Evaluation of the effect of low tube voltage on radiation dose and image quality

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Abstract. Number of Computed Tomography (CT) examinations performed worldwide is increasing. In 2010, the FDA issued an initiative to reduce unnecessary radiation exposure from CT imaging. The aim of this study is to evaluate the effect of low tube voltage on radiation dose and image quality using CTDI phantom. The CTDI phantom was scanned with dual energy CT at 80 kV and 120 kV with the tube current from 150 mAs to 350 mAs. Pitch was 1.0 while slice thickness was 1 mm and 5 mm. Results show if mAs was increased, the SNR values also will be increased. The 5 mm slice thickness shows higher SNR value compared to 1 mm slice thickness. As the voltage and tube current increased, the amount of dose absorbed is also increased because current is proportional to photon flux.

1. Introduction
Number of x-ray Computed Tomography (CT) examinations performed worldwide is increasing rapidly. The study investigates the best way to reduce the radiation dose absorbed by the patient from a dual energy CT using the concept as low as reasonably achievable (ALARA). Kun Tang et al (2012) found that scanning technique using low tube voltage is better than the standard tube voltage of 120 kV because the radiation dose at the center and periphery could be reduced by 35\% and 13\% without affecting the low contrast detectability.

2. Materials and Methods
Somatom Definition AS+128 Slice CT with a single source dual energy x-ray is investigated in the study. This study used CTDI phantoms made of a cylindrical polymethyl methacrylate (PMMA) and body phantom of 320 mm in diameter.

All scans were helical with pitch of 1.0 and slice thickness either 1 mm and 5 mm. Imaging was performed with two tube voltages of 80 kV and 120 kV. Tube current used were 150, 200, 250 and 300 mAs. Estimated CTDI\textsubscript{vol} body adult were recorded for each scan for dose estimation. CTDI\textsubscript{vol} is obtained from the CT given in CTDI\textsubscript{vol} unit.
For the evaluation of image quality, Weasis v.1.2.7 software was used. The signal to noise ratio (SNR) was measured using the software based on the CT number, CT background and standard deviation in the images. The signal to noise ratio was calculated by using equation (1)

$$SNR = \frac{CT \text{ number} - CT \text{ background}}{\text{Standard Deviation}}$$

(1)

3. Results

Analysis of SNR for 80 kV is shown in Figure 1 for 1 mm and 5 mm slice thickness. For slice thickness of 1 mm, the SNR is increased by 82.23% when the tube current is increased from 150 mAs to 350 mAs. However, for 5 mm slice thickness, the SNR is increased by 33.87% when the tube current is increased from 150 mAs to 350 mAs. Similar trend is seen in Figure 2 for 120 kV but higher increase of SNR was observed with mAs in the range of 300 too 300 mAs for 5 mm slice thickness.

![Figure 1. SNR for slice thickness 1 mm and 5 mm at 80 kV](image1)

![Figure 2. SNR for slice thickness 1 mm and 5 mm at 120 kV](image2)

Table 1 shows the CTDI_{vol} for slice thickness 1 mm and 5 mm at 80 kV and 120 kV. For 80 kV and 1 mm slice thickness, the amount of CTDI_{vol} was raised to 65.16% between the lowest (150 mAs) and the highest mAs (350 mAs). However, for slice thickness 5 mm, the amount of CTDI_{vol} was increased to 72.31%. Large increment happened on slice thickness 1 mm between 150 mAs to 200 mAs. There is an increment of 59.40% in CTDI_{vol} compared to 42.56% increment for 5 mm slice thickness.
A Mann-Whitney U test shows significant difference in the slice thickness 1 mm 80 kV (Md = 0.028900, n = 10) and 120 kV (Md = 0.046100, n = 5), U = 10.5, z = -1.789, p = .074, r = 0.4619 (This could considered a large effect size using Cohen (1988)) whereas for slice thickness 5 mm Mann-Whitney U test revealed significant difference in the 80 kV (Md = 0.047600 , n = 10) and 120 kV (Md = 0.25110, n = 10), U = 0, z = -2.611, p =0.009, r = .83.Effect size , r shows large effect .

Table 1. The CTDI_{vol} (mGy) for slice thickness 1 mm and 5 mm at 80 kV and 120 kV

| Tube Current (mAs) | 1 mm at 80 kV | 5 mm at 80 kV | 1 mm at 120 kV | 5 mm at 120 kV |
|-------------------|--------------|--------------|---------------|---------------|
| 150               | 0.0108       | 0.0337       | 0.1687        | 0.2021        |
| 200               | 0.0266       | 0.0428       | 0.2043        | 0.2215        |
| 250               | 0.0289       | 0.0476       | 0.0463        | 0.2511        |
| 300               | 0.0290       | 0.0699       | 0.0598        | 0.2658        |
| 350               | 0.0310       | 0.1217       | 0.1090        | 0.3056        |

An independent-sample t-test was conducted to compare the dose scores for 80 kV and 120 kV. There was significant difference in scores for 80 kV (M=0.024460, SD = 0.0082637) and 120 kV (M=0.117620 SD = 0.0682396; ; t (-0.3031). The magnitude of the differences in the means (mean difference = 0.0931600, 95% . Confidence interval of the difference -0.1775593 until -0.087607) was very large effect (eta squared = 0.5345)> The guidelines (proposed by Cohen 1988, pp 284-7) for interpreting this value .01= small effect, .06 = moderate effect, .14 = large effect.

4. Discussion
The image noise was found correlated to the tube current. From the result, with the increased of tube current the SNR will be increased. This is because the amount of photon flux increased. This study used different slice thickness because of its dependence on the thickness of the CT detector. Because the scanners collimate the beam to the width of the detectors, slice thickness is equal to the collimator width. So, different slice thickness could differentiate either 5 mm slice thickness or 1 mm slice thickness were better.

The number of studies showing the utility of CT scan reported in the literature has increased, In this study, the CT dose index volume (CTDI_{vol}) used based on manufacturer’s data for estimation of radiation dose. CTDI, expressed in terms of air kerma in milligray, was obtained directly from the computer without put any detector. CTDI_{vol} is a better measurement of CT radiation dose for applications where the patient table is incremented during the scan.

The results show that it is possible to reduce radiation dose between 80 kV and 120 kV tube voltage. However, it has limitations. CTDI_{vol} is an averaged dose due to homogeneous cylindrical phantom. The measurement is an approximation of patient dose. Besides that, CTDI_{vol} phantom does not provide sufficiently long scatter path relative to the typical length of a human. Hence, patient dose may be underestimated with CTDI_{vol}.

5. Conclusion
As a conclusion, this research shows the low tube voltage can still provide optimal image quality. Further work will be carried out to provide guidelines for hospital in addressing in the choice of imaging parameters for dual energy CT scan.

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