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# Optimization of Routine Pediatric Computed Tomography Examinations in Hawassa City, Sidama Regional State, Ethiopia

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## Abstract

*Computed tomography (CT) has considerable impact in patient care. However, it is the most irradiating medical imaging technique in diagnostic radiology department. Optimization of pediatric CT is not well-practiced in developing countries. Protocols for some age groups were missed, and scan parameters are not adapted to the patient body size and age group. Furthermore, there are no established diagnostic reference levels to enhance dose optimization for pediatric patients at the local, regional, and national levels. Therefore, this study aimed to assess the optimization of routine pediatric CT examinations in Hawassa city, Ethiopia.*

*A total of 360 pediatric dose records were reviewed for routine pediatric CT performed between January 1st, 2021 - May 30th, 2022. The data were analyzed using the statistical package for social science version 25 software. The Local Diagnostic Reference Levels (LDRLs) were established at the 75th percentile of CT dose quantities. The average KVp, mAs, and scan length used for pediatric head, chest, and abdomen CT were (112.8, 260.6, and 19.8), (112.9, 64.7, and 31.5), and (113.3, 79.4, and 32.9) respectively. The range of the established LDRLs in terms of volumetric CT dose index for the head, chest, and abdomen CT were (31.5 to 47, 2.3 to 6.1, 1.7 to 4.7) mGy. Whereas the range in terms of dose length product per scan for the head, chest, and abdomen CT were (723.4 to 1126.7, 55.9 to 258.9, and 38.1 to 242.5) mGy cm respectively. The obtained results show that the LDRLs for volumetric CT does index for head and chest CT were equivalent to the international studies. Whereas the local DRLs in terms of dose length product per scan were higher than the reports other studies except in Japan where the values for chest CT were comparable to the results of this study. Finally, the findings suggested that non-optimized pediatric head and chest CT were performed across all age groups.*

**Keywords:** Optimization, Pediatrics, Computed Tomography, LDRLs.

## 1. Introduction

People are exposed to ionizing radiation for medical purposes during their diagnosis or treatment. One of the medical imaging techniques that makes use of ionizing radiation is computed tomography (CT). Due to CT's better image quality and diagnostic capabilities, there have been an infinite number of CT examinations performed [1,2]. Compared to other radiological imaging modalities, CT scans offer a larger dosage of radiation [3]. Ionization radiation exposure during a medical operation needs to be justified and optimized. In developed nations, the As Low As Reasonably Achievable (ALARA) rationale and optimization principles are widely known and can result in a decrease in the unnecessary or excessive radiation dose associated with CT exams [4]. Of all pediatric medical imaging tests, CT contributes the most to the overall cumulative effective dosage [5]. Children are thought to be 10 times more radiosensitive than adults, which should raise alarm due to an increase in the usage of pediatric CT exams.

A recent study has found an increase in the prevalence of cancer in young people, making pediatric CT exams more concerning [6,7,8]. Another study that evaluated the frequency of pediatrics CT exams for patients under the age of 15 in 128 CT facilities in 28 developing countries of Africa, Asia, and Eastern Europe found that the frequency of pediatric CT exams was higher in Africa than in Asia and Eastern Europe [9]. According to a study done in Ethiopia, the Tikur Anbessa teaching hospital was able to use optimization and justification procedures to protect

11% of pediatric patients from unnecessary radiation doses [10]. However, the study mainly focused on the justification of CT request forms and rarely addresses individual patient scan parameters and CT dose quantities.

In the majority of lower and middle-income countries, there are insufficient published diagnostic reference levels (DRLs) data that will improve dosage optimization, with a lack being more prominent in low-income countries. Due to rising usage and elevated radiation risk concerns in children compared to adults, pediatric CT examination optimization in Africa requires careful consideration. In Ethiopia there was no patient radiation dose monitoring mechanism stated by the regulatory body, the status of a local practice was not known, no national, as well as local DRLs (LDRLs) for pediatric CT examinations, was established, and no such type of study had been conducted in Hawassa city.

## 2. Method

The study was conducted at Hawassa University Comprehensive Specialized Hospital (HUCSH), Yanet internal medicine specialty center (YIMSC), and Alatyon general hospital (AGH) in Hawassa, Ethiopia. The hospitals have a total three CT scan machine and are selected due to their high patient flow with more than 70 radiology visits per day. The average daily radiology visits for routine pediatric CT examinations were estimated to be: 2, 3, and 5 for AGH, YIMSC, and HUCSH respectively. The conceptual framework was adapted from the ICRP and European guideline to assess the optimization of routine pediatric CT examinations [5,12]. (Fig. 1) illustrates the conceptual framework used in this study to determine the local diagnostic reference level during regular pediatric CT scans in order to evaluate the level of optimization.

