Size-Specific Dose Estimate for Chest of Adult Patients in 128- Slice Computed Tomography at Rajavithi Hospital

ABSTRACT

Aims: To determine the patient radiation dose using Size-Specific Dose Estimates (SSDEs) for chest CT in adult patients performed with 128-slice CT technology.

Study design: A descriptive cross-sectional study was conducted as a retrospective analysis.

Place and Duration of Study: Department of Radiology, Rajavithi Hospital, between April 1 and September 30, 2021.

Method: We included 500 patients (209 males, 291 females). All patients underwent chest contrast enhancement with a venous phase protocol. The patient radiation dose in terms of SSDE was calculated based on AP+Lat dimensions, effective diameter, and water-equivalent diameter. SSDEs was measured from the middle slice of the scan range. The conversion factors following body size and composition were applied according to the AAPM Reports No. 204 and 220 recommendations. Additionally, the study assessed the effective dose and dose-length product (DLP). Key parameters, including DLP, CTDIvol, effective dose, and SSDEs at the 75th percentile, were evaluated to determine radiation dose levels. These values were then compared with established national and international diagnostic reference levels.

Results: The study found that the mean DLP was 301.74 mGy·cm, CTDIvol was 8.38 mGy, effective dose was 4.22 mSv, SSDE (AP+Lat) was 11.80 mGy, SSDE (Effective Diameter) was 11.86 mGy, and SSDE (Dw) was 12.91 mGy. When compared with reference radiation dose values from Thailand and international standards, the DLP, CTDIvol, and effective dose values were found to be lower than both Thai and international reference values. In contrast, the SSDE (AP+Lat) was also lower than previously reported findings. Additionally, the study found no available comparative data for SSDE (Effective Diameter) and SSDE (Dw).

Conclusion: The comparison of radiation dose values using SSDE across the three methods revealed highly consistent results. The SSDE values obtained from this study can serve as reference levels for the radiation doses received by patients undergoing CT scans at the Radiology Department of Rajavithi Hospital. These values are instrumental in assessing the appropriateness of radiation doses applied during CT imaging and can serve as benchmarks for future dose optimization efforts. Furthermore, this study highlights the significance of evaluating radiation doses in diagnostic imaging, providing valuable baseline data that enhances our understanding of the radiation risks associated with various types of examinations. Further research is warranted to investigate radiation exposure in computed tomography for other body regions.

***Keywords**: Size-Specific Dose Estimate (SSDE), Computed Tomography Dose Index Volume ($CTDI_{vol}$), Dose-Length Product (DLP), Diagnostic Reference Levels (DRLs), and Patient Size Conversion Factor (f_{size}).*

1. INTRODUCTION

The technology of computed tomography (CT) has continuously evolved over the past several decades, from the discovery of X-rays, which form the foundation of diagnostic imaging, to the development of modern CT scanners. With rapid advancements in engineering and computer science, modern CT scanners have significantly improved in performance compared to their predecessors, enabling more accurate diagnoses. Today, CT scanning is widely used and plays a critical role in diagnosis, treatment planning, and monitoring of therapeutic outcomes, leading to an increase in the frequency of its use annually. Furthermore, CT technology continues to advance, and as the capabilities of these high-performance machines improve, the radiation doses delivered to patients have also increased. CT examinations generally deliver higher radiation doses compared to other diagnostic imaging modalities (Table 1).When comparing the radiation dose from CT scans with the natural background radiation, it is evident that, while some CT examinations may deliver relatively low doses, there is limited discussion regarding the establishment of dose limits for each type of radiological examination. Even though the radiation dose from diagnostic imaging may be small or large, it still carries a potential risk for cancer development, as the impact of radiation exposure is influenced by factors such as age, organ type, location, dose, and the severity of exposure. Therefore, it is crucial to monitor and ensure that radiation doses are kept as low as reasonably achievable (ALARA) while still maintaining sufficient image quality for accurate diagnosis. Radiation doses should not exceed the Diagnostic Reference Levels (DRLs) as recommended by the International Atomic Energy Agency (IAEA) (Table 2). Consequently, organizations have increasingly focused on minimizing patient radiation exposure while ensuring optimal imaging quality. Thus, calculating the radiation dose received during CT examinations is essential for ensuring patient safety and compliance with radiation protection guidelines.

Fundamental Concepts in Measuring Radiation Dose for Patients Undergoing Computed Tomography (CT) Examinations[1]

Radiation Dose Metrics:

- CT Dose Index Volume (CTDIvol): Measures the average radiation dose per slice of a CT scan, reflecting the level of exposure during imaging.
- Dose-Length Product (DLP): Represents the total radiation dose over the entire scan, calculated by multiplying CTDIvol by the length of the scanned region.
- Size-Specific Dose Estimate (SSDE): Adjusts dose estimations based on patient size,providing a more accurate reflection of radiation exposure tailored to individual patient anatomy.

Principles of Measurement and Evaluation:

- The use of integrated dose monitoring systems within CT scanners to accurately track radiation exposure.
- Consideration of anatomical positioning and organ size to assess and optimize radiation delivery during scanning procedures.

Strategies for Radiation Dose Reduction:

- Implementing scanning protocols optimized for diagnostic requirements to limit unnecessary exposure.

- Modifying technical parameters such as tube current and voltage to align with the patient's physical characteristics.
- Adhering to the "As Low As Reasonably Achievable (ALARA)" principle to maintain image quality while minimizing radiation exposure.

This foundational knowledge plays a crucial role in enhancing patient safety and supporting effective diagnostic imaging, making it essential for clinical best practices and ongoing research efforts in radiology

The standard unit used to measure radiation for CT scanners is the CT Dose Index (CTDI), which represents the average radiation dose along the Z-axis. CTDI is a measure of kerma (Kinetic Energy Released per Unit Mass) expressed in units of mGy or mGy/mAs and does not directly represent the radiation dose received by the patient. Instead, it is a measurement of output that is used to compare radiation doses across different CT scanners. The most commonly used CTDI values include the Weighted CT Dose Index ($CTDI_W$), which represents the distribution of radiation at various positions of a phantom, and the Volume CT Dose Index ($CTDI_{vol}$)[(2)], which measures the radiation dose for patient diagnostic scans. $CTDI_{vol}$ reports the average radiation dose delivered during a scan, taking into account the pitch ratio in helical scan mode. In helical mode, the average radiation dose may be higher or lower than that from axial mode depending on the movement of the CT table. When the table moves slowly through the gantry's radiation beam, the radiation dose in the transverse section of the patient may be higher than in axial mode due to overlapping radiation beams (pitch < 1). Conversely, if the table moves faster, the radiation beams will not overlap but will continue in sequence (pitch = 1). If the table moves faster still, the radiation beams will be spaced apart (pitch > 1), which necessitates the incorporation of the total volume along with the pitch value in the assessment of radiation dose, resulting in the $CTDI_{vol}$.[(3)]

