Journal of Carcinogenesis
Covering Genesis to Therapeutics
Journal of Carcinogenesis, ISSN: 1477-3163
2025; Vol 24: Issue 2s, https://carcinogenesis.com/

Radiation Dose Assessment In Pediatric Chest Ct Protocols With Emphasis On Ctdivol And Dlp

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ABSTRACT

Pediatric chest computed tomography (CT) is an essential diagnostic tool, children's increased radiosensitivity and extended life expectancy present serious difficulties. With an emphasis on the Computed Tomography Dose Index volume (CTDIvol) and Dose Length Product (DLP), this paper evaluates the state of the art on radiation dose assessment in various pediatric chest CT protocols. By comparing radiation doses from normal, low-dose, high-resolution, and ultra-low-dose protocols, we highlight dose optimization techniques such iterative reconstruction, size-specific dose estimating (SSDE), and adherence to the ALARA (As Low As Reasonably Achievable) doctrine. In order to standardize and reduce radiation exposure while maintaining diagnostic quality, it is emphasized how crucial it is to create size-based diagnostic reference levels (DRLs). The purpose of this paper is to provide guidance to radiographers and physicians on safer imaging procedures/protocols for children.

Keywords: *Pediatric CT; Radiation Dose; CTDIvol; DLP; Chest Imaging; Dose Optimization; Low-Dose CT; ALARA; SSDE; DRLs..*

How to Cite: Rashmi Singh, Ajay Kumar, Akriti Johri, Deepak Katiyar, Sandeep Yadav, Nandhini, Rahul Gangwar, (2025) Radiation Dose Assessment In Pediatric Chest Ct Protocols With Emphasis On Ctdivol And Dlp, *Journal of Carcinogenesis*, *Vol.24, No.2s*, 431-436

1. INTRODUCTION

For the evaluation of medical conditions such lung infections, congenital defects, and trauma, chest CT is essential in pediatric diagnostics. However, because of their developing tissues and longer post-exposure lifespans, children are at a higher risk of acquiring radiation-induced cancers from ionizing radiation exposure from CT scans [1, 2]. While the dosage duration Product (DLP) calculates the overall radiation exposure by multiplying the Computed Tomography Dose Index volume (CTDIvol) by the scan duration, the CTDIvol quantifies the radiation dosage per slice [3, 7]. For evaluating and maximizing radiation dosages in pediatric imaging, these measures are essential [4, 6]. This review compares radiation exposures from standard-dose, low-dose, high-resolution CT (HRCT), contrast-enhanced, and ultra-low-dose pediatric chest CT procedures. We explore factors influencing dose variability, strategies for dose reduction, and the role of size-based DRLs in enhancing radiation safety. By synthesizing findings from recent studies, this paper underscores the need for tailored imaging protocols to minimize radiation risks while maintaining diagnostic accuracy.

CT Protocols in Pediatric Chest Imaging

Pediatric chest CT protocols are designed to balance diagnostic quality with radiation safety. Commonly used protocols include:

Standard-dose CT: Employed for detailed evaluations, particularly when low-dose imaging is inconclusive [7, 15].

Low-dose CT: Used for follow-up of conditions like pneumonia or cystic fibrosis, leveraging lower tube settings [8, 15].

High-Resolution CT (HRCT): Ideal for detecting interstitial lung diseases, requiring higher doses for fine detail [9, 15].

Contrast-enhanced CT: Applied in vascular or neoplastic assessments, with doses varying based on contrast requirements [10, 15].

Ultra-low-dose CT: An emerging modality using advanced algorithms to minimize radiation, suitable for screening [11, 15].

These protocols differ in parameters such as tube voltage (kVp), tube current (mA), pitch, and scan length, which significantly influence CTDIvol and DLP [12, 13]. Protocol selection is guided by clinical indication, patient size, and the need to adhere to ALARA principles [14].

Radiation Dose Assessment Using CTDIvol and DLP

CTDIvol and DLP are standardized metrics for evaluating radiation exposure. CTDIvol represents the average dose within a scan volume, while DLP reflects the total dose by incorporating scan length [3, 7]. Table 1 summarizes typical CTDIvol and DLP values across pediatric chest CT protocols, illustrating dose variability based on protocol type and patient size.