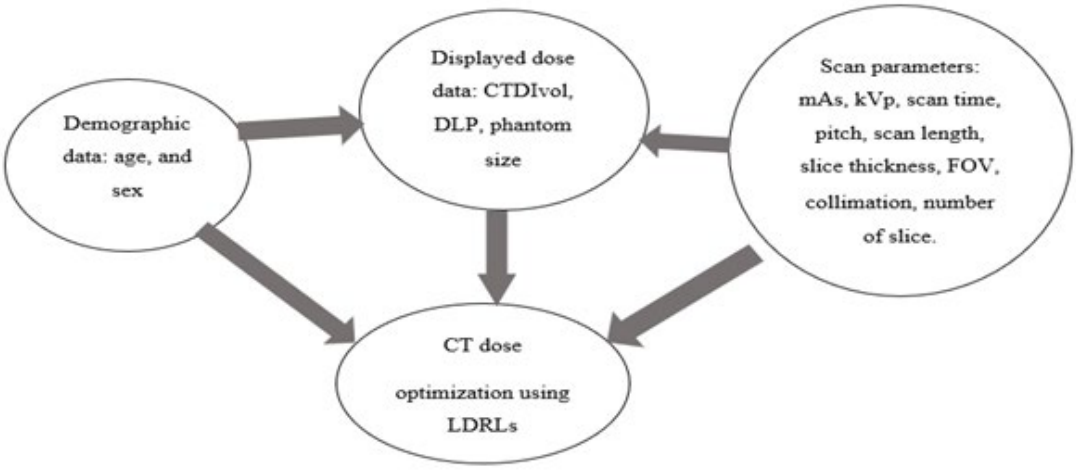


**Figure 1: Conceptual Framework used to Assess the Level of Optimization.**

All pediatric (≤ 15 years) charts or dose records of the radiology units of the three hospitals between January 1st, 2021, and May 30th, 2022, were reviewed from the PACS and radiology information system database of the CT-scan machines at the radiology units. The CT scanner machine used in this study is described in Table 1.

| Hospital | CT Company | Model | Number of slices | Year of installation | AEC |
|---|---|---|---|---|---|
| A | SIEMENS | SOMATOM go. Up | 64 | 2017 | Yes |
| B | PHILIPS | Brilliance 64 | 64 | 2014 | Yes |
| C | GE | Revolution ACTs | 8 | 2010 | Yes |

**Table 1: Characteristic of the CT Scanners in Each Imaging Unit of the Selected Hospitals**

### 2.1 Inclusion and Exclusion Criteria

All pediatric (aged ≤ 15 years) charts or dose records for head, chest, and abdomen CT tests (with and without contrast) performed between January 1st, 2021, and May 30th, 2022, were included. However, non-frequent CT examinations including CT angiography, perfusion investigations, and CT urography were excluded for pediatric dose data. Incomplete dose records and pediatric dose reports for numerous CT scans on the same patient were also excluded.

### 2.2 Data Collection

The pediatric dose records were categorized in to four age groups (≤1, (1-5], (5-10] and (10-15] years. For each age group and examination 30 dose records were reviewed from the three hospitals. In total, 360 dose records from the radiology units of the three hospitals for routine pediatric CT examination was obtained during the study period. Table 2 shows the sample size determination to assess optimization of routine pediatric CT examinations by establishing the LDRLs.

| The body part to be examined | Age group (years) | Sample for each age group |
|---|---|---|
| Head | ≤1 | 30 |
| | (1-5] | 30 |
| | (5-10] | 30 |
| | (10-15] | 30 |
| The total sample for the head | | 120 |
| Chest | ≤1 | 30 |
| | (1-5] | 30 |
| | (5-10] | 30 |
| | (10-15] | 30 |
| The total sample for the chest | | 120 |
| Abdomen | ≤1 | 30 |
| | (1-5] | 30 |
| | (5-10] | 30 |
| | (10-15] | 30 |
| The total sample for the abdomen | | 120 |
| The total sample size of the study | | 360 |

