



Radiation Exposure Assessment in Coronary Angiography Computed Tomography Scan: Establishing Diagnostic Reference Level for Northeast Assam Population

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Abstract

Background/Aim: Coronary angiography computed tomography (CT) scans play a pivotal role in diagnosing cardiovascular diseases, providing crucial information for treatment planning. However, concerns regarding radiation exposure have prompted the need for establishing region-specific diagnostic reference levels (DRLs) to ensure patient safety. This study aimed to assess radiation exposure during coronary angiography CT scans in the northeast Assam population and establish DRLs tailored to this demographic.

Methods: A total of 380 patients were referred to the Primus Diagnostic Centre and Heath City Hospital, Guwahati Assam with coronary artery disturbances. Data on the technical parameters used in CT procedures were taken in 2021-2022. Organ and surface dose to specific radiosensitive organs (chest) estimation was done using software *imPACT 1.0.4* from the National Radiological Protection Board (NRPB) SR250 Monte Carlo dataset.

Results: The study population (n = 380) comprised 190 men and 190 women with an age range from 29 to 75 years. The mean body mass index (BMI) and effective dose (ED) were 22.42 ± 1.06 kg/m² and 21.57 ± 4.27 mSv.cm, respectively. The mean the dose-length product (DLP) was 854.67 mSv.cm and the mean ED was 21.57 mSv.cm. The ED for males was 13-27 mSv and 13-29 mSv for females. The DRL for the male population was found to be 24.26 mSv.cm² whereas for the female population was 24.69 mSv.cm².

Conclusion: This study highlights the necessity of establishing tailored DRLs for coronary angiography CT scans in the northeast Assam population. By doing so, healthcare providers can ensure optimal image quality while minimising radiation exposure, ultimately enhancing patient safety and quality of care. These findings have implications for radiological practice in the region and contribute to the ongoing efforts to standardise radiation doses in medical imaging procedures.

Key words: Radiology; Computed tomography; Coronary angiography; Phantom; Heart.

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Introduction

In the 1970s, computed tomography (CT) was invented by British engineer Godfrey N Hounsfield and American surgeon AM Cormack by integrat-

ing X-ray technology with computers. This innovative X-ray method depicts not only bones but also surrounding tissues by collecting slice-by-

slice images of various body parts. A few years before, Cormack had developed an approach for determining the distribution and attenuation of X-rays within the body as well as a mathematical theory for image reconstruction. In 1979, the two scientists received the Nobel Prize in Medicine for their efforts and discovery.^{1,2} Understanding the balance between diagnostic benefits and potential radiation risks is crucial for informed decision-making.

Coronary arteries are the “arterial blood vessels” that provide the heart muscle with oxygenated blood *via* coronary circulation. The heart, like all other organs or tissue in the body, needs an ongoing oxygen supply to operate and survive.³ The coronary arteries encircle the whole heart. The right and left coronary arteries are two main types of coronary arteries that supply blood to the heart. These arteries can also be classified into different groups based on the regions of the heart that they supply with blood flow. These classifications are referred to as microvascular classifications, which supply blood to the innermost heart tissue, or near the endocardium and epicardial classifications, which supply blood across the epicardium, or the outermost heart tissue.⁴ A bridged coronary artery function may lead to less blood carrying nutrients and oxygen to the heart. This may have an impact on the heart’s capacity to circulate blood throughout the body as well as on the blood supply to the heart muscle itself. Consequently, any disease or illness of the coronary arteries could have a significant health effect and even cause heart attack, angina, or even mortality.⁵ The left coronary artery (LCA)

and right coronary artery (RCA) which each have multiple branches, make up the majority of the coronary arteries, as illustrated in Figure 1.

Using X-ray technology and computer processing, the medical imaging procedure known as CT angiography may provide precise pictures of the body’s blood vessels, including the coronary arteries of the heart. The process utilised in coronary computed tomography angiography (CCTA) or computed tomography angiography (CTA) is specially intended to assess blood flow and obstructions in the coronary arteries. Since there is no need for catheterisation or the insertion of any equipment into the body, the process is non-invasive. Instead, the patient is lying on a table and emits X-rays at various angles. A computer processes the X-ray pictures to produce finely detailed, three-dimensional views of the heart and blood arteries.

