Pediatric Head Trauma Imaging Do’s & Don’ts

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NO DISCLOSURES
Objectives

• Understand mechanisms of head injury: ACCIDENTAL VS NON-ACCIDENTAL
• Ordering appropriate imaging
• CT vs Radiography for trauma
• Image gently: radiation and imaging
• How to report child abuse (see appendix)
Case Based

ACCIDENTAL HEAD TRAUMA
Where is the fracture?

9-m, fell from couch onto floor
Accidental trauma

• Children more likely to have skull fx
  – Larger craniofacial ratio & thinner calvarium
  – Child <2-y: 10% higher threshold for fx than older pt

• Axonal injury more common younger pt (<2yrs)
  – Immature WM, cortical WM begins to myelinate around 4 months
  – Shear injury and subtle edema can be obscured on CT
  – Follow up MRI

J Am Coll Radiol 2014;11:939-947 ACR Appropriateness Criteria Head Trauma-Child
Imaging Pediatric Minor trauma

• 3-5% kids w/minor head trauma have abn imaging
  – 4% incidental findings w/blunt head trauma (Rogers)
• <1% require neurosurgical intervention
• Role of skull radiographs is uncertain
  – 21% of fractures detectable by CT may be missed
  – CT can replace radiographs in many instances
• Emesis is not reliable indicator when no other sx

-J Am Coll Radiol 2014;11:939-947 ACR Appropriateness Criteria Head Trauma-Child
-Rogers, et al. PEDIATRICS Volume 132, Number 2, August 2013
When to Image?

- Imaging not routine in minor trauma
  - normal post event mental status. No neuro signs or sx.
- Imaging when clinical exam is indeterminate
  - Clinical eval can be difficult in children, preverbal.
- PECARN (pediatric emergency care applied research network) prediction rule
  - predicts need for imaging
  - largest Prospective cohort study 42,412 <18yrs
  - out performed CHALICE & CATCH on validation studies
  - High sensitivity
    - 100% <2yrs & 98% >2yrs

*Lancet* 2009; 374: 1160–70
*Arch Dis Child* 2014;99:427–431
CT

- Excellent initial imaging test for suspected intracranial trauma
- Hemorrhage, midline shift, herniation
- 3D recons allow detection of fx missed on XRAY
- Contrast may obscure punctate hemorrhages
- Mild edema may be subtle
- Fast quick imaging
  - New flash imaging avoids sedation
  - Less motion artifact, avoids rescan
  -Decreases radiation dose
CT: WHAT ABOUT THE RADIATION?
1. The CT scan is immensely valuable and has been recognized as one of the most significant innovations of modern medicine (1). CT examinations can be lifesaving, and provide many benefits for the diagnosis and management of childhood disorders (2).

2. The benefits of a CT examination, when indicated and performed appropriately, far outweigh the risks or potential risks. For example, brain CT is commonly performed in the setting of head injury and multiple studies using clinical decision rules have concluded that the benefit for detection of brain injury occurs in at least 2% of children. This is more than 200 times greater than the proposed increased risk of a brain tumor cited in the Lancet article (3).
3 hour airline flight is 1.5 days of background radiation

**SOURCES OF RADIATION IN US (2009)**

- MEDICAL: 48%
- INTERNAL: 5%
- RADON GAS: 37%
- INDUSTRY: 2%
- COSMIC: 5%
- SOIL: 3%

**3 mSv/yr BACKGROUND RADIATION FROM NATURAL SOURCES**

**3 mSv/yr MAN-MADE SOURCES**

Source: NCRP 2009 report 160
Estimated radiation doses (mSv) to 5yr old child

- ANKLE XR: 0.0015
- A/P LAT ABD XR: 0.05
- BONE SCAN: 6.2
- ABD/PELVIS CT: 5
- CHEST CT: 3
- HEAD CT: 4
- CXR: 0.02
- NATURAL BKGD: 3

Pediatrics 2007;120;677
ALARA & IMAGE GENTLY
Basic Principles

• Growing child 2-5x more sensitive to radiation
• longer latency period than adults
• ALARA = As Low As Reasonably Achievable
  – Optimization of protocols, scan techniques, and pt prep to control exposure in children to ionizing radiation
• Dose reduction strategies in CT
  – combination of technique and new technology
Calculated effective dose:
0.4 mSv