**Table 2: Sample Size Determination of Routine Pediatric CT Examinations**

### 2.3 Statistics Analysis

The SPSS version 25 was used to analyze the data by age groups using descriptive statistics. The mean, median, standard deviation, range, minimum, and maximum of scan parameters and CT-dose quantities such as CTDIvol and DLP were calculated for each age group. The 25$^{th}$, 50$^{th}$, and 75$^{th}$ percentiles of CT-dose quantities were presented as the lowest, median, and established LDRLs for each examination. The reviewed data includes CT scan parameters such as peak tube voltage (KVp), tube current (mA), tube current-time product (mAs), pitch, scan length, number of slices, and slice thickness; CT doses quantities (CTDIvol and DLP), type of scanning (axial or helical), and demographic data such as age and sex for each routine pediatric CT examination and age group.

## 3. Result and Discussion

### 3.1 Result

#### 3.1.1 Scan Parameter Analysis Result

**A) Scan Range**

The obtained minimum, maximum, median, mean and standard deviation (SD) of scan ranges across each age group and examination is presented in the Table 4.

| Examination | Age group (year) | Minimum | Maximum | Mean ± SD |
|---|---|---|---|---|
| Head | ≤1 | 14.3 | 24.8 | 18.5 ± 0.5 |
| | (1-5] | 16.9 | 24 | 19.8 ±0.3 |
| | (5-10] | 7.4 | 25.4 | 19.8 ±0.9 |
| | (10-15] | 15.2 | 29.7 | 21.2 ±0.7 |
| Chest | ≤1 | 16.8 | 34 | 24.6 ±1.1 |
| | (1-5] | 16.5 | 44 | 27.0 ±1.1 |
| | (5-10] | 17.5 | 41.9 | 32.5 ±1.3 |
| | (10-15] | 26 | 49.8 | 42.0 ±0.9 |
| Abdomen | ≤1 | 17.2 | 40.2 | 27.3 ±1.4 |
| | (1-5] | 16.5 | 38 | 27.4 ±1.2 |
| | (5-10] | 23.3 | 46.3 | 34.8 ±1.0 |
| | (10-15] | 26.5 | 60.7 | 42.2 ±1.7 |

**Table 4: The Minimum, Maximum, Mean, and Standard Deviation of Scan Range (Centimeter) for Each Age Group Per Examination (Single Sequence)**

**B) Scan Time**

The scan time for pediatric head CT varied from 2.5 to 29.3 seconds and the interquartile range varied from 3.5 to 10.7 seconds. The scan time for pediatric chest CT varied from 3.1 to 39.3 seconds and the scan time interquartile range varied from 2.1 to 22.4 seconds. In addition, the scan time for pediatric abdomen CT varied from 3.3 to 37.2 seconds and the scan time interquartile range varied from 3.2 to 18.7 seconds. For each age group and examination (single sequence), the scan time is described in detail in the Table 5.

| Examination | Age group (year) | Minimum | Maximum | Median | Interq. Range |
|---|---|---|---|---|---|
| Head | ≤1 | 2.5 | 29.3 | 9.7 | 10.7 |
| | (1-5] | 3.6 | 22.2 | 7.6 | 5.7 |
| | (5-10] | 3.6 | 16.3 | 6.4 | 3.5 |
| | (10-15] | 2.5 | 45.3 | 9.5 | 6.7 |
| Chest | ≤1 | 3.1 | 18.3 | 4.5 | 2.1 |
| | (1-5] | 3.4 | 22.6 | 6.6 | 9.6 |
| | (5-10] | 3.6 | 39.3 | 8.6 | 22.4 |
| | (10-15] | 7.5 | 27 | 9.7 | 13.2 |
| Abdomen | ≤1 | 5.3 | 18.3 | 6.6 | 3.2 |
| | (1-5] | 3.3 | 22.3 | 9 | 14.0 |
| | (5-10] | 4.7 | 31.5 | 11.4 | 19.4 |
| | (10-15] | 3.5 | 37.2 | 22.7 | 18.7 |

**Table 5: Scan Time (Second) for Each Age Group Per Examination (Single Sequence)**

### C) Tube Voltage (kVp)

The tube voltage for the scout image in all age groups and examinations varied from (80 to 130) kVp. The tube voltage used for head, chest, and abdomen CT examinations varied from (80 to 130, 100 to 130, and 100 to 130) kVp respectively whereas the average tube voltage for the head, chest, and abdomen CT examinations was (112.75, 112.92, and 113.25) kVp respectively. The tube voltage used in each age group varied (80 to 120, 100 to 120, 100 to 130, and 110 to 130) kVp. For each age group and CT examination, the tube voltage is described in detail in the Table 6.