CTDIvol is used to calculate the radiation dose received by organs or the body during a CT examination, providing an estimate of the total radiation dose for that particular scan. It is generally observed that when the pitch is less than 1, the CTDIvol increases. In situations where high-quality images are required, a lower pitch is used, which results in higher radiation exposure to the patient. The challenge lies in balancing the need for high-quality images while ensuring that radiation levels do not exceed acceptable limits. CTDI serves as an index for the radiation dose from CT scans, but it does not directly measure the accuracy of radiation dose estimation for individual patients. To address this limitation, the American Association of Physicists in Medicine (AAPM) report 204[(4)] proposed a new method called Size-Specific Dose Estimate (SSDE), using the AP+Lat Dimensional, Effective Diameter methods. Additionally, the AAPM report 220[(5)] recommended a method for calculating SSDE that incorporates patient size and adjusts for radiation dose reduction, using the water equivalent diameter (Dw). This method involves defining the region of interest (ROI) around the patient's body in the cross-sectional CT image, calculating the volume, and using this data to more accurately assess the radiation dose. By considering patient size in the calculation, this approach allows for a more precise and accurate estimation of the radiation dose received by the patient.[(4,5)]

The objective of this study is to evaluate the Size-Specific Dose Estimate (SSDE) for chest CT examinations in patients, calculated using the AP+Lat Dimensional, Effective Diameter, and Dw methods. Additionally, the study aims to compare the SSDE values for chest CT examinations using these three methods, to establi reference radiation dose values for diagnostic radiology at Rajavithi Hospital. These values will serve as a baseline for comparison with national and international radiation dose reference levels. Ultimately, this research will contribute to ensuring that patients receive appropriate radiation doses, and it will support the development and refinement of imaging techniques to reduce patient radiation exposure in the future.

Table 1 presents the radiation dose values from CT examinations, which are higher than those from other types of diagnostic X-ray machines, according to medical standards in the United States, 2009.[6]

Table 1: The radiation dose values from CT Examination

Diagnostic		Typical effective dose (mSv)
General X-ray, Radiography	- Chest X-ray	0.1
	- Spine	1.5
	- Extremities	0.001
CT scan	- CT Brain	2
	- CT Chest	7
	- CT Abdomen	10
Bone Density (DEXA)		0.001
Intravenous Pyelography : IVU		3
Upper-Lower GI study		6

Table 2 presents the standard reference radiation dose values (DRLs) using the parameters $CTDI_{vol}$ (mGy), DLP (mGy·cm), and Effective Dose (mSv) from various countries, including Thailand.

Table 2: The standard reference radiation dose values (DRLs)

	$CTDI_{vol}$ (mGy)	DLP (mGy·cm)	Effective dose (mSv)
EUR 16262[7]	30	650	11.1
American 2009[6]	-	-	7
UK 2011[8]	-	610	6.1
IAEA 2006[9,10]	-	-	5.9
ICRP publication 87[11]	30	-	-
Japan 2015[12,13]	15	550	-
Thailand DRLs 2021[14]	18	665	-

2. METHODOLOGY:

2.1 Methods

This research is applied research with a cross-sectional study design, utilizing retrospective data collection. The study focused on patients who underwent chest CT scans at the Radiology Department of Rajavithi Hospital between April 1 and September 30, 2021. This period was chosen due to the implementation of a new CT scan protocol for chest examinations, which aimed to assess the radiation dose received by patients compared to the Diagnostic Reference Levels (DRLs). A total of 500 patients who were scanned during this time frame were included in the study.

2.2 Equipment for Data Collection

1.The CT scanner used in this study is a SIEMENS 128-slice SOMATOM DefinitionAS, located in the Radiology Department of Rajavithi Hospital. All patients who underwent chest CT scans with post-contrast imaging in the venous phase had their $CTDI_{vol}$ and DLP values recorded. The data were accessed through the hospital's Picture Archiving and Communications System (PACS) (Figure 1).

Table 3: Protocol for CT Chest Examination at the Radiology Department of Rajavithi Hospital

Protocol	kV	mA	Rotation time (sec)	Pitch (mm/rotation)	Collimation (mm)	Scan length (cm)	slice thickness (mm)	interval (mm)
Chest	120	CARE Dose4D	0.5	1.2	40	35	3	3

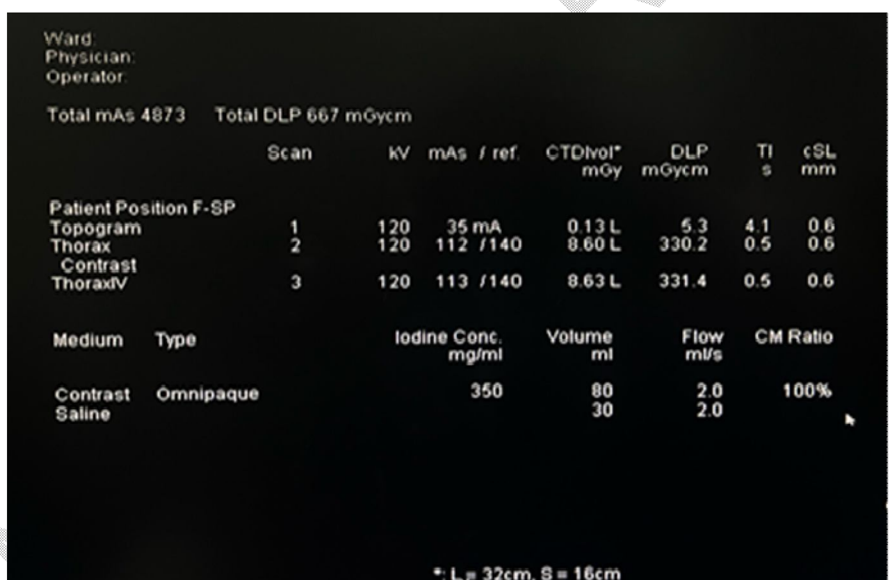


Figure 1 The radiation dose report from the SIEMENS 128-slice SOMATOM Definition AS CT scanner at the Radiology Department of Rajavithi Hospital.

3. General patient information, including gender, age, weight, and body mass index (BMI), is presented in Table 5-7

4. Scan data obtained from patients, as summarized in Table 8, includes the following parameters:

4.1. Measurement of dimensions from anteroposterior (AP) or posteroanterior (PA) views on transaxial CT images (cm).

4.2 Measurements of anatomical dimensions based on the lateral view in transaxial CT imaging (cm).

4.3. Combined dimensional measurements from anteroposterior (AP) or posteroanterior (PA) and lateral perspectives in transaxial CT images (cm).

