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## IMDOSE PHANTOM DEVELOPMENT FOR QUALITY ASSURANCE AND CONTROL IN COMPUTED TOMOGRAPHY IMAGING STUDY OF IMAGE QUALITY AND DOSAGE ASSESSMENT

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### KEYWORDS

Phantom, CT Scan; image quality; and dose

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### ABSTRACT

C.T. has made a great contribution to detecting and diagnosing patients' diseases. C.T., before being applied to patients, must pass quality assurance and control with phantom. However, the availability of phantoms is still minimal because of their high price. His study aims to create and evaluate cylindrical phantoms for quality assurance and control procedures based on image quality and dose parameters. The research method involves creating an image-quality phantom design that references the CatPhan phantom using Sketchup. The results show that the phantom image provides results from the standard phantom; the SNR, CNR, MTF, noise, and MTF values of the ImDose phantom are still within the standard phantom criteria. Based on statistical tests, the image quality of SNR, CNR, MTF, NPS, and noise is not statistically significantly different from the standard phantom ( $p > 0.05$ ). The uniformity value still needs to be improved because it has a significant difference from the standard phantom with an  $p$  value  $< 0.05$ . Increasing the voltage and current gave results proportional to improving image quality and dose. ImDose phantoms for quality assurance and C.T. control have been successfully developed.

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## INTRODUCTION

X-rays, such as in medical imaging, have been widely used in the health sector. X-rays can enter the body and interact with tissue to produce images of the body's internal anatomy based on differences in X-ray attenuation coefficients (Ance, 2021) (Agency & Dance, 2014). One medical imaging modality that has been widely used is Computed Tomography (C.T.) Scanner. C.T. Scan is a computerized tomography imaging technique with many-body X-ray measurements for disease diagnosis and radiotherapy treatment planning (Anam et al., 2019; Davis et al., 2017; Jeong & Lee, 2014). C.T. scans for diagnosis have been widely used and have increased sharply in medical imaging. According to the International Commissioning on Radiological Protection (ICRP), it has been reported that the frequency of use of C.T. scans is around 10% of all radiological examinations (Task Group on Control of Radiation Dose in Computed Tomography, 2000) and will continue to increase from year to year. C.T. scan image reconstruction is based on the attenuation difference value of the interaction of X-rays with tissue in the form of charge signal data known as the C.T. number on the Hounsfield Unit (H.U.) scale (Anam et al., 2016). This H.U. value is used to assess the disease suffered by the patient from the scanned tissue. This H.U. can be influenced by several factors, such as scanner design and calibration, reconstruction algorithm, beam hardening artefacts, body size, object orientation, and tube voltage (Hunter et al., 1983; Levi et al., 1982; Samei & Pelc, 2019). These factors cause C.T. number variability, which can significantly affect the reliability of the data

produced by the C.T. scan. Apart from the image quality aspect, you also need to pay attention to the dose received by the body. The dose received by the body must comply with the ALARA principle; namely, the dose received must be as minimal as possible without obscuring the resulting image information. Therefore, CT Scans must be managed through quality assurance and quality control (Q.C.).

Radiation protection authorities periodically perform C.T. scan acceptance tests and QA / QC tests to assess radiation dose and image quality. QA / QC testing of image quality and radiation dose is mandatory. QA / QC procedures related to image quality and dose in the C.T. Scan modality consist of quantitative assessment with a standard phantom. Quality Assurance (Q.A.) includes all procedures to ensure equipment meets quality requirements. In diagnostic radiology, Q.A. aims to perform the most appropriate X-ray examination for diagnosis with optimized exposure factors, providing high-quality images at acceptable doses.

Meanwhile, QC involves a process through which relevant performance parameters are measured and compared with existing standards, basic values, and accepted tolerances (Agency & Dance, 2014). The most important parameters for C.T. image quality are image noise, CT-number uniformity, spatial resolution, and low contrast resolution. Meanwhile, CT dose parameters use the C.T. Dose Index (CTDI) value [10, 11]. The quality assurance process certainly cannot use humans as test objects; of course, this is a loss for humans. Therefore, QA / QC procedures require a replacement object called a phantom.

