EVALUATION OF DIRECT CHEST CIRCUMFERENCE MEASUREMENT AS AN EFFICIENT TOOL IN THE REDUCTION OF RADIATION DOSE IN MULTI-SLICE COMPUTERIZED TOMOGRAPHY OF CHEST- A SUGGESTION FOR RADIOGRAPHERS

Bharat Bhusan Sharma,[1] Nitish Virmane,[2] Navreet Boora,[3] Mir Rizwan Aziz,[1] Arshad Alam Khan,[4] Natasha Nargotra,[1] Rohit Sharma,[1] and Abhivind Bhutani[1]

[1]Department of Radiodiagnosis, SGT Medical College Budhera (Gurgaon), A 6/7, First Floor, Vasant Vihar, New Delhi – 110057, [2]Deptartment of Radio-diagnosis, Faculty of Allied Health Sciences SGT University Budhera (Gurugram) 122505, [3]College of Paramedical Sciences, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India, [4]Faculty of Allied Health Sciences, SGT University, Gurugram, Haryana, India

ABSTRACT

Non-contrast computerized tomography (NCCT) is in rampant use in daily practice for the diagnosis of various chest diseases. In the era of COVID-19 pandemic, the use of chest NCCT has increased many fold. The reason was because it will resolve many issues and quick diagnosis can be made. The same was also required to see the behavior of the disease as well as in the follow-up. Basically two parameter are in use to described the amount of radiation dose received by the patient in volumetric CT. These are, one is CT Dose Index (CTDIvol) & its unit is mGy, and the second is dose length product (DLP). With normal pitch factor i.e. 1, the CTDIw is use on the description of CTDIvol. Multiplication of scan length and CTDIvol parameter is known as Dose Length Product (DLP). There was much concern about the radiation dose received by the individual. A total of twenty-six individuals were studied. The measurement of direct chest circumference before each CT chest examination and correlation of CT chest protocol parameter in combination use was an effective tool to reduce the amount of radiation dose in patients. Chest circumference values can also be correlated with body mass index (BMI) values for more accuracy in the reduction of radiation dose. Lower chest circumference patients should be irradiated with the least amount of radiation dose and so on.

KEYWORDS

Non contrast computerized tomography, COVID-19, CT Dose Index, dose length product, body mass index

***Received on**: February 17, 2021*
***Accepted for publication**: May 28, 2021*

CORRESPONDING AUTHOR

Prof. Dr. Bharat Bhusan Sharma
Professor & HOD, Dept.of Radiodiagnosis
SGT Medical College Budhera (Gurgaon), A 6/7, First Floor, Vasant Vihar, New Delhi – 110057
Email: bbhushan986@gmail.com
Orcid No: https://orcid.org/0000-0002-1311-2349
DOI: https://doi.org/10.3126/nmcj.v23i2.38503

