Managing Radiation Risk in Pediatric CT Imaging

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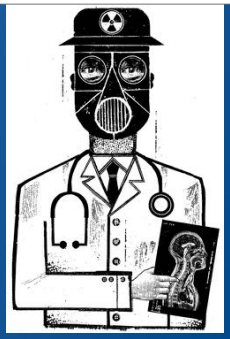
Why should we be concerned?

2001

2015



2014

Why children are more vulnerable to radiation than adults?

JOHNS HOPKINS MEDICINE

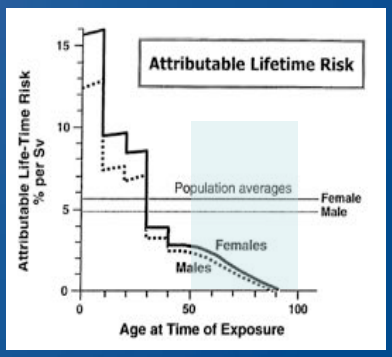
- Younger bodies more sensitive to radiation
- Longer lifetime for radiation effects to impart
- For given scan techniques, children absorb more radiation than adults

Equal Radiation Exposure:

Child Effective Dose > Adult Effective Dose

Cancer Risks

- Average risk for radiation induced cancer in general population is 5% per Sv
- Children are 2-3 times at higher risk than adults (as high as 15% per Sv)
- For persons aged > 50 years risk is 1/5th to 1/10th of that for younger adults

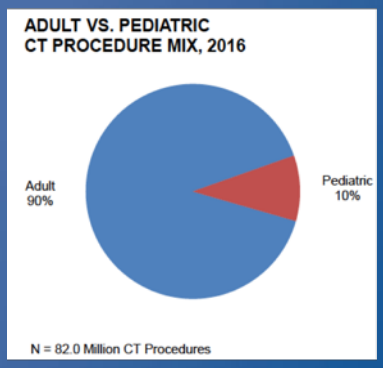


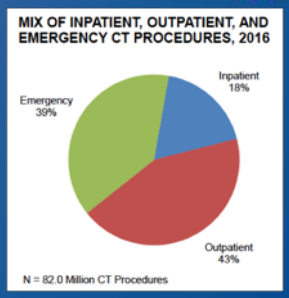
1 Sv = 100 rem
10 mSv = 1 rem

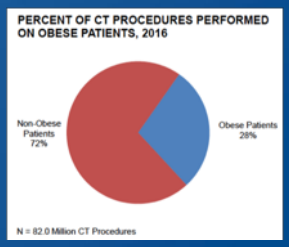
Hall EJ, Ped Radiol, 2002

Status of current CT practice

CT Procedures Mix in US



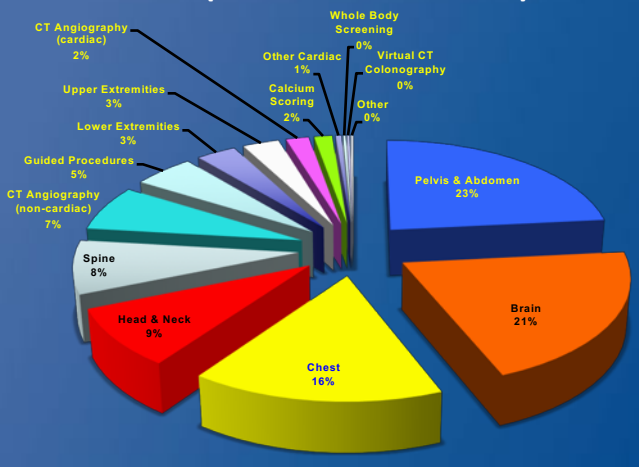




IMV Benchmark 2016

Categories of CT procedures

(78.7 million in 2015)



HCAP: ~76% of all CT procedures

IMV 2015

Radiological procedures performed in children (0-15 years) in health-care level I countries

Regions examined	Percentage of all the examinations of this type in each of these anatomical regions that are performed in children < 15 years
Radiography	
Head/skull	19%
Extremities	15%
Abdomen	13%
Spine AP (cervical, thoracic or lumbar)	7–12%
Chest (PA and lateral)	9–12%
Pelvis/hips	9%
Other radiographic procedures	3–9%
CT Scans	
CT head	8%
CT abdomen	4%
CT thorax	5%
CT spine	3%

[a] UNSCEAR (2010) defined health-care level I countries as those in which there was at least one physician for every 1 000 people in the general population.

Source: Adapted, with permission, from UNSCEAR (2013)

UNSCEAR 2013

What can we do to minimize risks?

Optimization!

What should we do to reduce radiation risks?

