International Journal of Allied Medical Sciences and Clinical Research (IJAMSCR)

ISSN: 2347-6567

IJAMSCR |Volume 8 | Issue 2 | Apr - Jun- 2020
www.ijamscr.com

Research article *Medical research*

Optimization of radiation dose for optimal image quality in head CT examination

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ABSTRACT

Indonesian Nuclear Energy Regulatory Agency (Bapeten) has set the head CT DRL value of 50 mGy. CT parameter settings will affect the dose and image quality. Tube current, rotation time, and pitch parameters that used in head CT protocol with infarction case in GoetengTaroenadibrata General Hospital produced a displayed CTDIvol of 78, 7 mGy. The aim of this study was to obtain a head CT protocol with infarction cases that are able to produce optimal image quality and radiation doses that do not exceed DRL. This study was conducted by applying four head CT protocols with tube current, rotation time, and pitch variation with the monitor's CTDIvol value does not exceed DRL in the low contrast resolution and spatial resolution phantom, also in four sample groups, each of which numbered 15 patients with clinical infarction in which each group received only one treatment. Measurement of physical image quality is done by measuring noise and SNR using the ROI software, and low contrast resolution and spatial resolution which were assessed visually by three medical physicists. Clinical quality was carried out by assessing anatomic and pathological information by three radiologists. Head CT protocol with parameters of 250 mA, rotation time 0.75 seconds, and pitch 0,750 produces the best physical and clinical image quality also radiation reduction up to 53, 8 %.

Keywords: Optimization, DRL, CTDIvol, Image Quality, Head CT protocol

INTRODUCTION

Utilization of CT scan modalities in the field is expanding, contributing 70% of the total radiation dose from all diagnostic imaging examinations. Radiation exposure can cause biological effects, which are divided into deterministic effects and stochastic effects [1]. Studies on the effects of radiation due to CT scan radiation have been carried out [3-5] and stated that the incidence rate of cancer is 24% higher in the group exposed to CT scan radiation compared to the group not exposed [4]. Head CT scan is the most examination; reaching 60% of the total CT scans [4], with the most pathological cases are strokes. According to the American Heart Association, 87% of strokes are ischemic (infarction) strokes. CT scan modalities are the first choice in diagnosing stroke because of the large population of tools, easy and fast examination procedures, and relatively affordable examination costs [6].

Computed Tomography Dose Index (CTDI) value for CT scan of the head is the highest value compared to other organs [7, 8]. Indonesian Nuclear Energy Regulatory Agency (Bapeten) has set the National Dose Reference Level (DRL) for a head CT scan to be 50 mGy. DRL values on CT scan internationally have been approved using CTDI data. CTDI value is the main concept in CT scan dosimetry. CTDI value is determined by the CT scan parameters used. As long as the CT scan output is measured using standardized measurement techniques, carried out periodically, and pass the conformity test by fulfilling the required value, then the CTDI value can be used to estimate the right dose [9]. However, CTDI alone cannot be used to determine the effective dose or potential risk of cancer, for this reason calculations must be made using patient size data, organ collecting, and length of the scan area [9]. CTDI is useful in evaluating patient dosage and examination protocols as part of a quality assurance program and can be used as a metric for comparing protocols in facilities and comparing different CT scanner based on the quality of the images produced [10].

The CT image quality must meet the clinical requirements of an examination that is to obtain clear diagnostic information so that it can detect a pathological abnormality [11]. This is related to the accuracy of CT numbers [12], noise, low contrast resolution, and spatial resolution [11], also related to the ability of images to display clear diagnostic information in relation to detecting pathological abnormalities [13]. The biggest challenge is finding a balance between radiation dose and image quality. The increasing complexity of CT scan technology makes selecting CT parameters difficult, due to a tradeoff from the use of selected parameters.

Previous studies on optimizing radiation doses have been carried out, and stated that a reduction in dosage of up to 40% with a reduction in mA and kV is possible without reducing the quality of diagnostic images [14, 15]. The use of high pitch on Thorax CT can reduce the dose to 52%, while the noise is not different, cardiac pulsation artifacts are slightly more visible, and other image qualities are relatively similar compared to standard protocols. Other research on optimizing radiation dose by reducing rotation time states that fast rotation time reduces acquisition time and motion artifacts, but produces high streak artifacts and noise, and poor image quality [16, 17].

