CT Dose Reduction in Pediatric Patients

By Kelly Firestine, RT(R)(CT)(M)

EXECUTIVE SUMMARY

- CT is an incredibly valuable imaging tool, but there are unique concerns with pediatric patients, including the increase of sensitivity to radiation, increase risk of cancer formation with the longer life expectancy, and larger radiation doses received when adult CT settings are used.
- With a grant from the AHRA and Toshiba Putting Patients First program, Memorial Hermann Healthcare System was able to better educate technologists and physicians which helped in reducing radiation dose to pediatric patients by as much as 60%.
- Standardizing CT protocols and properly training staff are very important. But to make improvements on a larger scale, strategies for tracking compliance and providing feedback must be used.

Many clinical decisions are based upon information derived from imaging procedures, so ensuring optimal image quality is crucial to the patient, clinician, and the efficiency of the healthcare system. The role of our computed tomography (CT) departments in providing safe, quality service to achieve this goal is of paramount importance. Last year, the Memorial Hermann Healthcare System in Houston, TX performed over 14,000 pediatric CT scans. The Toshiba and AHRA Putting Patients First grant helped us further our focus on pediatric CT quality and safety. Using the grant to educate our technologists and physicians has helped us succeed in reducing radiation dose to our pediatric patients by as much as 60%.

Soon, medical imaging, with CT scans as the largest contributor, will approach or potentially exceed background radiation as the single largest source of radiation for humans.[1] Research clearly indicates children are more sensitive to radiation and have a lifetime to manifest those changes.

CT is an extremely valuable, diagnostic instrument. But this tool is only valuable if the exams are performed properly by technologists. On the contrary, exams performed improperly could potentially harm patients. Also, if there are no well defined standards for optimal imaging techniques, clinically important information may be missed or patients may suffer long term effects. Standardizing CT protocols and properly training staff are very important. But to make improvements on a larger scale, strategies for tracking compliance and providing feedback must be used.

Radiation doses in pediatric imaging have become a very important topic, especially when performing pediatric CT. Although CT is an incredibly valuable imaging tool, a few unique concerns with pediatric patients are present. These concerns include the increase of sensitivity to radiation, increase risk of cancer formation with the longer life expectancy, and larger radiation doses received when adult CT settings are used. The American College of Radiology has noted, "Because they have more rapidly dividing cells than adults and have longer life expectancy, the odds that children will develop cancers from x-ray radiation may be significantly higher than adults."[2] It has been estimated by the National Research Council's Committee on the Biological Effects of Ionizing Radiation those children less than 10 years of age are several times more sensitive to radiation than middle-aged adults.[3] We recognize unnecessary radiation may be delivered when CT scanner parameters are not appropriately adjusted for patient size. When a CT scan is performed on a child with the same technique factors that are used for a typically-sized adult, the child receives a significantly larger effective dose than the full-sized patient.[4]

Every institution should evaluate their CT practices and try to emphasize the importance of keeping the radiation doses as low as reasonably achievable (ALARA) while still maintaining good diagnostic image quality. By standardizing pediatric exposure techniques, placing more emphasis on proper education and training of CT staff, as well as regular auditing of compliance we have shown good image quality can be obtained with a reasonable reduction in radiation dose.

Baseline Data

A case series study of CT scans on children and adolescents found in the Memorial Hermann archives was retrospectively performed. From four separate months, random samplings of the pediatric CTs performed at each facility were documented. From this documentation, the following data were compared: facility, patient age and weight, type of study, kVp, mAs, exposure time, pitch, the $CTDI_{vol}$ (volume computed tomography dose index, the average dose delivered to the scan volume for a specific examination), and dose length product (DLP) when available. The results were then compared to the recommended doses from the American College of Radiology, the Society for Pediatric Radiology, and the Image Gently™ campaign (an inititaive by the Alliance for Radiation Safety in Pediatric Imaging).

This evaluation of our current practices in regards to pediatric CT showed us that the overexposure of children or small adults can easily go unrecognized by radiologist and technologist because the image quality is not compromised or can even be improved. We recognized a need for continuous self monitoring and system wide standardization regarding pediatric patient techniques in CT.

