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Original paper

Patient-specific organ and effective dose estimates in pediatric oncology computed tomography

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ABSTRACT

Purpose: Estimate organ and effective doses from computed tomography scans of pediatric oncologic patients using patient-specific information.

Materials and Methods: With IRB approval patient-specific scan parameters and patient size obtained from DICOM images and vendor-provided dose monitoring application were obtained for a cross-sectional study of 1250 pediatric patients from 0 through 20 y-olds who underwent head, chest, abdomen-pelvis, or chest-abdomen-pelvis CT scans. Patients were categorized by age. Organ doses and effective doses were estimated using VirtualDose™ CT based on patient-specific information, tube current modulation (TCM), and age-specific realistic phantoms. CTDIvol, DLP, and dose results were compared with those reported in the literature.

Results: CTDIvol and DLP varied widely as patient size varied. The 75th percentiles of CTDIvol and DLP were no greater than in the literature with the exception of head scans of 16–20 y-olds and of abdomen-pelvis scans of larger patients. Eye lens dose from a head scan was up to 69 mGy. Mean organ doses agreed with other studies at maximal difference of 38% for chest and 41% for abdomen-pelvis scans. Mean effective dose was generally higher for older patients. The highest effective doses were estimated for the 16–20 y-olds as: head 3.3 mSv, chest 4.1 mSv, abdomen-pelvis 10.0 mSv, chest-abdomen-pelvis 14.0 mSv.

Conclusion: Patient-specific organ and effective doses have been estimated for pediatric oncologic patients from < 1 through 20 y-olds. The effect of TCM was successfully accounted for in the estimates. Output parameters varied with patient size. CTDIvol and DLP results are useful for future protocol optimization.

1. Introduction

Computed Tomography (CT) is an important diagnostic imaging tool that helps save lives, but it does expose patients to ionizing radiation in addition to natural background radiation. On average, CT scans account for half of all medical radiation exposure in the United States (US) [1]. One in four persons in the US (per capita) had a CT scan in 2015 [2]. Concerns about the high scan number and the large contributions to medical exposure have led to campaigns and guidelines for justification and optimization of image quality and dose in the radiological community [3–6].

The advent of multi-detector CT (MDCT) has enabled rapid image acquisition without loss of spatial or contrast resolution. This is particularly useful in the pediatric oncologic setting, where cooperation with breath holds and motion avoidance are especially challenging for the young patients, many of whom have previously undergone numerous medical tests. Modern MDCT decreases reliance on and utilization of anesthesia [7]. However, MDCT technology itself does not directly decrease radiation exposure [8]. Recent successful decreases in pediatric exposure have resulted largely from national campaigns, which have raised awareness of the issue of CT parameter optimization within pediatric radiology practices [5]. This issue is of the utmost importance in the care of pediatric oncologic patients, as these patients tend to require numerous follow-up exams and subsequently receive relatively high cumulative dose.

In oncologic imaging, both pediatric and adult patients frequently undergo CT scans. While it is always important to justify and optimize CT radiation dose, it is particularly important to control the CT radiation dose to children. Compared to adults, pediatric patients are considered to have a higher risk of developing radiation-induced diseases

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Table 1
Patient demographics.

Age Group	No. of Examinations					Age (y)	Weight (kg)
	Head	Chest	Abdomen and Pelvis	Chest, Abdomen, and Pelvis	Subtotal	Mean (Min-Max)	Mean (Min-Max)
< 1 year	2	13	1	3	19	0.0 (0.0–0.0)	6.9 (3.0–11.0)
1–5 years	41	55	17	98	211	2.8 (1.0–4.0)	14.4 (7.0–30.0)
6–10 years	26	94	21	128	269	6.8 (5.0–9.0)	22.3 (13.0–44.0)
11–15 years	20	130	26	79	255	12.3 (10.0–14.0)	49.0 (23.0–142.0)
16–20 years	53	222	55	166	496	17.6 (15.0–20.0)	67.1 (27.0–149.0)

Note: The mean and the minimum-to-maximum range in parenthesis are provided for age and body weight of patients in each age group.

Table 2
CT technique summary.

