Pediatric CT: More than Just “Right-sizing” the Dose

Kimberly E. Applegate, MD, MS
Emory University
Children’s Healthcare of Atlanta (CHOA)
Financial Disclosures

AIM (American Imaging Management) radiation protection advisory board and...
Media attention has heightened awareness

CT criticized for excessive radiation dose since 2001
Collaboration

ACR
American College of Radiology

Proud Supporter of image gently
The Alliance for Radiation Safety in Pediatric Imaging

AAPM

asrt
American Society of Radiologic Technologists
One size does not fit all...

There's no question — CT helps us save kids' lives!
But...When we image, radiation matters!
Children are more sensitive to radiation.
What we do now lasts their lifetime.
So, when we image, let's image gently.
More is often not better.

When CT is the right thing to do:
- Child size the kVp and mA
- One scan (single phase) is often enough
- Scan only the indicated area

A timely message from the Alliance for Radiation Safety in Pediatric Imaging.

Objective

• Discuss Top Ten Things YOU Can Do to Improve CT Dose Management
  – Team Effort is the key
  – Image Gently: Ten Steps You Can Take to Optimize Image Quality and Lower CT Dose for Pediatric Patients. Strauss K et al. AJR 2010;194:868-873
Number 1: Increase Awareness and Understanding of CT Dose Issues Among RTs

• Until 2007, physics of CT equipment not in RT curriculum
  – Provide further training; IG online modules
  – ASRT CT Basics course
• CT technologists at minimum should be ARRT registered
• Encourage techs to become ARRT CT certified
• Encourage techs to take the Image Gently pledge and to take free CE online CT courses on Image Gently web
Join with us.

Take the image gently pledge.

Today.
More Objectives

• Patient and Family Preparation

• Specific Protocols
  – Oral Contrast and Sedation
  – Abdominal CT for Inflammatory Bowel Disease?
  – PET/CT
  – Pectus Excavatum
  – Fungal Infections
  – ECMO

• Acceptable noise levels in pediatric CT
Why are Pediatric Protocols Different from Adult Protocols?

• Radiation dose is only one reason
• Safety issues (medication, sedation)
• Children do not cooperate until they understand and feel safe
• The pathology we look for is often different
  – Children have congenital anomalies and infections much more commonly than adults
  – When children have cancer, they have BIG sarcomas whereas adults have carcinomas. These cancers occur in different places and act differently
Preparing a Child and Their Family

- Remove fear, anxiety
- Explain the procedure
- The waiting room appearance matters and the literature (Image Gently, AAP)
- Reception staff and technologists REALLY MATTER
  - Minimize need for sedation
- Use distracters; rewards; social worker (‘child life’)
- Decorate the CT room and scanner
Preparation Techniques

• Immobilize the child using foam pads and velcro straps
  – Age <3 yr vendor papoose
• Train CT techs and nurses to stay in the room for the contrast injection, talking to the child
• Single Phase CT is all you really need, REALLY

Courtesy of Renee Ahmed
Sedation

- Typically: 6mo-4yr
  - Always try first without
  - Up to 50% need sedation
- Neonate: swaddle
- Non-contrast CT: intranasal versed first, then if needed propofol
- Infants/Children: IV propofol
  - Short-acting
  - Requires physician to admin

Courtesy of Renee Ahmed
Sedation

- Moderate sedation performed by nurse
  - Versed
  - Fentanyl
  - Newer agents: dexmedetomidine

- Sedation vs oral contrast: must stop the oral contrast some time prior to the CT exam (CHOA policy is 60 min)
When is enteral contrast needed?

• Less frequent with improved technology:
  – Thinner reconstructed images
  – 3 plane reconstructed images

• Systematic review, Am J Surg 2005; Anderson BA:
  – No oral contrast abdominal CT is equivalent or better than oral contrast for diagnosis of appendicitis

• ASER informal member poll 2011: 50% no longer use bowel contrast
Drinking Contrast

- VoLumen 15 ml/kg up to 450 mls (1 bottle) over one hour
- Teen: 1 bottle Q20 min; scan at one hour
- Compare to routine oral contrast:
  - Q30 min x 1 hour for age <7 yrs
  - Ditto x 90 min for age 7-12 yrs
  - Ditto x 2 hours for age > 12 yrs
- Neonate: 60ml 16 yrs: 960ml
Encouraging the Child to Drink Oral Contrast

• Make it taste good and make it fun:
  – Sweeten it (it can never be too sweet)
  – Give them control: choice of flavors
  – Silly straws
  – Use their favorite cup from home
  – Refridge gatorade/mix

• NGT is the last resort
Crohn Disease Evaluation: MR vs CT

- MR or CT Enterography (imaging of the small bowel)

  Abnormal Terminal Ileum

“Breath-hold” sequences on 3T: 20 minutes in adults, 45-60 min in children
Medical radiation exposure in children with inflammatory bowel disease estimates high cumulative doses

- 115 kids, 2002-2008
- Imaging for their dz only at one institution
  - CT > SBFT > all other imaging
- Median exposure 15.1 mSv CD vs 7.2 mSv UC
- 4.3 mSv/yr CD vs 3.4 mSv/yr UC

MRE vs CTE

• MR Pros: no radiation—repeat customers; superior accuracy for perianal fistula

• CT pros: less expensive; faster so less need for sedation if movie goggles not available
  – IBD onset typically after age 5 years

• Sedation risk: lower than BEIR VII estimate of lifetime fatal cancer induction of 1:1,000--10,000 per abdominal CT in children (depending on technique)
PET/CT in Children

