RESEARCH PAPER

Dose Comparison of Obese and Non-Obese During CT Abdomen Scan

Geetanjali[1*], Ashita Jain[2], Arshad Alam Khan[3], Disha Sharma[4], Manas Kumar Maharana[5], Hitesh Sharma[6]

[1]Assistant Professor, Radio Imaging Technology, School of Medical and Allied Science, Sanskriti University, Mathura, Uttar Pradesh - 281401(India)*
[2]Assistant Professor, Radio-Imaging Technology, School of Allied Health Science, SGT University, Gurugram -122505 (India).
[3]Assistant Professor, Radio-Imaging Technology, School of Allied Health Science, SGT University, Gurugram -122505 (India).
[4]Assistant Professor, Radio Imaging Technology, School of Medical and Allied Science, Sanskriti University, Mathura, Uttar Pradesh - 281401(India)
[5]Lecturer, Dept. Of Medical Imaging Technology, Acharya institute of allied health sciences, Bengaluru, Karnataka-560107(India)
[6]Assistant Professor, Department of radiography and imaging technology, School of Health and Allied Sciences, Sanskaram University, Jhajjar, Haryana - 124108(India)

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ABSTRACT
Computed tomography (CT) of the abdomen is an essential diagnostic modality but contributes significantly to patient radiation exposure, particularly in obese individuals. This prospective comparative study evaluated the relationship between body mass index (BMI), cross-sectional diameters, and radiation dose parameters during CT abdomen examinations. Eighty patients aged 15–85 years underwent non-contrast CT abdomen scans using a 16-slice multidetector CT scanner. Patient age, height, weight, BMI, anteroposterior (AP) and lateral diameters were recorded, and radiation dose indices including CT dose index (CTDIvol) and dose length product (DLP) were analyzed. Results demonstrated a strong positive correlation between BMI and radiation dose, with obese patients receiving significantly higher CTDI and DLP values compared to non-obese patients. AP diameter showed a stronger association with radiation dose than lateral diameter. The study highlights that patient size, particularly BMI and AP diameter, is a key determinant of radiation exposure in CT abdomen scans. Incorporating these parameters into dose optimization strategies may help reduce radiation risk while maintaining diagnostic image quality.
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INTRODUCTION

Computed tomography (CT) is a widely used medical imaging tool that plays a crucial role in modern imaging technology. CT scans have advanced imaging techniques that help in providing detailed anatomical information with cross-sectional imaging of body parts. It plays an important role in the diagnosis of various clinical conditions, treatment planning, and guidance for therapeutic interventional procedures[1]. It uses multiple X-ray projections from different angles around the patient's body and produces axial images or slices of body parts. The CT scanner was first developed by physicist Allan Macleod Cormack and an engineer Sir Godfrey Newbold Hounsfield in 1971. Later in 1979 both of them were awarded with Nobel Prize for their invention [2]. The first CT scanner was designed only for brain imaging and is known as an EMI scanner [3]. CT images or 2D slices are formed by mathematical techniques whenever the tube completes its rotation around the patient. The main specialty of CT is that cross-sectional images can be reconstructed into sagittal or coronal images or even 3D images with the help of post-processing techniques [4].

Fig 1.1 CT SIEMENS SOMATOM SCOPE 16 SLICE

**Author for Correspondence: geetanjalilagwal@gmail.com*

It allows continuous volume acquisition providing good image quality and reduced motion artifacts. It can provide three-dimensional images with more detailing due to its ability of thin slice imaging [5]. The gantry width of the scanner is 70 cm with a 30-degree tube tilt and 24-row adaptive detector array.

The abdomen is the region present between the thoracic and pelvic regions. CT is preferred as a diagnostic imaging modality for abdomen imaging because of its fast acquisition, non-invasive procedure, and its good diagnostic accuracy. The indications for a CT abdomen scan are some clinical conditions like appendicitis, diverticulitis, stones, bowel obstruction, perforation, etc[6]. When the radiation passes during a CT abdomen scan, the dose that is absorbed by body organs contributes to the patient's absorbed dose. The absorbed dose can be calculated by dose parameters like CT dose index (CTDI) and dose length product (DLP). However, some additional factors like age, patient size, sex, the area being scanned, fat tissue thickness in areas of interest, imaging protocols, modality, etc. affect the radiation dose [7].

