RESEARCH PAPER

Evaluate the Relation Between Body Mass Index and Radiation Dose in High-Resolution Computed Tomography Chest (NIIMS Hospital, Gautam Buddh Nagar)

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ABSTRACT

Background: High-resolution computed tomography (HRCT) of the chest is an important imaging modality for the diagnosis of various pulmonary conditions. However, this technique is associated with exposure to ionizing radiation. Dose can be affected by patient factors such as body mass index (BMI) through differences in attenuation and adjustments to scanner output. Understanding the correlation between BMI and radiation dose is essential to optimize imaging protocols that ensure diagnostic quality and follow radiation safety principles such as dose reduction and patient-specific optimization.

Aim: To evaluate how variations in Body Mass Index (BMI) influence the radiation dose delivered during High-Resolution Computed Tomography (HRCT) of the chest.

Objective: To determine if there is a statistically significant correlation between a patient's Body Mass Index (BMI) and the radiation dose received during a High-Resolution Computed Tomography (HRCT) scan of the chest. Quantify how BMI influences the amount of radiation delivered.

Material and Method: This study was conducted at NIIMS Hospital, Gautam Budh Nagar, using a prospective cross-sectional design during 2025–2026, with data collected from January to March. A total of 121 patients undergoing HRCT chest were included. Patients who were pregnant, uncooperative, or unwilling were excluded. Data such as age, sex, CTDIvol, and DLP were collected from the DICOM server and radiology information system. Radiation dose parameters were analyzed, and effective dose was calculated using DLP and a chest-specific k-factor (0.014). Statistical analysis was performed to evaluate the correlation between BMI and radiation dose, considering $p < 0.01$ as significant.

Result: The findings of this study revealed a statistically significant positive correlation between body mass index (BMI) and radiation dose parameters in HRCT chest examinations. With increasing BMI values, CTDIvol, DLP, and SSDE values increased ($p < 0.05$), implying that patients with higher BMI received higher radiation doses. This phenomenon is mainly due to increased photon absorption in larger body habitus, which requires higher tube current to achieve diagnostic image quality. The findings also suggest that BMI, along with other patient-specific factors such as weight and age, is an important factor influencing radiation exposure. Overall, the study confirms the importance of BMI as a predictor of radiation dose and the need for patient-specific dose optimization strategies in HRCT imaging.

Conclusion: The study reveals that patient-specific factors, primarily the body mass index (BMI), play a significant role in radiation dose in HRCT chest examinations. A positive correlation was observed between BMI and dose indices such as CTDIvol and SSDE, indicating that patients with higher BMI were given higher radiation dose to achieve adequate image quality. The findings emphasize the importance of dose optimization strategies such as ALARA principles, protocol adjustments, and the use of advanced dose-reduction technologies. Individualized scanning parameters can be applied to successfully optimize diagnostic accuracy and radiation safety to improve patient care while minimizing unnecessary radiation hazards.

Keywords: Body Mass Index (BMI), Radiation Dose, High-Resolution Computed Tomography (HRCT Chest), CTDIvol (Computed Tomography Dose Index Volume), Size-Specific Dose Estimate (SSDE), Dose Optimization / Radiation Protection.

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INTRODUCTION

1.1 Radiation

Radiation is the movement of energy from one location to the next as particles or waves. We are exposed to radiation every day. Among the most usual locations where radiation comes from are the sun, microwaves in our kitchens, and radios in our cars. Most of this radiation doesn't put our health at risk. But some do. Radiation is usually less dangerous at lower doses, but it may be more dangerous at higher doses. To protect our bodies and our surroundings to the impacts of radiation, while still capable of using it for its many purposes, we need to take different precautions depending on the kind of radiation [1].

There are two kinds of radiation: ionizing and non-ionizing. Non-ionizing radiation lacks the energy to displace electrons from atoms but is enough for creating movement or vibration in atoms within molecules. For example, visible light, microwaves, and radio waves are all types of radiation. Ionization is the process by which atoms lose their electrons because of the power of ionizing radiation. Ionizing radiation is hazardous for living things because it can change their atoms, which may damage tissue and DNA in genes. Radioactive materials, cosmic particles from space, and x-ray equipment emit ionizing radiation. Radioactive elements give off ionizing radiation as their atoms break down [2].

1.2 Ionizing Radiation

Ionizing radiation is a form of radiation with enough energy to separate electrons from atoms or molecules, altering everything, including living things, at the atomic level. These changes usually lead to the creation of the type of radiation ions, which are atoms or molecules that have an electric charge known as "ionizing" radiation. For example, ionizing radiation could come from unstable (radioactive) atoms that are giving off energy as they change into a more stable state. In Apha decay, two large, positively charged particles come out of decaying nuclei in alpha radiation to make them more stable. These particles can't get through our skin, so a single sheet of paper can often stop them from hurting us. In Beta decay radiation's electrons are more invasive than alpha particles as they contain more energy. For example, they can go through 1–2 centimeters of water. An aluminum layer that is a few millimeters thick can usually stop beta radiation. In Gamma, rays are a type of electromagnetic radiation, like X-rays. They can be used for many things, including treating cancer. Somegamma rays go right through the body without

harming it, but others are absorbed by the body and can harm it. Thick walls of concrete or lead can lower the intensity of gamma rays to levels that are less dangerous [1].

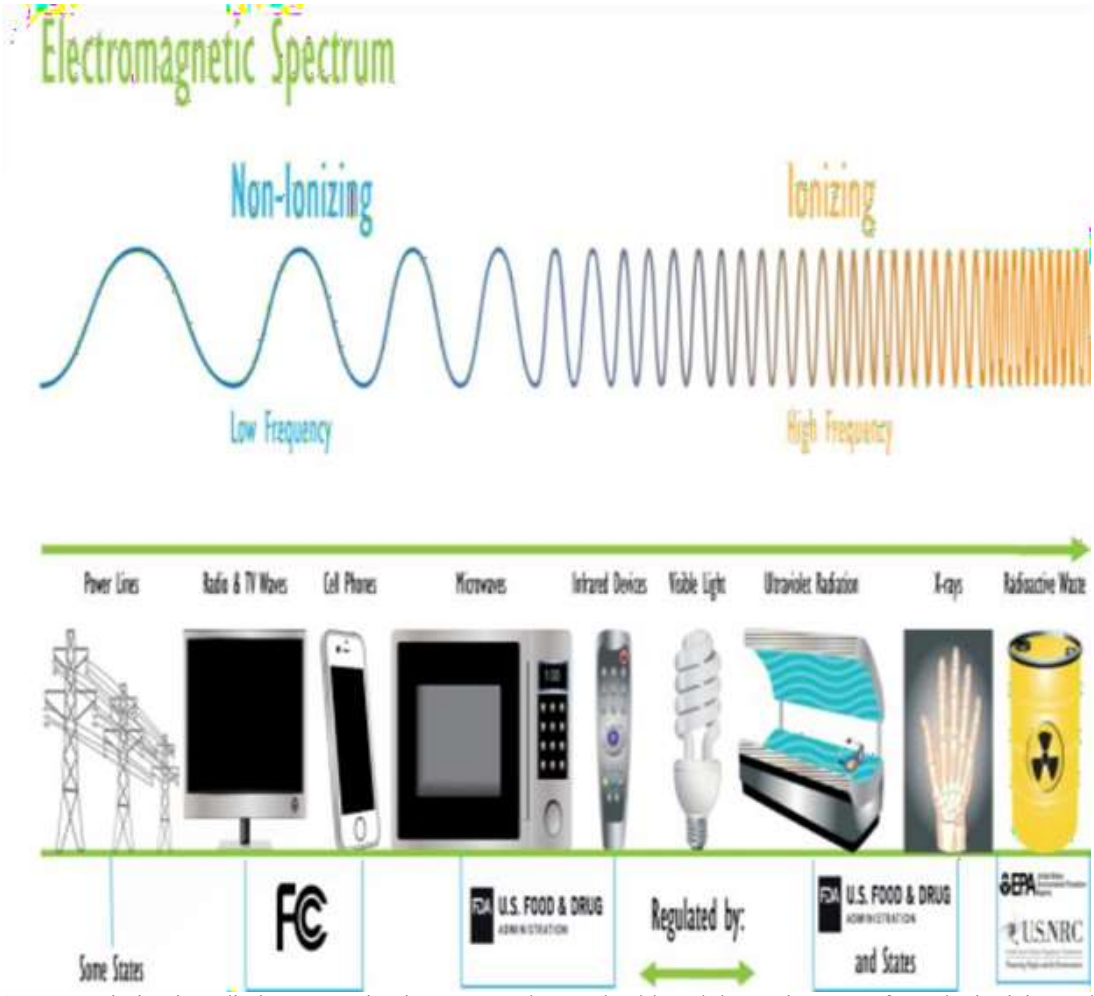

Fig.1.1 EPA's mission in radiation protection is to protect human health and the environment from the ionizing radiation that comes from human use of radioactive elements. Other agencies regulate the non-ionizingradiation that is emitted by electrical devices such as radio transmitters or cell phones (Ref: Radiation Resources Outside of EPA) [22].

