Study of Image Quality, Radiation Dose and Low Contrast Resolution from MSCT Head by Using Low Tube Voltage

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Abstrak. Effect of low tube voltage (80 kV) on image quality, radiation dose, and low contrast (LCD) detection capability on CT Scan head was studied by using a solid phantom contains four modules with scanning CT at 80 and 120 kV tube voltages, with tube current timing at 200, 250 and 300 mAs. The difference between image noise, noise to ratio contrast and LCD values obtained with 80 and 120 kV at 200, 250 and 300 mAs were then compared. Substantially the image noise increases with the use of low tube voltage. However, with the same dose, the LCD values are between 120 kV at 300 mAs and 80 kV at 200, 250 and 300 mAs (P> 0.05). The relative dose given at 80 kV against 200, 250 and 300 mAs is equal to 68%. By reducing the tube voltage from 120 kV to 80 kV at head CT, the radiation dose can be reduced by 32% without CNR and LCD degradation.

1. Introduction
One of the X-ray modalities often used in radiodiagnostics is CT Scan. In the development of the CT Scan has progressed quite rapidly starting from the first generation that only has one detector and uses pencil files, until now have used Multi-Slice Detector (MSCT) [1]. CT has undergone evolution leading to an increase in spatial resolution and temporal resolution. Spatial resolution alone is one of the parameters of image quality. The image quality produced by CT Scan becomes very important to note because the image will be used to diagnose a disease. If the resulting image is not good then it will have an impact on diagnostic errors that can result in biological effects on the patient. The estimated risk of dying from cancer for those undergoing CT is 12.5 / 10,000 population for each CT scan through the abdomen. Therefore, concern about the reduction of irradiation at CT doses is rare [2]. Although the decrease in tube currents is the most common way to reduce the radiation dose, it will reduce the factors that influence the diagnosis. Some studies have shown that scanning with low tube stress is possible to reduce the dose without reducing image quality. Thus, the purpose of this study was to determine the effect of low tube voltage usage on 80 kV on image noise (SD, standard deviation from CT Number), CNR and radiation dose from Multi-Slice Detector (MSCT) head.
CT Scan is a fairly complex medical imaging system so there is a risk of calibration error, failure of generating system function and X-ray detection. Therefore, CT Scan aircraft require QC (quality control) program to ensure image quality while maintaining the dose is still below the allowable limit [3].

2. Materials and Methods

2.1. Phantom Description
Phantom ACR accreditation CT (Gammex 464) is a solid phantom that contains four modules and is made of materials equivalent to water. Each module with a thickness of 4 cm and a diameter of 20 cm. There is a transverse and perpendicular line of white to reflect the laser marker on the phantom so that there are no slope of the axial, coronal and sagittal axes. There is also a "HEAD" and "FOOT" sign in the phantom to help position the front and back.[2]

2.2. CT Scanning Phantom
This study uses axial head protocol. Scanning is done on a standard 120kV tube voltage and a low tube voltage of 80 kV with a tube current arrangement of 200, 250 and 300 mAs.

2.3. Radiation Dose Measurement
This study used CTDIvol to estimate the radiation dose. CTDIvol was obtained on standard tube voltage and low tube voltages at various mAs (tube currents).

2.4. CNR measurements
In phantom ACR section module, 2 is used to assess low-contrast resolution. This module consists of a series of cylinders of different diameters. There are four cylinders of diameter: 2 mm, 3 mm, 4 mm, 5 mm and 6 mm. The space between each cylinder is equal to the diameter of the cylinder and a cylinder 25 mm in diameter. CT number measurements were performed on a 25 mm diameter cylinder and mid between a 25 mm and 6 mm diameter cylinder. [4,5]

The low-resolution contrast (CNR) is calculated by the formula: \( \text{CNR} = \frac{A - B}{SD} \), In this case, A records the ROI signal inside the 25 mm cylinder (target), B records the ROI signal outside the 25 mm cylinder (Background), and SD is a Standard Deviation (SD) from ROI outside cylinder 25 mm.

![Figure 1. Low Contrast Resolution.](image)
2.5. Statistical analysis
We used t-student test to evaluate the image quality (CNR) and radiation dose (CTDIcon) at a standard 120 kV tube voltage and a low tube voltage of 80 kV with a tube current arrangement of 200, 250 and 300 mAs. The relationship between CNR and CTDIcon was investigated using linear regression analysis and Pearson correlation coefficient (r). All statistical analyses were performed with commercially available software packages [2].

