Emergency Imaging in Vulnerable Populations: The Pediatric Patient

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RSNA 2014

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Health Science Center
at Houston

How are Children Vulnerable?

- Unable to communicate effectively
- Unable to understand instructions and cooperate
- Pathologies differ from adults
- Unexpected conditions or misleading histories
- Higher risk with radiation exposure

Objectives

- Recognize the special challenges and risks of emergency imaging in pediatric patients
- Understand how patient age determines optimal choices for imaging modality and technique
- Avoid pitfalls in interpretation of imaging studies in children with emergency conditions and injuries

www.uth.tmc.edu/radiology/presentations

Risk of Medical Radiation in Children

- Organ sensitivity, larger dose/body area, longer life span
- Use of radiation-based imaging studies
  - At least 1 study in 40% of children (during 3 yrs)
  - CT
    - 11% of all CT exams performed on children
  - Radiography
    - 85% of all exams (2% of total radiation dose)
    - Potentially increased with digital XR
  - Fluoroscopy
    - 2% of exams
    - Dose highly variable

Dorfman AL, Arch Pediatr Adol Med, 2011 May; 165(5):458-464

Potential risk of higher radiation exposures in children highly publicized

ARTICLE

ONLINE FIRST

The Use of Computed Tomography in Pediatrics and the Associated Radiation Exposure and Estimated Cancer Risk

Diana L. Miglioretti, PhD; Eric Johnson, MS; Andrew Williams, PhD; Robert T. Greenlee, PhD, MPH; Sheila Weinmann, PhD, MPH; Leif I. Solberg, MD; Heather Spencer Feigelson, PhD, MPH; Douglas Roblin, PhD; Michael J. Flynn, PhD; Nicholas Vanneman, MA; Rebecca Smith-Bindman, MD

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

RESEARCH

Cancer risk in 680 000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians

OPEN ACCESS

John D Mathews *epidemiologist*[1], Anna V Forsythe *research officer*[1], Zoe Brady *medical physicist*[1,2], Martin W Butler *data analyst*[3], Stacy K Goergen *radiologist*[4], Graham B Byrnes *statistician*[5], Graham G Giles *epidemiologist*[6], Anthony B Wallace *medical physicist*[7], Philip R Anderson *epidemiologist*[8,9], [redacted][10], Timothy M Cain *radiologist*[11], James G [redacted]*cientist*[1], Sarah C Darby *statistician*[10]

The British Journal of Radiology, 85 (2012), 53–60

Radiation exposure from CT in early childhood: a French large-scale multicentre study

[1]M-O BERNIER, MD, [2]J-L REHEL, BSc, [3,4]H J BRISSE, MD, PhD, [1]X WU-ZHOU, BSc, [1]S CAER-LORHO, BSc, [1]S JACOB, PhD, [4,5]J F CHATEIL, MD, PhD, [2]B AUBERT, PhD and [1]D LAURIER, PhD

Use of CT and Cancer Risk

- Use is beginning to moderate
  - Increased by 2 to 3 times from 1996-2005
  - Stable from 2005-2007
  - Decreased slightly from 2007-2010
- Studies with effective doses >20mSv (2001-11)
  - 14-25% of Abd/pelvis CT
  - 6-14% of spine CT
  - 3-8% of chest CT
- Risk of solid tumor – 1/300-390 Abd/pelv
- Reducing highest 25% of doses could prevent 43% of radiation-induced cancers

Miglioretti, JAMA Pediatr online; June 2013

Minimizing Radiation Exposure

- Strategies for keeping dose low in children
  - Minimizing the extent of exposure
    - Collimation
    - Positioning
    - Shielding
    - No grid for parts less than 10-12 cm in thickness
  - Using lower dose techniques
    - Raising tolerance for image noise
  - Consider using alternative imaging modalities

Advice for Decreasing Dose in Pediatric CT Goske et al, AJR (2008)

- "Child-size" your CT (kVp, mA)
  - Pediatric protocols on IG website (www.imagegently.org)
  - Lower dose protocols for certain body regions
    - Chest
    - Skeleton
    - Paranasal sinuses
  - Indications
    - Renal stones
    - Shunt malfunction
- Lowering dose
  - Low dose localizer, decreased tube current or voltage, increased pitch, scan length, iterative reconstruction

Singh, J Am Coll Radiol. 2012 Jan;9(1):77-9.

Pediatr Radiol
DOI 10.1007/s00247-014-3088-8

IMAGE GENTLY ALARA CT SUMMIT: HOW TO USE NEW CT TECHNOLOGIES FOR CHILDREN

Developing patient-specific dose protocols for a CT scanner and exam using diagnostic reference levels

Keith J. Strauss

- Many resources to help child-size your pediatric protocols

Pediatr Radiol (2010) 40:1324–1344
DOI 10.1007/s00247-010-1714-7

REVIEW

Multidetector CT in children: current concepts and dose reduction strategies

Rutger A. J. Nievelstein · Ingrid M. van Dam · Aart J. van der Molen

Annals of the ICRP

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-L. Khong, H. Ringertz, V. Donoghue, D. Frush, M. Rehani, K. Appelgate, R. Sanchez

Advice for Decreasing Dose in Pediatric CT

- Scan only when necessary
  - Must develop better definitions of “necessary”
  - PECARN Head CT decision rule (children< 2 yrs)
    - Normal mental status
    - No scalp hematoma (except frontal)
    - No LOC > 5 secs
    - Non-severe injury mechanism
    - No palpable skull fracture
    - Acting normally according to parents
  - NPV=100%, sensitivity 100%

Kupperman, Lancet 2009; 374: 1160–70

CT for Pediatric Chest Trauma

- CT will identify more pathology than CXR
  - Contusion/consolidation – 77% vs. 42%
  - Pneumothorax – 33% vs. 7%
  - Rib fracture – 21% vs. 4%
  - Mediastinum (nonvascular) – 10% vs. 2%
- Conditions requiring intervention are virtually all visible on based on CXR
  - Occult pneumothoraces on CXR rarely need tube therapy

    Holscher et al, J of Surg Research 184(2013): 352-357

    Lee et al, Acad Emerg Med (2014) 21:440-448
- CT indicated with high risk mechanism,abnormal CXR
- CT not necessary when CXR is normal

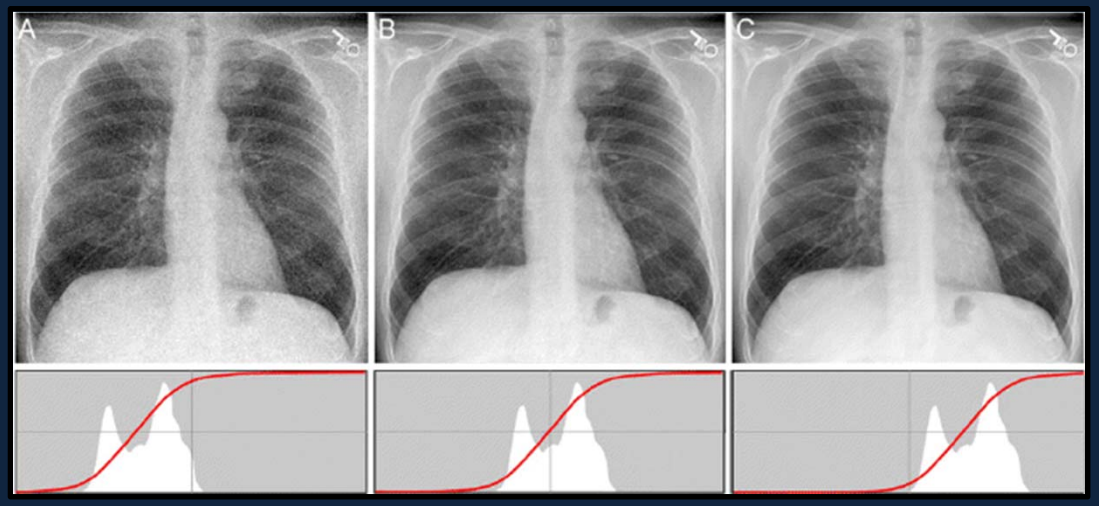
Advice for Decreasing Dose in Pediatric CT

- Scan only the indicated region
  - Requires point of care protocoling
- Scan only once
  - Delayed imaging for trauma scans should be restricted to those cases with high risk injuries on initial pass images

Dose Reduction in Digital Radiography

- Why worry about radiography?
  - 85% of ionizing radiation exams in children
  - Avg. child will have 7 XR exams by age 18
- Digital radiography can lead to increasing radiation dose
  - Caused by lack of direct visual feedback

Digital imaging (CR/DR): Equipment compensates for overexposure; film appears to be properly exposed



A. Underexposure
B. Optimal
C. Overexposure

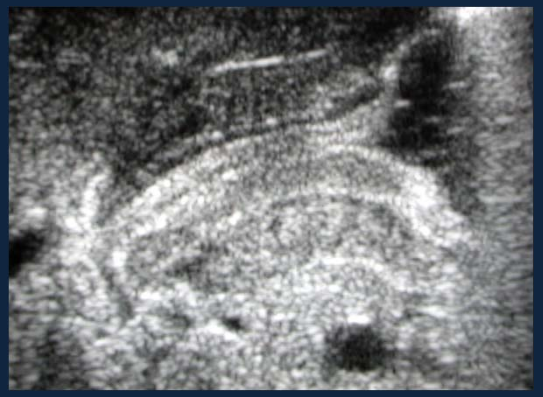
Seibert, Pediatr Radiol 41(5): 573-581.