The necessity for enhancing blood flow or repairing blocked arteries may need a different technique because there is no catheter insertion performed during a CT coronary angiography (CTCA). The coronary calcium scan is a different method that is comparable to a CTCA. It employs specialised CT images rather than contrast media to evaluate the amounts of calcium or plaque in the constricted arteries. When estimating the risk of main contrary cardiac procedures, a CT angiogram is superior to a coronary CT calcium scan.⁶ Although the importance of the low radiation doses utilised in “diagnostic imaging” is uncertain, there is serious concern about the possibility of an increase in cancer incidence

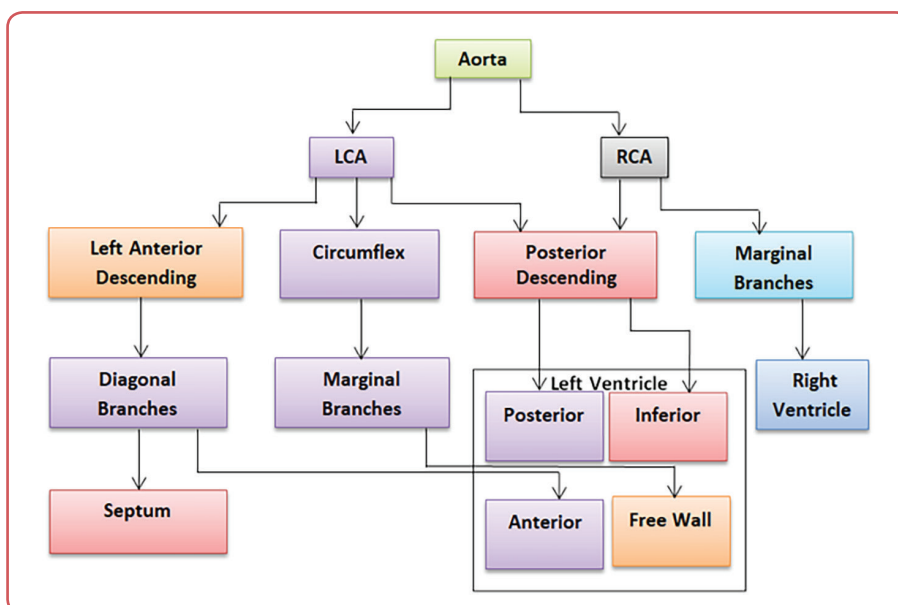


Figure 1: Flow chart depicting the branches of the left and right coronary arteries

in the community. This impending risk must be balanced in contradiction of the risk of failure to identify serious medical issues, such as coronary artery disease, in a particular individual.^{7,8} The diagnostic reference level (DRL) is an essential parameter in medical imaging that helps ensure patients receive the appropriate amount of radiation during procedures such as CTCA.

DRLs is an important dose optimisation tool used in medical imaging recommended by many professional and international organisations, including the International Commission on Radiological Protection (ICRP), the American College of Radiology, the American Association of Physicists in Medicine, the Health Protection Agency and the International Atomic Energy Agency. As a part of the optimisation process and to reduce patient doses in CT examinations, the ICRP introduced DRLs in 1996. As a part of the optimisation process, DRL has been introduced by the ICRP in ICRP publication No 73 in 1996 for common diagnostic procedures and implemented them in a in various regions and countries. DRLs are dose levels determined as 75th percentile of “dose distribution” for X-ray diagnostic investigations, collections of standard phantoms or standard-sized patients for widely different kinds of equipment. In general, when standard procedures are used, it is anticipated that these thresholds will not exceed regular processes. A DRL is never given to a single patient; rather, it is given to a group of individuals. However, comparing a patient’s dose to the DRL for a particular examination will give some perspective on whether the dose is reasonable; if it is too high or too low, one must consider the clinical justification for the use of the dose or the image quality, respectively.⁹ DRLs are officially described in the ICRP reports as “a type of research level that is applied to an easily measurable quantity, typically the radiation dose absorbed in air or objects that are equivalent to tissue on the surface of a simple standard phantom or a model patient”.¹⁰ This explanation highlights that DRLs are not dose limits and do not assist in distinguishing between suitable and improper medical activity. DRLs are different from dose limits, as they can be exceeded if it is clinically necessary to do so. Unlike dose limits for occupational exposure, which only require justification and optimisation, medical exposures are based on clinical judgment. The dose received by a patient during a CT scan can be influenced by factors such as weight and body size. DRLs must not be defined as effective doses (EDs); instead, they

