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by Choirul Anam

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Analysis of the Effect of Phantom CT Scan Diameter Variations on Radiation Dose with IndoseCT

Intan Andriani[*1,3], Wahyu Setia Budi[2], Heri Sutanto[2], and Choirul Anam[2]

[1]*Graduate Master of Physics of Diponegoro University, Semarang, Central Java, Indonesia*
[2]*Department of Physics, Diponegoro University, Semarang, Central Java, Indonesia*
[3]*Widya Husada Institute of Health Science, Semarang, Central Java, Indonesia*
***Corresponding Author**: **IntanAndriani**
Email id: intanandriani@st.fisika.undip.ac.id

ABSTRACT

The dose received by a patient who performs a CT scan is influenced by several factors, namely slice thickness, pitch, position and size of the patient, range of scanning and type of scanning. The amount of radiation dose received from the scan also depends on phantom geometry, form and material. The method of calculating a patient's dose on a CT scan is known as the Computed Tomography Dose Index (CTDI). According to research that has already been carried out, it is explained that CTDI represents only the surface dose of the body. SSDE is then used to calculate the central dose of phantom and phantom edge. The purpose of this study was to determine the dosage size for variations in phantom diameter and SSDE values with the IndoseCT program for variations in phantom diameter. The measurement method in this study was carried out using a piranha detector and IndoseCT software. The results of the study found that there were differences in the values of CTDIc, CTDIw, and CTDIvol, each having a range of 0.93% to 147.96%, 26.65% to 62.48%, 11.51% to 41.46%. SSDE values for phantom size 8 cm, 16 cm, 24 cm, 32 cm and 40 cm respectively are as follows: 29 mGy, 23.09 mGy, 16.86 mGy, 12.35 mGy, 9.27 mGy. The conclusion of this study is that the greater the effective diameter of phantom the smaller the SSDE.

Keywords: *CT-scan, CTDIw, CTDIvol, SSDE, Effective diameter*

INTRODUCTION

CT Scan is one of the imaging modalities in the radiodiagnostic field which is capable of producing axial, coronal, sagittal slices of the object or the patient conducting the examination. So that it is possible to show the inner parts / organs shown in each slice. CT Scan can be applied to enforce trauma diagnoses to cancer cases. The use of CT-Scan aircraft certainly provides a radiation dose that is quite large compared to other diagnostic imaging modalities [1].

AAPM in 2011 issued report No. 204 on the dose of CT scans, known as size-specific dose estimates (SSDE). This SSDE is calculated based on the CTDI value and conversion factor (f) obtained from the effective diameter of the patient. During this time, the dose of CT scan was expressed in CTDIvol quantities, even though the metric was only to show the radiation output of the

CT scan, not to show the radiation dose of the patient. To show the patient's radiation dose, currently using the SSDE amount. The SSDE calculation method can use the IndoseCT software that is able to estimate the direct dose for each individual patient using the patient's image [2-7].

In this study, measurements of radiation doses received by internal organs, namely SSDE, were carried out when CT scan was performed. During this time CTDI was considered as the dose value received by patients. In fact, according to research that has already been carried out, it is explained that CTDI represents only the body surface dose.

MATERIAL AND METHOD

The aim of this study was to determine the dose size for phantom diameter variations and determine the SSDE value with the IndoseCT program for variations in phantom diameter. Variations in diameter used were 8 cm, 16 cm, 24 cm, 32 cm, and 40 cm. phantom used in research made of acrylic. Each diameter variation is measured and calculated CTDIc, CTDIw, CTDIvol, and SSDE values. Calculation method using the piranha detector and IndoseCT software. Phantom scanning is done using body parameters.