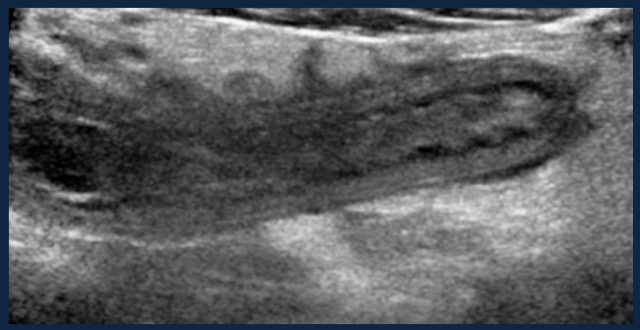
Exposure Creep in DR

- Emergency Care Research Institute 2015 list of top healthcare hazards
  - Exposure creep in digital radiography #7
    - Loss of immediate feedback about overexposure
    - Excessive exposure reduces noise, image looks better
    - Technologists will err on side of overexposure
    - Can lead to progressively increased exposures
  - Attention to exposure indices, better defined pediatric techniques are needed

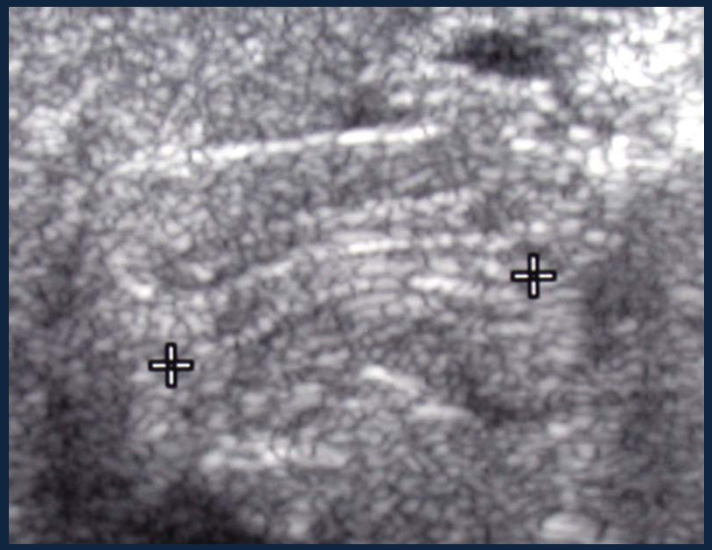
Alternative Imaging Modalities

- Ultrasound an effective screening study for many clinical problems
  - Hypertrophic pyloric stenosis
  - Intussusception
  - Appendicitis



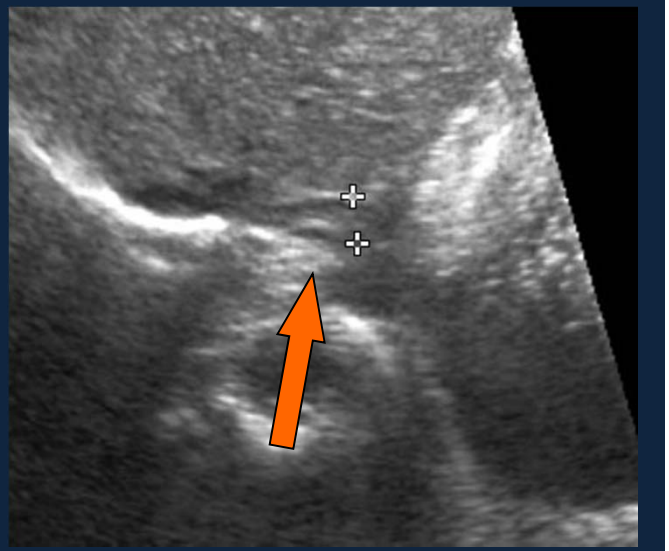


Experience Counts in Ultrasound



False positive - stomach was not distended with fluid

False negative –
GE junction mistaken for pylorus



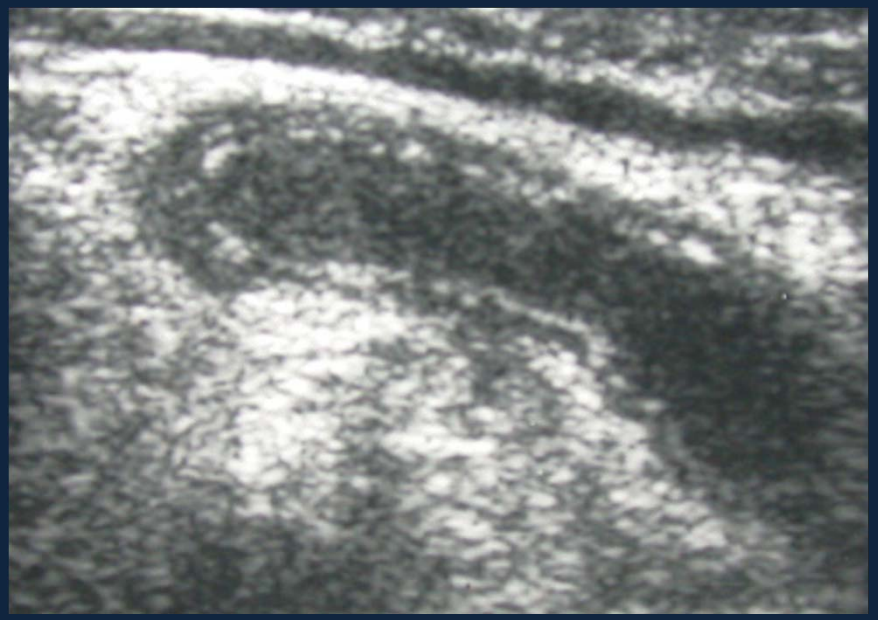
Appendicitis

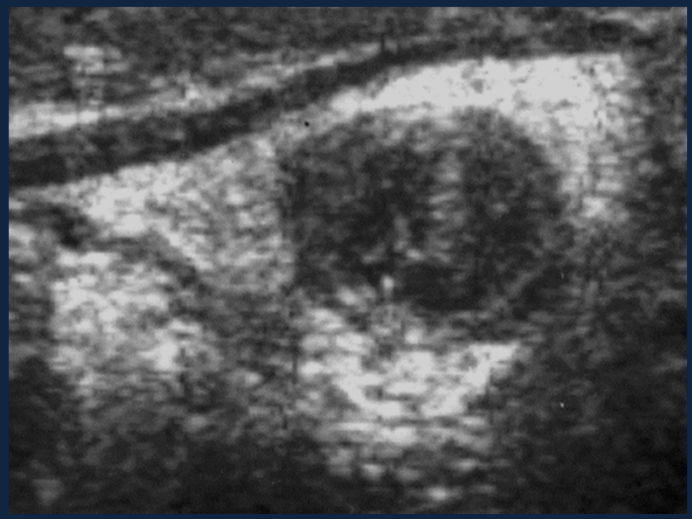
- Presenting symptoms in children differ from adults:
  - No migration of pain in >50% of children
  - No anorexia in > 50% of children
  - No rebound tenderness in > 50% of children
  - Time course of pain commonly less than 24 hours
  - Diarrhea is not uncommon
  - Pain often poorly localized

US for Appendicitis

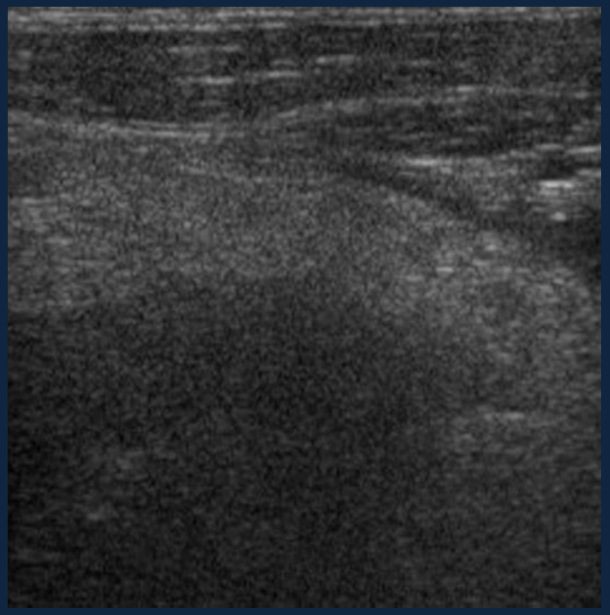
- Still accepted as best first screening exam
- Staged approach using CT for equivocal cases highly accurate
  - Sensitivity 98.6%
  - Specificity 90.6%
  - CT avoided in 53%