1.1 Computed Tomography (CT scan)

A common name for computed tomography is a CT scan. A CT scan is a way to take pictures of the inside of the body using computers and X-rays. You can observe every part of the body in detail, including bonestructure, muscle mass, body fat, organs, and blood vessels. CT scans give more information than regular X-rays. In a normal X-ray, a beam of radiation is aimed at the body parts being studied. The energy beam passes through the skin, muscle, bone, and other tissues before hitting a Plate positioned behind the human body part. A regular X-ray can show a lot of information, but it can't show a lot of detail about organs and other structures inside the body [3].

Computed tomography (CT) scanners were initially created in 1972 by Sir Godfrey Hounsfield, an electrical engineer. Allan McLeod Cormack, a physicist, created a comparable method at the same time, and the two of them won the 1979 Nobel Prize in Physiology or Medicine [4].

During a CT scan, the X-ray beam goes around the body. This gives you a lot more information and lets you examine the identical organ or structure from a lot of different points of view. The computer receives the X-ray data, decodes it, and then shows it on a monitor in two dimensions. Newer computer software and hardware make it possible to make three-dimensional graphics. CT scans can be used to check for internal injuries or damage, investigate internal bleeding, or assist in the diagnosis of malignancies. A tissue or fluid biopsy can also be performed using CT [3].

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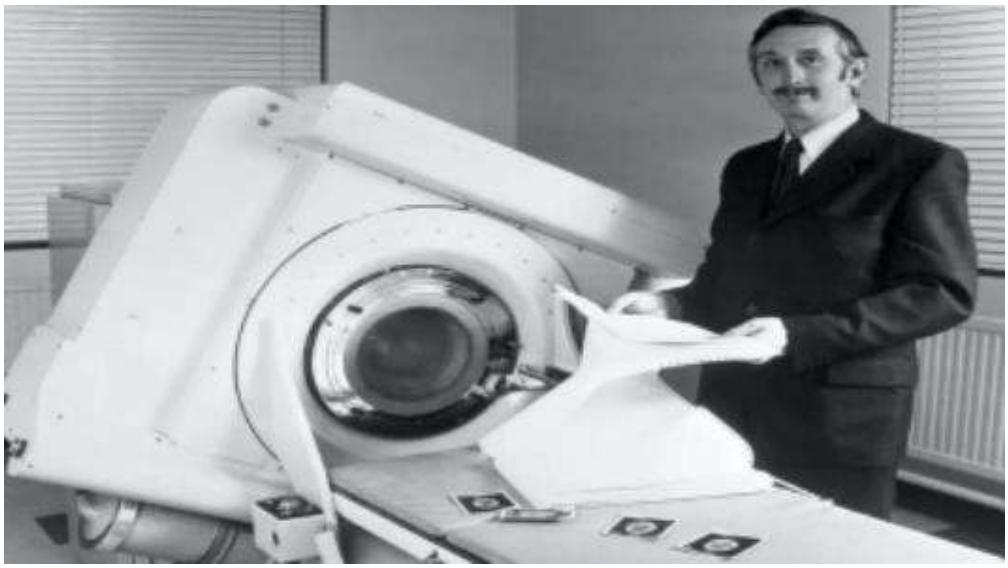

Fig.1.2 Godfrey Hounsfield stands beside the EMI-Scanner in 1972.(Ref: PA Images via Getty Images)[25]

1.2 High Resolution Computed Tomography (HRCT Scan)

HRCT chest, also known as HRCT lungs, HRCT thorax, or High-resolution computed tomography of the chest, is a type of CT scan that takes very thin cross-sectional images of the chest and lungs. This is a complex radio imaging tool that gives very clear images of the lungs. It serves to find or evaluate several lung and airway problems, especially idiopathic pulmonary fibrosis and pneumoconiosis. It describes the physical characteristics of the lungs and airways to help find and evaluate different diseases that affect the lung parenchyma, alveoli, and airways, especially the smaller ones [5].

High-Resolution Computed Tomography (HRCT) gives a more detailed cross-section image of the lungs than a regular chest CT or chest X-ray. HRCT Chest uses special technologies to make the pictures clearer, with fine details about the lungs that are good for evaluation. The HRCT scan covers all the lung tissue, which helps doctors find out where the problems are coming from. This method can be assessed to find both short-term and long-term problems with lung tissue and airways. HRCT may be more sensitive and accurate for finding diffuse lung disease. HRCT can find even tiny nodules in the lungs, which can help plan the best course of treatment and find serious problems early [8].

When there are normal or unclear chest radiography results, HRCT of the chest can identify lung disease. Refinement of the differential diagnosis and a more certain diagnosis are made possible by the more precise and thorough evaluation of lung parenchymal abnormalities by HRCT. As a result, HRCT is now a helpful diagnostic tool for those who have widespread pulmonary illnesses. Traditional computed tomography of the chest looks at 7–10 mm slices that are taken at intervals of 10 mm. Using a narrow collimation and a high-spatial-frequency reconstruction technique, high-resolution CT analyzes 1.0- to 1.5-mm slices at 10-mm intervals and provides a better representation of lung parenchymal features than conventional CT. To get closer to a pathologic depiction of a disease process, this method aims to optimize spatial resolution [7].

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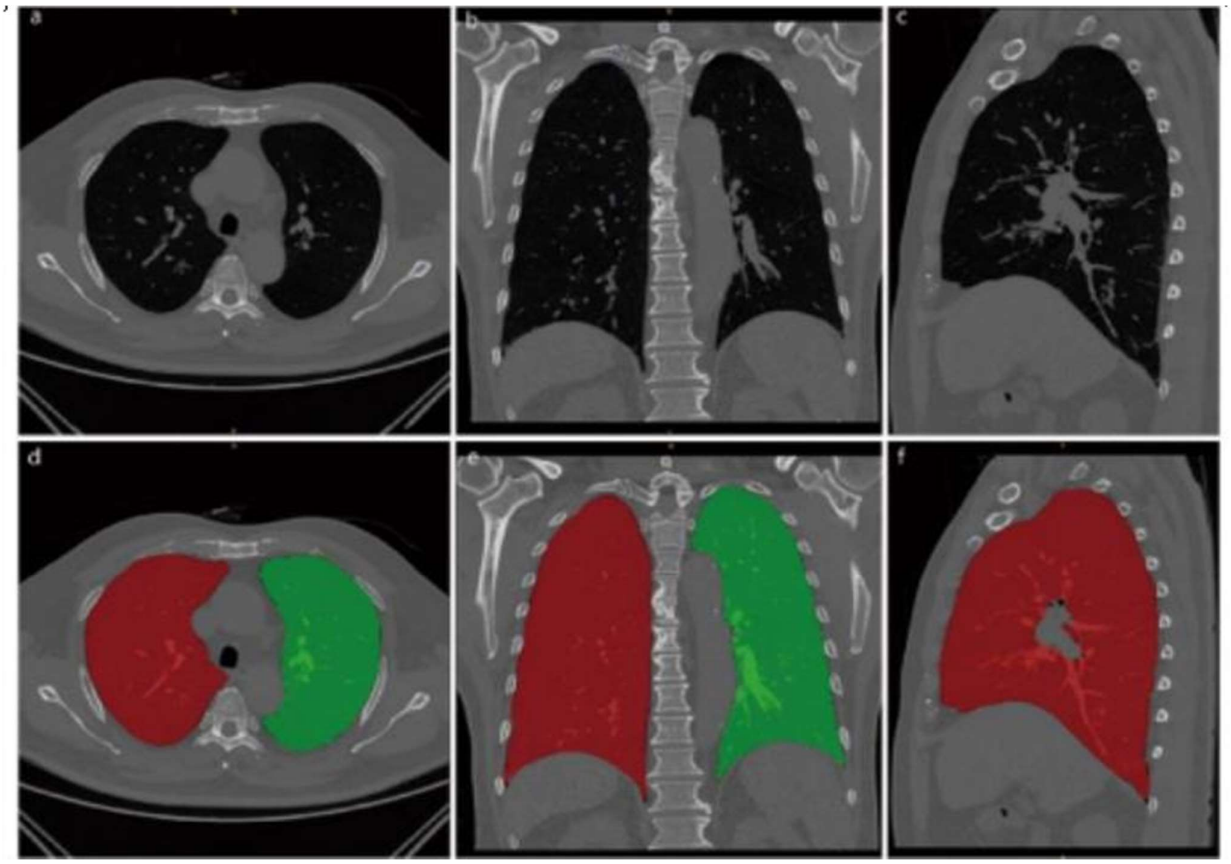