Fantom is a real imitation model that has parity with the real network. The equality referred to is that the attenuation value of the phantom material tissue is equivalent to the real tissue (White, 1993). Standard phantoms for QA / QC are generally made from polymethyl methacrylate (PMMA) material. This standard PMMA phantom has two diameters, one with a diameter of 16 cm representing the head and another with a diameter of 32 cm to replace the patient's body. This phantom is cylindrical with a length of 15 cm. This phantom has five holes in the centre and four others at the edges (Mubarok et al., 2016). However, this standard phantom is very expensive, and many hospitals in Indonesia still need it. Fantom is very useful for independent quality assurance, training and education. Several studies related to C.T. phantom materials have been carried out (Sookpeng et al., 2016) used nylon as head and body phantom material to measure CTDI and reported that the C.T. number value was around 20 H.U. lower than standard PMMA phantoms (Sookpeng et al., 2016). Apart from that (Hilmawati et al., 2020) made a CTDI phantom from methyl ethyl ketone peroxide (MEKP), which gave an H.U. value of 1 – 9% greater than the PMMA phantom. The two phantoms are still for testing the quality of radiation doses, there is not yet a phantom package to guarantee image quality and dose. Apart from that, the level of precision during manufacture still allows for errors. Therefore, this research will propose the ImDose Image and Dose phantom to guarantee image quality and radiation dose using Polylactic Acid (PLA) material using 3D printing technology. PLA material is similar to human tissue, with a density of around 1 – 1.23 g/cm<sup>3</sup> [15].

This research has several benefits to be achieved, namely, Providing research references in the development aspect of the ImDose phantom for quality assurance and control in X-ray modalities. This will help increase understanding of ImDose phantom development and the importance of quality assurance and control.

Provide knowledge about suitable materials for phantoms, quality assurance processes, and controls that can be carried out independently. With this knowledge, this research will improve the ability to select appropriate materials for phantoms and effectively carry out quality assurance and control processes.

They provide independence for affordable medical equipment in Indonesia through education, training, quality assurance and control processes for hospital imaging equipment. This will help increase access to education and training in medical imaging and help hospitals in Indonesia maintain the quality and control of their imaging equipment at an affordable cost.

The objectives of this research are divided into general objectives and specific objectives covering various aspects. This research aims to create a prototype ImDose phantom that can be used for quality assurance and control in radiological examinations, with assessment based on image quality and dose in the same examination protocol. This research will also examine the effect of voltage and current on the image quality and dose produced by the ImDose phantom.

The specific objectives of this research include:

- a) Design an ImDose phantom design that meets quality assurance and control standards for image and dose quality assessment.
- b) I am realizing the phantom design into a prototype using 3-dimensional printing technology.
- c) Evaluate the image quality of the ImDose phantom using the parameters Hounsfield Unit (H.U.), Signal Noise to Ratio (SNR), noise level (noise), contrast to noise level (CNR), Modulation Transfer Function (MTF), and Noise Power Spectrum (NPS) at a tube voltage of 120 kV and a current of 200 mA, and compare it with a standard phantom.
- d) Investigating the effect of variations in tube voltage (90 kV, 120 kV, and 140 kV) on the image quality of the ImDose phantom using the parameters Signal Noise to Ratio (SNR), noise level (noise), Contrast to Noise Level (CNR), Modulation Transfer Function (MTF), and Noise Power Spectrum (NPS).
- e) Evaluate the impact of changes in tube current (50 mA, 200 mA, 300 mA) on the image quality of the ImDose phantom using the parameters Signal Noise to Ratio (SNR), noise level (noise), Contrast to Noise Level (CNR), Modulation Transfer Function (MTF), and Noise Power Spectrum (NPS) at a tube voltage of 120 kV.
- f) I compared the CT Dose and CT Dose Volume Index (CTDIvol) produced by the ImDose phantom with a standard phantom at a voltage of 120 kV and a current of 200 mA.
- g) Assess the CT Dose and CT Dose Volume Index (CTDIvol) of the ImDose phantom with variations in tube voltage (90 kV, 120 kV, and 140 kV) and tube current variations (50 mA, 200 mA, 300 mA) at a voltage of 120 kV.