Krishnamoorthi, Radiol Jan. 2011

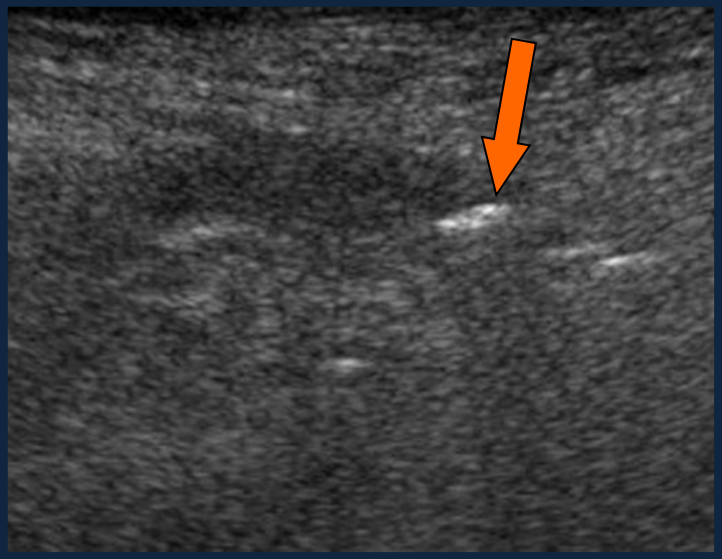


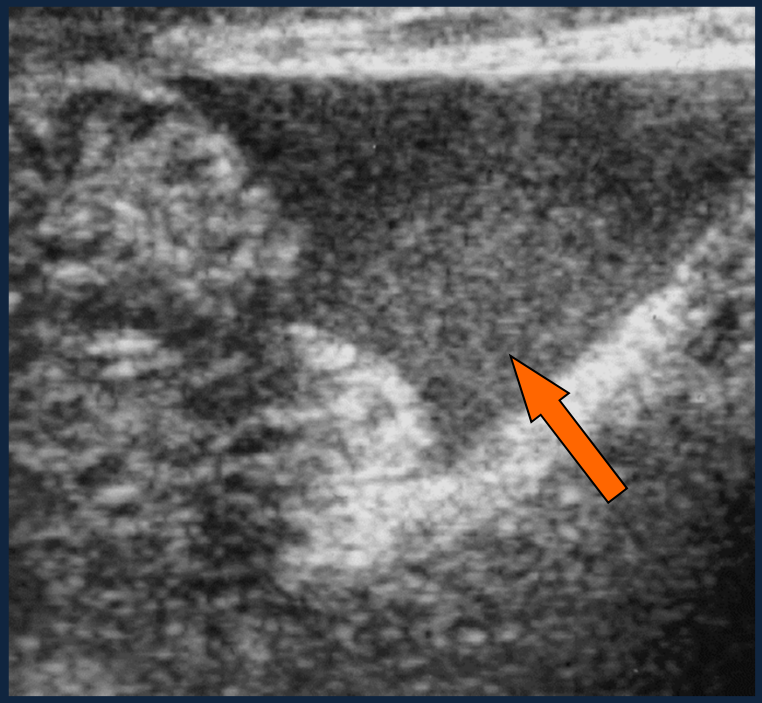


Secondary findings can be important clues when the appendix is not visible on US



Absent peristalsis in RLQ = adynamic ileus



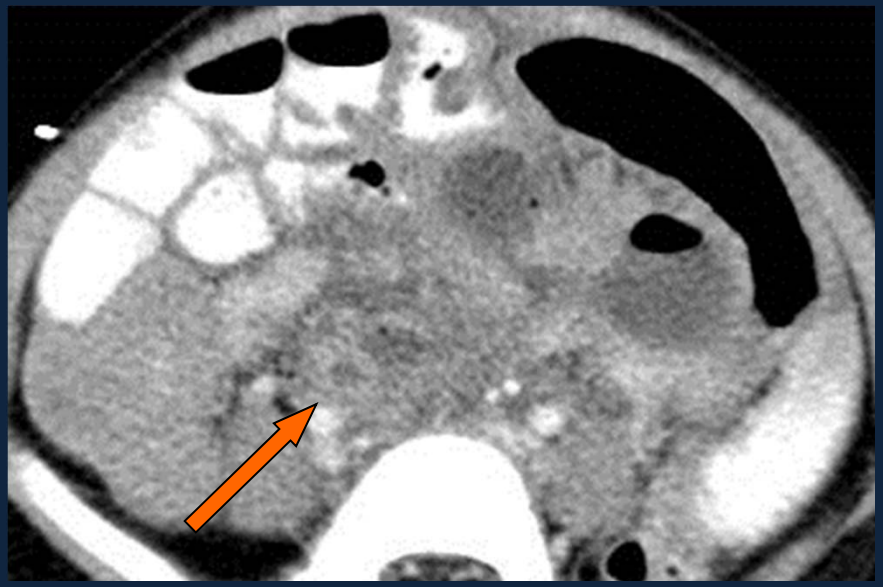


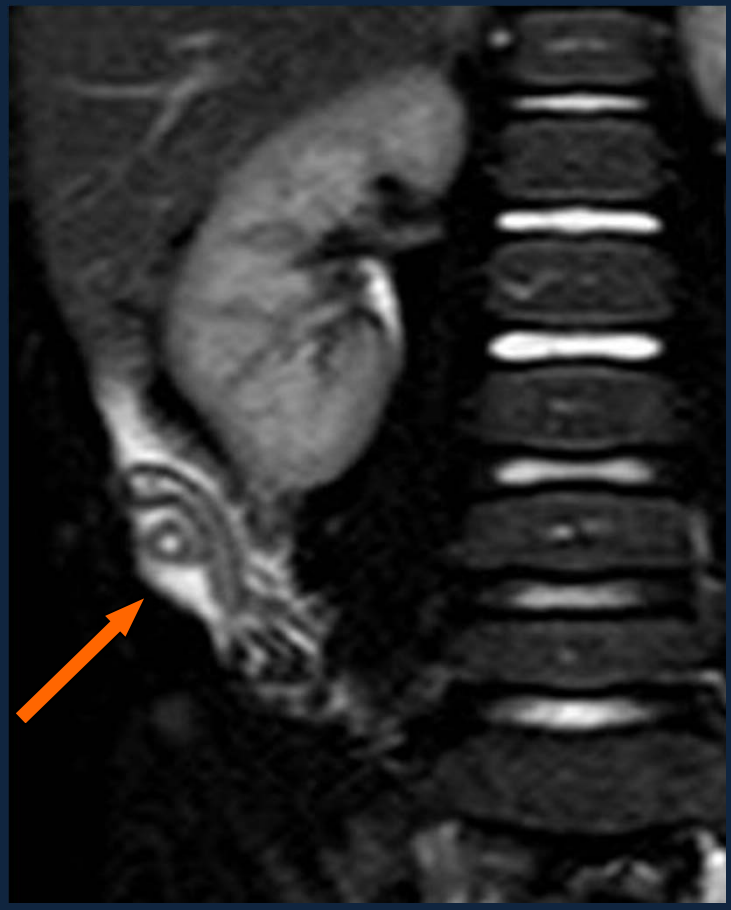
Complex free fluid = peritonitis

Thickened Echogenic Fat = Inflammation

CT very good but not ideal in young children

- Lack of intra-abdominal fat



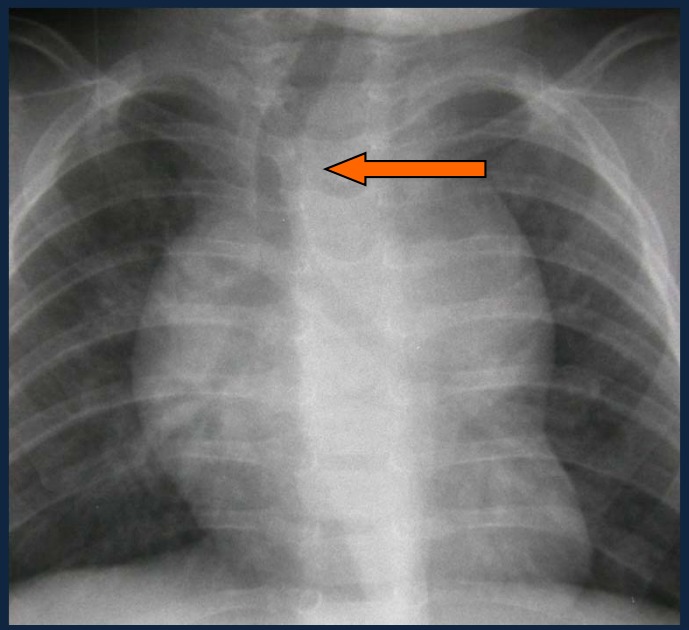


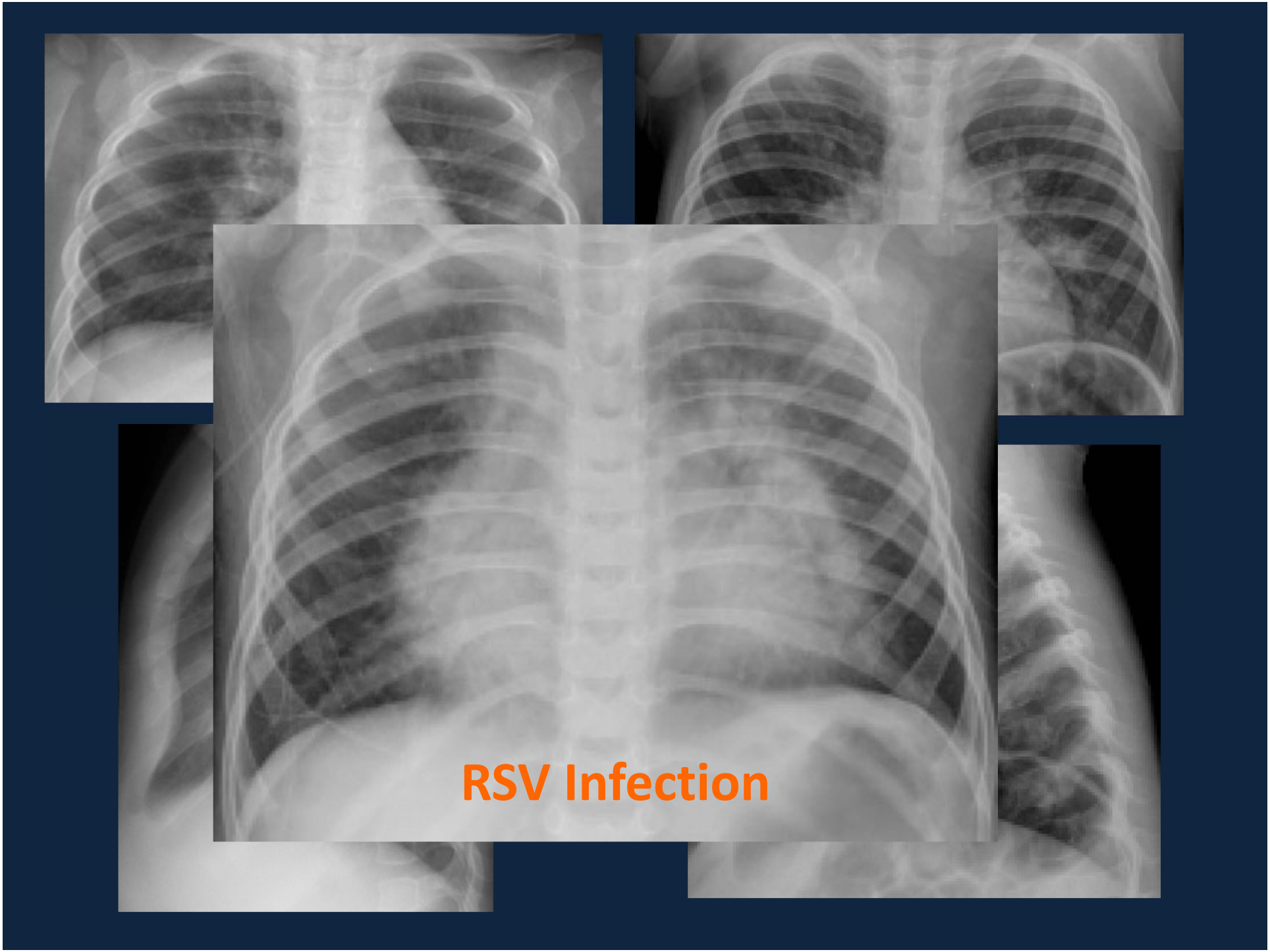
Johnson, AJR, Jun 2012; 198:1424
Moore, Pediatr Radiol, Mar 2012; 42:1056
Herliczek, AJR, May 2013; 200: 969
Orth, Radiology, July 2014; 272:233.