Improvement Process

Our pediatric dose reduction project followed this systematic approach:

1. Analysis of current practices
2. Standardization of protocols
3. Implementation of policies and procedures
4. Education and training
5. Measuring performance
6. Reporting results
7. Continued quality improvement

The first part of the improvement process was to develop standardized pediatric CT protocols. A set of pre-programmed weight and age protocols was developed for pediatric exams by using the recommendations from the Image Gently™ campaign as a starting point.[5] Under the supervision of pediatric radiologists throughout the system and a professor of pediatric radiology for the University of Texas, the scan techniques were reduced in an incremental fashion to avoid unacceptable deterioration in image quality. Gradually, the protocols were adjusted and the CT images were checked against the image criteria given in the European Commission for Quality Criteria for Computed Tomography and against the American College of Radiology's Image Quality Guidelines.[6-8] Current scan protocols are now felt to be approaching the optimum and any further attempts at dose reduction would necessitate a more in depth analysis of image quality. Examples of some CT protocols are listed in Table 1.

TABLE 1. Project budget for VWCs EHR implementation. (Note: This budget does not reflect an endorsement of any vendor or system, it is only one example of an EHR implementation in a multi-facility ambulatory environment.)

WEIGHT kg	TIME	SPEED	Pitch	mA	kVp	SLICE	INDEX	SFOV	Dose
0-10 kg	0.5	27.5	1.375:1	60-80	120	3.7mm-5mm	3.7mm-5mm	small	2.2mSv
10-20 kg	0.5	27.5	1.375:1	90-100	120	5mm	5mm	small	3.2mSv
20-30 kg	0.5	27.5	1.375:1	120-140	120	5mm	5mm	Large	4.1mSv
30-40 kg	0.5	27.5	1.375:1	140-160	120	5mm	5mm	Large	4.8mSv
40-50 kg	0.5	27.5	1.375:1	150-200	120	5mm	5mm	Large	5.7mSv
50-75 kg	0.5	27.5	1.375:1	220-240	120	5mm	5mm	Large	7.3mSv
75kg- 100kg	0.8	27.5	1.375:1	270-330	120	5mm	5mm	Large	8.6mSv

BOX 1. Pediatric CT dose and image quality audit form.

Pediatric CT Dose and Image Quality Audit

MR #:	Age of patient: :	Type of exam:
Patients documented weight: kg		Patients estimated weight*: kg
Date of exam:	Time of exam:	
Facility:	Type of Scanner:	
Reason for exam:	Ordering Physician:	
Technologist's initials:	Auditor's initials:	Audit Date:

	Scan Sequence (Scout)	Scan Sequence 2	Scan Sequence 3
kVp			
mA			
Time per rotation (s)	NA		
Display FOV (cm)/ Scan FOV (Phantom)	NA		
Reconstruction Algorithm	NA		
Axial (A) or Helical (H)	AXIAL		
Collimation	NA		
Pitch/Table Speed	NA		
Contrast media used (concentration and volume)	NA		
CTDI vol	NA		
Dose Length Product	NA		

Evaluation Criteria	Acceptable	Not Acceptable	Comments	Score
Exam technique and Dose**:				50
Noise:				15
Area scanned: (i.e. positioning, over scanning,)				25
Dose report in PACS				10
Total score				
Was the patient's weight documented?	Yes	No		Pass/ Fail

Corrective action required: Yes No
Corrective action plan:
Comments:

*If no weight is documented in Pacs, the patients weight will default to the 50 percentile weight for age as noted on the growth charts developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion.

** Dose is determined by CTDIvol

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These standardized protocols were programmed in all CT scanners and password protected to prevent any unauthorized changes. Along with these protocols, new polices were implemented such as saving the patient dose profile page with the study and when not to proceed with a study due to patient motion.