Scanning region	Tube potential (kVp)	Tube current (mA)	Revolution time (s)	Collimation (mm)	Pitch	CTDIvol (mGy)	DLP (mGy·cm)	SSDE (mGy)
Head	100 or 120	226.1 (120.0–300.0)	1.0 (1.0–1.0)	17.3 (10.0–40.0)	1.01 (0.98-1.07)	45.3 (26–65.3)	841.4 (339.7–2036.3)	NA*
Chest	100 or 120	111.6 (40.0–380.0)	0.6 (0.5–0.8)	33.2 (20.0–40.0)	1.26 (0.98–1.38)	5.5 (1.0–15.0)	202.3 (20.9–676.6)	8.7 (2.2–16.4)
Abdomen and pelvis	100 or 120	201.4 (60.0–435.0)	0.7 (0.4–0.8)	39.2 (20.0–40.0)	1.22 (0.98–1.38)	8.4 (1.7–21.3)	441.2 (43.5–1218.9)	12.7 (3.2–28.4)
Chest, abdomen and pelvis	100 or 120	178.7 (50.0–380.0)	0.6 (0.5–0.8)	40.5 (20.0–160.0)	1.31 (0.98–1.38)	6.4 (1.4–21.2)	444.2 (45.7–1750.1)	10.1 (2.6–24.6)

Note: The mean and the minimum-to-maximum range in parenthesis for all ages are provided. CTDIvol = Volumetric Computed Tomography Dose Index, DLP = Dose Length Product, SSDE = Size Specific Dose Estimate, NA = Not Applicable.
* SSDE for head scans were not used in this study.

Table 3
Mean and 75th percentile comparisons with international data for various pediatric age groups.

Exam	Age	CTDIvol			DLP		
		This study	Galanski et al. (2005)*	Shrimpton et al. (2003)†	This study	Galanski et al. (2005)*	Shrimpton et al. (2003)†
Head	< 1 y	26 (26)	26 (34)	25 (28)	340 (340)	302 (393)	230 (270)
	1–5 y	34 (35)	36 (49)	34 (43)	594 (5 5 8)	452 (6 1 1)	383 (4 6 5)
	6–10 y	36 (38)	44 (58)	44 (51)	599 (6 0 7)	582 (7 1 1)	508 (6 1 9)
	11–15 y	49 (48)	53 (65)	56 (64)	810 (8 1 5)	764 (9 2 0)	694 (7 8 7)
	16–20 y	58 (60)	61 (60)	56 (64)	1183 (1119)	881 (1100)	694 (7 8 7)
Chest	< 1 y	1 (1)	3 (4)	11 (12)	28 (29)	40 (49)	159 (204)
	1–5 y	3 (4)	3 (4)	11 (13)	86 (101)	61 (73)	198 (228)
	6–10 y	4 (5)	5 (6)	14 (17)	124 (153)	102 (128)	303 (368)
	11–15 y	5 (7)	6 (8)	10 (12)	198 (230)	180 (244)	402 (488)
	16–20 y	7 (8)	11 (10)	10 (12)	277 (318)	368 (345)	402 (488)
Abdomen and pelvis	< 1 y	2 (2)	3 (4)	NA	43 (43)	79 (82)	NA
	1–5 y	4 (6)	4 (5)	NA	162 (220)	115 (147)	NA
	6–10 y	6 (7)	6 (7)	NA	247 (293)	180 (227)	NA
	11–15 y	8 (10)	8 (10)	11 (13)	438 (502)	328 (402)	473 (534)
	16–20 y	11 (12)	13 (15)	11 (13)	611 (719)	568 (980)	473 (534)

Note: Dose data are mean (75th percentile). CTDIvol = Volumetric Computed Tomography Dose Index, DLP = Dose Length Product, NA = Not Applicable.
* Adult data is used for 16–20 years group.
† Adult data is used for both 11–15 years group and 16–20 years group.

Table 4
Median and 75th percentile comparisons with U.S. data for 16–20 years group.

Examination	CTDIvol (mGy)		DLP (mGycm)		SSDE (mGy)	
	This study	Kanal et al. (2017)*	This study	Kanal et al. (2017)*	This study	Kanal et al. (2017)*
Head without contrast	60 (60)	49 (57)	958 (1078)	849 (1011)	58 (60)	NA
Chest without contrast	6 (8)	9 (12)	259 (338)	334 (443)	9 (11)	11 (15)
Chest with contrast	7 (9)	10 (13)	281 (359)	353 (469)	9 (12)	11 (15)
Abdomen and pelvis with contrast	12 (12)	12 (15)	648 (708)	608 (755)	17 (19)	15 (18)
Chest, abdomen, and pelvis with contrast	9 (11)	12 (15)	637 (878)	779 (947)	13 (16)	14 (18)

Note: Dose data are 50th percentile (75th percentile). CTDIvol = Volumetric Computed Tomography Dose Index, DLP = Dose Length Product, SSDE = Size Specific Dose Estimate, NA = Not Applicable.
* Adult data is used for comparison.