4.4. Effective diameter, calculated as $\left(\sqrt{AP \times Lat}\right)$, derived from transaxial CT images (cm).

4.5. CTDIvol (Computed Tomography Dose Index volume), measured in transaxial CT imaging (mGy)[2].

4.6. Water Equivalent Diameter (Dw), as determined from transaxial CT imaging.

4.7. Dose Length Product (DLP), measured in transaxial CT imaging (mGy·cm).

4.8. The conversion factor, based on measurements from a 32 cm PMMA phantom, as referenced in AAPM Report 204.

4.9. The conversion factor, based on measurements from a 32 cm PMMA phantom, as outlined in AAPM Report 220.

5. Size-Specific Dose Estimate (SSDE), calculated based on patient size and imaging parameters (mGy).

6. Computed Tomography (CT) images

6.1 Computed tomography (CT) images obtained in the transaxial plane for CT chest scans, showing measurements of the image dimensions in the anteroposterior (AP) and lateral directions, as outlined in AAPM Report 204[4]. The AP and lateral dimensions are combined (AP + lateral) and the effective diameter is calculated using the formula $\left(\sqrt{AP \times Lat}\right)$, where the product of the AP and lateral measurements is square-rooted to obtain the effective diameter. The combined (AP + lateral) measurements and the effective diameter are then compared to determine the conversion factor (f_{size}) according to the table in AAPM Report 204[4] (Figure 2).

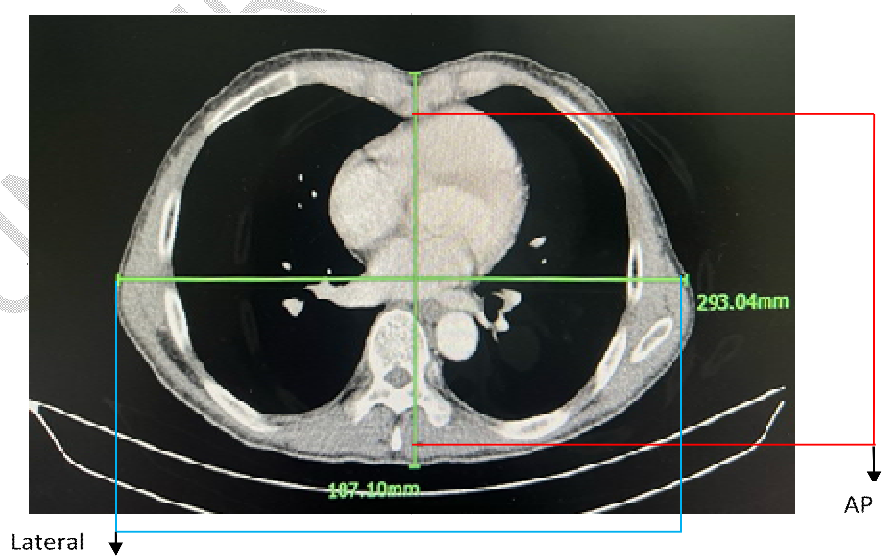


Figure 2 A transaxial CT image of the chest showing dimensional measurements in the anteroposterior (AP) and lateral directions.

6.2 A transaxial CT chest image with the outlined region of interest (ROI), used to calculate the volume and the water equivalent diameter (Dw), as described in AAPM Report 220[5]. The area (A) of the ROI and the mean CT number (M) in Hounsfield Units (HU), obtained from the outlined region, are applied to the equation for calculating the water equivalent diameter (Dw), as shown in Figure 3.

$$Dw = 2\sqrt{A_w/\pi}$$

$$Dw = 2 \times \sqrt{\left[\frac{CT(x,y)_{ROI}}{1000} + 1\right] \times A_{ROI}/\pi}$$

The water equivalent diameter (Dw), obtained from the previous calculation, is used to compare and determine the conversion factor (f_{size}) based on the table outlined in AAPM Report 220[5]

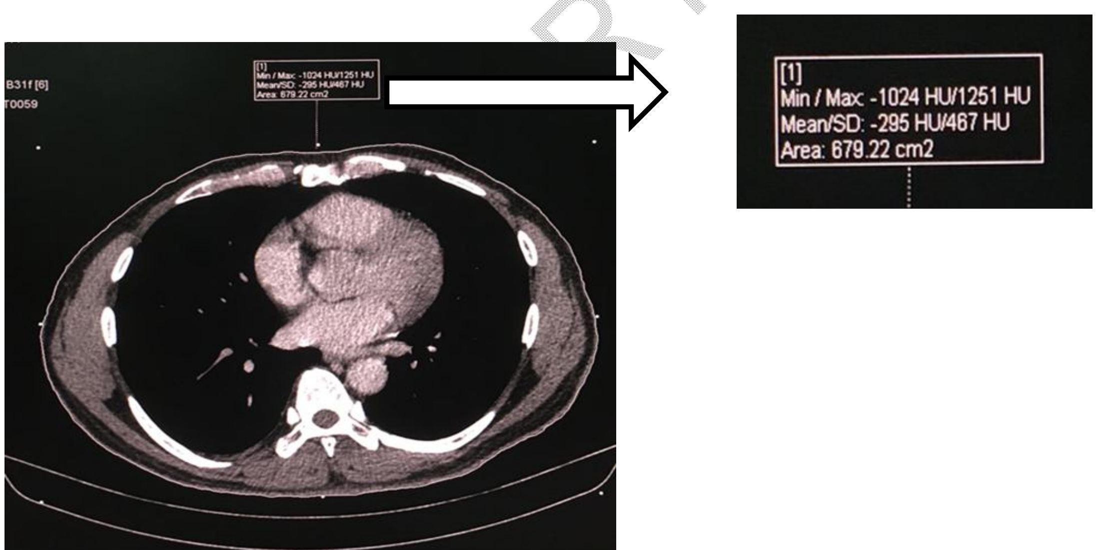


Figure 3 A transaxial CT image of the chest, with the outlined region of interest (ROI) delineating the area of focus on the transaxial slice.