The use of CT scan has been rapidly increasing in clinical imaging for the past few decades due to its great diagnostic accuracy but due to the use of ionizing radiation, it can cause harmful effects on living tissue. It is a serious concern about patient safety and health due to rise in dose from CT examinations. Some studies show 49-68% dose contribution of CT scan among all other diagnostic radiologic examinations [8]. There is a probability of damaging cellular DNA, genetic mutations, or increased risk of cancer induction due to the absorption of ionizing radiation [9]. To reduce the chances of these risks and optimization of radiation dose there are some guidelines and diagnostic reference levels (DRLs) provided by ICRP in 1991. Several strategies for dose reductions and radiation protection are implemented to keep the dose levels of patients as low as reasonably achievable (ALARA). It is a principle of radiation protection that states that the dose should be possibly low when living tissue is exposed to ionizing radiation to acquire an image with good diagnostic value. The principle also emphasizes the need for evaluation of the risk versus benefit ratio of the scan to each patient[10].

The major factor that influences radiation dose is the patient size. Larger patients require high radiation exposure to acquire good imaging quality with good diagnostic accuracy. Obesity is also increasing at a concerning speed at the current time. It is noted that obese patients receive higher doses in comparison to routine dose levels due to more absorption or attenuation in anterior subcutaneous fat layers during a CT abdomen scan. Obesity categorization is based on BMI (body mass index). Body mass index calculates the amount of fat with the help of the patient's height and weight. BMI score then categorizes patients on the basis of comparison with standard score [11]. BMI score is calculated by dividing the square of patients' height by body weight [12]. Figure 1.2 shows BMI categorization. According to WHO overweight patients have a BMI score above or equal to 25 and a BMI score above 30 is considered obesity [13].

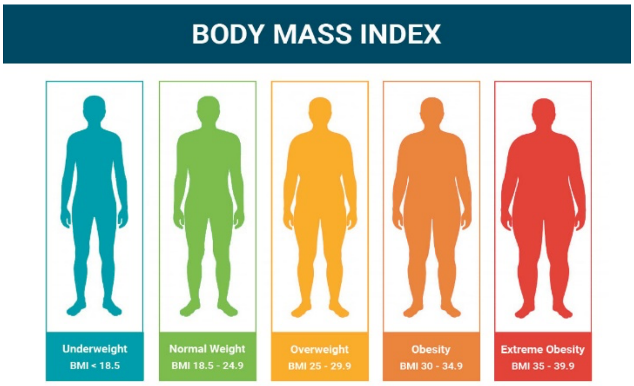


Fig 1.2: BMI categorization[14]

The relationship between patient size and radiation dose is very complex as it is affected by various factors including imaging protocols, imaging technique, and anatomy being scanned [15]. However, some studies show that the radiation dose received by larger-size patients is much higher which is a concerning issue [16]. The AP diameter is one of the measures for obese patients. It is the measurement from front to back on an axial image slice and varies widely among patients. Most obese patients have more AP diameter due to more subcutaneous fat layers in the abdominal region. It is also supposed to influence radiation dose as it affects the amount of scattering of X-rays passing through the patient's body during the scan [17].

To calculate the overall radiation dose received by the patient two major parameters are included i.e. CTDI and DLP. CTDI is a most common radiologic index used to calculate the radiation dose delivered to a given anatomical portion of the patient. CTDI is measured in mGy [18,19,20,21,22]. However, DLP is the dose delivered to the patient in any particular length of the scanning plane. The unit of DLP is mGy.cm. DLP is used with the conjugation of CTDIvol to calculate the overall radiation dose delivered to the patient during the **CT scan.**

DLP = CTDIvol × length of scan in cm [19].

Therefore, patient size is an important consideration during the calculation of radiation dose levels of CT scans. So, in addition to examining the relationship between obesity and radiation dose, the study will also investigate other potential factors that may influence radiation dose during a CT abdomen scan. These factors include patient age, BMI, and cross-sectional diameter.