Fig.1.3 Ref: (Original chest HRCT images (a-c) and segmentation results (d-f) of typical lung regions in transverse, coronal, and sagittal planes based on the original chest HRCT images, respectively. The red mask is the right lung parenchyma, and the green one is the left lung parenchyma. HRCT (high-resolution computed tomography) [26]

Energy-integrating detectors (EIDs) are used in standard HRCT systems. They use scintillator materials that react with X-ray photons to make visible light. A photodiode that makes electric signals picks up the light that we can see. A reflecting substance (septa) is placed between each EID detector element to keep light from moving between them. This creates a part of the detector surface that doesn't make an electrical signal. Due to this, the dead area on the detector makes the system's spatial resolution and also geometric dose-efficiency lower [6].

1.3 Radiation Dose

When electromagnetic radiation (ionizing) passes through a person or an object, it transmits energy behind them. A dose is the amount of energy that radiation emits when it hits something. There are three ways to talkabout radiation dose amounts: absorbed, equivalent, and effective [9].

1.4 Absorbed Dose

A dose that is absorbed is the quantity of energy that radiation gives to the body. The gray (Gy) is the unit used to measure the absorbed dose. One gray is the same as inserting one joule of energy into one kilogram of a substance [9].

1.5 Equivalent dose

The equivalent dose is a way to measure how well radiation protects people by looking at how different types of ionized radiation affect human tissue. To get it, you multiply the absorbed dose by a radiation weightingfactor, which shows how effective the radiation is at causing biological damage (for example, alpha particles do more harm than X-rays or gamma rays for the same absorbed dose). An equivalent dose is the amount of radiation that reaches a certain organ or tissue. It helps figure out how likely it is that radiation will cause harm. It is measured in sieverts (Sv) and is mostly used to compare how different types of radiation affect the same tissue. This is an important step in figuring out effective doses [10].

1.6 Effective dose

Effective dose is a measure of radiation protection that helps us figure out how likely it is that ionizing radiation can harm the human body. It doesn't just look at the amount of radiation taken in; it also looks at the kind of radiation and how sensitive different organs and tissues are to it. To look for the effective dose, add the equivalent doses received by all the irradiated organs. Each organ's equivalent to the dose is increased by a tissue weighing factor which indicates how much that organ adds to the total radiation harm. It is measured in sieverts (Sv) and is very helpful for comparing the radiation risk of different diagnostic imaging procedures (like X-rays, CT scans, and nuclear medicine) and for setting limits on how much radiation people can be exposed to at work and in public. The ICRP came up with the idea of "effective dose" to give

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a single number that shows the stochastic health risk, radiation exposure [10] mostly cancer and hereditary effects, from low-level

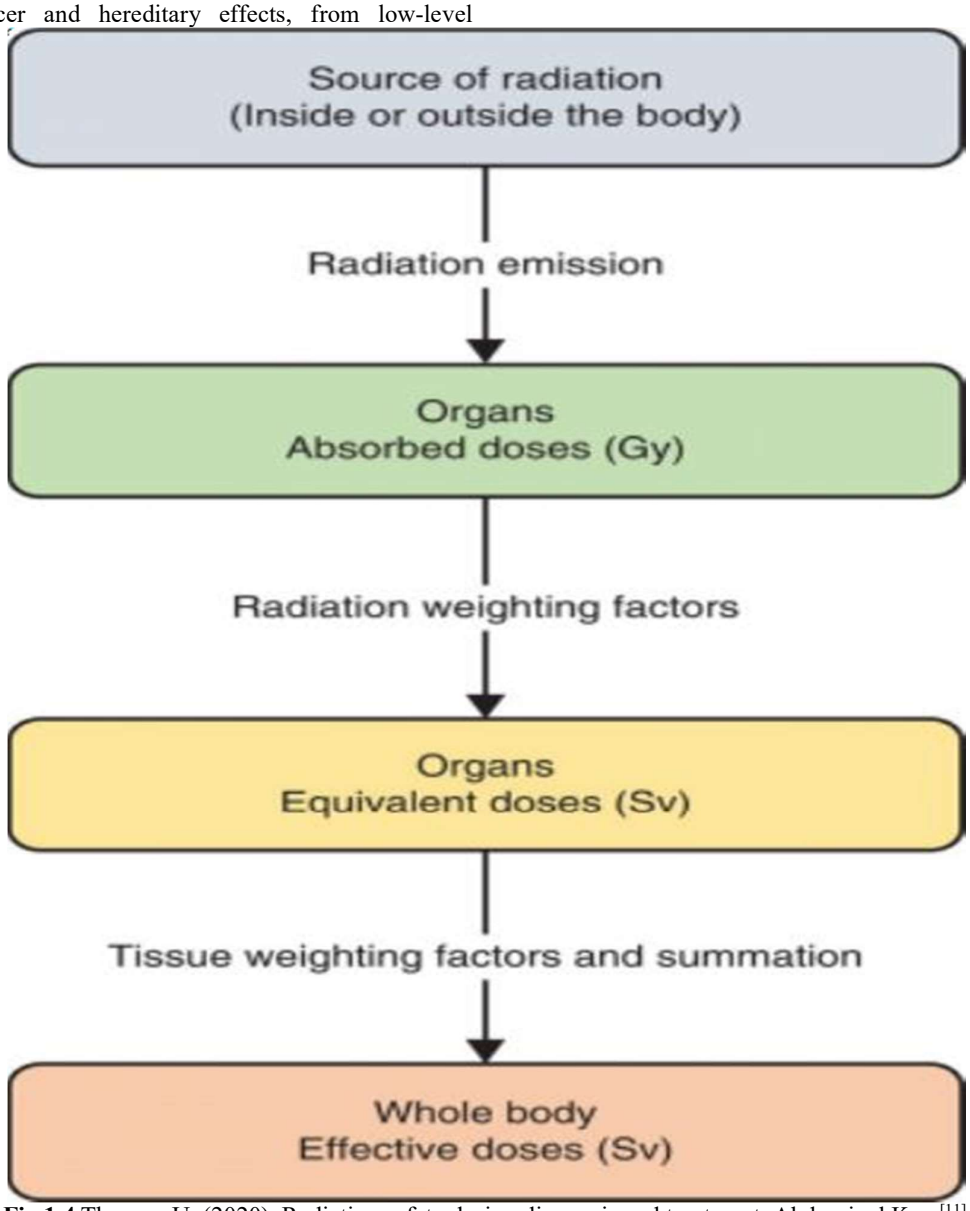
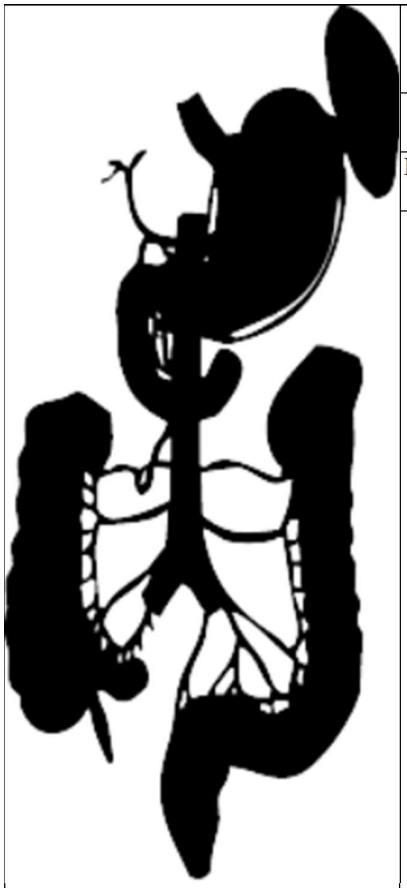


