Dosimetric Verification of Computed Tomography (CT) Systems Using CTDI Phantom

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ABSTRACT

Background: Computed tomography (CT) is a medical imaging modality that contributes widely over the world for the diagnosis of disease and for treatment planning in the radiotherapy department. The purpose of the study is to measure the accuracy of dose of CT System for quality treatment.

Materials and Methods: The study was executed in a 16 slice SOMATOM Emotion CT Scanner of Delta Hospital Ltd. with Tube voltage 130 KV and Tube current 25 mA using Computed Tomography Dose Index (CTDI) phantom (CIRS) of MPD, Atomic Energy Centre, Dhaka. IBA pencil ionization chamber was used to measure the dose at different positions inside the CTDI phantom and data were collected using IBA MagicMax Universal software. The CT radiation doses were estimated using formalisms in the AAPM Report 96 and 111.

Results: For the Adult Body Phantom Console displayed dose was 16.03 mGy and estimated dose was found as16.40 mGy. For the Adult Head Phantom, console displayed dose was 32.40 mGy and estimated dose was found as 34.60 mGy. Between the estimated and console displayed doses for Adult Body Phantom and Adult Head Phantom a deviation was realized of 2.3% and 6.8% respectively.

Conclusion: Hence CTDI of the above mentioned machine comply with reference value within a tolerance of ± 20 % according to Food and Drug Administration (FDA).

Keywords: Computed Tomography Dose Index (CTDI), MagicMax Universal, FDA

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INTRODUCTION

Bangladesh is an overpopulated country, and people are suffering a lot from different types of diseases. Hence, the use of Computed tomography (CT) for diagnostic purposes is increasing with time. Dose delivered from CT machine is 50 to 500 times higher than X-ray or mammography. In Radiotherapy, it is used as an important imaging tool for the planning of treatment (1, 2). The CT machine's large dose poses a significant cancer risk to patients and the general population due to its small yet significant impact.

CT radiation dose is measured using a parameter called volume CT dose index (CTDIvol). It is used to compare different scan techniques on a single scanner or between scanners. The CT console gives CTDI vol for different settings of the machine according to manufacture. The purpose of this study is to determine the dosimetric verification of the CT scanner by comparing the CTDIvol of the CT machine obtained from the CTDI phantom with the console value.

MATERIALS AND METHODS

The experimental works shown in Figure 1 were done by 16 slice SOMATOM Emotion CT Scanner of Delta Hospital Ltd. The CTDI were measured by 3-part PMMA CTDI phantom with Tube voltage 130 KV and Tube current 25 mA. 3-part PMMA CT-Phantom were (1) Adult Body Phantom (Diameter 32 cm with 4 holes) (2) Adult Head / Paediatric Body Phantom (Diameter 16 cm with 4 holes) and (3) Paediatric Head Phantom (Diameter 10 cm with 5 holes). A DCT10-MM Ionization chambers was used to measure the CTDI value at different positions inside the CTDI phantom and data were collected using IBA Magic Max Universal software.