Ultrafast MRI as good or better for some children

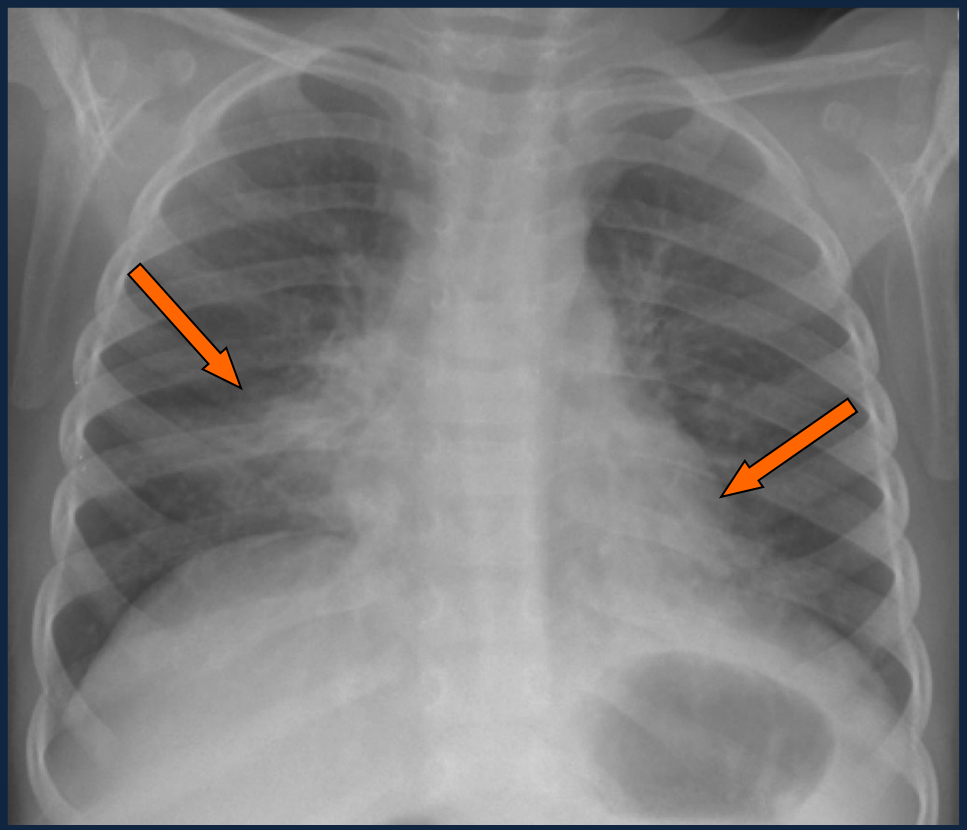
Differences in Pathology from Adults

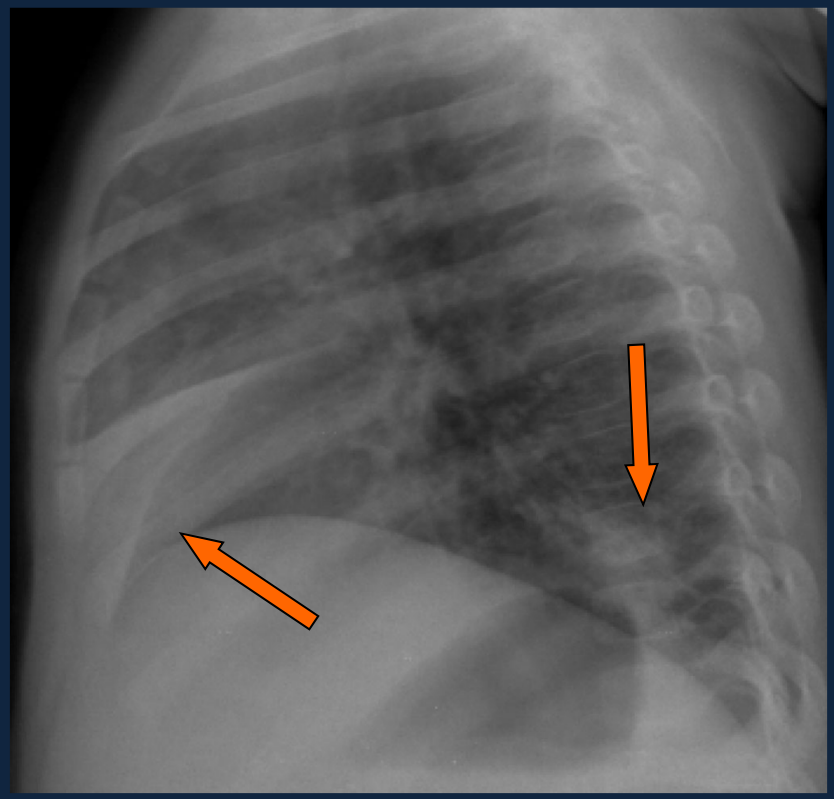
- Infection, trauma, congenital/developmental abnormalities common
  - Neoplasms, vascular disease, chronic conditions uncommon
- Anatomical differences mimic pathology

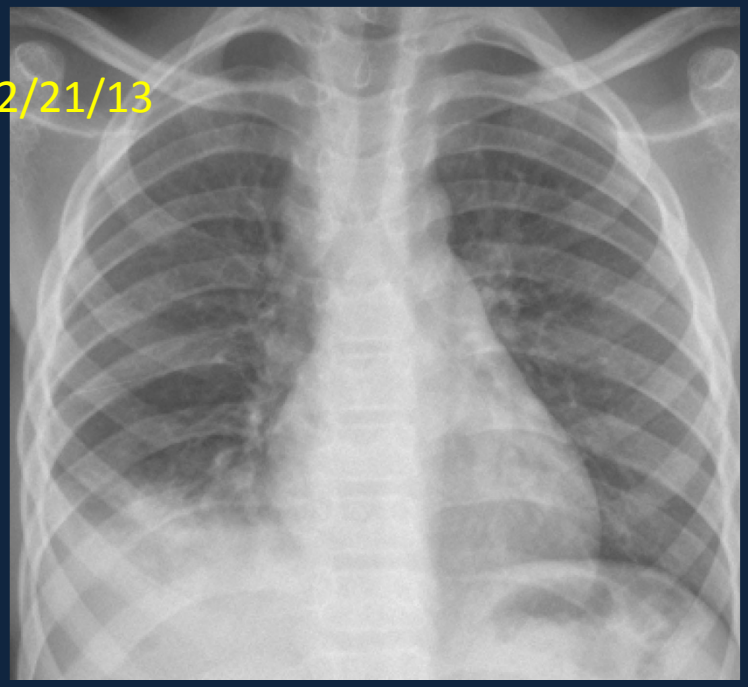



RSV Infection

Viral Infection with Atelectasis



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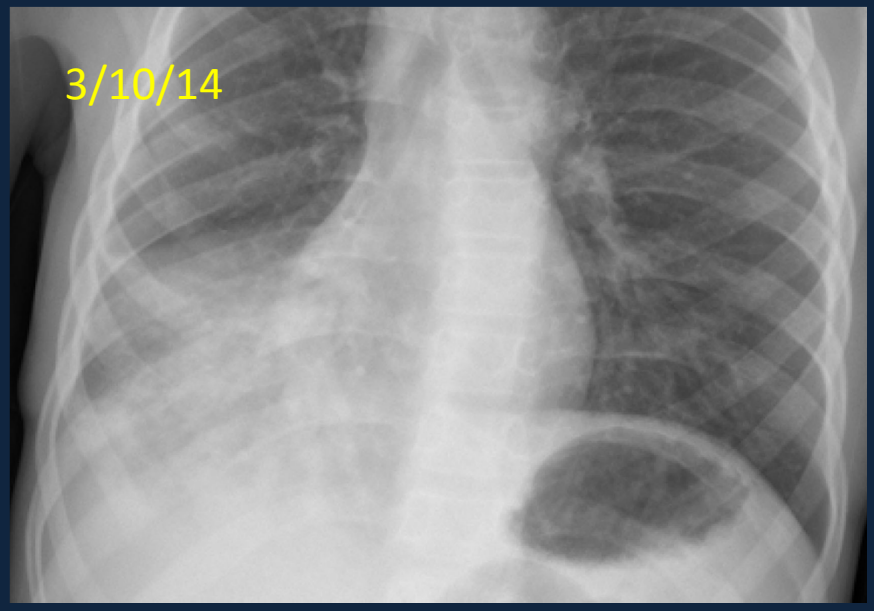
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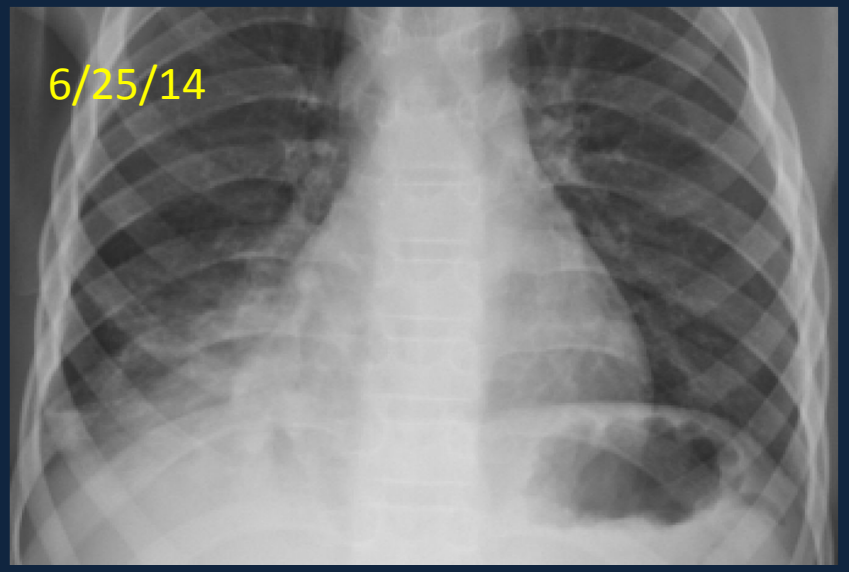
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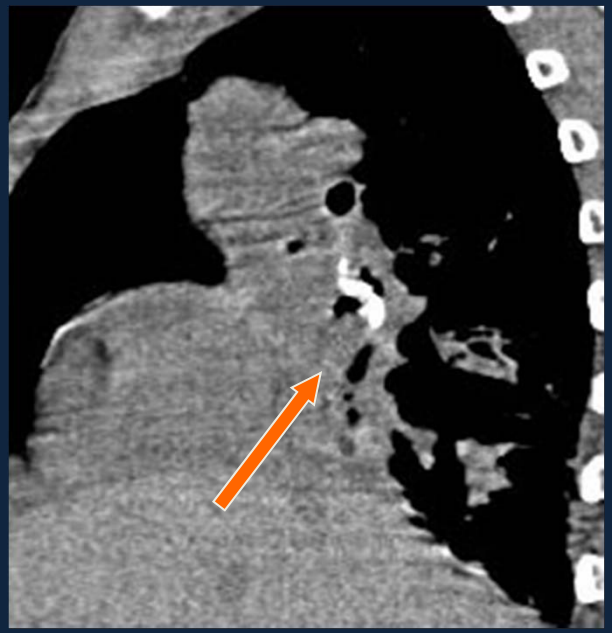