INTRODUCTION

In recent years, Non-Contrast Computed Tomography (NCCT) Chest has emerged as a fast, reliable, and non-invasive technique for the diagnosis of lung disease. Earlier CT Scanner equipment was meant to be a single slice acquisition technique, but advanced computed tomography (CT) equipments are able to acquire the large volume of data set in a few seconds with less radiation dose to patient. This technique is known as helical or volumetric CT. CT's fundamental principle is based on the density of tissue passed by the X-Ray beam and that can be calculate as the attenuation coefficient value. The principal of CT is the X-ray tube is rotate 360^0 around the patient and from a spiral or helical path around the patient, it also acquire images from multiple angles in axial plain, which can be further reconstructed in multiple planes like sagittal and coronal by applying recon techniques.[1] In a majority, two parameters are used to describe the amount of radiation dose received by the patient in volumetric CT. These are,one is CT Dose Index ($CTDI_{vol}$) and its unit is mGy, and the second is dose length product (DLP). With normal pitch factor i.e. 1, the $CTDI_w$ is use on the description of $CTDI_{vol}$. Multiplication of scan length and $CTDI_{vol}$ parameter is known as Dose Length Product (DLP). To measure the accurate amount of radiation dose or total exposure in each patient's, the $CTDI_{vol}$ and DLP is widely used, although the $CTDI_{vol}$ is known for the amount of radiation dose release from the X-Ray tube, in a specific volume (region of interest) and DLP is known as the amount of radiation dose as per total scan length.[2] American Association of Physicists in Medicine introduces the size-specific dose estimation (SSDEs) in 2011.[3] The term as low as reasonably achievable (ALARA) is suggested by each regulatory board worldwide. So, the radiographer must practice ALARA in all possible ways. In CT procedures, the amount of radiation dose mainly depends upon the values of the $CTDI_{vol}$. The $CTDI_{vol}$ is obtained through a 100-mm-long pencil-shaped ionization chamber in one or two different phantom sizes i.e. 16 cm or 32 cm. 16 cm phantom is use most commonly to measure the head/brain radiation dose and 32 cm is to measure the other body part's radiation doses.[4] Dose length product (DLP) is another descriptor to measure the amount of radiation dose in CT but with combination of $CTDI_{vol}$. $CTDI_{vol}$ gives a measurement of the amount of radiation dose per slice and DLP provides a measurement of total amount of radiation dose exposure for a series of slices.[4,5]

$$DLP = CTDI_{vol} \times \text{Scan length.}$$

In NCCT Chest the amount of radiation dose received by thoraxorgans such as chest skin, breast, heart, lungs, mediastinum, thymus gland, etc., is major concern in each patient. In recent decades, the use of CT scanner equipment is tremendously increased in medicine. Nowadays, CT scanner is considered as an eminent tool to diagnose lung lesions, through several different parameters and techniques like Single slice acquisition, multi-slice acquisition, high resolution CT, etc. As CT scanner uses increases, the physician/radiologist responsibility is to focus on the amount of patient'sabsorbed radiation dose should not increase. $CTDI_{vol}$ is used as the dose descriptor after the multiple scan average dose.[5-7] The area density and size of Chest circumference is different in each patient, therefore, the necessity of amount of the radiation dose for CT imaging is different for each patient. It has been hypothesized that in CT procedures the amount of absorbed radiation dose is affected by the circumference of the anatomy of interest. To decrease the amount of absorbed radiation dose, circumference of the scanning area must measure prior to the scan. Therefore, the aim of this study was to correlate the radiation dose variations with a chest circumference of the individual's in NCCT Chest.

MATERIALS AND METHODS

This study was conducted after the approval of institutional ethical committee; each patient was informed in their local language and informed written consent in dual (English and local) languages were taken before the examination. All scans were performed on Siemens Somatom Scope 16 Slice at Radiology Department. The parameters like exposure time per rotation (0.8s), kVp (130), data acquisition matrix (64 x 0.625mm), and pitch(1) were the same for all patients. Total 26 patients were referred for NCCT Chest for different clinical diagnostic needs. Out of 26 patients, 18 male (69.2%) and

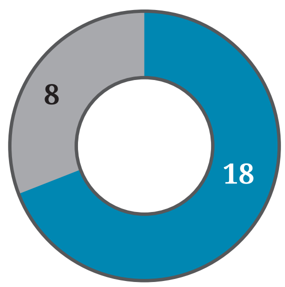

Fig. 1: Pie Chart showing the distribution of the scans as per the sex

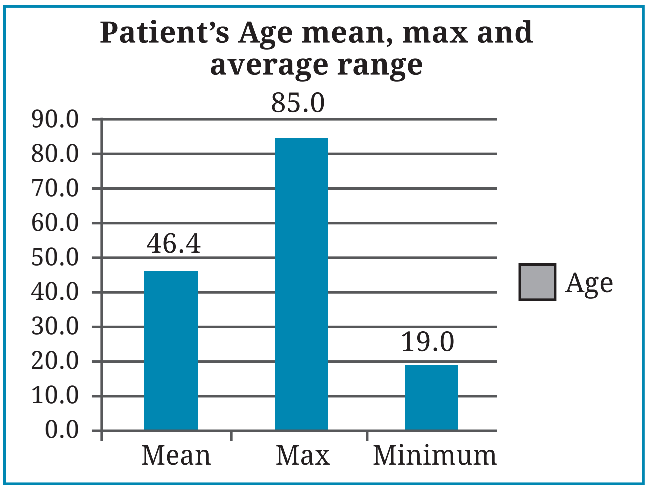

Fig. 2: Bar chart depicting the mean, minimum and maximum ages of the patients as per distribution.

