Use of a Dedicated Pediatric CT Imaging Service Associated With Decreased Patient Radiation Dose

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Purpose: The growing use of CT as a diagnostic imaging tool has led to increased concern over radiation dose, particularly in pediatric patients. The ALARA concept has been popularized in dose reduction. ALARA supports the use of low-dose, pediatric-specific protocols. Strict adherence to low-dose protocols can be challenging, particularly in a high-volume radiology department that scans both pediatric and adult patients. The aim of this study was to determine whether the relocation of pediatric radiologic services from a combined high-volume pediatric and adult hospital to a children's hospital improves compliance with adjusted lower CT exposure parameters and thus the estimated effective dose of radiation delivered to pediatric patients.

Methods: A retrospective review of abdominal and pelvic CT console dose and exposure parameter data on 495 patients from a combined pediatric and adult radiology department and subsequently 244 patients from a dedicated pediatric radiology department was performed. The console dose-length product was converted to estimated effective dose. Patients were divided into 1 of 8 weight categories for analysis.

Results: A statistically significant decrease in the estimated effective dose for abdominal and pelvic CT studies was observed in all but one of the weight categories at the pediatric radiology department compared with the pediatric and adult radiology department.

Conclusions: Imaging pediatric patients in a dedicated pediatric imaging department with dedicated pediatric CT technologists may result in greater compliance with pediatric protocols and significantly reduced patient dose. Conversely, greater scrutiny of compliance with pediatric dose-adjusted CT protocols may be necessary for departments that scan both children and adults.

Key Words: Pediatric, CT, ALARA, radiation dose

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INTRODUCTION

CT is one of the most valuable imaging tools available. Although the use of CT has led to important advances in medical treatment, it carries the notable disadvantage of radiation exposure and the potential risk for future malignancy. The utilization of CT as an imaging tool has increased dramatically in recent years, and this increase has been accompanied by a growing concern for patient safety with respect to radiation [1-3]. Pediatric patients are particularly at risk for adverse effects from overexposure to radiation because of several factors, including increased tissue sensitivity and longer life expectancy [3,4].

Furlow [5] reviewed the topic of radiation protection in pediatric patients and discussed it in light of the principle of ALARA. He listed some basic things to consider when contemplating the use of imaging in young patients (eg, need and benefit of the examination, image quality needed, careful positioning of patients). He also mentioned the need for periodic review of scan protocols to ensure that the ALARA principle is being scrupulously followed at the institution. However, strict adherence to low-dose protocols can be challenging, particularly in a high-volume imaging department that scans both pediatric and adult patients. The challenges of a combined department are multifactorial but are due primarily to a lack of strict

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adherence to pediatric protocols and inconsistent performing technologists, in our experience.

Before January 2011, a combined pediatric and adult radiology department (PARD) provided imaging to all pediatric patients at our institution. The development of a pediatric-specific radiology department (PRD), in conjunction with the opening of our new children's hospital, gave us a unique opportunity to compare our CT dose data. The purpose of this study was to determine if the use of a PRD, staffed by dedicated pediatric technologists, would result in lower radiation dosage given to patients.

METHODS

A retrospective cohort study design was used. The protocol was reviewed and approved by the Spectrum Health institutional review board. The research plan involved collecting CT dose data from abdominal and pelvic CT examinations performed on patients aged <18 years at Helen DeVos Children's Hospital from January 1, 2009, through January 1, 2010, and from January 1, 2011, through June 30, 2011. The earlier time period reflected CT examinations performed at the PARD, while the latter time period covered CT examinations at the PRD.