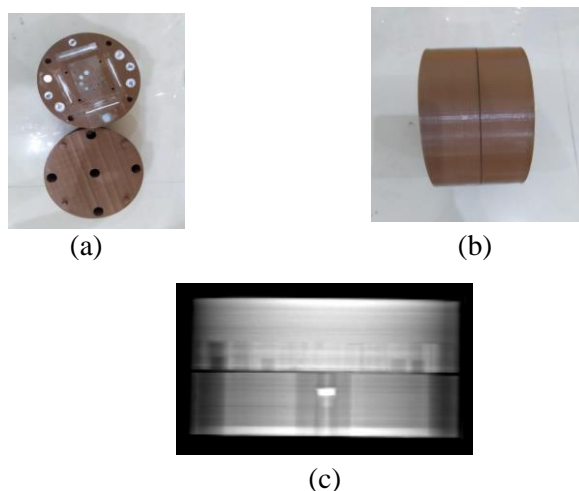
## **METHOD**

This research is a research and development type research by making a CT-Scan phantom prototype for quality assurance and control of image quality and dose. The samples for this study were six image samples and dose data from the ImDose phantom and standard phantom obtained from the C.T. Scan modality at the Radiology Installation at Simpang Lima Gumul Hospital, Kediri. The data was then analyzed for image quality by performing ROIs of the same size ten times on different slices and doses.

## **RESULTS AND DISCUSSION**

### **A. ImDose phantom creation results**

ImDose phantoms are made using 3D Printing with the filament deposition method. 3D Printing uses a 0.4 mm nozzle with an accuracy of 0.2 mm. The filament is made using Polylactic Acid material with a filling percentage of 100% and a wall thickness of 2 mm. The results of creating the ImDose phantom and topogram image are shown in Figure 1.



**Figure 1** Results of (a) image and dose phantom fabrication using 3D Printing, (b) preparation of the ImDose phantom, (c) C.T. tomogram image of the ImDose phantom.

The results of making the ImDose phantom have been successful using a 3D Printed machine. In addition, the ImDose phantom can be read using a C.T. scan. For the next discussion, we will compare the image quality of the ImDose phantom with the standard phantom from Philips.

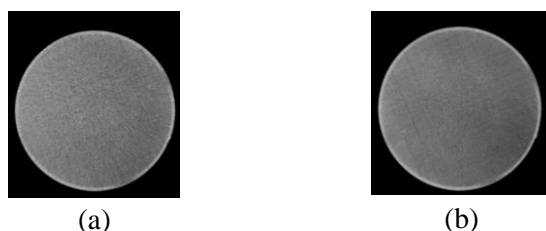
#### **Imdose Phantom Image Results and Standard Phantoms**

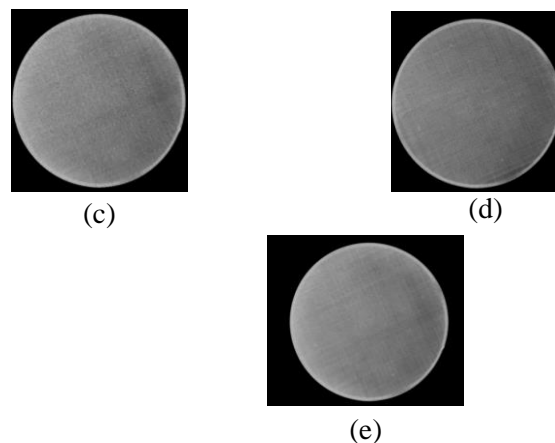
The standard phantom image results were taken using a Philips Healthcare MX 16 Slice CT Scanner using a voltage of 120 kV, 200 mA, as shown in Figure 1(b). Meanwhile, for ImDose phantom C.T. data collection, there are five phantom image data with C.T. settings, namely 90, 120, and 140 kV at a current of 50 mA (3 sample groups), 200 and 300 mA at a voltage of 120 kV (2 sample groups). In the first part, standard phantom and ImDose image data were compared at the same voltage, 120 kV, 200 mA, and evaluated in 5 slices (Anam et al., 2022)



**Figure 2** ImDose 16 cm phantom image results and standard phantom

From Figure 1, qualitatively phantom (a) has image results that are similar to standard phantoms. The salient difference between Figures 1(a) and (b) is the skin sheath of the phantom. The ImDose phantom lacks a high-density outer layer, while the standard phantom uses a high-density outer layer. Meanwhile, the results of the Fantom Image with variations in voltage and current are shown in Figure 3.