Education

The next piece of the improvement process was education. Not only do technologists performing the studies need to be educated, but also the physicians ordering the exams. First, an all day seminar was held for technologists. Representatives from each of the 21 CT departments were invited to learn more about radiation dose. Technologists spent the day learning about x-ray production, biological effects of radiation, and how to use proper scan techniques to achieve optimal image quality. To provide additional incentive to attend this very important seminar, technologists were rewarded with continuing education credits from the ASRT for their participation. The seminar was also professionally recorded and set up to view as web based training for those unable to attend. An educational handout was also created for referring physicians to inform them of goals and give them resources when referring a child to one of our imaging centers.

TABLE 2. ACR CT Accreditation Dose Pass/Fail Criteria and Reference Levels Examination

	Pass/Fail Criteria	Reference Levels
	$CTDI_{vol}$ (mGy)	$CTDI_{vol}$ (mGy)
Adult Head	80	75
Adult Abdomen	30	25
Pediatric Abdomen (5 year old)	25	20

Compliance

The final part of the improvement process was the compliance audit. The pediatric CT dose audit is performed monthly on pediatric CT abdomens and head. The exams are scored, using a pediatric CT dose and image quality audit form (see Box 1). This form assigns a certain weight for each category. This audit not only monitors CT exams for reduced dose, but also for image quality. The goal is to achieve the lowest radiation dose while still maintaining good image quality.

The dose threshold for the audit is set at 20 mGy for CT abdomen. This threshold is based on the American College of Radiology's Pass/Fail criteria (Table 2).[9] The dose threshold for CT head is 70 mGy. This number was derived from the ACR's adult head threshold since no pediatric head threshold has been set by the ACR yet. Anything that exceeds these numbers is considered "over-dose" by ACR. These numbers are the national benchmark the audit is based on.

The results of this audit are presented monthly to the Memorial Hermann Imaging Council which is comprised of all the radiology directors and led by the CEO of Memorial Hermann's retail healthcare businesses, which includes 21 outpatient imaging centers, 8 breast care centers, 10 ambulatory surgery centers, 25 sports medicine and rehabilitation centers, and 19 diagnostic labs. The audit brings attention to areas in which improvement is needed. The audit also lets the technologists know they will be held accountable for quality on the studies they perform. Awareness of this very important issue has been kept on the forefront by this audit and feedback process. The audit shows we are diligent in our continued success in lowering pediatric CT dose. In the last year, not only has each department exceeded the audit score goal of 98%, but we have actually achieved 100% scores system wide for seven out of the last 12 months. We will continue to monitor monthly to ensure compliance is ongoing.

Documented Improvement Outcomes

Pediatric head CT protocols are chosen by patient's age due to differences in skull formation. Figure 1 demonstrates the monthly average $CTDI_{vol}$ (CT dose index) of all pediatric head CTs sampled before and after the implementation of the pediatric CT protocols. This graph demonstrates the decline in the $CTDI_{vol}$ for pediatric heads. A decrease is shown in dose for every age group, well below the dose audit threshold of 70mGy. Over the last year, the low pediatric CT head doses have leveled off and have been maintained throughout the year for each age group. A reduction in dose is shown over 50% for patients 0 to 5 years old and over 40% for patients 6 to 15 years old.

Pediatric abdomen CT protocols are chosen by weight. Figure 2 demonstrates the quarterly average $CTDI_{vol}$ of all pediatric abdomen CTs sampled. The current dose for patients 0 to 27 kg has been reduced 67% when compared to the doses delivered before the implementation of the standardized pediatric protocols. Also for patients 28 to 45 kg the dose has been reduced 60% and 45% for patients 46kg and greater.

