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Size-specific dose estimate (SSDE) and age-based local diagnostic reference levels (LDRLs) for pediatric CT head examinations

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ABSTRACT

Purpose:
To evaluate the Size Specific Dose Estimate (SSDE) based on the AAPM report TG-293 for pediatric head CT, and to propose local diagnostic reference levels (LDRLs) in the Canadian province of Nova Scotia.

Methods:
The study analyzed 358 routine unenhanced head CT examinations. Data were retrospectively extracted from PACS; the survey incorporated five scanners in three hospitals, including a dedicated pediatric facility and two regional general hospitals. Patients were grouped as <1, 1–5, 6–10, and 11–15 years old. The SSDE was calculated using volume CT dose index ($CTDI_{vol}$) and a conversion factor according to the methodology from AAPM Report TG-293. Differences between scanners for all dose metrics were assessed using the Kruskal–Wallis test, with $p<0.05$ denoting statistical significance. A pairwise comparison of scanners was also performed.

Results:
Differences in the dose metrics between scanners were statistically significant for all age categories, and median dose values from the pediatric hospital were highest in the province for patients <1 year and 1–5 years old. The $CTDI_{vol}$ and SSDE values demonstrated a strong correlation with Pearson correlation coefficient of 0.905. Larger differences between $CTDI_{vol}$ and SSDE were observed in older patient groups. Provincial LDRLs were determined for each age category as the 75th percentile of the pooled data and expressed as CT dose indices and SSDE.

Conclusions:
The proposed LDRLs expressed as SSDE and CT dose indices provide a useful benchmark for optimizing pediatric head CT and improving protocol standardization.

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INTRODUCTION

Computed tomography (CT) plays a major role in neurodiagnostics, with the non-contrast head CT being the most ordered pediatric CT examination globally [1]. Where CT imaging is unavoidable, it is vital to minimize radiation doses. Diagnostic reference levels (DRLs), which represent the dose to an average patient, were introduced by the ICRP as an operational tool to optimize radiation dose [2]. DRLs are determined as the 75th percentile of a dosimetric dataset. Local DRLs (LDRLs) are defined as the 75th percentile of the pooled dose distribution in a single large facility or 2–3 small facilities [3]. The volume CT dose index ($CTDI_{vol}$) and dose-length product (DLP) are radiation dose metrics used to express DRLs in CT. However, these metrics are based on standard-sized head and body phantoms that do not represent pediatric patients. Therefore, the size-specific dose estimate (SSDE) may allow more accurate DRL values in pediatric CT imaging.

METHODS AND MATERIALS

Data from pediatric unenhanced head CTs were retrospectively collected from a dedicated pediatric facility and two regional general hospitals in the Canadian province of Nova Scotia (Table 1). All scanners were capable of automatic current modulation and iterative image reconstruction. Automatic voltage selection was available only on the newest scanner #5, with a reference kV set to 100 for pediatric head CT. Other scanners performed all examinations at 120 kV except for the youngest age group, where this was set to 100 kV. The patients were grouped by age as <1, 1–5, 6–10, and 11–15 years. Most examinations were conducted in 2020–2023, with some studies dating back to 2016 due to limited pediatric data from general hospitals. Consequently, the sample size for each scanner ranged from 4 to 30 patients under 1 year, and 13–30 cases in other age groups. Data collected included patient age, DLP, $CTDI_{vol}$, and anterior to posterior (AP) thickness measured immediately superior to the glabella. The latter was used to determine the patient's water-equivalent diameter (D_w), employing recommendations from the AAPM Report 220 [4]. The SSDE was calculated as SSDE = $f^{H16} \cdot CTDI_{vol}$. The conversion factor f^{H16} was obtained following AAPM Report 293 [5]: $f^{H16} = \alpha \cdot e^{-\beta D_w}$, where $\alpha = 1.9852$ and $\beta = 0.0486$. Differences between scanners for all dose metrics were assessed using the Kruskal–Wallis test, with $p<0.05$ denoting statistical significance. A pairwise comparison across all scanners was performed at the 5% significance level. Provincial LDRLs were proposed as the 75th percentile of the pooled dose distributions for each age group.

