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| RESEARCH ARTICLE

Optimizing Radiation Dose Using Ctdi Value Analysis and Image Quality in the Thorax Low Dose CT Scan (LDCT) Technique with Reduced Dose Variations Using Idose Software

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| ABSTRACT
Radiation exposure to patients with higher cumulative effective doses on thorax CT scanning is very detrimental for cancer patients undergoing follow-up and raises the level of concern about the harmful effects of radiation doses received by patients. Reducing the tube voltage will reduce the radiation dose and image quality. To maintain good image quality, the iDose strength level is set. iDose is able to reduce radiation dose and improve image quality by maintaining low noise. Analyze the optimization of radiation dose and image quality in the thorax Low Dose CT Scan (LDCT) examination protocol with tube voltage settings and variations in the use of iDose software. This type of research is True-Experimental research with a Posttest-Only Control Design. The object used is a water phantom with tube voltage settings of 80 kVp, 100 kVp and 120 kVp and the use of iDoe 3 - 5. Assessment includes radiation dose, noise, SNR and NPS. After getting optimal results from setting the tube voltage and iDose strength level, these results were applied to a Thorax CT Scan examination in patients, and a subjective assessment of image quality was carried out. Reducing the tube voltage (kVp) from 120 kV to 80 kV was able to reduce the radiation dose by 69.8%, and reducing the tube voltage from 120 kV to 100 kV in the Thorax CT Scan protocol was able to reduce the radiation dose by 34.2 %. There is an influence of setting the tube voltage and setting the iDose strength level on the radiation dose and image quality of the Low Dose CT Scan of the Thorax. Setting tube voltage and high iDose strength levels can improve image quality in CT scans, characterized by decreasing noise and NPS values and increasing SNR values. Tube voltage settings and iDose level settings affect the radiation dose and image quality. The use of a tube voltage of 80 kVp and strength level iDose 5 is able to provide optimal radiation dose and image quality on Thorax Low Dose CT Scan.

| KEYWORDS

Thorax Low Dose CT Scan, tube voltage, iDose, radiation dose, SNR, Noise, NPS, Image Quality

| ARTICLE INFORMATION

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1. Introduction

CT Scan is a medical imaging tool that utilizes X-ray ionizing radiation. This examination aims to determine whether there are abnormalities in human organs using ionizing radiation without surgery so that a more precise diagnosis can be obtained (Hutami et al., 2021). Good CT scan image quality can provide accurate diagnostic results and can minimize errors in diagnosis resulting from poor image quality (Hutami et al., 2021) . The quality of the CT scan image must meet the clinical requirements of an examination in obtaining clear diagnostic information so that it can detect pathological abnormalities early (Elnour et al., 2017) .

With the increasing use of CT scans for medical purposes, the radiation dose received by patients has received serious attention (Kalender, 2014) . CT scanning has a much higher radiation dose than other radiology modalities (Bauhs et al., 2008) . And the higher the radiation dose the patient receives, the higher the risk of developing cancer (Brenner et al., 2001) . With CT scanning, the effective dose for chest examination can reach 5 to 7 mSv, whereas with conventional radiography, patients only receive 0.1 to

0.2 mSv (Bauhs et al., 2008) . The use of a relatively high exposure factor, namely a voltage of 120 kVp and a time multiplication of around 200 mAs, is the cause of the high radiation dose from CT scans. The tube current in a CT scan greatly influences the intensity of radiation received on the patient's body, while the tube voltage greatly influences the penetrating power of X-rays that pass through the patient's body (Silvia et al., 2013) .

Things that must be considered when involving radiation in the diagnostic process are the radiation dose received and the impact of radiation on the patient's body. When viewed in terms of radiation dose, the effects experienced by the body when exposed to radiation are deterministic effects and stochastic effects. A deterministic effect is one that occurs when a certain amount of radiation is applied to a specific organ or tissue of the body. Cell death due to radiation exposure above a predetermined threshold dose has a deterministic effect. Meanwhile, the stochastic effect is the impact that arises from getting a low portion of radiation throughout the body that is only experienced by people who get the dose after a certain time or by their offspring. Unlike the deterministic effect, the stochastic effect does not recognize a threshold dose. Stochastic effects can occur no matter how low the dose received (Protection & Hospitals, 2015) .

The International Commission on Radiological Protection (ICRP) has recommended the ALARA (As Low As Reasonably Achievable) method, which includes justification, optimization, and limitation, as a means to limit individual radiation exposure. This ALARA specifies that radiation exposure should be as low as possible, and the benefits must outweigh the risks. Radiographers must be able to optimize the parameters of the CT scan to obtain good image quality with the lowest possible radiation dose (Almohiy et al., 2016) .

During a CT scan of the chest, optimizing radiation is very important to reduce the risk of ionizing radiation for the patient. In this case, the radiographer is very responsible for providing the lowest possible radiation dose while obtaining optimal image quality (Agostini et al., 2019) . Radiation exposure received by patients with higher cumulative effective doses is very detrimental for cancer patients undergoing follow-up and increases the level of concern regarding the harmful effects of radiation doses received by patients and other health workers (Scharf et al., 2017; Singh et al., 2014) . To overcome concerns about the dangerous effects of radiation dose, it is necessary to reduce the radiation dose. The Nuclear Energy Regulatory Agency (BAPETEN) has currently issued a dose limitation regulation, namely the Decree of the Head of the Nuclear Energy Regulatory Agency Number 1211/K/V/2021 regarding the Indonesian Diagnostic Reference Level (IDRL) value where in non-contrast Thorax CT examinations the allowable dose limit is amounting to 11 mGy.

The American College of Radiology (ACR) and the Society of Thoracic Radiology have recommended that the LDCT parameter category with a Computed Tomography Dose Index volume (CTDIvol) value limit of 3 mGy, inclusion in patients with a standard body weight of 72.5 kilograms (kg), height 170 centimeters (cm), and with a body mass index (BMI) <25.08 (Kalra, 2017) . The need for low dose CT Scan techniques is necessary and must be able to be applied to all types of CT Scan equipment from different manufacturers (Radpour et al., 2020) . Many technologies have been developed for CT scan equipment by provider companies to meet the needs of this LDCT examination technique, including Auto mA technology, CARE kV, ultra fast ceramics (UFC) detectors, iterative reconstruction algorithms, and the use of pre-patient filters in X-ray tube systems (Kelcz et al., 1979; Setiawan et al., 2022)

Reducing this dose, however, in principle, by reducing the radiation dose, the resulting image quality will cause quite a lot of noise, and this can reduce the quality of the diagnosis on a CT scan. With the latest technology from Philips, with low doses, perfect image quality is obtained, and it is given simultaneously in CT Scan imaging. However, until now, there has been no data regarding a very optimal reduced dose without reducing image noise on a thorax CT scan.