| Examination | Age group (year) | Minimum | Maximum | Mean ± SD |
|---|---|---|---|---|
| Head | ≤1 | 80 | 120 | 107.7 ± 1.8 |
| | (1-5] | 100 | 120 | 109.7 ± 1.3 |
| | (5-10] | 100 | 120 | 113 ± 1.3 |
| | (10-15] | 110 | 130 | 120.7 ± 1.2 |
| Chest | ≤1 | 100 | 110 | 101.3 ± 0.6 |
| | (1-5] | 100 | 120 | 112 ± 1.3 |
| | (5-10] | 100 | 130 | 115 ± 1.3 |
| | (10-15] | 120 | 130 | 123.3 ± 0.9 |
| Abdomen | ≤1 | 100 | 110 | 106 ± 0.9 |
| | (1-5] | 100 | 120 | 107.7 ± 1.1 |
| | (5-10] | 100 | 120 | 116 ± 1 |
| | (10-15] | 120 | 130 | 123.3 ± 0.9 |

**Table 6. KVp for Each Age Group and Examination**

### D) Tube Current-Time (mAs)

The tube current-time product for the scout image in all age groups and examinations varied from (13 to 399) mAs. The tube current-time product used for head, chest, and abdomen CT examinations varied from (80 to 399, 13 to 189, and 17 to 250) mAs respectively. For each age group and examination, the tube-current-time product is described in Table 7.

| Examination | Age group (year) | Minimum | Maximum | Mean ± SD |
|---|---|---|---|---|
| Head | ≤1 | 80 | 399 | 126.6 ± 20.3 |
| | (1-5] | 164 | 399 | 262.4 ± 15.8 |
| | (5-10] | 172 | 399 | 271.5 ± 14.8 |
| | (10-15] | 160 | 399 | 282 ± 14.9 |
| Chest | ≤1 | 13 | 60 | 46.7 ± 2.1 |
| | (1-5] | 19 | 125 | 64.1 ± 6 |
| | (5-10] | 20 | 125 | 66.5 ± 5.9 |
| | (10-15] | 22 | 189 | 81.6 ± 7 |
| Abdomen | ≤1 | 17 | 51 | 31.8 ± 2.7 |
| | (1-5] | 17 | 150 | 95.5 ± 9.6 |
| | (5-10] | 20 | 250 | 113.4 ± 13.5 |
| | (10-15] | 29 | 139 | 75 ± 5.2 |

**Table 7: The Tube Current-Time Product (mAs) for Each Age Group and Examination**

### 3.1.2 Comparation Result Between Hospitals

For each examination and age group, a total of 40 patient dose records from the three hospitals were reviewed and the average of the CT dose quantities was presented. The comparison of the average of CTDIvol (mGy), DLP per scan (mGy.cm), and total DLP (mGy.cm) of the head, chest, and abdomen CT examination between the three hospitals showed that for head CT examinations the three dosimetric quantities for hospital B were higher compared to the values of hospital A and C (Table 8 A). The average of the CT dose quantities (CTDIvol, DLP per scan, and total DLP) for pediatric chest and abdomen CT examination showed that the values for Hospital A were lower than for hospital B and hospital C (Table 8 B and C).

| Examination | Age group (years) | Dose type | Hospital A N=40 | Hospital B N=40 | Hospital C N=40 |
|---|---|---|---|---|---|
| Head | ≤1 | DLP per scan | 562.3 | 630.9 | 446.1 |
| | | DLP per exam | 1031.1 | 1195.7 | 892.6 |
| | | CTDIvol | 25.9 | 27.9 | 25.4 |
| | (1_5] | DLP per scan | 574.3 | 1003.6 | 729.8 |
| | | DLP per exam | 796.9 | 1373.7 | 1004.4 |
| | | CTDIvol | 27.4 | 38.4 | 25.4 |
| | (5_10] | DLP per scan | 660.1 | 1058.9 | 634 |
| | | DLP per exam | 845.3 | 1316.5 | 945.3 |
| | | CTDIvol | 28.4 | 37.8 | 37.6 |
| | (10_15] | DLP per scan | 880.6 | 1173.8 | 795.3 |
| | | DLP per exam | 1091.6 | 1896.4 | 896 |
| | | CTDIvol | 34.5 | 43.3 | 41.8 |