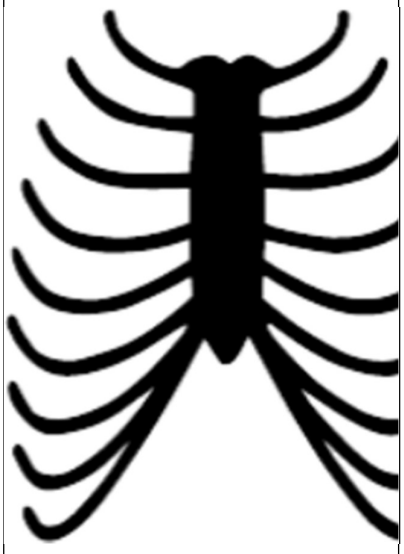
Fig.1.4 Themes, U. (2020). Radiation safety during diagnosis and treatment, Abdominal Key [11].

1.7 Effective radiation dose in adults

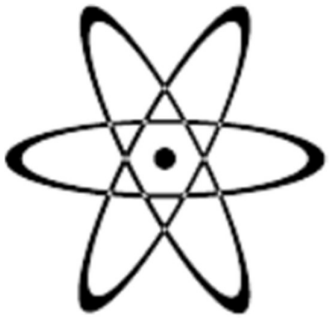
Table 1.1 Radiological Society of North America (RSNA) and American College of Radiology (ACR) (no date) Radiation dose, Radiologyinfo.org. [12].

ABDOMINAL REGION	Procedure	Approximate effective radiation dose	Comparable to natural background radiation for:
	Computed Tomography (CT)– Abdomen and Pelvis	7.7 mSv	2.6 years
	Computed Tomography (CT)– Abdomen and Pelvis, repeatedwith and without contrast material	15.4 mSv	5.1 years

	Computed Tomography (CT)–Colonography	6 mSv	2 years
	Intravenous Urography (IVU)	3 mSv	1 year
	Barium Enema (Lower GI X-ray)	6 mSv	2 years
	Upper GI Study with Barium	6 mSv	2 years
BONE	**Procedure**	**Approximate effective radiation dose**	**Comparable to natural background radiation for:**
	Lumbar Spine	1.4 mSv	6 months
	Extremity (hand, foot, etc.) X-ray	Less than 0.001 mSv	Less than 3 hours
	Procedure	**Approximate effective**	**Comparable to natural background**
		radiation dose	**radiation for:**
CENTRAL NERVOUS SYSTEM	Computed Tomography (CT)–Brain		

		1.6 mSv	7 months
	Computed Tomography (CT)– Brain, repeated with and without contrast material	3.2 mSv	13 months
	Computed Tomography (CT)–Head and Neck	1.2 mSv	5 Months
	Computed		
	Tomography (CT)–	8.8 mSv	3 years
	Spine		
CHEST 	**Procedure**	**Approximate effective radiation dose**	**Comparable to natural background radiation for:**
	Computed Tomography (CT)– Chest	6.1 mSv	2 years
	Computed Tomography (CT)–Lung CancerScreening	1.5 mSv	6 months

	Chest X-ray	0.1 mSv	10 days
DENTAL 	**Procedure**	**Approximate effective radiation dose**	**Comparable to natural background radiation for:**
	Dental X-ray	0.005 mSv	1 day
	Panoramic X-ray	0.025 mSv	3 days
	Cone Beam CT	0.18 mSv	22 days
HEART 	**Procedure**	**Approximate effective radiation dose**	**Comparable to natural background radiation for:**
	Coronary Computed Tomography Angiography (CTA)	8.7 mSv	3 years
	Cardiac CT for Calcium Scoring	1.7 mSv	6 months
	Non-Cardiac Computed Tomography Angiography (CTA)	5.1 mSv	Less than 2 years
MEN'S IMAGING	**Procedure**	**Approximate effective radiation dose**	**Comparable to natura background radiation for:**
	Bone Densitometry (DEXA)	0.001 mSv	3 hours

NUCLEAR MEDICINE 	Procedure	Approximate effective radiation dose	Comparable to natural background radiation for:
	Positron Emission Tomography–Computed Tomography (PET/CT) Wholebody protocol	22.7 mSv	7.6 years
WOMEN'S IMAGING	**Procedure**	**Approximate effective radiation dose**	**Comparable to natural background radiation for:**
	Bone Densitometry (DEXA)	0.001 mSv	3 hours
	Screening Digital Mammography	0.28 mSv	34 days
	Screening Digital Breast Tomosynthesis (3DMammogram)	0.34 mSv	42 days

1.8 Radiology anatomy of chest

Radiological chest anatomy is the study of the normal structures of the thorax as seen on chest imaging, which is usually done with chest radiographs (PA and lateral views) or computed tomography (CT). A standardposteroanterior (PA) chest radiograph shows the lungs as radiolucent fields that are split into lobes by fissures. However, fissures are not always easy to see. The trachea is a column of air that runs down the middle of the body and splits into the right and leaves the main bronchi at the carina. The heart and mediastinum make up the central soft-tissue opacities. The right atrium is on the right border of the cardiac silhouette, and the left ventricle is on the left border. The aortic arch makes the aortic knuckle in the upper left mediastinum; veins and the pulmonary arteries make the hilar shadows. Bones like the ribs, clavicles, scapulae, sternum, and thoracic vertebrae are dense (radio-opaque) structures that help with navigation [13].