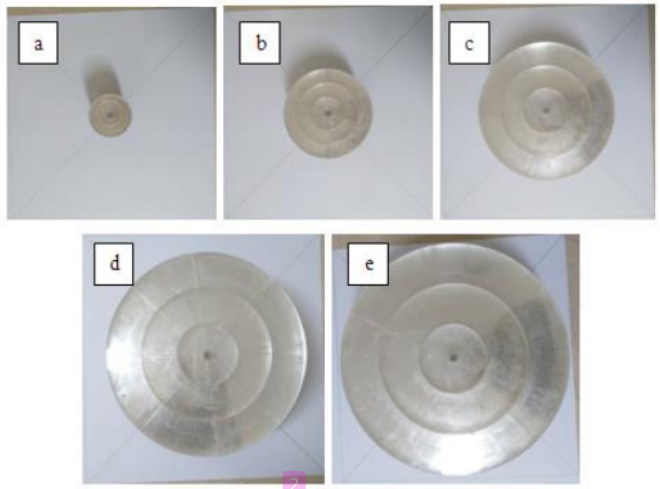

Fig 1. Variations in phantom diameter size: 8 cm (a), 16 cm (b), 24 cm (c), 32 cm (d) and 40 cm (e)

The calculation formula for each quantity sought is as follows:

$$CTDI_{w} = \frac{1}{3} CTDI^{center} + \frac{2}{3} CTDI^{peripheral} \quad \text{eq.1}$$

$$\text{CTDIvol} = \frac{CTDIw}{pitch} \quad \text{eq.2}$$

$$SSDE = CTDIvol \; x \; f \quad \text{eq.3}$$

RESULT AND DISCUSSION

Radiation Dose

Table 1 and figure 2 shows the recapitulation of dose measurements with a piranha detector.

Table 1: CTDIc, CTDIw, CTDIvol measurement data using radiation detectors

No	Effective Diameter (cm)	Effective mAs	CTDIc Normalized	CTDIw Normalized	CTDIvolNormalized
1	8	14	25.90	39.53	46.51
2	16	24	23.31	35.57	39.44
3	24	51	10.61	16.20	19.06

4	32	120	5.83	8.90	10.47
5	40	141	3.74	5.71	6.71

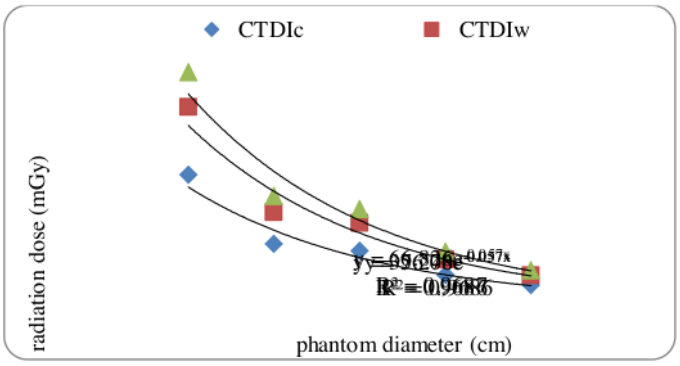

Fig. 2 Measurement charts for CTDIc, CTDIw and CTDIvol

Figure 2 shows the results obtained from detector measurements the greater the size of the phantom diameter the smaller the radiation dose. The CTDIc value has the lowest value compared to CTDIw and CTDIvol because CTDIc is the dose value at the phantom center.

Comparison of Data on Radiation Detector Measurement Results with IndoseCT

Data obtained by measuring radiation detectors were compared with IndoseCT. In this study phantom scanning was carried out using body part parameters for the five phantoms and the measurement points were only in the middle of the phantom, so that the phantoms with even small diameters could obtain the same dose profile curve according to the phantom parameter settings of the body parts. Dose profile curves that should have been obtained for each small diameter phantom (head) and large diameter phantoms (body parts) are shown in the figure 3[8].

