Radiation Dose Assessment for Common Computed Tomography Examination at a Teaching Hospital in Ghana

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ABSTRACT

Computed tomography (CT) plays a pivotal role in clinical decision-making, particularly in the early detection and diagnosis of diseases affecting internal organs. CT uses X-rays and has the potential to cause cancer. Hence, it is imperative to keep radiation as low as reasonably achievable through optimized imaging protocols anchored in routine dosimetry and quality assurance. This study aimed to assess the radiation dose imparted to patients during common CT examinations with a newly installed 128-slice CT scanner at a teaching hospital in Ghana. CT examination data for 380 patients, collected from the Picture Archiving and Communication System (PACS) of the radiology department of a teaching hospital, were analyzed. Dose indices such as CTDIvol, DLP, and ED were analyzed and compared to international standards. Data analysis was performed using SPSS version 25.0. Of the 380 CT scans analyzed, 58.2% were male and 41.8% were female. Head CTs were the most common (63.2%), followed by abdominal (23.2%) and chest scans (13.7%). Males had higher CTDIvol and DLP for head CTs, while females had higher values for chest and abdominal scans. The 46–65 age group had the highest scan frequency (30.3%). Head CTs had the highest radiation exposure, peaking at 30.73 mGy (CTDIvol) and 699.18 mGy·cm (DLP) in middle-aged adults, while the lowest doses were recorded in pediatric patients (1–5 years). ED values for head CT were higher in males than in females for chest and abdominal scans. Despite some variation in CT doses between the genders, they were within the European Commission Radiation Protection No. 180 and ICRP publication 103 recommended dose reference levels, suggesting dose optimization.

Keywords: computed tomography, pediatric, patients, radiation dose

1.0 INTRODUCTION

Computed tomography (CT) plays a pivotal role in clinical decision-making, particularly in the early detection and diagnosis of diseases affecting internal organs (Gorleku et al., 2021; Mokhtar et al., 2017). Despite its significant contributions to modern healthcare, CT imaging utilizes ionizing radiation, which is a well-established carcinogenic agent. Given the known risks associated with ionizing radiation, there is growing concern regarding the increasing frequency of CT examinations and the corresponding rise in patient radiation exposure for diagnostic purposes (Ferrero et al., 2019; Schultz et al., 2020). Over the past few decades, the global volume of CT examinations has surged by approximately 70%, leading to a substantial increase in the cumulative radiation dose to the population (Ferrero et al., 2019).

This is particularly concerning, as CT imaging delivers significantly higher radiation doses typically 10 to 100 times greater compared to conventional radiographic procedures (Smith-Bindman, 2009; Joyce et al., 2020; Power et al., 2016). Studies show significant variation in radiation doses for identical CT exams across institutions, mainly due to differences in imaging protocols, operator expertise, and scanner models. Consequently, the risk of radiation-induced stochastic effects may be higher than in other ionizing radiation-based imaging modalities (Mileto et al., 2017; Rehani et al., 2020; Yu et al., 2009). Zhang et al. provided the first direct evidence linking CT and nuclear medicine exams to an increased thyroid cancer risk in adults (Zhang et al., 2015). Similarly, Shao et al. found an association between CT scans and thyroid cancer, leukemia, and, in patients under 45, a higher risk of non-Hodgkin's lymphoma (Shao et al., 2020). The swift progression of CT technology mandates a nuanced comprehension of radiation dose dynamics, especially with the deployment of next-generation CT systems. Such proficiency is imperative to harmonize the diagnostic yield of CT imaging with the inherent radiological risks (Smith-Bindman, 2009).

To mitigate unnecessary radiation exposure, routine dosimetric assessments are essential as part of quality control measures. These evaluations enable healthcare facilities to monitor and optimize radiation dose levels, ensuring adherence to the As Low As Reasonably Achievable (ALARA) principle. Key radiation protection strategies recommended by international regulatory bodies, including the International Atomic Energy Agency (IAEA), the International Commission on Radiological Protection (ICRP), and the European Commission (EC), emphasize the importance of justification, dose optimization, and the implementation of Diagnostic Reference Levels (DRLs). DRLs serve as benchmarks for dose optimization, with volume CT dose index (CTDI vol) and dose length product (DLP) being the primary parameters used to establish these reference levels (Liang et al., 2017; IAEA, 2018; Sakhnini, 2018).

Given these considerations, this study assessed patient radiation doses for CT examinations of the head, chest, and abdominopelvic regions. Utilizing dose data from the newly installed 128-slice CT scanner at the Radiology Department of a Teaching Hospital in Ghana, the study aimed to develop optimization strategies to reduce patient radiation exposure while maintaining diagnostic image quality.