Paying attention to the problem above, the author is interested in researching more deeply how effective the iDose software on the Philips Ingenuity CT Scan tool is used in producing an optimal image with the minimum possible radiation dose in the research "Optimizing Radiation Dose Using Analysis of CTDI Values and Image Quality in Low Dose CT Examination Techniques Thorax Scan (LDCT) With Reduced Dose Variations Using iDose Software ".

2. Literature Reviews

2.1 Thorax Anatomy and Physiology

The thorax is the area of the body that lies between the neck and abdomen. In front and behind, the thorax is flat and curved on the sides. The superior area of the thorax is connected to the neck via the superior thorax aperture, and inferiorly, it is separated from the abdomen by the diaphragm (Murad et al., 2022) . The parts of the thorax include the chest frame, thorax cavity, mediastinum, lungs, lung lobes, pulmonary bronchus, and lung hilus (Boll & Haaga, 2017; Golding, 1991; Murad et al., 2022) .

2.2 Thorax CT Scan Examination Technique

The first image of the mediastinum made is a coronal (AP) view of the thorax; then, an axial section is made from the apex of the lung to the diaphragm (Webb & Higgins, 2010) . Indications for a thorax CT scan include tumors, masses, aneurysms, hilus or mediastinal lesions, and aortic surgery (Webb & Higgins, 2010) . The preparation for the examination includes patient preparation, preparation of tools and materials, and preparation of contrast media and drugs (Murad et al., 2022; Puspita et al., 2018) . The examination technique is carried out with the patient positioned supine on the examination table with the head close to the gantry; Object position: The patient is positioned so that the midsagittal plane (MSP) of the body is parallel to the longitudinal indicator light. The patient's arms are placed above the head. The knees are propped for patient comfort. The patient is informed to take a breath when the examination begins (Webb & Higgins, 2010) . A chest CT scan can be performed using contrast or non-contrast media. Photos during CT scans of the thorax were made before and after the introduction of contrast media. For cases such as tumors, photos are made before and after the introduction of contrast media. The purpose of taking photos before and after inserting contrast media is to see if there is tissue that absorbs a lot of contrast, little or not at all (Golding, 1991) . In spiral technique scanning, if the patient can hold his breath for a long time, a single breathhold can be used (scanning is done in one breath hold, while if he cannot hold his breath for a long time, 2 or 3 scans can be done. Scanning is done during full inspiration (Webb & Higgins, 2010) .

2.3 Low Dose Thorax CT Scan

A low dose protocol can be defined as a protocol that aims to reduce the radiation dose given to the patient by changing parameters, especially kVp and mAs. (Azadbakht et al., 2021) . Low Dose CT is a Non Contrast CT Scan protocol which refers to a scanning technique that uses a tube current of less than 100 mAs. MSCT Thorax Scan with a low dose protocol is usually used when examining children, screening patients (for example: lung cancer), and repeat examinations for follow-up (Bhalla et al., 2019) . Parameter adjustments such as tube voltage and, decreased pitch, and increased slice thickness in the low dose protocol. There are several things that can be done so that the radiation dose can be reduced, namely by: adjusting the mAs according to the patient's body size, avoiding the use of high kVp (especially above 120), increasing the pitch, limiting the use of thin slice thickness, avoiding repeated use of CT (except needed), and use image reconstruction.

2.4 High Resolution CT Scan of the Thorax

HRCT (High Resolution Computed Tomography) was first established as a lung diagnostic technique in 1985. HRCT is considered capable of providing lung imaging with very detailed and quite good spatial and anatomical resolution. The HRCT technique is capable of displaying normal and abnormal pulmonary interstitium through visible morphological characteristics (Webb et al., 2014) . HRCT (High Resolution Computed Tomography) is a technique used for imaging the lung parenchyma. HRCT uses thin slices with a thickness of ≤ 1.5 mm and uses 3 data acquisition techniques, namely inspiration, expiration, and prone position, as well as high spatial reconstruction (bone), carried out without intravenous contrast (Mart\'\inez-Jiménez et al. , 2017) . In general, HRCT can be used in evaluating a variety of diffuse lung diseases. Indications for Thorax HRCT examination include detection of diffuse lung disease, characterization of diffuse lung disease, diagnosis and follow-up, and routine evaluation of abnormalities.

2.5 CT Scan Image Quality

CT Scan parameters have an influence on the quality of the resulting image on a CT Scan examination. Image quality is a concept that applies to all types of images, including images produced for medical purposes. In a CT scan, image quality is related to its usefulness in providing an accurate diagnosis, judging by how well the image represents the object being scanned. There are four main factors that influence the image quality of a CT scan, namely spatial resolution, contrast resolution, noise and artifacts (Seeram, 2016) .

2.6 Iterative Reconstruction (IR) Algorithm

The increasing use of CT scanning modalities has raised concerns about the potential biological effects resulting from radiation exposure. So as to increase awareness to be able to reduce the dose received by patients on a CT-scan examination. However, using a low dose will result in high noise in the image, so it is very important to consider various ways to reduce the resulting noise.

Since the 1970s, the Filtered Back Projection (FBP) algorithm has been the main reconstruction algorithm in CT. However, the use of FBP is still less effective because it produces quite a lot of noise and increases the radiation dose to the patient. Therefore, another algorithm is needed that is able to produce images with good quality while taking into account the reduction of radiation dose. Recently, Iterative Reconstruction (IR) algorithms have been developed to reduce image noise when using lower exposure factors and, at the same time, improve image quality and reduce artifacts in the presence of metal implants, beam hardening effects, and photon starvation (SEERAM, 2016) .

There are several IR algorithms available from CT manufacturers based on different physical methods and concepts. This algorithm is divided into three categories, namely Iterative methods without modeling, Statistical methods with modeling of photon counting statistics, and Model-based methods that exceed statistical modeling. There are several IR algorithms available from CT manufacturers, such as GE Healthcare, Siemens, Philips Healthcare, and Toshiba Medical. Each vendor offers an IR algorithm that provides better image quality with reduced noise in low-dose CT imaging compared to the FBP algorithm. In general, there are three steps in the IR algorithm reconstruction process, including input, IR Loop, and output (Seeram, 2016) .

2.7 Noise, Signal-to-Ratio (SNR) and Noise Power Spectrum (NPS)

Noise in a CT scan is an unwanted pixel value but rather an image inhomogeneity. Often, noise is defined as the rough appearance of an image in a cross-sectional image. This is quantum mottle. This noise can simply be described as “salt-and-paper” grains, which will be clearly visible in under-exposed images (Romans, 2011) . If a CT scan image is made from an object that has a uniform density, such as a water phantom, then all measurement points in the image should, in theory, be the same because the object being measured is the same, but in practice, they are not the same. Fluctuations of the CT Number at adjacent points indicate noise in the image. The measured standard deviation indicates the amount of variation between pixel values indicated by the Region of Interest (ROI). The standard deviation measured by the ROI is known as phantom uniformity, which indicates the degree of image noise. The smaller the standard deviation, the smaller the noise value and the better the contrast resolution capacity (Romans, 2011) . This also follows from the influence of noise level, which will affect resolution contrast.