The purpose of our study is to identify the relationship between increased body mass, age, and increased cross-sectional diameter with the radiation dose. The study aimed to provide valuable insights into the factors affecting radiation dose in CT abdomen scans and to better understand how to optimize radiation dose by altering exposure parameters to reduce the risk of radiation-related cancer while still ensuring better image quality.

METHODOLOGY

This was a prospective and comparative study, and was carried out for 2 years on CT SIEMENS SOMATOM scope 16 slices in the Department of Radio-Diagnosis of SGT Hospital and research institute according to the demand of thesis to conduct my study. In this study CT abdomen scans of patients with any abdominal indication for CT were performed. Patient parameters like height, weight, and age were collected along with the collection of cross-sectional diameters, CTDI, and DLP from scan images. Then calculated parameters were compared to find the relationship between them and compared with DRLs.

Patients who underwent CT scan were taken on the following basis

Inclusion Criteria:

CT abdomen patients of the 15-85 age group

Male & Female patients were included

Exclusion Criteria:

Post contrast scan

Pregnancy

Follow up or repeat patients

In this study 80 patients were included for CT abdomen scans. Informed and written consent was obtained from the patients or patient attender to participate in the study. The patient's height, weight, and age were noted before the scan for BMI calculations. CT examinations were performed using SEIMENS SOMATOM 16-slice MDCT scanner. It uses a curved array of detectors including approximately 700 detector elements with a wide fan beam of 40 - 60 º. Standard imaging protocols were used to perform the scan and an AEC software controlled the tube current according to patient size to acquire good image quality with low radiation dose levels. CTDI and DLP were collected from the dose report generated by the system itself. AP and Lateral diameters were measured from the cross-sectional images. CTDIvol and DLP were then compared with calculated BMI, AP, and Lateral diameters and were further analyzed based on age. The results were analysed with the help of STATISTICAL SOFTWARE according to the patient's size, and study design with the help of a statistician. A P value of less than .05 was used to indicate a statistically significant difference.

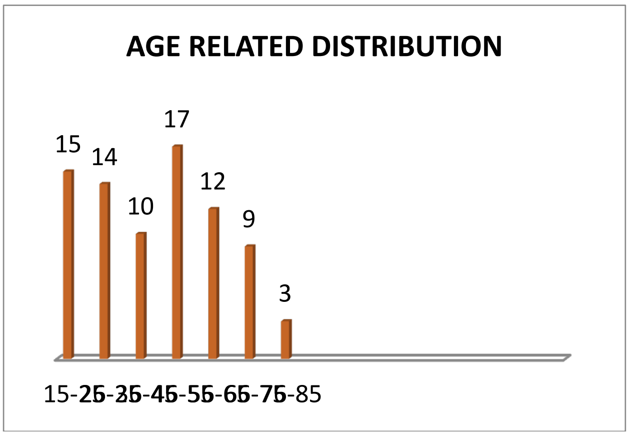
RESULT

In this study, 80 patients underwent for CT abdomen scan in the Department of Radio-Diagnosis and Imaging at SGT Hospital and Research Centre Gurugram, Haryana. The hospital is located in a rural area and the patients with symptoms of abdominal pain, abdominal sepsis, and bowel obstruction were referred and taken for study.

The age of patients studied ranges from 15 years to 85 years. The mean age among all the patients is 45. There are 15 cases noted in 15-25 years age of the patient (18.75%), 14 patients in 26-35 years age group (17.5%), 10 patients in 36-45 years age group (12.5%), 17 patients in 46-55 years age group (21.25%), 12 patients in 56-65 years age group (15%), 9 patients in 66-75 years age group (11.25%), 3 patients in 76-85 years age group (3.75%), Most of the patients noted in the 46-55 age group (21.25%) as shown in **Table 1**

Table 1 Age distribution of the studied population

Age Group	Frequency (n)	Percentage
15-25	15	18.75%
26-35	14	17.5%
36-45	10	12.5%
46-55	17	21.25%
56-65	12	15%
66-75	9	11.25%
76-85	3	3.75%