Table 1: CTDIvol and DLP Across Pediatric Chest CT Protocols[15]

CT Protocol	CTDIvol (mGy)	DLP (mGy·cm)	Indications
Ultra-low-dose CT	0.3–1.0	10–30	Screening, chronic disease follow-up
Low-dose CT	0.5–2.0	20–60	Infection follow-up, initial evaluation
Standard-dose CT	2.0–4.0	60–120	Detailed diagnosis, trauma
HRCT	3.0–5.0	80–150	Interstitial lung disease
Contrast-enhanced CT	2.5–4.5	90–160	Tumor evaluation, vascular imaging

CTDIvol and DLP values vary from 0.4 to 8.0 mGy and 7 to 241 mGy•cm, respectively, based on studies [2]. Smaller patients (those under 13 cm in diameter) are given much smaller doses (CTDIvol: 0.4 mGy, DLP: 7 mGy•cm) than larger patients (greater than 29 cm in diameter, CTDIvol: 8.0 mGy, DLP: 241 mGy•cm) [2]. As compared to standard helical CT, low-dose procedures which are improved by iterative reconstruction techniques like ASIR can achieve dose reductions about up to 80% (e.g., CTDIvol: 2.1 mGy vs. 9.7 mGy) [1].

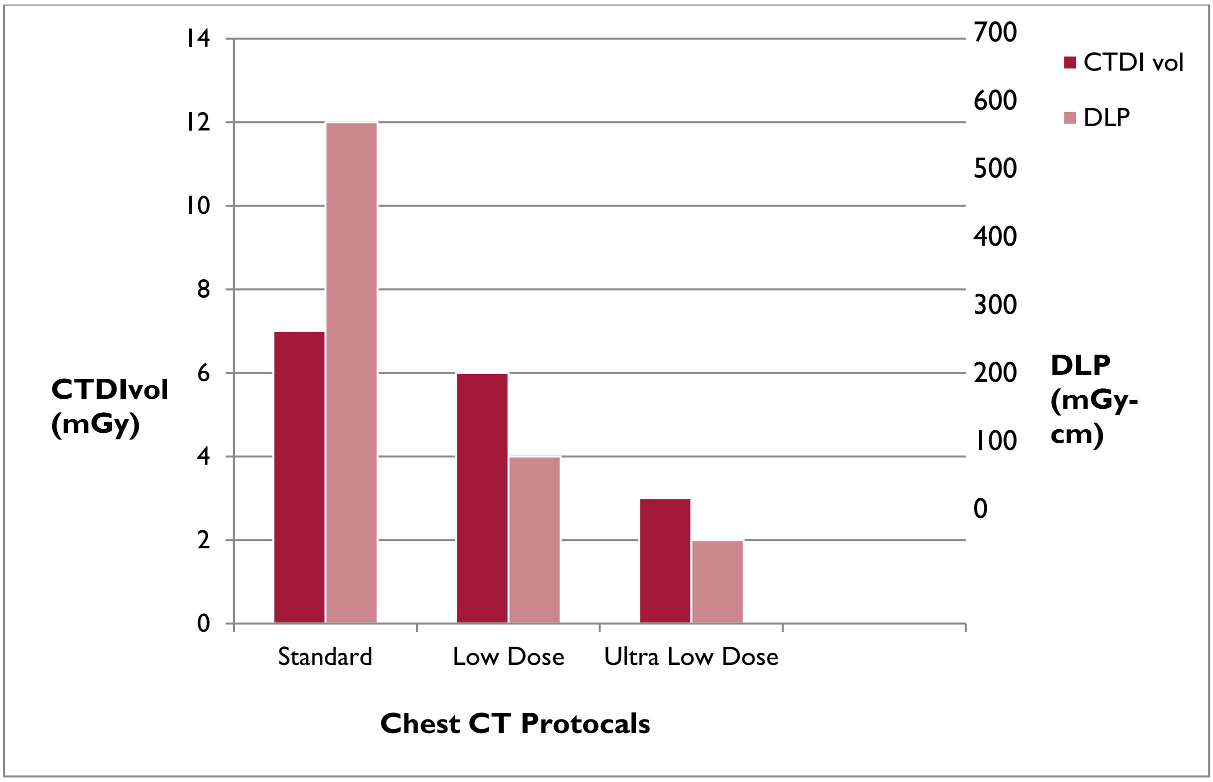

Figure 1: Comparison of CTDI AND DLP Across Standard, Low and Ultra low Doses

Factors Influencing Radiation Dose

Several factors contribute to dose variability in pediatric chest CT:

Patient Size and Weight: Smaller patients require lower doses to avoid overexposure, necessitating size-specific protocols [16].

Scan Length and Coverage: Reducing scan length directly lowers DLP [17].