In a CT scan, the number of X-ray photons detected per pixel is also often referred to as signal-to-noise (SNR). This SNR can simply be measured by measuring the signal to noise ratio (SNR) by comparing the level of the photon signal to the background noise level. The higher the ratio, the lower the noise produced (Kenneth A Miles, James D Eastwood, 2007) . This noise is influenced by several factors, including mAs, Slice Thickness, Patient Size, Reconstruction algorithm, noise matrix, magnitude and texture (Bushberg et al., 2012) .

Noise Power Spectrum (NPS) is a useful measure providing a more complete description of noise than a simple standard deviation as it evaluates noise in terms of both noise magnitude and noise texture. NPS describes the variation of noise as a function of the spatial frequency and the texture characteristics of the noise. When combined with variable doses, it can be used for comparisons between scanners and protocols and has proven useful in translating protocols from a single CT scanning platform. (Bushberg-The Essential Physics of Medical Imaging_2ed.Pdf, 2002)

In Figure 2.3. it can be seen that the two CT-Scan images of the test object have the same variance value (σ2) in the background, but there is a marked difference in the appearance of the noise. Even though the amount of noise (variance) is the same, the dependence on the frequency of the noise is different. The frequency dependence of noise can be characterized by the noise power spectrum NPS (f), for 2D images I (x, y)2 can be formulated in the equation (Bushberg et al., 2012)

If the noise in each pixel of a 2D image does not depend on the noise values in the surrounding pixels, then there will be no noise correlation, and the NPS (f) will basically be a flat and horizontal line (Figure 2.4). This type of correlated noise is called white noise. Processing on the imaging system results in some blurring. This blurring means that noise from a detector element can leak into adjacent detector elements, causing noise correlation between adjacent pixels in the image. There are many types and causes of noise correlation (including anticorrelation, where positive noise in one pixel will tend to induce negative noise values in adjacent pixels), including reconstruction algorithms in tomography, but in general, the result of noise correlation is that NPS does not produce white noise and forms The NPS(f) for a particular imaging system is a technical description of the broader noise texture (see Figure 2.5).

2.8 CTDI Radiation Dosagevol

The radiation dose in Multislice CT is much greater (about 10%) than single slice CT following the change in the size of the focal spot of the X-ray tube, and the amount of radiation in MSCT is known as the "Over-Beaming Phenomenon" (24). The amount of radiation dose received by the patient when using the MSCT modality is very necessary to know in order to be able to consider the benefits and risks that the patient may receive during the MSCT examination patients (SEERAM, 2016) .

Several methods are used to measure CT scan doses, including using the pencil ionization chamber method or using Thermoluminisence Dosimetry (TLD) which is calculated using the CT Dose Index (CTDI) and multi scan average dose (MSAD) methods. CTDI is a method of calculating the patient's average dose in one scan, while MSAD is a method of calculating the average patient dose in multiple scans on a CT scan (SEERAM, 2016) .

Another method for calculating the effective dose involving the conversion factor of a general anatomic region is also described in the European Guidelines on Quality Criteria for Computed Tomography, which is based on the work of Jessen et al. In this approach, CTDIw and distance are used to calculate the Dose Length Product (DLP). The dose length product is measured in mGy.cm. The mathematical equation used in DLP calculations (SEERAM, 2016; Tack et al., 2012)

The resulting CTDIw value is then multiplied by a specific conversion factor to calculate the effective dose. These conversion factors range 0.0023 mSv/mGy cm for the head, 0.017 mSv/mGy cm for the chest, and 0.019 mSv/mGy cm for the pelvis. For example, a chest scan performed with a CTDIvol = CTDIw / pitch factor 50 scanner at 120 kVp, 250 mAs, 5-7 mm collimation, and a pitch of 1, the CTDIW would be 15 MGy, and the CTDIvol would be 15 mGy. If it is assumed that the scan length is 25 cm, the DLP will be 375 mGy cm (McNitt-Gray, 2002) .

2.9 Water Phantoms

Phantoms and CT Scan equipment can be organized into three general categories, namely image quality phantoms, geometric phantoms and quantitative phantoms and dosimetry and instrumentation. Many of these Phantoms are available by vendor and packaged in a purchase agreement. Water phantom is used for quality control measurements on CT Scan planes for CT Number and Linearity CT Number measurements. And all vendors provide necessary procedures and phantoms. Usually, the phantom for some CT scans is an acrylic cylinder filled with water with a diameter of 20 cm. The phantoms provided by the respective manufacturers are easy to use as they can be easily mounted in a cradle for a head CT scan. The water phantom must be filled with water so that it can be used for dimensional scanning and CT scan construction. The cross-section of the water phantom must be circular. The wall cross-section must be 39 Plexiglas material less than 1 cm thick. Other materials may be substituted for the siding if the difference in the linear attenuation coefficient of the water can be shown to be smaller than that of Plexiglas for all scanning operating conditions.

3. Methodology

3.1 Type and Research Design

This research is a True-Experimental research with a Posttest-Only Control Design. This research aims to determine the effect of using iDose with variations in tube voltage and mA, which are modulated and analyzed analytically and statistically to evaluate how effective the use of iDose software is in reducing radiation dose and image quality in the form of Noise, SNR, NPS texture values. This research began with a Scanning Water Phantom with several voltage variations (80,100,120) and iDose variations. Then, each group analyzed its CTDI vol value, analyzed the image quality and measured the noise, SNR and NPS values. Then, for noise texture analysis, one image from each group was selected and then analyzed using IndoQCT. Then, after getting a baseline picture which is good from the protocol, then the image quality results from a low dose protocol with good image quality are used as a protocol for thorax CT scans and analyzed subjectively. The design is as in the following image.