2.0 MATERIALS AND METHODS

2.1 Study Design

A quantitative-retrospective study design approach was used for the study. Data for the study were collected from past computed tomography examinations.

2.2 Technical Specifications of the 128-slice Siemens CT Scanner

The CT scanner used in this study was a 128-slice multidetector system manufactured by Siemens. This advanced imaging system was newly installed and commissioned in October 2020 at the Radiology Department. The technical specifications of the equipment are detailed in Table 1 below.

2.3 Study Population

The study population included previous data records of paediatrics and adult patients, aged 1 to 100 years, who had undergone CT scan examinations of the brain, chest, and abdomen using a newly installed CT scanner at a teaching hospital in Ghana. Paediatrics were included because of their high sensitivity to ionizing radiation and long-life span to manifest the stochastic biological effects due to irradiation.

2.4 Sample Size

It was estimated that, on average, 30 CT scans are performed on a daily basis using this newly installed scanner. The sample size was calculated based on the study population using a statistical formula. The statistical formula below, used by Israel (1992), was adopted to compute the sample size for the study.

Table 1: Technical specifications

Manufacturer	**Name**	**Year of installation**	**Peak Kilo Voltage (KVp)**		**milli Ampere (mA)**		**No. Of slices**	**Serial No.**	**Model No.**
			Max.	**Min.**	**Max.**	**Min.**			
Siemens	Somatom Perspective	2020	130	80	345	1.0	128	76900	10495243

Table 2: Average number of CT cases done at the study area with the new scanner

Cases	Daily	Weekly (×5 working days)	Monthly (×20 working days)	8 months
Head	20	100	400	3200
Chest	4	20	80	640
Abdomen	6	30	120	960
Total	30	150	600	4800

Below details the sample size computation:

$$n = \frac{N}{1+N*e^2} \quad (1)$$

Where;

n Is the sample size =?

N is the population

E is allowed margin of error = 5%

$$n = \frac{4800}{1 + 4800 \times (0.05)^2}$$

$$n = \frac{4800}{1 + 4800 \times (0.0025)}$$

$$n = \frac{4800}{13}$$

$$\boldsymbol{n = 369}$$

Based on the computation using the statistical formula above, 369 was arrived at as the sample size and used for the study, but during the data collection, 380 data points were taken from the CT control console. Out of this number, there was no specific number selected for any of the cases (head, chest, and abdomen), whether it was children or adults. The previously recorded data were collected randomly from the CT control console.

2.5 Data Collection and Procedure

From the CT control console, patients' data were reviewed based on the protocols set by the CT scanner. A dose data collection sheet was developed to record patient details and radiation dose data for each anatomical part, which includes: patients' age, gender, diagnostic purpose of examination (patient's brief history), CTDIvol and DLP, scan length, pitch, mAs, and KVp. The effective dose for each selected anatomical part was estimated. The effective doses estimated were determined by using a DLP-based method in which the CT effective doses estimated were calculated by multiplying a DLP value and an appropriate conversion factor (k) (Sakhnini,2018).

Table 3: Patients' characteristics and protocol parameters for image acquisition

SEX	AGE (YEARS)	EXAM (BODY PART)	DOSE DESCRIPTORS				PITCH		EXPOSURE PARAMETERS				SCAN LENGTH	
			CTDIvol (mGy)		DLP (mGy.cm)				KVp		mAs		`	
	RANGE		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
M/F	1-93	Head	11.49	43.12	54.15	972.67	0.55	0.60	80	110	62	217	152.20	268.80
M/F	1-76	Chest	0.56	14.44	11.42	463.59	0.85	1.40	80	110	58	315	189.20	491.70
M/F	1-78	Abdomen	1.07	14.92	40.67	700.60	0.60	1.40	80	110	63	320	293.00	571.50

2.5 Ethical Consideration

Permissions were obtained from the ethical review board, medical directorates of Komfo Anokye Teaching Hospital (KATH) and the head of the radiology department through letters. Permission was also sought from the technical head and radiographers before the study to seek their consent. Ethical clearance was sought from the University of Cape Coast's ethical review committee. All data collected was kept on a laptop with password protection. After the research, the data were disposed of per the University of Cape Coast research protocol. The study adhered to principles outlined in the Declaration of Helsinki. All participants' data were anonymized to prevent a breach of confidentiality.

