CT Dose Reduction Strategies and the Pediatric Patient

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Review of motivation

- Winter 2001
  - Articles in AJR on Pediatric CT dose issues
    - risk analysis (Brenner)
    - survey of pediatric techniques (Paterson)
    - suggested pediatric CT techniques (Donnelly)
- National spotlight
- USA Today article

01/22/2001

CT scans in children linked to cancer

By Steve Sternberg, USA TODAY

Each year, about 1.6 million children in the USA get CT scans to the head and abdomen — and about 1,500 of those will die later in life of radiation-induced cancer, according to research out today.

What's more, CT or computed tomography scans given to kids are typically calibrated for adults, so children absorb two to six times the radiation needed to produce clear images , a second study shows. These doses are "way bigger than the sorts of doses that people at Three Mile Island were getting," David Brenner of Columbia University says. "Most people got a tenth or a hundredth of the dose of a CT." ….…

"Effect of low doses of ionizing radiation in infancy on cognitive function in adulthood"

- 1930-1959, 2551 boys under 18 mos. rec'd radiation therapy for cutaneous hemangioma
- Estimated therapy dose, assumed CT head scan dose of 120mGy (!)
- Relation between high school attendance, cognitive tests and therapy dose received.
- Statistical difference in outcome w/respect to therapy dose.

BMJ 2004; 328:19-24

- No control group
- Significant decrease in high school attendance for over 100 mGy group
- Pediatric CT head dose ??
- No discussion of dose distribution differences in therapy & CT

Hall, Adami, Trichopoulos, et.al.

Triple Whammy

- Children more sensitive to radiation than are adults
- Children have longer to develop radiation induced diseases
- More CT exams are performed on children every year

Approaches to reducing dose in CT exams:

- Decrease mA
- Decrease time (sec)
- Increase pitch
- Decrease kVp

Decreasing mAs

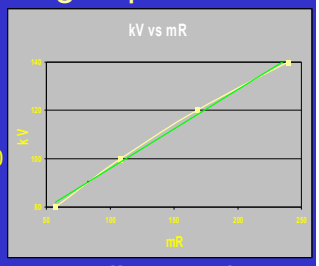
- Dose scales linearly with mAs
  - Reduce mAs by half, reduce CT dose by half
- Noise generally increases when mAs is reduced (Low-Contrast detectabilty)
- Depending on the imaging task, radiologists may be able to 'read through' a large amount of image noise.

Increasing Pitch

- Dose scales linearly with pitch
- (Axial CT Dose)/pitch = Helical CT Dose
- If pitch = 1.5, CT dose reduced by 1/3
- If pitch = 0.75, CT dose increased by 1/3
- Effectively increases slice thickness
  - May affect image noise
  - May increase partial volume averaging

Decreasing kVp

- Dose scales almost linearly with kVp in the 80 kVp to 140 kVp range
  - Reduce kVp from 140 to 80, dose drops by factor of 4



- kVp changes the penetration efficiency of x-ray photons
  - Subtle changes in tissue density
  - Potentially large beam hardening effects

Recent Pediatric CT Research

Goal: Find a compromise between CT dose and image quality within the comfort level of radiologists and clinicians.
AJR 182: 849-859, 2004.

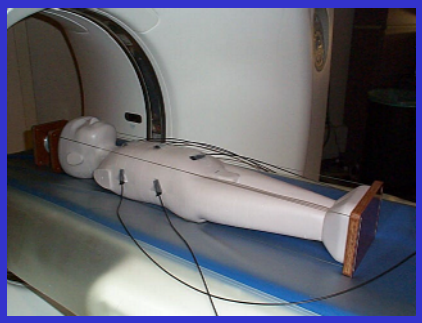
- Develop a logical strategy for combining technique changes (mAs and kVp) to formulate a Pediatric CT protocol
- Using multi-detector CT (4 – channel)
- Using realistic phantoms

Anthropomorphic Phantoms

Surface Dose Detectors

- Tiny crystal emits light when irradiated
- Individual monitor via fiber optic cable
- Developed for fluoroscopy

Surface Dose Measurement Set Up



Chest & Abdomen/Pelvis for 1 yr old

Skin Dose Measurement

Abdomen/Pelvis for Adult

CT Scanner

GE LightSpeed Plus

4-channel
0.5 sec rot.