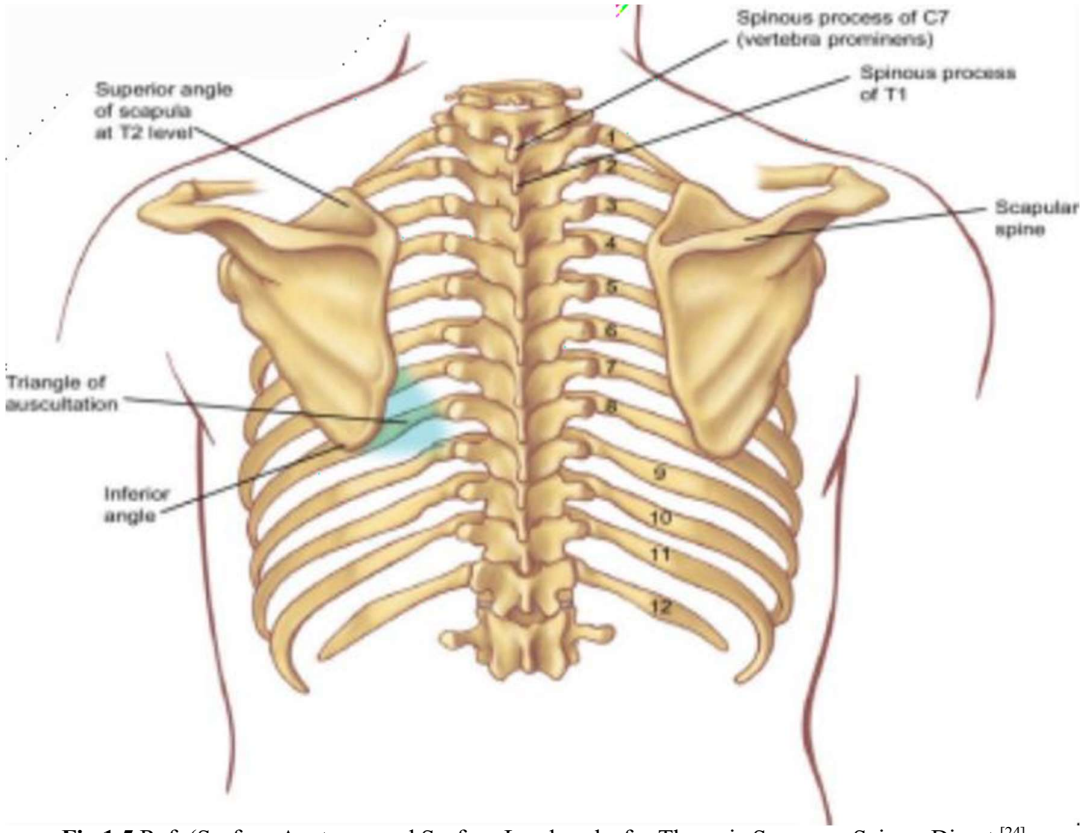


Fig.1.5 Ref: (Surface Anatomy and Surface Landmarks for Thoracic Surgery - ScienceDirect [24]

The trachea splits into two parts at the carina, which is located at the T4–T5 vertebral level, opposite the sternal angle. On a normal chest of X-rays, it looks like a vertical air column in the middle or slightly to the right. The tops of the lungs are two to three centimeters above the middle ends of the clavicles. The lung fields are areas on both sides of the mediastinum that are not visible on X-rays. The left side lung has a notch for the heart, and the right lung is a little shorter and wider. The oblique fissure goes from the back of the T3 vertebra to the front of the sixth costochondral junction, and the horizontal fissure of the right lung goes along the fourth rib. These two fissures and the lobes that make them up are usually not visible on a normal chest X-ray. [14].

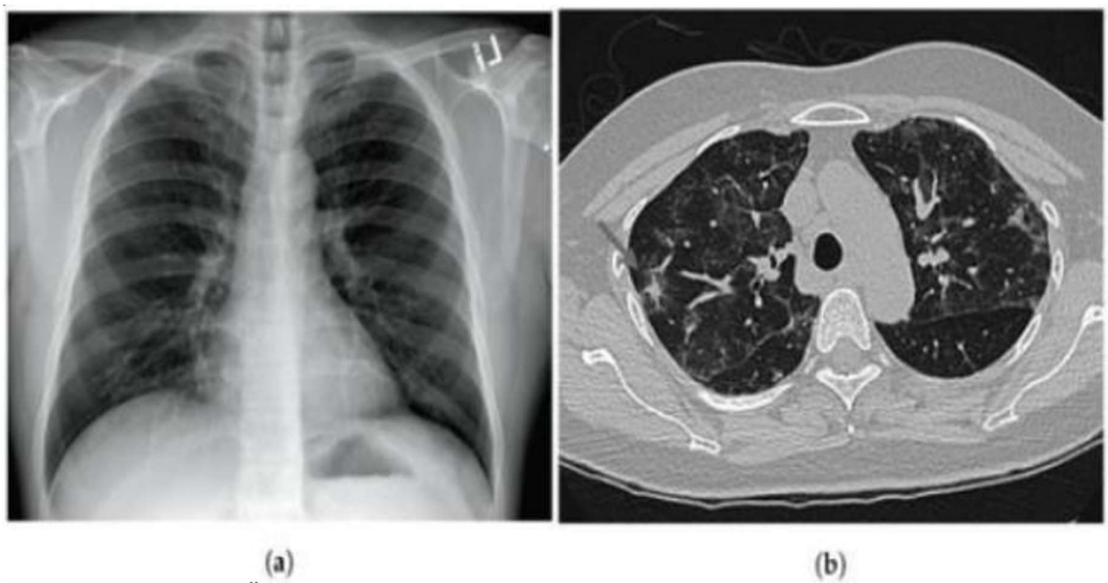


Fig.1.6 Thoracic medical imaging. (a) Example of CXR taken from [1]. (b) Example of a CT scan [27].

The right atrium is on the right side, and the left ventricle is on the left side to make up most of the cardiac silhouette.

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In adults, the normal cardiothoracic ratio on a PA view does not go above 50%. The mediastinal shadowincludes the trachea, the aortic arch (also called the aortic knuckle), the superior vena cava, and the heart. The diaphragm looks like two domes, with the right dome usually being 2 cm higher than the left. In healthy people, the costophrenic angles are sharp. The bony parts, like the ribs, clavicles, scapulae, and thoracic vertebrae, are important surface landmarks. You might also be able to see soft tissue shadows, like breast and nipple shadows[14].

1.9 Computed Tomography (Body Mass Index)

Computed Tomography BMI (Body Mass Index in the CT context) is the patient's body mass index, which is calculated by dividing their weight in kilograms by their height in meters squared. CT BMI is clinically significant in computed tomography because a patient's body size has a big effect on the quantity of radiation they get and how good the pictures are, even though it is not a built-in radiation dose parameter. In CT imaging, BMI is commonly used as a substitute for patient size when choosing or changing scan settings like tube current (mA) and tube voltage (kVp), especially when ATCM systems are used Patients with an increased BMI absorb more X-

rays, so the CT scanner has to increase the tube current to keep the picture noise at an acceptable level [15].

This increases the radiation output and dose indices. BMI helps with changing protocols and checking doses, but it is a rough way to measure patient size and does not accurately show body shape or cross-sectionaldiameter. This is why more advanced metrics like size-specific dose estimate (SSDE) are used to find out the amount of radiation an individual will get. Why BMI matters in CT: it affects X-ray attenuation, image noise, automatic tube current modulation (ATCM) radiation dose, and patients with a higher BMI need: Higher tube current (mA) and sometimes higher kVp cause CTDIvol and DLP to go up [15].

$$BMI = \text{Weight (kg)} / \text{Height (m)}^2$$

1.10 Computes Tomography Dose Index Volume (CTDIvol) in CT scan

The Computed Tomography Dose Index–Volume (CTDIvol) is a standardized measure that shows the average amount of radiation a CT scanner emits for a certain scanning protocol over the scanned volume. To take helical scanning into account, the weighted CT dose index (CTDIw) is divided by the pitch factor and given in milli-gray (mGy). To measure CTDIvol, which is automatically displayed on the CT console after each scan, standardized polymethyl methacrylate (PMMA) phantoms with a 16 cm diameter for head exams and a 32 cm diameter for body exams are used. CTDIvol is often used to compare protocols, check quality, and make sure that diagnostic reference levels (DRLs) are being followed, but it doesn't accurately show the amount of radiation one patient gets because it doesn't take consider the patient's size, anatomy, or organ sensitivity. CTDIvolmay therefore underestimate the dose for larger patients and overestimate it for smaller patients, emphasizing the necessity for patient-specific adjustments like SSDE. CTDIvol indicates scanner radiation output, protocol comparison, quality assurance, and regulatory compliance, rather than the actual patient dose, and it does not consider patient size or organ sensitivity [16].

1.11 Relationship Between CT Body Mass index (BMI) and Computed Tomography Dose Index Volume (CTDIvol)

Numerous studies demonstrate a positive correlation between BMI and CTDIvol: as BMI increases, CTDIvol also increases, mainly because larger body size requires a higher radiation dose to maintain diagnostic image quality [17] [18].