2.6 Data Analysis

Data was analyzed using the Statistical Package for the Social Sciences (SPSS) version 25.0. Descriptive statistical analyses were done. Data were presented in tables, charts, and percentages. ED values were compared to values from ECRP publication No. 180 and ICRP Publications 103. CTDIvol and DLP values were compared to those of the European Commission, Radiation Protection No. 180.

3.0 RESULTS

3.1 Age and gender distribution

A total of 380 CT dose data encompassing the head, chest, and abdominal regions were retrieved from the PACs. Out of this number, males were 221 (58.2%), and females were 159 (41.8%). The mean and the standard deviation (SD) of the ages of the patients were 43.49±20.94 years, ranging from 1 to 100 years.

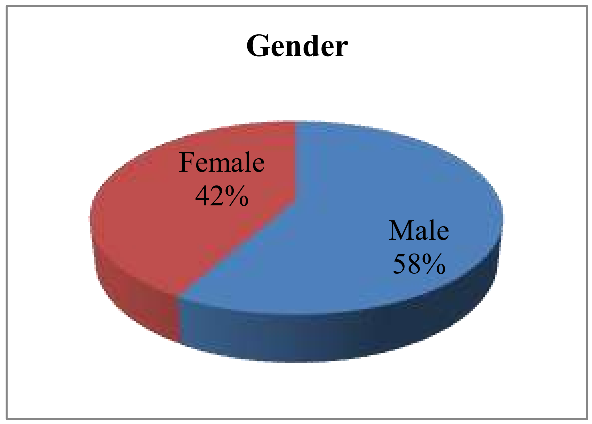

Figure 1: Gender distribution

2.7 Distribution of the examination

As shown in Figure 2, head CT scans accounted for the majority of examinations, comprising 240 cases (63.2%), while chest and abdominal scans constituted 52 (13.7%) and 88 (23.2%) cases, respectively. This indicates that head CT scans are the most frequently performed examinations at the center.

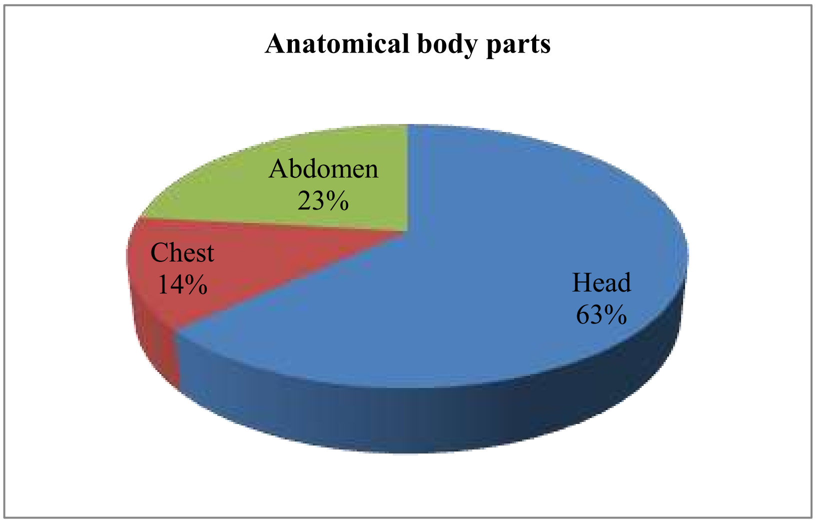

Figure 2: Distribution of the anatomical parts evaluated in the study

2.8 Mean radiations with respect to gender

The analysis of radiation dose parameters, including the volume CT dose index (CTDIvol), dose-length product (DLP), and effective dose (ED) for head, chest, and abdominal CT examinations across male and female patients (Table 3).

For head CT scans, males exhibited higher mean CTDIvol (28.70 ± 6.12 mGy) and DLP (630.33 ± 148.94 mGy.cm) compared to females (26.72 ± 5.00 mGy and 542.34 ± 146.33 mGy.cm, respectively). Similarly, the mean ED was slightly higher in males (1.45 ± 0.34 mSv) than in females (1.25 ± 0.34 mSv). However, in chest CT examinations, females had a higher mean CTDIvol (6.22 ± 3.53 mGy) than males (4.78 ± 1.35 mGy). The DLP was also higher in females (227.12 ± 109.45 mGy.cm) compared to males (200.45 ± 70.62 mGy.cm). The mean ED values were 3.86 ± 1.86 mSv for females and 3.41 ± 1.20 mSv for males. For abdominal CT scans, females again showed higher radiation dose values, with a mean CTDIvol of 7.39 ± 2.82 mGy, DLP of 353.18 ± 137.58 mGy.cm, and ED of 5.29 ± 2.06 mSv. In comparison, males had lower values for these parameters: CTDIvol (5.07 ± 1.93 mGy), DLP (244.09 ± 97.42 mGy.cm), and ED (3.66 ± 1.46 mSv).