6.3 The Size-Specific Dose Estimate (SSDE) was calculated using three different methods, each derived from its respective equation.

$$\text{Size Specific Dose Estimate (SSDE)} = f_{size} \times CTDI_{vol}$$

$$f_{size} = f_{size}^{32x}$$

$$\mathrm{CTDI_{vol}} = \mathrm{CTDI}^{32}_{\mathrm{size}}$$

7. The effective dose (mSv) was assessed[15].

The effective dose represents the total radiation absorbed by the body, accounting for the varying radiosensitivity of different organs. This measurement is crucial for evaluating the risks associated with radiation exposure. Calculating the effective dose can be complex; however, the American Association of Physicists in Medicine (AAPM) provides guidance through Report No. 96[16], which outlines a simplified calculation method. According to the report, the effective dose is determined by multiplying the conversion factor by the Dose Length Product (DLP). The conversion factor, expressed in millisieverts per milligray-centimeter (mSv/mGy·cm), varies depending on the patient's age and the specific area under examination, as detailed in Table 4.

$$\mathrm{ED} = \mathrm{DLP} \times \text{Conversion factor}$$

Table 4: The recommended conversion factors as outlined in AAPM Report No. 96[16].

Examination area	Conversion factor (measured in millisieverts per milligray-centimeter, mSv/mGy·cm)				
	0-1 years	1-5 years	5-10 years	10-15 years	Above 15 years
Head and neck	0.013	0.0085	0.0057	0.0042	0.0031
Head	0.011	0.0067	0.0040	0.0032	0.0021
neck	0.017	0.012	0.011	0.0079	0.0059
Chest	0.039	0.026	0.018	0.013	0.014
Abdomen	0.049	0.030	0.020	0.015	0.015

2.3 Statistical methods used for data analysis

The researcher verified the accuracy and completeness of the data in the personal records and patient scan records before entering the information. The data were subsequently analyzed using Excel 2016 for statistical analysis as follows.

1. Descriptive Statistics

The general demographic data, presented as categorical variables, are reported in terms of frequencies and percentages. For continuous variables, if the data follows a normal distribution, the results are expressed as the mean and standard deviation. In cases where the data does not follow a normal distribution, the data are reported as the median, along with the minimum, maximum, interquartile range (IQR), and percentile range.

2. Inferential Statistics

The comparison of CTDIvol (mGy), effective dose, DLP, SSDE, mean AP+Lat effective diameter, and Dw, which are categorical variables, was performed using the Chi-square test, Fisher's Exact test, or McNemar test. For the comparison of continuous data in two related populations, if the data followed a normal distribution, a paired t-test was applied. If the data were not normally distributed, the Wilcoxon Signed Rank test was used. For comparing continuous data between two independent populations, if the data were normally distributed, a Student's t-test was applied. If the data were not normally distributed, the Mann-Whitney U-test was used. For comparisons of continuous data among more than two groups, if the data followed a normal distribution, One-way ANOVA was employed. If the data were not normally distributed, the Kruskal-Wallis test was used. Factors associated with the variables were analyzed using Pearson correlation and linear regression, with risk reported using odds ratios (OR) and 95% confidence intervals (95% CI). All statistical tests were considered significant at a p-value of < 0.05.

3. RESULTS

The study included 500 adult patients aged 18 years and older, with a mean age of 57.27 ± 14.73 years, ranging from 18 to 88 years. The average body weight was 58.82 ± 13.44 kg, with a minimum of 26.70 kg and a maximum of 100 kg. The average body mass index (BMI) was 23.18 ± 5.08 kg/m², with a minimum of 12.34 kg/m² and a maximum of 43.56 kg/m². Among the patients, 209 (41.8%) were male, with an average age of 58.20 ± 14.44 years, ranging from 18 to 87 years. The average body weight was 62.92 ± 12.44 kg, with a minimum of 36 kg and a maximum of 100 kg. The average BMI was 23.03 ± 4.23 kg/m², with a minimum of 12.76 kg/m² and a maximum of 34.77 kg/m². The remaining 291 (58.2%) patients were female, with an average age of 56.60 ± 14.92 years, ranging from 22 to 88 years. The average body weight was 55.87 ± 13.37 kg, with a minimum of 26.70 kg and a maximum of 95 kg. The average BMI was 23.29 ± 5.62 kg/m², with a minimum of 12.34 kg/m² and a maximum of 43.56 kg/m². These data are presented in Tables 5-7.

Table 5: The general characteristics of the patients (n=500).

Characteristic	Number	Percentage
Gender		
Male	209	41.8
Female	291	58.2
Age (years)		
Mean ± Standard Deviation (Minimum – Maximum	57.27±14.73 (18-88)	
Body Weight (kg)		
Mean ± Standard Deviation (Minimum - Maximum	58.82±13.44 (26.70-100)	
Body Mass Index (kg/m²)		
Mean ± Standard Deviation (Minimum – Maximum	23.18±5.08 (12.34-43.56)	

Table 6 The general characteristics of male patients (n=209).

Characteristic	Mean±SD	Minimum	Maximum
Age (years)	58.20±14.44	18	87
Body Weight (kg)	62.92±12.44	36	100
Body Mass Index (kg/m²)	23.03±4.23	12.76	34.77

Table 7 The general characteristics of female patients (n=291).

Characteristic	Mean±SD	Minimum	Maximum

Age (years)	56.60±14.92	22	88
Body Weight (kg)	55.87±13.37	26.70	95
Body Mass Index (kg/m²)	23.29±5.62	12.34	43.56

3.1 Patient data and radiation dose received from the slice at the mid-position of the CT chest scan.

Adult patients aged 18 years and older who underwent chest CT scans at the Department of Diagnostic Radiology, Rajavithi Hospital, were included in the study. A total of 500 patients participated, consisting of 209 males and 291 females. The average measurement of the anteroposterior (AP) diameter was 20.62±2.54 cm (minimum 13.00 cm, maximum 29.10 cm), and the average lateral diameter was 31.82±3.46 cm (minimum 19.40 cm, maximum 53.40 cm). The average combined AP + lateral diameter was 52.45±5.54 cm (minimum 37.50 cm, maximum 75.30 cm). The average conversion factor for the AP + lateral diameter was 1.44±0.14 cm (minimum 0.96 cm, maximum 2.01 cm). The average effective diameter was 25.59±2.73 cm (minimum 17.85 cm, maximum 35.13 cm), with an average conversion factor for the effective diameter of 1.45±0.15 cm (minimum 1.02 cm, maximum 1.91 cm). The average mean CT number (HU) was -263.41±68.52 (minimum -468, maximum -50). The average area of the region of interest (ROI) was 579.97±116.38 cm² (minimum 298.98 cm², maximum 1011.29 cm²). The average water equivalent diameter (Dw) was 23.21±2.86 cm (minimum 16.10 cm, maximum 33.30 cm), with an average conversion factor for Dw of 1.58±0.17 (minimum 1.10, maximum 2.06). The average dose-length product (DLP) was 301.74±110.03 mGy·cm (minimum 47.50, maximum 794.30). The average CT scanner output (CTDIvol) was 8.38±2.94 mGy (minimum 1.76, maximum 20.18). The average effective dose was 4.22±1.54 mSv (minimum 0.67 mSv, maximum 11.12 mSv). The average size-specific dose estimate (SSDE) for AP + lateral was 11.80±3.26 mGy (minimum 2.70 mGy, maximum 27.94 mGy). The average SSDE for effective diameter was 11.86±3.22 mGy (minimum 2.66 mGy, maximum 23.27 mGy). The average SSDE for Dw was 12.91±3.46 mGy (minimum 2.97 mGy, maximum 25.05 mGy). The data are presented in Table 9.