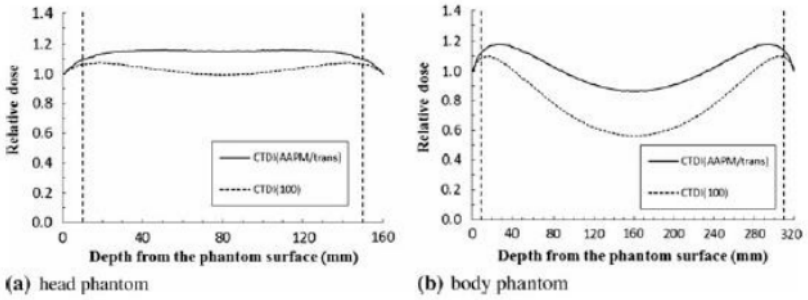

Fig. 3 Dosage profile curve

CTDIc measurement data is shown in table 2. The CTDIc value forms a pattern similar to IndoseCT, can be seen in figure 4 the graph pattern obtained is the same because the measurement of the dose by the detector is done at the center of the phantom.

Table 2: CTDIc measurement value

No	Effective Diameter (cm)	Effective mAs	CTDIc (mGy) M 1	M2	M 3	$\bar{M}$ (mGy)	Standard deviation	CTDIc normalized (mGy)	IndoseCT (mGy)	Difference in detector measurement with IndoseCT (%)
1	8	14	4.09	4.15	2.64	3.63	1.72	25.90	29.00	11.94
2	16	24	5.59	5.58	5.61	5.59	0.03	23.31	23.09	0.93
3	24	51	5.34	5.34	5.56	5.41	0.26	10.61	16.86	58.85
4	32	120	7.26	7.13	6.61	7.00	0.68	5.83	12.35	111.63
5	40	141	5.13	5.29	5.39	5.27	0.26	3.74	9.27	147.96

M1 = Measurement 1, M2=Measurement 2, M3= Measurement 3, $\bar{M}$= Average of measurement

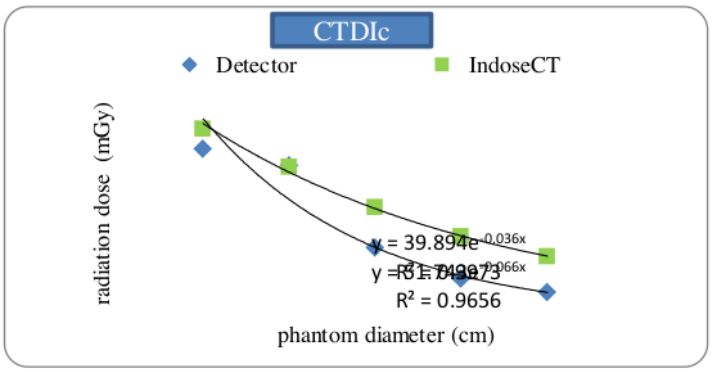

Fig. 4 Graph the relationship of variations in phantom diameter to CTDIc

Data obtained from the study also showed a change in tube currents (mAs) at each exposure of the CT scan. This change occurred because the CT Scan in the Diponegoro National Hospital Radiology Installation (RSND) used the auto mAs setting. Auto setting mAs causes changes in the value of mAs at each scanning for different phantom diameter variations. The CTDIc value of the detector measurements of each diameter has a smaller value than IndoseCT because the CTDIc value with the detector only measures the dose at the phantom center.The average difference between detector measurements and IndoseCT for CTDIcfor phantom diameter 8 cm, 16 cm, 24 cm, 32 cm, and 40 cm has a range of 0.93% to 147.96%.

CTDIw measurement data is shown in table 3. Measuring the CTDIw value using a piranha radiation detector is calculated automatically using a database based on body part parameters. Whereas for dose calculation using IndoseCT uses conversion factors and the calculation method according to the AAPM report 204 standard adjusts the size of phantom diameter [2]. Figure 5 shows a comparison of dose measurements using a radiation detector with IndoseCT. On figure 5 it is shown that the larger the diameter of the phantom the smaller the dose received.

