Pediatric Radiology Update

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Objectives

• Review radiation biology and safety practices for pediatric imaging

• Discuss imaging workup of a few common presenting pediatric problems
Why Should We Care?

• Children are more sensitive to radiation than adults
• Children have a longer lifespan in which to manifest radiation induced injury
• Each exam involving ionizing radiation increases risk
In 2006, Americans were exposed to 7X as much ionizing radiation exposure from medical procedures than in the early 1980’s.

The increase is due mostly to higher utilization of computed tomography (CT) and nuclear medicine PET/CT imaging.
Startling Facts

• CT procedures have increased from 3 million procedures to 60 million procedures in only 25 years

• Atomic bomb survivors show statistically significant increase in cancer at doses in excess of 50 mSv

• CT and NM PET procedures have effective dose ranges of 10-25 mSv
R² = 0.9993
Typical Radiation Doses (mSv)

- Natural background radiation: 3.5 mSv
- Doug Rivard, DO (2010): 4 mSv
- Dental x-rays: 0.09 mSv
- Chest x-ray: 0.01 mSv
- Barium enema: 8.75 mSv
- CT chest/abd/pelvis: 15 mSv
- PET/CT: 23.3 mSv
### Equivalent Radiation Exposures

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Effective Dose</th>
<th>Compared to Natural Background (3 mSv/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest X-Ray</td>
<td>0.1 mSv</td>
<td>10 days</td>
</tr>
<tr>
<td>Mammogram</td>
<td>0.7 mSv</td>
<td>3 months</td>
</tr>
<tr>
<td>CT Head</td>
<td>2 mSv</td>
<td>8 months</td>
</tr>
<tr>
<td>CT Chest</td>
<td>8 mSv</td>
<td>$2\frac{2}{3}$ years</td>
</tr>
<tr>
<td>CT Chest/Abd/Pel</td>
<td>15 mSv</td>
<td>5 years</td>
</tr>
<tr>
<td>PET/CT</td>
<td>23 mSv</td>
<td>7+ years</td>
</tr>
</tbody>
</table>

Source: [www.radiologyinfo.org](http://www.radiologyinfo.org)
What do all those numbers mean?

The real question from both health care professionals and patients is what do these numbers mean or what effect will they have on a health and well-being of the child.

• Risk vs. Benefit
Fatal Cancer Risk

• Estimated
• Debated
• May be zero
• May be, in children, 1 in 500-1000 risk from a single CT scan (your risk of getting some form of cancer is 230/1000 without any radiation)
• Remember, the dose you give today lasts a lifetime!
What Should You Be Doing?

• Does the facility you refer to have pediatric imaging protocols?

• Does your facility annually review their pediatric CT protocols?

• Accredited techs, board certified radiologists, ACR accredited facility?
Dose Reduction Strategies

• Reduction of technical parameters to minimum that allow for diagnostic images (kVp, mAS)

• Iterative reconstruction techniques

• Image filtering/post processing software
How different are CT protocols?

- Unpublished data from CMH vs outside head CTs 2009-2011
  - 44% lower dose at Children’s Mercy Hospital compared to outside head CTs
Dose Reduction Strategies

• Image only body part needed

• Try to use US, MRI when possible

• No multiphase scanning (arterial, venous, delayed CT)
Vomiting/ Regurgitation in young children

- Most common cause of vomiting and regurgitation in infants is **gastroesophageal reflux**.
- These patients typically maintain normal weight and developmental milestones.
Natural history of infant regurgitation

• 47% of 1 month old infants had 1 or more daily episodes of vomiting/regurgitation, decreased to 29% at 4 mos, and 6% at 7 mos.

• Spilling of feeds reached peak prevalence of 41% between 3 and 4 mos and decreased to less than 5% by 13 mos.
Upper GI study

Stomach

Reflux in esophagus
Vomiting/ Regurgitation in young children

• Most patients do **NOT** require imaging with an upper GI exam as this study defines anatomy, and reflux may or may not be seen.

• In cases of persistent or severe regurgitation, pH probe monitoring may be helpful.

• Imaging should be considered if there are airway symptoms or bloody or bilious emesis.
pH probe in esophagus
Newborn Bilious Emesis

• **Bilious emesis in a newborn is an emergency** which should be promptly evaluated with an upper GI examination to exclude malrotation and volvulus. (SBFT is **NOT** required to diagnose)

• Patients should have an NG or OG tube placed to confirm the presence of bilious material as well as facilitating the UGI exam.
Upper GI study

Volvulus
Normal duodenojejunal junction (ligament of Treitz)
Pyloric Stenosis

• Common cause of early infantile intestinal obstruction.
• Also known as Hypertrophic Pyloric Stenosis (HPS).
• Multifactorial causes suggested including:
  – Hereditary
  – Exposure to macrolide antibiotics (erythromycin)
  – Abnormal myenteric plexus innervation
  – Infantile hypergastrinemia
Pyloric Stenosis