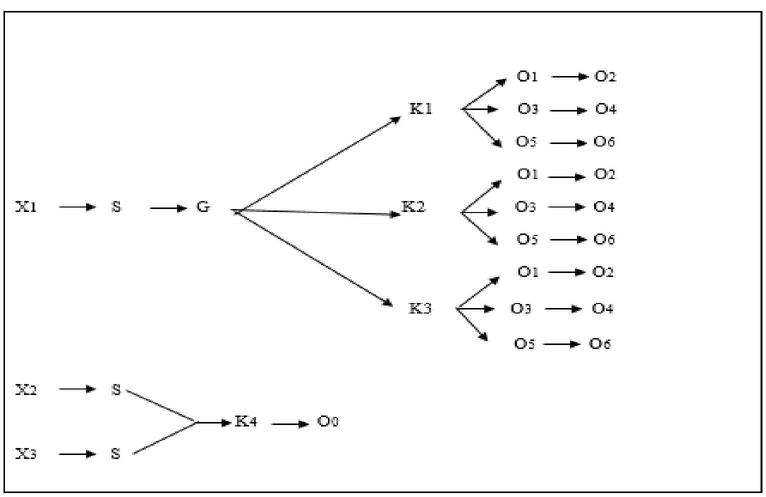

Figure 1. Research Design

3.2 Population and Sample

The population in this study were water phantom and Thorax CT Scan patients using voltage variations and iDose, which had the best results from water phantom analysis. The research samples in this experiment were 9 water phantom images using the Thorax CT Scan protocol at variations of kV 80, 100, 120 and iDose levels 3 - 5 and images of 20 Thorax CT Scan patients where 10 patients used the optimal parameters of the analysis results on the phantom and 10 patients using standard CT Scan Thorax parameters.

The criteria for sampling included patients with non-contrast or contrast thorax CT scans, adult patients from outpatient and inpatient care, male and female gender, patients who were uncooperative in examination, and pediatric patients.

3.3 Tools and Materials

The equipment used in this research is a CT Scan machine Brand: Philips Ingenuity 128 slice, Power supply: ≤ 105 kW, Heat Storage: 8 MHU, Tube voltage range: 80, 100, 120, 140 kV, mA range: 20 - 665 mA. Image quality measurements were carried out by scanning the Water Phantom using a Philips workstation and data processing with IndoQCT software. The materials used in this study were 9 CT-Scan images from water phantom scanning and Thorax CT Scan images from 20 patients, where 10 patients used optimal parameters from the water phantom analysis results and 10 patients used standard Thorax CT Scan parameters.

3.4 Data Processing and Analysis Techniques

This research data management is carried out through the data checking (editing) stage in checking the measurement data during the research and during the research to ensure that there is no incomplete data. The coding stage makes it easier to read, the data entry stage (entering), and the tabulating stage for compiling and calculating research data to be presented in tables for easy reading and analysis.

Data analysis was carried out by describing the characteristics of each research variable, which were presented in a frequency table. After processing data on noise values, SNR, and NPS using indoQCT software, then presented using tables and comparison graphs. Furthermore, the creation of a script for calculating image quality using the noise calculation method, signal to noise ratio and noise power spectrum with IndoQCT is presented in the form of an overview in the form of noise textures and NPS graphs and then for the analysis of recorded CTDIvol data presented in the form of a bar chart. Furthermore, the image results from Low Dose CT Scan Thorax scanning in patients were assessed subjectively by 2 radiologist respondents; the results were carried out by the Kappa test to determine whether there was agreement between the several respondents, then processed and analyzed.

4. Results and Discussion

4.1 Results on Water Phantom

CTDIvol and DLP measurements are carried out by recording the radiation dose produced and displayed on the CT Scan tool console immediately after the scanning process has been completed on the water phantom. CTDIvol and DLP measurements at various tube voltage and iDose strength levels are shown in the following table:

Table 1 CTDIvol and DLP measurement results

IR	tube voltage (kV)	CTDIvol (mGy)	DLP (mGy.cm)
iDose 3	80	4	85.4
	100	8,6	184
	120	13.2	282
iDose 4	80	4	85.3
	100	8,7	186
	120	13.1	280
iDose 5	80	4	85.3
	100	8,7	186
	120	13.2	283

Based on this table, it is known that using a lower kV with a modulated mAs value can reduce the radiation dose. With a comparison percentage of standard kV usage with 80 kV, it decreased by 69.8%, while at 100 kV, it decreased by 34.2%. Therefore, it is necessary to select the optimal kV, taking into account the quality of the resulting image. From the results of the research carried out, a two way anova test was carried out, and a regression analysis was obtained between tube voltage and iDose on the CTDI radiation dose value, namely the Idose coefficient of 0.017, with a t stat value = 0.626 < t table = 1.96 and a prob value = 0.555 > alpha = 0.05 means there is not enough evidence that the difference in idose affects the CTDI value. The voltage coefficient is 4,583, with a t stat value = 172,024, t table = 1.96 and a prob value = 0.00 < alpha = 0.05, meaning that an increase of 20 kVp will increase CTDI by 4,583 points assuming other variables are constant. This proves that there is a close relationship between tube voltage and radiation dose value.

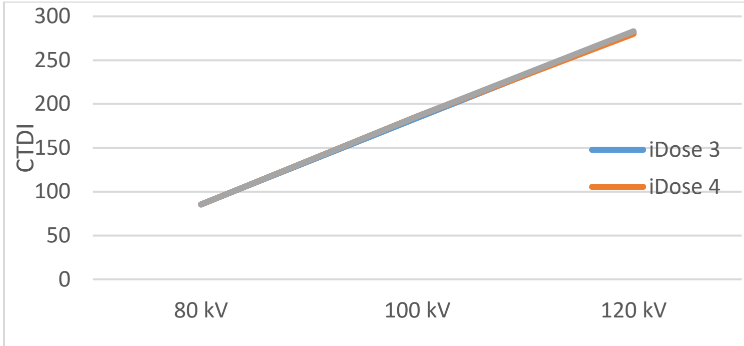

Figure 2. Graph of the influence of tube voltage on chest CT scan radiation dose

Based on this figure, the radiation dose increases, followed by increasing tube voltage (kVp). The highest radiation dose was produced from a tube voltage of 120 kVp, namely 13.2 mGy, while the lowest dose was obtained when using a tube voltage of 80 kVp, namely 4 mGy. The linear equation has a positive value, which means that the higher the tube voltage setting used, the higher the radiation dose obtained.

4.2 Noise Measurement Results

Noise values were measured using IndoQCT software by calculating the standard deviation value of the CT mean value in the ROI placed in the center of the phantom image. When simultaneously measuring the CT mean value, the standard deviation value of the CT mean value is obtained, which is the image noise value.