should be established as clearly quantifiable and highly reproducible dose metrics for people with standard sizes or phantoms.¹¹

Before establishing DRLs, dose measurements are made using a method that has been previously standardised for each kind of radiation examination. Due to the effect of optimisation, DRL may not always apply to current procedures with smaller dose distributions. DRLs developed in specific countries or regions are also frequently assessed to ensure compliance with modifications to standard clinical practice and equipment.

The founding of DRL has provided an enhanced diagnostic advantage across the globe. Data from medical CT procedures must be compared to the reference values to establish DRL. As there are no studies to establish the DRL in Northeast India, it is crucial to establish the standard dose. As recommended by the ICRP in 1991, it is vital to optimise the usage of ionising radiation in healthcare and the current study aimed to compare all the existing data from India and generate baseline information about the existing practice.

This study aimed to assess radiation exposure during CTCA scans in the northeast Assam population and establish DRLs tailored to this demographic.

Methods

Dose-response curve as well as the ED received by the patient was analysed. The information used in this research came from one hospital in the Kamrup district of the Assam state (Hospital 1) and one diagnostic centre (Hospital 2). In Hospital 1, CT scan used was *Siemens, Definition AS 12* (128-Slice), Siemens, Munich, Germany. In Hospital 2 a *Philips Ingenuity128* (128-Slice), Philips, Amsterdam, Netherlands scan was used. The study determined a cohort sample size of 380 participants using *Raosoftware*, Inc software. This calculation was based on a margin of error of 5 % and a confidence level of 95 %, for a population size of roughly 2,000,000 individuals in Guwahati, Assam. The sample size was determined with consideration of the precision and confidence level desired for the study’s results, relative to the estimated population size in the studied area.

For the purpose of this research, data was collected from two different CT scanners. There was one public hospital and one private diagnostic centre having a radiology department that each included the required equipment. In advance of any data collection, the equipment carried out all quality control tests in accordance with the recommendations of Atomic Energy Regulatory Board (AERB). Experiments were carried out by a Radiological Safety officer who had received authorisation from the AERB. Any data tallies that were within a range that was deemed appropriate were included in the study.

To ensure CT scan accuracy, a patient-specific data sheet was used. Every CT machine had a dosimetry CT unit. A data sheet was created