The distribution of patient ages across different groups is presented in Table 4. The highest proportion of CT examinations was performed on patients aged 46–65 years (30.3%), followed by those aged 18–35 years (21.1%). In contrast, the least frequent age group was 86–100 years, accounting for only 0.8% of cases.

Table 4: Mean and standard deviation (SD) values for CTDIvol, DLP, and ED for all examinations between genders

GENDER	BODY PART	MEAN AND STANDARD DEVIATIONS OF CTDIvol, DLP, AND ED		
		CTDIvol (mGy)	DLP (mGy.cm)	ED (mSv)
MALE	HEAD	28.70 ± 6.12	630.33 ± 148.94	1.45 ± 0.34
	CHEST	4.78 ± 1.35	200.45 ± 70.62	3.41 ± 1.20
	ABDOMEN	5.07 ± 1.93	244.09 ± 97.42	3.66 ± 1.46
FEMALE	HEAD	26.72 ± 5.00	542.34 ± 146.33	1.25 ± 0.34
	CHEST	6.22 ± 3.53	227.12 ± 109.45	3.86 ± 1.86
	ABDOMEN	7.39 ± 2.82	353.18 ± 137.58	5.29 ± 2.06

Table 5: Age distribution in groups

Age (Year)	1 - 5	6 -11	12-17	18 -35	36 -45	46 - 65	66 -75	76-85	86-100
Frequency	13	18	21	80	71	115	41	18	3
Percentage (%)	3.4	4.7	5.5	21.1	18.7	30.3	10.8	4.7	0.8
Group	1	2	3	4	5	6	7	8	9

2.9 Comparison of the CTDIvol of each body part across the age groups

Figure 3 below illustrates the variation in CT dose index volume (CTDIvol) across different age groups for head, chest, and abdominal CT examinations.

Head CT scans consistently exhibited the highest radiation dose across all age groups, with the peak values observed in Group 4 (30.38 mGy), Group 5 (29.77 mGy), and Group 7 (30.73 mGy). Chest CT scans had significantly lower CTDIvol values, with the highest dose recorded in Group 5 (6.37 mGy) and Group 6 (6.66 mGy). Abdominal CT scans showed moderate dose levels, with the highest CTDIvol observed in Group 5 (6.36 mGy) and Group 6 (6.67 mGy).

The lowest CTDIvol values were observed in Group 1 (ages 1–5 years) for all scan types, with the chest and abdomen receiving particularly minimal exposure (0.5 mGy and 1.09 mGy, respectively).

2.30 Comparison of DLP (mGy.cm) of each body part across the age groups

Figure 4 presents the variation in Dose-Length Product (DLP) across different age groups for head, chest, and abdominal CT examinations. Head CT scans consistently exhibited the highest DLP values across all age groups, with the highest recorded in Group 4 (699.18 mGy·cm), followed by Group 5 (629.71 mGy·cm) and Group 7 (628.72 mGy·cm). Chest CT scans had significantly lower DLP values, with the highest dose in Group 7 (306.94 mGy·cm) and Group 6 (313.39 mGy·cm). Abdominal CT scans showed moderate DLP values, peaking in Group 7 (196.04 mGy·cm) and Group 6 (188.51 mGy·cm). The lowest DLP values were observed in Group 1 (ages 1–5 years) across all scan types, with chest (11.37 mGy·cm) and abdomen (53.02 mGy·cm) receiving the least exposure.