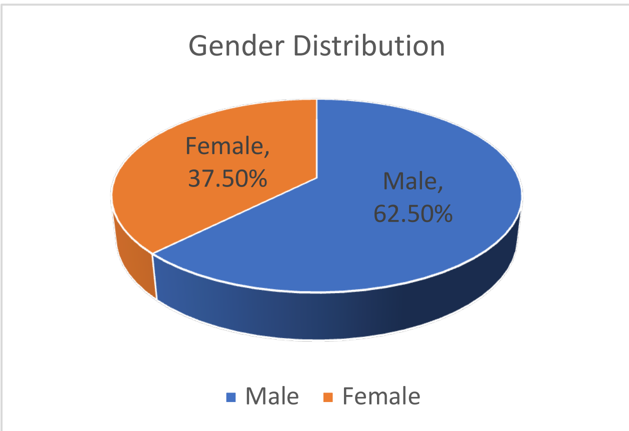


Graph 1 Age distribution

The bar graph shows the distribution of patients based on age group. More no. of patients belong to the 46-55 age group (21.25%) and the minimum no. of patients belongs to the 76-85 age group (3.75%).

Table 2: Distribution of Gender

Gender	Frequency (n)	Percentage
Male	50	62.5%
Female	30	37.5%
Total	80	100%

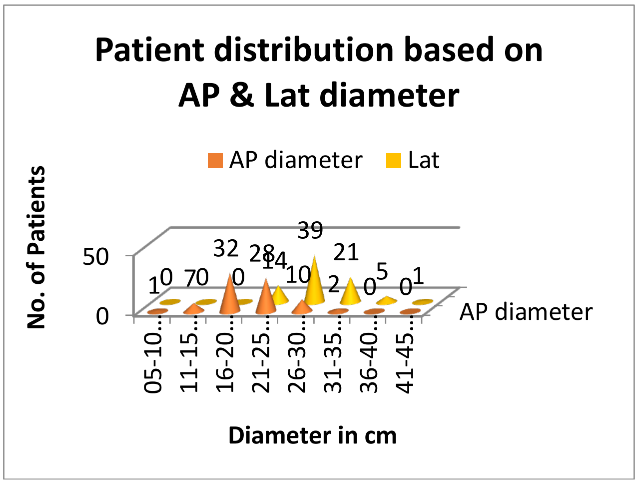


Graph 2 Pie chart showing gender-based distribution

Pie chart showing the distribution of patients based on gender in Graph 2 where most of the population is male (62.5%) and the rest are females (37.5%).

Table 3 Distribution of patients according to AP diameter

Diameter range	Frequency (AP)	Frequency (Lat)
5-10 cm	1	0
10-15 cm	7	0
16-20 cm	32	0
21-25 cm	28	14
26-30 cm	10	39
31-35 cm	2	21
36-40 cm	0	5
41-45 cm	0	1



Graph 3 Distribution of patients according to AP & Lat diameter

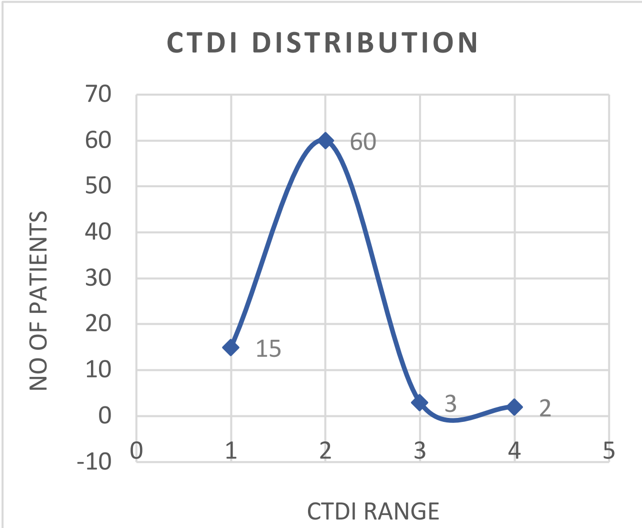
The distribution of patients according to the measurement of AP diameter. The mean AP diameter is 21cm and mean Lat diameter is 29cm. The maximum no. of patients i.e. 32 had AP diameter in the range of 16-20 cm and the minimum no. of patients i.e. 1 had AP diameter in the range of 5-10 cm. However, maximum no. of patients i.e. 39 had Lat diameter in the range of 26-30 cm and the minimum no. of patients i.e. 1 had Lat diameter in the range of 41-45 cm as shown in Table 5.3. The minimum AP diameter noted was 8.34cm and the lateral diameter noted was 23.77cm. The maximum AP diameter noted was 34.23cm and the lateral diameter noted was 43.86cm.

