Reducing Radiation Exposure in Pediatric CT – A Shared Responsibility

M. Khatonabadi, T. Hall, I. Boechat, S. Muir, C. Cagnon, M. McNitt-Gray, S. Borgheian, M. Woo

David Geffen School of Medicine at UCLA, Los Angeles, CA

Purpose

- To describe an **ongoing quality improvement program** to reduce radiation dose to pediatric patients. In this program **radiologists**, **technologists**, and **medical physicists** worked together to **standardize and implement new protocols**, **follow compliance** and **ensure diagnostic content** of the new protocols.
- This Quality Improvement Program used **even more aggressive dose reduction for pediatric patients** than proposed by Image Gently Campaign by **adjusting kVp and Quality Reference mAs by weight** as well as using **tube current modulation (TCM, e.g. CareDose4D from Siemens).** This required more input from team members to ensure that protocols were correctly implemented and that acceptable image quality was obtained for all studies.

Methods

- New weight based **pediatric chest and abdomen/pelvis CT scan protocols** adapted from Kim et al (below) were implemented for use in inpatient and outpatient practices.

Weight	Chest		Abdomen / Pelvis	
	kVp	Qual. Ref. mAs	kVp	Qual. Ref. mAs
< 5 kg	80	45	80	45
6-15 kg	80	55	80	55
16-60 kg	100	55	100	65
> 61 kg	120	55	120	65

Kim J-E, Newman B. Evaluation of a Radiation Dose Reduction Strategy for Pediatric Chest CT. Am. J. Roentgenol. 194(5): 1188-1193.

Quality reference mAs: A parameter defined by Siemens to represent the image quality that would have been achieved if a **fixed tube current** exam had been performed at that specific mAs level on an **average sized patient**. It is set by the user to select the desired image quality for a **tube current modulated exam**.

- These protocols were approved by the **radiologists** and implemented into the scanners.
- **Technologists** were educated to use the appropriate kVp and quality reference mAs based on the patients' weight.
- Patients' protocol and raw data (projection data collected by the detectors) were collected at the end of each week by the **physicists** to generate a spreadsheet with scan information such as *scan date*, *date of birth*, *scan type*, *kVp*, *quality reference mAs*, *average effective mAs*, *collimation*, *rotation time*, and *weight* for further analysis.

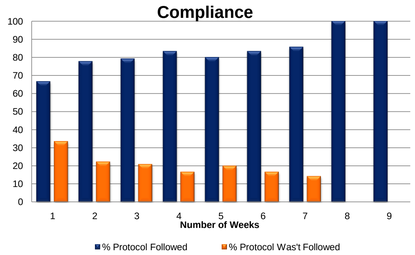
Pt. MRN	Scanner	Scan Date	Weight	DOB	Age	Operator	Exam	KVP	Quality ref. mAs	effective mAs	Collimation	Rotation time	According to the protocol?	Average mAs > Quality ref. mAs	Reader 1	Score 1) OK 2) Noisy	Recons. Slice Thick (mm)	Reader 2	Score 1) OK 2) Noisy	Recons. Slice Thick (mm)
####	Sensation 64	30-Sep-09	97kg	#####	18	xxxx	Chest w/c	100	55	249	1.2	0.5	NO, kVp shoul	YES	xxxx	1	3mm	xxxx	a bit noi	3mm
####	Sensation 64	30-Sep-09	97kg	#####	18	xxxx	AP w/c	100	65	250	1.2	0.5	NO, kVp shoul	YES	xxxx	1	5mm	xxxx	1	5mm
####	Sensation 16	1-Oct-09	68kg	#####	13	xxxx	Chest w/c	120	55	165	1.5	0.5	YES	YES	xxxx	1	3mm	xxxx	1	3mm
####	Sensation 16	1-Oct-09	9kg	#####	1	xxxx	AP	80	55	80	1.5	0.5	YES	YES	xxxx	1	3mm	xxxx	1	3mm
####	Sensation 16	24-Sep-09	13kg	#####	1	xxxx	AP	80	55	75	1.5	0.5	YES	YES	xxxx	1	3mm	xxxx	1	3mm
####	Sensation 16	24-Sep-09	13kg	#####	1	xxxx	AP delay	80	55	77	1.5	0.5	YES	YES	xxxx	1	3mm	xxxx	1	3mm
####	Sensation 64	6-Oct-09	54.5kg	#####	12	xxxx	AP w/c	100	65	165	1.2	0.5	NO, qual. Ref	YES	xxxx	1	5mm	xxxx	1	5mm
####	Sensation 64	6-Oct-09	63.6kg	#####	15	xxxx	AP w/c	100	65	250	1.2	0.5	NO,kVp shoul	YES	xxxx	1	5mm	xxxx	a bit noi	5mm
####	Sensation 64	6-Oct-09	15kg	#####	2	xxxx	Chest	120	55	84	1.2	0.5	NO, kVp shoul	YES	xxxx	1	3mm	xxxx	1	3mm
####	Sensation 64	5-Oct-09	55kg	#####	18	xxxx	AP	100	65	172	1.2	0.5	NO, qual. Ref	YES	xxxx	1	5mm	xxxx	1	5mm