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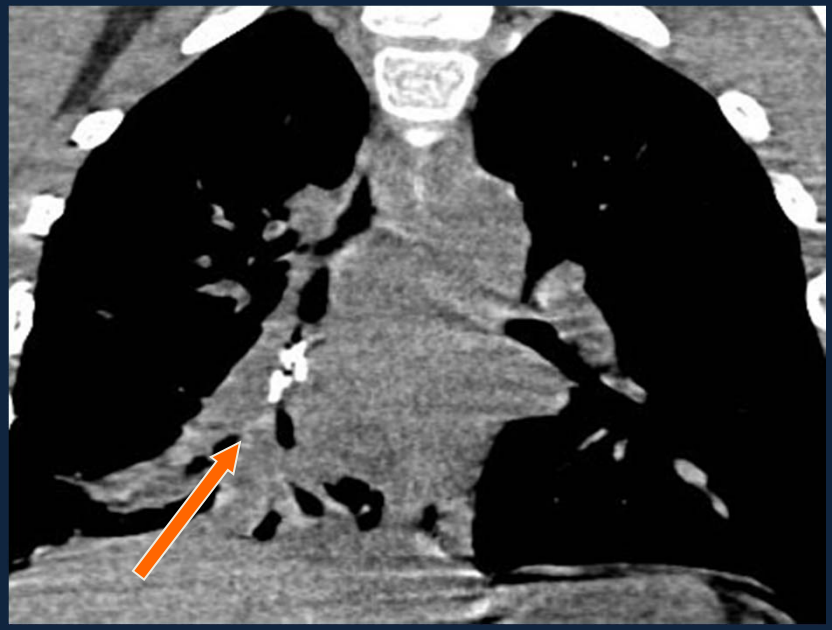


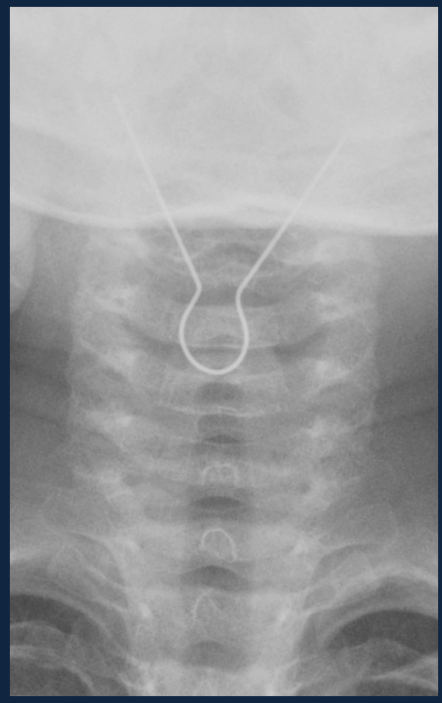
11/6/14

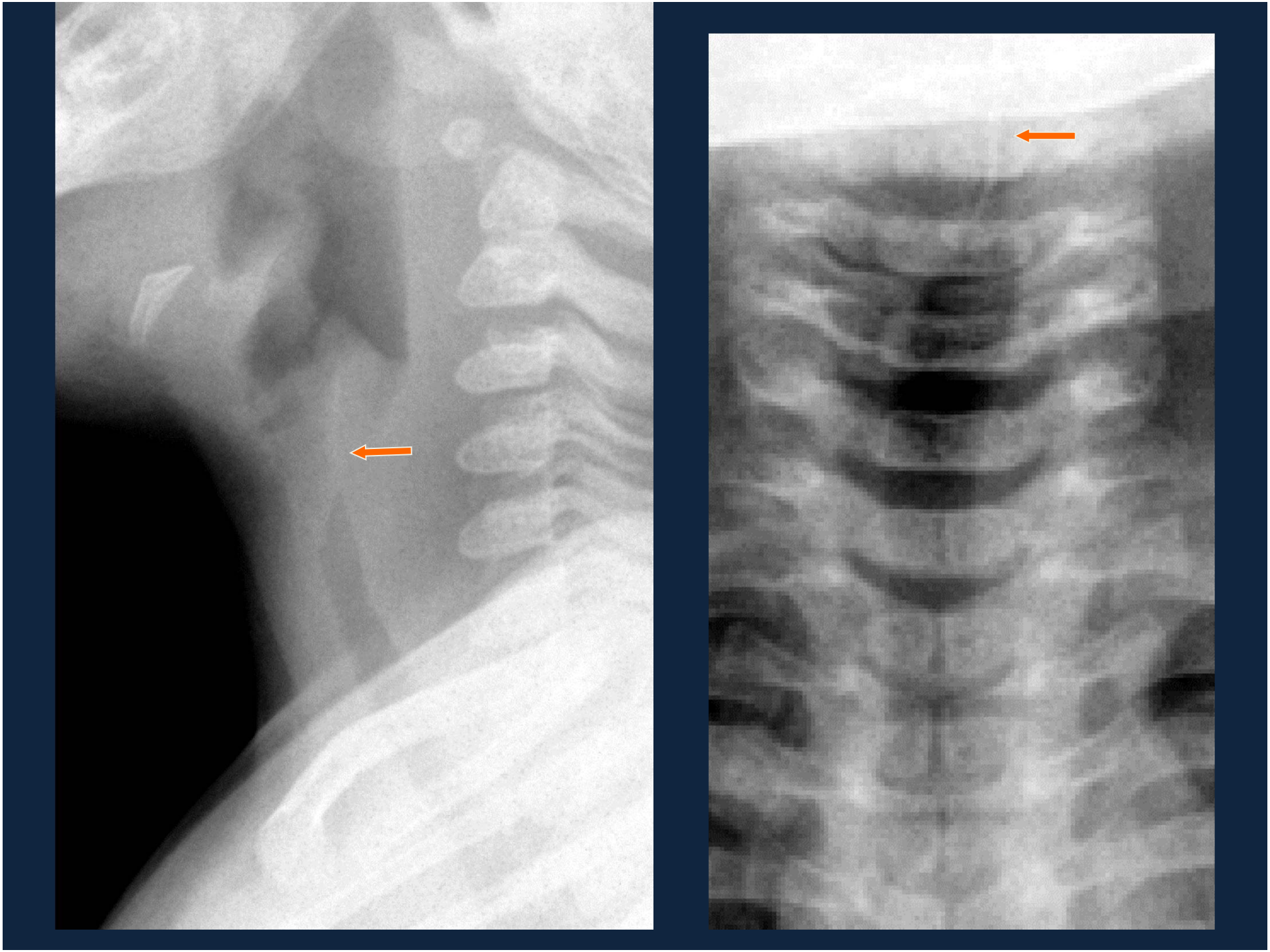
Unexpected Conditions

- Common in young children with poor ability to communicate problems

Foreign Object Ingestion/Aspiration

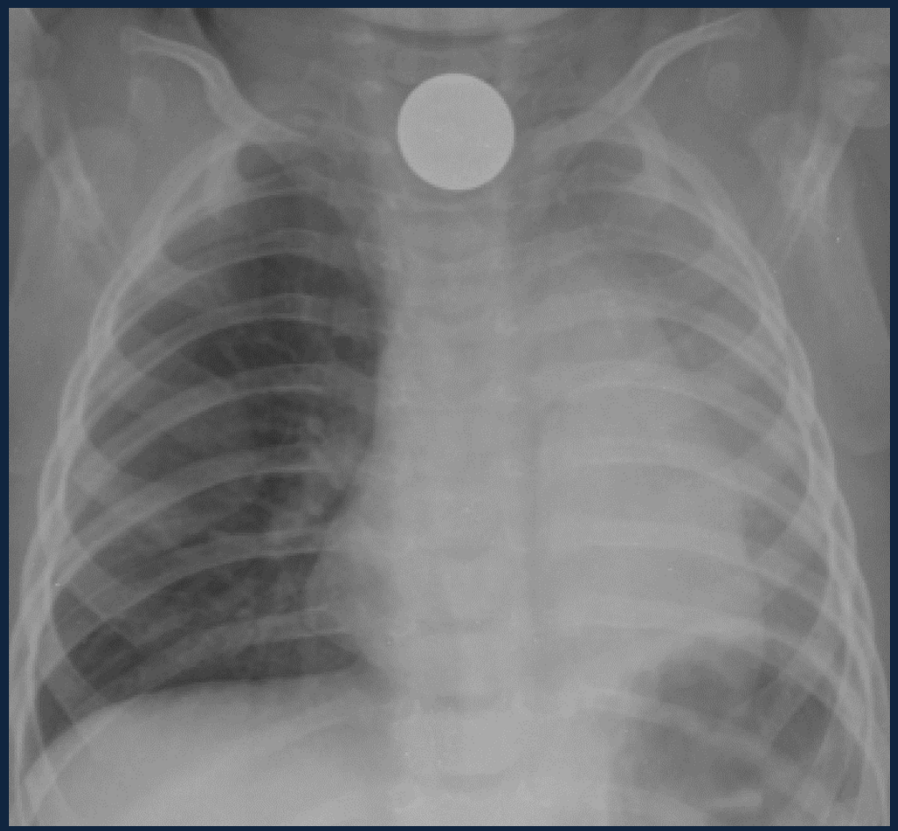
- Often unwitnessed
- Non-specific presenting symptoms
  - Cough
  - Wheezing