The distribution of patients according to the CTDI. The mean CTDI noted is 7.7 mGy. The minimum CTDI noted was 4.84 mGy and the maximum CTDI noted was 16.78 mGy as shown in table 4.

Table 4 Patients distribution according to CTDI

CTDI	Frequency
1-5	15
6-10	60
11-15	3
16-20	2

Maximum no. of patients i.e. 60 had CTDI in the range of 6-10 mGy and minimum no. of patients i.e. 2 in the range of 16-20 mGy.



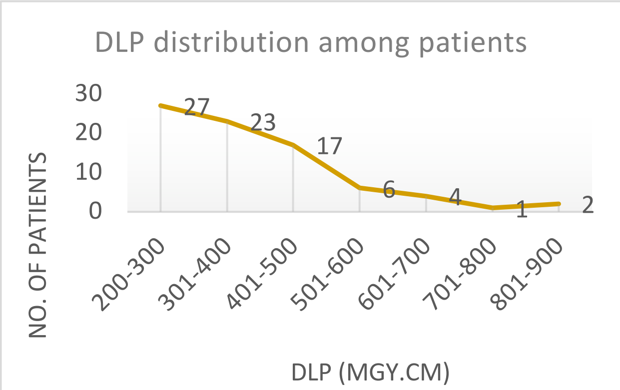
Graph 4 Distribution of patients according to CTDI

The distribution of patients according to DLP shows that the mean DLP is 392mGy.cm, maximum no. of patients who had DLP in the range of 200-300 mGy.cm are 27 and the minimum no. of patients in the range of 701-800 mGy.cm are 1 as shown in Table 5

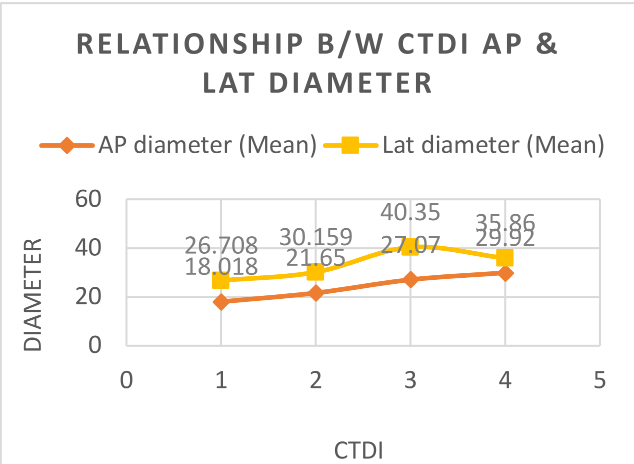
Table 5 DLP distribution among patients

DLP (mGy.cm)	Frequency
200-300	27
301-400	23
401-500	17
501-600	6
601-700	4
701-800	1
801-900	2

The distribution of patients according to DLP shows that the minimum DLP noted was 205.66 mGy.cm and the maximum DLP noted was 846.86 mGy.cm.