**Figure 3** Imdose phantom images (a) voltage 90 kV, 50 mA; (b) voltage 120 kV, 50 mA; (c) voltage 140 kV, 50 mA; (d) voltage 120 kV, 200 mA; and (e) voltage 120 kV, 300 Ma

**H.U. value between Imdose phantom and Standard phantom**

The H.U. value of the Imdose phantom with the standard phantom is taken using a voltage of 120 kV, 200 mA. Calculation of H.U. phantom values using Radiant Viewer software. This is part of the QA/QC testing regarding the H.U. value of low to high-density materials. H.U. measurements were carried out by making ROI on ten different slices. The ROI area for each slice is made the same. The calculation results are shown in Table 1

**Table 1** Insertion number values of the Imdose phantom and standard phantom

Phantom Type	Insert	H.U. value	
		Average	Range
ImDose Fantom	Gypsum	462.74	439 to 889
	PLA 90%	-65.89	-150 to -52
	PLA 75%	-108.96	-203 to -95
	PLA 50%	-379.38	-474 to -388
	PLA 25%	-509.49	-710.7 to -689
	PLA 15%	-651.27	-848 to -768
	PMMA	25.08	0 to 40
	Agarose	12.6	7 to 17
	Air	-937.12	-944 to -922
	PLA100%	43, 35	-12 to 109
Philips Standard Fantom	Teflon	913.4	886 to 936
	Lexan	97.22	72 to 123
	Perspex	123.48	96 to 143
	Polyethylene	-77.92	-111 to -52
	Water	0	-10 to 10
	Aculon	88.54	71 to 107
	Acrylic/PMMA	3, 54	-75 to 74
Organs (Kalender et al., 2024; Mar'Ie et al., 2020)	Soft tissue	-	-199 to 120
	Bone	-	121 to 1600
	Lungs	-	-949 to -120
	Water	-	-1000 to -950

From Table 1, the Imdose phantom value has an average H.U. value range from 462.74 to -937.12. Meanwhile, the standard phantom only has an average value ranging from -77.92 to 913.4. The Imdose phantom generally has a larger range value than the standard phantom. This is a positive thing because the density of human organs is from -949 (lung organs) to 1600 (dense bones).

The H.U. between the ImDose phantom insert, and the standard phantom has a difference of 15.43% for PLA, 90% with Polyethene, and 7% for agarose with water. For the range of H.U. values between ImDose phantoms, Gypsum represents Teflon, PMMA represents lexan, Perspex, and aculon, and agarose represents water. Standard phantoms have higher-density inserts than ImDose phantoms. In general, the Imdose phantom can be used to test H.U. values.

**Uniformity value of Imdose Fantom H.U. and Standard Fantom**

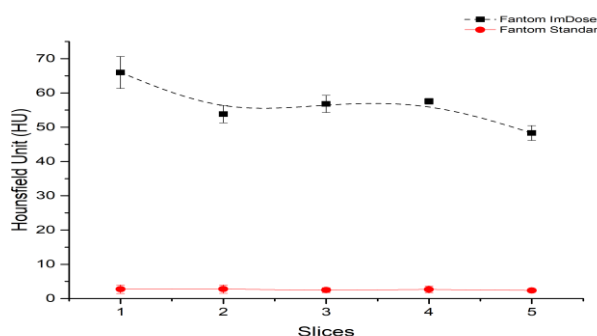
The H.U. uniformity value between ImDose phantoms is calculated by determining the H.U. value at 4 points at the edge and 1 point in the middle, as shown in Table 2. Apart from that, testing for uniformity of H.U. values was also carried out for several slices at the midpoint. The CT uniformity value between the Imdose phantom and the standard phantom was tested using a voltage of 120 kV, 200 mA. The results of calculating the uniformity value are shown in Figure 4.

**Table 2**H.U. consistency in uniformity modules in ImDose and Standard phantoms.

The centre and average H.U. of the four edges of each phantom are displayed. The edge values presented are the average values of the four edge points' four positions.

Uniformity is the standard deviation of the centre and edge areas.

Fantom	Slice	Nilai HU		Standar deviasi
		tengah	Rata-rata area tepi	
Fantom ImDose	1	69,27	62,68	4,66
	2	55,65	52,04	2,55
	3	58,56	55,04	2,49
	4	58,18	56,98	0,85
	5	49,86	46,79	2,17
Fantom standar	1	3,623	1,86	1,25
	2	3,654	1,92	1,23
	3	2,985	1,96	0,72
	4	3,412	1,94	1,04
	5	2,698	2,04	0,46



**Figure 4**Imdose vs standard phantom uniformity

Table 2 shows the uniformity values of ImDose and standard phantoms. Fantom ImDose has a uniformity in the range of 0.85 – 4.66. Meanwhile, standard phantoms have uniformity in the range of 0.46 – 1.25. The uniformity value is best if the standard deviation value is smaller.