Conclusion

CT scans help save the lives of children, but it is recognized that children are more sensitive to radiation. As a result, imaging departments must take steps to adjust imaging procedures to meet the special needs of children. This project has proven that good quality pediatric CT examinations can be obtained at a reasonable dose of radiation exposure, thus reducing the risk to children. The AHRA and Toshiba Putting Patients First Grant

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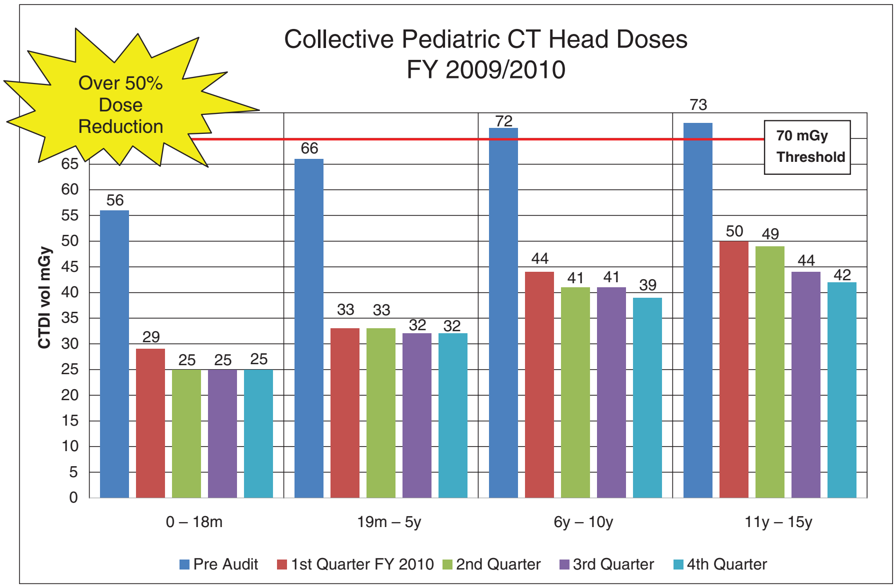

Figure 1 • Monthly average $CTDI_{vol}$

enabled us to educate our technologists and physicians, significantly contributing to the awareness of this important issue. By performing internal quality audits, creating system standardization, educating staff, and monitoring conformity, a cycle of continuous quality improvement is ensured.

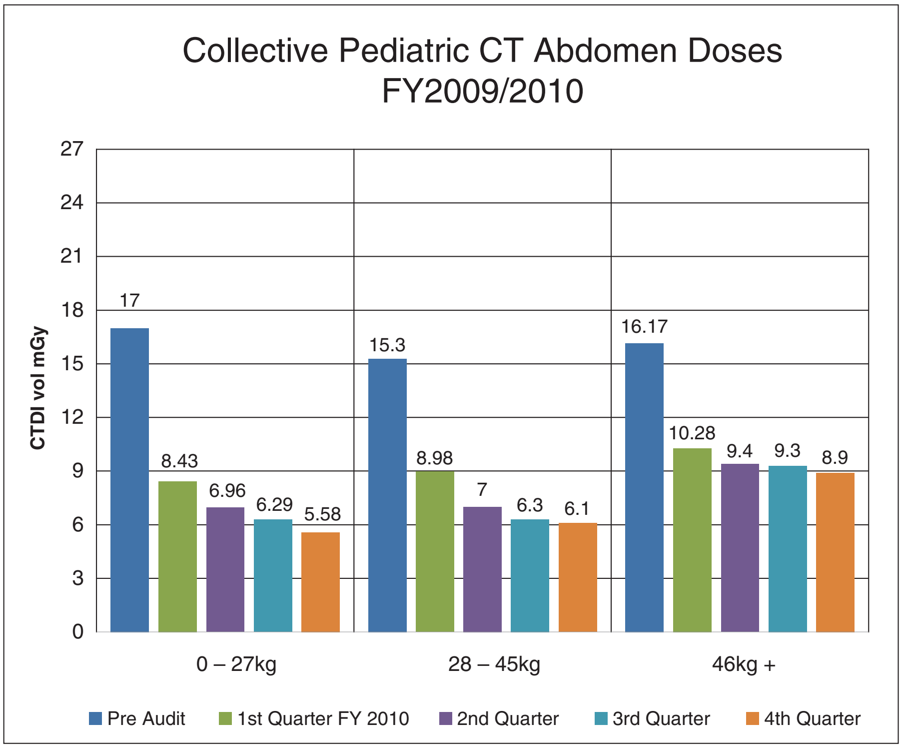

Figure 2 •

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