Calculated effective dose:
0.5 mSv

- Natural background radiation dose: 3 mSv/yr
- MCH facial bones CT w/out contrast range: 0.3-0.5 mSv
- LOW DOSE CT TECHNIQUE
FACIAL BONE TRAUMA
Facial Bone Fractures

• Interpretation pedi facial XR is challenging
  – Particularly midfacial and condylar fractures

• **CT is best modality**

• Facial fx lowest infants and inc with age

• Usually associated severe trauma-MVA & sports

• Nasal bone fx most common followed by mandibular fx

Mildly displaced fracture only apparent on CT:

Negative Nasal Bone series, however clinically obvious deformity
Orbital roof fracture:
ER 4yr old jumping on bed & fell
Low Dose Bone Protocol & 3D
Facial Bone Fracture:
14-y assaulted with bat, +LOC

NEGATIVE XR

NASAL BONE FX TOO!
Mandibular FX: GET A CT!
Radiation similar to facial bones XR!!!

XRAY NEGATIVE

panorex neg
Low subcondylar fx

Comminuted fx condyle & ant wall external auditory canal

Mandibular fx 2nd most common fascial fx
Panorex vs CT

**Panorex**
- requires special equipment
- Patient cooperation needed
- Technologist dependent
- Imaging performed upright
- Condyles may be obscured

**CT**
- readily available
- Flash avoids motion artifact
- Curved & 3D reformats
- Coronal and Sag reformats
- Additional soft tissue injury
Fx & Scalp Laceration

15yr old ATV accident not wearing helmet  parietal bone visible on PE. Pt found by friends with LOC

Developed osteomyelitis skull
Additional findings SDH & Punctate Contusions
Csp negative
ER PT: accidentally hit corner of dresser

Story fit the injury & bone survey negative
Contusions, diffuse axonal injury, subcortical injury

INTRACRANIAL TRAUMA
Mechanisms

- Projectile, Gun shot etc.
- Penetrating
- Direct impact
- Superficial injury usually results of skull fx, direct
- Blunt trauma results of shear-strain deformation
- Intra-axial injury-result rotational acceleration
- Parenchymal injury:
  - Abusive head trauma: ischemia & infarction
  - Accidental trauma DAI
Projectile injury:
12-y GSW, 0.22 caliber rifle NONDOMINANT hemisphere required decompressive craniotomy
Penetrating injury:
dural patch required
Trauma and Intracranial hemorrhage

- Extra-axial hemorrhages
- Cerebral contusion
- Diffuse axonal injury
- Subcortical injury
Epidural hematoma (EDH)

- Usually at coup side
- Lentiform shape on CT
- Does not cross sutures
- Arterial bleed usually middle meningeal a.
- Associated with skull fracture, 50-60%
- Non enhanced CT best imaging modality

SUBACUTE Fall from bed

Fall from bed 2 days after falling from a bicycle
Subdural hematoma (SDH)

- Typically contrecoup
- Ruptured bridging veins
- Crescent shape
- Hyperdense, isodense, hypodense
- Infants - child abuse
- Neonate - perinatal injury
- Density does not determine age of trauma

SUBACUTE ON CHRONIC SDH

\[ N \text{ CHRONIC SDH & child abuse.} \]

ACUTE SDH
2nd floor fall
Subarachnoid Hemorrhage (SAH)

- Between pia & arachnoid
- Usually adjacent to contusion, SDH, fx
- Spreads into sulci, fissures & cisterns
- Traumatic & child abuse
- Usually clears in a few weeks

1-m fell to floor 2-3 ft
Intraventricular hemorrhage

- Shearing injury
- Usually Intracerebral hemorrhage that ruptures into ventricle
- Disruption subependymal veins
- Associated Corpus callosal DAI

3-y hit by car
Initial CT negative for bleed
Cerebral Contusion

- Acceleration/deceleration injury
- Moderate/severe closed head injury
- Confusion most common initial symptom
- Temporal & Frontal lobes most common locations - bony protuberance, falx
- Evolve with time - Early CT maybe neg or edema
- Injury to superficial GM, WM is spared
- Capillary disruption leads to bleeding and edema
Cerebral Contusion: Coup-Contrecoup

16yr M Slip & Fall off flat bed truck while washing
Became combative & required sedation and

Typical location (50% temporal)
F/U 1 mo later
injury Confined to Cortex
Contusions may undergo encephalomalacia & atrophy