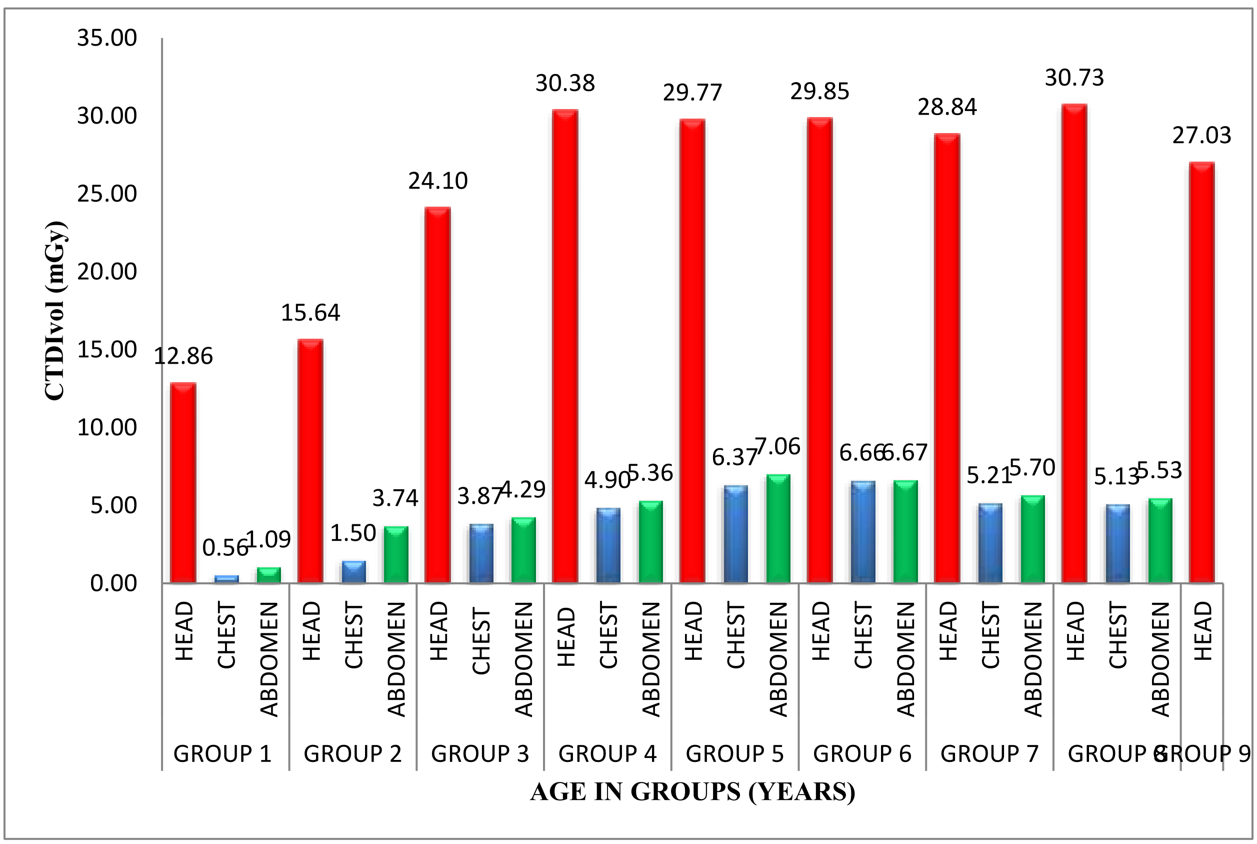

Figure 3: CTDIvol (mGy) for age groups

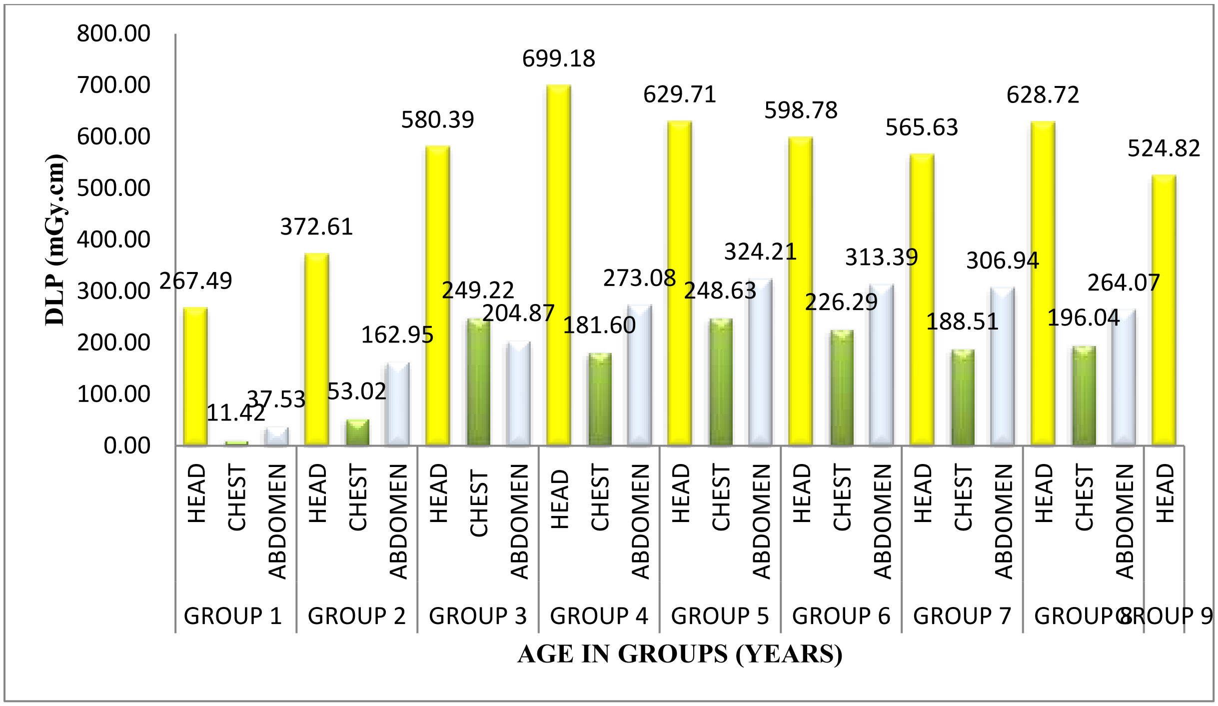

Figure 4: DLP (mGy.cm) for age groups

2.31 Comparison of the effective dose (mSv) of each body part across the age groups

Figure 5 also illustrates the variation in Effective Dose (ED) across different age groups for head, chest, and abdominal CT examinations. Head CT scans generally had the highest ED values across all age groups, with the peak in Group 4(18-35 years) (4.86 mSv), followed by Group 5(36-45 years) (4.23 mSv) and Group 3(12-17 years) (4.24 mSv). Chest CT scans showed moderate ED levels, with the highest values in Group 6 (46-65years) (3.85 mSv) and Group 5(36-45 years) (3.10 mSv). Abdominal CT scans had relatively lower ED values, peaking in Group 7(66-75) (3.33 mSv) and Group 6 (3.20 mSv). The lowest ED values were observed in Group 1 (1–5 years) for all scan types, with chest (0.19 mSv) and abdomen (0.56 mSv) receiving the least exposure.

2.32 Comparison of CT Dose Parameters with European Commission Radiation Protection No. 180 and ICRP values

The European Commission's Radiation Protection No. 180 (2014) provides reference values for CTDIvol, DLP, and Effective Dose (ED), which serve as benchmarks for evaluating radiation exposure levels across different anatomical regions. Table 5 presents the reference values established by the European Commission for CT dose parameters. The most common CTDIvol for head scans is 60 mGy, with a range of 50–75 mGy.

