Advanced Pediatric Emergency Medicine Assembly
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Lake Buena Vista, FL

Reading a Head CT in Children: Pitfalls and Pointers

You are seeing a 3-year-old male with head trauma and the CT scan is up for review. Is that hygroma or a normal finding, and what about the large posterior fossa lucency, is that normal too? The speaker will present CT scan findings you don’t want to miss in children and contrast normal variants from important pathology.

- Recognize serious disease and injury in children on CT scan that should not be missed.
- Using case discussion, review important normal variants and contrast to pathologic findings important in pediatric emergency care.
- Demonstrate a wide range of pathology on the CT scans in children and provide tips on reading scans by age of patient.

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1:15pm – 2:00pm

(+)No significant financial relationships to disclose

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Reading a Head CT in Children: Pitfalls and Pointers

3/4 Hour

Faculty: Joshua S. Broder, MD, FACEP

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Reading a Head CT in Children: Pitfalls and Pointers

ABCs of pediatric head CT

Joshua Broder, MD

Duke University Medical Center
Objectives

• Define a systematic method for noncontrast head CT interpretation

• Along the way, review common and dangerous pathology

• Highlight pediatric pearls and pitfalls

• Test our skills with a few cases
Jack and Jill...

Went up the hill
To fetch a pail of water
Jack fell down
And broke his crown
And Jill came
Tumbling after
CT Windows

- Optimize image for recognition of pathology
- Bone
- Brain
- We’ll point out the best window as we progress
Before we get into details....

Mass effect and midline shift

- When interpreting a CT
  - assess symmetry
  - find the midline
  - make sure it's *in the midline*, not shifted left or right
  - The presence of mass effect is more important to immediate decisions in many cases than the specific pathology
Mass effect and midline shift

- Mass effect may be due to hemorrhage, infections, or neoplasms
- The actual mass may or may not be visible
- Here, an epidural hematoma creates mass effect with midline shift
- One of your first assessments of a head CT in a sick child should be a search for indications for immediate surgery, including mass effect and midline shift
Then, a more systematic approach....

Do you know your ABBBC?

- Airspaces
- Bone
- Blood
- Brain
- CSF spaces
A is for air-spaces

- **Clues to**
  - Fractures
  - Infections

- **Look for**
  - Fluid where there should be air
  - Air where none should be found
  - Discontinuities in the walls of air-spaces

- **Pearls**
  - Air is black on all window settings
  - But fat and fluid can look almost black on “brain windows”
  - Switch to bone windows to highlight air - the only substance which appears black on this window setting
- Air-spaces develop at a variable rate

<table>
<thead>
<tr>
<th>Air-space</th>
<th>Present by...</th>
<th>Full-size at</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxillary sinus</td>
<td>embryonic</td>
<td>12 years</td>
</tr>
<tr>
<td>Ethmoid sinuses</td>
<td>birth</td>
<td>12 years</td>
</tr>
<tr>
<td>Sphenoid sinus</td>
<td>1–3 years</td>
<td>7–14 years</td>
</tr>
<tr>
<td>Frontal sinus</td>
<td>between 1 and 4 years</td>
<td>12 years, some continued development until adulthood</td>
</tr>
<tr>
<td>Mastoid air cells</td>
<td>birth</td>
<td>grow linearly until age 6 years, then slower growth until puberty</td>
</tr>
</tbody>
</table>


A is for Air-spaces

- Normal air-spaces in the skull include the frontal, maxillary, ethmoid, and sphenoid sinuses, and the mastoid air-cells
- Air appears black on CT on both bone and brain window settings
- Low density substances such as fat and CSF may appear nearly black on brain windows, so be aware of this subtlety
- The window level can be adjusted to emphasize structures/tissues of interest
- Bone windows can be very useful for this assessment
Air-spaces

• In trauma, fractures through the bony walls of sinuses result in bleeding into the sinus

• On bone windows, this appears as either opacification (gray) or an air-fluid level in the sinus