- Explore using Ultrasound and MRI prior to ordering CT exam
- Ensure CT exam is absolutely necessary
- Discuss options to reduce dose
- Radiologists
  - Need to understand radiation doses
  - Review requests for high dose studies
  - Use dose optimized protocols

How can we minimize radiation risk to my child?

- Image when there is clear medical benefit
- Use amount of radiation exposure based on size of the child
- Image only indicated area
- Avoid multiple scans
- Use alternative diagnostic studies if possible

Practical steps to minimize radiation risks

- Patient selection
- Triaging CT protocols
- Tube current modulation
- Tube voltage selection
- Collimation
- Focus on repeat patients – limited scans
- Radiation Risks vs Other Risks (sedation, contrast)

Scan Parameters impacting Radiation Dose and Image Quality in CT

Primary Factors

- Tube Current (mA)
- Tube Voltage (kV)
- Scan Time
- Pitch
- Scan Acquisition Type

Secondary Factors

- Scan Field of View (SFOV)
- Display Field of View (DFOV)
- Beam Collimation
- Reconstructed Slice Width
- Reconstruction Interval
- Reconstruction Algorithms

Other Factors

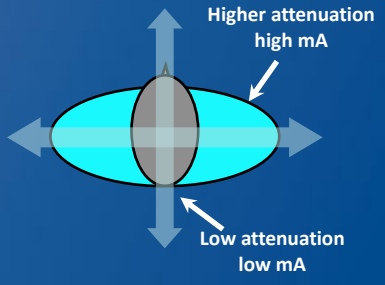
- Patient Size
- Patient Motion
- Geometry and Detector Efficiency
- Training and experience

Mahesh M. MDCT Physics: The Basics…, Lippincott, 2009

Tube Current Modulation

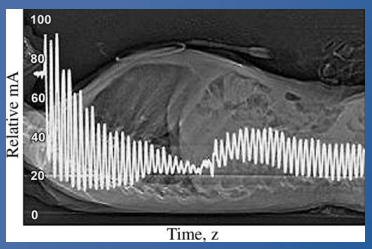
Tube Current Modulation

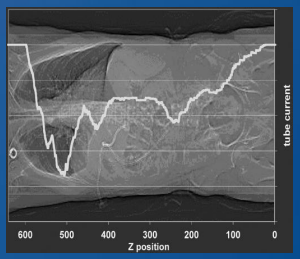
- X-ray attenuation lower in AP and higher in lateral projection



- However, CT doses are uniform on the surface and decreases radially towards center
- Various dose reduction options are possible

Spatial Dose Modulation





McCollough, C. H. et al. Radiographics 2006

- Body protocols
- Tube current variations based on spatial variations (patient thickness)

How effective is dose modulation?

- Dose modulations is effective for most adult and pediatric protocols
- Studies have shown to reduce dose
  - Chest CT - 14% to 38%
  - Abdominal CT – 20% to 35%
  - Head CT - ~35%

Singh S, et al. JACR, 2011

Tube Potential Selection

Tube Voltage

- Most CT applications use 120 kV, however, for thin patients and pediatric patients lower tube voltages such as 100 kV, 80 kV and 70 kV are recommended
- Lower tube voltage decreases radiation dose and also improved image contrast
- For obese and thicker anatomy, higher tube voltage (140 kV) is advantageous

Tube Voltage (kV)

Decreasing tube voltage significantly reduces dose typically (KV^2)

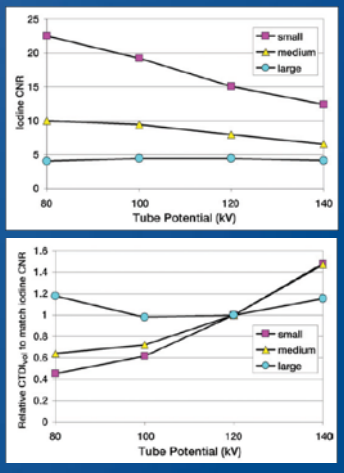
- 140 KV – 2.3 mSv
- 120 KV – 1.6 mSv
- 100 KV – 1.0 mSv
- 80 KV – 0.5 mSv

kV ↓ = dose ↓

IAEA

Tube Voltage Modulation

- Lower tube voltage improves image contrast and reduce dose
- As tube voltage decreases, tube current may have to be increased to maintain image noise