Table 1. Characteristics of CT scanners included in the survey. Hospital #1 is a dedicated pediatric facility

Hospital	Scanner	Model	Install year	Det. Config.	IR
1	1	Canon Aquilion Prime	2014	80 x 0.5	AiDR
2	2	GE LightSpeed VCT	2010	64 x 0.625	ASiR
	3	GE Optima 660	2012	64 x 0.625	ASiR
3	4	GE Optima 660	2013	64 x 0.625	ASiR
	5	Siemens Somatom Definition Edge	2022	2 · 64 x 0.6	ADMIRE

RESULTS

Overall, 358 patient studies were included in the survey. The calculated SSDE values were lower than $CTDI_{vol}$, with the largest discrepancy of 35–39% in the oldest patient group of 11–15 years (Figure 1). Differences in the dose metrics between all scanners were statistically significant for all age categories, and median dose values from pediatric scanner #1 were the highest in the province for the patient groups of <1 year and 1–5 years old (Figure 2). The $CTDI_{vol}$ and SSDE values demonstrated a strong correlation with the Pearson correlation coefficient of 0.905 for pooled data across all scanners and patient ages (Figure 3). Results of the pairwise comparison are shown in Table 2. There were no significant differences for all age groups in the SSDE values distribution between pairs of scanners #2 – #3, and #3 – #4. The equality of distributions between #1 and any other scanner is rejected for the oldest and the youngest groups, except for scanner #4. The SSDE data from the newest scanner #5 are statistically different from all other scanners only for 1–5 years. These results demonstrated that standardization of the protocols is needed across all scanners, including the same models.