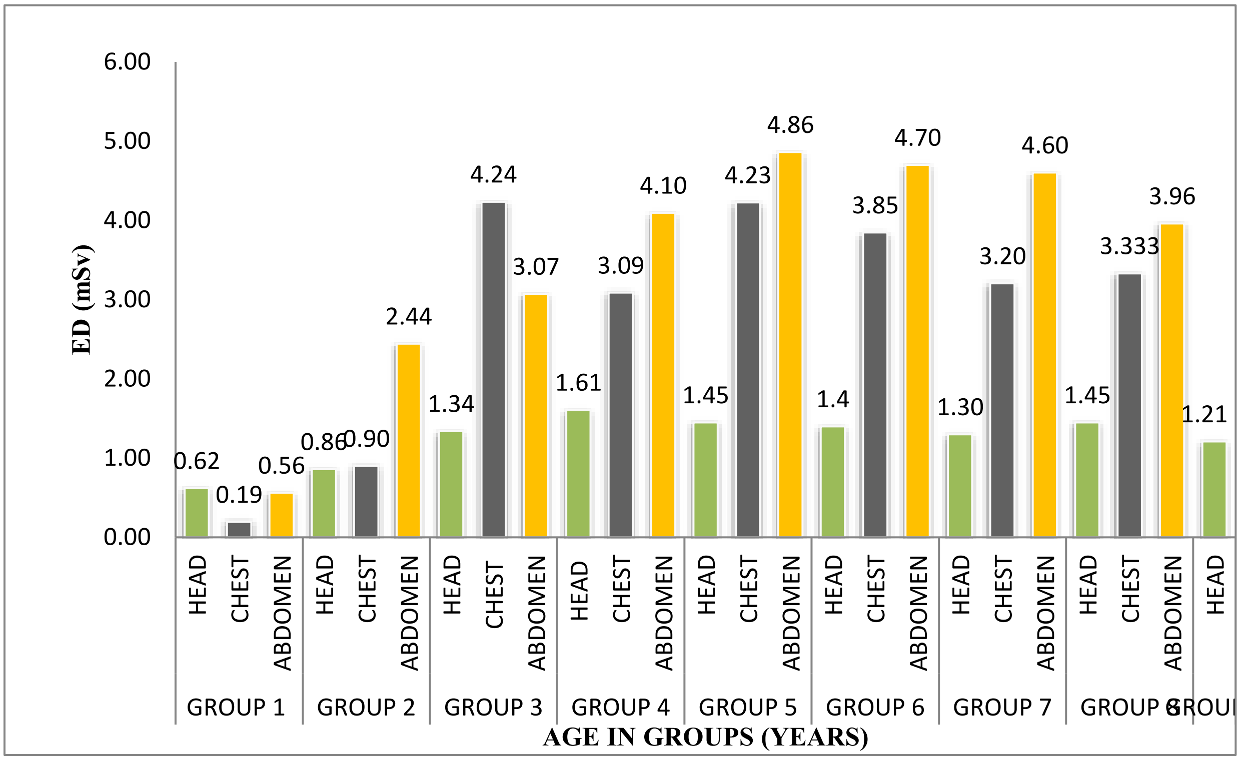

Figure 5: Effective dose for age groups

In comparison, the chest and abdomen CTDIvol values are significantly lower, with the most common values of 10 mGy and 25 mGy, respectively. The DLP values for head, chest, and abdomen scans are 1000 mGy.cm, 400 mGy.cm, and 800 mGy.cm, respectively, with varying ranges indicating differences in scanning protocols and techniques across different facilities. According to ICRP Publication 103, the estimated ED for head scans is 0.9 mSv, while the chest and abdomen scans have higher ED values of 8.2 mSv and 12.7 mSv, respectively (ICRP, 2007). These variations highlight the need for careful radiation dose management, especially for chest and abdominal CT examinations, where the potential radiation risks are relatively higher.

Table 6: CTDIvol (mGy) and DLP (mGy.cm) and effective Dose (ED) (mSv) values from European Commission, Radiation protection No. 180 (ECRP, 2014) and ICRP Publication 103 (ICRP, 2007)

Anatomical region - CTDIvol	**Most common value**	**Range**
Head	60	50-75
Chest	10	10-30
Abdomen	25	13-35
DLP (mGy.cm)		
Head	1000	760-1300
Chest	400	270-700
Abdomen	800	460-1200

Anatomical region	**ECRP, 2014 ED (mSv) values**	**ICRP 103, 2007 ED (mSv)**[16]
Head	2.30	0.90
Chest	6.80	8.20
Abdomen	12.00	12.70

4.0 DISCUSSION

A total of 380 patient dose records were analyzed in this study, with a male predominance (58.2%) compared to females (41.8%). This gender distribution suggests a higher utilization of CT imaging among males, which could be attributed to factors such as differences in disease prevalence, referral patterns, or healthcare-seeking behavior. This aligns closely with the findings of which reported that 221 (64.9%) of CT trauma cases were attributed to the males out of 44,218 cases in a study which analyze the propensity of CT utilization for diagnosing headaches (Gorleku et al., 2021). The variation in radiation dose may be attributed to differences in body composition, scan protocols, and clinical indications for CT imaging. Since males generally have larger body sizes, a higher radiation output may be required to achieve optimal image quality. Additionally, differences in scan parameters and anatomical structures could contribute to the observed disparity (Maidamma et al., 2021; Ismail et al., 2018; McCollough et al., 2011; Rehani et al., 2025).

The study found that females had a higher mean CTDIvol (6.22 ± 3.53 mGy) than males (4.78 ± 1.35 mGy) in chest CT examinations. Similarly, DLP was greater in females (227.12 ± 109.45 mGy.cm) than in males (200.45 ± 70.62 mGy.cm). This difference may result from higher tissue attenuation in females, particularly in the breast and thoracic region, requiring increased radiation output for optimal image quality. Variations in scanner settings and automatic exposure control (AEC) adjustments could also contribute to this disparity (Yu et al., 2009, Inoue et al., 2018). Despite this, chest CTDIvol values for both genders remained within the acceptable range set by the European Commission, Radiation Protection No. 180 (Yadav et al., 2023). Both genders had lower abdominal CTDIvol values (male = 5.07 ± 1.93; female = 7.39 ± 2.82). This variation could be due to difference in tube current time product as CTDIvol is directly proportional to tube current time product (mAs) (McCollough et al., 2011, Silov et al., 2023). Furthermore, Males exhibited higher Dose-Length Product (DLP) values (630.33 ± 148.94 mGy.cm) compared to females (542.34 ± 146.33 mGy.cm), which may be attributed to the higher frequency of head CT referrals for trauma among males (Gorleku et al., 2021, Ismail et al., 2018) . In cases of head trauma, the scan length is often extended to encompass the entire head, thereby increasing the DLP. Variations in abdominal DLP values between genders may also be attributed to differences in patient height, which can affect the length of the abdominal region and consequently influence scan length (Nagel, 2007). The abdominal DLP values for female was higher than male but both values were significantly lower than the reference values reported by the European Commission in Radiation Protection No. 180.