8 female (30.8%) patients were added (Fig. 1). The minimum age was 19 years and maximum age was 85 years and the average age was 46.4 years (Fig. 2). The inclusion criteria for this study- NCCT Chest routine patient's technical/ protocol data, OPD and IPD cases. The exclusion criteria for this study- No dual studies in one patient like CECT & NCCT were added. No other patient's data set apart from the plain chest scan, No I.V contrast studies. Pregnant patients were not included in the study.

Measurement of chest circumference on NCCT Chest image: Measurement of chest circumference was done on a single-user DICOM software and the reference point for circumference measurement was intervertebral disc space (IVD) of the thoracic vertebra (TV) at the level of 4th and 5th. Right to left linear measurement was made on axial and reconstructed coronal section, from the starting point of the tissue from one end to another. At the same reference point (IVD of T4 and T5) the anterior to posterior measurement was made on reconstructed sagittal and axial images. The calculation of chest circumference was done through a conventional method by using a formula-

$$Chest\ Circumference = \sqrt{AP^2 + RL^2}$$

Where AP is Anterior to Posterior and RL is Right to left in centimeters and $\sqrt{}\sqrt{}$ is square root.

Estimation of effective radiation dose estimation: The parameters like mean mAs, $CTDI_{vol}$ and DLP were recorded by inbuilt software of Siemens CT equipment. Each parameter was automatically recorded and the same values took from there. The mean $CTDI_{vol}$

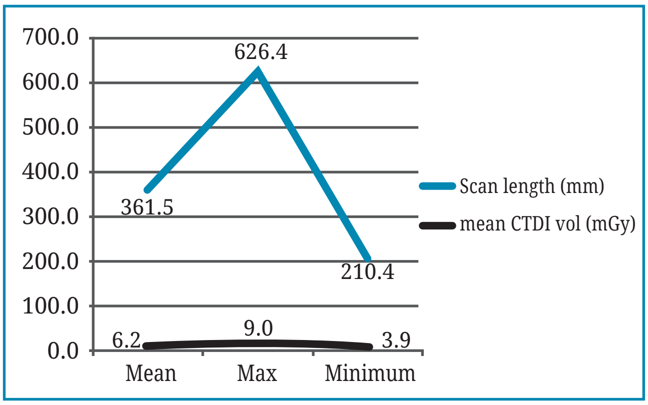

Fig. 3: Bar chart showing mean, max and minimum value of mean CTDI vol (mGy) per scan length (mm) distribution.

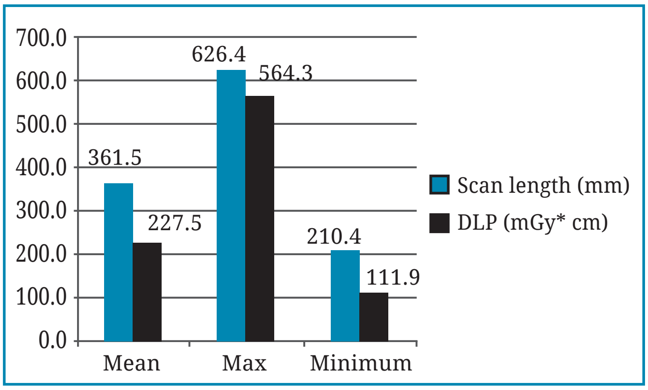

Fig. 4: Bar chart showing mean, max and minimum value of mean DLP per scan Length (mm) distribution.