Table 8 presents the patient data and the radiation dose received from the slice at the mid-position of the CT chest scan. The data are provided as the mean, standard deviation, minimum, and maximum values obtained from the chest CT scans of adult patients aged 18 years and older at the Department of Diagnostic Radiology, Rajavithi Hospital (n=500). Among the participants, 209 were male, and 291 were female.

Table 8: The patient data and the radiation dose received from the slice at the mid-position of the CT chest scan.

	Mean±SD	Minimum	Maximum
AP diameter (cm)	20.62±2.54	13.00	29.10
Lat diameter (cm)	31.82±3.46	19.40	53.40
AP+Lat diameter (cm)	52.45±5.54	37.50	75.30

Effective diameter (cm)	25.59±2.73	17.85	35.13
Mean CT number (HU)	-263.41±68.52	-468	-50.00
Area of ROI (cm^2)	579.97±116.38	298.98	1011.29
Water equivalent diameter (Dw) (cm)	23.21±2.86	16.10	33.30
conversion factor ของ AP+Lat diameter (cm)	1.44±0.14	0.96	2.01
conversion factor ของ effective diameter (cm)	1.45±0.15	1.02	1.91
conversion factor ของ Water equivalent diameter (Dw)	1.58±0.17	1.10	2.06
DLP (mGy·cm)	301.74±110.03	47.50	794.30
$CTDI_{vol}$ (mGy)	8.38±2.94	1.76	20.18
Effective dose (mSv)	4.22±1.54	0.67	11.12
$SSDE_{AP+Lat}$ (mGy)	11.80±3.26	2.70	27.94
$SSDE_{effective\ diameter}$ (mGy)	11.86±3.22	2.66	23.27
$SSDE_{Dw}$ (mGy)	12.91±3.46	2.97	25.05

3.2 The comparison of SSDE values calculated from the AP + Lat diameter, effective diameter, and Water Equivalent Diameter (Dw) at the mid-position slice of the CT chest scan.

The study found that the SSDE calculated using the AP + Lat diameter method had a mean value of 11.80±3.26 mGy, the SSDE calculated using the effective diameter method had a mean value of 11.86±3.22 mGy, and the SSDE calculated using the Water Equivalent Diameter (Dw) method had a mean value of 12.91±3.46 mGy. The results indicated a statistically significant correlation between the SSDE values calculated by all three methods ($P < 0.001$), with the mean SSDE values presented in Table 9.

Table 9 presents the mean Size-Specific Dose Estimate (SSDE) values calculated using the AP + Lat diameter method, the effective diameter method, and the Water Equivalent Diameter (Dw) method from the slice at the mid-position of the CT chest scan for 500 adult patients (209 male and 291 female).

Table 9: The mean Size-Specific Dose Estimate (SSDE) values

	Mean±SD	P-value
$SSDE_{AP+Lat}$ (mGy)	11.80±3.26	< 0.001

SSDE$_{effective\ diameter}$ (mGy)	11.86±3.22	
SSDE$_{AP+Lat}$ (mGy) SSDE$_{Dw}$ (mGy)	11.80±3.26 12.91±3.46	< 0.001
SSDE$_{effective\ diameter}$ (mGy) SSDE$_{Dw}$ (mGy)	11.86±3.22 12.91±3.46	< 0.001

* Statistical significance was considered at the 0.05 level (p-value < 0.05) using a two-tailed test.

The SSDE values, calculated using the AP + Lat diameter, effective diameter, and Dw methods, are presented in box plots. These plots illustrate the distribution of SSDE values across a cohort of 500 adult patients. The boxes represent the interquartile range (IQR), with the lower and upper edges corresponding to the 25th and 75th percentiles. The black line within the box denotes the median value, while the cross inside the box indicates the mean value of the data, as shown in Figure 4.

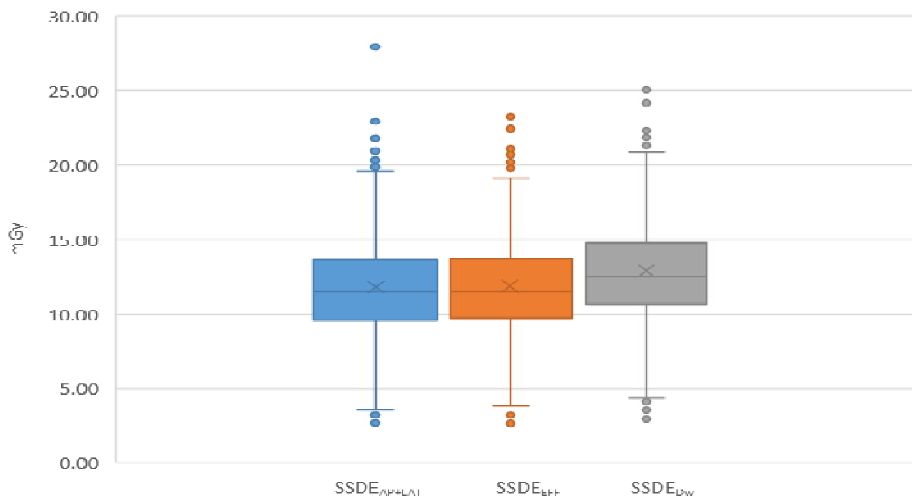


Figure 4: The box plot of SSDE values calculated using the AP + Lat diameter, effective diameter, and Dw methods from the middle slice of the scan range.

3.3 The relationship between SSDE and CTDIvol

The study examined the relationship between the values of SSDE (AP + Lat), SSDE (effective diameter), or SSDE (Dw) and CTDI$_{vol}$ in CT chest examinations, as shown in Table 10.

- A very strong linear correlation between SSDE (AP + Lat) and CTDIvol was found, with an R^2 value of 0.9870 and a p-value < 0.001.
- A very strong linear correlation between SSDE (effective diameter) and CTDI$_{vol}$ was observed, with an R^2 value of 0.9863 and a p-value < 0.001.