Tabel 1.2 Relationship Between CT Body Mass index (BMI) and Computed Tomography Dose Index Volume (CTDIvol)

Key Findings	Conclusion on BMI & CTDIvol Relationship
CTDIvol increases with increasing BMI due to higher X-ray attenuation.	Higher BMI requires higher CTDIvol for image quality.
Automated tube current modulation adjustsCTDIvol upward for higher BMI.	Positive correlation between BMI and CTDIvol.
Statistically significant increase of CTDIvol with each BMI category increase.	BMI is a strong predictor of CTDIvol in adults.
CTDIvol rises with BMI, suggesting a need for BMI-adapted protocols.	BMI-based adjustments reduce unnecessary exposure.

1.12 To Know About Non-Contrast Computed Tomography (NCCT), High Resolution Computed Tomography (HRCT) and Contrast Enhanced Computed Tomography (CECT) Thorax

Plain NCCT thorax is a non-contrast CT scan used largely for examination of lung parenchyma, pulmonary nodules, pneumothorax, pleural calcifications, and bony thoracic structures; however, it has limited ability to define mediastinal arteries and lymph nodes. Iodinated contrast is administered intravenously during CECT thorax, which is primarily used to assess mediastinal masses, lymphadenopathy, lung cancer staging, vascular pathologies like pulmonary embolism and aortic disease, pleural lesions, and chest wall tumors because it improves the delineation of soft-tissue and vascular structures. HRCT thorax is a specialized thin-section CT technique (0.5–1.5 mm slice thickness) optimized for detailed evaluation of lung parenchyma and is the imaging modality of choice for interstitial lung diseases, bronchiectasis, small airway diseases, and early

diffuse lung pathology; it is usually performed without contrast and provides limited information about the mediastinum [19] [20] [21].

Table 1.3 To Know About Non-Contrast Computed Tomography (NCCT), High Resolution Computed Tomography (HRCT), and Contrast Enhanced Computed Tomography (CECT) Thorax.

Feature	Plain NCCT Thorax	CECT Thorax	HRCT Thorax
Definition	CT scan of thorax without contrast	CT thorax performed after IV contrast injection	Thin-section CT optimized fo lung parenchyma
Contrast use	Not used	Iodinated IV contrast used	Usually not used
Slice thickness	5–10 mm	3–5 mm	0.5–1.5 mm
Main purpose	General lung and bone assessment	Evaluation of mediastinum vessels, masses	Detailed assessment o lungparenchyma
Best for	Lung nodules, pneumothorax, calcifications, pleura	Lung cancer staging, mediastina masses, lymphadenopathy vascular lesions	Interstitial lung disease bronchiectasis, small airwaydisease
Mediastinal evaluation	Limited	Excellent	Poor
Vascular assessmen	Poor	Excellent	Poor
Lung parenchyma detail	Moderate	Moderate	Excellent
Common indications	Pulmonary nodules, trauma, pleural disease	Tumors, infections with complications, pulmonary embolism	ILD, hypersensitivity pneumonitis early lung disease
Radiation dose	Moderate	Moderate to high	Variable (may be high i volumetric)

MATERIALS AND METHODS

4.1 Source of Data: This study was carried out in the Department of Radiology and Imaging Technology, NIIMS Hospital, Gautam Buddh Nagar, Uttar Pradesh, India.

4.2 Study Design: A prospective cross-sectional study carried out among patients who came for the HRCT chest in the Department of Radiology and Imaging Technology, NIIMS Hospital, Gautam Buddh Nagar. The project was approved by the college review.

4.3 Study Period: This study was carried out for the time period of 1 year (July 2025 to April 2026). At the department of Radiology and Imaging Technology, NIIMS Hospital Gautam Buddh Nagar, Uttar Pradesh, India

4.4 Data Collection Period: The data was collected for a period of 3 months from January 2026 to March 2026. At the Department of Radiology and Imaging Technology, NIIMS Hospital, Gautam Buddh Nagar, Uttar Pradesh, India.

4.5 Study population: The size of population was 121 patients. The study population was consisted of all patients, including male and female, who came for HRCT chest examination in radiology department. Excluding the patient is unwilling to undergo HRCT chest scan.

4.6 Sampling Technique: The Correlation was evaluated using the point-biserial correlation coefficient. The result was considered statistically significant when the p-value < 0.01.

4.7 Selection Criteria: Inclusion Criteria: All patients referred to HRCT Chest.

Exclusion Criteria: -

1. Pregnancy.
2. Uncooperative patients.
3. The patient is unwilling to undergo HRCT chest scan.

4.8 Method of data collection: The data was obtained from the digital imaging and communications in medicine server (PACS) and radiology information system (RIS) using a filtered data form (age, sex, History, CTDIvol [mGy]) and dose length product (DLP [mGy.Cm]). CTDIvol and DLP were used to calculate the average and mean patient dose and compared with each other throughout the study. Effective dose, a dose descriptor reflecting the biological sensitivity of irradiated regions of interest, was calculated by taking the product of total DLP and the k-factor (the proportionality constant between the effective dose and the DLP). The k-factor for the chest is 0.0140

RESULT

6.1 Patients' Demographics and Protocol Description

There were 121 adult patients in all, with almost the same number of men (57.72%, n = 65) and women (46.28%, n = 56). The average age was 60.9 years, with a range of 17 to 93. The most common patient was underweight (BMI <18.5, 64.50%, n = 78), which is the most important group for dose optimization strategies. The second most common group was healthy weight (31.40%, n

= 38), and the third most common group was overweight (4.10%, n = 5). Chest pain was the most common clinical indication (34.93%, n = 95), followed by cough (25.74%, n =

70), COPD (16.54%,

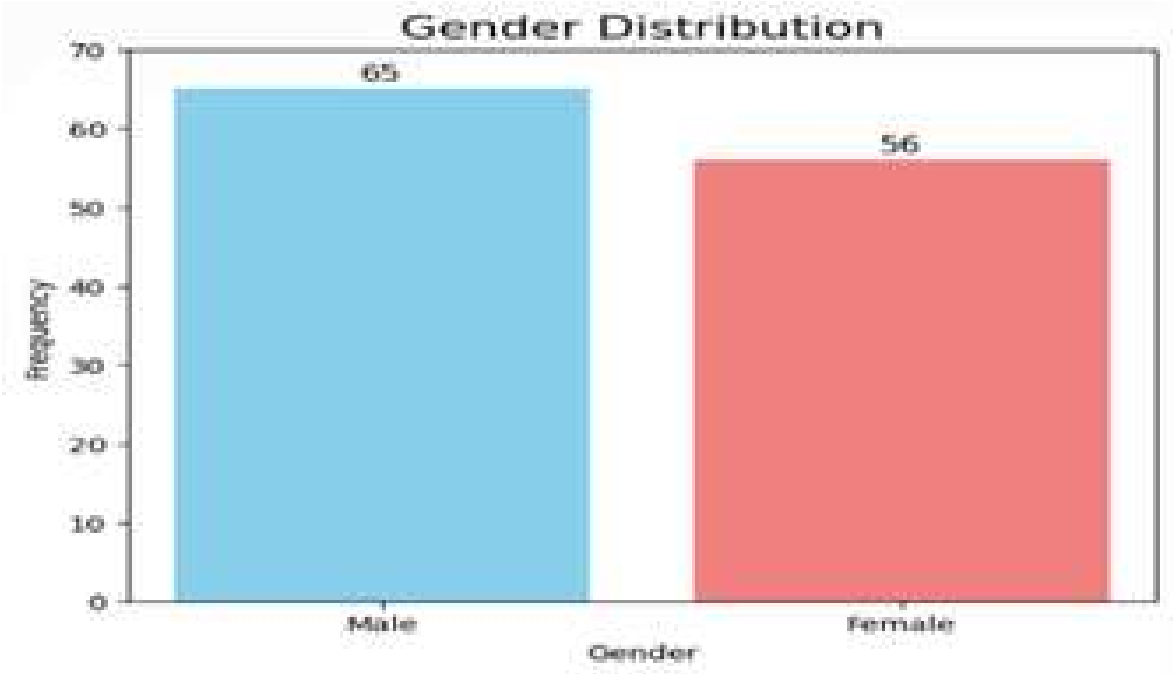
n = 45), fever (7.35%, n = 20), cold (6.62%, n = 18), chest angina (6.62%, n = 18), and hypotension (2.21%, n = 6).