GoetengTaroenadibrataPurbalingga General Hospital uses a routine CT scan examination protocol which is also used in clinical infarction, which is 150 mA, 120 kV, rotation time 1.5 seconds, pitch 0.688, with mA modulation off. Using the acquisition technique and protocol, the CTDI that appears on the monitor CT is 78.7 mGy, with the deviation between the monitor CTDIvol and the measured CTDIvol at 1.9% based on the results of the conformity test in 2018. The CTDIvol value is higher than the CTDI value recommended by Bapeten. This high CTDI value can increase the risk due to radiation exposure in patients.

The purpose of this study was to obtain a head CT scan protocol with infarction cases that can produce acceptable radiation doses (CTDIvol) and image quality. Parameters that are still possible to vary are tube current, rotation time, and pitch. The tube voltage parameter (kVp) cannot be varied because only 120 kV is calibrated. The other purposes are to find out the effect of tube current, rotation time, and pitch in each variation of the head CTprotocol with infarction cases on dose (CTDIvol) and image quality (physical and anatomical), to compare dose values (between monitor CTDIvol, measured CTDIvol, and DRL Bapeten)in the four head CT protocols with infarction cases, also to compare the values of the measurement results of image quality (physical and anatomical image quality) on the application of the head CT scan protocols with infarction cases.

METHODS

This research is a true experimental study with a post test only control design research design where the study sample only gets one treatment so it is not exposed to unnecessary radiation exposure. This study measures and compares physical image quality (noise, SNR, low contrast resolution, and spatial resolution) and clinical image quality (anatomical and pathological infarction information) from four head CT protocols, then the protocol that produces the best image quality with radiation doses that do not exceed the national DRL set by Bapeten is chosen. A correlation test between the measured CTDIvol value and the quality of physical and clinical images was carried out, also a correlation test between the quality of physical and clinical images.

Selection of head CT protocols

The selected head CT protocols (tube current, rotation time, and pitch variations) are protocols with monitor CTDIvol value that do not exceed the national DRL of 50 mGy (table 1).

Table 1 Variation of Parameters Used in Research

Protocols	Parameters Variation	Monitor CTDIvol(mGy)
I	150 mA, pitch 0,750, rotation time 1,0 s	40,65
II	150 mA, pitch 0,812, rotation time 1,0 s	37,68
III	200 mA, pitch 0,750, rotation time 0,75 s	40,65
IV	250 mA, pitch 1,0, rotation time 0,75 s	41,98

The parameters used in this study are in the range of recommended values by the European Commission (EC), the American College of Radiology (ACR), and the American Association of Physicists in Medicine (AAPM).

Application of protocols in patient samples

Four selected head CT protocols were applied in routine head CT examinations in sixty patients with clinical infarction which were divided into four groups of fifteen patients each, one protocol applied only to one group of patients. Noise and SNR measurements were performed on sixty series head CT images from four protocols. Noise is measured as the standard deviation of the background image, which is the area outside the object but still in FOV. SNR is measured in two slices of head CT images, which are as high as the basal ganglia to measure SNR of the nucleus caudatus, capsulainterna, thalamus and lateral ventricle, and as high as the Centrum semi oval to measure SNR of white matter and gray matter.

Anatomical structure and pathological visualization was assessed using a questionnaire by three experienced radiology specialists, of sixty series of axial head CT images with WW 95 and WL 40. Anatomical structure assessed includes differentiation and boundaries between white matter and gray matter, basal ganglia (putamen, nucleus caudatus, and internal capsula), thalamus, corpus callosum, cerebellum, cysterna and ventricular system, with measurement scales:

1) Difficult to determine, unclear
2) Unclear, unclear boundaries
3) Clear, firm boundaries

Assessment of visualized infarction on head CT images includes infraction visualization and infarction location. The scale of measurement of infarction visualization is

1) Infarction cannot be distinguished from other pathological disorders
2) Infarction is less distinguishable from other pathological abnormalities
3) Infarction is clear; it can be distinguished from other pathological abnormalities