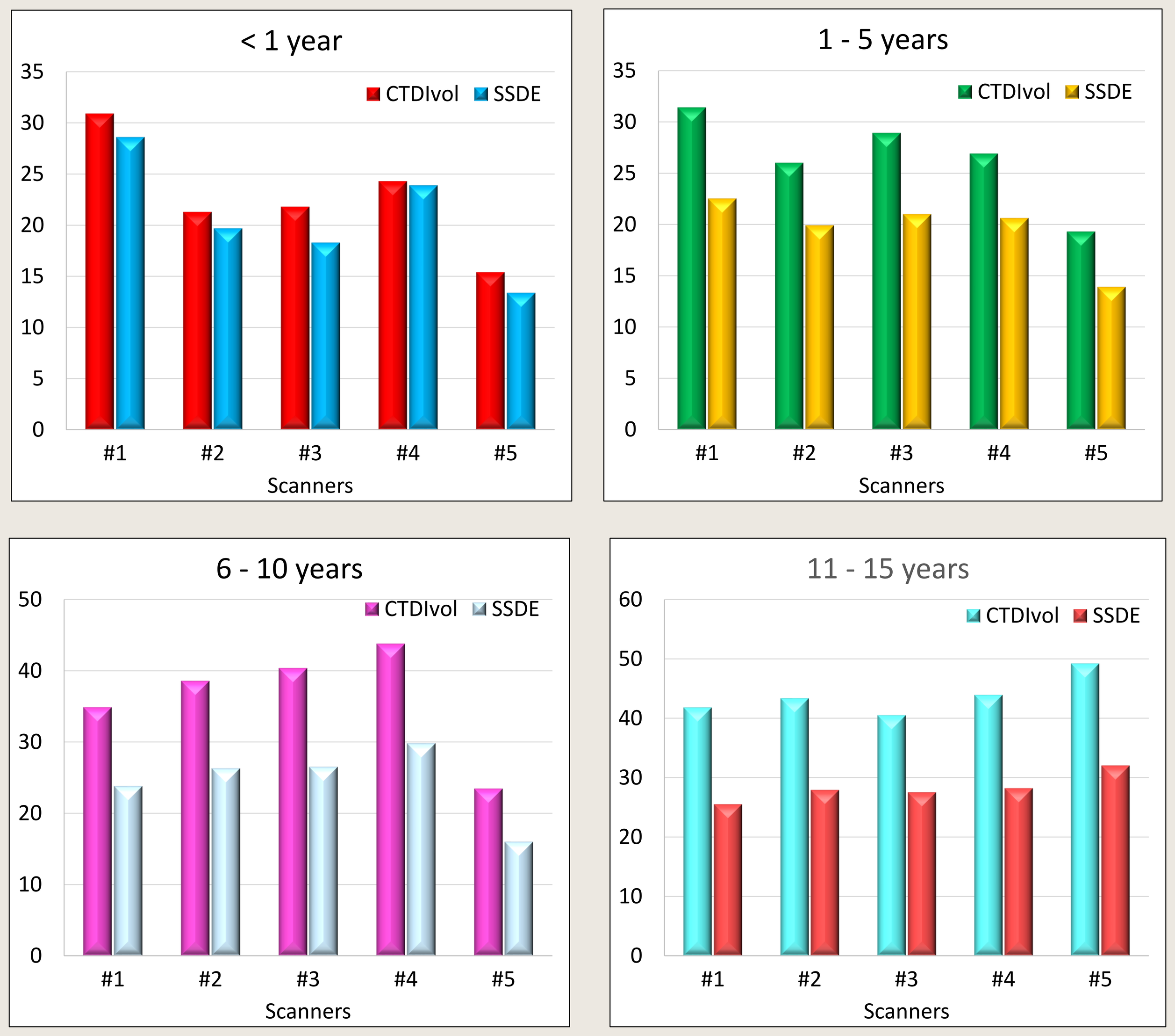

Figure 1. Median values of the $CTDI_{vol}$ and SSDE for different age groups.

Table 2. Results of post-hoc Dunn's test of pairwise comparisons of SSDE values with Benjamini-Hochberg adjustment of p-values.

Scanners	1 vs 2	1 vs 3	1 vs 4	1 vs 5	2 vs 3	2 vs 4	2 vs 5	3 vs 4	3 vs 5	4 vs 5
< 1 year	0.039	0.000	0.171	0.000	0.626	0.393	0.219	0.143	0.195	0.029
1–5 yrs	0.262	0.201	0.350	0.000	0.981	0.876	0.002	0.975	0.001	0.000
6–10 yrs	0.341	0.121	0.001	0.604	0.664	0.050	0.205	0.054	0.082	0.001
11–15 yrs	0.008	0.039	0.000	0.000	0.592	0.239	0.013	0.113	0.004	0.175

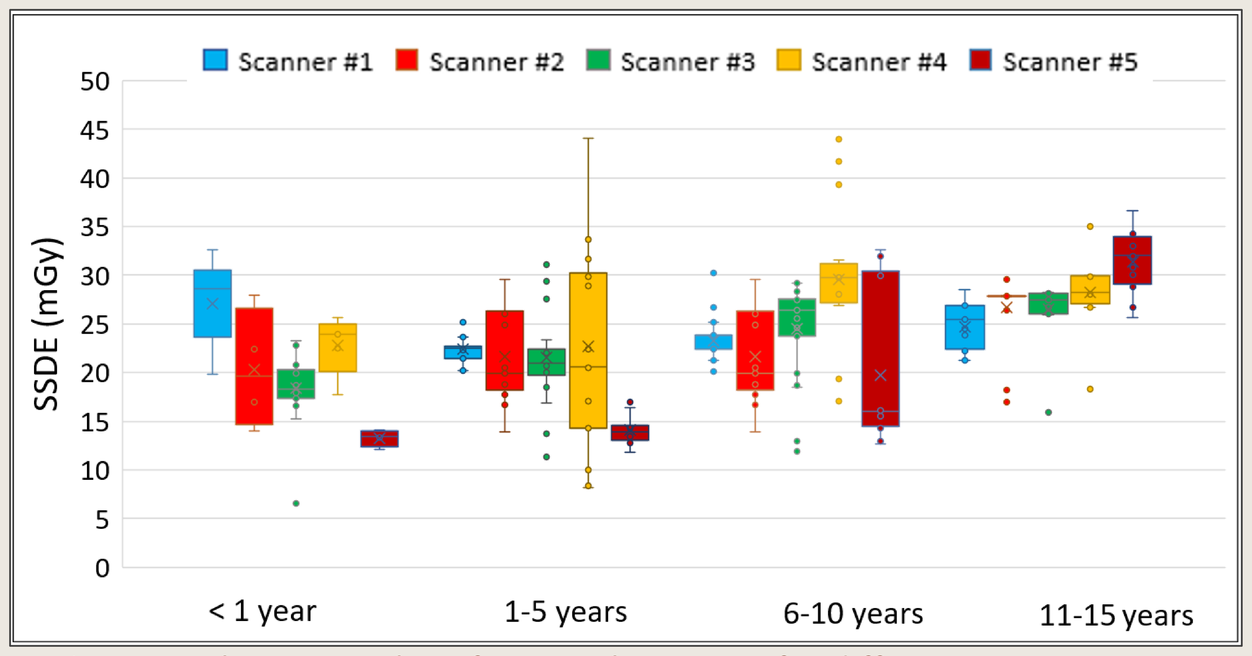

Figure 2. The SSDE values from each scanner for different age categories. Scanner #1 is located at the pediatric hospital.

