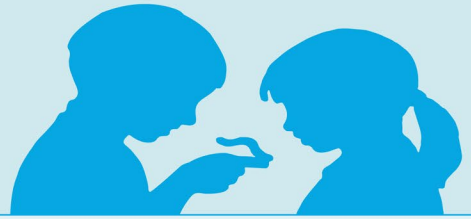

Imaging in Pediatric Trauma

Controversies and Best Practices

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Associate Trauma Medical Director

musc Children's Health

Medical University of South Carolina

Changing What's Possible

Disclosures

- None

- I am sort of an amateur trauma surgeon

Summary

Pediatric Trauma Care at MUSC

- **ACS Pediatric Level 1 Trauma Center**
- ~700 patients annually
- Patients 16 years of age or less
- ~20% penetrating trauma
- 5 pediatric surgeons

The Medical University of South Carolina
Shawn Jenkins Children's Hospital

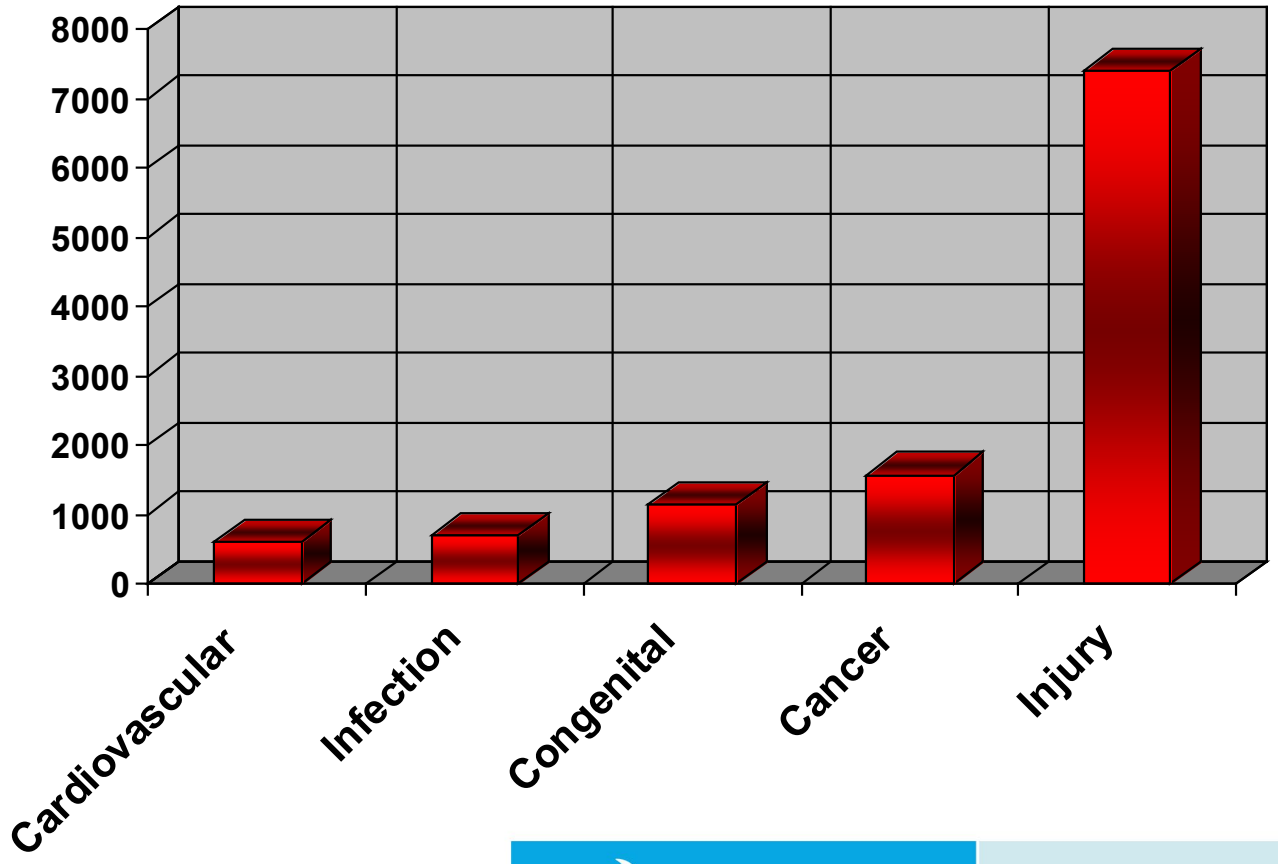
Pediatric Trauma Care at MUSC

Rules of Pediatric Trauma

- Unstable patients need therapeutics before diagnostics
- An arterial line never saved a kid's life
- The younger the kid, the more likely they are to injure their head
- The older the kid, the more likely likely they are to injure their body
- "It takes a village"
- Listen to moms (and dads)
- Think about child abuse
- Children are not small adults
- Kids' clotting mechanisms are amazing
- Hypotension in a child is bad news

Why Should You Care?

- Trauma is the leading cause of death in children after 1 year of age
  - National Center for Injury Prevention and Control



Children are not little adults

- Mechanistically
- Anatomically
- Physiologically
- Psychologically
- Developmentally