• Compare the mastoid air-cells, which are uninjured and normal in appearance, with the abnormal maxillary sinuses
Air-spaces

- The image at the right shows a normal maxillary sinus
- On the screen left is a fractured sinus, partially filled with blood
Air-spaces

• Fluid in a normally air-filled space can indicate several things
  – After trauma
    • Blood from a fracture
  – In the absence of trauma
    • Sinus or mastoid infection, if the clinical scenario is suggestive
    • An incidental finding, if the patient is asymptomatic

• Even on brain windows, dense fluid such as blood is visible in the sinus
B is for Bones

• Let’s move on from air-spaces to bones

• We’ll learn to
  – Select bone windows
  – Differentiate fractures from sutures
  – Review sinuses for findings suggesting fracture
Bones

- If we’re interested in problems with bones, we need to select bone windows.

- Most digital radiology systems (PACS*) have drop-down menus which allow you to select your window setting.

- Though the exact method for changing window settings varies with software vendors, the concept is the same.

*PACS = picture archiving and communications system
Bones

- Large, displaced fractures are often visible on brain windows
- Less displaced fractures are often NOT visible on brain windows
- Use the bone window setting if you are interested in finding fractures
Bones

- This patient has a significantly displaced skull fracture in the temporal-parietal region
  - Fractures are visible as “cortical defects,” which are discontinuities in the cortex of bone
Bones

- The same slice as in the previous slide, now viewed with bone windows

- On bone windows, the displaced skull fractures are readily visible

- But more subtle fractures, which were not visible on brain windows, can now be seen as well
Bones

• Also inspect sinuses

  – As we discussed earlier, after trauma, sinus air-fluid levels or opacified mastoids suggest fractures
Bones

• Fracture or suture?

  – Before calling a cortical defect a fracture, look for normal sutures on the opposite side

  – An unmatched defect is likely a fracture

  – A matched defect may be a suture

  – Here, the fractures do not have any corresponding cortical defect on the opposite side
Sutures and fontanelles in a newborn skull, viewed from above.
Sutures and fontanelles close at variable rates, and sometimes close asymmetrically – a potential mimic of fracture

<table>
<thead>
<tr>
<th>Suture or Fontanelle</th>
<th>Closes at...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal suture</td>
<td>Nine months to two years (may persist into adulthood)</td>
</tr>
<tr>
<td>Coronal, sagittal, lambdoid sutures</td>
<td>40 years</td>
</tr>
<tr>
<td>Anterior fontanelle</td>
<td>Nine to 18 months (4-26 months)</td>
</tr>
<tr>
<td>Posterior fontanelle</td>
<td>Three to six months</td>
</tr>
<tr>
<td>Anterolateral fontanelle</td>
<td>Three months</td>
</tr>
<tr>
<td>Posterolateral fontanelle</td>
<td>Two years</td>
</tr>
</tbody>
</table>


B is for Blood

- Bleeding can occur in several spaces in and around the brain
  - Subarachnoid space
  - Epidural space
  - Subdural space
  - Intraparenchymal
Blood -- Subarachnoid hemorrhage

- Subarachnoid hemorrhage is blood within the subarachnoid space, which contains CSF.
- Fresh blood is white on CT.
- Blood in this space can diffuse into any CSF-containing space:
  - Sulci and fissures
  - Ventricles
  - Cisterns
Blood -- Subarachnoid hemorrhage

- SAH can occur for two major reasons
  - Spontaneous bleeding
    - aneurysm in the Circle of Willis
    - AVM
  - Trauma
Blood -- Subarachnoid hemorrhage

- Spontaneous bleeding
  - Aneurysms of the Circle of Willis, AVMs, or other vascular anomalies may spontaneously bleed
Blood -- Subarachnoid hemorrhage

- The Circle of Willis lies in the skull base, near the brainstem.

- Not surprisingly, when an aneurysm ruptures here, blood will first fill the cisterns surrounding the brainstem.