Tube Current Modulation: Automatic exposure control (AEC) adjusts dose based on tissue density, reducing exposure by 20–40% [18].

Shielding: Thyroid and breast shielding may offer additional protection, though their use remains debated [19].

Reconstruction Techniques: Iterative and AI-based reconstructions enable high-quality imaging at lower doses, reducing noise [20, 21].

Patient Positioning and Breathing: Minor variations can cause dose inconsistencies, even with AEC, leading to 8–10% dose variations in follow-up scans [5].

Dose Optimization Strategies

Optimizing radiation dose in pediatric chest CT is critical to minimizing risks while ensuring diagnostic efficacy. Key strategies include:

Pediatric-Specific Protocols: Tailoring parameters to age, weight, and clinical indication can reduce doses by 30–60% [1, 15].

Automatic Exposure Control (AEC): Dynamically adjusts tube current, achieving 20–40% dose reductions [18].

Lower Tube Voltage: Using 80–100 kVp instead of adult settings reduces doses by up to 40% [6, 15].

Iterative and AI-Based Reconstruction: Enables 30–70% dose reductions by minimizing noise in low-dose images [21, 22].

Size-Specific Dose Estimation (SSDE): Adjusts CTDIvol based on patient size, improving dose accuracy [4].

Collimation and Scan Planning: Limits radiation to the region of interest, reducing DLP by 15–25% [12].

Regular DRL Updates: Size-based DRLs, rather than age-based, enhance dose standardization [2, 6].

Table 2: Impact of Dose Optimization Strategies[1,15]

Optimization Strategy	Impact on Radiation Dose
Pediatric protocols	30–60% dose reduction
AEC and tube modulation	20–40% dose reduction
Iterative/AI reconstruction	30–70% dose reduction
Lower kVp settings	Up to 40% dose reduction
Scan length reduction	15–25% dose reduction

Diagnostic Reference Levels (DRLs) and SSDE

DRLs serve as benchmarks for typical CT examinations, guiding dose optimization without imposing strict limits [6]. Recent studies advocate for size-based DRLs using water-equivalent diameter, as opposed to age-based DRLs, to account for variability in pediatric body sizes [2, 4]. SSDE further refines dose estimation by adjusting CTDIvol for patient size, offering a more individualized risk assessment [4]. For example, a Jordan-based study reported DRLs for chest CT, with CTDIvol ranging in different age groups and SSDE values providing a more precise dose metric [4].

Table 3: Chest CT DRLs Based on Age and SSDE[4]

Age Group (Years)	CTDIvol (mGy)	DLP (mGy·cm)	SSDE (mGy)
<1 year	5.65	124	13.91
1–4 years	7.37	221	14.68
5–10 years	12.57	384	22.45
11–18 years	12.94	496	20.49

Clinical Implications and Recommendations

Selecting the appropriate CT protocol requires balancing diagnostic needs with radiation risks [7]. Clinicians should consider:

Alternative Modalities: Non-ionizing imaging (e.g., ultrasound, MRI) should be prioritized when feasible [8, 13].

Dose Tracking Systems: Implementing dose audits and national DRLs ensures consistent monitoring [17].

Education and Training: Continuous training for radiologists and technologists enhances adherence to safety standards [4].

Patient and Caregiver Communication: Educating families about radiation risks fosters informed decision-making [4].

2. RECOMMENDATIONS:

Prioritize non-ionizing modalities when clinically appropriate [13].

Adhere to ALARA principles to minimize radiation exposure [2].

Use size-based DRLs and SSDE for precise dose estimation [4, 6].

Implement dose-reduction technologies, such as iterative reconstruction and AEC [20].

Regularly update institutional protocols based on emerging evidence and technological advancements [10].

3. CONCLUSION

CT scans, fast for emergencies and use radiation, which slightly ups leukemia risk in paediatrics[23]. the advanced imaging technologies like CT scans and high-resolution CT, now have powerful tools to examine the detailed imaging , three-dimensional structures and having low-dose and ultra-low-dose techniques[24]. while CTDIvol and DLP are important measures for assessing radiation dose in pediatric chest CT, which shows considerable variation across regimens. Significant prospects for dose reduction without sacrificing diagnostic quality are provided by low-dose and ultra-low-dose procedures in conjunction with size-based DRLs and iterative reconstruction. Children's radiation safety can be improved by physicians using ALARA principles, implementing pediatric-specific protocols, and utilizing cutting-edge technologies. Research, education, and ongoing monitoring are crucial to protecting this susceptible group and improving dosage optimization techniques..

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