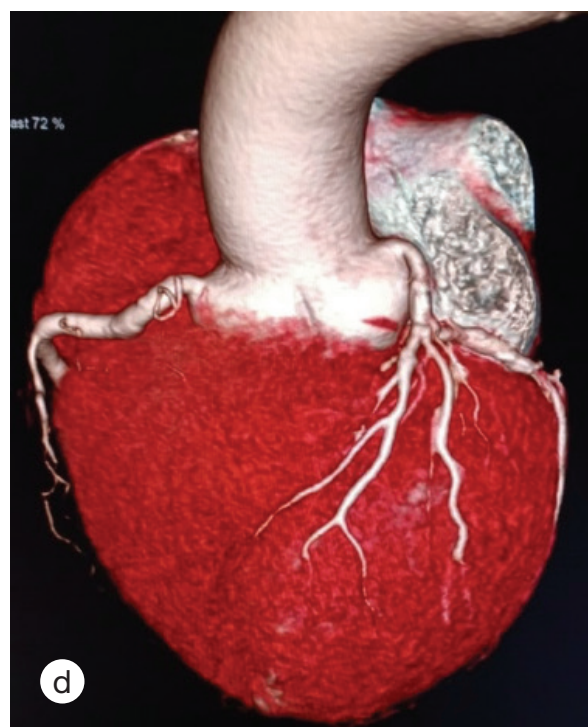
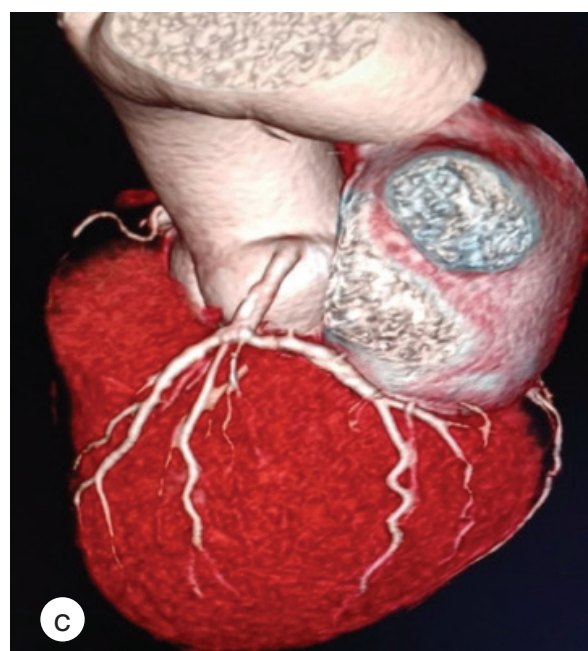
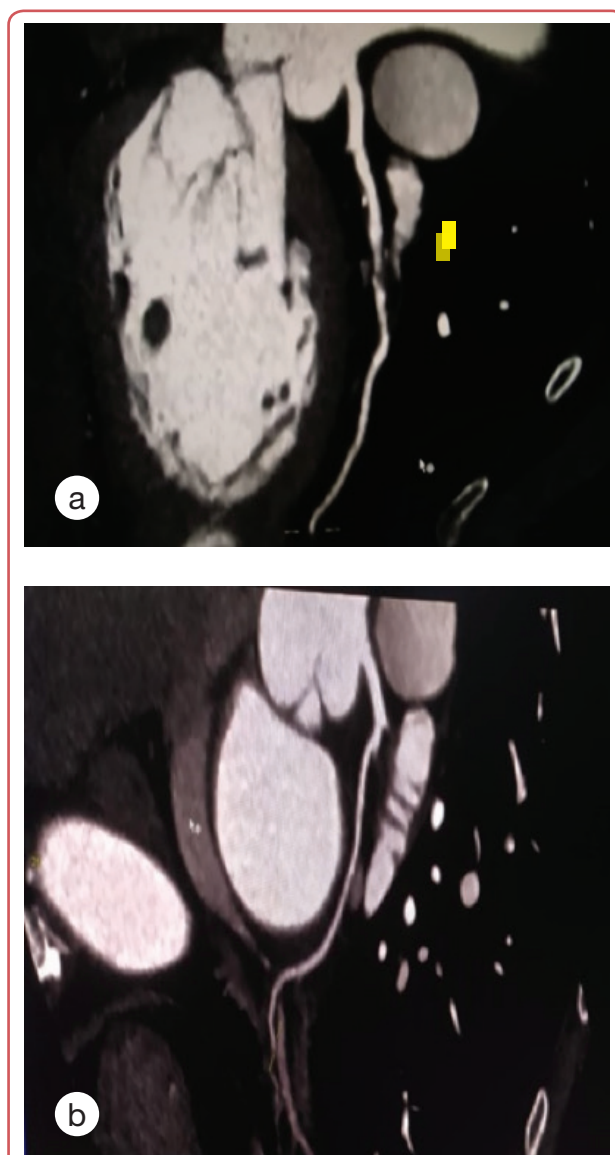


Figure 2: Reconstructed computed tomography - maximum intensity projection (CT-MIP) images (a, b, c, d) illustrating the coronary artery branches

to evaluate patient doses and radiation-related factors. Gender, age, tube potential (mA), tube current-time product settings (mAs), pitch, slice thickness and slice count were collected. All scanning parameters, the dose-length product (DLP) in mSv.cm and the CT dose index volume (CTDIvol) were recorded. Each variable affected

radiation dose differently. The AERB-authorized radiological safety officer had undertaken quality control tests on the hospitals and diagnostic centre's CT equipment and found that they met this research's standards. Ethics were based on ICRP and AERB guidelines (Figures 2-4).