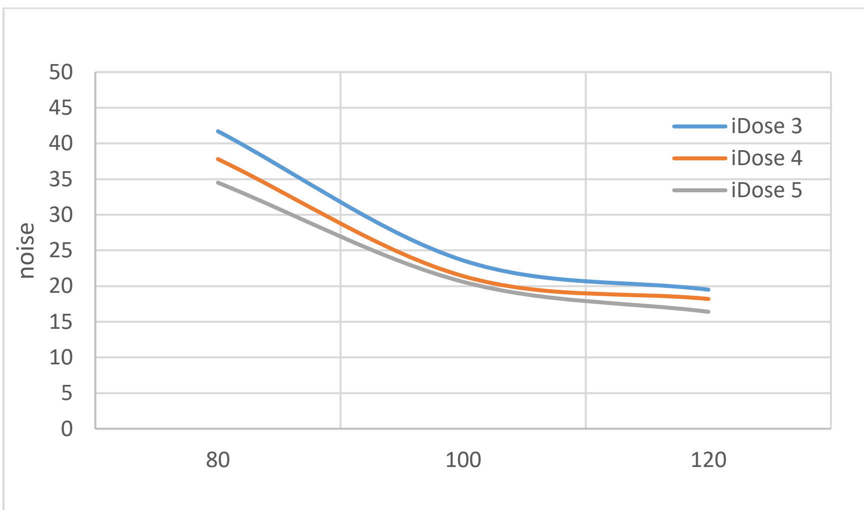

Figure 3 Graph of the Effect of tube voltage on Noise

Based on the figure, the noise decreased, followed by an increase in the tube voltage (kVp) setting and an increase in the iDose level. The lowest noise was obtained at 41.71 at the 80 kVp tube setting at iDose 3. And the lowest noise was obtained at 120 kVp voltage at the iDose 5 level, which is equal to 16.4. Figure 4.4 also shows a linear equation which has a gradient with a negative value, which means that the greater the tube voltage setting, the smaller the noise value obtained. From then on, a normality test is carried out, and because the results are normally distributed, a homogeneity test is carried out. From the results of the values sign = 0.365 then, it is considered that the data variance is a homogeneous variant.

Table 2. Regression Test Results

	B	std. error	*sign*
Noise	50,363	1,452	0.00
iDose	-2,222	,493	0.00
Voltage	-9,970	.493	0.00

4.3 Results of Measurement of Signal to Noise Ratio (SNR)

The measurement results show that the highest SNR results are produced from a tube voltage of 120 kVp, namely 42.521 at iDose level 5, while the lowest SNR value is produced at a tube voltage of 80 kVp at iDose level 3.

Table 3. SNR Value Measurement Results

Tube Voltage	SNR		
	iDose 3	iDose 4	iDose 5
80 kV	16,383	16,394	18,228
100 kV	17,738	27,431	25,362
120 kV	42,521	45,465	45,871

The research results also show that the SNR value increases with each increase in tube voltage on each iDose strength level graph. The SNR value increases with each increase in iDose strength level. SNR is the ratio of signal strength to noise strength. The less noise in the image, the higher the resulting SNR value. Based on the SNR formula, the SNR value is influenced by the signal value and noise value in the image. SNR is the signal value of each image pixel, the average of the background signal values, and the standard deviation of the uniform background in the image. Noise measurements with SNR with changes in tube voltage found that the higher the voltage given, the greater the SNR value obtained, indicating good quality image results. The higher the resulting SNR value, the better the image quality.

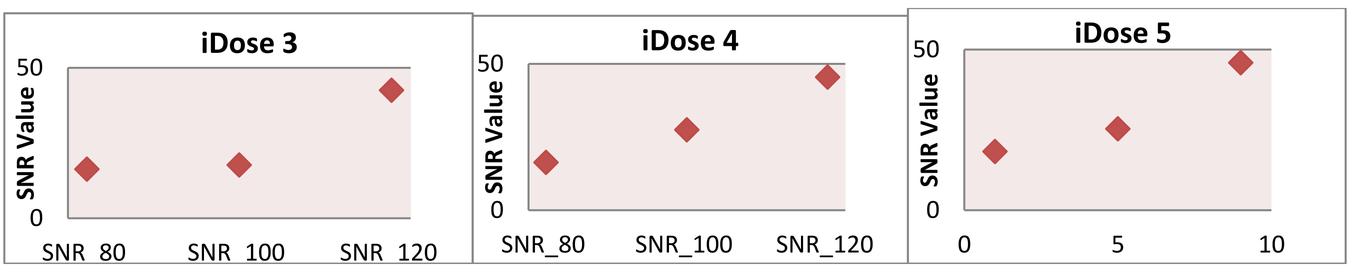

Figure 4. SNR Value at Each iDose Level (a) iDose 3, (b) iDose 4, (c) iDose 5

4.4 Noise Power Spectrum (NPS) Measurement Results

Noise level measurements in the images in this study were also carried out with NPS (Noise Power Spectrum). NPS is a useful measure providing a more complete description of noise than simple standard deviation. NPS describes the variation of noise as a function of spatial frequency and the texture characteristics of the noise (Boone et al., 2012) .

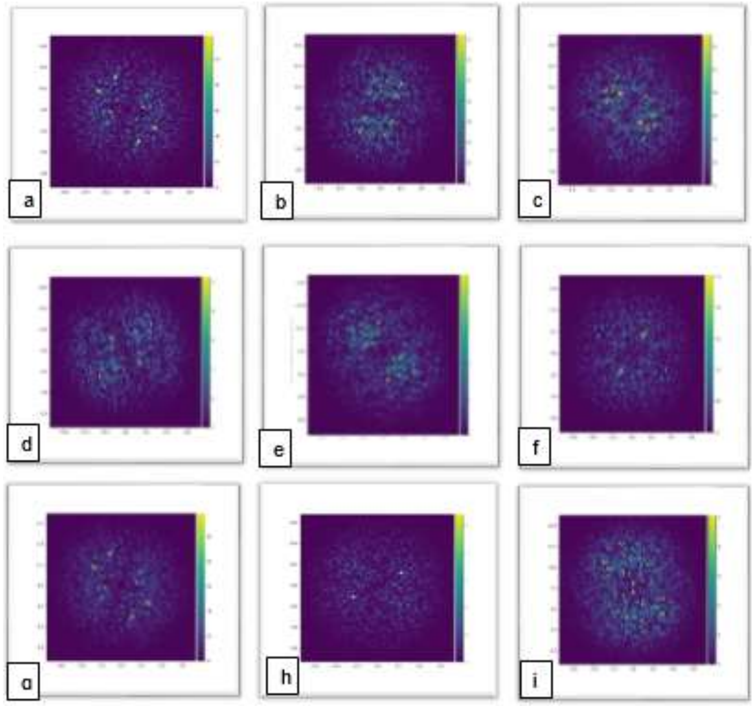

Figure 5. Noise texture in each image according to iDose level and tube voltage: a) iDose 3, 80 kV, b) iDose 3, 100 kV, c) iDose 3 120 kV, d) iDose 4, 80 kV, e) iDose 4 , 100 kV, f) iDose 4, 120 kV, g) iDose 5, 80 kV, h) iDose 5, 120 kV, i) iDose 5, 120 kV

This image is the result of an ROI image taken from the Phantom image in Figure 1b. Images a to i are images of the same Water Phantom, taken with exposure factors sequentially 80 kV, 100 kV, 120 kV and sequentially at iDose 3, iDose 4 and iDose 5 levels. In the nine images, it can be seen that the tube voltage changes, and the iDose produces changes in noise texture. The next step is to measure NPS by performing a Fourier transformation on the average pixel value in each ROI.

