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Comparison of Central, Peripheral and Weighted Size Specific Dose in CT to Dose Results from IndoseCT Software

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ABSTRACT

The purpose of this study was to calculate the average dose of a phantom with a diameter of 16 and 32 cm, as well as the dose distribution in the center and periphery. The results were then compared to those from the IndoseCT software. In this study, a standard PMMA phantom with a diameter variation of 16 and 32 cm was used. The phantom was scanned using fixed parameters, namely 120 kVp voltage, 100 mAs time current, 10 mm collimation width, 100 mm scan length, and 1 s tube rotation. This research was conducted at the Indriati Solo Baru Hospital using the GE CT scanner type Revolution EVO 64/128 slice. The results of this study show that for a 16 cm phantom diameter at the center position the difference in detector measurements with IndoseCT is 1.34% at the phantom edge position is 4.38% and the weighted dose is 2.59 %, while for a 32 cm phantom diameter, the difference is 8.1 percent, at the edge of the phantom it is 1.26 %, and the weighted dose is 0.62 %. Based on the results obtained from IndoseCT, it showed an insignificant difference with the measurement of radiation dose using a phantom. Overall, the difference in percentage is ±10% while the difference in percentage that is still acceptable is ±20%.

Keywords: Pencil ion chamber, PMMA phantom, dose distribution, size-specific dose estimate (SSDE), central dose, peripheral dose, weighted dose, IndoseCT 20.b.

INTRODUCTION

The internal organs of the human body are examined using x-rays by the diagnostic assistance tool known as a computed tomography (CT) scan [1,2]. CT scans are widely used in clinical examinations because they have high radiographic contrast so that the available contrast from CT scan images is far superior to conventional radiography [3]. The dose on CT scan is very large when compared to conventional radiology modalities. The relatively higher doses on CT scans have the potential to pose risks to people undergoing CT scans [4]. To overcome this problem, it is necessary to measure the amount of radiation dose received by the patient and released by the device [5,6].

Computed Tomography Dose Index (CTDI) is a quantity used to calculate the quantity of radiation in determining the dose received by a patient on a CT scan. CTDI measurements are usually performed using a standard phantom polymethyl methacrylate (PMMA), which has a diameter of 16 cm to represent the patient's head and a diameter of 32 cm to represent the patient's body with a length of 14 to 15 cm [6,7]. The CT scan dose is expressed in terms of the CTDI volume (CTDIvol), whereas this metric only shows the radiation output of the CT scan [7,8]. Due to this, the American Association of Physicists in Medicine (AAPM) in 2011 released Report No. 204 about the dose in patients undergoing a CT scan. This report describes the Size Specific Dose Estimate (SSDE), which is computed using the CTDI value and the conversion factor (f) obtained from the effective diameter of the patient or the patient's body size [9]. However, the dose received by the patient is also influenced by the ct scan radiation output (ie kV, mAs, pitch, rotation time and collimation width), also determined by the characteristics of each individual patient [10]. Therefore, the American Association of Physicists in Medicine (AAPM) published Report No. 220 in 2014 to determine SSDE based on individual patient characteristics, also known as water equivalent diameter (D_W) [11]. The SSDE value can also be determined automatically by the IndoseCT software, which makes it simpler for users to determine the SSDE value, in addition to being determined from direct measurements [12].

Anam et al [13] conducted a study to calculate several organ doses, namely liver and kidney using the SSDE concept and compared the results with the doses calculated using the Monte Carlo method. The percentage difference between the doses of the proposed method and the Monte Carlo method was 5.47% in the liver, 21.77% in the right kidney and 22.64% in the left kidney, respectively.

The purpose of this study was to measure the value of the dose distribution in the center, the edge of the phantom, and the average dose of the phantom with a diameter of 16 and 32 cm and then the results were compared with the values obtained in the IndoseCT software.

METHODS AND MATERIAL

This study was carried out at the Indriati Solo Baru Hospital. The fixed parameters used are 120 kVp tube voltage, 100 mAs time current, 10 mm collimation width, 100 mm scan length, and 1 s tube rotation.

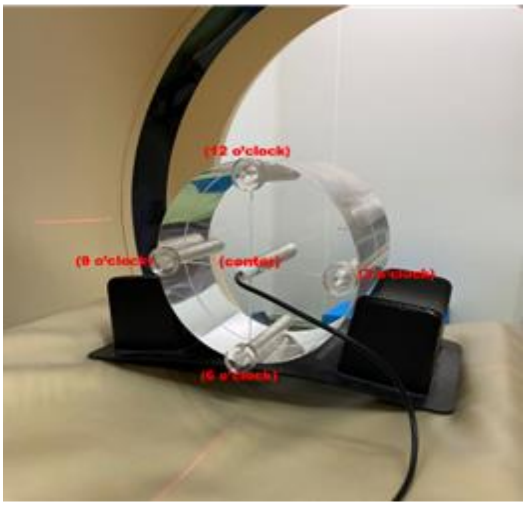

Figure 1. Detector position for CTDI measurement

This research was conducted using a pencil ion chamber and a PMMA phantom with a diameter of 16 and 32 cm. The phantom is positioned precisely according to the horizontal and vertical laser crossing. The Pencil Ion Chamber is placed in the center of the phantom to obtain the CTDIcenter (CTDIc) value. While the pencil ion chamber is placed on the four edges of the phantom to get the CTDI peripheral (CTDIp) value (figure 1).