- Increasing use with less clear outcomes compared to adults
- Use new Collaborative Consensus Guidelines for Administered Radiopharmaceutical Activities In Children and Adolescents
  - Society for Nuclear Medicine, Society for Pediatric Radiology, American College of Radiology (Image Gently)
- Continued occurrence of diagnostic CT day 1; PET/CT day 2: unnecessary radiation
PET/CT of Lymphoma in 11 year old girl

- CT non-dx technique:
  - 30 mA
  - Skull to ankles
- Use very low dose technique
- Increased prevalence of bone pathology in children—image to ankles
PET/CT: No Double CTs Please

Langerhans Cell Histiocytosis
Pectus Excavatum: Pre-operative Assessment

• Congenital abnormality of chest wall
• Can be present at birth but typically develops at puberty
• Many proposed techniques to decrease dose:
  – Low mA (20-30)
  – Decreased scan coverage AND low mAs
  – 2 view CXR
  – MRI
Pectus CT Protocol

- Tech marks deepest impression, scan coverage limited to area of interest
- 100 kVp
- 25 mA
- Rotation time 0.5 sec
- Acquisition 0.625mm
- Recon thickness 0.625mm ax; 5mm--all 3 planes
Pectus CT Image at Deepest

mA=25
cvp=120
HI=3.6
AW=17ym

CTDIv 0.63 DLP 11.2
Fungal Infections

• Liver, Spleen, and Kidney microabscesses, e.g. candidiasis in immunocompromised patients, especially leukemic children

• Appearance: Tiny hypodense areas in solid organs (subtle)

• Suggest raising mAs for chest and abdomen CT protocols (or abdomen MRI)
  – mA 20% higher for all of our protocols
CT of Candidiasis in two immunocompromised patients
Extra-Corporeal Membrane Oxygenation

- ECMO; mechanical ventilation
- Very ill babies; intensive care unit
- Typically newborns with respiratory disease or congenital heart disease
- At risk for intraparenchymal bleeding...head CT
  - Portable head CT
- May also undergo portable CT of chest or abdomen if needed
Portable CT of ECMO Babies

- Exposure doses similar to in department protocols (CTDI\textsubscript{v})
- Head CT image quality nearly equivalent
  - Acute bleed vs no bleed
- Except for contrast bolus timing: injection is typically via the ECMO infusion catheters and will have different timing compared to peripheral IV
Portable CT

1 yr girl with pleural hemorrhage
Pediatric Noise Levels

• Matter of ongoing discussion
• Automatic exposure control systems are variable in “dialing down” exposures—too noisy? Not enough?
• Dose reduction is a significant goal, but not at the expense of diagnostic performance
• “Dialing down” iteratively (e.g. start with Image Gently recommendations and slowly decrease over time), with ongoing consensus on image quality and diagnostic confidence feedback, can result in even lower doses
Pediatric Body CT Noise Levels

• CHOA experience: dose ‘moderates’, not liberals, not conservatives…

• Noise Index for head CT:
  – Adult 3.8 vs Pediatric 2.5 (CTDIv 17 for peds head)

• NI for CT routine body CT:
  – Adult 15 vs Pediatric 27.6
  – Renal Stone Protocol: younger 60mA; older 100 mA
  – Auto-mA, with narrow ranges, Acq 0.625mm
  – Generally, recons at 2.5mm if less than age 4 yr and 5mm if 4 yr or older (wt based protocols)
Use of Iterative Reconstruction

- We use ASIR at low levels:
  - All Neuro CTs: 10%
  - All Body CTs: 20%
- Toronto Sick Kids: 50%
Pediatric CT and ACR Accreditation

• Noise levels for submission of images for CT accreditation set lower than current practice at some Children’s Hospitals in USA
  – Informal Poll of Image Gently Steering Committee

• Is there an opportunity for applicants to submit images at their ‘normal’ protocols at which they interpret even if noisier images than ACR criteria?

• The ‘standard’ pediatric noise level is higher than adults but a moving target
Summary

• Preparation of patients and family is critical to success of pediatric CT
  – Less sedation and optimal images
• Pediatric protocols (and pathology) differ from adult protocols in many ways
• Pediatric radiologists, in general body CT imaging, are comfortable with noisy images—trading image quality for lower dose
  – Understanding the clinical question that needs to be answered BEFORE the study is performed
Questions?

• keapple@emory.edu
Some common CT scenarios where there is evidence that CT use could be reduced:

- CT for minor head trauma (observation)
- CT for VP shunt malfunction (fast MRI)
- CT for renal colic (U/A; US)
- CT for abdominal pain/appendicitis (US, MRI)
- CT for blunt abdominal and chest trauma (FAST*, observation)

*Focused Assessment with Sonography in Trauma
Examples

• **CATCH clinical prediction rule:** high sensitivity, specificity for head CT need in minor pediatric head trauma

• **Chest CT in blunt pediatric trauma**
  – J Trauma 2009. TA Markel et al.
  – Significant drop in CXR use with sig increase in CT use
  – CXR identified all severe abnormalities

• **Head CT for VP shunt malfunction evaluation**
  – Same kVp, lowered mA from 220 to 80 without significant change in image quality
Summary: Improving CT Dose Management

• It is a team effort

• The medical physicist, technologist, and radiologist must work together to:
  – Advocate for patients to referring providers
  – Optimize image quality

• Decision support for CPOE systems will bring needed evidence to the referring provider to allow justification of CT imaging