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Deviation Value of CTDI100 for Phantom Regional Territories by Using Chamber Ionization Detector

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ABSTRACT

Determining CTDI100 and CTDI100 deviation values at the central and side region of the phantom by using head protocols have been performed as CT-Scan test parameters. Methods and materials of Axial CT scanning are used at the head phantom that contains a chamber ionization detector. The head phantom is a PMMA given a hole in the middle of the phantom, the top side (clockwise 12), right side (clockwise 3), bottom side (clockwise 6) and left side (clockwise 9). Head phantom has 16 cm of diameter and 15 cm of length. In this study, to determine the comparison of CTDI100 values at the phantom center against all sides phantom against CTDI100 factory baseline values. The result shows that the comparison of CTDI100 at the top side is highest value about 26.87 mGy and the smallest at the bottom side about 25,15 mGy. On the right side is 26.12 mGy, on the left side is 25.92 mGy, and at the center is 25.84 mGy. For smaller deviations at the center is 9.82% compared to other phantom sides, the highest deviation value at the bottom side is 12.83% while at the top side is 12.05%, at right side is 11.65% and at the left side is 11.72 %, but this deviation value is still within the tolerance limit of ≤ 20%.

Keywords: CTDI, Phantom Head, Ionization Detector Chamber
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1. INTRODUCTION

Radiation dose on the CT scan is relatively greater than the other radiological modality. For example, for thoracic imaging, the effective dose of CT Scan is 5-7 mSv, while for thoracic imaging on conventional radiography, the effective dose is 0.1-0.2 mSv. The dose on CT scan is relatively high, because CT scan has the ability to get the image of one single slice, the patient should be irradiated at least 360 times, which is from an angle of 10o to 360o. The projection result of each degree will be reconstructed to gain cross-sectional image (cross section) [1].

High doses of CT scan was not only coming from the primary radical of each slice, but also from the scattering radiation from the slices on the right and left sides. Therefore, CT Scan dosimetry is very complex [2]. In the beginning, CT Scan dose can be estimated using multiple scan average dose (MSAD). MSAD was calculated from multiple-scanning dose profile along the scanning axis, and then, averaging in the center of the dose profile. However, MSAD takes a long time, so it is less effective. Subsequently, the concept of CT dose index (CTDI) is introduced [2,3].

CTDI is obtained by integrating a dose profile for one single scanning, divided by the width of the collimation [3]. This technique is practically be used with ionizer chamber with 100 mm of length, and used standard phantom of PMAA with diameter 16 cm or 32 cm [4]. Since the introduction of CTDI concept, it has become the standardization of dosimetry in the world. Even since 2002, CTDI should be displayed on the monitor screen on the CT Scan console [5].

The aims of this research is to determine CTDI100 value at center area and phantom side by using head protocol. Methods and materials: Axial CT scanning was used on a head phantom that contains a chamber ionization detector. In this research will be measured CTDI100 value at the center and side of phantom with the purpose of knowing the different level of both values [6].

The head phantom is PMMA phantom that was given hole in the middle of the phantom, the top side (clockwise 12), right side (clockwise 3), bottom side (clockwise 6) and left side (clockwise 9). The phantom head have diameter 16 cm and length 15 cm [7] [8]. In this study, we determined comparison of CTDI100 values at the phantom center of all phantom side with the CTDI100 factory baseline value [9].

2. METHODOLOGY

Detectors, using pencil ionization chamber with length 100 mm, and using standard phantom of PMAA with diameter 16 cm [9].

Fig. 1. Phantom CTDI [9]

The radiation dose of CT-scan is the largest in radiology examination. Accurate dosing of CT scans is very essential. Although many methods are used in dosing measurements however, this study will only discuss the method of pencil ionization chamber and CT Dose Index (CTDI) method. Ionization Methods Chamber (Ionization Tube) is the easiest method to implement with accurate probability and often used for dose reporting. Scanning uses axial head protocol with 120 kV, 10 mm technical slice, picth 1.0 and FOV 22 cm [4] [10].