The scale of infarction location measurement

1) The location of infarction cannot be determined with certainty
2) The location of infarction cannot be determined
3) The location of infarction can be determined without difficulty

Application of protocols to ACR phantom

Low contrast resolution and spatial resolution tests were performed using CT Image Quality Phantom Gammex ACR CT Accreditation Phantom 454 SN 804882-4929, which was exposed with four selected protocols. One protocol was exposed three times. In the low contrast resolution module image there are five groups containing four cylinders with diameters of 2 mm, 3 mm, 4 mm, 5 mm, and 6 mm, and 1 cylinder with a diameter of 25 mm. Whereas in the spatial resolution module image there are 8 groups of line pairs that represent spatial frequencies namely 4, 5, 6, 7, 8, 9, 10 and 12 pairs of lines per centimeter (lp/cm). The low contrast resolution and spatial resolution phantom images were assessed by three medical physicists who assessed visually the groups that were able to visualize the four cylinders clearly in the phantom low contrast resolution images, and the groups that were able to visualize the lines and spaces between them clearly in the phantom spatial resolution images. Low contrast resolution is also objectively assessed by measuring CNR between cylinders with a diameter of 25 mm and background (area between cylinders) with the same ROI diameter of 104 mm2 using the formula (1) below :

$$CNR = \frac{2(C_o - C_b)^2}{\partial_o{}^2 + \partial_b{}^2}$$

Co = cylinder signal with a diameter of 25 mm

Cb = background signal

∂o = standard deviation of the cylinder with a diameter of 25 mm

∂b = standard deviation of background

CTDIvol measurement

CTDIvol measurements were carried out using CTDI Phantom CATO SN 10022-029 and CT Dose Profiler RTI Electronics Piranha 657 SN DP2-15060054 for four predetermined protocols. Measurement of each protocol was carried out three times.

STATISTICAL ANALYSIS OF RESEARCH RESULTS

Data analysis was performed statistically using SPSS software. Different test were performed on noise, SNR, low contrast resolution, spatial resolution, anatomical structure and pathological visualization of the four treatment groups, and correlation tests between measured CTDIvol values and physical and clinical image quality, and correlation tests between physical and clinical image quality.

Determination of the selected protocol

The best head CT protocols for brain infarction cases are determined based on the results of measurements of noise, SNR, low contrast resolution, spatial resolution, anatomical structure and pathological visualization from the four protocols studied. The protocol that produces the highest physical and clinical image quality, with a radiation dose (measured CTDIvol) that does not exceed the national DRL selected.

RESULT AND DISCUSSION

Bivariate analysis was performed to determine differences in image quality of the four protocols studied (figure 1) which included noise, SNR, anatomical structure and pathological visualization, low contrast resolution, spatial resolution and measured CTDIvol. Also to find out the correlation between image quality and measured CTDIvol and the correlation between physical and clinical image quality.

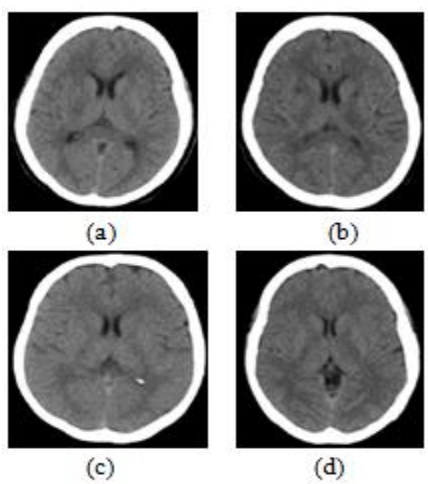

Figure 1 Axial Image of Head CT at the Level of Basal Ganglia ((a). Variation I,(b) Variation II, (c) Variation III and (d). Variation IV)

Noise

There are differences in noise in the four protocols studied. The lowest noise is obtained in variation IV, while the highest noise is obtained in variation II. Variations I and III with the same measured CTDIvol value produce the same noise value (table 4). Difference in measured CTDIvol value up to 2.74 mGy does not produce a significant noise difference. Noise value decreases if the measured CTDIvol value increases, and results in the same noise value at the same measured CTDIvol value. This is consistent with the results of previous studies which stated that noise is influenced by tube current and rotation time (effective mAs) and pitch, where the three parameters will also affect the radiation dose [20]. Higher doses of radiation will produce lower noise.