Calibration of surface detectors

Skin dose monitor output calibrated to standard CT ion chamber using in-air measurement for each monitor, all kVp stations.

(In CT gantry)

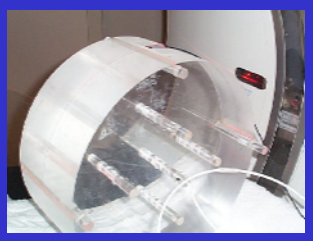
Standard $CTDI_{100}$

16-cm CTDI phantom

32-cm CTDI phantom

Peripheral locations ONLY

f-factor = 0.93 cGy/R



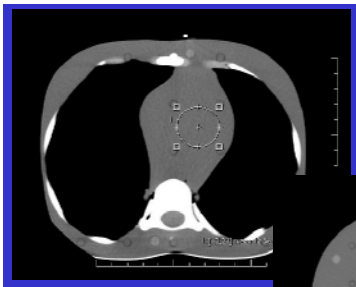
Measurements

AXIAL CT Radiation Dose:

- Rotation time held constant at 1 sec
- 4 x 5 mm detector configuration
- mA varied: 50, 100, 200, 240
- kVp varied: 80, 100, 120, 140 (abd.)

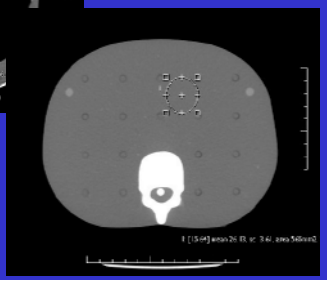
Image Quality:

- From resulting images – noise estimates (std. dev.)

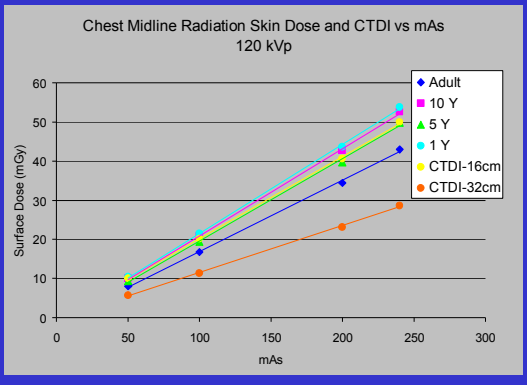


Noise samples (standard deviation)

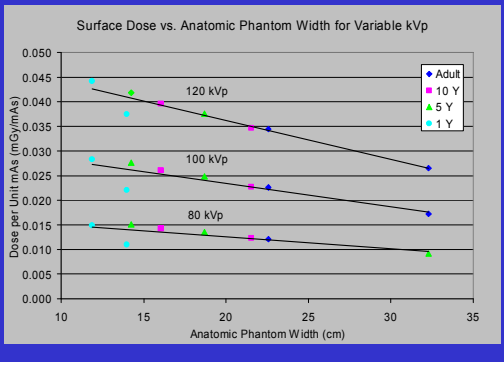
Four tissue types



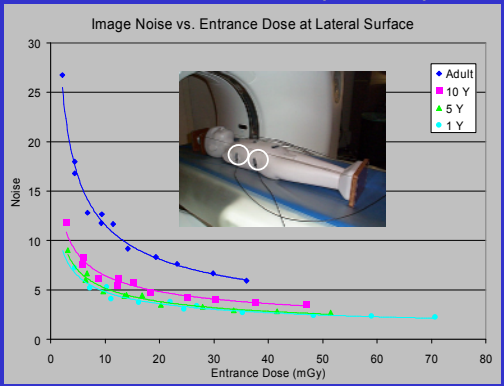
How does CTDI compare?