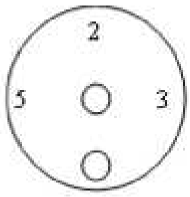

Fig. 2. Position of Detector Ion Chamber [4]

Placement of the position of chamber ion detector in phantom CTDI head as shown in Figure 2. Where number 1 showes the central phantom region, the number 2 is the up side area of phantom (clockwise 12), the number 3 is the right side region (clockwise 3), the number 4 is the bottom side area (clockwise 6) and the number 5 is the left side region (clockwise at 9) [4].

CTDI100 is calculated not from dose profiles for some scannings, but just one scanning. CTDI was calculated from the integration of the dose once scanning profile curve divided by the width of the collimation or slice width [11].

$$C_{1} = \frac{k}{N}$$

Where k is the electrometer correction factor, E is the dose rate (mGy), L is length of ion chamber (mm), N is the number of slices in the axial channel data acquisition and T is the nominal width slice on one data channel (mm) [4]. $CTDI_{100}$ center value compared with $CTDI_{100}$ value of all sides and compared with $CTDI_{100}$ factory's baseline value, so it is known that the value of $CTDI_{100}$ produced will not be exceed from the value of Tolerance by Nuclear Power Control Agency (BAPETEN) [12].

3. RESULT AND DISCUSSION

The research measured $CTDI_{100}$ value at central area and side of phantom head was compared with factory baseline value and then analyzed value of deviation of center area and four phantom sides with result as shown in Table 1.

Table 1 shows the $CTDI_{100}$ value at the detector position at the center and the side of the phantom head. The highest average $CTDI_{100}$ was 26.87 with the position of the top side detector (clockwise 12) while the lowest average $CTDI_{100}$ was 25.15 with the bottom side detector position (clockwise 6). The average value of $CTDI_{100}$ in the position of the detector top side has the highest value because the position of the detector is closer to the position of the tube. The other way, average value of $CTDI_{100}$ in bottom side detector position is lower because it is farther from the position of the tube.

Table 1. $CTDI_{100}$ values at central and phantom side detector positions

Position of Detector	$CTDI_{100}$ value	
	Mean	SD
Center	25.84	14.07
Top side (o'clock 12)	26.87	14.52
Right side (o'clock 3)	26.12	14.74
Bottom side (o'clock 6)	25.15	14.27
Left side (o'clock 9)	25.92	14.62

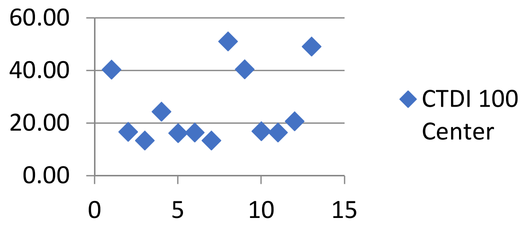

Fig. 3. Data of distribution CTDI100 position detector in center phantom.

Can be seen in Figure 3 that the distribution of CTDI100 value of detector position at center phantom has the lowest value of 13.4 mGy, while the highest CTDI100 value is 51,1 mGy. The distribution of CTDI100 data is highest among the above 10 mGy up to under 30 mGy.

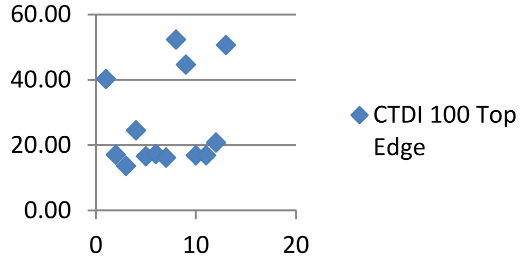

Fig. 4. Data of distribution CTDI100 position detector in top side phantom

On the Figure 4, it can be seen that the $CTDI_{100}$ value at the top side detector position of phantom has the highest $CTDI_{100}$ value of 52.4 mGy and the lowest $CTDI_{100}$ value of 13.8 mGy. We can also see that the $CTDI_{100}$ value is higher when compared to other $CTDI_{100}$ values because the detector position is closer to the X-ray tube. For data distribution $CTDI_{100}$ ranges from 10 mGy to 30 mGy.