At both the PARD and the PRD, the CT technologists chose among 8 standardized dose protocols on the basis of patient weight (13-25, 26-31, 32-40, 41-49, 50-69, 70-89, 90-120, and >120 lb). All patients weighing <13 lb are scanned using the protocol for those weighing 13 to 25 pounds. These dose protocols did not change between the PARD and the PRD. For our analysis, we retrospectively reviewed each patient's CT imaging study dose page (in PACS; McKesson Corporation, San Francisco, California), CT scanner console data (GE Healthcare, Milwaukee, Wisconsin), and the hospital patient information system to collect the imaging exposure parameters (tube voltage, tube current), dose report (CT dose index [CTDI], dose-length product [DLP]), patient weight, age, phantom size, and protocol type. The DLP information was converted to effective dose using the method described by Thomas and Wang [6]. For comparison between the PARD and the PRD, these data were subdivided into the 8 patient weight categories of our CT scanning protocols.

Summary statistics were calculated for the data, with quantitative results expressed as mean ± SD. The Mann-Whitney *U* test was used to determine differences between the two groups (PARD vs PRD) for each of the weight categories. Significance was assessed at $P < .05$.

RESULTS

There were 495 patients in the PARD group and 244 in the PRD group. Tables 1 to 3 compare the CT effective dose, DLP, and CTDI between patients who were scanned at the PARD and those scanned at the PRD. For each of the 8 different weight categories, the values for effective dose, DLP, and CTDI were significantly less for the PRD group relative to the PARD group. The one exception was the DLP for the 32 to 40 lb weight group, for which the difference between the PARD and PRD was not significant. However, the effective dose and the

Table 1. Comparison of CT effective dose for patients scanned at the PARD and the PRD

Weight Category (lb)	PARD		PRD		
	n	Effective Dose	n	Effective Dose	P
13-25	34	3.5 ± 1.8	9	2.0 ± 0.4	.003
26-31	21	3.7 ± 1.0	4	1.9 ± 0.4	.004
32-40	54	4.0 ± 1.9	15	4.0 ± 6.8	<.001
41-49	47	4.6 ± 3.0	17	2.5 ± 0.5	<.001
50-69	85	5.1 ± 2.1	34	3.4 ± 0.7	<.001
70-89	73	6.4 ± 3.4	22	4.1 ± 0.7	<.001
90-120	90	8.6 ± 3.9	52	5.1 ± 1.7	<.001
>120	91	13.3 ± 7.8	91	7.8 ± 8.0	<.001

Note: Data are expressed as mean ± SD. PARD = combined pediatric and adult radiology department; PRD = pediatric radiology department.

Table 2. Comparison of CT DLP for patients scanned at the PARD and the PRD

Weight Category (lbs)	PARD		PRD		
	n	DLP	n	DLP	P
13-25	34	103 ± 56	9	58 ± 15	.007
26-31	21	123 ± 34	4	78 ± 13	.009
32-40	54	152 ± 113	15	194 ± 339	.105
41-49	47	198 ± 111	17	127 ± 22	<.001
50-69	85	267 ± 101	34	195 ± 37	<.001
70-89	73	366 ± 167	22	271 ± 48	<.001
90-120	90	538 ± 222	52	338 ± 114	<.001
>120	91	881 ± 519	91	523 ± 533	<.001

Note: Data are expressed as mean ± SD. DLP = dose-length product; PARD = combined pediatric and adult radiology department; PRD = pediatric radiology department.

Table 3. Comparison of CTDI for patients scanned at the PARD and the PRD

Weight Category (lbs)	PARD		PRD		
	n	CTDI	n	CTDI	P
13-25	34	2.7 ± 1.1	9	1.4 ± 0.3	.002
26-31	21	2.6 ± 1.1	4	1.5 ± 0.5	.032
32-40	54	3.0 ± 1.4	15	2.9 ± 5.1	.001
41-49	47	3.4 ± 1.6	17	1.9 ± 0.5	<.001
50-69	85	4.2 ± 2.0	34	2.3 ± 0.4	<.001
70-89	73	4.9 ± 2.3	22	3.0 ± 0.5	<.001
90-120	90	6.7 ± 3.9	52	4.3 ± 1.7	<.001
>120	91	9.2 ± 5.1	91	7.1 ± 4.4	<.001

Note: Data are expressed as mean ± SD. CTDI = CT dose index; PARD = combined pediatric and adult radiology department; PRD = pediatric radiology department.