**A: Head**

| Examination | Age group (years) | Dose type | Hospital A N=40 | Hospital B N=40 | Hospital C N=40 |
|---|---|---|---|---|---|
| Chest | ≤1 | DLP per scan | 23.2 | 43.0 | 49.9 |
| | | DLP per exam | 47.1 | 86.5 | 100.6 |
| | | CTDIvol | 0.9 | 1.9 | 2.3 |
| | (1_5] | DLP per scan | 40.3 | 115.2 | 100.6 |
| | | DLP per exam | 81.0 | 232.0 | 204.4 |
| | | CTDIvol | 1.5 | 3.7 | 4.5 |
| | (5_10] | DLP per scan | 73.1 | 131.1 | 154.1 |
| | | DLP per exam | 147.5 | 264.9 | 228.2 |
| | | CTDIvol | 2.1 | 5.0 | 4.5 |
| | (10_15] | DLP per scan | 142.3 | 284.8 | 218.8 |
| | | DLP per exam | 281.0 | 573.0 | 438.0 |
| | | CTDIvol | 3.7 | 6.9 | 5.1 |

**B: Chest**

| Examination | Age group (years) | Dose type | Hospital A N=40 | Hospital B N=40 | Hospital C N=40 |
|---|---|---|---|---|---|
| Abdomen | ≤1 | DLP per scan | 38.2 | 71.7 | 71.5 |
| | | DLP per exam | 76.9 | 148.7 | 146.4 |
| | | CTDIvol | 1.5 | 2.5 | 2.5 |
| | (1_5] | DLP per scan | 53.8 | 116 | 100.6 |
| | | DLP per exam | 108.1 | 233.3 | 202.8 |
| | | CTDIvol | 1.7 | 5.4 | 3.1 |
| | (5_10] | DLP per scan | 105.3 | 176.5 | 129.4 |
| | | DLP per exam | 242.9 | 363.1 | 258.3 |
| | | CTDIvol | 2.6 | 4.7 | 3.7 |
| | (10_15] | DLP per scan | 279.9 | 321.8 | 122 |
| | | DLP per exam | 543.1 | 665 | 243.4 |
| | | CTDIvol | 5.1 | 7 | 2.8 |

**Table 1: Average CTDIvol (mGy), DLP Per Scan (mGy.cm), and total DLP (mGy.cm) of the Head, Chest, and Abdomen CT Examinations of Three Hospitals**

### 3.1.3 Computed Tomography Dose Quantities

As per the recommendation of ICRP and European DRLs guidelines, the LDRLs for the routine pediatric CT examinations per each age group of this study were established using the 75$^{th}$ percentile of the CT dose quantities (CTDIvol and DLP). In addition, the 25$^{th}$, and 50$^{th}$ percentiles of the CT-dose quantities CTDIvol and DLP per scan were described in Table 8.

| Examination | Age group (years) | CTDIvol (mGy) | | | DLP per scan (mGy cm) | | |
|---|---|---|---|---|---|---|---|
| | | 25$^{th}$ | 50$^{th}$ | 75$^{th}$ | 25$^{th}$ | 50$^{th}$ | 75$^{th}$ |
| Head | ≤1 | 21.1 | 23.6 | 31.5 | 351 | 443 | 723.4 |
| | (1-5] | 26.6 | 28.9 | 38.7 | 568 | 645.5 | 1032.7 |
| | (5-10] | 28.1 | 31.5 | 38.7 | 596.2 | 738 | 1037.4 |
| | (10-15] | 34.8 | 38.7 | 47.0 | 747.7 | 992.1 | 1126.7 |
| Chest | ≤1 | 0.9 | 2 | 2.3 | 19.9 | 38.2 | 55.9 |
| | (1-5] | 1.87 | 3.5 | 4.1 | 49.4 | 94.4 | 109.4 |
| | (5-10] | 2.6 | 4.1 | 5.1 | 89.5 | 114.8 | 145.0 |
| | (10-15] | 3.87 | 5.2 | 6.1 | 150.1 | 205.3 | 258.9 |
| Abdomen | ≤1 | 1.2 | 1.65 | 1.7 | 33 | 38.1 | 38.1 |
| | (1-5] | 2.25 | 3.15 | 3.2 | 66.6 | 96.3 | 96.3 |
| | (5-10] | 2.2 | 3.95 | 4.0 | 82.5 | 136.1 | 136.1 |
| | (10-15] | 2.8 | 4.69 | 4.7 | 126.5 | 242.2 | 242.5 |