From Figure 4, the Imdose phantom has good uniformity values with a constant curve. This means that the H.U. value between slices does not have a significant difference. Meanwhile, the H.U. value between the ImDose phantom compared to the standard phantom is much higher and has a difference of 56.72. However, the H.U. value is between -119 to 120, including soft tissue (Kalender et al., 2024). This means that the H.U. value between the two phantoms still reflects the soft tissue value.

**ImDose phantom Signal Noise to Ratio (SNR) value**

The SNR value calculation is obtained from the ratio of the average H.U. value to the average standard deviation. The ROI was selected according to the phantom size and was carried out ten times. The results of the average SNR value between Imdose phantom vs standard phantom and variations in voltage and current are shown in Table 3.

**Table 3 SNR calculation results on the ImDose phantom with variations in voltage and current**

Phantom	Voltage (kV)	Current (mAs)	SNR
ImDose Fantom	90	50	8.25
	120	50	17.5
	140	50	23.3
	120	200	22.1
Standard Fantom	120	300	25.4
	120	200	21.7

From Table 3 it can be seen that the highest SNR value is 25.4 at a voltage of 120 kV and a current of 300 mA, while the lowest SNR value is 8.25 at a voltage of 90 kV and 50 mA. Meanwhile, the SNR value of the ImDose phantom and standard phantom has a difference of 1.84%.

**Contrast Noise to Ratio (CNR) Values of ImDose Fantom and Standard Fantom**

The Contrast Noise to Ratio (CNR) values of the ImDose phantom and Standard phantom were carried out at a voltage of 120 kV and a current of 200 mA. The results of the CNR calculation are shown in Table 4. Contrast to Noise Ratio (CNR) measures how contrast (well) the target/lesion can be distinguished from the background. The CNR value is determined by selecting an ROI between the inset target area placed in the centre and the surrounding area/ background (top, right, left) for each target. The targets chosen for the inserts are gypsum and Teflon targets.

**Table 4 CNR Value Calculation Results**

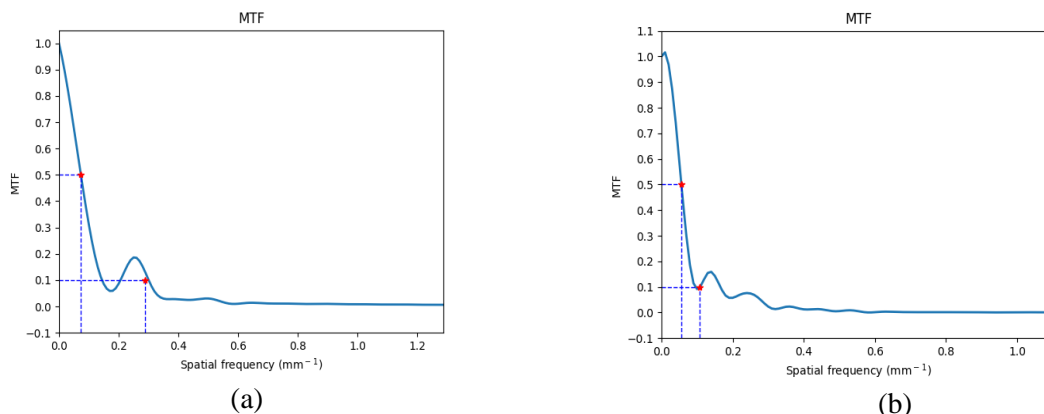
Phantom	Target	Voltage (kV)	Current (mAs)	CNR	
ImDose Fantom	Gypsum	90	50	19.58	
		120	50	20.65	
		140	50	24.60	
		120	200	25.24	
		120	300	27.26	
		90	50	-2, 33	
	PLA90%	120	50	-2, 53	
		140	50	-3, 73	
		120	200	-5, 83	
		120	300	-6, 46	
		PMMA	90	50	4, 49
			120	50	6, 29
	140		50	8, 33	
	120		200	9, 44	
	120		300	10, 16	
	90		50	3, 86	
	Agarose	120	50	7, 23	
		140	50	9, 19	
120		200	8, 33		
120		300	9, 48		
PLA 75%		90	50	-5, 56	
		120	50	-6, 41	
	140	50	-7, 92		
	120	200	-7, 39		