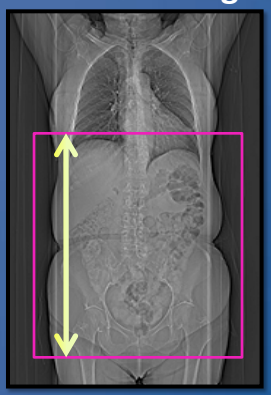


Radiology 2012; 264(2): :567-580

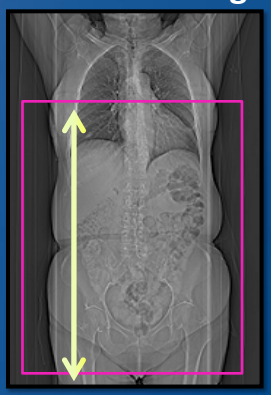
Collimation

Comparing scan ranges

Correct Z- range



Incorrect Z- range



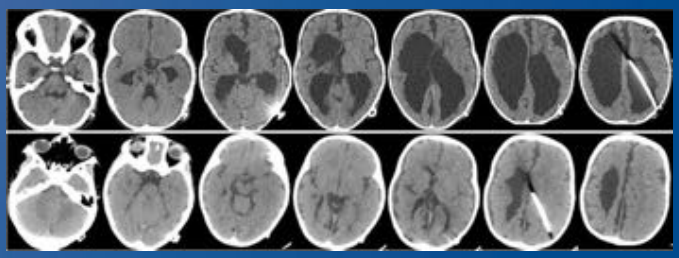
- Decreasing scan range along Z axis of patient will directly reduce patient dose

Limited Sequence versus Entire Scan

- Scans limited to region of interest for evaluating clinical conditions during repeat studies
  - Example: Follow-up of shunt position in hydrocephalous patients
  - No significant difference in evaluation between entire head scan versus limited head scans, limited scans were performed

Images from limited sequence head CT scan during follow up

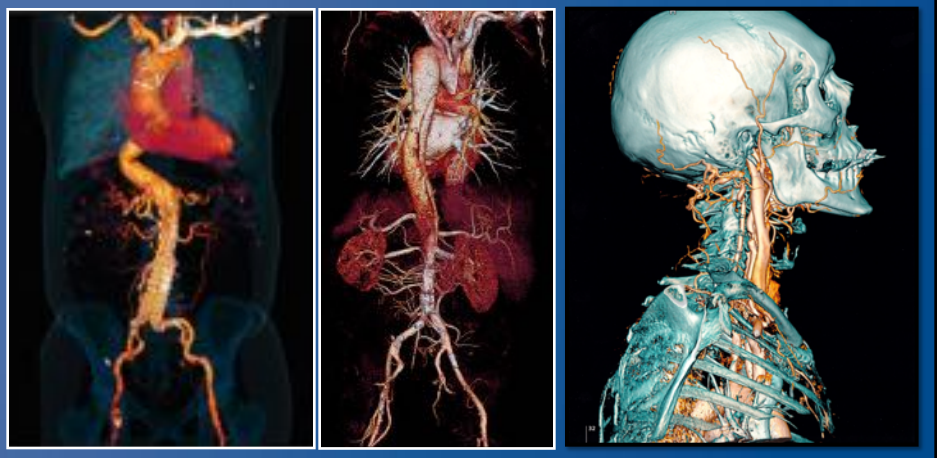
Images at similar location from entire head CT scan



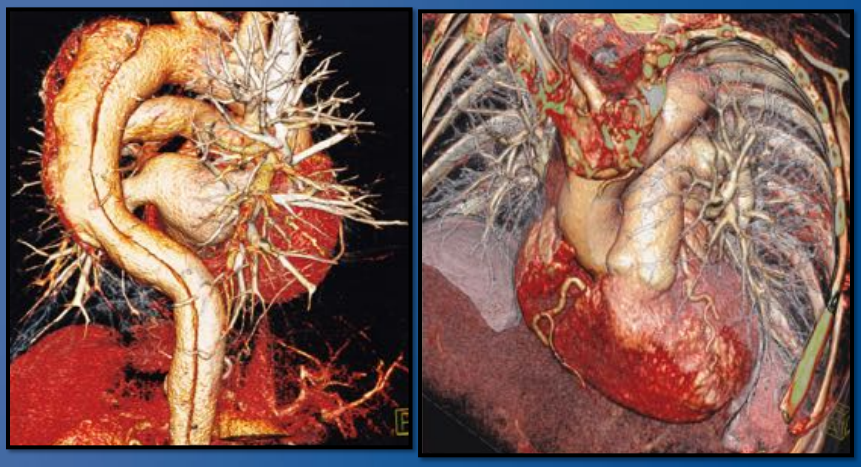
J Neurosurgery: Pediatrics. Sept, 2013

What is now possible?