**Table 8: The 25th, 50th, and Established LDRLs (75th percentile) of CTDIvol and DLP per Scan for Each Age Group of Head, Chest, and Abdomen CT Examinations**

### 3.1.4 Comparison of Established LDRLs of this Study to the International Reports

International DRLs reports used as a reference were compared to the established LDRLs of this study for each age group and pediatric CT examinations presented in Table 9.

| Examination | Age group | US (37) | | Belgium (40) | | Germany (39) | | Japan (38) | | This study | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CTDIvol | DLP per scan | CTDIvol | DLP per scan | CTDIvol | DLP per scan | CTDIvol | DLP per scan | CTDIvol | DLP per scan |
| Head | ≤1 | 23 | 344 | 22 | 420 | 30 | 300 | 30 | 480 | 31.5 | 723.4 |
| | (1-5] | 27 | 440 | 30 | 540 | 35 | 450 | 40 | 660 | 38.7 | 1032.7 |
| | (5-10] | _ | _ | 40 | 660 | 50 | 650 | 55 | 850 | 38.7 | 1037.4 |
| | (10-15] | 55 | 910 | 45 | 780 | 55 | 800 | 60 | 1000 | 47 | 1126.7 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chest | ≤1 | 1.7 | 27 | 1.2 | 25 | 1.7 | 25 | 3 | 70 | 2.3 | 55.9 |
| | (1-5] | 2.2 | 49 | 1.5 | 35 | 2.6 | 55 | 4 | 95 | 4.1 | 109.4 |
| | (5-10] | 2.5 | 70 | 2 | 55 | 4 | 110 | 6.5 | 175 | 5.1 | 145 |
| | (10-15] | 4.1 | 128 | 3 | 100 | 6.5 | 200 | 6.5 | 230 | 6.1 | 258.9 |
| Abdomen | ≤1 | 2.4 | 60 | _ | _ | _ | _ | 5 | 110 | 1.7 | 38.1 |
| | (1-5] | 2.9 | 100 | 3 | 100 | _ | _ | 6 | 190 | 3.2 | 96.3 |
| | (5-10] | 4.6 | 170 | 4 | 150 | 5 | 185 | 7.5 | 265 | 4 | 136.1 |
| | (10-15] | 7.9 | 358 | 6 | 280 | 7 | 310 | 9 | 450 | 4.7 | 242.5 |

**Table 2: International DRLs Compared with the Established LDRLs in Terms of CTDIvol (mGy) and DLP Per Scan (mGy cm)**

## 4. Discussion

The DRLs for pediatric patients is still incomplete due to the lack of sufficient data for dose surveys and establishing the DRLs. Hence, this study aimed to close the gap by evaluating the radiation dose of the head, chest, and abdominal CT examinations from three hospitals to assess optimization and establish LDRLs. In this study optimization of routine pediatric CT examinations were assessed by describing scan parameters, establishing the LDRLs, and comparing the established LDRLs to international reports by using pediatric age groups (≤1, (1-5], (5-10], and (10-15]) years.

During CT examination, it is recommended that all youngsters should be done with a tube current of 80mA, but in the findings of this study the three hospitals rarely used 80 mA and the maximum tube current-time product used by Hospital B was 399 mAs which significantly increased the dose. KVp can also reduce the patient dose exponentially, 70 to 120 KVp was recommended to perform the pediatric CT examinations, in this study none of the three hospitals were using the 70KVp and the most common KVp settings used were 100, 110, and 120 as well as occasionally they used 80KVp. For pediatric Chest CT, the recommended KVp was not more than 100 KVp but the findings of this study showed that the maximum KVp used was even up to 130KVp [13,14].