- 2-4 cases/1000 live births in U.S., male:female ratio 4:1
- 95% diagnosed between 3 and 12 weeks of age.
- Nonbilious emesis which becomes projectile.
- May have a palpable “olive” on exam.
Pyloric Stenosis

• A limited abdominal ultrasound is the diagnostic study of choice.
  – Highly sensitive and specific
  – No radiation
  – No sedation
Pyloric Ultrasound

Elongated pyloric channel

Thickened pyloric muscular wall
Intussusception

- Most common cause of intestinal obstruction in children aged 3 to 36 mos., 60% < 1 y.o., 80% < 2 y.o.
- Majority are idiopathic.
- Seasonal patterns associated with gastroenteritis, possibly due to hypertrophy of lymphoid tissue in the terminal ileum.
- Increased incidence after some forms of rotavirus vaccine.
Intussusception

• Pathologic lead point in some cases:
  – Meckel’s diverticulum
  – Enteric duplication cyst
  – Lymphoma
  – Polyps
  – Henoch-Schönlein purpura (intramural hemorrhage)
Intussusception

- Present with sudden onset of crampy, intermittent abdominal pain with drawing-up of legs and inconsolable crying.
- May develop vomiting and currant-jelly stools.
- Diagnostic work-up includes abdominal radiographs and ultrasound.
- Treated with air enema reduction.
Abdominal Ultrasound

Ileocolic intussusception
Intussusception

- Contraindications to enema reduction:
  - Pneumoperitoneum
  - Clinical peritonitis or unstable patient
- Surgery required for incomplete reduction, free air, multiple recurrent episodes (possible lead point).
- Incidental small bowel-small bowel intussusception which may be seen on US or CT is typically transient and asymptomatic.
Additional causes of obstruction

- Older infants and children:
  - Appendicitis
  - Adhesions
  - Incarcerated hernia
  - Meckel’s diverticulum
Appendix Ultrasound

Shadowing stone in dilated appendix
Stone within an inflamed appendix
Inguinal hernia noted on physical exam; Gas-filled bowel loops seen on X-Ray performed for vomiting.
Abnormal fluid filled structure on Pelvis CT
Nuclear Medicine Meckel’s Scan (Tc99m-Pertechnetate)

Meckel’s diverticulum
• Most vomiting/ regurgitation in infants is due to reflux and does not require imaging.
Summary

• Most vomiting/ regurgitation in infants is due to reflux and does not require imaging.
• **Bilious emesis is an emergency** which should be evaluated by an upper GI study.
Summary

• Most vomiting/ regurgitation in infants is due to reflux and does not require imaging.
• Bilious emesis is an emergency which should be evaluated by an upper GI study.
• Ultrasound is an important tool in the diagnosis of pyloric stenosis and intussusception.
Summary

• Most vomiting/ regurgitation in infants is due to reflux and does not require imaging.
• Bilious emesis is an emergency which should be evaluated by an upper GI study.
• Ultrasound is an important tool in the diagnosis of pyloric stenosis and intussusception.
• When in doubt about the imaging work-up, consult your radiology colleagues
Misshapen Head

- Craniosynostosis
- Macrocephaly
Craniosynostosis

• Definition:
  – Premature fusion of cranial sutures

• Synonyms:
  – Craniostenosis, sutural synostosis, cranial dysostosis

• M:F = 3:1
Craniosynostosis Imaging

Imaging is based on 3 categories:

1. **Low risk** - Developmentally normal or posterior flattening only
   - Plain films (4 view skull)

2. **Intermediate risk** - Healthy children with head deformity
   - CT head

3. **High risk** - Obviously misshapen head
   - 3D CT needed for surgical planning
Craniosynostosis

- Incidence: 3-5 cases per 10,000 live births
  - Sagittal – 56% (1/3600)
    - Scaphocephaly
Craniosynostosis

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    - Scaphocephaly
  - Coronal – 26% (1/7700)
    - Brachycephaly
Craniosynostosis

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  - Sagittal – 56% (1/3600)
    - Scaphocephaly
  - Coronal – 26% (1/7700)
    - Brachycephaly
  - Metopic – 8% (1/25,000)
    - Trigonocephaly
Craniosynostosis: Low Risk

History: Developmentally normal child with posterior flattening

Diagnosis: Normal sutures

Sagittal

Coronal

Lambdoid

Diagnosis: Normal sutures
Craniosynostosis: Intermediate Risk

History: Developmentally delayed child with parieto-occipital flattening

**Diagnosis:**
Plagiocephaly (parieto-occipital flattening, but no craniosynostosis)
Craniosynostosis: High Risk

History: Child with obvious abnormally shaped head

**Diagnosis:** Sagittal synostosis

**Diagnosis:** Lambdoid synostosis
Craniosynostosis

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>Imaging</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low risk</strong> - developmentally normal and posterior or posterolateral flattening only</td>
<td>No imaging, or 4-view skull (plain films)</td>
</tr>
<tr>
<td><strong>Intermediate risk</strong> - children who don’t clearly fit into the low or high risk group</td>
<td>Low-dose head CT</td>
</tr>
<tr>
<td><strong>High risk</strong> - developmentally abnormal and/or obvious head deformity almost certainly needing surgery</td>
<td>Standard head CT with 3D reformations</td>
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</tbody>
</table>