Phantom	Target	Voltage (kV)	Current (mAs)	CNR
Standard Fantom		120	300	-8, 12
	Teflon	120	200	47.63
	Lexan	120	200	15, 06
	Perspex	120	200	17, 84
	Polyethylene	120	200	-6, 02

Based on Table 4, it is known that in the ImDose phantom, the gypsum insert has a CNR value in the range of 19.58 to 27.26, the 90% PLA insert has a CNR value from -2.33 to -6.46, the PMMA insert has a CNR value of 4, 49 to 10.16, the agarose insert has a CNR of 3.86 to 9.48, and 75% PLA has a value range of -5.56 to -8.12. When compared with the inserts in standard phantoms, gypsum inserts have a difference of 22.39 with Teflon inserts, PLA 90% inserts have a difference of 0.22 with Polyethylene, PMMA inserts have a difference of 8.4 with Perspex, and agarose inserts have a difference of 8.4 with Perspex. 6.73 of Lexan inserts at 120 kV voltage, 200 mA current.

**Fantom Imdose and Standard Fantom Modulation Transfer Function (MTF) values**

Analysis of MTF results from ImDose phantom images using IndoQCT software. The results of the MTF analysis are shown in Figure 5.



**Figure 5 MTF calculation results between the ImDose Fantom and the standard Philips Fantom**

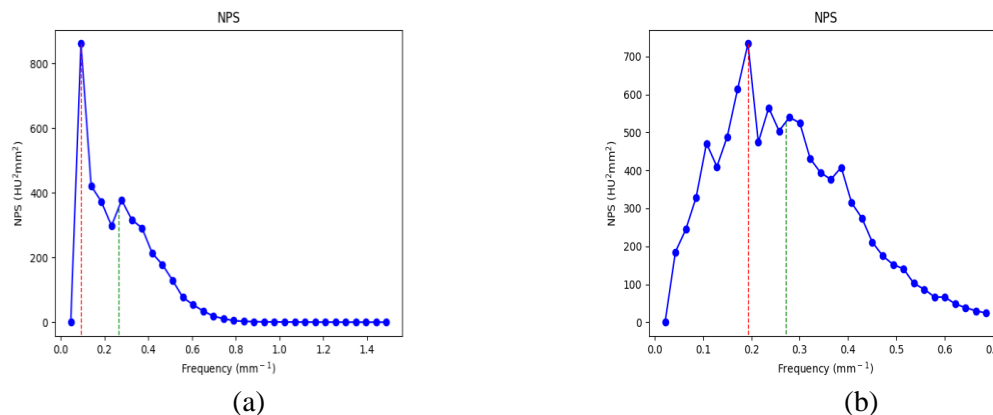
Based on testing, the spatial resolution MTF value of the ImDOSE and standard phantoms is equivalent at MTF50%, namely 0.06 and MTF 10%, which has a difference of 0.11 greater than the ImDose phantom. The greater the MTF value, the greater the phantom has higher spatial resolution and good image results. Here, it was found that the ImDose phantom had better resolution than the standard Philips phantom. The results of the ImDose phantom evaluation based on voltage and current are shown in Table 5.

**Table 5 MTF Value Calculation Results**

Phantom	Voltage (kV)	Current (mA)	MTF	
			50%	10%
ImDose Fantom	90	50	0.06	0.17
	120	50	0.08	0.22
	140	50	0.15	0.33
	120	200	0.17	0.24
Standard Fantom	120	300	0.2	0.37
	120	200	0.06	0.11

### Fantom Imdose and Fantom Standard Noise Power Spectrum Values

The results of the NPS value analysis in the first part will compare the NPS value between the ImDose phantom and the standard shown in Figure 6.



**Figure 6** Evaluation results of NPS values between (a) ImDose phantom; (b) standard phantom

**Table 6** NPS Value Calculation Results

Phantom	Voltage (kV)	Current (mA)	NPS	
			Noise (H.U.)	NPS Integral
ImDose Fantom	90	50	15.05	16.55
	120	50	13.22	15.63
	140	50	10.52	12.52
	120	200	7.64	9.23
Standard Fantom	120	300	6.9	8.35
	120	200	8.04	10.98

Apart from that, from Table 6, the noise value decreases as the voltage and current increase. This is also by the NPS value, the higher the voltage and current, the lower the NPS value. This indicates that the image quality improves as the voltage and current increase.