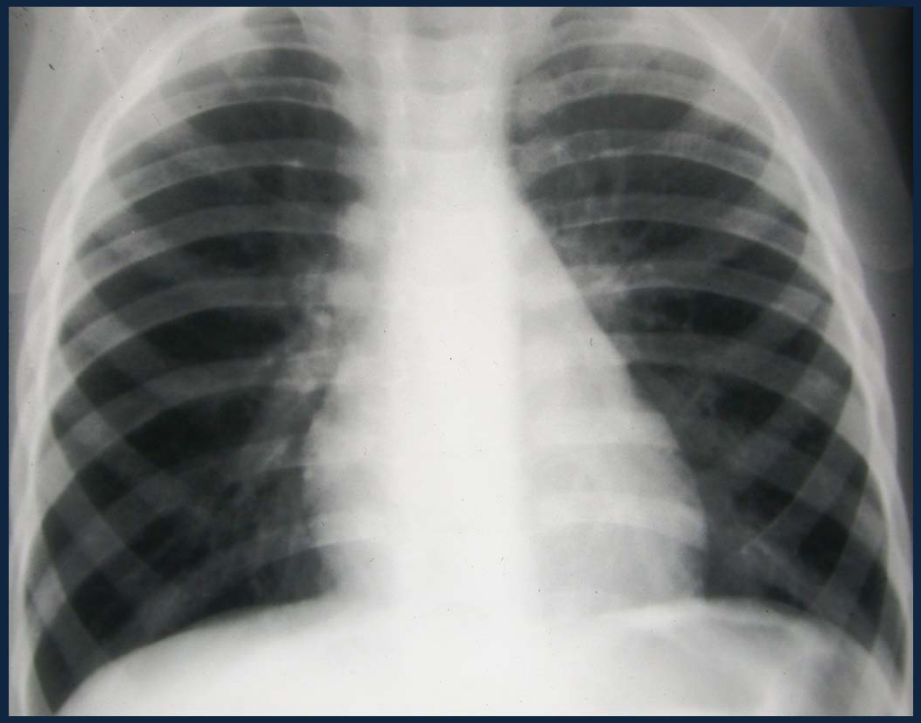
Peanut in L bronchus

Esophageal foreign bodies don’t cause major airway obstruction

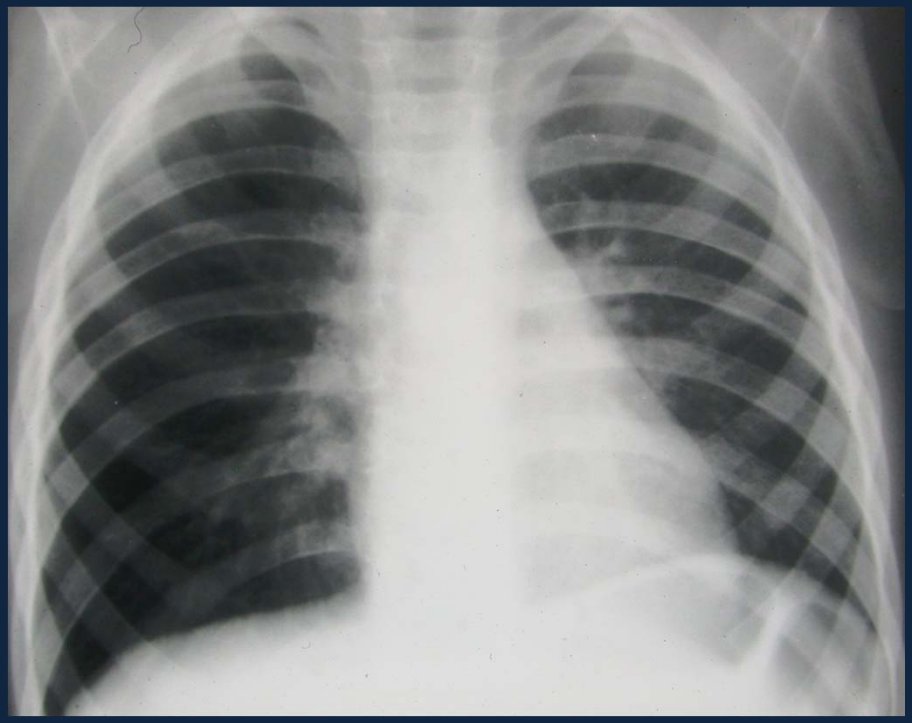


Expiratory radiographs can show air-trapping that is subtle on inspiratory views

- Worthwhile whenever the history suggests aspiration



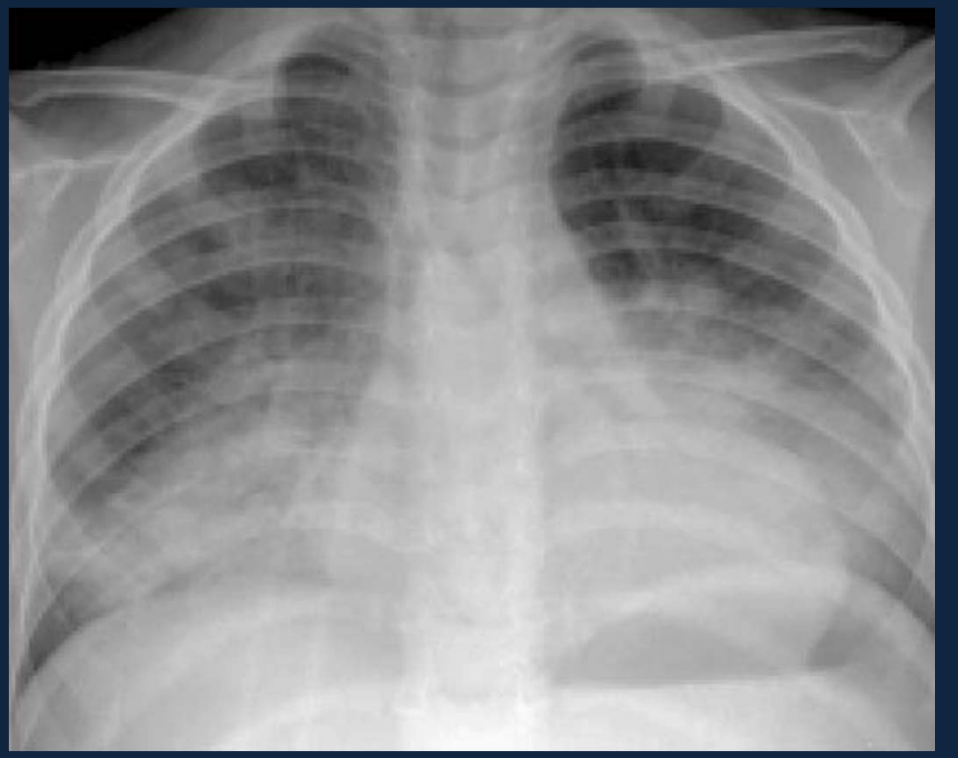
Inspiration



Expiration

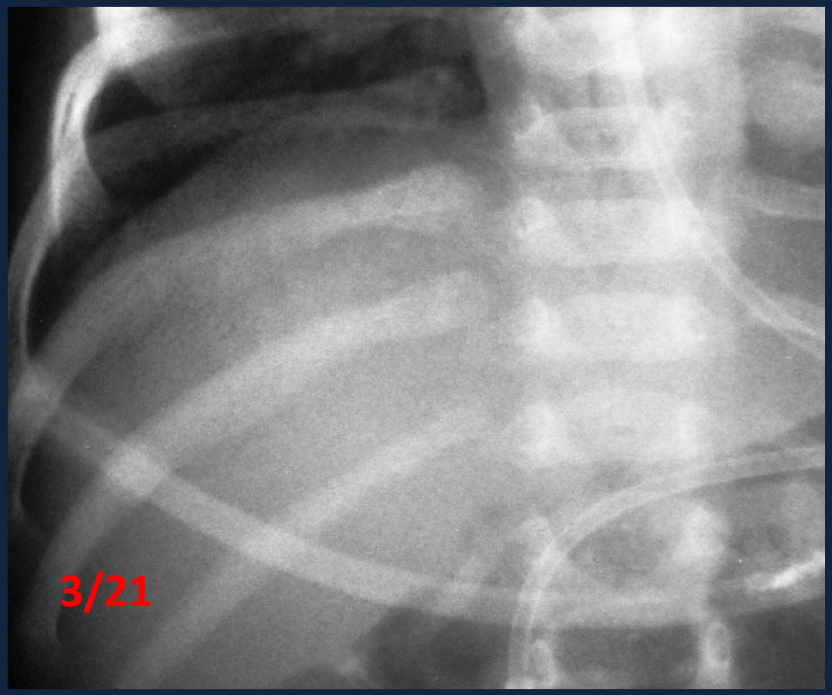
Aspiration Pneumonitis with Toxin Ingestion