The distribution shows common situations in which personalized radiation dose management is useful (Table 6.1, 6.2).

Table 6.1. Patients and procedural characteristics: descriptive statistics.

		n
Gender	Male	65 (53.72)
	Female	56 (46.28)
BMI Range	Underweight	78 (64.50)
	Normal	38 (31.40)
	Overweight	5 (4.10)
Indications	Chest Pain	95 (34.93)
	Cough	70 (25.74)
	COPD	45 (16.54)
	Fever	20 (7.35)
	Cold	18 (6.62)
	Chest Angina	18 (6.62)
	Hypotension	6 (2.21)

Graph 6.1. The bar represents gender distribution.



Graph 6.2. The bar represents the distribution of clinical indications among patients.

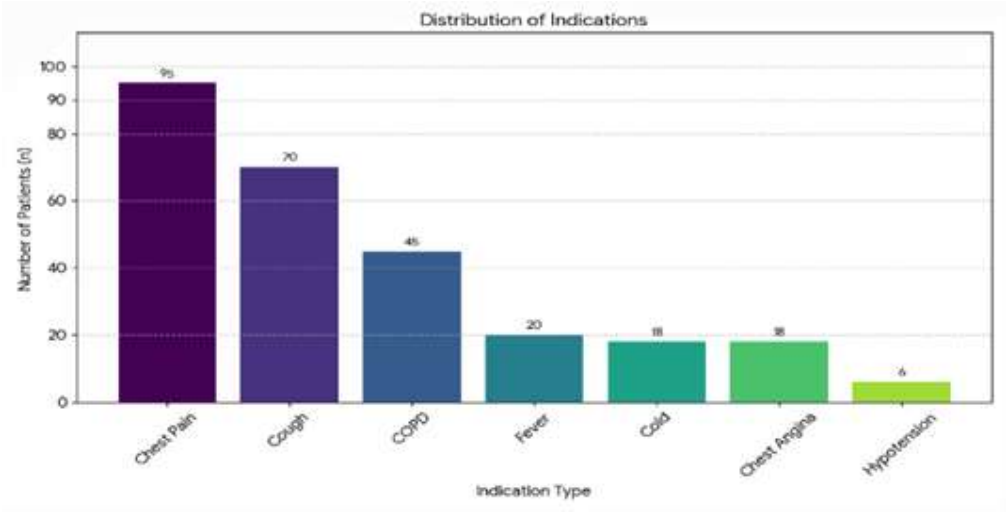
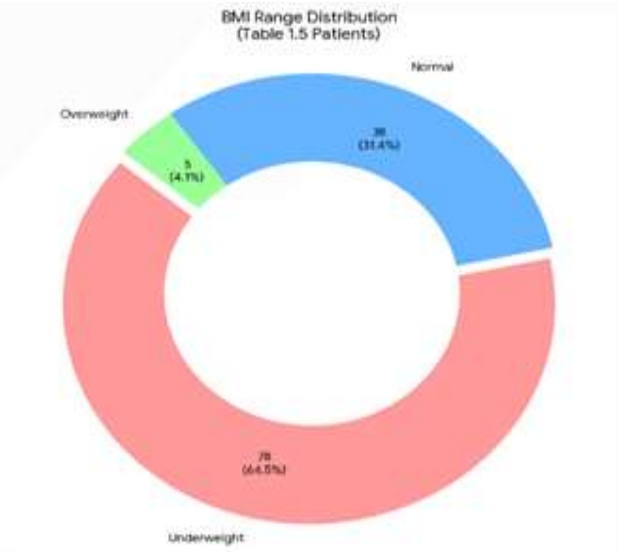


Table 6.2. BMI Classification.

BMI Category	Range	Frequency (n)	Percentage (%)
Underweight	<18.5	78	64.50%
Normal	18.5-24.9	38	31.40%
Overweight	25-29.9	5	4.10%

Graph 5.3. The pie represents the distribution of participants according to the BMI range.



6.2 Dosimetric Analysis of HRCT Chest Scans

Presents a full statistical breakdown of the dosimetric parameters from the HRCT chest scans, such as the DLP, CTDIvol, SSDE, and ED. The analysis includes the study population's mean, standard deviation (SD), minimum and maximum values, and the 25th, 50th (median), and 75th percentiles.

Table 6.3. The mean values, standard deviation, and the 25th, 50th, and 75th percentiles for the DLP, CTDIvol, SSDE, and E103 are given for the whole population.

			Percentile		
	Mean ± SD	Min–Max	25	50	70
DLP (mGy·cm)	267.4 ± 87.6	123 - 647	194	246	291
CTDIvol (mGy)	7.92 ± 2.5	3.86 - 18.5	5.60	7.18	9.05
SSDE (mGy)	11.3 ± 2.6	5.1 - 17.8	9.10	11.10	12.80

E103 (mSv)	3.72 ± 1.52	1.72 - 9.06	2.716	3.444	4.074

The average DLP was 267.4 mGy·cm, with a standard deviation of 87.6 mGy·cm and a range of 123 to 647 mGy·cm. The distribution shows that 25% of scans had DLP values lower than 194 mGy·cm, 50% had values lower than 246 mGy·cm, and 70% had values lower than 291 mGy·cm.

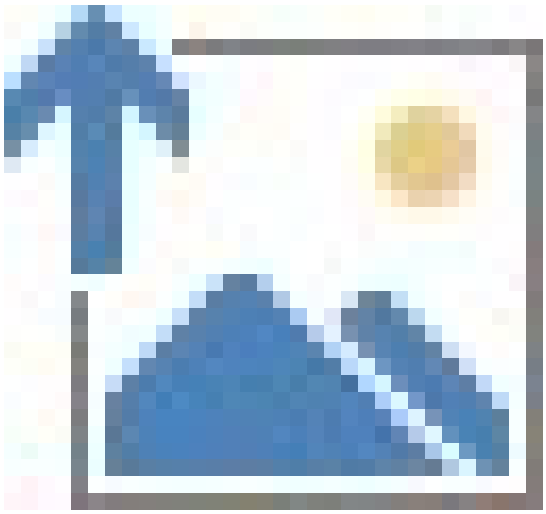
The mean for the CTDIvol was 7.92 mGy, with a standard deviation of 2.5 mGy. The values ranged from 3.86 to 18.5 mGy. The 25th, 50th, and 70th percentiles for the CTDIvol were 5.60, 7.18, and

9.05 mGy, respectively. This shows how different the scan protocols were.

The SSDE, which is based on the size of the patient, had a mean value of 11.3 mGy and a standard deviation of 2.6 mGy. The values ranged from 5.1 to 17.8 mGy. The 25th, 50th, and 70th percentiles were 9.10, 11.10, and 12.80 mGy, respectively. This means that most scans had SSDE values that were not too far from the median. The effective dose (E103) was 3.72 mSv on average, with a standard deviation of 1.52 mSv and a range of 1.72 to 9.06 mSv. The percentiles for the E103 were 2.716, 3.444, and 4.074 mSv. This shows that the effective dose was evenly spread across the study population.

In Graph 6.4, there is a clear difference in the frequency distribution of the effective dose (ED) ranges in HRCT scans across dose intervals. The ED range that comes up the most often is 3.514–3.976 mSv (26 scans), followed by 3.01–3.486 mSv (22 scans) and 2.506–2.982 mSv (18 scans). The ranges of 2.128–2.492 mSv (16 scans) and 4.06–4.494 mSv (13 scans) show moderate frequencies. There are lower frequencies in the ranges of 1.722–1.946 mSv, 4.536–4.732 mSv, and 5.068–5.824 mSv (each with 7 scans). The ranges that happen at the least often are 6.342–6.44 mSv (2 scans) and 7.406–9.058 mSv (3 scans). The distribution shows that most HRCT scans are in the mid-dose ranges (about 2.5–4.0 mSv), which means that most of the exams are done at the best dose levels. Higher dose ranges are less common because people follow radiation safety rules and dose optimization methods.