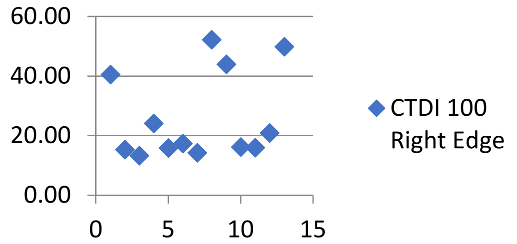

Fig. 5. Data of distribution $CTDI_{100}$ position detector right side phantom

Figure 5 shows the $CTDI_{100}$ value is almost equal to the $CTDI_{100}$ in the Top side detector position of 52.2 mGy while the lowest $CTDI_{100}$ is 13.3 mGy. Distribution of data of $CTDI_{100}$ value mostly in area 10 mGy to 30 mGy, although there is still distribution of $CTDI_{100}$ data whose value is 40 mGy to 55 mGy

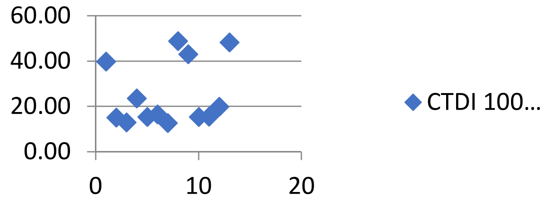

Fig. 6. Data of distribution $CTDI_{100}$ position detector bottom side phantom

Figure 6 shows the $CTDI_{100}$ value at the Bottom side detector position of 48.9 mGy while the lowest $CTDI_{100}$ is 12.6 mGy. It is also obtained the lowest $CTDI_{100}$ value when compared with the value $CTDI_{100}$ of other positions. It is because the position of the detector farther than the X-Ray tube.

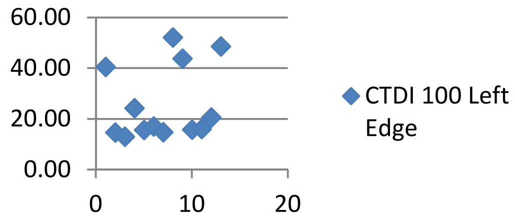

Fig. 7. Data of distribution $CTDI_{100}$ position detector left side phantom

From the Figure 7, at the left side detector position at 9 o'clock direction can be seen the lowest data of distribution value of $CTDI_{100}$ is 13.0 mGy while the highest is 52.1 mGy. Data distribution obtained 69.2%

in the area of 10 mGy to 30 mGy while 30.8 % in the area of 40 mGy to 55 mGy.

Table 2. The $CTDI_{100}$ Deviation Value againts $CTDI_{100}$ Base Line Value

Position of Detector	$CTDI_{100}$ Deviation Value		
	Mean	SD	SNI
Center	9.82	4.10	20
Top side (o'clock 12)	12.05	6.05	20
Right side (o'clock 3)	11.65	5.53	20
Bottom side (o'clock 6)	12.83	4.11	20
Left side (o'clock 9)	11.72	5.41	20

Table 2 shows deviation value $CTDI_{100}$ against $CTDI_{100}$ base line of the CT-Scan aircraft manufacturer. Overall deviation value in all detector positions are still below the limit value permitted by BAPETEN as regulatory body that is smaller or equal to 20%. The position of the detector at the center of the phantom obtained an average value of deviation of 9.82% with a standard deviation of 4.10. At the clockwise 12 or top side position the average value is 12.05 with a standard deviation of 6.05. The position of clockwise 3 or the right side of the phantom of the head obtained by the value of 11.65% and the standard deviation of 5.53 then at the bottom side of the direction of the clockwise 6 obtained an average deviation value of 12.83% with a standard deviation of 4.11, while on the left side position of the clockwise 9, the average value deviation of 11.72% with a standard deviation of 5.41.

4. CONCLUSIONS

From the analysis of data that has been conducted, $CTDI_{100}$ values' position of top side detector (clock direction 12) has larger dose than the $CTDI_{100}$ at the central detector position, right side detector position (3 o'clock direction), and the bottom side (clock direction 6) and the left side (clock direction 9) while the value of $CTDI_{100}$ in bottom side detector position is lower than the side or other position. The deviation value of $CTDI_{100}$ against the value of $CTDI_{100}$ manufacturer baseline at all detector positions is still below the Indonesian National Standard of ≤ 20% issued by BAPETEN. For further research can use the more complete data and the latest method by using computation process or Artificial Intelligence such as Firefly Algorithm (FA) and others.

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