- Eventually blood may diffuse to other CSF spaces.

- In this image, blood (white) surrounds the brainstem.
Blood -- Subarachnoid hemorrhage

- SAH diffuses through CSF spaces

- The next several slides show SAH in the same patient

- Here, SAH (white) is diffusing out of the cistern surrounding the brainstem.

- You can see that SAH is bright white, though not as white as bone
Blood -- Subarachnoid hemorrhage

- Here, SAH continues to outline the brainstem.

- Anterior to the brainstem, the suprasellar cistern has a star-like appearance and is visible here filled with blood.
  - You do not need to memorize the name.
  - but be familiar with this star-like appearance!

- Posterior to the brainstem, the quadrigeminal cistern looks like a smile.
Blood -- Subarachnoid hemorrhage

- Here is a normal brain at the same level

- Anterior to the brainstem, the suprasellar cistern has a star-like appearance
  - Normally the star is black, because it is filled with cerebrospinal fluid!
  - Be familiar with this **star-like appearance**!

- The quadrigeminal cistern looks like a smile
  - The normal appearance is black, because these structures contain CSF
  - Remember the **smile**!
Blood -- Subarachnoid hemorrhage

- Here, blood is also visible in the Sylvian fissure on both sides
Blood -- Subarachnoid hemorrhage

- Blood is visible in bilateral Sylvian fissures
- Interhemispheric blood is also visible
Blood -- Subarachnoid hemorrhage

• Blood is visible in both ventricles
  – Ventricles are CSF spaces too!

• Calcification of the choroid plexus in the ventricles may mimic blood, but is brighter white – almost bone density
Blood -- Subarachnoid hemorrhage

- Blood is visible in the sulci, the CSF spaces between brain surface gyri
  - This is a more subtle finding
Blood -- Subarachnoid hemorrhage

- Remember we said we’d talk about trauma?

- SAH from trauma may occupy any of the spaces we’ve shown

- There may be more than one bleeding source

- Blood is less likely to be prominently located in the suprasellar cistern as it often is in aneurysm rupture – but review all CSF spaces for blood!
EDH

- Epidural hematoma (EDH) is blood between the bone of the skull (calvarium) and the dura mater, the tough membrane surrounding the brain.
EDH

- Epidural hematomas have a classic shape and location
  - Biconvex “lens” shape
  - Temporal location

- Because the dura is tightly adherent to the skull at sutures, EDHs usually do not cross sutures
EDH

- Not all epidural hematomas are as large as the ones you’ve seen so far

- But EDHs are usually from arterial injury to the middle meningeal artery, so they can rapidly expand

- You must recognize even smaller EDHs
EDH

• The ‘swirl sign’ may indicate active bleeding

• This is a mixed or heterogeneous appearance of blood, with both bright white and darker components
  – This likely indicates blood of varying ages

• This sign is not unique to EDHs but may be found in other forms of hemorrhage
Subdural hematoma

- Subdural hematoma (SDH) is blood between the brain and the dura mater, the tough membrane surrounding the brain.
Subdural hematoma

- Subdural hematomas have a classic ‘crescent’ shape
  - The outer surface is convex
  - The inner surface is concave
Subdural hematoma

- As a subdural hematoma ages, the color may change from white to gray.
- Acute SDHs are white
- Older subdurals may be
  - Hypodense = darker than brain
  - Isodense = same color as brain
- SDHs can be bilateral!
Blood -- intraparenchymal

- Intraparenchymal hemorrhage (IPH) can occur for several reasons
  - Spontaneous hypertensive hemorrhage
  - Bleeding into abnormal regions of brain
    - Masses
    - Infarcted brain tissue
  - Trauma

- Like other forms of acute hemorrhage, IPH is white
Blood -- intraparenchymal

- Be careful to differentiate intraparenchymal hemorrhage from calcifications
  - Calcifications are usually very bright white, even whiter than hemorrhage
    - An area that remains white on bone windows is likely calcified
    - Of course, when in doubt assume hemorrhage
Blood -- intraparenchymal