Graph 6.4. The bar graph represents the effective dose frequency distributions.



6.3 Correlation Analysis of Patient Factors and Radiation Dose Parameters

There was a statistically significant positive correlation between BMI and all dose metrics. Specifically, BMI showed a moderate positive correlation with CTDIvol ($r = 0.42$, $p < 0.001$), DLP ($r = 0.46$, $p < 0.001$), and Effective Dose ($r = 0.44$, $p < 0.001$). Additionally, BMI demonstrated a mild-to-moderate positive correlation with SSDE ($r = 0.39$, $p < 0.01$).

Table 6.4 Pearson Correlation Between BMI and Dose Parameters.

Variable	Correlation with BMI (r)	P-value	Interpretation
CTDIvol	0.42	<0.001	Moderate Positive
DLP	0.46	<0.001	Moderate Positive
Effective Dose	0.44	<0.001	Moderate Positive
SSDE	0.39	<0.01	Mild-moderate

Finally, there was a statistically significant increase in CTDIvol ($F = 6.84$, $p = 0.002$), DLP ($F = 7.92$, $p < 0.001$), and effective dose ($F = 7.11$, $p = 0.001$) across BMI categories. Post hoc trends indicate that radiation dose parameters progressively increased from underweight to overweight patients. Linear regression analysis demonstrated a significant positive association between BMI and effective dose ($\beta = 0.18$, $p < 0.001$), indicating that effective dose increases by 0.18 mSv for each unit increase in BMI. These findings suggest that BMI is a

strong determinant of radiation dose in CT imaging.

Table 6.5. Comparison of Radiation Dose Parameters Across BMI Categories Using One-Way ANOVA

Parameter	BMI Category	Mean ± SD	F-value	p-value
CTDIvol (mGy)	Underweight	7.12 ± 2.1	6.84	**0.002**
	Normal	8.54 ± 2.3		
	Overweight	10.62 ± 3.1		
DLP (mGy·cm)	Underweight	241.3 ± 72.4	7.92	**<0.001**
	Normal	289.7 ± 81.5		
	Overweight	342.5 ± 95.2		
Effective Dose (mSv)	Underweight	3.25 ± 1.21	7.11	**0.001**
	Normal	3.98 ± 1.32		
	Overweight	4.86 ± 1.45		

Table 6.6 Linear Regression (BMI vs Effective Dose)

Parameter	Beta Coefficient (β)	Standard Error	p-value
BMI	0.18	0.04	<0.001

DISCUSSION

The current study shows a statistically significant positive relationship between Body Mass Index (BMI) and radiation dose indices, such as CTDIvol, DLP, SSDE, and effective dose in HRCT chest examinations. These results show that as BMI goes up, radiation exposure goes up as well. This is mostly because larger body types absorb more photons, which means that the tube current and output have to be higher to keep the quality of the diagnostic images. This finding aligns with earlier studies that have identified BMI as a significant factor influencing variations in radiation dose. For instance, Mohamed Abuzaid et al. found a strong link between BMI and radiation dose (rpb = 0.445, $p < 0.01$), which backs up the idea that the size of the patient is important for dose optimization (ROL: 1). The same as Brett W. Sperry et al. established that radiation exposure escalates proportionally with BMI across various imaging modalities, underscoring the necessity of tailored imaging protocols (ROL: 2).

From a clinical perspective, these findings underscore the necessity of implementing size-specific dose estimation (SSDE) and automatic exposure control systems in standard CT practice. Standard dose metrics like CTDIvol and DLP alone may not accurately represent the radiation burden

specific to individual patients, especially those with elevated BMI. Research conducted by Yusuke Inoue et al. and Mohammad Reza Deevband et al. underscores that the inclusion of body size indices enhances the precision of dose estimation and bolsters patient safety (ROL: 6, 7). Moreover, Sunyoung Lee et al. established that both BMI and body composition substantially affect radiation dose, indicating the necessity for more precise patient-specific modifications (ROL: 8). Therefore, the present study endorses the continued clinical transition from standardized protocols to individualized CT imaging approaches.

This study can be very useful for clinical practice because it can help radiologists improve their protocols based on the BMI of their patients. Using BMI-based changes can help lower unnecessary radiation exposure, especially in overweight patients, while keeping the image quality high enough for diagnosis. This is especially important for HRCT chest imaging, where patients with chronic lung diseases may need to have scans done more than once. The results also help to raise standards for radiation safety and are in line with the ALARA (As Low as Reasonably Achievable) principle, which is widely used in radiology (ROL: 1, 10).

For future perspective, this study emphasizes the necessity of incorporating advanced technologies, including artificial intelligence (AI)-driven dose modulation systems, automated patient size measurement instruments, and real-time adaptive imaging protocols. Future studies ought to concentrate on integrating BMI with additional variables, including body composition, tissue density, and machine learning algorithms, to enhance the accuracy of dose prediction models. Furthermore, extensive multicenter studies are necessary to authenticate BMI-based dose optimization strategies across varied populations and CT systems. Using advanced reconstruction methods like iterative reconstruction and deep learning-based image enhancement could help lower radiation dose even more without hurting the quality of the diagnosis.

Finally, this study shows that BMI is a strong predictor of radiation dose in HRCT chest imaging. It also shows how important it is to have imaging protocols that are tailored to each patient. By combining current dose optimization methods with new technologies, radiology can move toward safer and more effective imaging practices that help both patients and healthcare providers.

CONCLUSION

The study concludes that the Body Mass Index (BMI) has a significant impact on radiation dose in HRCT chest examinations. A statistically significant positive correlation was observed between BMI and all major radiation dose parameters, including CTDIvol, DLP, SSDE, and effective dose. As BMI increases, radiation dose also increases due

to higher X-ray attenuation and the need for increased exposure to maintain diagnostic image quality. The study further demonstrated that radiation dose parameters progressively increased across BMI categories from underweight to overweight patients, confirming BMI as a strong predictor of radiation exposure.

This result contributes to the biological impact of ionizing radiation on human tissues, which can manifest as both stochastic and non-stochastic effects. Stochastic effects are probabilistic in nature, meaning their likelihood increases with dose, but there is no definite threshold; even low levels of radiation exposure may carry some risk. These effects are primarily associated with long-term outcomes such as carcinogenesis and genetic mutations. In contrast, non-stochastic (deterministic) effects are dose-dependent and occur only after a certain threshold has been exceeded. The severity of these effects increases with higher radiation doses and may include tissue reactions such as skin erythema, fibrosis, or organ dysfunction. So, taking this in Consideration In diagnostic imaging, the biological effects of ionizing radiation—ranging from stochastic risks such as malignancy to non-stochastic tissue reactions—highlight the need for strict radiation safety practices. The principle of As Low as Reasonably Achievable (ALARA) must be consistently applied and integrated into routine professional practice as a cardinal law of radiation protection. This involves the appropriate use of shielding devices, proper collimation, maintaining optimal distance, and minimizing exposure time. Additionally, the use of advanced and well-maintained radiation protection equipment within the department is essential to safeguard both patients and healthcare workers. Optimization of scanning parameters, such as reducing tube voltage (kVp), adjusting tube current (mAs), employing automatic exposure control, and using iterative reconstruction techniques, can significantly lower radiation dose without compromising diagnostic image quality. So, it collectively helps in minimizing the biological effects of radiation while ensuring effective imaging outcomes.

Additionally, linear regression analysis indicated that effective dose rises proportionally with BMI, reinforcing the importance of patient size in dose estimation. These findings highlight the necessity of implementing patient-specific dose optimization strategies, such as BMI-based protocol adjustments and the use of SSDE, to ensure accurate dose assessment and minimize unnecessary radiation exposure.

ETHICAL APPROVAL

This study has been approved by the research committee of the School of Allied Health Sciences, Noida International University, Gautam Buddh Nagar, Uttar Pradesh.

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