The *ImPACT CT patient dosage calculator version 1.0.4*, which is a CT dosimetry program that is available for purchase was utilised. In order to compare and validate the dose values that were generated by the CT scanners to evaluate the accuracy of the dose levels generated by the machines.

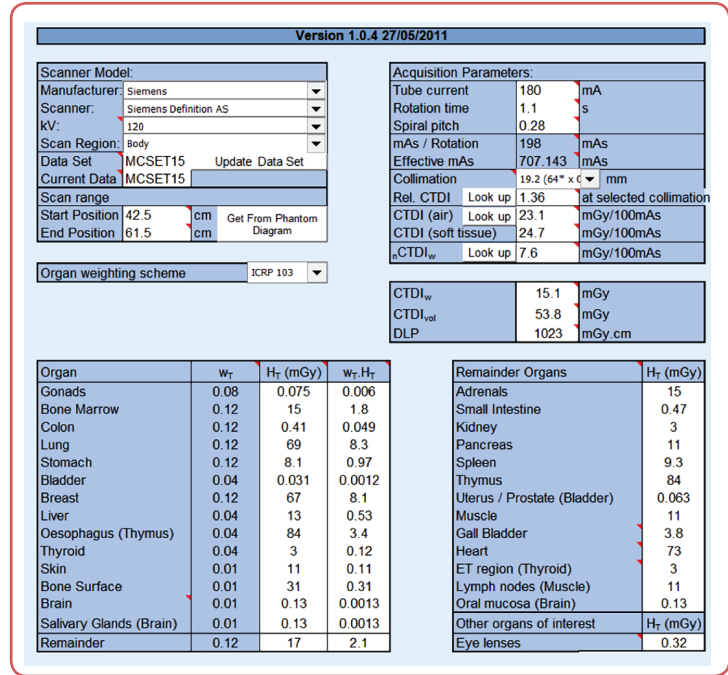


Figure 3: Calculation of effective dose (ED) using imPACT 1.0.4.