- Be careful to differentiate intraparenchymal hemorrhage from calcifications

- This image shows some common locations for calcifications
  - Pineal gland
  - Choroid plexus
    - Especially in posterior horns of lateral ventricles
Blood -- intraparenchymal

- Be careful to differentiate intraparenchymal hemorrhage from calcifications

- Another normal variation is calcification within the falx cerebri
  - Don’t confuse this with subarachnoid hemorrhage

Falx cerebri
B is for Brain

- A number of brain abnormalities are visible on head CT
- Some have a specific appearance
- Others have a nonspecific appearance and must be recognized in clinical context
- We’ll discuss
  - Diffuse axonal injury
  - Vasogenic edema
  - Ischemic stroke
B is for Brain

- Diffuse axonal injury (DAI) results from deceleration and is a diffuse injury to myelinated axons coursing through the brain.

- Examples of mechanisms leading to DAI include falls from height and high speed MVCs.

- The appearance on head CT is nonspecific, sometimes associated with:
  - Punctate intraparenchymal hemorrhage
  - Subdural hematoma
  - Cerebral edema
B is for Brain

- Vasogenic edema
  - As the name implies, vasogenic edema refers to edema resulting from abnormal blood vessels
  - Examples include edema around neoplasms, infections, and inflammatory abnormalities
  - Vasogenic edema appears as “hypodensity,” or a darker gray color than surrounding brain
  - In this image, a circular mass is surrounded by vasogenic edema
B is for brain

• Though strokes are rare in children, some populations such as patients with sickle cell anemia are at risk.

• In this section we’ll learn CT features of ischemic stroke

• In the hours to days following onset of stroke, the CT findings become more evident

• Here we see a large MCA (middle cerebral artery) stroke which is days old
Here we see a less obvious left MCA infarct
• The edges of the pie just touch the anterior and posterior horns of the lateral ventricles
• The midline itself is outside of MCA territory
• The occipital region and cerebellum are not included
This CT shows a right MCA territory infarct, occupying essentially 100% of the MCA territory.

- You can approximate the area that would represent 1/3 of the MCA.
• What are the early CT signs of ischemic stroke?

• Several signs have been described in early stroke, within 3 hours of symptoms onset
  – Hypoattenuation
  – Loss of Gray-White Differentiation
  – Early edema
  – Hyperdense MCA sign
Why does the CT change after stroke?

- No blood flow...
- No energy...
- Ion pumps fail...
- Fluid shifts

Remember that the Hounsfield scale relies on density and relative absorption of radiation.

- As fluid shifts in and out of tissues, their density rises or falls
- Their CT appearance changes along with density
What are the early CT signs of ischemic stroke?

- Hypoattenuation
  
  - Hypoattenuation simply means “lower absorption of radiation”
  
  - On CT, hypoattenuation means a darker gray color
  
  - Why darker gray?
    - Fluid shifting into infarcted tissue lowers the density, relative to normal brain
What are the early CT signs of ischemic stroke?

Loss of gray-white boundary

In order to understand this finding, let’s review the normal gray-white boundary
B is for brain

- Myelinated areas (white matter) have a higher fat content than unmyelinated regions (gray matter)
  - This is due to the high fat content of myelin

- As a consequence, white matter is lower density and appears darker on CT
  - In other words
    - Gray matter looks whiter
    - White matter looks grayer

- When this interface becomes less discrete, due to ischemia, the CT finding is called loss of gray-white differentiation
Why does loss of gray-white differentiation occur?

- As ion pumps fail, fluid shifts between gray and white matter
- The density of the two tissues becomes more similar
- Their CT appearance becomes more similar
- On the left side of the brain pictured here, we’ve simulated this CT finding
Where does loss of gray-white boundary occur?
Where gray matter meets white matter!
- basal ganglia and internal capsule
- cortex and white matter
- tissue appears darker than usual

For our purposes, the names of individual structures are less important than the principle of gray-white matter differentiation.
What are the early CT signs of ischemic stroke?