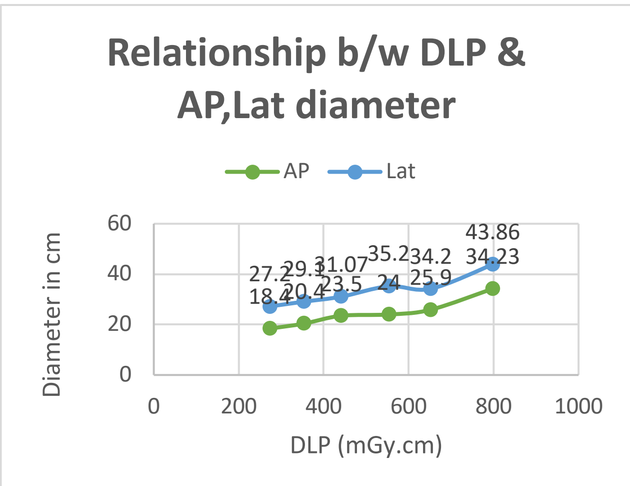


Graph 5 Distribution of patients according to DLP



Graph 6 Distribution of CTDI with AP and LAT diameter

The graph shows the positive correlation between CTDI and cross-sectional diameter (AP & Lat). As there is an increase in cross-sectional diameter the increment in CTDI is also seen. AP diameter is more in positive correlation with CTDI as compared to Lat diameter as there is a small decline seen in Lat diameter after some point as CTDI increases.

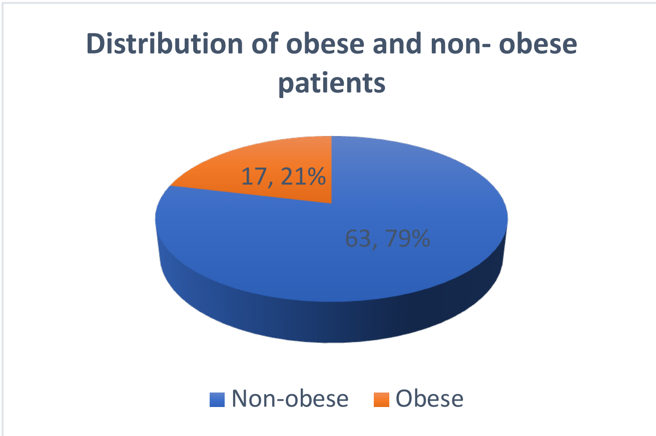


Graph 7 Distribution of DLP with AP, Lat diameter

The Graph shows the positive correlation between AP, Lat diameter, and DLP. There is a constant increase in DLP as AP diameter increases but in the case of Lat diameter as the DLP increases the rise in Lat diameter is inconsistent or uncertain.

Table 6 BMI distribution of patients

BMI	No. of patients	Percentage	Category
15-20	4	5%	Underweight
21-25	34	42.5%	Normal
26-30	25	31.25%	Overweight
31-35	15	18.75%	Obese
36-40	2	2.5%	Extreme obese

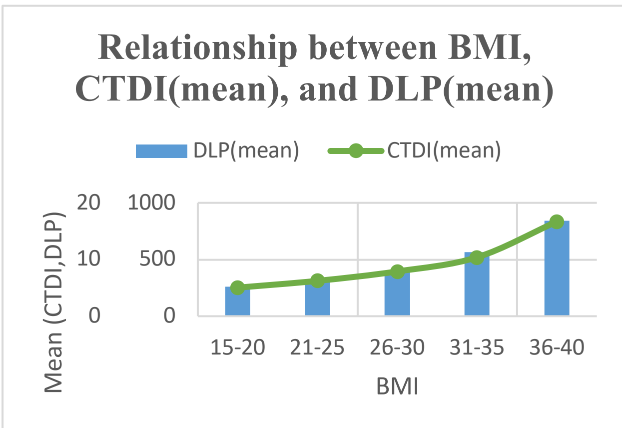


Graph 8 Patient distribution based on BMI

Pie chart showing the distribution of patients based on BMI values in graph 5.8 where the majority population is non-obese (79%) and the rest is obese (21%).

Table 7 Relationship between BMI, CTDI, and DLP

BMI	CTDI (mean)	DLP (mean)
15-20	5.04	263
21-25	6.24	299
26-30	7.9	402
31-35	10.4	563
36-40	16.7	841



Graph 9 Distribution of BMI based on CTDI and DLP

Graph 5.9 showing a strong and positive relationship between BMI and mean values of CTDI and DLP. There is a persistent increase in CTDI and DLP values as BMI increases which means there is an increase in radiation dose to patients as their BMI increases.