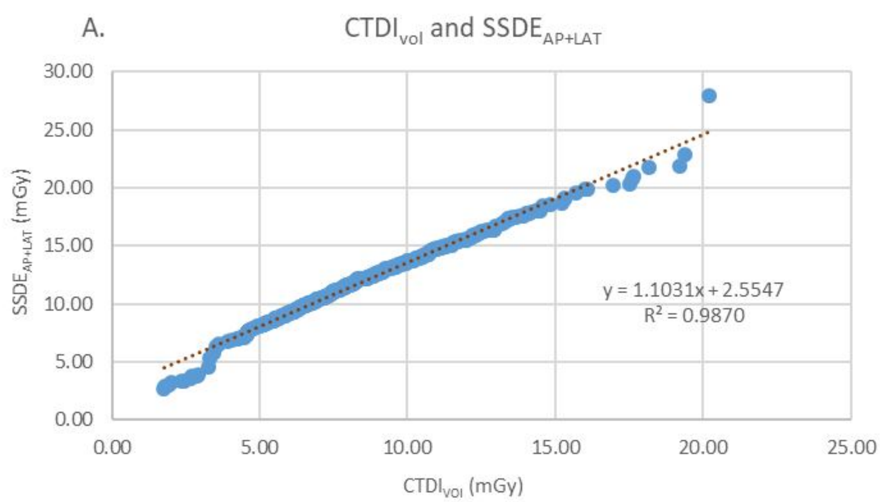
- A very strong linear correlation between SSDE (Dw) and $CTDI_{vol}$ was demonstrated, with an R^2 value of 0.9841 and a p-value < 0.001.

Table 10: The relationship between SSDE values and $CTDI_{vol.}$

	$SSDE_{AP+Lat}$ (mGy)	$CTDI_{vol}$ (mGy)	R^2	p-value< 0.001
Mean±SD	11.80±3.26	8.38±2.94	0.9870	
	$SSDE_{effective\ diameter}$ (mGy)	$CTDI_{vol}$ (mGy)		p-value< 0.001
Mean±SD	11.86±3.22	8.38±2.94	0.9863	
	$SSDE_{Dw}$ (mGy)	$CTDI_{vol}$ (mGy)		p-value< 0.001
Mean±SD	12.91±3.46	8.38±2.94	0.9841	

- A statistically significant relationship at the **0.05 significance level** (**p-value < 0.05**) (two-tailed).

The line graph depicting the relationship between CTDIvol and SSDE from the slice at the mid-position of the CT chest scan is presented in Figure 5.



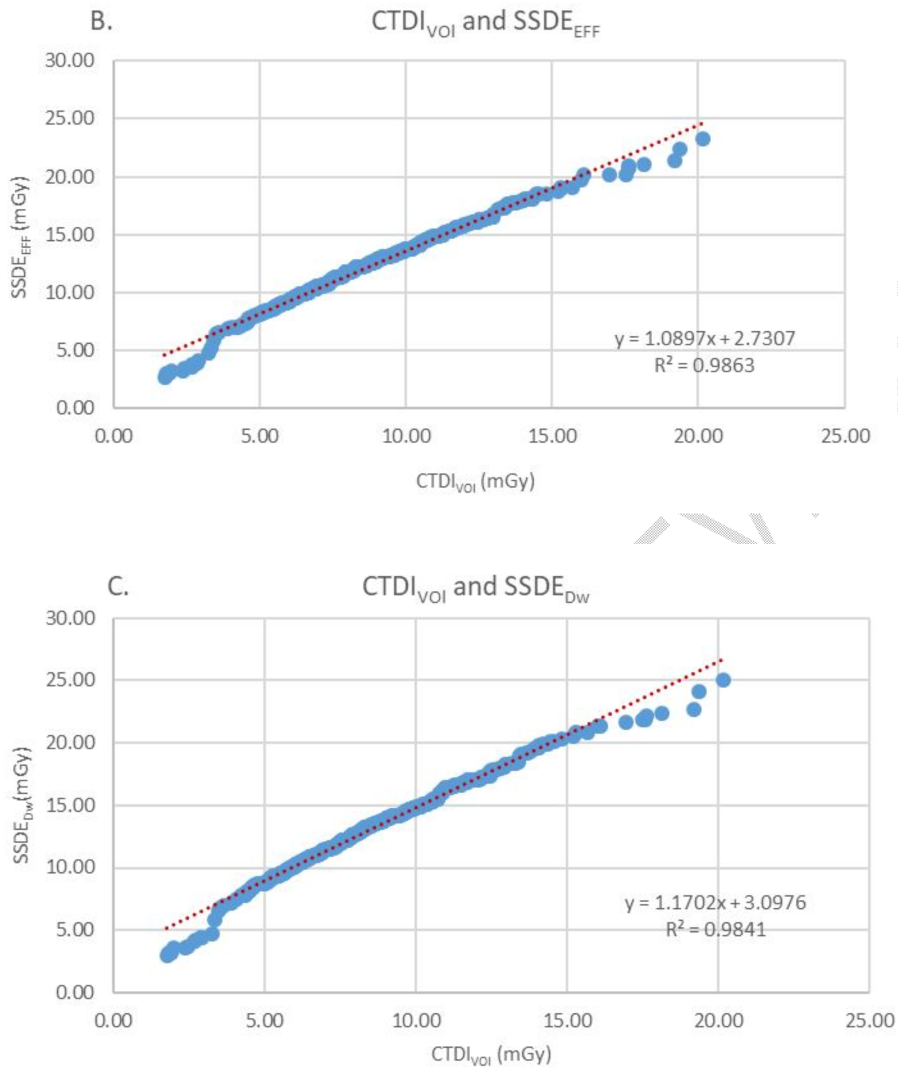


Figure 5 (A-C): Linear graphs illustrating the relationship between CTDI$_{vol}$ and SSDE from the slice at the mid-position of the CT Chest scan. (A) CTDI$_{vol}$ and SSDE$_{AP+Lat}$, (B) CTDI$_{vol}$ and SSDE$_{effective\ diameter}$, and (C) CTDI$_{vol}$ and SSDE$_{Dw}$

4. DISCUSSION

Modern computed tomography (CT) scanners represent a significant advancement in imaging technology, incorporating high efficiency and the ability to quantify radiation exposure through parameters such as the Volume Computed Tomography Dose Index (CTDI$_{vol}$)[1] and the Dose Length Product (DLP)[1]. The amount of radiation received by a patient during a CT scan depends on both the patient's body size and the radiation output of the CT scanner. However, the CTDI$_{vol}$ represents only the radiation emitted by the scanner, which is calibrated using phantom models provided by the manufacturer, typically with only two reference sizes: 16 cm and 32 cm. This approach does not take into account the actual body size of the patient, thereby limiting the accuracy of radiation dose estimates for individual patients.