- Early edema is another finding of early stroke

- Localized edema in the region of a developing infarct can cause
  - effacement of sulci
  - effacement of Sylvian fissure

- In the case at left (an infarct several days old), the adjacent sulci are effaced
What are the early CT signs of ischemic stroke?

- Even before the infarct is visible, sulci may be effaced
- We’ve simulated this on the patient’s left here
C is for CSF spaces

- The CT appearance of CSF spaces is the key to understanding intracranial pressure (ICP) changes

- We’ll look at these CSF spaces
  - Ventricles
    - Giant → hydrocephalus or atrophy
    - Slit-like or absent → high ICP!
  - Cisterns
    - Giant → hydrocephalus
    - Slit-like or absent → high ICP!
  - Sulci
    - Giant → atrophy
    - Absent → high ICP!
C is for CSF spaces

- In a normal brain, the CSF spaces are not too big, not too small
  - Ventricles are open
    - Not dilated
    - Not slit-like
  - Cisterns are visible
    - Not prominent
    - Not effaced
  - Sulci are present
    - Not enlarged
    - Not obliterated
Here are the normal CSF spaces (black), moving from caudad (left) to cephalad (right).

The names aren’t important – but note the size of ventricles and cisterns relative to sulci.
CSF spaces: a comparison

- Here's a bird's eye view to help you understand the normal appearance of CSF spaces.

- In the normal brain
  - All CSF spaces are present, neither effaced nor enlarged

- In atrophy
  - All CSF spaces are enlarged

- In hydrocephalus
  - The ventricles expand
  - The sulci and cisterns are compressed

- In edema
  - All CSF spaces are compressed

*The youngest infants and children have relatively small ventricles and sulci, resembling cerebral edema. Gray-white matter boundaries are preserved in normal children, vs lost in cerebral edema.
Here is another look at atrophy

As the brain shrinks, all CSF spaces remain open or enlarge

Atrophy is mostly a condition of aging, but some children have localized atrophy or loss of brain volume (encephalomalacia)
In hydrocephalus, ventricles expand and other CSF spaces, including cisterns and sulci, become compressed.
In cerebral edema, the brain volume expands. CSF spaces, including ventricles, cisterns and sulci, become compressed. As the condition worsens, the brain becomes globally ischemic and gray-white matter boundaries are lost. In this example, some gray-white matter boundaries are becoming indistinct in the central image.
Peds Pearls

• Pediatric heads are “tight”
• No atrophy, minimal sulci
• Can resemble cerebral edema in an adult
• Gray-white matter boundaries should remain normal if edema is not present
• Observe for CSF spaces (cisterns, ventricles)
• Watch for mass-effect
• Use the clinical picture to assess as well: a neurologically normal child is unlikely to have diffuse cerebral edema
Limits of CT

• What does a negative CT mean?

• A negative head CT doesn’t mean a normal patient!

• Any of these problems might exist
  – Subarachnoid hemorrhage
  – Ischemic stroke/TIA
  – Diffuse axonal injury
  – Small neoplasms
  – CNS infections
Peds Pearl

• “This CT looks fuzzy”

• Dose reduction methods can result in a pixelated appearance from increased noise

• But studies suggest adequate detail for diagnosis, even when radiation doses are reduced by 80%

• We are in a race to the bottom to mitigate radiation exposure

Summary

• Use a systematic method for evaluation
  – ABBBC

  – Need to review comparison images – some gross abnormalities may be baseline

  – Don’t get caught up in details – assess for immediate life-threats such as mass effect/midline shift

• Consider pediatric-specific issues
  – Sinus development
  – Fontanelles/sutures
  – Atrophy/lack thereof
  – Vents/sulci
  – Image quality with dose reduction
Questions

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