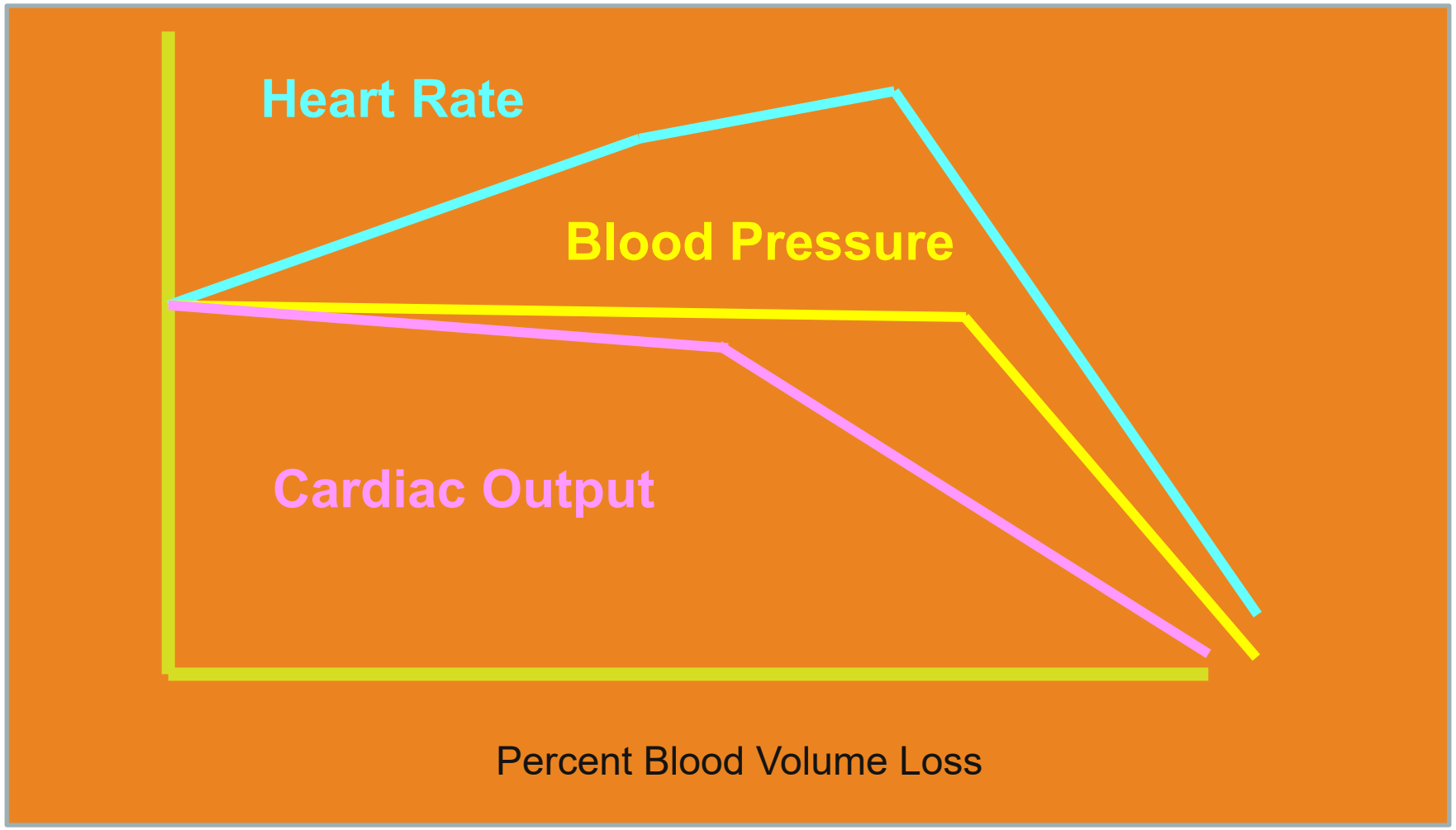
Physiologic Differences

Normal heart rate by age (beats/min)	
Age	**Awake rate**
Newborn to 3 months	85–205
3 months–2 years	100–190
2–10 years	60–140
>10 years	60–100
Normal respiratory rate by age (breaths/min)	
Infants (<12 months)	30–60
Toddler (1–3 years)	24–40
Preschool (4–5 years)	22–34
School age (6–12 years)	18–30
Adolescence (13–18 years)	12–16
Systolic blood pressure hypotension reference ranges (mmHg)	
Term neonates (0–28 days)	<60
Infants (1–12 months)	<70
Children 1–10 years	<70 + (age in years × 2)
Children >10 years	<90

Not a lot of blood to bleed

Age	Estimated blood volume (mL/kg)
Premature infant	90–100
Term infant to 3 months	80–90
Children older than 3 months	70
Obese children	65