Possibilities with modern CT scanners



Siemens



Routine AP scan*

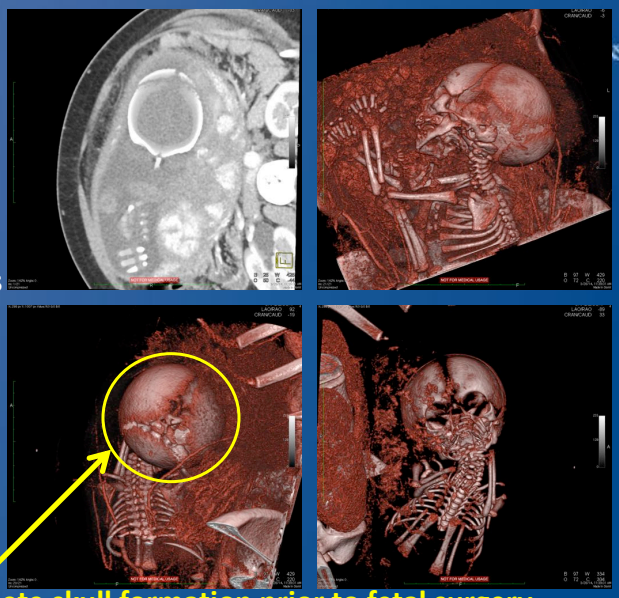
kV: 120 kV

mAs: 243/290 eff mAs

CTDIvol: 16.5 mGy

DLP: 347 mGy-cm

Eff Dose: 5.2 mSv



Identifying incomplete skull formation prior to fetal surgery

Johns Hopkins on Siemens FLASH

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Benefits vs Risks!

Factors Influencing Risk Perception

How the experts perceive risk		How the public perceive risk
Hazard x exposure x susceptibility		Hazard + [fear, anger, outrage]

World Health Organization, 2016

Benefits of CT exams

- MDCT is faster than older CT scanners, reducing need for sedation and general anesthesia
- Faster CT allows children to hold their breath
- CT scanning is painless, noninvasive and accurate
- Ability to image bone, soft tissue and blood vessels all at same time
- In emergency room settings, CT exams are fast, simple and reveal internal injuries and bleeding quickly enough to save lives

Benefits of CT exams

- CT scans shown to be cost-effective imaging tool
- CT is less sensitive to patient movement than MRI
- CT can be performed even if a child has medical device of any kind, unlike MRI
- Radiation dose used for most CT exams should have no immediate side effects

Benefits of CT imaging for Pediatric Patients

- Quick
- Fast
- High quality images
- Minimize contrast use
- Seldom needs sedation
- Should not be avoided just for radiation sake and perform MRI, since MRI has its own issues

What will be a child experience during and after the procedure?

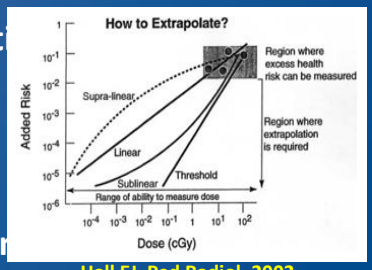
- CT exams are generally
  - Painless
  - Fast
  - Easy
  - Patient needing to "lie still" is reduced
- Parent can often stay inside CT room with apron and comfort child so as to make experience good

Risks of CT

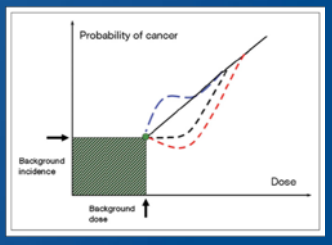
- Allergic reaction to contrast materials such as iodine is rare but manageable
- Since children are more sensitive to radiation, they should have CT study only if it is essential for making diagnosis
- Should not repeat CT studies unless absolutely necessary!

Uncertainty in Cancer Risk Estimation

- Typical doses for most diagnosti medical imaging procedures ranges from
  - <0.1 mSv to 30 mSv
- No strong evidence for long ter cancer risk
- Uncertainty has muddled discussion on radiation risk



Hall EJ, Ped Radiol, 2002



JNM 2011; 52: 1240-1251

Image Gently®

- Increase awareness for need to decrease radiation dose to children and adults with medical x-ray imaging

CT

Image Wisely®

Fluoroscopy

Take Home Points

- Use CT dose modulation
- Select low tube voltage
- Collimate to region of interest
- Ensure image quality is not jeopardized at cost of reducing dose

Conclusions

- Advances in CT technology and user awareness are paving way to performing much pediatric CTs at much lower dose
- Justification and Optimization are critical to minimize risks for pediatric patients
- Education and Awareness of Benefits and Risks of CT imaging is key for optimal use