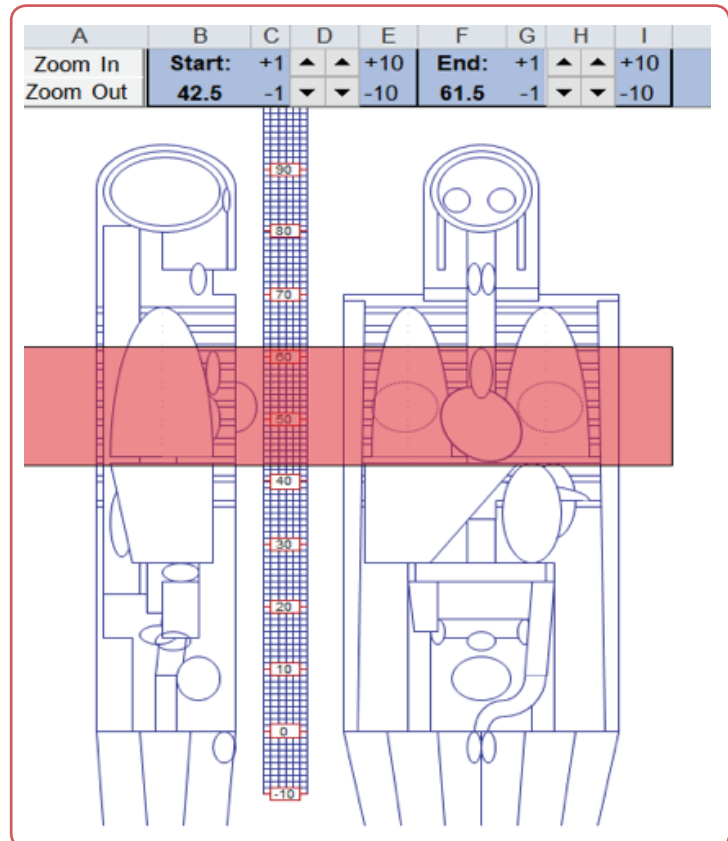


Figure 4: Using a mathematical phantom, effective dose (ED) was calculated. The cardiac scan is shown with a darkened zone between Z = 42.5 and 61.5.

The *imPACT* dose evaluator is a system that uses the SR250 Monte Carlo dataset provided by the National Radiological Protection Board in order to simulate exposure circumstances in mathematical phantoms of many well-known brands of CT scanners. These simulations were performed using the *imPACT* (Figures 2, 3).

Results

In two hospitals, 380 CT scans were measured for radiation exposures for this study. Hospital 1 utilised a *Siemens Definition AS* (128-slice) scanner, whereas Hospital 2 used a *Philips Ingenuity* (128-slice) scanner. The study evaluated DRLs for the two hospitals and gave the dosage measurements in terms of DLP and ED.

Table 1: Patients demographic data for both male and female population

Parameters	Height (m)	Body mass (kg)	Age (years)	BMI (kg/m ²)
Range (Max-Min)	1.65-1.57	78-62	75-29	24-19.68
Mean ± SD	1.60 ± 0.02	72.33 ± 4.03	54.67 ± 9.40	22.42 ± 1.05
Median	1.60	72	54	22.42

BMI: body mass index;

Table 1 shows patient demographic data and body mass index (BMI) for both male and female population. The BMI ranged from the minimum weight of 19.68 kg/m² to the maximum weight of 24 kg/m², mean BMI was 22.42 ± 1.05 kg/m².

The statistical analysis of the correlation between BMI and ED for CTCA showed a robust positive correlation between BMI and the radiation received during CTCA (Figure 5). The Pearson $r = 0.992$ suggested a highly significant linear correlation between BMI and ED, with increasing ED, BMI increases. With an R^2 value of 0.988, the variance accounted for around 98 % of the variance in ED in BMI. This suggests that BMI was a very good predictor of ED for CTCA and that other factors may had little impact on the ED beyond the influence of BMI.

The link between BMI and ED showed a distinct and substantial association between the two factors (Figure 5). Greater BMI levels were shown to correlate to greater EDs, indicating a linear link between the two. The fluctuation in BMI may

be used to account for 9.84 % of the variation in the ED, according to the R^2 value of 0.098. A linear connection between BMI (X) and ED (Y) was shown by the equation $Y = 1.034X - 0.3428$.

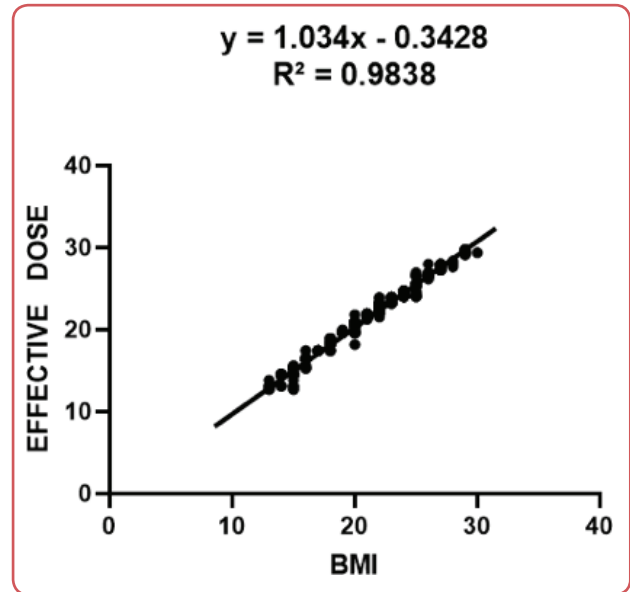


Figure 5: Pearsons correlation of body mass index (BMI) and effective dose (ED)