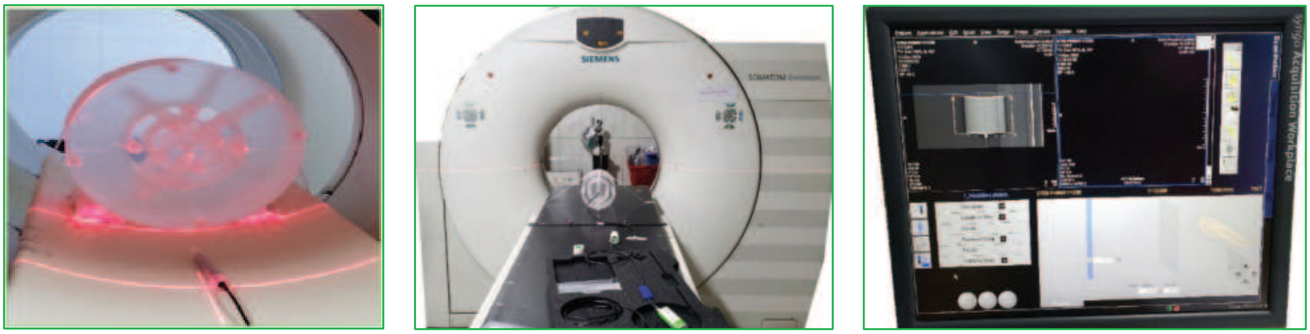

Figure 1: Experimental Set up for measuring CTDI100

At first, Adult Body Phantom (32 cm) was placed on the table, fixed into the tomographic plane and aligned properly using CT laser lights. 100mm pencil ionization chamber was placed into the centre hole of the phantom whereas all other holes were filled by PMMA plugs. The temperature and pressure of the experiment environment was recorded as 20.90C and 1015.5 kPa respectively and was given as an input to the MagicMax software on the computer. Proper scan protocol was selected from the CT console and the values of CTDI100 were recorded.

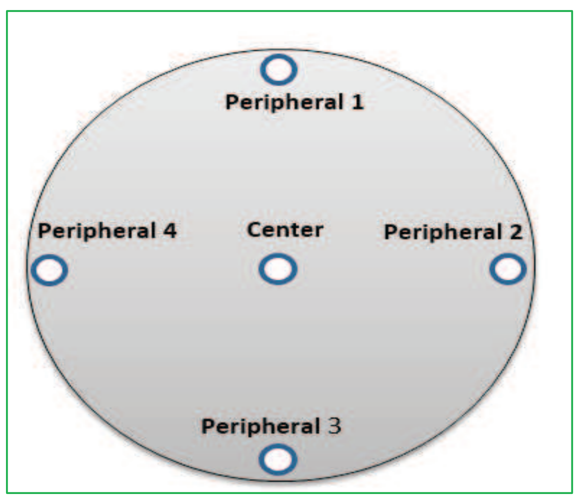

Figure 2: Location of Holes in the CTDI Phantom

Figure 2 shows the position of holes inside the phantom. Pencil ionization chamber was repositioned in the P1, P2, P3 and P4 position in the phantom and the steps were repeated. Same process is done for the Adult Head Phantom.

CTDI100 in the above equation describes the measurement of the dose distribution, D(z), along the z-axis. The CTDI100 is defined as, (3)

$$\boldsymbol{CTDI} = \frac{1}{nT}\int_{50mm}^{50mm} \boldsymbol{Dzdz}$$

The weighted CTDI is defines as (3)

$$\boldsymbol{CTDI} = \frac{1}{3}\boldsymbol{CTDI}_{100,\ central} + \frac{2}{3}\ \boldsymbol{CTDI}_{100\ periphery} \ \text{..........................} \ \text{(ii)}$$

The Computed Tomography Dose Index Volume $CTDIv_{ol}$ is defined as (3)

$$\boldsymbol{CTDI}_{vol} = \frac{\boldsymbol{CTDI}\ w}{\boldsymbol{Pitch}} \ \text{...........................} \ \text{(iii)}$$

Where,

n=Number of slices in a single axial scan

T=Width of one slice (mm)

Pitch = Ratio of the table feed per table gantry rotation divided by the beam width

RESULT

The CTDI100 at the center and periphery of the CTDI phantom are represented in Table 1.

Table 1: Measurement of CTDI100 Test results for Adult Body and Adult Head Phantom.

S/N	Hole Position	Adult Body Phantom $CTDI_{100}$ (cGy)	Adult Head Phantom $CTDI_{100}$ (cGy)
1	Central (C)	0.99	3.22
2	Peripheral 1 (P1)	1.73	3.34
3	Peripheral 2 (P2)	1.7	3.86
4	Peripheral 3 (P3)	2.03	3.32
5	Peripheral 4 (P4)	2.4	2.82

The Central to Peripheral Dose Ratio for Adult Body and Adult Body Phantom was found to be 1:2 and 1:1 respectively (Figure 3 and 4). Meanwhile, Figure 5 and 6 show the value of CTDI100 in cGy of different position of the two phantoms.