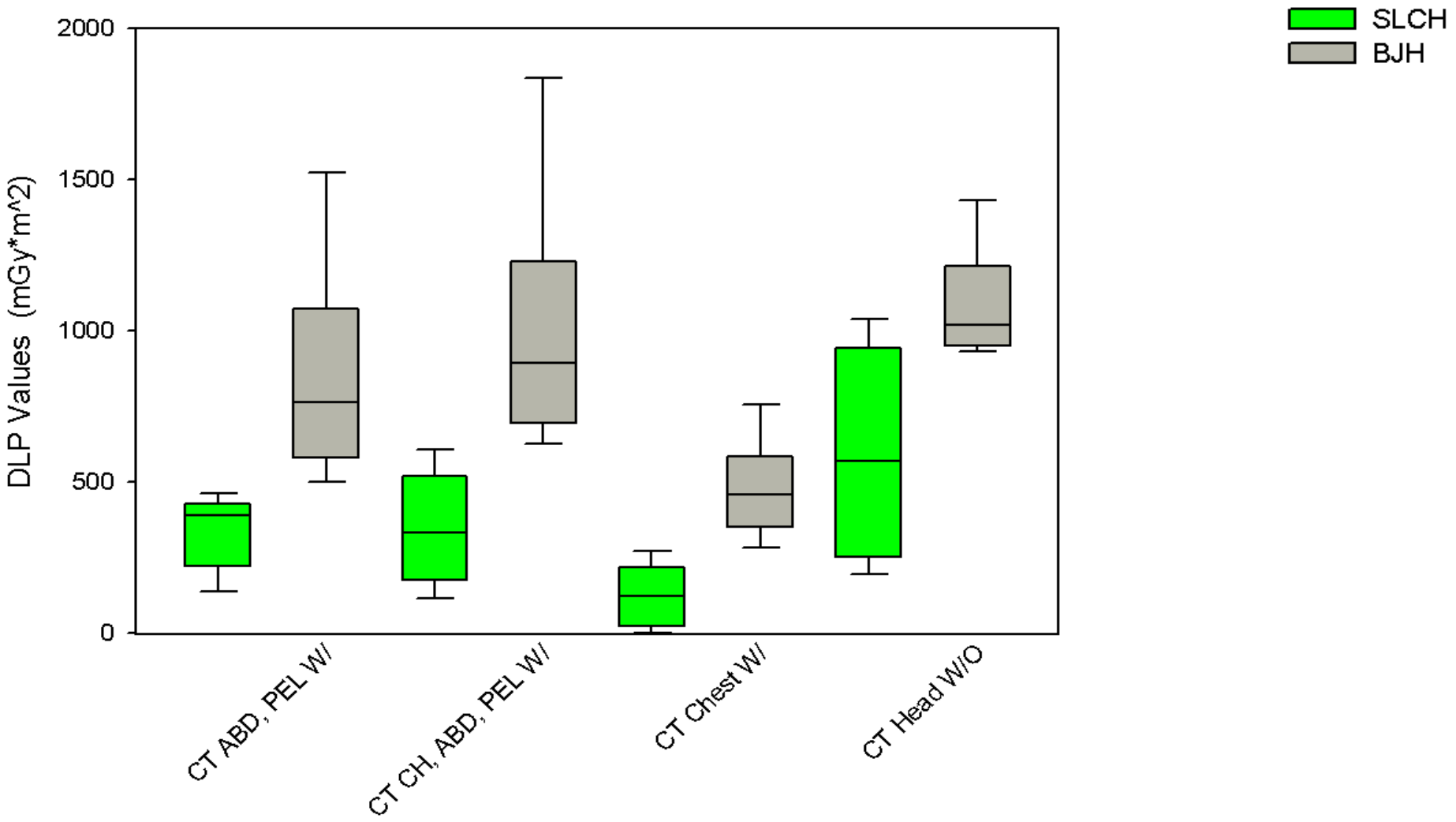
Physiologic Cliff



Why discuss pediatric imaging?

- Accurate/prompt diagnoses important to prevent morbidity/mortality
- Facilities have different capabilities
  - Less comfort with pediatric trauma care – lower volume, high stakes
- Must consider long-term consequences along with short term
- American Pediatric Surgical Association (APSA) Committee on Trauma has made minimizing unnecessary radiation a priority

Balancing injury diagnoses with radiation dose



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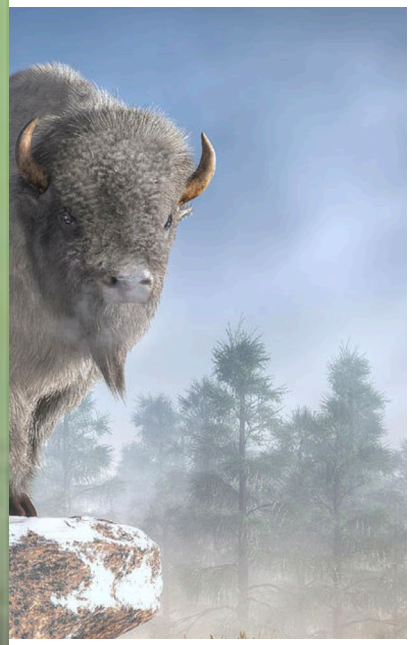
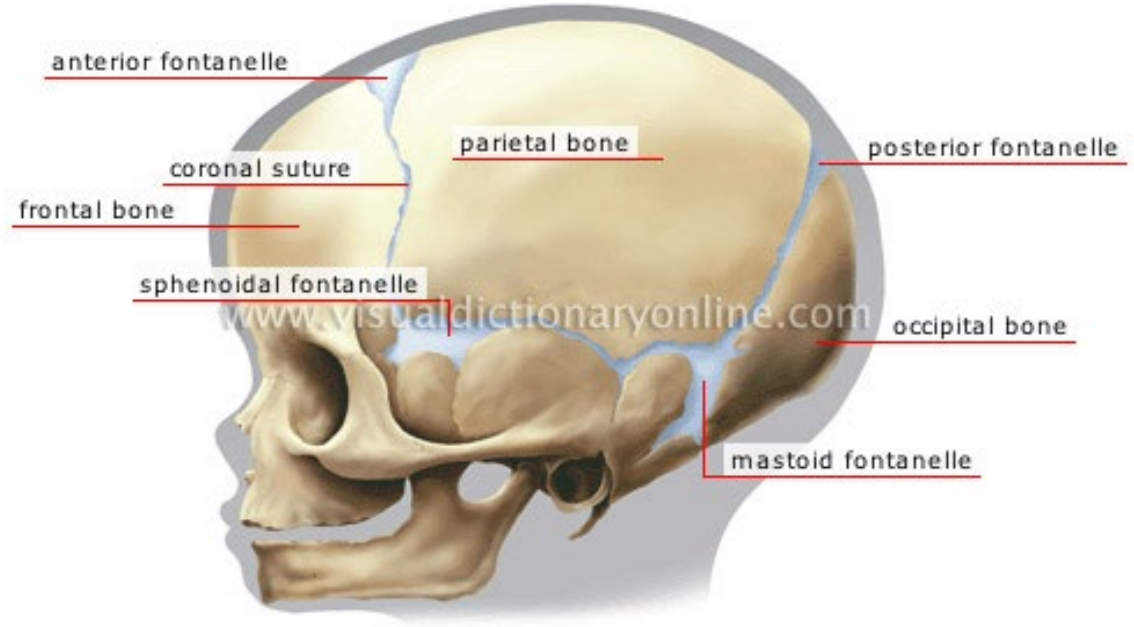


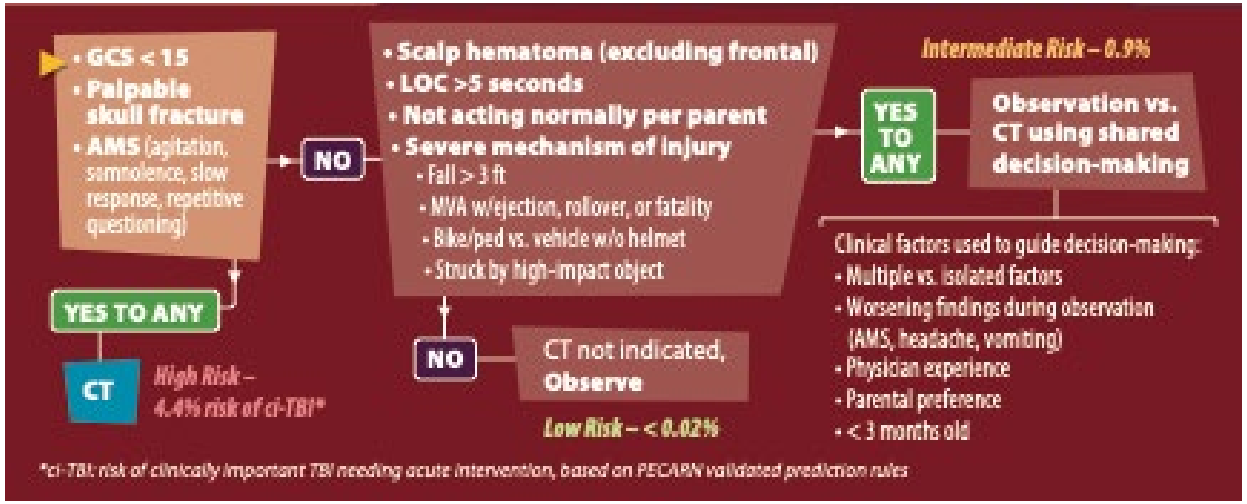
Anatomy: Head

- Proportionally larger
  - Greater incidence of injury
- Thinner skull
  - Less protective
- Incompletely ossified
  - Less protective
- Open fontanels
- Brain plasticity
- Prominent occiput in young children
  - Can make C-spine stabilization difficult