- This approach to imaging craniosynostosis and posterior plagiocephaly reduces both unnecessary imaging and radiation exposure
Imaging macrocephaly

**Definition:** Head greater than 95%
- If the head circumference levels out—no imaging
- If the head growth rate continues to increase or developmental abnormality, do imaging

**Imaging approach:**
- **US** is used if the child is less than 6 months or if they still have an open fontanelle
- **CT** is used if the child is greater than 6 months and no fontanelle
- **MRI** if associated neurological symptoms
Macrocephaly: developmentally normal child with open fontanelle

**History:** Normal subarachnoid space contains vessels

**Diagnosis:** Benign enlarged subarachnoid spaces
Benign enlarged subarachnoid spaces (BESS)

- Usually presents between 3 months and 3 years of age (esp. 6-18mo)
- Most common cause of macrocephaly in a developmentally normal child
- Parents often have big head
- Resolves spontaneously
Macrocephaly in a neurologically abnormal child

- 4-month-male with macrocephaly and lethargy

*Diagnosis: Choroid plexus papilloma*
### Imaging macrocephaly

<table>
<thead>
<tr>
<th>Clinical presentation and age</th>
<th>Imaging approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Developmentally normal infant/child with open fontanelle</td>
<td>Head ultrasound</td>
</tr>
<tr>
<td>• Developmentally normal infant/child with closed fontanelle</td>
<td>CT or MRI</td>
</tr>
<tr>
<td>• Developmentally abnormal infant/child with open or closed fontanelle</td>
<td>MRI</td>
</tr>
</tbody>
</table>
Imaging Torticollis: Based on age and history

- **Infant with torticollis:**
  - Most often due to fibromatosis coli (hematoma of sternocleidomastoid muscle)
  - More common in forceps delivery
  - Sonography is diagnostic
  - Rx: Physical therapy or surgical release

- **Beyond young infants the work up depends on history**
Torticollis: Beyond infants

• **History of isolated torticollis (no trauma)**
  – Usually rotatory subluxation (self-limiting, due to muscle spasm)
  – No imaging needed unless persistent after a week or 2 of conservative treatment
  – Isolated, persistent – do CT then consider dynamic scan with head in neutral, right, and left positions

• **History of trauma**
  – Plain films or CT without contrast

• **History of sore throat/signs of infection**
  – CT with contrast

• **History of torticollis with neurological signs**
  – MRI
Infantile Torticollis

Hx: 6-week-male with torticollis and forceps delivery

Diagnosis: Fibromatosis coli
Isolated Torticollis in a child

History: 10-year-male awakened with neck stuck to left 1.5 weeks ago; No response to conservative treatment

Coronal image demonstrates asymmetry between C1 and C2

Notice abnormal widening between C1 and dens widens with head turning to the left (toward torticollis)

Notice normalization of distance between C1 and dens with head turning to the right (away from torticollis)
Isolated persistent torticollis:

Diagnosis: Rotatory Fixation

Abnormal alignment with head turning right

Note C1 is looking a different direction than C2-C7
Torticollis with fever

History: 1-year-female with sore throat and difficulty swallowing

Axial CT neck demonstrates fluid pockets both on the right and at midline

Lateral view of the neck demonstrates prevertebral swelling of soft tissues

Diagnosis: Peritonsillar and retropharyngeal infection
Torticollis with neurological symptoms

History: 1-yr-female with persistent torticollis & scratching of the left arm

Diagnosis: Spinal cord astrocytoma
## Imaging torticollis based on history

<table>
<thead>
<tr>
<th>Clinical history and age</th>
<th>Initial imaging approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 3 months; asymptomatic except for torticollis</td>
<td>Ultrasound</td>
</tr>
<tr>
<td>&gt; 3 months; asymptomatic except for torticollis</td>
<td>No imaging; conservative Rx 1-2 weeks;</td>
</tr>
<tr>
<td></td>
<td>Persistent symptoms – CT without contrast</td>
</tr>
<tr>
<td>Any age with history of trauma</td>
<td>CT without contrast</td>
</tr>
<tr>
<td>Any age with symptoms of infection</td>
<td>CT with IV contrast</td>
</tr>
<tr>
<td>Any age with neurological symptoms</td>
<td>MRI</td>
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</table>
Summary

- Radiation is associated with increased lifetime risk of cancer
- Children are much more sensitive to radiation than adults
- Imaging strategies should take these into consideration
Summary

When in doubt what the best test to order is

CONSULT A RADIOLOGIST!!