(mGy) values; maximum 626.4, minimum 210.4 and the average 361.5 were found (Fig. 3) also the Dose Length Product (DLP) with corresponding to scan length the maximum 564.3, minimum 111.9, and an average of 227.5 (Fig. 4). In the correlation of chest circumference and $CTDI_{vol}$ (mGy), the chest circumference values are minimum 27.7, maximum 45.2 and average 37.5 and $CTDI_{vol}$ values are minimum 3.9, maximum of 9.0 and average 6.2 $CTDI_{vol}$(mGy) (Fig. 5).

Statistical analysis: In present data set on four variables i.e mean mAs, mean $CTDI_{vol,}$ DLP and Chest circumference, a Pearson correlation and a linear regression line statistical analysis was made on SPSS 21.0 version. Analysis was made in 5 different patterns-

1. Mean mAs values were correlated with mean $CTDI_{vol,}$ DLP and chest circumference values (Pearson correlation)

2. Mean $CTDI_{vol}$values were correlated with means mAs, DLP and chest circumference values (Pearson correlation)

3. DLP values were correlated with mean

mAs, mean $CTDI_{vol}$ and chest circumference values (Pearson correlation)

4. Chest Circumference values were correlated with mean mAs, mean $CTDI_{vol}$ and DLP values (Pearson correlation)
5. Chest Circumference and $CTDI_{vol}$ values were correlated through Pearson correlation and linear regression line.

RESULTS

In this study, a total of 26 patients were included, in which 69.2 % were male (n=18) and 30.8 % were female (n=8) patients. The radiation dose values $CTDI_{vol}$ and DLP were automatically calculated by CT equipment through inbuilt software and the values were taken without manipulation. The level of significance was set to $p<0.05$ for the results.

$CTDI_{vol}$ is 3.9 mCgy and 9.0 cGy respectively at minimum value of chest circumference (27.73 cm) at the maximum value of chest circumference (45.24 cm). $CTDI_{vol}$ is 6.2mCgy at the average value of chest circumference (37.49 cm)

The compression of mean, average and maximum values of chest circumference and $CTDI_{vol}$ were found to be non-uniform and the amount of radiation dose was on the higher side (Fig. 5). Pearson Correlation significant 2-tailed test was performed on all four variables and/ or numerical parameters of mean mAs, mean CTDI, DLP and chest circumference were

Table 1: Table showing Pearson Correlation in between mean mAs, mean CTDI, DLP and Chest Circumference.

Correlations		Mean mAs Value in each CT Chest	Mean CTDI (mGy) value of each CT Chest	DLP (mGY*cm)	Square root value of Chest Circumference
Mean mAs Value in each CT Chest	Pearson Correlation	1	.993**	.708**	.666**
	Sig. (2-tailed)		.000	.000	.000
	Sum of Squares and Cross-products	10381.846	621.212	33527.765	1526.670
	Covariance	415.274	24.848	1341.111	61.067
	N	26	26	26	26
Mean CTDI (mGy) value of each CT Chest	Pearson Correlation	.993**	1	.722**	.680**
	Sig. (2-tailed)	.000		.000	.000
	Sum of Squares and Cross-products	621.212	37.695	2060.268	93.979
	Covariance	24.848	1.508	82.411	3.759
	N	26	26	26	26
DLP (mGY*cm)	Pearson Correlation	.708**	.722**	1	.403*
	Sig. (2-tailed)	.000	.000		.041
	Sum of Squares and Cross-products	33527.765	2060.268	215970.898	4216.350
	Covariance	1341.111	82.411	8638.836	168.654
	N	26	26	26	26
Square root value of Chest Circumference	Pearson Correlation	.666**	.680**	.403*	1
	Sig. (2-tailed)	.000	.000	.041	
	Sum of Squares and Cross-products	1526.670	93.979	4216.350	506.357
	Covariance	61.067	3.759	168.654	20.254
	N	26	26	26	26