MRI: delinates injury better then CT

skate board fall
NO HELMET
LOC & seizure
EVOLVING CONTUSIONS:
10 yr F LOC fall off golf cart. Persistent confusion

INITIAL

48Hr F/U
Diffuse Axonal injury (DAI)

- LOC & Coma
- Traumatic axonal stretch injury/Shear injury
  - Cortex & Deep structures
  - cellular swelling & cytotoxic edema (ischemia GM/WM)
  - Multifocal punctate hemorrhages
- CT initially normal 50-80%
- 30% have negative CT but positive MRI
- Tragic—often brain stem spared—vegetative state
DAI: DWI, Edema & Ischemia
Special sequences

- MRI is best modality: SWI & DWI
- Symptoms disproportionate to imaging findings
  - Multifocal punctate foci at GM/WM jct.
  - Temporal & frontal location common
DAI: CHILD ABUSE
5-wk hx of fall

CT Showed SAH & small contusions
48hr f/u MRI: DWI shows superficial & deep edema
Hypoxic Injury: 2yr F Near drowning, 10min in pool found by grandparents. Organ donor.

reversal sign.
“I really think it's crazy that we hit our kids... Kids are the only people in
the world that you're aloud to hit. Do you realize that! They are the most
vulnerable and the most destroyed by being hit, but it is totally okay to
hit them... If you hit a dog they will ... put you in jail...”
--LOUIS CK

NON ACCIDENTAL HEAD INJURY
“Non accidental” Head injury (NAHI)

- Leading cause morbidity & mortality abused child under 2yrs 80% of deaths from head injury
- Outcome is worse in NAHI than accidental
- High rate of mental disability
- Brain can be injured w/out skull fx due to deformational changes of infant skull
Mechanism of Injury
Head trauma-shaken baby syndrome

- Clinical presentation: seizures, apnea coma, cardiopulmonary arrest
- Main relate Injuries: subdural hemorrhages, retinal hemorrhages, bone fx & spine injury
- Cervical injury < 6mo old due to undeveloped cervical musculature
- Hypoxic-ischemic injury
  - brain stem injury causing cardiopulmonary arrest and apnea resulting in brain swelling and DAI

NAHI-what to order

• Non-enhanced CT
  – Initial work up
  – 3D bone reconstructions
    • Excellent differentiate skull fractures from sutures
• MRI brain
  – neurologic symptoms
  – other signs of abuse
  – history of head trauma
  – If abnormal CT add cervical spine
  – Infarcts include MRA
• CT & MRI are complimentary
Dating Hemorrhages

- Evolution of attenuation changes cannot give an exact time frame as changes may vary patient to patient.
- Serial imaging may be needed.
- MRI may be helpful in dating hemorrhages.

- Hypodense < 3 hours
- Hyperdense Hrs to wks
- Isodense 2-3 weeks
- Hypodense > 3 weeks
Patterns of skull fracture in NAHI

- Soft tissue swelling maybe absent
- Multiple fractures
- Fractures that cross sutures
- Bilateral fractures
- Diastasis >3 mm, stellate, depressed & pingpong
- Bone scan & NaFl not as accurate for skull fractures-
  XRAY/CT is best
Same Patient
Diffuse edema & multiple hemorrhages
NAHI: Acute SDH, diffuse edema & ischemia supposedly hit by brother with toy truck

Bone Survey: multiple rib fractures
NAHI: diffuse cortical laminar necrosis
17-m unresponsive after staying w/mother’s boyfriend.
NAHI: HYPOXIC ISCHEMIA & LATE EFFECTS

2-m unresponsive, multiple fx in different states of healing

hyperdense cerebellar sign

Cystic Encephalomalacia
PIT FALL CASE:
1 yr w/head swelling. Study read at adult hospital!

Typical appearance of metastatic neuroblastoma
Stay on target: Take Home Points

• CT is a valuable tool!
• Head, Sinus or Facial Bones CT have radiation similar to 1 yr bkgd radiation
• Use NECT 1st for emergent eval
• 3D recon especially if <2yrs
• IF CT avail preferable to Facial XR
• MRI if neurologic or worsening sx.
• Skeletal Survey REQUIRED in suspected child abuse! DO NOT MISS NON ACCIDENTAL TRAUMA!
Comments & Questions

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Please check Appendix in syllabus for references, medical legal issues & reporting child abuse