Table 3: CTDIw measurement value

No	Effective Diameter (cm)	Effective mAs	CTDIw (mGy)			$\bar{M}$ (mGy)	Standard deviation	CTDIw normalized (mGy)	IndoseCT (mGy)	Difference in detector measurement with IndoseCT (%)
			M1	M 2	M 3					
1	8	14	6.25	6.33	4.02	5.53	2.62	39.53	29.00	26.65
2	16	24	8.54	8.51	8.56	8.54	0.05	35.57	23.09	35.08
3	24	51	8.14	8.15	8.49	8.26	0.39	16.20	16.86	4.10
4	32	120	11.08	10.88	10.09	10.68	1.04	8.90	12.35	38.67
5	40	141	7.83	8.09	8.22	8.05	0.39	5.71	9.27	62.48

M1 = Measurement 1, M2=Measurement 2, M3= Measurement 3, $\bar{M}$= Average of measurement

CTDIw takes into account the central dose of phantom and the phantom edge dose. In this study only measurements were made at the phantom center so that the CTDIw values obtained did not match the small diameter phantom size. In phantoms with small diameters the CTDIw value is greater than the CTDIc value. The phantom with a small diameter size (head size phantom) should have a CTDIw value smaller than CTDIc [8]. Data obtained from measurements with piranha show the CTDIw results that are close to the actual values. In phantoms with small diameters CTDIw values were obtained using a larger detector than the IndoseCT measurement, because the voltage setting is 130 kV for all phantom diameters. The CT scan voltage affects the penetrating power of X-rays [9], so that smaller phantoms have more intensity of X-rays which are passed to the detector as a result the larger dose received by the detector. The CTDIw measurement with the piranha radiation detector is invalid because the phantom used has a different size. This also occurs in measuring the value of CTDIvol using a piranha detector. The average difference between detector measurements and IndoseCT for CTDIw for phantom diameter 8 cm, 16 cm, 24 cm, 32 cm, and 40 cm has a range of 26.65% to 62.48%.

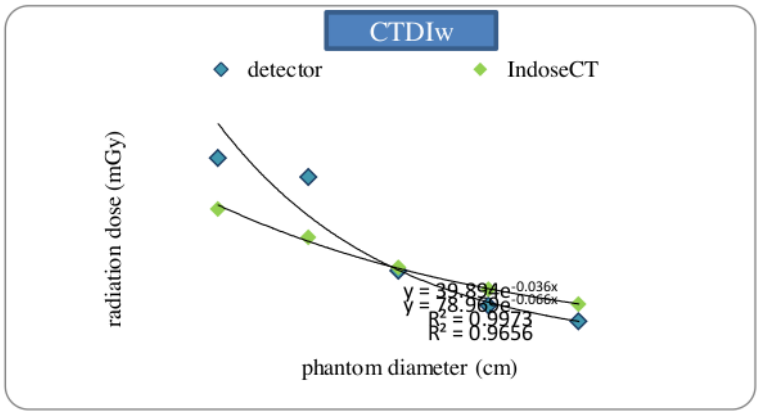

Fig. 5 Graph the relationship of variations in phantom diameter to CTDIw

Table 4 and Figure 6 show that the CTDIvol measurement value using a radiation detector (piranha) with indoseCT software has almost the same graphic form. The average difference between detector measurements and IndoseCT for CTDIvolfor phantom diameter 8 cm, 16 cm, 24 cm, 32 cm, and 40 cm has a range of 11.51% to 41.46%.