SNR

There are differences in SNR in the four protocols studied. The highest SNR was obtained in variation IV, while the lowest SNR was obtained in variation II. Variations I and III have the same measured CTDIvol and noise values, but have different SNR values. SNR in variation III is higher compared to variation I (table 4). SNR is calculated by dividing the HU value of the object with noise. Variation III uses a faster rotation time of 0.75 seconds compared to variation I which is 1 second. Fast rotation time will reduce motion artifacts [16]. In CT, artifacts are defined as the systematic difference between the HU value and the attenuation coefficient of the actual object. Motion artifacts can affect the radio density measurement or HU on CT images. The signal measurements in artifacts area results lower radio density, this causes the object's HU value at variation I to be lower than variation III. The post hoc test results showed that a significant SNR difference was seen between variations I and IV also between variations II and IV. Variations I and II used the same effective mAs from the same tube current and rotation time variations of 150 mA and 1 second rotation time, while the variation IV uses greater effective mAs that is 187.5 mAs from the variation of the 250 mA and the rotation time of 0.75 seconds.

Anatomical structures evaluation

There were differences in anatomical structures scores in the four protocols studied. The highest anatomical structures score was obtained in variation IV, while the lowest was obtained in variation II (table 4). Of the seven questions in the anatomical assessment questionnaire, which showed a difference (p value <0.05) was the visualization of the basal ganglia and corpus callosum, while the visualization of the thalamus, cerebellum, cysterna, and ventricular system also the differentiation of white matter and gray matter did not differ (p value> 0.05). Post hoc test results state that significant differences in anatomical structures scores are seen between variations II and IV and between variations III and IV. Variation II uses a tube current of 150 mA which in theory will produce higher noise and lower SNR compared to variation IV which uses a tube current of 250 mA [16]. Meanwhile, although variation I and III use the same effective mAs which is 150 mAs, and variation I has a slightly lower SNR value, but variation I has a higher anatomical structures score. This happened because the difference in SNR values between variations I and III were not significant, and because the anatomical structures score in this study was assessed subjectively by radiology specialists, so the assessment results were strongly influenced by perception and visual observer ability.

Pathological evaluation

There was no difference in pathological scores in terms of visualization and location infarction in the images of the four protocols (p value> 0.05). But based on the mean value, the highest pathological score was obtained in variation IV, while the lowest value was obtained in variation II (table 4). In this study, images from all four variations were able to visualize infarction on head CT images. All head CT images can be received diagnostically and can be interpreted by radiology specialists. Measured CTDIvol reduction of 33.08 - 37.04 mGy or 46-51% (from the initial protocol 78.7 mGy) did not result in differences in the pathological score of infarction. Previous studies suggest that a reduction in dosage of 30-40% still produces images that can be received diagnostically, whereas other studies say a reduction in dosages of 60% is still possible without loss of diagnostic quality, but images produced with surface doses of less than 30 mGy cannot be interpreted [14].

Low contrast resolution

There was no difference in low contrast resolution either based on visual assessments by medical physicists and based on CNR measurements between a 25 mm cylinder and the background (figure 2).

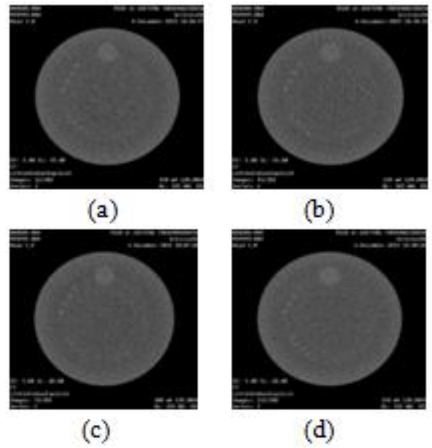

Figure 2 Image of Low Contrast Resolution Phantom (a) Variation I,(b) Variation II, (c). Variation III, (d) Variation IV