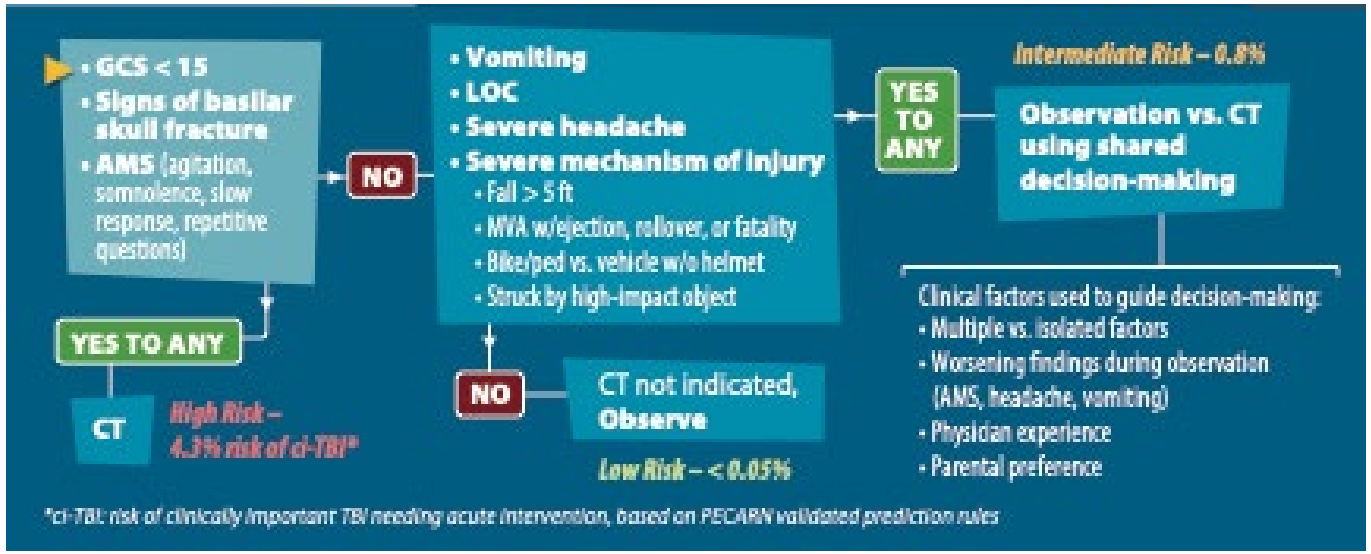


Imaging the pediatric head

← < 2 years of age



> 2 years of age →

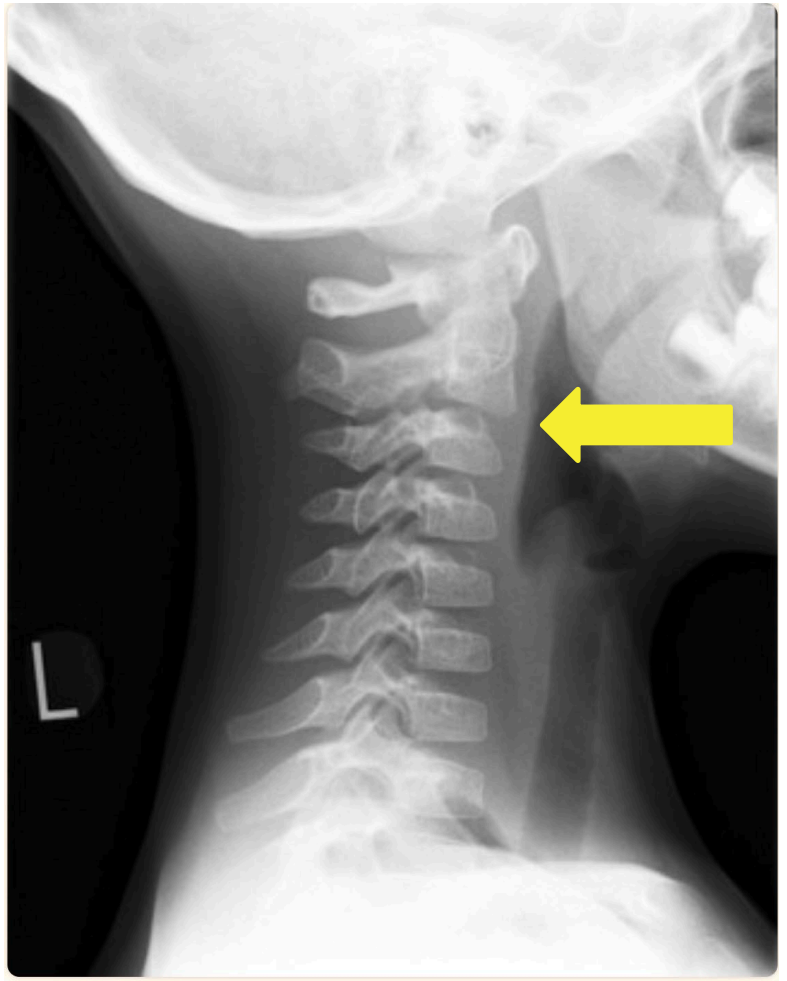


The pediatric cervical spine

- Incidence of injury in children is low (~1.5% of trauma activations)
- Neurologic impairment in a child is devastating for both child and families
- Anatomy/physiology differs in significant ways
- Must weight costs/benefits carefully
- Radiation exposure to the neck not without consequences

The pediatric cervical spine

- Intrinsic elastic properties
  - Causes immediate reduction in injuries → bones are aligned → SCIWORA
- Physiologic pseudosubluxation (C2/C3)
- Underdeveloped facet joints
- Variable ossification