In 2011, the American Association of Physicists in Medicine (AAPM) published report No. 204[4], which introduced a new approach for evaluating Size-Specific Dose Estimates (SSDE) in computed tomography (CT) imaging. This methodology was further elaborated in AAPM report No. 220[5] in 2014. The aim of these reports was to enhance the accuracy and precision of radiation dose assessments for patients undergoing CT scans. Both reports emphasize the importance of considering the patient's body size when evaluating radiation exposure. Specifically, the reports recommend measuring the patient's size, comparing it to a conversion factor (f_{size}) provided in the tables of AAPM reports No. 204[4] and 220[5], and then multiplying the $CTDI_{vol}$ value by the appropriate conversion factor to derive the SSDE, thereby providing a more precise estimation of radiation dose.

In this study, the patient size correction factor (conversion factor; f_{size}) from AAPM reports No. 204[4] and 220[5] was utilized to calculate the Size-Specific Dose Estimate (SSDE) for chest CT scans using a 128-slice CT scanner. Additionally, two other radiation dose parameters, the Effective Dose and Dose Length Product (DLP), were assessed. In practice, calculating the Effective Dose can be quite complex. However, the American Association of Physicists in Medicine (AAPM), in report No. 96[16], provided a simplified method for this calculation. It suggests calculating the Effective Dose by multiplying the correction factor by the Total DLP, with the correction factor measured in millisieverts per milligray-centimeter and differentiated based on patient age and scan region (as shown in Table 8).

In this study, the radiation dose received by patients of varying sizes during chest CT scans using a 128-slice CT scanner was evaluated in 500 adult patients at the Radiology Department, Rajavithi Hospital. Three methods for calculating the Size-Specific Dose Estimate (SSDE) were employed: $SSDE_{AP+Lat}$, $SSDE_{effective\ diameter}$, and $SSDE_{Dw}$. These methods were used as dose descriptors to assess the radiation doses received by patients during CT scans, and were compared with reference radiation dose levels to ensure patients received appropriate and justified doses. This approach is considered to provide a more accurate estimate than the $CTDI_{vol}$ value displayed on the CT scanner monitor.The SSDE calculation in this study involved multiplying the $CTDI_{vol}$ by the conversion factor (f_{size}), based on patient size measurements in both the anterior-posterior (AP) and lateral (Lat) orientations, in order to obtain the true size of the patient. The average SSDE value obtained using the AP+Lat method was 11.80 ± 3.26 mGy, with the 75th percentile value at 13.65 mGy. For the Effective Diameter method, the average SSDE was 11.86 ± 3.22 mGy, with the 75th percentile at 13.72 mGy. For the Dw method, the SSDE value averaged 12.91 ± 3.46 mGy, with the 75th percentile at 14.82 mGy. The average $CTDI_{vol}$ value at Rajavithi Hospital's Radiology Department was 8.38 ± 2.94 mGy, with the 75th percentile at 9.99 mGy. Additionally, the study evaluated the Dose-Length Product (DLP) and Effective Dose. The average DLP was 301.74 ± 110 mGy·cm, with the 75th percentile at 365.00 mGy·cm. The average Effective Dose was 4.22 ± 1.54 mSv, with the 75th percentile at 5.11 mSv. When compared with established reference radiation dose levels (DRLs) from various sources, including the European Association, the International Commission on Radiological Protection (ICRP)[11], Japan 2015[12,13], and Thailand's DRLs,[14] the average $CTDI_{vol}$ and 75th percentile values from this study were found to be lower than the reference levels provided by the European Association (EUR 16262), ICRP publication 87[11], Japan 2015[12,13], and Thailand's reference levels (Tables 11 and 12). Furthermore, the DLP values in this study were found to be lower than the reference levels from both the European Association and Thailand's DRLs (Table 11). Similarly, the Effective Dose values were lower than the reference levels from the European Association (EUR 16262)[7], the United States (USA 2009)[6], the United Kingdom (UK 2011)[8], and the International Atomic Energy Agency (IAEA 2006)[9-10]. The SSDE values from this study were also compared with those previously reported findings[17]. It was found that the average SSDE values from chest CT scans at Rajavithi Hospital were lower than previously reported findings[17]. (Table 9).

In conclusion, this study successfully assessed the SSDE values for evaluating radiation doses in chest CT scans using three methods. The average SSDE values for $SSDE_{AP+Lat}$, $SSDE_{effective\ diameter}$, and $SSDE_{Dw}$ were 11.80 ± 3.26, 11.86 ± 3.22, and 12.91 ± 3.46 mGy, respectively, with a p-value < 0.001 (Table 9). The correlation between SSDE values obtained from the three methods and $CTDI_{vol}$ demonstrated strong consistency, with correlation coefficients (R^2) of 0.9870, 0.9863, and 0.9841, respectively, and p-values < 0.001 (Table 10).

In 2021, the Radiology Department at Rajavithi Hospital implemented a revised protocol for chest CT examinations, recognizing the importance of reducing radiation exposure to patients while maintaining diagnostic image quality. The updated protocol aimed to eliminate unnecessary radiation doses that do not contribute to improving image quality. This was achieved by adjusting several scan parameters, including scan length, tube potential (kVp), tube current (mA), and the use of automatic exposure control techniques. Radiologists played a crucial role in ensuring the quality of the CT images, ensuring that the detection of pathological features was not compromised.The study conducted evaluated the radiation doses patients received under this new protocol and compared the results with Diagnostic Reference Levels (DRLs). The findings revealed that the radiation doses were lower than the reference levels, suggesting the success of the protocol in optimizing radiation exposure. However, ongoing monitoring and management of radiation doses remain essential to ensure optimal exposure levels, balancing image quality with radiation safety[18-20].

Table 11: The mean, standard deviation, maximum value, minimum value, and the 75th percentile of radiation doses obtained from this study, compared with reference radiation dose values from various countries and Thailand.

	$CTDI_{vol}$ (mGy)	DLP (mGy·cm)	Effective dose (mSv)	$SSDE_{AP+Lat}$ (mGy)	$SSDE_{effective\ diameter}$ (mGy)	$SSDE_{Dw}$ (mGy)
Mean±SD	8.38±2.94	301.74±110.03	4.22±1.54	11.80±3.26	11.86±3.22	12.91±3.46
Minimum	1.76	47.50	0.67	2.70	2.66	2.97
Maximum	20.18	794.30	11.12	27.94	23.27	25.05
Percentiles 75	9.99	365.00	5.11	13.65	13.72	14.82
EUR 16262	30	650	11.1	-	-	-
American 2009	-	-	7	-	-	-
UK 2011	-	610	6.1	-	-	-
IAEA 2006	-	-	5.9	-	-	-
ICRP publication 87	30	-	-	-	-	-

Japan 2015	15	550	-	-	-	-
previous studies(17)	-	-	-	21.8	-	-
Thailand DRLs 2021	18	665	-	-	-	-

Table 12: A comparison of the radiation dose received by patients during chest CT scans using a 128-slice CT scanner in this study, against the reference radiation dose levels from various countries and Thailand.