DISCUSSION

Our study aimed to propose provincial LDRLs expressed as SSDE values for pediatric CT head examination, based on the data collected from dedicated children's and general regional hospitals (Table 3). It was found that SSDE values were consistently lower than scanner-generated $CTDI_{vol}$, with higher discrepancies for older age groups. The pediatric hospital did not produce the lowest dose in most age categories and, on the contrary, showed the highest median SSDE values in the younger age categories. The scanner installation year is one of the decisive factors restricting dose optimization. Older CT hardware and first-generation iterative reconstruction algorithms offered only limited dose-saving options, preventing dose reduction without degrading image quality. Moreover, a dedicated pediatric site faces a variety of clinical indications, which is a consideration not only for optimizing routine scanning protocols but also for creating an array of protocols with differing doses for scanning across varying indications.

Table 3. Provincial DRLs for different age categories.

Provincial DRLs	Age group	< 1 year	1–5 years	6–10 years	11–15 years
Dose Indices	CTDIvol (mGy)	30.9	31.4	41.1	43.8
	SSDE (mGy)	**27.40**	**22.68**	**27.71**	**28.22**
	DLP (mGy*cm)	490.7	599.0	799.1	870.4

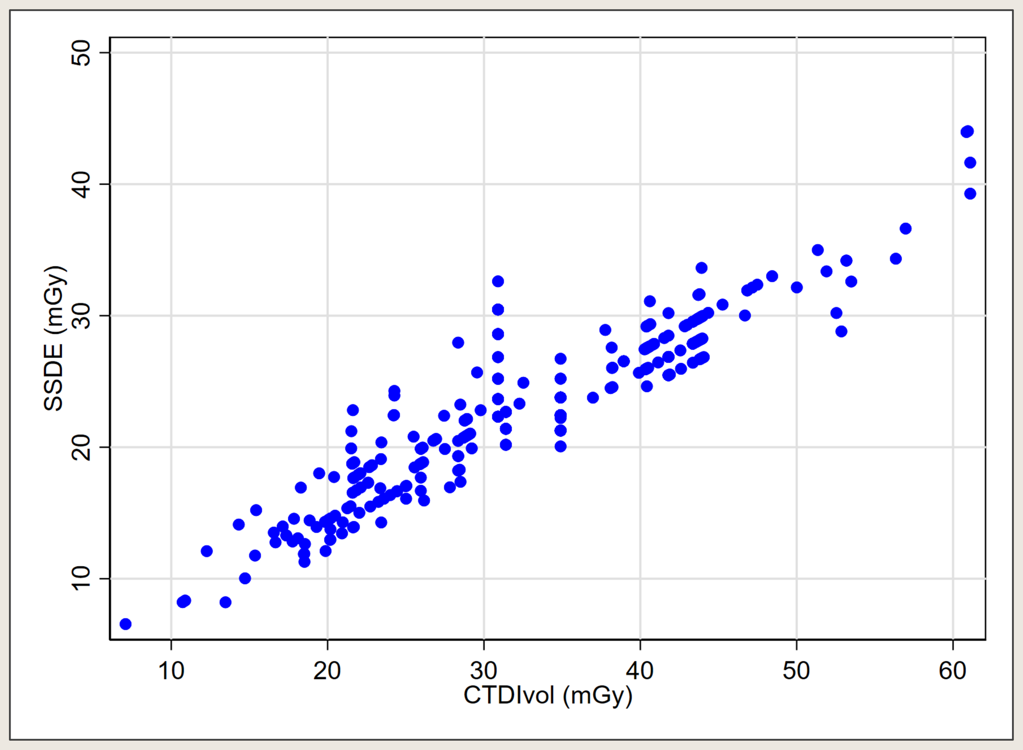

Figure 3. The scatter plot of the SSDE vs $CTDI_{vol}$ values.

CONCLUSIONS

Our study demonstrated that CT head at a pediatric facility, contrary to expectations, may result in higher radiation doses compared to general hospitals in the province.
The proposed local DRLs expressed as SSDE and CT dose indices provide a benchmark for optimizing pediatric head CT examinations and improving protocol standardization.

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