Management of cervical spine trauma in children

Phillip Correia Copley[1] · Vicky Tilliridou[2] · Andrew Kirby[3] · Jeremy Jones[3] · Jothy Kandasamy[1]

European Journal of Trauma and Emergency Surgery (2019) 45:777–789

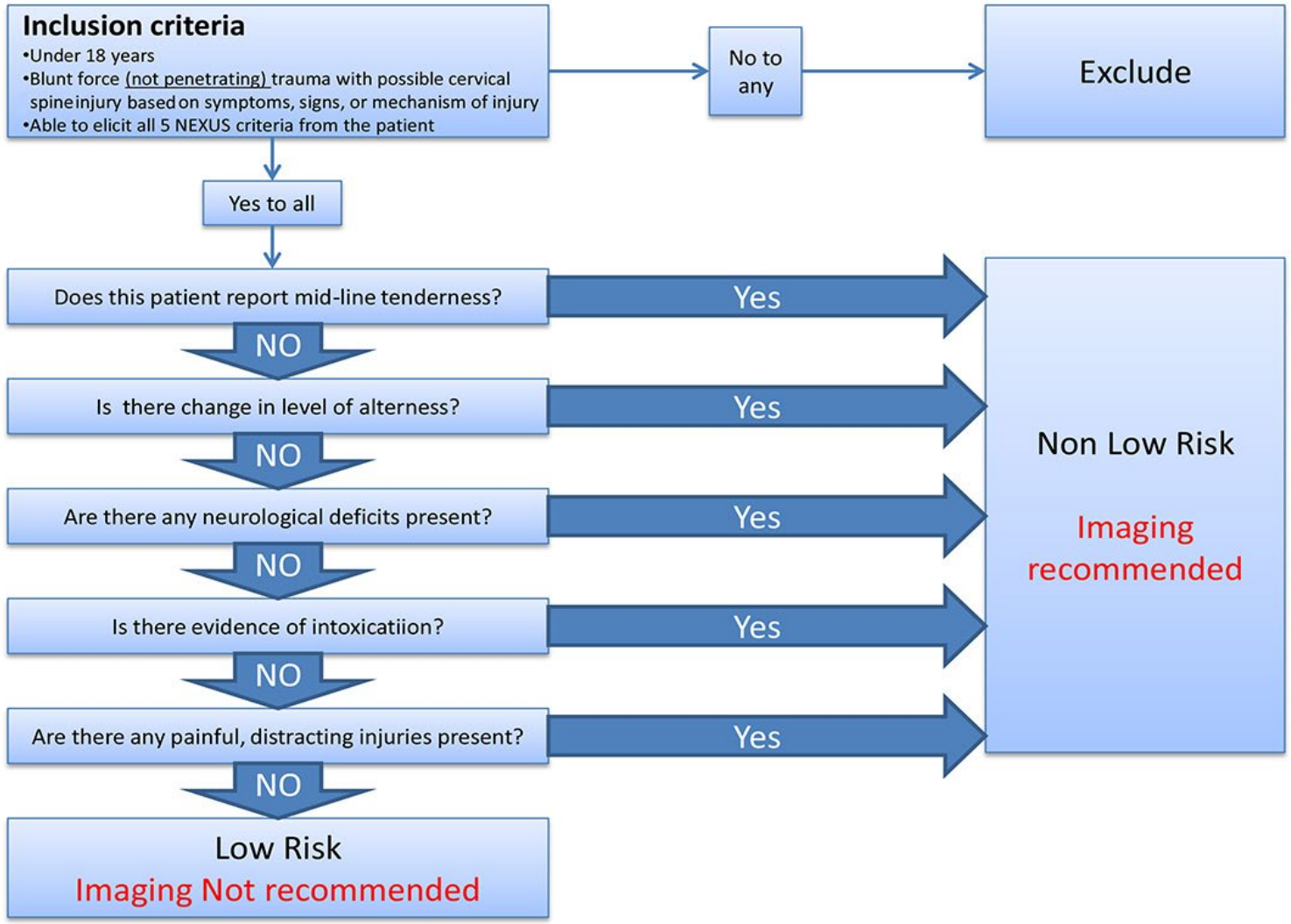
The pediatric cervical spine

- Prominent occiput in young children → increased flexion
  - Thoracic elevation or occipital recess on spine board

Emergency transport and positioning of young children who have an injury of the cervical spine. The standard backboard may be hazardous

J E Herzenberg [1], R N Hensinger, D K Dedrick, W A Phillips

Pediatric NEXUS



- There is good data for the value of AP/Lateral plain film in younger children
  - Odontoid view of limited value

- Should consider plain films as initial study in a non-communicative child or those < 3 years of age

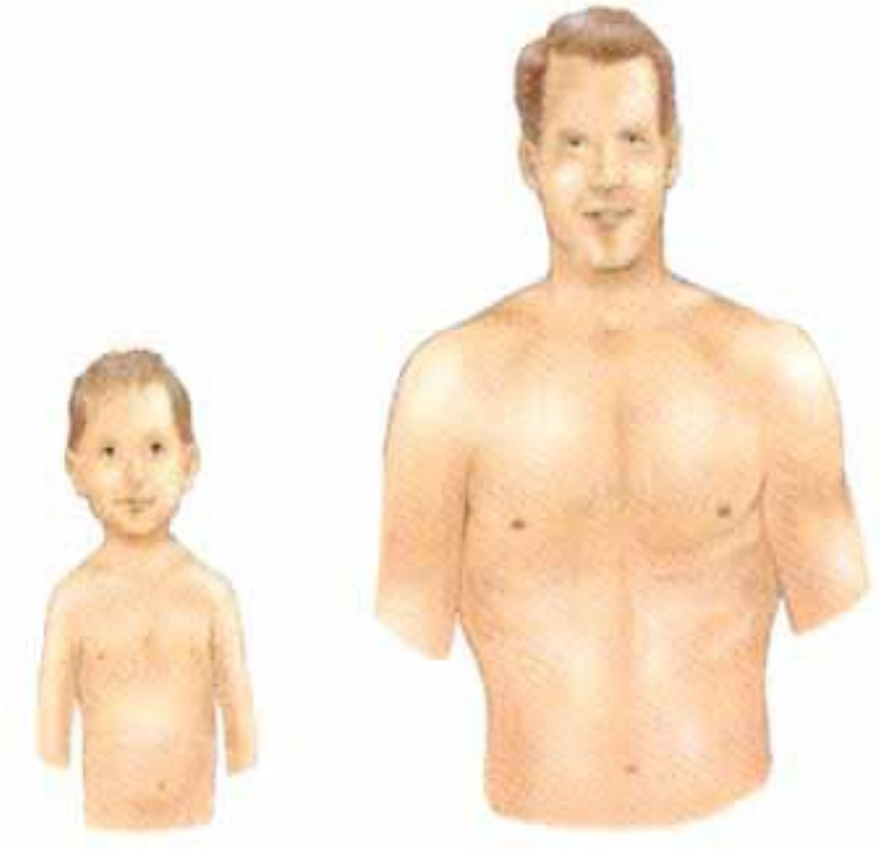
The pediatric cervical spine – future directions?