CTDI were both significantly lower for this same group at the PRD.

Evaluation of compliance with the pediatric protocols at the PARD before the move compared with the PRD demonstrated a compliance rate of only 21% to 44% across the 8 weight-based categories. After the move to the PRD, compliance was 93% to 100%. There were 3 (1.2%) documented protocol errors related to CT dose at the PRD: 2 involved the inadvertent use of a lower tube current because of the use of an incorrect patient weight, and 1 involved the inadvertent use of a high-dose adult protocol (a patient in the 32 to 40 lb category). The low-tube current scans were able to be interpreted and did not result in repeat patient scanning.

DISCUSSION

When performed and monitored properly, the benefits of CT scans outweigh the long-term risk of radiation. To minimize the potential adverse effects of radiation exposure to pediatric patients, it is necessary to reduce the dose of radiation delivered to these patients while preserving the diagnostic quality of the images produced. There are many strategies for reducing radiation dose. The use of protocols with adjusted exposure parameters for pediatric patients on the basis of child size, organ system scanned, and the size of the region scanned is most notable [4,7-9]. Compliance with these protocols can be challenging for technologists, particularly when scanning a combination of adult and pediatric patients [10]. The relocation of pediatric CT services to a dedicated pediatric hospital removes many of the challenges associated with performing scans in a combined adult and pediatric space, including compliance with CT dose regimens.

Our study suggests that greater scrutiny of pediatric ALARA protocol compliance may be necessary for those facilities that scan both pediatric and adult patients. Although we anticipated that compliance with pediatric dose-adjusted protocols would be comparatively lower at the PARD compared with the PRD, the magnitude of the difference we found between the 2 was unexpected. Ten years before our children's hospital opened, we began to enlist pediatric subspecialty technologists throughout the PARD in an attempt to optimize our pediatric imaging, including compliance with ALARA protocols. During this time, one pediatric CT technologist was recruited for each first and second weekday shift. Both these CT technologists now work at the PRD. While at the PARD, these pediatric CT technologists were not restricted from scanning adults, but we expected that they would scan most of the children and also share pediatric techniques with the pool of general CT technologists. However, our study suggests that general radiology departments that rely on a few embedded pediatric subspecialty technologists may underestimate their ability to maintain compliance with pediatric protocols, making diligent monitoring of greater necessity.

Additive potential methods of optimizing CT dose that we have implemented at our institution include providing technologists with expected CTDI reference ranges for each protocol and defaulting the CT scanner to pediatric protocols or placing a warning on the CT scanner that will give the technologist pause before choosing an adult protocol. Recently we also created an obese child protocol, which has since reduced CT dose without compromising quality. Technologist education and involvement, root-cause assessment, and a coaching culture are also key concepts that we support.

The limitations of this study include the retrospective nature and the inherent error in calculation and estimation of dose using CTDI and DLP and conversion coefficients. Additionally, the potential differences in CT scanner CTDI dose measurements in the PARD compared to the PRD was considered but was not great enough to affect the statistical significance of the data.

Since our move to the PRD, we have continued to evaluate and refine our weight-based CT dose regimens for other body regions, particularly those with potentially greater sensitivity to long-term radiation effects, such as the neck and chest. Furthermore, we have modified the methodology of this study to allow us to continue to actively track and optimize the radiation dose for our CT examinations.

CONCLUSIONS

Pediatric patients will be exposed to less radiation by following ALARA principles and implementing low-dose CT protocols. However, imaging pediatric patients in a dedicated pediatric imaging department with strict adherence to weight-based dose regimens collectively results in greater protocol compliance and a further decrease in patient radiation dose. Conversely, adherence to pediatric ALARA protocols may be more difficult in radiology departments that image both children and adults, which may require an increased level of vigilance to maintain low-dose CT examinations.

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