This measurement was carried out 15 times scanning for each phantom with fixed parameters so that the total measurement was 30 scanning times because 3 measurements were carried out for each phantom hole. The phantom image is stored in a DICOM file. The data were processed using the IndoseCT 20.b to calculate the dose values for one phantom center hole and four phantom edges for 16 and 32 cm phantom diameters, respectively.

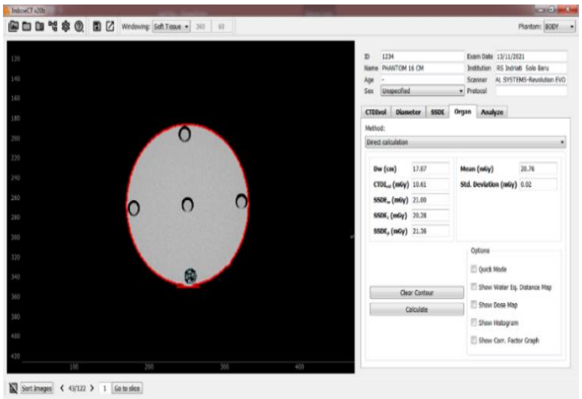

Figure 2. Contouring organs of CTDI phantom

The IndoseCT 20.b calculated the dose in phantoms with diameter variations of 16 and 32 cm using interpolation between the central SSDE (SSDEc) and the four phantom periphery (SSDEp). The calculation begins with the contouring of the organ manually. Organ contours aim to determine the location and area of the organ that will be used to measure the average dose of the organ and its standard deviation. In this software, organ contouring cannot be performed for two organs simultaneously, so the contouring process is carried out for each organ. The contour was carried out 10 times for each variation of the 16 and 32 cm phantom because each had 5 phantom holes, namely the middle hole and four at the edges of the phantom (Figure 2).

The SSDE value was calculated from the measurements made for each hole, one measurement on the center hole (SSDc) and four on each side of the phantom edge (SSDEp). The SSDEc and SSDEp for estimating phantom organs dose distribution can be calculated based on the conversion coefficient (k and h) and $CTDI_w$ Eq (1) (2).

$$SSDE_c = h \times CTDI_w \qquad (1)$$

$$SSDE_p = k \times CTDI_w \qquad (2)$$

The SSDE weight values (SSDEw) were computed using the SSDEc and SSDEp values as a function of the equivalent diameter based on Eq (3).

$$SSDE_w = f_w \times \frac{CTDI_w}{pitch} \qquad (3)$$

Conversion factors h and k have been stored in IndoseCT 20.b. Thus, when calculating the dose distribution, it will be calculated automatically by the indosect 20.b as shown in figure 2. After obtaining the measured radiation dose values on the surface and the four phantom edges as well as the radiation dose value from IndoseCT 20.b then calculate the percentage difference based on Eq (4).

$$\%\ Difference = \frac{A-B}{A} \times 100\% \quad (4)$$

With A indicating the CTDI value measured in phantom and B indicating the CTDI value calculated using the IndoseCT 20.b.

RESULTS AND DISCUSSION

This study aimed to compare the dose measured directly with the dose calculated from IndoseCT 20.b using standard phantom diameter variations of 16 and 32 cm both in the center of the phantom and at the periphery of the phantom. This research was conducted at Indriati Solo Baru Hospital using the GE CT scanner Revolution EVO 64/128 slice type. This research was conducted using fixed parameters, namely tube voltage 120 kVp, current 100 mAs, collimation width 10 mm, scan length 100 mm, and tube rotation 1 s.

Dose measurement with a Pencil Ion Chamber

The results of the dose measurement on the PMMA phantom showed that the dose values in the center of the phantom were 20.01 and 6.57 mGy, the peripheral were 22.34 and 13.48 mGy, and the weighted dose values were 21.56 and 11.17 mGy for phantoms with diameters of 16 and 32 cm, respectively.

The dose value at the five detector placement positions is inversely proportional to the variation of the phantom diameter. In this case, the phantom with a diameter of 32 cm produces a smaller radiation dose compared to the radiation dose at the edge of the phantom. The radiation dose ratio at the four edges of the phantom hole is almost the same value, while at the phantom center the radiation dose value is the lowest.

Dose Calculations Using IndoseCT 20.b

The results shown on the IndoseCT software are 20.28 mGy and 7.10 mGy for the dose values in the central position, 21.36 mGy and 13.31 mGy for the dose values at the periphery of the phantom, and 21.00 mGy and 11.24 mGy for the weighted dose with phantom diameters of 16 cm and 32 cm, respectively.