Based on the CNR mean values, the highest low contrast resolution was obtained in variation IV, while the lowest was obtained in variation II (table 4). The CNRs of the four protocols were more than 1.0, meet the ACR standard. While based on a visual assessment by three medical physicists, the four protocols showed the same result that the cylinder group that is clearly visible is cylinder group with a diameter of 5 mm (table 4), which meaning that it still meets the ACR standard (at least a cylinder group with a diameter of 6 mm must be seen in the image) [3]. The ability of CT images to detect and characterize low contrast lesions cannot be compromised in an effort to reduce the level of radiation dose [21]. Low contrast resolution is strongly influenced by noise, so parameters that affect noise will also affect low contrast resolution, including mA, rotation time, and pitch. In this study, visualized low contrast resolution showed no difference in the four variations even though there was a statistical difference in noise. Because the difference in noise from the four protocols is small, proportional to the dose difference which is also small, that is 1.22 - 3.96 mGy (3.2% - 11.4%). This is in line with the results of other studies which state that a 25% - 50% lower dose difference results in lower contrast resolution [21].

Spatial resolution

The evaluation of three medical physicists on the low contrast resolution phantom image stated that the four protocols showed the same results, the line pairs that were able to visualize the lines and the space between them clearly was 8 lp / cm. This means that the four protocols still meets the ACR standard which states the pairs of lines must be clearly visible on images of at least 5 lp / cm for abdominal and head protocols, and 6 lp / cm for high resolution protocols on the thorax CT [3]. Spatial resolution is influenced by several factors, including focal spot size, detector size, pixel size, reconstruction algorithm and pitch [22]. The size of the focal spot is related to tube current. Large focal spot size is used on large tube current, and vice versa. To compensate for the potential reduction in spatial resolution due to this, a longer rotation time and lower pitch are used, but this will affect the length of examination and radiation dose [20]. In this study, protocols I, II and III use "small" focal spots, whereas in variation IV use "large" focal spots because of the use of large tube currents (250 mA). Variation IV also uses a greater pitch compared to variations I, II and III. But the results of the spatial resolution assessment on variation IV do not differ from variations I, II and III (table 4). Because the spatial resolution assessment is a subjective assessment. So the assessment results are strongly influenced by the observer's perception and visual ability. Previous research stated that tube currents from 30 to 190 mA with increments of 20 mA and kV remained, did not produce different spatial resolutions.

Measured CTDIvol

The measured CTDIvol in this study is lower than the monitor CTDIvol with a deviation range between 8.98% - 9.02% (table 2). The measured CTDIvol in this study is the average of three measurement results.

Table 2 CTDIvol Measurement Results

Protocol	Measured CTDIvol (mGy)	Monitor CTDIvol (mGy)	Deviation (%)
I	37,30	40,65	8,99
II	34,56	37,68	9,02
III	37,29	40,65	9,01
IV	38,52	41,98	8,98

The monitor CTDIvol value for each CT scanner is a value that has been set by the manufacturer, which is different for each brand and type of CT scanner [23]. The deviation between the monitor CTDIvol and the measured CTDIvol depend on the CT scanner performance, so it is important to periodically evaluate the accuracy of the CTDIvol value. The deviation between the measured CTDIvol and monitor CTDIvol value in this study can be used as a reference in optimizing the image quality in the other indication of head CT examination, because the results of three measurements for four different parameter variations show a consistent deviation value of 9 ± 0.2 %.

Measured CTDIvol and noise correlation

There is a correlation between measured CTDIvol and noise with a moderate level of relationship, an increase in measured CTDIvol will cause a decrease in noise (table 3). This is consistent with the statement that the dose affects the noise, where the decrease in the dose that occurs due to the setting of the CT scan parameters, will increase the noise value in the image [20]. In this study, if the measured CTDIvol value increases by 1 then the noise will decrease by 0.078. The results of previous studies stated that a dose reduction of 10 mGy caused an increase in image noise of 0.5 HU to 1.8 HU with a correlation coefficient between 0.62 and 0.97.