Table 2: Statistical analysis of effective dose (ED in mSv) for contrast coronary CT angiography related to patients gender

Gender	Dose (mSv)		
	Range (Max-Min)	Mean ± SD	Median
Male	27.99-13.10	21.29 ± 3.80	22.12
Female	29.74-12.73	21.85 ± 4.66	22.99
All patients	29.74-12.73	21.57 ± 4.27	22.12

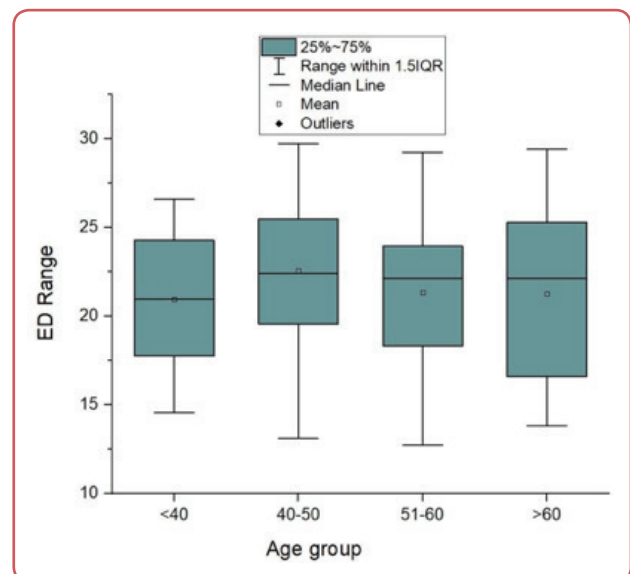


Figure 6: Effective dose (ED) related to age in the studied population

Values of ED related to gender is shown in Table 2. Mean ED were 21.29 ± 3.80 , 21.85 ± 4.66 and 21.57 ± 4.27 , for males, females and both sexes, respectively. Male patients received a slightly lower radiation dose than female patients during contrast CTCA, however, the difference was insignificant. ED related to age is shown in Figure 6.

Table 3: The diagnostic reference levels (DRL) for the studied population

Population	DRL (mSv.cm ²)
Male	24.26
Female	24.69
All	24.45

The correlation in DRL for CTCA cases across all cases is shown in Table 3. The DRL values were 24.26 mSv.cm² for males, 24.69 mSv.cm² for females and 24.45 mSv.cm² for all patients.

Discussion

The demographic profile of patients undergoing CTCA can provide important information that can aid in the diagnosis, treatment and prevention of cardiovascular diseases.¹⁶ Some important aspects of a patient's demographic profile relevant to CTCA include age, gender, race/ethnicity, medical history and lifestyle factors such as smoking, diet and exercise habits.¹⁷ The mean and median values being close to each other suggest that the distribution of BMI values is roughly symmetric. The relatively small standard deviation of 1.05 kg/m² indicates that the BMI values are tightly clustered around the mean. Overall, this information suggests that the population or sample from which the BMI values were obtained has a relatively narrow range of BMI values and is likely to be relatively homogeneous with respect to BMI. Numerous studies have focused on the relationship between BMI and ED for CTCA. A study discovered a positive correlation between BMI and ED for CTCA, with an average increase of 18 % in ED for every increment of 5 kg/m² in BMI.¹⁸ According to another study, the ED for CTCA rose by 13 % with each 5 kg/m² increase in BMI.¹⁹ They recommended that for patients undergoing CTCA, radiologists should be aware of the association between BMI and radiation exposure and take steps to minimise the radiation dose whenever possible, such as by using lower tube voltage and current settings, optimising scan parameters and using dose-reduction techniques.