The NPS curve describes how a CT Scan system processes noise variations. It can be seen from the curve that noise with low spatial frequency (large size) and high spatial frequency (small size), which is at the right and left ends of the curve, has a low NPS, which means that the noise is not processed optimally by the detector. Noise with moderate spatial frequency (the middle part of the curve) has a high NPS, which means that the noise is maximally processed by the detector.

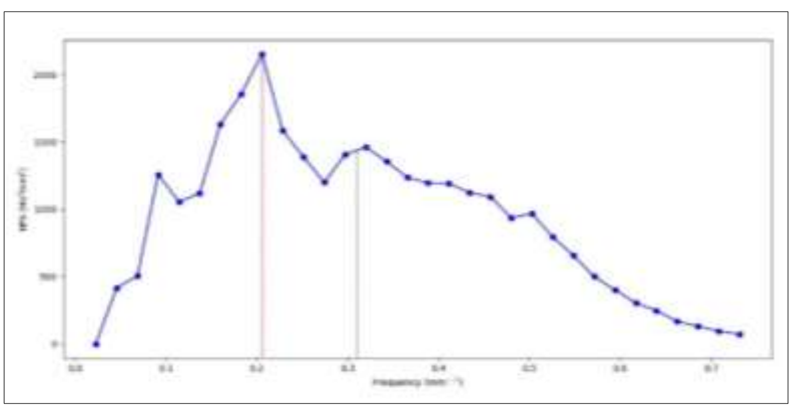

Figure 6 NPS Measurement Results Curve

This study shows that the highest NPS result was produced from a tube voltage of 80 kVp, namely 2151.97 at the iDose 3 level, while the lowest NPS value was produced at a tube voltage of 120 kVp at the iDose 5 level.

Table 4. NPS Value Measurement Results

Tube Voltage	NPS		
	iDose 3	iDose 4	iDose 5
80 kV	2151.97	1750.71	1699,42
100 kV	1004,41	771.43	527,93
120 kV	458.57	338,48	267.19

4.5 Optimal Tube Voltage Selection and iDose Strength Level Results

Based on the results of the above study, it can be concluded that the voltage of the tube used produces a radiation dose, namely CTDIvol, which does not exceed the recommendations from BAPETEN for Low Dose Thorax CT Scan or Thorax CT Scan without contrast, namely 11 mGy. Whereas the noise value produced exceeds the BAPETEN standard, which is 2.0, but can be reduced by iDose treatment to produce images that have optimal quality. Based on this research on the water phantom, it can be concluded that setting the tube voltage and setting the iDose strength level that is able to provide optimal radiation dose and quality is setting the tube voltage 80 kVp and using the strength level iDose 5.

Table 5. Image measurement results on tube voltage 80 kVp

Parameter	iDose 3	iDose 4	iDose 5
Noise	41.71	21.4	16.4
SNR	16,383	16,394	18,221
NPS	2151.97	1750.71	1699.41

4.6 Results of Subjective Evaluation of Thorax CT Scans in Patients

Thorax CT Scans on patients in this study were carried out using the results of variations in tube voltage and optimal iDose strength levels from the results of research on water phantoms, namely tube voltage 80 kVp and iDose levels 5 and 10 patients using standard parameters usually carried out in CT Scan examinations. The thorax is tube voltage 120 kVp and iDose level 4. The image results from using these two parameters are displayed in the questionnaire attachment in the image of the mediastinal window and lung window in the axial section, as in Figure 7.

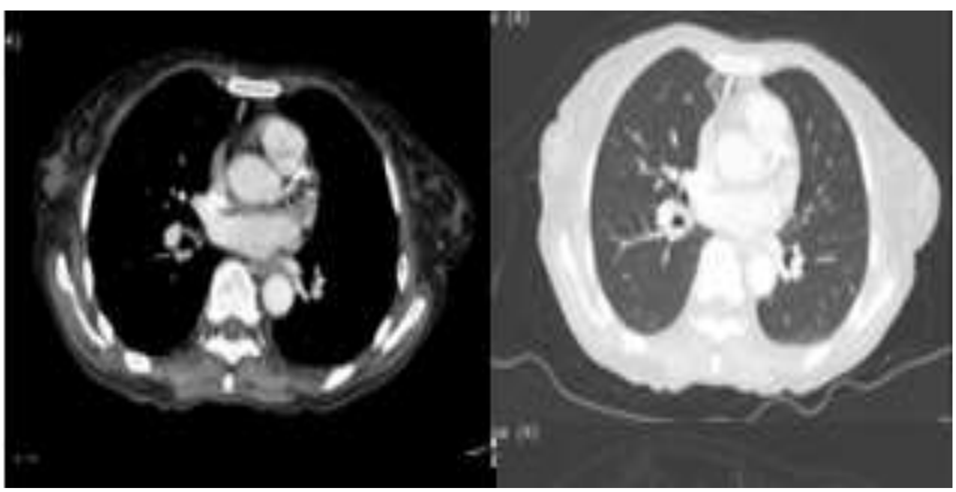

Figure 7 Thorax CT Scan image displayed on the questionnaire sheet (a) mediastinal window, (b) lung window.

Conformity analysis between respondents was carried out to assess the subjective assessment results of image information on Thorax CT scans. The CT scan image assessment was carried out by 2 radiologists who are experienced in the CT scan field. Evaluation of all images carried out by the respondent disguised the identity of the patient. Respondents assessed the CT scan images of 20 patients, of which 10 patients were CT scans with the new research parameters and 10 images from CT scan patients with standard parameters. Respondents filled out a questionnaire in the form of an image scoring table with a scoring system to see the anatomical characteristics of Thorax CT Scan images in the Lung window and Mediastinum window. Respondents filled out the questionnaire using a scoring system (score 1 = very unclear, score 2 = less clear, score 3 = clear, score 4 = very clear). by assessing the results of Thorax CT Scan images using the yield parameters, namely tube voltage 80 kVP and iDose level 5 and assessing the results of Thorax CT Scan images using standard parameters, namely tube voltage 120 kVp and iDose level 4. The images displayed on the questionnaire sheet are taken in sections axial image of the thorax at 9-10 thorax height, or if there are abnormalities or lesions, the image display containing the lesion is displayed on the questionnaire sheet and the assessment results of the two respondents.