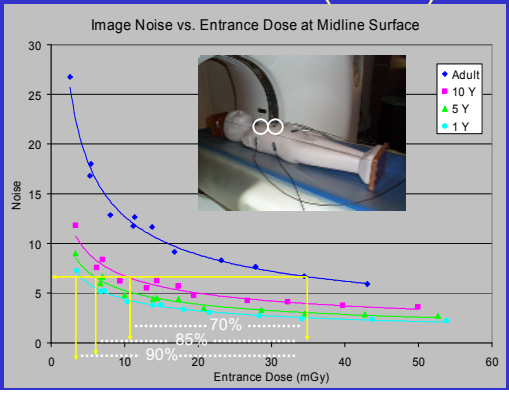
Dose is dependent on patient size

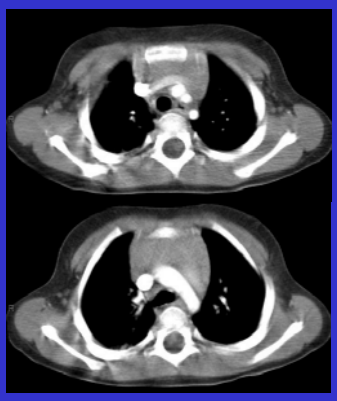


Noise vs Dose (Chest)



Noise vs Dose (Chest)





21 month old
cervical
neuroblastoma

chest exam
80 kVp
160mA
0.5 sec
4 x 5 mm
pitch 1.5

4 year old, Stage V Renal Wilms' Tumor
Image Thickness constant at 5mm

Dose ~
29 mGy

120 kVp, 128 mAs, 4 x 3.75 mm, pitch = 1.5

80 kVp, 120 mAs, 4 x 5 mm , pitch= 1.5
Dose ~ 9 mGy (70% reduction)

100 kVp, 128 mAs, 4 x 5 mm, pitch = 1.5
Dose ~ 18 mGy (40% reduction from initial scan)

Caveats...

- A few clinical examples are not proof of validation of this approach
- Matching image noise from adults to pediatric images - appropriate?
- Noise difference in axial to helical images

Color Coding for KIDS

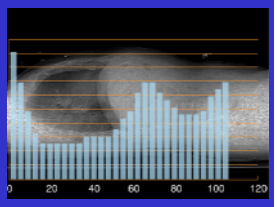
Weight-Based Pediatric Protocols

mA modulation approaches

- Stepping toward tool similar to photo-timing for pediatric CT
- Requires some acceptable level of image quality – noise – be established
- Usually demand an mA range be set to operate within

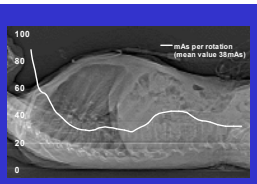
GE approach

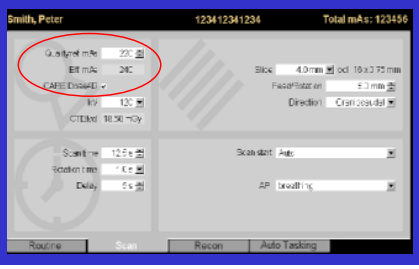
- Requires single scout
- User defines:
  - 'Noise Index' target
  - mA range (min, max)
- 'Noise Index'
  - Std.Dev. of water phantom w/ std. algo.
- Adjusts for: anatomic variation, kVp, image thickness, mAs, pitch.



Siemens Approach

CARE Dose4D





So, how do YOU proceed?

- Start from existing protocols using similar scanners (cards)
- From these starting points, construct technique charts:
  - Small/medium/large children?
  - Based on Age, Weight, CSA, DFOV, ?
  - Separate chart for each scanner platform

What we can expect in the future?

- More of the same… (Pedi CT focus)
- Adjust technique for both very small and very large adult patients?
- Accumulated CT dose monitoring?
- Technique designed for imaging task?

Any Questions?

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- Please complete the evaluation forms