Thus, the ImDose phantom has been successfully created, with image quality equivalent to a standard Philips phantom. Apart from that, the higher the voltage and current, the better the image quality. However, this must pay attention to the dose received by the patient. Dose evaluation will be discussed in subchapter 9.

### Standard phantom CTDI<sub>vol</sub> and Imdose values

CTDI<sub>vol</sub> measurements used a standard phantom head with a diameter of 16 cm owned by the Surabaya Health Facilities Security Center (HFSC) on September 6 2023. Measurements were carried out at 4 points at the edges and 1 point in the centre. Head phantom CTDI measurement results with parameters 120 kV, 200 mA, and slice thickness 5 mm. The results of standard head phantom CTDI measurements are shown in Table 7.

**Table 7** Measurement and calculation results CTDI<sub>vol</sub> standard head phantom

Location	Measurement results		
	Dosage (mGy)	CTDI <sub>w</sub>	CTDI <sub>vol</sub>
Center	33.01		
Edge 1	38.23		
Edge 2	35.01	34.84	51,751
Edge 3	36.45		
Edge 4	33.33		

Meanwhile, to measure C.T. dose and CTDI<sub>vol</sub> from the ImDose phantom using the same scanning parameters as the ImDose phantom. The results of measuring and calculating C.T. dose and CTDI<sub>vol</sub> from the ImDose phantom at a voltage of 120 kV and 200 mA are shown in Table 8.

**Table 8 CTDI<sub>vol</sub> measurement and calculation results from the ImDose phantom**

Location	Measurement results		
	Dosage (mGy)	CTDI <sub>w</sub>	CTDI <sub>vol</sub>
Center	29.45		
Edge 1	30.66		
Edge 2	30.78	30.32	45,259
Edge 3	32.57		
Edge 4	29.03		

From Tables 7 and 8, the C.T. dose from 5 measurement points shows that the C.T. dose from the standard phantom is greater than the ImDose phantom. The average difference in dose measurements at 5 points was 12.88%. This difference can be caused by several factors, namely a placement error, and perhaps the height of the C.T. table also has an influence. Furthermore, based on the CTDI<sub>vol</sub> value, the standard phantom and ImDose phantom have values of 51.751 and 45.259. From these results, the difference between standard phantom and ImDose is 14.34%. This difference is still within the tolerance range. The threshold for CTDI head phantom suitability testing is at most 20%. These results indicate that the ImDose phantom has performance or capabilities that can be used for C.T. dose index measurements. Furthermore, CT dose and CTDI<sub>vol</sub> measurements were carried out for various voltage and current variations, as shown in Tables 9 – 12

**CT dose and CTDI<sub>vol</sub> phantom ImDose values for voltage and current variations**

The results of C.T. dose and CTDI<sub>vol</sub> phantom ImDose measurements at various voltages and currents are shown in Table 9 – 12. The results show that the greater the voltage simultaneously, the higher the C.T. dose. This also applies to C.T. doses with current variations at the same voltage.

**Table 9 CTDI<sub>vol</sub> phantom ImDose Measurement Results  
for voltage 90 kV and 50 mA**

Location	Measurement results		
	Dosage (mGy)	CTDI <sub>w</sub>	CTDI <sub>vol</sub>
Center	2,960		
Edge 1	3,666		
Edge 2	3,389	3,23	4,196
Edge 3	3,416		
Edge 4	2,996		

**Table 10 CTDI<sub>vol</sub> phantom ImDose Measurement Results  
voltage 120 kV and 50 mA**

Location	Measurement results		
	Dosage (mGy)	CTDI <sub>w</sub>	CTDI <sub>vol</sub>
Center	6,891		
Edge 1	8,013		
Edge 2	7,523	7,28	9,455
Edge 3	7,584		
Edge 4	6,782		

**Table 11 ImDose phantom CTDIVol measurement results of 140 kV and 50 mA**

Location	Measurement results		
	Dosage (mGy)	CTDI <sub>w</sub>	CTDIVol
Center	9,663		
Edge 1	11.38		
Edge 2	10.95	10,	13, 470
Edge 3	10.77	37	
Edge 4	9,805		

**Table 12 ImDose phantom CTDIVol measurement results for voltage 120 kV and 300 mA.**

Location	Measurement results		
	Dosage (mGy)	CTDI <sub>w</sub>	CTDIVol
Center	40.4		
Edge 1	48.11		
Edge 2	44.64	56, 53	54, 00
Edge 3	45.89		
Edge 4	41.73		

The results show that the measurement above has the largest dose; the right, left, and centre edges show close dose results. Meanwhile, the deepest point provides the smallest dose. So, the deeper the dose decreases due to the thickness factor. The comparison of the CTDIVol dose measured with the ImDose phantom with the indexed Console results is shown in Table 13.