Measured CTDIvol and SNR correlation

There is a correlation between measured CTDIvol and SNR, with a moderate level of relationship, an increase in measured CTDIvol will cause an increase in SNR (table 3). This is consistent with the statement that the use of higher doses will result in a decrease in image noise, which will also affect the value of the image SNR because the SNR is calculated by dividing the signal object with noise. In this study, if the measured CTDIvol increases by 1, the SNR value will increase by 0.691.

Measured CTDIvol and anatomical structures correlation

There is a correlation between measured CTDIvol and anatomical structure scores, with a weak relationship level, an increase in measured CTDIvol will cause an increase in anatomical structure scores (table 3). In this study, if the measured CTDIvol value increases by 1, the anatomical structure score will increase by 0.047. The results of this study are in accordance with the results of previous studies which state that the increase in measured CTDIvol by 25% only slightly increases the value of the anatomical structures scores of the image, with a tendency to increase weakly [25].

Measured CTDIvol and pathological visualization correlation

There is a correlation between measured CTDIvol and pathological visualization score, with a weak relationship level, an increase in measured CTDIvol will result an increase in pathological visualization scores (table 3). If the measured CTDIvol increases by 1, the pathological visualization scores will increase by 0.049. Previous study of radiation dose reduction states that decreasing the dose by 30-60% still produces images that can be received diagnostically, but in these studies no further correlation analysis was performed.

Measured CTDIvol and low contrast and spatial resolution correlation

Correlation test between measured CTDIvol and low contrast and spatial resolution cannot be done because the value of both low contrast resolution and spatial resolution is constant. Measured CTDIvol values with a range of 34.56 mGy - 38.52 mGy or a difference of 3.96 mGy does not produce different low contrast resolution and spatial resolutions.

Physical and clinical image quality correlation

Physical image quality (noise & SNR) and clinical image quality (anatomical structure & pathological visualization scores) is shown in table 3.

Table 3 Measured CTDIvol and Image Quality Correlation and Physical and Clinical Image Quality Correlation

Correlation	p value	Correlation Coefficient	Correlation Level
CTDIvol - Noise	0,001	-0,408	Moderate
CTDIvol – SNR	0,000	0,444	Moderate
CTDIvol – Anatomical Structure	0,017	0,307	Weak
CTDIvol – Pathological Visualization	0,031	0,278	Weak
Noise – Anatomical Structure	0,822	0,030	No Correlation
Noise – Pathological Visualization	0,568	0,075	No Correlation
SNR – Anatomical Structure	0,182	0,175	No Correlation
SNR – Pathological Visualization	0,765	0,039	No Correlation

Table 3 shows that there is no correlation between physical image quality (noise and SNR) and clinical image quality (anatomic scores structure and pathological visualization). Because in this study the value of noise and SNR have small difference. The small difference in noise and SNR due to the selection of CTDI values in this study has a slight difference, because it considers the range of examination parameter values recommended by the international radiology and medical physics institute / commission. The small difference in HU in the image will not be seen visually difference. And in this study, anatomical structure scores and pathological visualization scores are assessed subjectively which is influenced by the ability of the observer's eye and observer's competence in assessing the visibility of anatomic structures and pathological abnormalities in the image.

Although in this study there is no correlation between physical quality (noise, SNR, low contrast resolution, and spatial resolution) and clinical quality (anatomical structure scores and pathological visualization scores), it is still important to measure physical quality and clinical quality. Physical quality measurements can be used as consideration and added value in analyzing contrast and detail quality in CT images, while clinical quality measurements must be performed to fully represent the actual clinical image quality performance [24], then used as consideration in determining best protocol as an effort to optimize the radiation dose in a CT examination procedure. The tabulated values for measurement and assessment of noise, SNR, low contrast resolution, spatial resolution, anatomical structure scores, pathological visualization scores, and measured CTDIvol are as in table 4.