	CTDI$_{vol}$ (mGy)						SSDE (mGy)		
CT chest	EUR 16262	ICRP'87	Japan 2015	Thailand 2021	this study 2024	previous studies(17)	this study 2024 SSDE$_{AP+Lat}$	SSDE$_{effective\ diameter}$	SSDE$_{Dw}$
	30	30	15	18	8.38	21.80	11.80	11.86	12.91

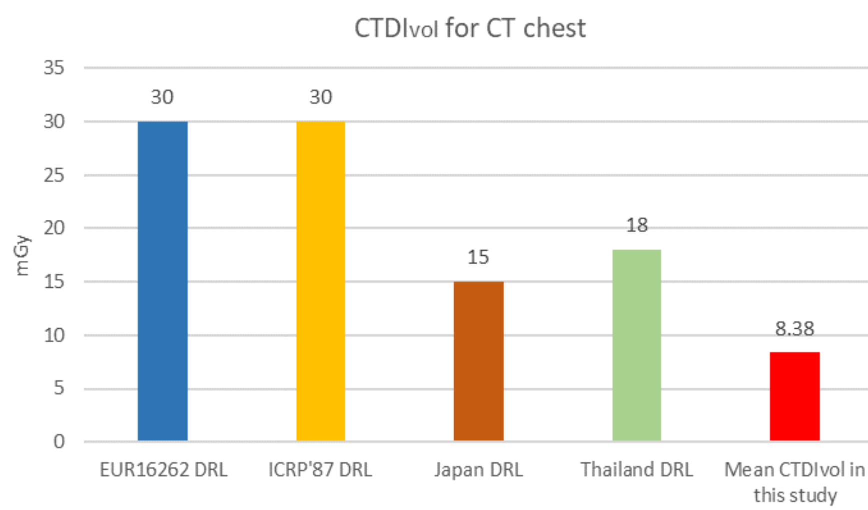


Figure 6 A comparison of the CTDI$_{vol}$ values with the Diagnostic Reference Levels (DRLs) and the results from this study on chest CT scans using a 128-slice Computed Tomography (CT) scanner.

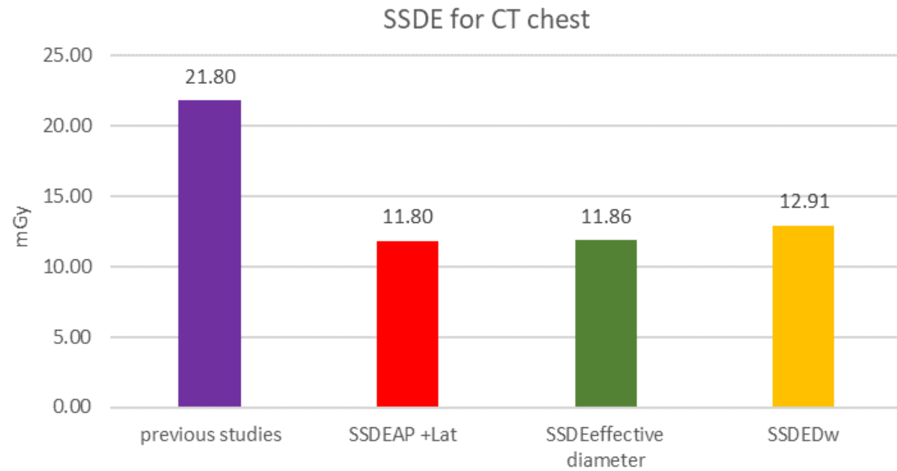


Figure 7 A comparison of the radiation dose values obtained using the SSDE method with the results from previous studies[17]., as well as the findings from this study involving chest CT scans conducted with a 128-slice CT scanner.

5. CONCLUSIONS

This study demonstrated the radiation doses received by patients of different sizes during chest CT scans using a 128-slice CT scanner at Rajavithi Hospital's diagnostic radiology department. The Size-Specific Dose Estimates (SSDE) were calculated using three methods: $SSDE_{AP+Lat}$, $SSDE_{effective\ diameter}$, and $SSDE_{Dw}$. The results showed that the average SSDE values for each method were 11.80 mGy, 11.86 ± 3.22 mGy, and 12.91 ± 3.46 mGy, respectively, while the $CTDI_{vol}$ value was 8.38 mGy. Statistical analysis revealed significant differences with a p-value < 0.001. Furthermore, the correlation between the SSDE values from all three methods and the $CTDI_{vol}$ was found to be very strong, with correlation coefficients (R^2) of 0.9870, 0.9863, and 0.9841, respectively, all with p-values < 0.001. These results suggest that all three methods can be reliably used to estimate the radiation dose received by patients, providing accurate assessments of radiation exposure during chest CT scans[21].

The comparison of radiation doses received by patients of varying sizes during chest CT scans using a 128-slice CT scanner at the Rajavithi Hospital's Diagnostic Radiology Department, as compared to the reference radiation levels from various countries and other research studies[17], revealed that the radiation doses were lower than the reference levels. This reduction is attributed to the implementation of optimized protocols, which include adjustments to key parameters such as the scan length, tube potential (kVp), tube current (mA), and the use of automatic exposure control techniques. Additionally, Radiologists are involved in assessing the image quality to ensure that diagnostic accuracy is maintained without compromising the ability to detect abnormalities. These measures align with the principles of optimization to achieve the most appropriate balance between image quality and radiation exposure.(18-20)

Therefore, the radiation dose values obtained from this study can be used as reference levels for levels for assessing the radiation dose received by patients undergoing chest CT scans at the the Radiology Department of Rajavithi Hospital. These reference levels can help evaluate whether whether appropriate radiation doses are being applied during CT imaging and can serve as a basis for a basis for future dose optimization efforts. The aim is to develop strategies to prevent patients from patients from receiving unnecessary radiation during image acquisition.

6. LIMITATIONS

This study focused solely on adult patients who underwent chest CT scans at the Diagnostic Radiology Department of Rajavithi Hospital. Therefore, the radiation doses received from chest CT scans in this study cannot be used as reference radiation levels for all patients. However, the data obtained can serve as a foundation for further studies aimed at evaluating risks and developing guidelines for the appropriate use of radiation doses in the future.

ETHICAL APPROVAL

The retrospective study was approved by the Ethics committee, Rajavithi Hospital (no 166/2024).

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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