Table 1. CTDIcon value on various kVp and mAs.

| Tube current-time product (mAs) | CTDIcon (mGy) |
|-------------------------------|---------------|
|                              | 120 kVp | 80 kVp |
| 200                           | 30.69    | 9.93   |
| 250                           | 38.36    | 12.37  |
| 300                           | 45.86    | 14.81  |

Table 2. The CT numbers, image noise, and CNR obtained at each set of acquisition condition.

| Tube current-time product (mAs) | CT Number | Image noise | CNR |
|---------------------------------|-----------|-------------|-----|
|                                 | 120 kVp   | P Value     | 120 kVp | 80 kVp | P Value | 120 kVp | 80 kVp | P Value |
| 200                             | -4.0      | -5.7        | < 0.001 | 3.8    | 9.0      | < 0.001 | 1.64   | 0.76   | 0.043   |
| 250                             | -5.4      | -5.7        | < 0.001 | 3.7    | 7.2      | < 0.001 | 1.54   | 0.79   | 0.036   |
| 300                             | -4.1      | -6.8        | < 0.001 | 3.6    | 6.4      | < 0.001 | 1.94   | 0.93   | 0.049   |

3. Results and Discussion

3.1. Radiation Dose
CTDIcon is an estimate of the radiation dose obtained from each of the irradiation conditions. The results obtained are shown in table 1. In the same tube time arrangement with different tube voltages, CTDIcon obtained at 80 kV is approximately 68% of 120 kV, thereby reducing the received radiation by 32%.

3.2. Image Quality Results
The noise and CNR values in the CT scan image of each of the irradiation conditions can be seen in table 2. At the same irradiation of tubular currents and different tube voltages, the noise values from the lowest to the highest can be seen in figure 2. The noise value obtained at 120 kV with 300 mAs as the standard tuning condition for CT scan is higher than the noise value obtained at 80 kV with 200-300 mAs, so its significance value (P < 0.001) (table 2). There was a strong correlation between CNR and CTDIcon with Pearson correlation coefficient r = 0.875 (P < 0.001) for irradiation at 80 kV tube voltage, while r = 0.510 (P < 0.001) on 120 kV tube tension. CTDIcon on the use of 80 kV tube voltage produces a lower CNR
compared to CNR at 120 kV (figure 3). Using a two-tailed Student t-test, the CNR obtained at 80 kV with 200-250 mAs was significantly lower than 120 kV with 300 mAs (P <0.05) (table 2). However, there was no statistically significant difference between CNR obtained at 120 kV with 300 mAs and CNR obtained with 80 kV at 200 mAs and 250 mAs (P> 0.05) (table 2).

![Figure 2. The relationship of noise value with mAs.](image1)

![Figure 3. Relation of CNR value to CTDIvol (mGy).](image2)
3.3. CT Scan is one of the medical methods that are now widely used in the medical world
CT Scan or commonly referred to as Computed Tomography is a method of medical depiction using tomography, which relies on X-rays in producing images from the inside of an object, which in this case is human. Current CT scans are often used to confirm the diagnosis of patients suspected of having cancer disorders. Besides, CT scan can cause the risk of death from cancer, especially for patients who have CT scan more than 1 times. The management of patient doses is of major concern at the head MSCT examination.

In previous studies conducted on abdominal CT with the outcome the CNR value decreases when the CT acquisition is performed at an 80 kV tube voltage and an identical tube current setting, CNR increases substantially when identical CTDIvol is used. Compared to CNR obtained at 120 kV and 300 mAs, there was no statistically significant difference at 80 kV and 550 mAs, 600 mAs, and 650 mAs ($P > 0.05$). [6] In this study, we used the CT dose index (CTDIvol) for the radiation dose present in the monitor expressed in mGy. CTDIvol as the intensity of the radiation dose will facilitate the comparison of the accuracy of the radiation dose at different tube voltages. For example, the radiation dose between the tube voltage is 80 kV and 120 kV. Our results show that to reduce radiation exposure, substantially by lowering tube voltage from 120 kV to 80 kV. However, it has its limitations. Because radiation exposure is the average dose of a homogeneous cylindrical phantom. Therefore, the patient dose should be estimated with CTDIvol[2]. In our study, our findings show that there is a direct correlation between CNR and CTDIvol. The higher the CTDIvol, the higher the CNR value. CNR obtained at 120 kV and 300 mAs, there was no statistically significant difference at 80 kV and 200 mAs and 250 mAs ($P > 0.05$). This indicates that to reduce the radiation dose received by the patient does not always rest on the use of a 120 kV tube voltage, with the use of a tube voltage below 120 kV the patient's received radiation dose can be reduced to 32%.

3.4. Limitations of the study
This study uses phantom as a substitute for the human body, so it does not take into account the variability of body composition, therefore, whether these results are appropriate for clinical use. Marin et al. [7] showed that techniques with low tube stress at 80 kV could be applied to significantly reduce the radiation dose received by the patient. Possible to do with head CT scan.

5. Conclusions
In this phantom CT study, we have shown that although the image noise increases at low tube voltage, it is possible to reduce radiation doses by up to 32% without CNR decrease by reducing tube voltage from 120 kV to 80 kV and increasing tube current of more than 250 mAs. CT Scan examination with low tube voltage technique has a huge advantage for patients, especially patients who undergo CT scan more than once so that negative effects of radiation can be avoided.

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