The estimated chest and abdomen ED values for both males and females were lower than those reported in ECRP 2014 and ICRP Publication 103. The estimated head ED values for both male and female were lower than that reported in ECRP 2014. The head CTDIvol values remained relatively consistent across age groups 4 to 9, which fall within the adult category. This consistency can be attributed to the automatic exposure control (AEC) system, which adjusts radiation dose without specifically accounting for anatomical measurements beyond age and gender. Consequently, patients within the same adult age category tend to receive similar dose levels. As illustrated in Figure 3, head CTDIvol values across all age groups were lower than those reported by the European Commission in Radiation Protection No. 180. The overall increase in CTDIvol with age may be explained by differences in body size and anatomical thickness, leading to higher mAs settings, as dose increases proportionally with mAs (Maidamma et al., 2021). The mean chest DLP values varied across groups 4 to 8, with some similarities and slight differences between them. Notably, groups 3 and 5 recorded comparable values, likely due to their classification within the adult age category. This consistency can be attributed to the AEC system, which selects exposure parameters based on age and gender rather than precise anatomical measurements. As a result, patients within the same age group tend to receive similar doses. Furthermore, minor differences in chest DLP values among groups 4, 7, and 8 may be explained by the presence of disease conditions or incidental findings, which can extend scan length and consequently increase DLP. Compared to international standards, the chest DLP values reported by the European Commission in Radiation Protection No. 180 were higher than those recorded in this study for all age groups. A similar trend was observed for abdominal DLP values, which showed a steady increase from groups 1 to 5, corresponding with age-related increases in scan length. However, from groups 6 to 8, abdominal DLP values began to decline while remaining relatively consistent within this range. This trend is likely due to the fact that these age groups fall within the adult category, where variations in scan length are minimal. Despite this decline, the abdominal DLP values for age groups 5, 6, and 7 were still lower than those reported by the European Commission as well as other age groups. For head, chest and abdominal examinations, the ED values for all age groups were lower than those reported in ECRP publication No. 180.

Dose optimization and image quality assessment.

The CT system is equipped with age-stratified, preset examination protocols that are specifically optimized for both pediatric and adult patients. These preconfigured protocols are designed to deliver diagnostically excellent image quality while ensuring that radiation exposure and scan parameters are appropriately tailored to each patient group. The protocol library covers a comprehensive range of clinical examinations, with each preset rigorously validated to produce images that meet the highest standards for diagnostic confidence and clinical decision-making, without compromise to image quality.

5.0 CONCLUSION

This study analyzed 380 CT examinations at a Teaching Hospital to estimate CT radiation dose levels in terms of CTDIvol, DLP, and ED. The results revealed that male patients outnumbered females, with the majority of patients falling within the middle adulthood age group. Among the types of CT scans performed, head CT was the most frequently conducted, surpassing chest and abdominal CT scans. A key observation was that males recorded higher head DLP values than females, primarily due to the higher frequency of head CT referrals for trauma cases. In contrast, females exhibited higher DLP values for chest and abdominal scans. Additionally, differences in CTDIvol values were noted between genders. The ED values for head CT were higher in males, largely due to increased DLP values and the longer scan lengths required to cover the entire cranial volume. Overall, the estimated dose levels in this study were within the Diagnostic Reference Levels (DRLs) recommended by the European Commission, Radiation Protection No. 180 and ICRP publication 103. These findings suggest that the radiation doses administered by the CT scanner were well-optimized for both pediatric and adult patients, ensuring effective dose management while achieving diagnostic accuracy.

ACKNOWLEDGEMENTS

None

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APPENDIX

DATA COLLECTION SHEET

Table 7: The table below shows the sample of the data collection sheet with patients' characteristics and protocol parameters for image acquisition

SEX	AGE (YEARS)	EXAM (BODY PART)	DOSE DESCRIPTORS		PITCH	EXPOSURE PARAMETERS		SCAN LENGTH
			CTDIvol (mGy)	DLP (mGy.cm)		KVp	mAs	