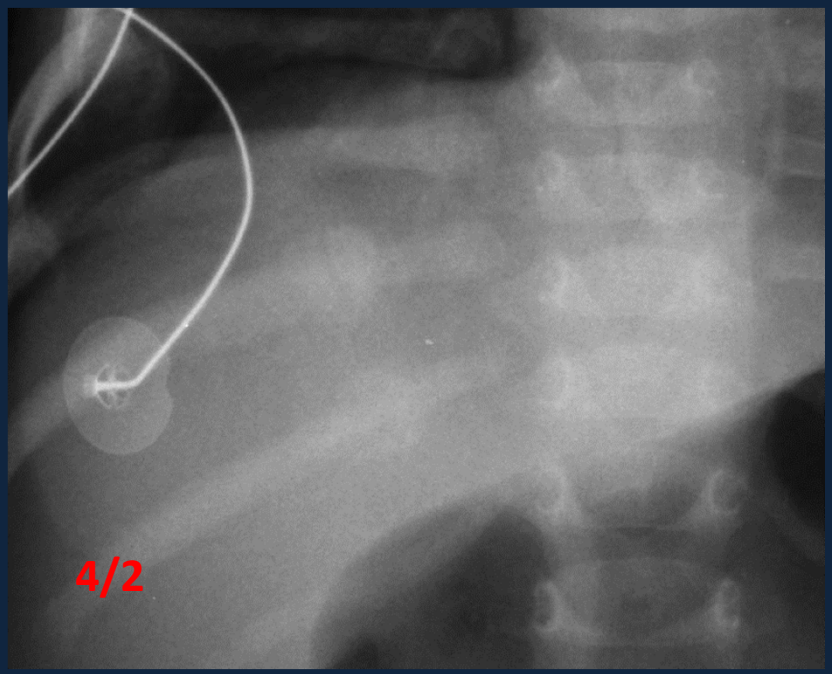
- Hydrocarbon ingestion
  - Lamp oil
  - Lighter fluid
  - Ingestion often witnessed
- Lipoid pneumonia
  - Mineral oil for constipation
  - Suppresses cough reflex
  - Aspiratin may not be suspected

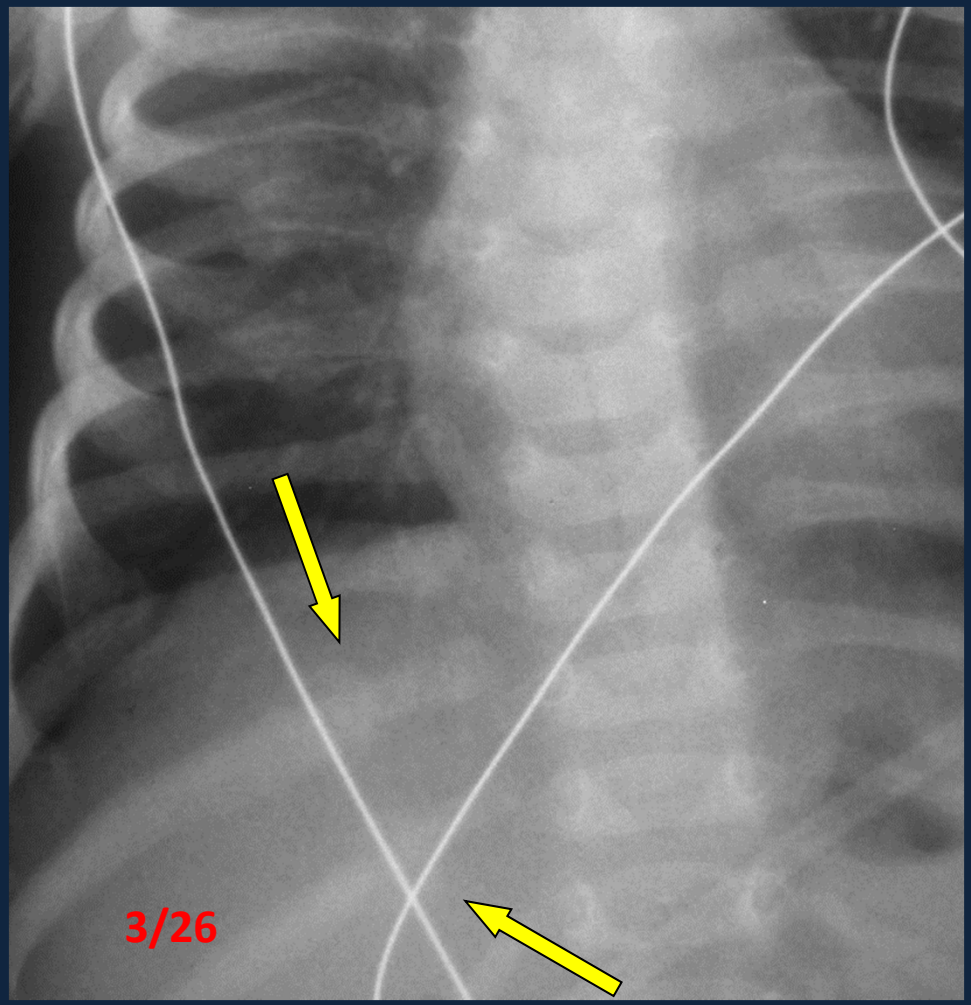


Non-accidental Trauma

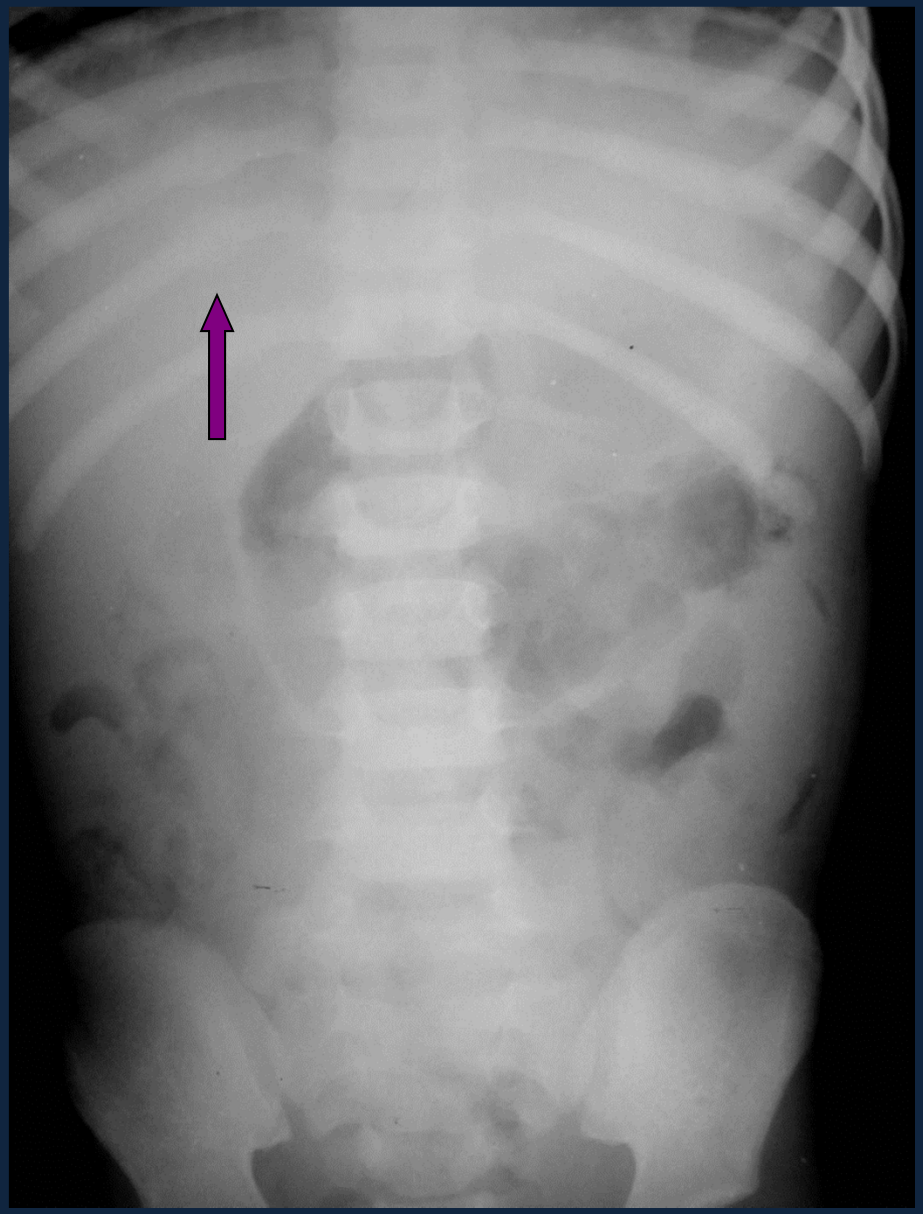
- Histories usually obscure or absent
- Injuries often subtle in young children
- False negatives and false positives common on skeletal imaging
  - Occult rib fractures in acute stage
  - Normal variants that resemble fractures
  - Uncertainty about timing/ mechanism of detected fractures