The results of the assessment of the two respondents were analyzed using statistical methods using IBM SPSS Statistics 26.0. The method used is Cohen's Kappa test, which aims to determine the correlation of agreement on the similarity of perceptions between the two respondents in assessing the image. Cohen's Kappa test is performed first for the results of image assessment using yield parameters. The results of the Cohen's Kappa test for image information, which was assessed at 0.630 for respondent one and respondent two, showed the following results.

Table 6. Cohen's Kappa Test Results

Respondent Assessment	Kappa Value	Meaning of agreement
Result Parameters	0.630	Strong (Good)
Standard Parameters	0.630	Strong (Good)

Based on the results above, a similarity is obtained in the results of the Kappa test, where for the results of the parameter assessment the results have a kappa index of 0.630, which means it has a strong or good validation level and the standard parameter assessment results also have a kappa index of 0.630, which means a strong or good validation level between the 2 respondents.

5. Discussion

5.1 Effect of tube voltage settings and iDose levels on CTDI and DLP values

Dose is the amount of radiation contained in a radiation field that is received by the material it passes through so that it affects an organism biologically. BAPETEN implements a national dosage standard called Dose Reverence Level (DRL), which is a dose amount determined to be a reference in identifying the dose received by the patient so that it can optimize the dose received by the patient. This research refers to BAPETEN Perka Number: 1221/K/V/2021 of 2021, where BAPETEN determines IDRL to calculate and report doses as an indicator for administering radiation doses in carrying out diagnostic examinations. Calculations and reporting on CT Scan examinations can be done in two ways, namely direct and indirect methods. In this research, researchers used an indirect method, namely measurements carried out by analyzing certain quantities that are easy to measure and read or have been installed in the modality used. The indicator installed on the modality is called the dose indicator, and the CT Scan modality shows the dose value, namely Computed Tomography Dose IndexVolume (CTDIvol) and (DLP). The results of this research showed that the CTDIvol and DLP values increased as the tube voltage (kVp) settings increased. The lowest CTDIvol and DLP values in the results of this study were 4 mGy at a tube voltage setting of 80 kV at iDose 3, iDose 4, and iDose 5 settings and a DLP value of 85.3 m.Gy.cm at a tube voltage of 80 kV and strength levels iDose 4 and iDose 5. Meanwhile, the highest value in the results of this study was 13.2 mGy at the tube voltage setting of 120 kV on iDose 3 and iDose 4.

The radiation dose is greatly influenced by the energy of the electrons hitting the anode. These electrons will affect the energy of x-ray photons in penetrating organ tissue. In addition, the radiation dose is directly proportional to the square of the tube voltage (kVp). So, in choosing a high voltage tube setting, it can provide a higher radiation dose. In this study, the reduction of tube voltage (kVp) from 120 kV to 80 kV reduced the radiation dose by 69.8%. Decreasing the tube voltage from 120 kV to 100 kV in the Thorax CT Scan protocol was able to reduce the radiation dose by 34.2%.

According to the literature, there are several factors that need to be considered which can affect the radiation dose on a CT scan, namely exposure factors, number of detectors, x-ray beam collimation, patient centering, pitch, and algorithm reconstruction (SEERAM, 2016) . The Iterative Reconstruction (IR) algorithm reconstruction method is a development of the traditional reconstruction method of Filtered Back Projection (FBP), which was developed to maintain image quality on CT scans with low exposure factors. Low exposure factors can be obtained by reducing tube voltage (kVp), tube current (mA), and scan time (s) or a combination of the three, as in the study of Brady et al. (2014) and Gervais & Thrall (2012); optimize the exposure factor by reducing the tube voltage (kV) (Brady et al., 2014; Singh et al., 2014) .

And in the research of Halinda et al. (2019), they also optimized the exposure factor by reducing the tube voltage (kVp). The decrease in tube voltage causes the X-ray photon energy to penetrate the organ to decrease so that the radiation dose given to the patient will also be reduced (Fatmayanti et al., 2019). The results of the three articles show that reducing the exposure factor and using an iterative reconstruction algorithm does not reduce the quality of the resulting image because the IR algorithm plays a role in maintaining image quality when using a low exposure factor to minimize the radiation dose received by the patient.

The results of this study are in accordance with previous literature, which states that the tube voltage value is the intensity of x-ray photons and the ability of x-rays to penetrate organs. Tube voltage will determine the energy and intensity of x-ray photons and is directly related to the radiation dose. Experimentally, the change in radiation dose was between 2.5 to 3.1 times. So, the higher the tube voltage used, the higher the radiation dose produced.

5.2 Influence of Tube Voltage and IDose Level on Noise

From the results of this study, it was found that the noise value decreased as the tube voltage setting increased and the strength level iDose changed. The lowest mean noise value obtained was 16.4 at the 120 kV tube voltage setting and iDose 5 level, while the highest mean noise value obtained was 41.7 at the 80 kV tube voltage setting and iDose 3 level. These results indicate that there is a change in the value noise when reducing tube voltage and applying dose reduction. From these data, it appears that the smaller the tube voltage value used, the higher the noise generated, and the greater the dose reduction setting used, the noise value will also increase.

Noise in CT scan images is related to the number of X-ray photons that contribute to each small area of the radiographic image, whereas in CT scan images, x-rays contribute to detector measurements and not individual pixels. So, noise in CT images is associated with the number of X-rays that contribute to each detector measurement and changes in the quantity and quality of X-rays can affect the noise level in the image (Goldman, 2007) .

The increase in tube voltage causes a decrease in the noise value. Because with increasing tube voltage and slice thickness, more photons are produced in the X-ray tube, so the number of received photons also increases. This causes reduced noise. Attenuation is a reduction in the intensity of a radiation beam when it passes through an object; some photons are absorbed, but others are scattered. After experiencing this attenuation, the intensity of the x-rays will decrease after penetrating the object. The intensity of the x-ray radiation depends on the number of photons produced by the x-ray tube; because the voltage of this tube has a homogeneous image and high penetrating power of x-ray energy, a good noise level value is obtained so that it can help accuracy in making a diagnosis. In general, it is important to relate the tube voltage to the attenuation coefficient on the photon energy to reduce contrast in the soft tissue and to produce high radiation in the detector. These reasons are important for optimum detector response, such as to reduce artifacts caused by changes in the thorax, which can be small changes in attenuation in soft tissues and to minimize artifacts resulting from beam effects.

The use of tube voltage, iDose strength level and other things that influence the noise value need to be optimized so that the noise value formed during reconstruction can be reduced so that the body part that is the object of examination can be diagnosed properly. According to the regulation of the Nuclear Energy Supervisory Agency (BAPETEN) no. 2 of 2018 concerning suitability tests for diagnostic and interventional radiology X-ray aircraft, the permitted noise tolerance limit is ≤ 2 HU (BAPETEN, 2018) .