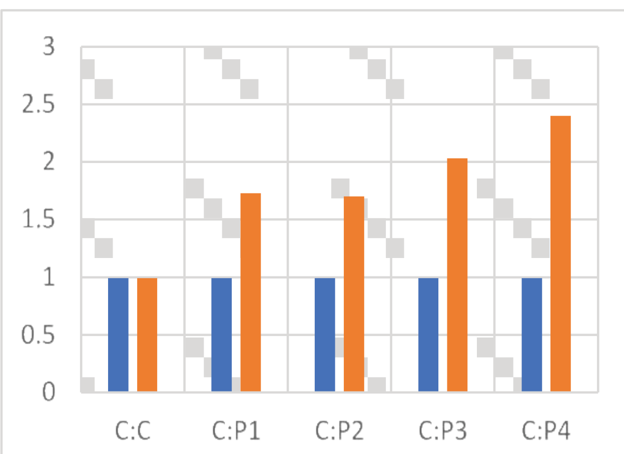

Figure 3: Central to Peripheral Dose Ratio for Adult Body Phantom (1:2)

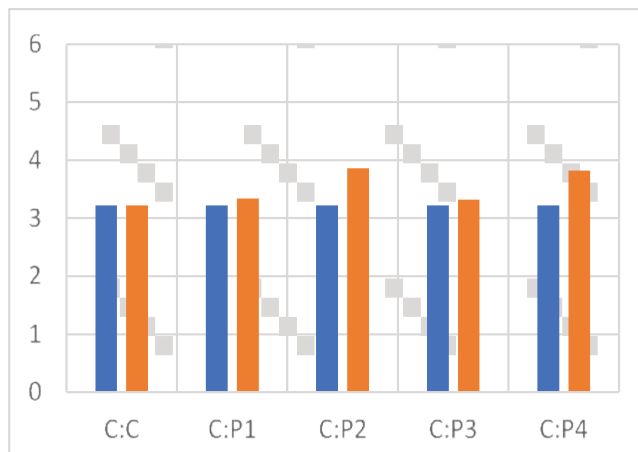

Figure 4: Central to Peripheral Dose Ratio for Adult Body Phantom (1:1)

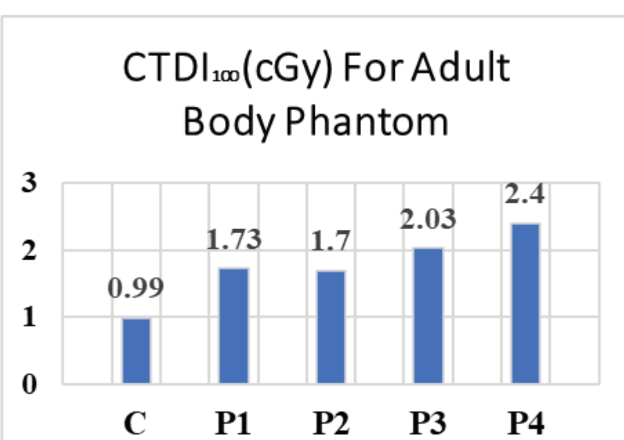

Figure 5: $CTDI_{100}$ for Adult Body Phantom.