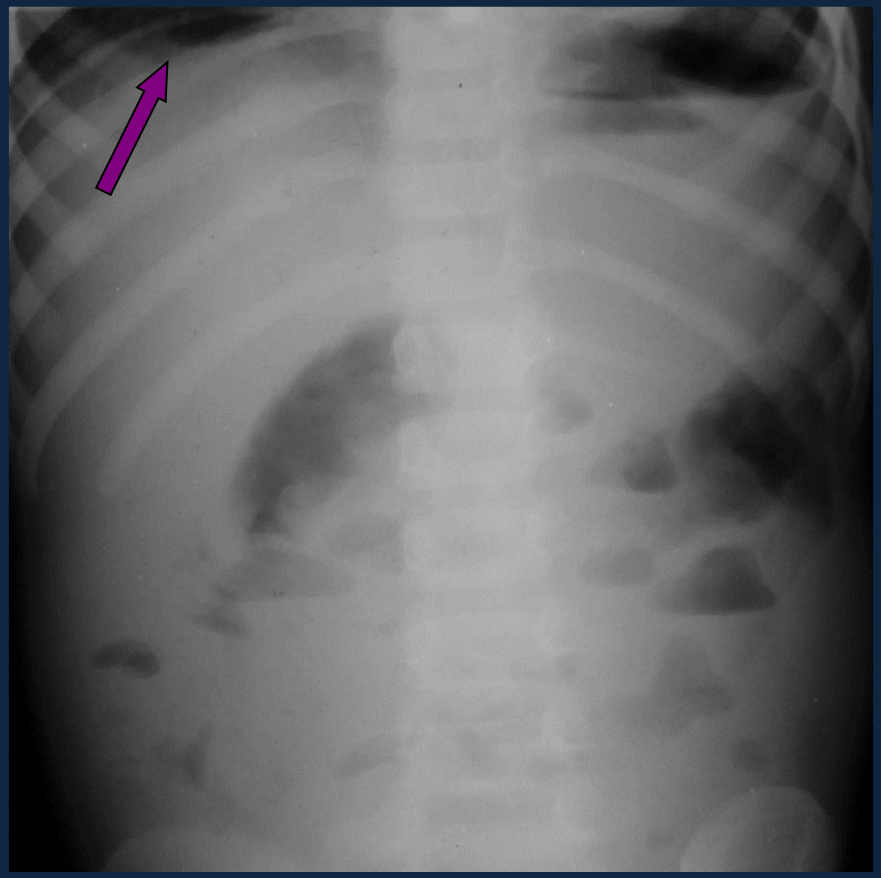






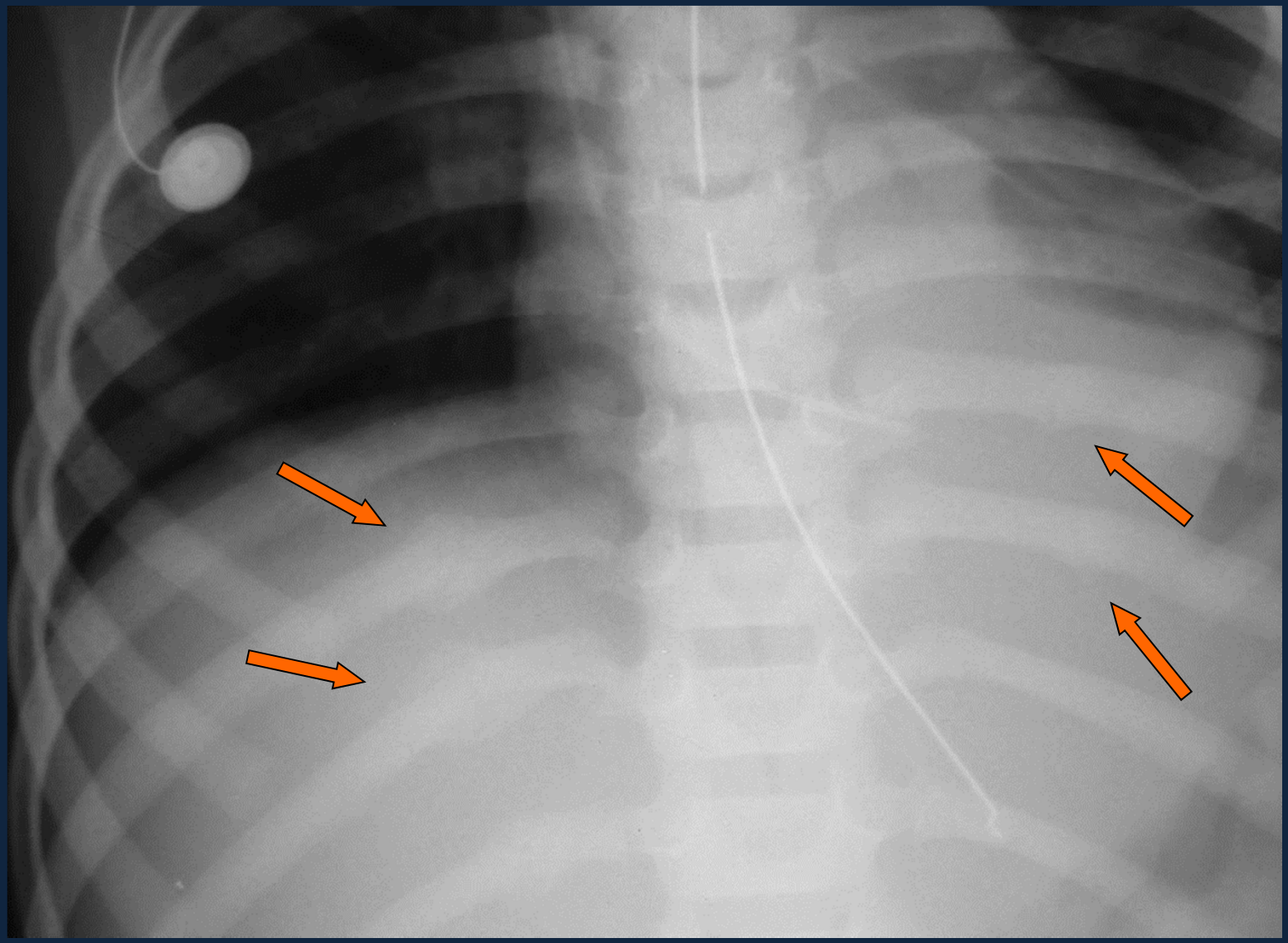
Acute rib fractures may not be visible until healing





8 month old with vomiting and distended abdomen

Perforated jejunum in a battered child



Abdominal Trauma in the Battered Child

- 4 -15% of abdominal trauma in children in U.S. is inflicted.
  - >25% of AT in infants is abusive
- > 50% of these children are in critical condition when they present
  - Delay in bringing for care
  - Mortality rate – 13-45%
- Recognition of the injuries is often delayed in the ED

Differentiating Accidental from Non-Accidental

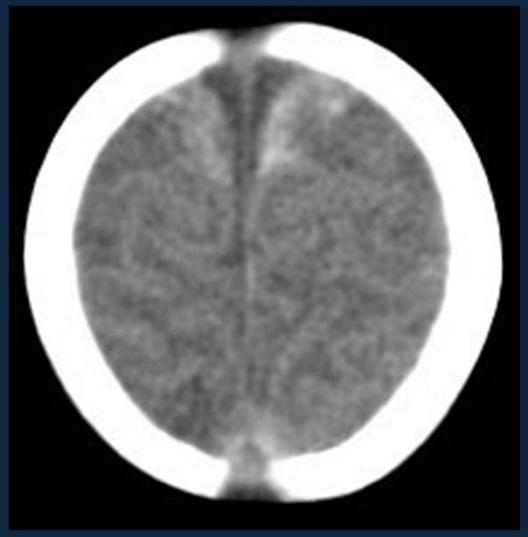
- Keep a high index of suspicion, but keep common accidental injuries in perspective

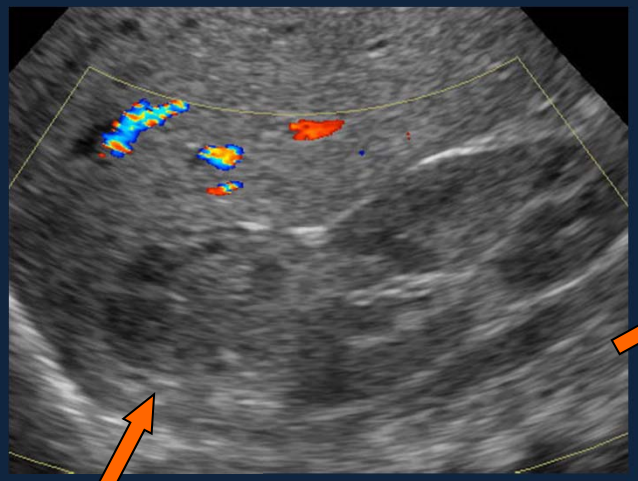
11 day old infant

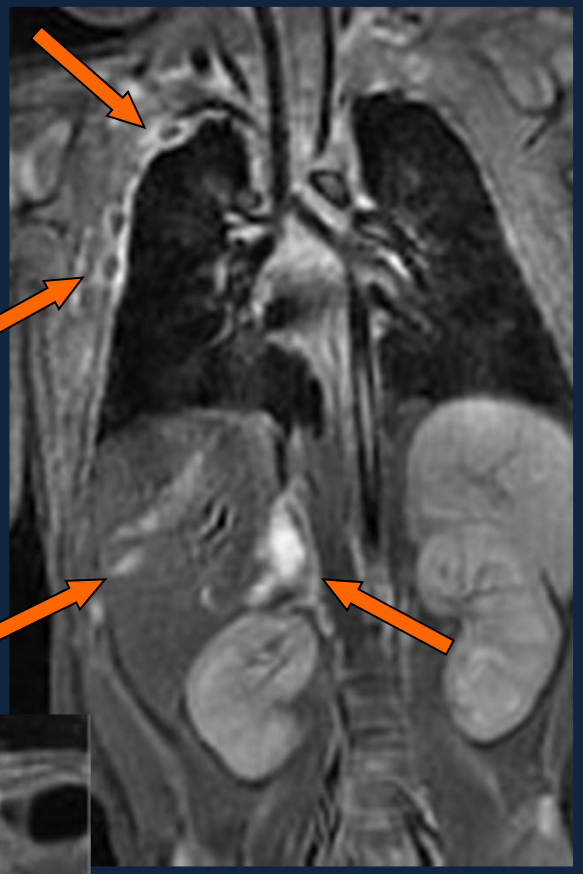
Traumatic vs Non-traumatic Intracranial Hemorrhage

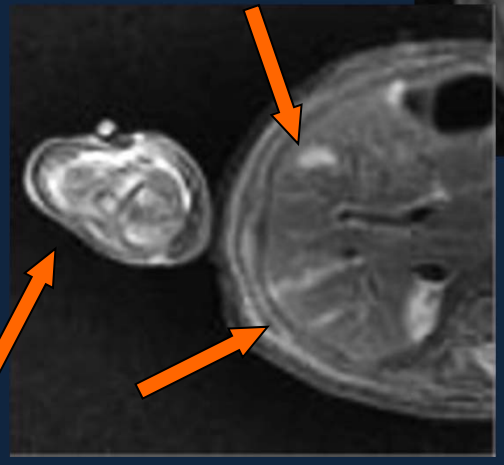
- Unexplained intracranial hemorrhages raise suspicion of NAT, but causes for non-traumatic brain hemorrhage exist:
  - Sinus thrombosis
  - Infection
  - Metabolic/clotting disorders
  - Stroke
- Evidence of trauma elsewhere in the patient tilts the scales toward NAT
- MRI may be helpful in some cases

5 month old found non-responsive in crib









Points to Remember

- Use alternatives to CT, whenever sensible
  - US is great for many conditions, but is best when used by those experienced with pediatrics
  - MRI applications are growing in younger patients
- Keep CT doses low with child-sized protocols, single passes, arms over head
- Use patient age to help prioritize possible diagnoses, plan imaging
- Remember that histories can be misleading