Table 4 Measurement Result of Noise, SNR, Anatomical Structure Score, Pathological Visualization Score, Low Contrast Resolution, Spatial Resolution, and Measured CTDIvol

Protocol	Noise	SNR	Anatomical Scores	Pathological Scores	Low Contrast Resolution	Spatial Resolution	Measured CTDIvol(mGy)
I	1.46	14.97	2,74	2,91	5	8	37,30
II	1.63	13.98	2,62	2,78	5	8	34,56
III	1.46	15.36	2,63	2,88	5	8	37,29
IV	1.30	17.05	2,84	2,98	5	8	38,52
Min	1.63	13.98	2,62	2,78	5	8	34,56
Max	1.30	17.05	2,84	2,98	5	8	38,52

To determine the best protocol of tube current, rotation time, and pitch variation, which is capable of producing optimal image quality and measured CTDIvol values not exceeding BAPETEN recommendations, normalization of noise data, SNR, and anatomical structure scores is performed. Pathological visualization scores, low contrast resolution and spatial resolution data were not normalized because there were no differences in the four treatment groups, as well as the measured CTDIvol values because the values of the four treatment groups did not exceed BAPETEN recommendations of 50 mGy. The results of normalization of noise data, SNR, and anatomical structures score are shown in table 5.

Table 5 Normalization of Noise, SNR, and Anatomical Structure Score

Protocol	Noise Score	SNR Score	Anatomical Structures Score	Final Score
I	6	4	6	16
II	1	1	1	3
III	6	5	1	12
IV	10	10	10	30
Min	1	1	1	3
Max	10	10	10	40

CT is a radio diagnostic examination that uses exposure to low radiation doses, with a dose range of 5-50 mSv. But the potential effects of radiation due to CT radiation exposure should not be ignored because no matter how low the radiation dose is received, there is always the opportunity for changes in biological systems at both the molecular and cellular levels. In addition, other studies reveal that exposure to low-dose radiation triggers induction which causes instability of genetic material after exposure which may play a role in the process of cancer formation. So that optimization of radiation doses is absolutely necessary, even at low doses of radiation exposure.

In this study, the use of faster rotation time on variation IV (0.75 seconds) compared to variations I and II (1 second) still resulted in higher noise, SNR, anatomical structure scores and pathological visualization scores compared to variation I and II. The helical pitch used in this study is still in the range recommended by IEC and AAPM. Although the helical pitch in variation IV is greater than variation I, II, and III which theoretically have the potential to increase the emergence of streak artifacts, this does not make noise, SNR, an atomic structure scores, and pathological visualization scores on CT images variation IV become lower. Because effective mAs variation IV is higher (187.5 mAs) compared to variations I, II and III (150 mAs). The effective mAs value is linear with the radiation dose, if the effective mAs is lowered then the radiation dose will also decrease, and the reduction in the radiation dose will increase the noise and subsequently will affect the image quality.

CONCLUSION

From the above explanation, it can be seen that the protocol of the variation of tube current, rotation time, and pitch in routine head CT examination with infarction cases that are able to produce optimal image quality and can be received diagnostically based on noise, SNR, anatomical structure scores, and scores pathological visualization of infarction is variation IV with a measured CTDIvol of 38.52 mGy. This means that there is a decrease in CTDIvol of 33.1 mGy from the CT protocol of the head with infarction cases that are applied at the Goeteng Taroena dibrata Purbalingga General Hospital with a measured CTDIvol of 71.62 mGy.

It can be concluded that this study succeeded in getting a substitute protocol that was able to reduce the radiation dose to 46.22% of the head CT head with infarction cases used in GoetengTaroenadibrataPurbalingga General Hospital, which is a protocol with a variation of 250 mA, rotation time 0.75 seconds, and pitch 0.750. With this dose reduction, the patient does not get excessive radiation exposure, and in accordance with Bapeten's recommendations, so that the chances of biological effects on patients due to radiation exposure to head CT scans can be reduced.

Further research needs to be done with a wider range of measured CTDIvol values, also with a wider variety of scan parameters to determine the effect of each scan parameter on the physical images quality and clinical image quality, and the correlation between physical image quality and clinical image quality. In grouping research samples, it is necessary to control body weight and head diameter to ensure homogeneity of study samples.

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How to cite this article: WidyaNurmayanti, Ari Suwondo, Jeffri Ardiyanto, Tunggul Drajat. Optimization of radiation dose for optimal image quality in head CT examination. Int J of Allied Med Sci and Clin Res 2020; 8(2): 265-275.

Source of Support: Nil. **Conflict of Interest:** None declared.