**Table 13 CTDIVol comparison results of ImDose phantom measurements with console**

Tool settings		CTDIVol (mGy)		Difference (%)
kV	mA	Console	Measurement	
90	50	3, 720	4, 196	12.80
120	50	8,790	9, 455	7.57
140	50	13,010	13, 470	3.54
120	300	51.45	56,530	9.87

Table 13 shows the CTDIVol comparison between measurements with the ImDose phantom and console. Table 4.13 shows that the largest difference in CTDIVol is 12.80%, and the smallest is 3.54%. These results show that the ImDose phantom can work with variations in voltage and current.

#### **Statistical Test Analysis of ImDose Fantom with Standard Fantom**

The ImDose HU phantom and standard phantom statistical tests used the independent T-test statistical test method with a significance value 0.05. Tests were carried out on data between the ImDose phantom and a standard phantom with a voltage of 120 kV, 200 mA. Before the data is tested, the independent t-test must look at the normality distribution of the data. The data normality test uses Shapiro Wilk because this research data is below 30. The data normality test uses a significance value of 0.05. The test results are shown in Table 1 four below. The ImDose fathom normality distribution results for all parameters were normally distributed with a p-value > 0.05. Meanwhile, the standard phantom normality test results were normally distributed for all parameters with a p-value > 0.05. Except for the standard phantom SNR parameters, it is not normally distributed with a p-value < 0.05.

**Table 14** normality tests data from image quality parameters on the  
**ImDose phantom and Standard phantom at voltages of 120 kV and 200 mA**

Image quality test parameters	ImDose	Standard Phantom
	Fantom	Sig.
Uniformity	0.122	0.494
SNR	0.230	0.017
CNR	0.575	0.851
MTF	0.389	0.057
NPS	0.982	0.079
Noise	0.864	0.945
CTDI Dosage	0,650 _	0, 753

Next, an independent t-test was carried out because the test was conducted to ensure the normality assumption was met. The results of the statistical independent t-test analysis are shown in Table 15.

**Table 15** t tests for image quality between the ImDose phantom and the  
 Standard phantom at 120 kV and 200 mA.

Image quality and dose test parameters	p-value
Uniformity	0.002
SNR	0.988
CNR	0.291
MTF	0.294
NPS	0.654
Noise	0.053
CTDI Dose	0.585 _

## CONCLUSION

Based on the results of the analysis that has been carried out, several things can be concluded as follows: The ImDose phantom was successfully created using 3D printing technology and can be used to measure image quality and dose in one phantom. ImDose Fantom has a Hounsfield Unit (H.U.) value in the range of soft tissue H.U. values. The results of the intercomparison of the H.U. value of the ImDose phantom with the standard phantom show that the H.U. value of the ImDose phantom is higher than the standard phantom. This result is also statistically significant, with a p-value < 0.05, indicating a significant difference in the uniformity of H.U. values between the ImDose phantom and the standard phantom. Image quality parameters such as Signal-to-Noise Ratio (SNR), Contrast-to-Noise Ratio (CNR), Modulation Transfer Function (MTF), noise level (noise), and Noise Power Spectrum (NPS) on the ImDose phantom show no difference, which is statistically significant (p-value > 0.05). However, the uniformity parameter has a significant difference, with a p-value < 0.05.

ImDose phantom quality parameters, such as SNR, CNR, and MTF, further improve with increasing current and voltage. This indicates that the phantom can produce better images with a clearer background. In addition, the noise level and NPS tend to decrease as the voltage and current increase, indicating an increase in image quality. The C.T. dose and CTDIvol testing results between the ImDose phantom and the standard phantom showed a difference of 12.88% for the C.T. dose and 14.34% for the CTDIvol dose. The CT dose in the standard phantom is higher than in the ImDose phantom. The effect of voltage and current on C.T. dose and CTDIvol shows an increase in dose values with increasing voltage and current. However, the difference between measurements and CTDIvol was still below 20%, indicating good consistency in dose measurements. These results

provide a clear picture of the ImDose phantom's ability to measure image quality and dose and the impact of voltage and current variables on measurement results.

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