Table 2: Table showing Highly significant Pearson correlation in between Chest circumference and mean CTDI value

Correlations		Square root value of Chest Circumference	Mean CTDI (mGy) value of each CT Chest
Square root value of Chest Circumference	Pearson Correlation	1	.680**
	Sig. (2-tailed)		.000
	N	26	26
Mean CTDI (mGy) value of each CT Chest	Pearson Correlation	.680**	1
	Sig. (2-tailed)	.000	
	N	26	26

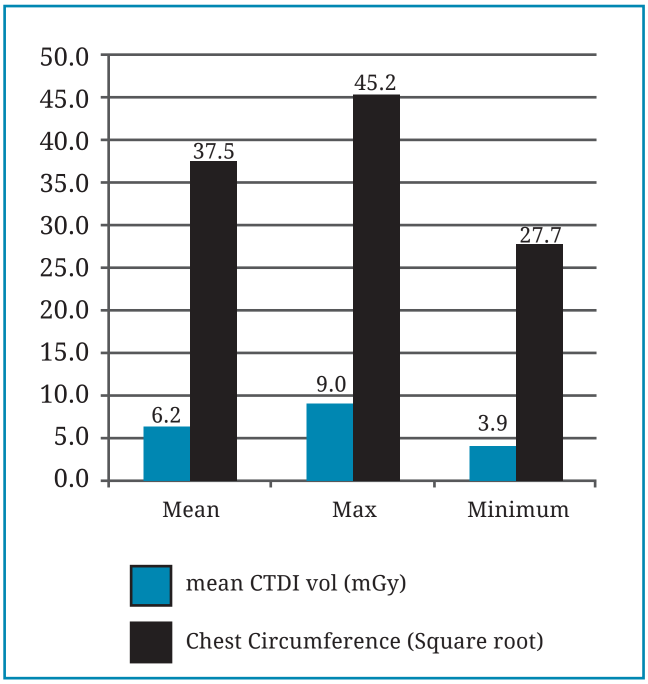

Fig. 5: Bar chart depicting mean, max and minimum value of mean CTDI vol (mGy) in correlation of chest circumference distribution.

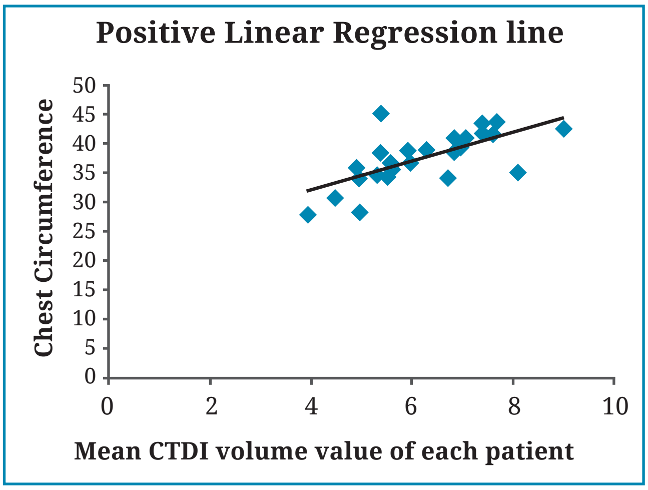

Fig. 6: Linear regression chart shows positive correlation in between chest circumference and mean CTDI values in each patient.

found to be normally distributed (Table 1 and 2). Each one of the four variables mean mAs, mean CTDI, DLP and chest circumference was found to be individually correlated with rest of the three variables. Correlations values are mean mAs with mean CTDI (0.993), DLP (0.708) and Chest Circumference (0.666) were found to be highly significant positive relationship. Mean CTDI with mean mAs (0.993), DLP (0.722), and chest circumference (0.680) had a highly significant positive relationship. DLP with mean mAs (0.708), mean CTDI (0.722) and chest circumference (0.403) had a highly significant positive relationship. Chest circumference with mean mAs (0.666), mean CTDI (0.680) and DLP (0.403) were also found highly significant. Pearson correlation between chest circumference and mean CTDI (mGy) was found to bepositive with a highly (p=0.680) significant relationship, and linear regression line showed that the variables were gradually affected by each other (Fig. 6).