Table 4: CTDIvol measurement value

No	Effective Diameter (cm)	Effective mAs	CTDIvol (mGy)				Standard deviation	CTDIw normalized (mGy)	Indose CT (mGy)	Difference in detector measurement with IndoseCT (%)
			M 1	M 2	M 3	M̄ (mGy)				
1	8	14	7.35	7.45	4.73	6.51	3.08	46.51	29.00	37.65
2	16	24	9.61	9.44	9.35	9.47	0.27	39.44	23.09	41.46
3	24	51	9.58	9.59	9.99	9.72	0.46	19.06	16.86	11.51
4	32	120	13.03	12.8	11.87	12.57	1.23	10.47	12.35	17.89
5	40	141	9.21	9.51	9.67	9.47	0.47	6.71	9.27	38.11

M1= Measurement 1, M2=Measurement 2, M3= Measurement 3, M̄= Average of measurement

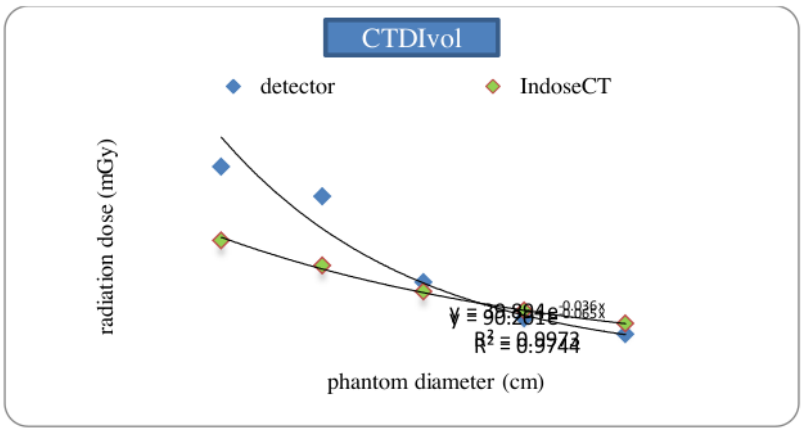

Fig. 6 Graph the relationship of variations in phantom diameter to CTDIvol

Figure 7 shows the relationship between effective diameter and SSDE. The larger the effective diameter size, the smaller the SSDE. It happens because there is absorption of x-ray intensity by acrylic material.

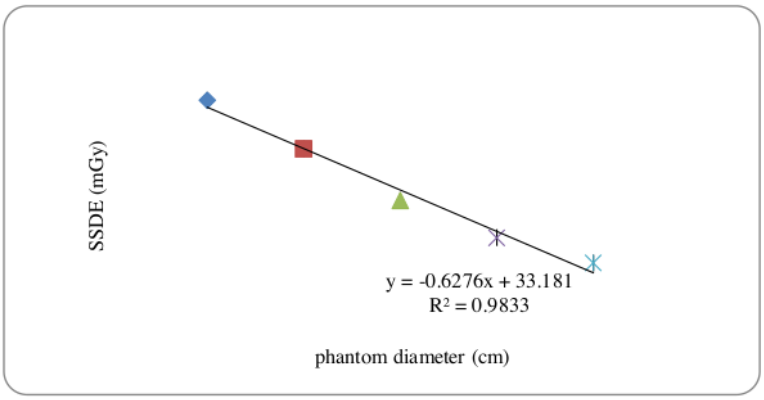

Fig. 7 Graph of Effective diameter relationship with SSDE

CONCLUSIONS

The radiation dose on the CT Scan plane uses the IndoseCT calculation and the measurement of the piranha detector drops exponentially with the effective diameter increase of the phantom. Differences in dose of IndoseCT calculations and measurements using piranha detectors for 8 cm, 16 cm, 24 cm, 32 cm, 40 cm diameters in the CTDIccalculation are 0.93% to 147.96%, CTDIw is 26.65% to 62.48%, CTDIvol is 11.51% to 41.46%. SSDE values from the IndoseCT calculation for phantom effective diameters of 8 cm, 16 cm, 24 cm, 32 cm and 40 cm respectively are 29 mGy, 23.09 mGy, 16.86 mGy, 12.35 mGy, 9.27 mGy. IndoseCT can be used to estimate patient doses with fairly good accuracy.

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