- Some centers are scanning C1-C3 along with the head in younger children
  - Injuries less likely in C4-8
  - Avoids thyroid radiation

- "Fast" MRI of head/C spine
  - AKA no sedation MRI, can be performed in 5-20 minutes
  - Motion-insensitive sequences
  - Can be performed in stable patients along with MRI head
  - Parent can "ride-along" in MRI
  - Babies can get a feed and a swaddle and will sleep through entire exam

The pediatric chest

- Increase rib flexibility and compliance until 8-10 years of age
- Decreased ossification
- Small size to body surface area
- Transmission of traumatic energy internally



Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study

Mark S Pearce, Jane A Salotti, Mark P Little, Kieran McHugh, Choonsik Lee, Kwang Pyo Kim, Nicola L Howe, Cecile M Ronckers, Preetha Rajaraman, Sir Alan W Craft, Louise Parker, Amy Berrington de González

Lancet 2012; 380: 499–505

- A CT scan may triple the risk of leukemia and brain cancer over subsequent 10 years
- In absolute terms: for every 10,000 CT scans → 1 additional brain cancer, 1 additional leukemia

Chest computed tomography imaging for blunt pediatric trauma: not worth the radiation risk[1]

Courtenay M. Holscher, MD,[a,*] Leonard W. Faulk, MBA, MD,[a] Ernest E. Moore, MD,[a,b] Clay Cothren Burlew, MD,[a,b] Hunter B. Moore, MD,[a,b] Camille L. Stewart, MD,[a,b] Fredric M. Pieracci, MD,[a,b] Carlton C. Barnett, MD,[a,b] and Denis D. Bensard, MD[a,b]

JOURNAL OF SURGICAL RESEARCH 184 (2013) 352–357

- CT did not change management, only changed radiation exposure

Guidelines for CT scans in pediatric blunt thoracic injury

Concern for injury → CXR. If abnormal findings → CT

Application of a Thoracic CT Decision Rule in the Evaluation of Injured Children: A Quality Improvement Initiative

Katie Downie, MSN, RN, CPN ■ Alicia McIntire, MSN, CPNP-PC ■ Joseph Tobias, MD ■ Sanjay Krishnaswami, MD, FACS, FAAP ■ Mubeen Jafri, MD, FACS, FAAP

KEY POINTS

- Traumatic injuries of the chest are rare in children.
- Application of decision rules can safely limit ionizing radiation and cancer risk in injured children.
- Pediatric imaging protocols are recommended as best practice.
- Electronic medical records functionality standardizes and supports clinical workflows.

Table 2. Pre- and Postprotocol Chest Radiography and Thoracic Computed Tomography Utilization

	Preprotocol $N = 488$	Postprotocol $N = 568$	p
No imaging of chest	240 (49.2%)	340 (59.9%)	
Chest radiography only	119 (24.4%)	156 (27.5%)	
TCT only	74 (15.2%)	55 (9.7%)	
Chest radiography and TCT	55 (11.3%)	17 (3.0%)	
Total TCT	129 (26.4%)	72 (12.7%)	<.05
Compliance		501 (88%)	

Note. TCT = thoracic computed tomography.