DISCUSSION

This prospective study evaluates the relationship among BMI, AP, and lateral diameters with the radiation doses CTDI and DLP received by the patient during a CT abdomen scan. As the role of CT scanners is increasing currently, the main concern is to limit the radiation dose to patients. To minimize the risk of cancer and mutation from ionizing radiation exposure, the dose delivered during a CT scan should be as low as is practicable. However, the reduction in CT dose is limited to some extent to acquire a good-quality image. DICOM-SR and Monte Carlo simulation are proven as fast, accurate, and reliable tools for radiation dose estimation of CT scans in studies conducted by J. Boos et al. and Adam C. Turner et al. Another study shows patients with more body weight receive more radiation dose so BMI should be considered as a parameter during radiation dose calculation as proved in a study by Victoria O. Chan et al. This study also results in a strong relationship between BMI and radiation dose parameters as shown in Graph 9, increase in CTDI and DLP values as BMI increases. In this study, it is found that the cross-sectional diameter of the patient is the more effective parameter to calculate the radiation dose as it is helpful in dose reduction techniques. The study shows that the AP diameter of the patient has a strong positive relationship with CTDI and DLP values as shown in Graphs 6 and 7 respectively. It shows that whenever there is an increase in the AP diameter of the patient there is an overall increase in the radiation dose received by the patient. As discussed by Morsbach, Fabian, et al. the integrated circuit, or AEC in abdominal CT is helpful in noise reduction, improving image quality but Sebastian T. Schindera shows in their study that there is an increase in dose to overweight patients due to the use of tube current modulation during the scan and suggested that the noise index needs to be adjusted according to body anatomy including patient weight. The study performed by Israel, Gary M., et al. shows that the dose delivered to overweight patients is doubled when weight is increased by 40 kg. It is suggested that the use of modified CT protocols can help in acquiring good image quality while reducing patient radiation dose. In our study, it is seen that AP diameter is in positive correlation with dose parameters but Lat diameter is not a stronger predictor of radiation dose during CT dose calculation. There is a small decline in Lat diameter is seen as there is an increase in dose parameters as shown in Graph 6 The study shows that body weight and transverse diameter did not strongly affect the CTDI and DLP values which raises the concern about their application in radiation dose reduction modification of dose reference levels. Some studies suggested different techniques regarding dose reduction of obese patients during CT scans including CARE KV software, iterative reconstruction methods, variable tube current (mAs), hybrid reconstruction technique with filtered back projection, and thinnest layer of fat towards image receptor [27,28,30,39]. It is suggested to consider AP diameter and BMI as important parameters during the use of any dose reduction technique as it is strongly correlated with the radiation dose of the patient. Whenever there is an increase in the cross-sectional diameter of the patient the dose parameters also increase. As Patrick D. McLaughlin et al. discussed adipose tissue is the strongest predictor of radiation exposure and it suggested that it should be considered in future dose estimations [29]. The adipose tissue is obtained by measuring thickness from the internal abdominal layer to the outer skin layer on the axial section of the scan. However adipose tissue will be automatically included during the AP diameter measurements. Thus, AP diameter is the strongest predictor of radiation dose to reduce the dose during CT scan.

The cross-sectional diameter can be measured before the examination with the help of measuring tapes or during the scan when the patient lies on the table, by calculating the patient's height from the back of the patient (touches the table) to the top of the patient. Another method can be a post-processing tool for measurements on axial section images.

CONCLUSION

Our study has shown that obese patients receive more radiation doses as compared to non-obese patients. Both AP diameter and BMI show a positive correlation with CTDI and DLP. As the patient's BMI and AP diameter increase, there is a constant increase in CTDI and DLP. It can be concluded that including body weight, BMI, and, patient size there should be the use of AP diameter in dose reduction techniques and the establishment of new DRLs for CT abdomen scans. However, further investigation regarding this conclusion to properly prove the sole contribution of AP diameter for DRL establishments

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