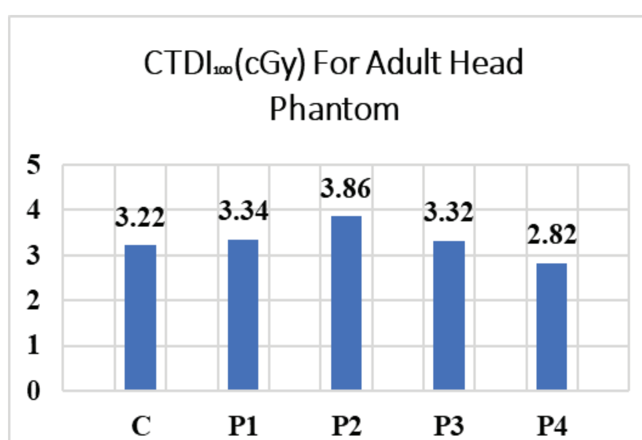

Figure 6: $CTDI_{100}$ for Adult Body Phantom.

Combining the central and peripheral measurements using a 1/3 and 2/3 weighting scheme provides a good estimate of the average dose to the phantom (at the central CT slice along z), using equation (2) giving rise to the weighted CTDI. The pitch was found as 0.1 from the CT scanner. Then by using equation (3) we found the CTDIvol represented in table 2. CT console Volume was obtained from CT scanner. The CTDIvol obtained from CT scanner for Adult Body Phantom and Adult Head Phantom were 16.03 mGy and 32.40 mGy.

Table 2: Measurement of $CTDI_{vol}$ using CTDI phantom

Phantom	CTDIw	Pitch	Practical CTDIvol (mGy)
Adult Body Phantom	1.64	0.1	16.40
Adult Head Phantom	3.46	0.1	34.60

DISCUSSION

A study by Francis Hasford, B. V., in 2015 for the determination of dose delivery accuracy in CT examinations represents an average dose within a scan volume for a standardized CTDI phantom. The dose index (CTDIvol) for head and body PMMA phantoms has been estimated in this study, and comparisons have been made with the corresponding console-displayed doses. The body (pelvic) scan technique of 120 kV and 100 mAs produced a dose estimate of 20.08 mGy in the body phantom, deviating by 3.05% from the console-displayed dose (4). Another study by John A. Bauhs in 2008 in CT Dosimetry stated that both CTDI and point dose measurement are valuable for evaluating CT scanner output and estimating patient dose (5). A study by Tadelech Sisay in 2022 for measuring CT scanner quality control using a quality assurance phantom and a PMMA phantom. The radiation dose performance parameters that were evaluated were volume computed tomography dose index (CTDIvol) and dose length product (DLP). The results of that study were all image quality and CT dose index parameters tested within the acceptable standard limits (6).

The CT radiation doses of the present study were estimated using formalisms in the AAPM Report 96 and 111 (7, 8). For the Adult Body Phantom Console displayed dose was 16.03 mGy and estimated dose was found as 16.40 mGy. A deviation of 2.3% was realized between the estimated and console displayed doses. For the Adult Head Phantom Console displayed dose was 32.40 mGy and estimated dose was found as 34.60 mGy. A deviation of 6.8% was realized. According to FDA, CTDI must comply with the reference value within a tolerance of ± 20 %. By using the CTDIvol, Dose Length Product (DLP) can be determined by multiplying the CTDIvol with the scan length. Finally effective dose can be measure by using the normalized effective dose coefficient (k).

Table 3: Comparison of the present CTDIvol result with those published in the literature.

References	Adult Body Phantom	Adult Head Phantom
Present Study	16 mGy	34 mGy
Hasford et al. (2015)	20 mGy	44 mGy
Bongert et al. (2004)	15 mGy	60 mGy

Table 3 shows the Comparison of estimated CTDI vol (mGy) that was found in this study and published literature. This study shows similarities with those authors and within International Diagnostic Reference Level.

CONCLUSION

The CTDI100 was measured by the pencil ionization chamber and analyzed using the MagicMax Universal software at different locations of the CTDI phantom. CTDIvol of the above mentioned machine comply with reference value within a tolerance of ± 20 % according to Food and Drug Administration (FDA). As CT machine produces a large amount of dose, dosimetrist verification of CT machine of every institute is required to deliver accurate dose.

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