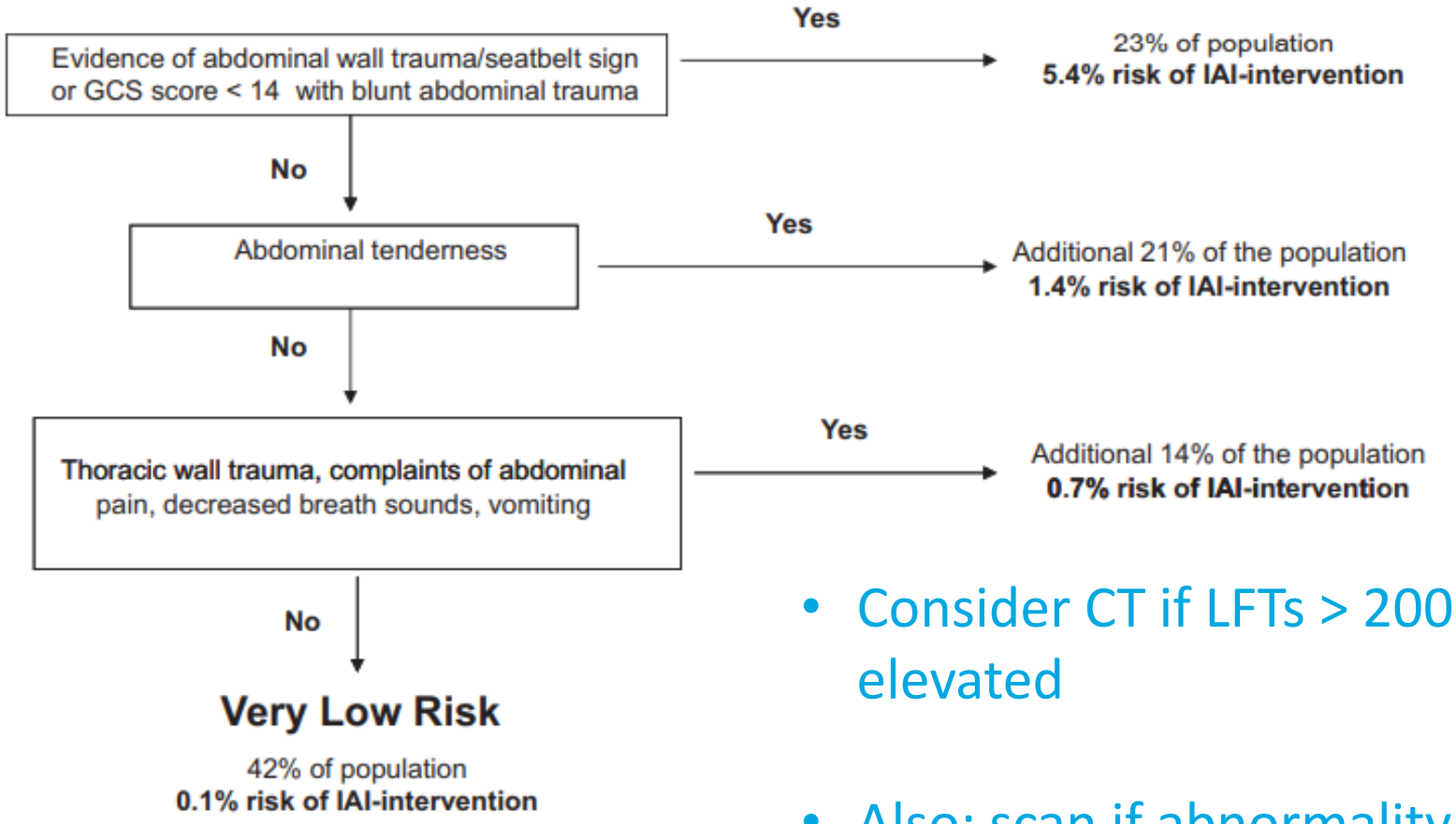
OHSU

The pediatric abdomen

- Abdominal wall poorly developed
- Compliant chest wall/diaphragm
- Reduced visceral/perinephric fat
- Transmission of traumatic energy internally
- Organ specific differences exist

Who gets a CT A/P?

- PECARN Data; 12K enrolled children; 6.3% had intra-abdominal injury (IAI)



- Consider CT if LFTs > 200 or pancreatic enzymes elevated
- Also: scan if abnormality on FAST

Holmes et al. Identifying children at very low risk of clinically important blunt abdominal injuries. Ann Emerg Med. 2013 Aug;62(2):107-116

Seat belt sign

- Triad of abdominal wall ecchymosis, intra-abdominal injury, and chance fracture of lumbar vertebrae
  - May result in injury to hollow viscus, occasionally pancreaticoduodenal complex
  - Injury to visceral vessels, especially the aorta
- All children with true seat belt sign → CT

Seat belt sign

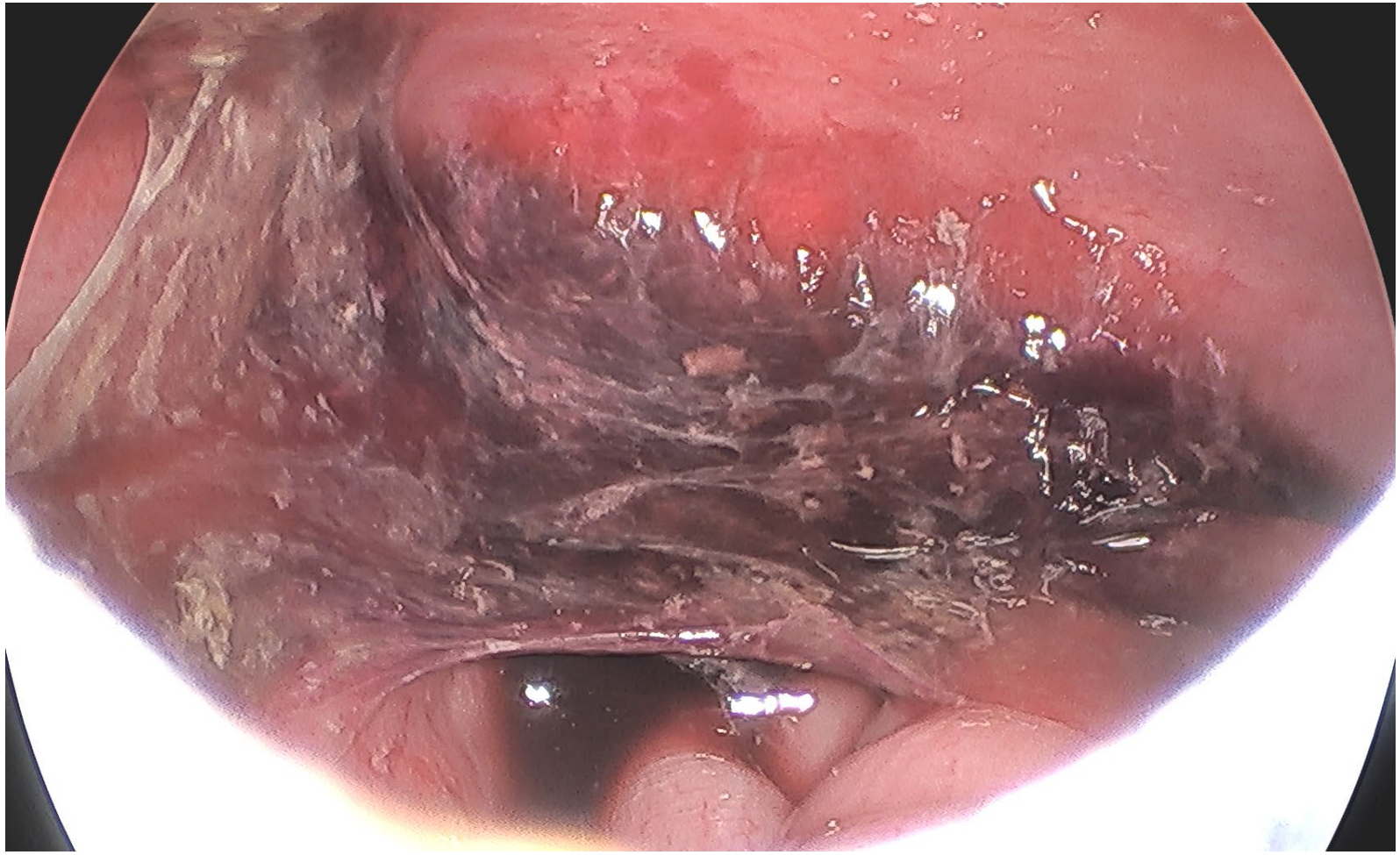
- 8 year-old male
- Free fluid in the pelvis → either blood or succus or both