For pediatric body imaging, it is recommended to use a pitch of approximately 1.3 to1.4 and a short rotation time (~ 0.5 seconds) [14]. However, this study showed that for head CT examinations a pitch of as low as 0.3 was used which indeed would have a significant contribution for the increased dose of pediatric head CT. Where the shortest possible scan time is recommended for children, the highest scan time was used by Hospital C (45.3) second, which may be associated with the small detector size of the machine (8-row) detectors. The higher DLP in head CT could mainly be due to the over-ranging beam (29.7cm for head and 60.7cm for abdominal CT) when scanning was performed. Furthermore, the average DLP per scan and total DLP of pediatric chest CT for hospital A were lower compared to the other two hospitals in all age groups. The radiation exposure is varied by parameters and protocols, including tube voltage (KVp), effective (mAs), pitch, and slice thickness, and the reason for the lower DLP values may be associated with the higher slice thickness (5mm), higher pitch (1.68), and lower KVp (80) and mAs as low as (13) were used in hospital A than hospital B and C [15].

The LDRLs are a vital part of the optimization of radiation doses, without which it is quite difficult for operators to readily identify when excessive levels of radiation dose are being delivered. This study established the first hospital based LDRLs according to the specific age groups for head, chest, and abdomen CT examinations for pediatric patients. Apart from establishing the LDRLs, a comparison was done with other international DRLs to evaluate the status of the local practice.

The established LDRLs of this study in terms of CTDIvol (mGy) for pediatric head and chest CT examinations were comparable with the international DRLs (US, Belgium, Germany, and Japan [17-19,37]. However, the findings for abdominal CT examinations were lower than DRL reports of the US, Belgium, Germany, and Japan [16-19]. The established LDRLs of this study in terms of DLP per scan (mGy cm) showed that higher DLP per scan values (723.4, 1032.7, 1037.4, and 1126.7) mGy cm were used during pediatric head CT examinations for all age groups (≤1, (1-5], (5-10] and (10-15]) years respectively compared to the international DRLs where the maximum DLP per scan was 1000 mGy cm used in Japan for age group (10-15] years [19]. This difference could be due to the selection mode of acquisition axial or helical scanning, CT scanning parameter settings, and different manufacturers of the CT scanners used [20].

The findings of this study also showed the DLP per scan (55.9, 109.4, 145, and 258.9) mGy cm for pediatric chest CT were comparable with the reports of Japan ( 70, 95, 175, and 230) mGy cm and higher than the reports of US, Belgium, Germany in all age groups. On the contrary, the DLP per scan (38.1, 96.3, 136.1, and 242.5) mGy cm of this study for abdominal CT examinations were lower than international reports of the US, Belgium, Germany, and Japan for all age groups (≤1, (1-5], (5-10] and (10-15]) years respectively [16-19].

## 5. Conclusion

Appropriate selection of scan parameters is crucial for the optimization of dose during pediatric CT examinations. This study showed that higher scan parameter settings (KVp, mAs, and scan time) were used for all age groups and examinations.

The average CTDIvol of the three hospitals were comparable to each other but the DLP per scan and total DLP of hospital B were higher compared to the other two hospitals in all age groups of head and abdomen pediatric CT examinations. This study showed that the established LDRLs in terms of CTDIvol for head and chest pediatric CT were comparable with the reports of the US, Belgium, Germany, and Japan but in the case of abdominal pediatric CT, the findings were lowered. This suggests that proper scan parameter selections may be applied for head and chest pediatric CT examinations. The findings of this study showed that the established LDRLs in terms of DLP per scan for pediatric head CT examinations were higher in all age groups. For pediatric chest CT, the findings were compared with the reports of Japan but higher than the reports of the US, Belgium, and Germany. Furthermore, the findings for pediatric abdominal CT were lower than the reports in US, Belgium, Germany, and Japan for all age groups. Finally, the findings of this study suggested that non-optimized pediatric CT was performed for head and chest CT examinations.

## 4. Declarations

### Ethics Approval and Consent to Participate

An ethical approval was obtained from the institutional review board of Bule Hora institute of Health, Bule Hora university, with permission number BHURPD/871/13. All methods were carried out in accordance with the ethical standards established in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

### Consent for Publication

Informed consent was not obtained; thus, the Bule Hora institute of Health ethical review committee waived this requirement. Participants' anonymity and privacy were upheld, and the data were sufficiently anonymized.

### Availability of Data and Materials

The datasets used during the current study are available from the corresponding author upon reasonable request.

### Competing Interests

The authors declare no competing interests.


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### Authors' Contributions

All the authors made significant contributions to the work reported, whether by conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; by drafting, revising or critically reviewing the article; by giving final approval of the version to be published; by agreeing on the journal to which the article has been submitted; and by agreeing to be accountable for all aspects of the work.


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