DISCUSSION

Soon after the invention of CT Scanner equipment, the major concern was to decrease the amount of radiation dose and the radiation dose should be as low as reasonably achievable. To decrease the risk of absorbed radiation dose in each patient, the size-specific radiation dose estimation tool was found significantly effective in the studies done by Khawaja *et al* and Cheng *et al* study.[7,8] However, the amount of radiation dose correlation with BMI values and BMI values with iterative reconstruction method, also a successful method to reduce the amount of radiation dose by Boos *et al*[6] and Hosch *et al.*[12] But, in this study the chest circumference was found to be a more effective and easy method to reduce each patient's absorbed radiation dose. In NCCT Chest irradiation length of each body part is always on higher side, the applied CT protocol like mAs or mean mAs should be as low as reasonably achievable to decrease the harmful effects of radiation in patients. Waszczuk *et al*[9] study recommended size-specific estimation tool and this study recommends chest circumference measurement. In special procedures like coronary angiography and cardiac scans, the amount of radiation dose received by patients is always on the higher side. To reduce the amount of radiation dose in these procedures prospective / retrospective electrocardiogram (ECG) triggering and/or simulated electro-cardiographically controlled tube current modulation (ECTCM) are used.[10-12] Image quality in CT procedures is important. Good quality of image can be achieved through optimum amount of radiation dose to area of interest. The use of automatic exposure control (AEC) is not a reliable tool and neither does it completely free the radiographers' hands. A study on radio-photoluminescence glass dosimeters (RPLDs), inside or outside an anthropomorphic phantom correlation was done with International Commission on Radiological Protection (ICRP) recommendation values for CT procedures and those were not matched also found on the higher side. To reduce the radiation dose; awareness, knowledge and skill of radiographers is necessary.[13-15] The relationship between patient radiation dose and image quality in CT matters. Therefore, the chest circumference values are helpful to modify mAs values depending upon the are involved. This helps in to reduce the amount of absorbed radiation dose in easy and fruitful way.

The study concludes that no change was made in CT Chest protocol/parameter for different sizes of patients, and mean mAs, CTDIvol, and DLP values were found to have positive significant correlation in the data-set of patients. The measurement of direct chest circumference before each CT chest examination and correlation of CT chest protocol parameter in combination use was an effective tool to reduce the amount of radiation dose in patients. Chest circumference values can also be correlated with BMI values for more accuracy in the reduction of radiation dose. Lower chest circumference patients should be irradiated with the least amount of radiation dose and so on.

Suggestions:

1. This has been observed that radiographers do not bother to change CT protocol in different sizes of patients, they use the same pre-decided protocol in each patient like the same pediatric protocol for each pediatric age group (6 years to 14 years) patients and same adult protocol for adult age group (age more than 18 years). As a result, the amount of absorbed radiation dose in a patient was increased. This comes under the malpractice and must be avoided.

2. Apart from Body Mass Index, chest circumference must be considered as a tool to reduce the amount of absorbed radiation dose in patients because of the following reasons:

   A. In the minimum values of chest circumference 27.72 cm the $CTDI_{vol}$ values is 3.9 mGy, if this value assumed as an optimum radiation dose for 27.72 cm chest circumference, then approximately 21% increased absorbed radiation dose variation is found in average (mean) and maximum values of chest circumference.

   B. After simple mathematical calculation of Chest circumference and $CTDI_{vol}$ values, study recommends that approximately 8% amount of absorbed radiation dose can be reduced if Chest circumference values taken under consideration before each CT Chest examination.

ACKNOWLEDGEMENTS

We are thankful to Ms. Veenu, M Com, admission counselor and financial advisor, for the positive input in shaping this article.

Source of Fund: None

Conflict of Interest: None

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