Methods

- Weekly scan data was then analyzed for protocol adherence to established weight based parameters and feedback provided to technologists to improve **compliance**.
- To ensure **adequate diagnostic content** of new protocols, **27 cases** were selected at random and each was independently reviewed by **two pediatric radiologists**, who were blinded to both the scan parameters and each other's ratings.
- The radiologists only evaluated the image noise and either identified the case as **acceptable** or **noisy**.
- The physicists investigated the cases that were rated as noisy and gave feedback to the group.

Results

- The adoption of the new protocols was very rapid, after the first month of the implementation the compliance was over **80% by all shifts**, in both inpatient and outpatient settings; by the end of the last week of data collection it reached **100%.**



- Pediatric Radiologist analysis of **the 27 selected randomized** cases, ranging **from 4 months to 18 years of age**, demonstrated agreement between both radiologists in all cases and two of the 27 were rated as too noisy.
- Physicist analysis of the two noisy cases revealed that one had been scanned using the **adult size reference** but technique factors had been modified to those appropriate for **pediatric patients**.
- However, because tube current modulation was based on **adult size reference** with different reference mAs, this resulted in a (further) **decrease** in tube current by the algorithm to compensate for the **"small"** size of the patient which resulted in a very noisy image.

Figure 1: A thoracic scan performed to evaluate interstitial lung disease in a pediatric patient which was rated as noisy by a radiologist. The correct *pediatric chest protocol (100 kVp and 55 mAs)* was used but the *adult size reference (70kg)* was inadvertently chosen for this scan. As a result the scanner compensated for the *small size* of the patient and so *decreased* the tube current. The average effective mAs in this scan was 32 (lower than quality reference mAs).

Results

- Furthermore it was observed that in **93%** of all the collected data the **average effective mAs** was **greater** than the **quality reference mAs**.
- When new protocols were compared to the old ones, it was observed that just by **reducing the kVp form 120 to 100**, the **$CTDI_{vol}$** reduced by almost a factor of **2**.

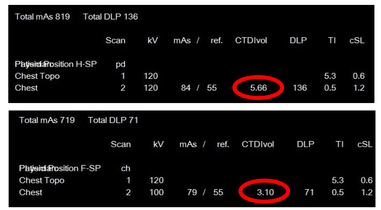
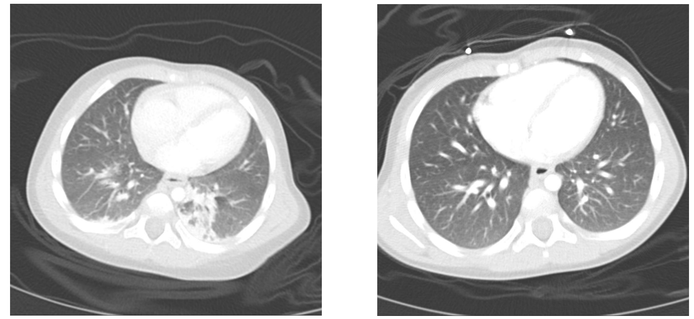


Figure 2: Patient protocols of a patient captured at two different time points. The upper protocol shows the resulting *$CTDI_{vol}$* value of *5.66* from 120 kVp and 55 mAs (quality reference mAs) and the lower protocol shows a *$CTDI_{vol}$* of *3.10* from 100 kVp and 55 mAs.

Figure 3: Two chest scans of the same patient at two different time points. The image on the *left* was acquired using an *older pediatric chest protocol*, the image on the *right* was obtained using the *newly implemented pediatric chest protocol* (quality reference mAs of 55, 100 kVp and tube current modulation, CareDose4D from Siemens).



Discussion and Conclusions

- Reducing radiation dose to pediatric patients while maintaining image quality is a challenging task most effectively handled as a **shared responsibility** of **radiologists**, **technologists**, and **medical physicists**. This is especially true when using technical features such as the **tube current modulation** which must be well understood to implement appropriately.
- Technologist training and quick feedback, resulted in **rapid compliance** by all shifts.
- Pediatric radiologists determined that techniques provided **diagnostic image quality**.
- Medical Physicists assisted in implementation and evaluation of techniques.
- When properly used (correct patient size reference , patient placement), Tube Current Modulation schema like CareDose4D, is a form of automatic exposure control that **tailors** the mAs to patient size to maintain a desired image quality; **therefore, an increase in mAs is to be expected in patients larger than the reference size**.
- An institution wishing to reduce dose via TCM should instead focus on selection of Quality Reference mAs; adjusting downward to reduce actual patient dose while balancing the need for appropriate diagnostic image quality.

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