Seat belt sign

- 8 year-old male
- Intra-operative findings

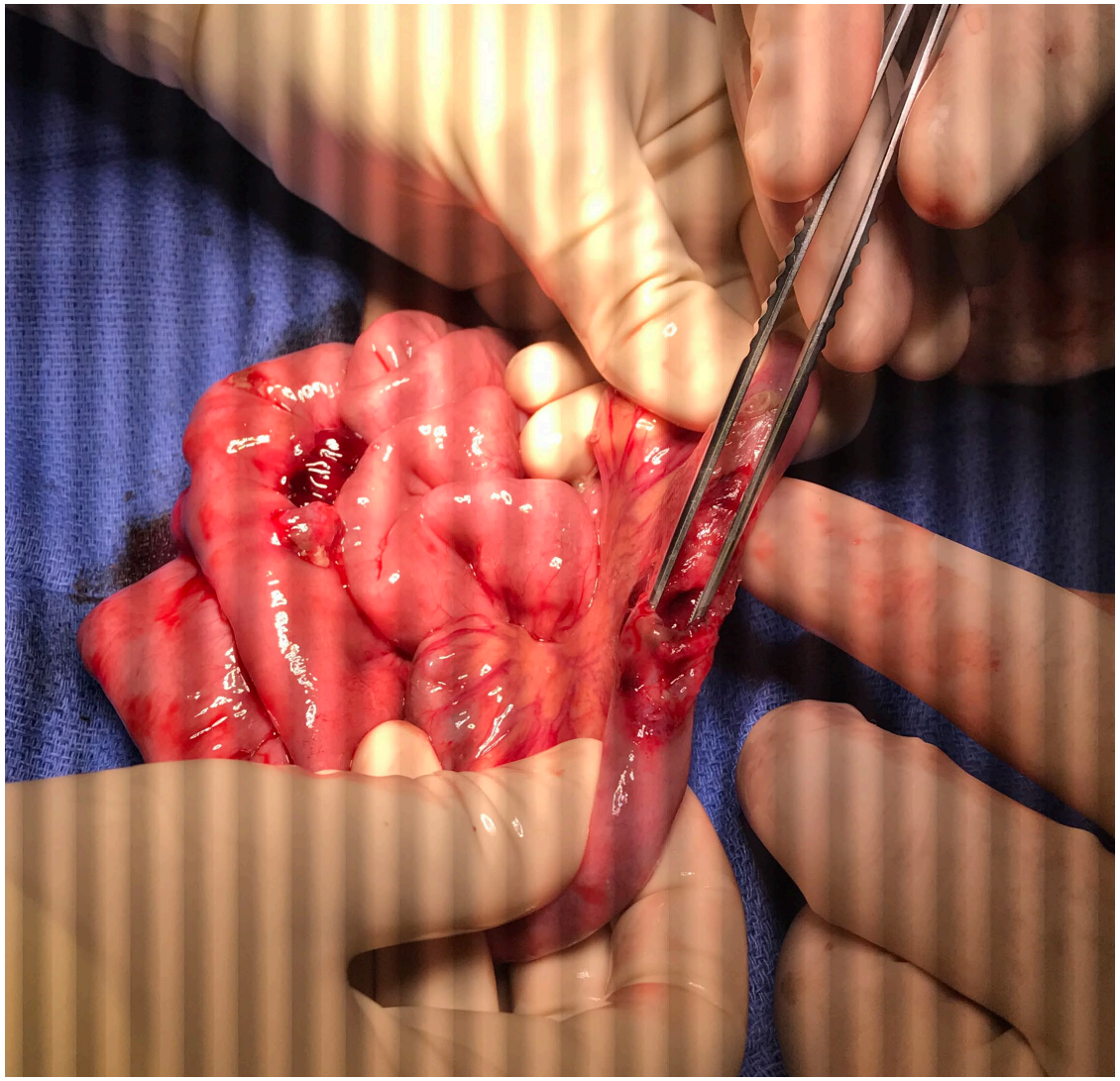
Seat belt sign

- 8 year-old male
- Intra-operative findings



Seat belt sign

- 8 year-old male
- Intra-operative findings
- Mesenteric bleed (~1L blood in abdomen)
  - Note: slightly tachycardic but no evidence of shock otherwise
- Multiple enterotomies → small bowel resection



Seat belt sign

4 year old, aortic transection

9 year old, chance fracture

Seat belt sign of the neck?

- Consider CTA to evaluate blunt cerebrovascular injury

- Limited data in pediatric trauma patients to guide imaging for blunt cerebrovascular injury

Screening **RECOMMENDED**

High energy transfer mechanism with *any* of the following:

- Cervical spine fracture*
- Skull base fracture
- LeFort II/III fracture
- Clothesline type injury or neck abrasion with significant swelling, pain, or altered mental status
- New onset anisocoria
- Neurological exam NOT explained by brain imaging
- Severe epistaxis

CONSIDER Screening

High energy transfer mechanism with *any* of the following:

- Clavicle fracture
- Other skull fracture
- GCS ≤ 8

* The following cervical spine injuries are considered high risk for blunt cerebrovascular injury:
    - Unilateral or bilateral facet subluxation (includes jumped, perched, fractured)
    - Antero/Retro Listhesis of vertebral bodies
    - Fracture of the transverse foramina (where the vertebral artery runs)
    - Any fracture of C2 or C3
    - Any injury concerning for distraction of the cervical spine
    - Any injury involving the occipital-cervical junction stability

Blunt cerebrovascular injury

Child abuse

- Liberalize CT scanning a bit
- If AST/ALT are elevated above 80, then there is good data to suggest it is worth scanning
  - injuries may present in a delayed fashion → lower threshold to scan
  - Need for documentation/understanding of injuries
- *Need a high index of suspicion*

The final word about trauma imaging in children

- A complex issue – competing interests
- ALARA principle (As Low As Reasonably Achievable)
- “Pan-scanning children should be condemned” – APSA Committee on Trauma
- BUT--if something just isn’t right, don’t be afraid to scan

  (except for the chest; don’t scan the chest)

THANK YOU

MUSC Health
Medical University of South Carolina

→

OREGON HEALTH & SCIENCE UNIVERSITY