Comparison of phantom measurement dose values with IndoseCT 20.b

Figure 3 shows the comparison between the dose value from the IndoseCT software and the dose on the radiation detector. The dose difference for a 16 cm diameter phantom in the center position was 1.34%; at the periphery of the phantom position of 4.38% and the weighted dose was 2.59%; and for the 32 cm phantom diameter, the dose difference was 8.1% at the center position, 1.26 % at the periphery position, and 0.62 % at the weighted dose.

Figure 3(a) shows a graph with almost the same graphic appearance between measurements using a detector with IndoseCT software. The SSDEc dose value from the detector measurement has a smaller dose value compared to the dose result in the IndoseCT software. The difference in percentage between the two is the largest 8.1% in the center position of the phantom with the diameter of the phantom is 32 cm. Figure 3 (b) shows a graph of the comparison of dose values on the edge of the phantom with IndosECT software showing almost the same pattern. For a phantom diameter of 16 cm, the percentage difference is greater than that of a phantom diameter of 32 cm. For Figure 3 (c) the value of the weighted dose at a phantom diameter of 32 cm, the percentage difference is very small, namely 0.62%.

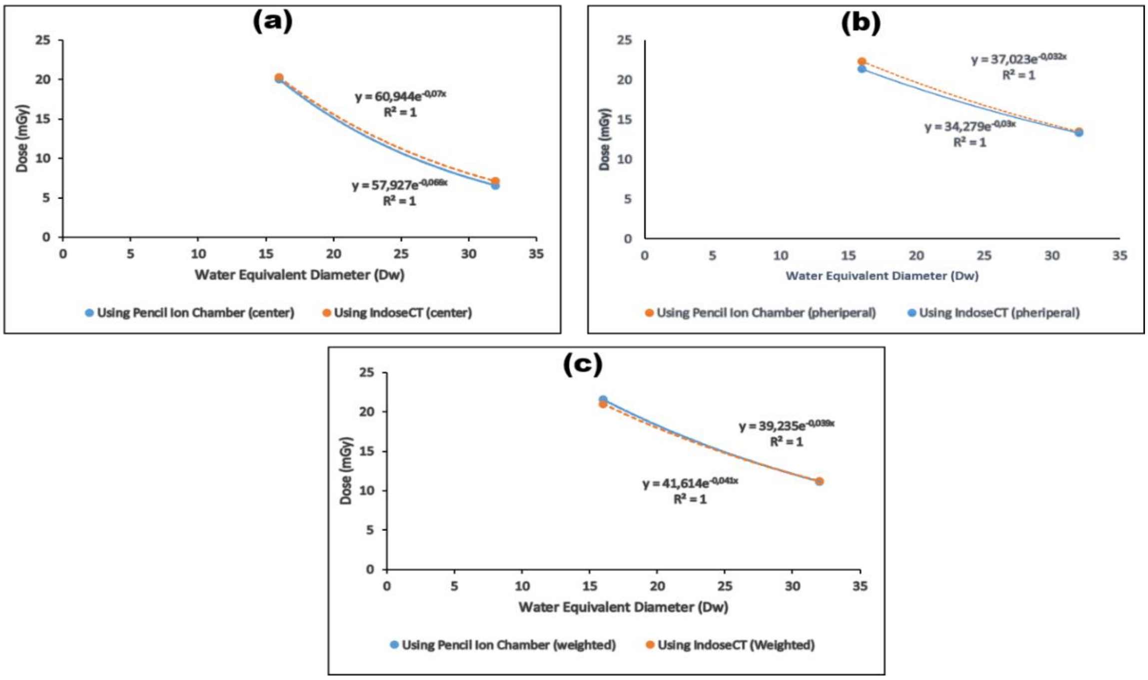

Figure 3. Graph of dose comparison on phantom with IndoseCT software on (a) SSDc (b) SSDEp (c) SSDEw

In this work, the radiation dose was measured using a pencil-shaped ion chamber detector with PMMA phantoms that varied in diameter from 16 to 32 cm. This measurement was carried out to compare the dose results from the IndoseCT software to the dose correlation in each phantom hole using a pencil ion chamber. The increase in the phantom diameter is inversely proportional to the dose value. This indicates that the measured dose value decreases as the phantom diameter increases. In comparison to the 32 cm phantom diameter, the 16 cm phantom diameter has the highest dose value.The results obtained indicate that the difference in results is almost the same between direct measurements in each phantom hole and the dose results in the IndoseCT software. According to AAPM 204, the diameter variation from various methods can only reach 16% for small diameters [9]. Therefore, AAPM recommends an acceptable SSDE limit of 20% [9].

CONCLUSION

The results of this study show that for a 16 cm phantom diameter at the center position, the difference in the percentage of detector measurements with IndoseCT software is 1.34%, at the phantom edge position, it is 4.38%, and the weighted dose is 2.59%, while for a 32 cm phantom diameter, the difference is 8.1 percent, at the edge of the phantom it is 1.26 %, and the weighted dose is 0.62 %.

Based on the results obtained from IndoseCT, it showed an insignificant difference with the measurement of radiation dose using a phantom. Overall, the difference in percentage is ±10% while the difference in percentage that is still acceptable is ±20%.

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