Similar studies have demonstrated that a higher BMI is linked to an increased radiation dosage because adipose tissue absorbs less radiation due to its lower density than other tissues.^{20, 21} Another study found that higher BMI was associated with increased radiation exposure during medical imaging, particularly for CT scans. The authors noted that this could have important implications for cancer risk, given the known association between radiation exposure and cancer.²² The R² value of 0.098 suggested that only 9.8 % of the variability in ED can be explained by BMI. While this relationship is statistically significant, it is relatively weak and other factors such as age, sex and the specific imaging procedure being performed may also play a role in determining an ED.

ED is a measure of the amount of radiation energy that is absorbed by the body during a medical imaging test and it considers the type of radiation and the sensitivity of the different organs in the body to radiation. Male patients received a slightly lower radiation dose than female patients during contrast CTCA, which was also reported in other CT studies.¹³

The mean ED ranges for males and females were approximately 13 to 28 mSv and 12 to 29 mSv, respectively. This indicates that there is a wide variability in the amount of radiation exposure that patients receive during this type of imaging test. It is essential to minimise radiation exposure to patients during imaging tests, especially for those who may require multiple tests or who are more sensitive to radiation. This is where radiation dose reduction techniques become important. These techniques involve optimising the imaging parameters, such as the tube current, tube voltage and scan duration, to reduce the radiation exposure while still obtaining high-quality images for accurate diagnosis. It is crucial to note that the ED range shown is influenced by several factors, including patient size, the type of scanner used, the scan protocol and the operator's skill level. Therefore, it is essential to follow standard imaging protocols and to have well-trained operators to minimise the variability in radiation exposure between patients.^{23, 24}

It is important to regard age as a potential factor when optimising imaging protocols and reducing radiation doses in patients. It is generally understood that age may have a substantial impact on how much radiation is exposed during medical imaging exams.^{14, 15} Older patients may require

higher radiation doses to obtain images of sufficient quality due to factors such as increased body size, higher BMI and the presence of medical comorbidities. It is vital to note that radiation exposure from medical imaging tests, including contrast CTCA, can pose potential risks to patients, especially those who are more vulnerable, such as children and pregnant women.^{22,25} Therefore, it is crucial to use the as low as reasonably achievable (ALARA) principle to reduce radiation exposure in patients while preserving diagnostic image quality.^{26,27}

The use of the phantom to quantify CT dosage was the study's principal flaw. Since it considers both controllable (imaging technique, tube voltage, tube current) and uncontrollable (patient orientation, collimation and distance) factors, the use of the patients may have been preferable. Even though using phantom produces almost identical exposures, it only addresses elements under our control.²⁸

DRLs are recommended levels of radiation exposure for typical patients undergoing a specific type of imaging procedure.²⁹ They are meant to be a benchmark to optimise imaging protocols and reduce unnecessary radiation exposure while maintaining image quality.³⁰ It should be emphasised that these values do not represent absolute limits and certain patients may require higher doses for diagnostic purposes based on factors such as their age, body size and the specific medical condition being examined. Nevertheless, medical practitioners should carefully evaluate the potential risks and benefits of the imaging procedure and aim to use the lowest possible dose that will still provide the necessary diagnostic information. Individuals with a low pre-test probability of CAD, such as women with a narrow anteroposterior chest diameter, anxiety and mitral valve prolapse, who are commonly diagnosed with false positive exercise or echocardiology stress test, should not undergo CTCA. Another category for which CTCA could be avoided is represented by elderly males with increased cardiovascular disease burden and high pre-test probability of CAD. The latter should directly undergo coronary angiography especially if they are symptomatic.³¹

Conclusion

The current study findings pertaining to the population heterogeneity to DRLs level may be helpful for diagnosis purposes in this part of the country. Also, the reduction in the dose in exposure purpose by the present study may be taken into consideration in reduced exposure at the same time without compromising the images. It is advised that the current study contributes to the establishment of scanning parameters with regard to the patient's size and the body region of interest being scanned.

Ethics

Study was approved by the Assam Down Town University Ethical Committee, decision No AdtU/Ethics/PhD Scholar/2021/009, dated 24 September 2021.

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Conflicts of interest

The authors declare that there is no conflict of interest.

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Data access

The data that support the findings of this study are available from the corresponding author upon reasonable individual request.

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