Water phantom images that have been evaluated for image quality in the different tests carried out, the image noise value for each combination of tube voltage variations and iDose level shows a significance value of <0.000 (P-value <0.05). This shows that the use of iDose with higher strength will further reduce noise in the image, and it can be concluded that there is a difference in noise with variations in tube voltage settings and iDose strength levels in CT Scan images.

5.3 Influence of tube voltage and iDose Level on SNR

The quality of the CT image in the selection of protocol parameters used in CT Thorax examination for variations in kVp and iDose, then the minimum value is 16.383 at 80 kV on iDose3, and the maximum SNR value is at 120 kV on iDose5, namely SNR 45.871. The HU value increases due to changes in the kV value but does not experience a significant change when the iDose changes. For SNR image quality parameters, there was an increase due to changes in kV values and changes in iDose.

From Irsal et al. research (2021), the analysis results for the SNR image quality parameters increased due to changes in kV values and changes in iDose. Determining optimization in the head CT examination protocol can use SNR image quality measurements, whereby increasing the SNR value, it is certain that the radiographic image will experience an increase in quality with a decrease in the noise value, which will cause a decrease in image quality, but increasing the SNR value will certainly increase the kV parameter and mAs.

5.4 Effect of Tube Voltage and iDose on NPS

In research by Doharmansyah et al. (2019), changing the tube voltage from 80 kV to 130 kV reduces the area under the noise power spectrum (NPS) curve, which means that the greater the kV value, the lower the noise level as measured by the Noise Power Spectrum (NPS). The NPS curve is parabolic, with 2 slopes, namely at low spatial frequency and high spatial frequency, which means the CT-Scan system does not process noise with low and high spatial frequencies optimally. The NPS curve can be used to see the noise level and noise texture (Putra et al., 2020) . The NPS value is inversely proportional to the number of incoming X-ray fluences, which is also proportional to the radiation dose, so measuring NPS in clinical conditions is very necessary (Solomon et al., 2012) .

In this study, it was found that the NPS value decreased with increasing tube voltage and a significant increase in iDose strength level. Where the minimum NPS value at tube voltage 120 kVp and iDose level 5 was 267.19, while the maximum NPS value at tube voltage 80 kVP and iDose level 3 . And from this research, it was found that by increasing the iDose level, the ability to reduce image noise will also increase.

5.5 Recommended Combinations For Setting Tube Voltage And iDose Strength Levels

In this study, it was concluded that the tube setting and iDose strength level in research using a water phantom with the Thorax CT Scan protocol that was able to provide optimal radiation dose and image quality was the tube setting of 80 kVp and iDose level 5.

In this study, the tube voltage setting that provides the lowest radiation dose is the tube voltage setting of 80 kVp. However, a tube voltage of 80 kVp provides decreased image quality compared to 120 kVp and 100 kVp. This is indicated by higher noise values, lower SNR values and high NPS values, and this states that the noise at the 80 kVp tube voltage setting is higher. However, with iDose's iterative reconstruction, the resulting image quality experiences a different increase and a different noise value at each iDose strength level. This increase in optimal image quality can be seen in the results of setting the iDose strength level, where in the table, it can be seen that the iDose 5 level has better image quality because it displays less noise than iDose 3 and iDose 4.

This is also reinforced by the spatial frequency results from the NPS measurement results. The greater the Spatial frequency value, the lower the noise value produced. From the data below, the highest spatial frequency value is obtained at the tube voltage setting of 80 kVp and iDose 5 level. With a peak shift in the noise power spectrum (NPS) curve, which shifts towards higher frequencies, the noise value is lower for setting tube voltage 80 kVp and at level setting iDose 5.

Based on the above research results, it can be concluded that this study obtained an exposure factor that resulted in the optimal dose and image quality on a Thorax CT scan, namely 80 kVp with iDose level 5. Indirectly, the use of iDose iterative reconstruction was able to reduce radiation dose and still maintain image quality remains good and acceptable. By reducing this dose, the patient will receive radiation exposure that is not excessive and in accordance with Bapeten's recommendations so that the chances of biological effects occurring in patients due to Thorax CT scan radiation exposure can be reduced. This is in accordance with the principle of radiation dose optimization, which is intended to ensure that the radiation dose given to patients is kept as low as possible (ALARA). Basically, the principle of optimization refers to reducing the radiation dose while maintaining the image quality needed to make a diagnosis (Padole et al., 2015) .

Efforts to optimize radiation dose, which is often associated with a decrease in image quality, can now be done using iterative reconstruction such as iDose. So, the increase in noise carried out on a decrease in tube voltage (kVp) can be corrected by using this reconstruction.

6. Conclusion

In setting the tube voltage and iDose strength level setting it can affect the radiation dose and image quality of Low Dose CT Scan Thorax. At a low tube voltage setting, it will reduce the radiation dose and reduce the quality of the CT scan image. Setting a high iDose strength level can improve image quality on a CT scan, marked by a decrease in noise and NPS values and an increase in SNR value.

The CTDIvol and DLP values increase as the tube voltage (kVp) setting increases. The lowest CTDIvol and DLP values in the results of this study were 4 mGy at 80 kVp tube voltage settings at iDose 3, iDose 4, iDose 5 settings and DLP values of 85.3 m.Gy.cm at tube voltage 80 kV and iDose 4 and strength levels iDose 5. Meanwhile, the highest value in the results of this study was 13.2 mGy at the tube voltage setting of 120 kVp on iDose 3 and iDose 4. Reducing the tube voltage (kVp) from 120 kV to 80 kV reduced the radiation dose by 69.8%, and reducing the tube voltage from 120 kV to 100 kV in the Thorax CT Scan protocol was able to reduce the radiation dose by 34.2%. Setting the tube voltage and using the iDose strength level can influence the radiation dose on a CT scan.

Setting a high tube voltage and a high iDose strength level will improve the quality of the image on a Thorax CT scan, marked by a decrease in the noise value. Setting a high tube voltage and setting a high iDose strength level will improve the quality of the image on a Thorax CT Scan, marked by an increase in the value of the signal to noise ratio (SNR), which means reduced noise in the CT Scan image. Setting the iDose tube voltage and strength level affects the Noise power Spectrum (NPS) value, where the higher the iDose tube voltage and strength level, the NPS value decreases, which means a decrease in the noise value in the image.

Optimization of radiation dose and optimal image quality is obtained by setting the tube voltage to 80 kVp and iDose strength level 5. A decrease in tube voltage is followed by a decrease in radiation dose. Setting the tube voltage to 80 kV and the strength level iDose 5 on the Thorax CT Scan image, the patient was able to visualize the anatomical structures, soft tissue, lungs and lesions well; this was proven by the subjective assessment of the Thorax CT Scan results using these parameters.

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