Evaluation of radiation dose in pediatric head CT examination: a phantom study

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Abstract. The aim of this study was to evaluate the radiation dose in pediatric head Computed Tomography examination. It was reported that decreasing tube voltage in CT examination can reduce the dose to patients significantly. A head phantom was scanned with dual-energy CT at 80 kV and 120 kV. The tube current was set using automatic exposure control mode and manual setting. The pitch was adjusted to 1.4, 1.45 and 1.5 while the slice thickness was set at 5 mm. The dose was measured based on CT Dose Index (CTDI). Results from this study have shown that the image noise increases substantially with low tube voltage. The average dose was 2.60 mGy at CT imaging parameters of 80 kV and 10 – 30 mAs. The dose increases up to 17.19 mGy when the CT tube voltage increases to 120 kV. With the reduction of tube voltage from 120 kV to 80 kV, the radiation dose can be reduced by 12.1% to 15.1% without degradation of contrast-to-noise ratio.

1. Introduction
The Computed Tomography (CT) technology, performance and clinical application undergoes tremendous evaluation. Numerous procedures have been done to reduce radiation dose to children during CT including modulation of tube current and lowering the tube voltage [13]. There is a need to investigate the CT imaging protocol to evaluate the radiation dose received by pediatric patients. CT is widely used in medical imaging to treat adult and pediatric. The use of low tube voltage in CT imaging is recommended to increase the image contrast enhancement. However, the radiation dose varies according to tube voltage and patient size. Theoretically, the tube current increases when lower tube voltage is used in the study. This is to maintain image quality obtains from the CT imaging.
2. Materials and methods

2.1 CT phantom imaging

A CT Dose Index phantom (figure 1) with 10 cm diameter was scanned with Siemens Somatom Definition AS+128 Slice CT scanner. This phantom was used to mimic the pediatric head in this study. The CTDI phantom has four holes at periphery and a hole in the center. The phantom was scanned at 80 kV and 120 kV while the tube current was set manually and using AEC mode. The pitch was adjusted to 1.4, 1.45 and 1.5 while the slice thickness was set at 5 mm. The radiation dose was measured with ion chamber detector that was inserted in each hole during the experimental work. The CTDI weighted values was computed based on equation 1.

\[
CTDI_w = \frac{1}{3} CTDI_{100\text{center}} + \frac{2}{3} CTDI_{100\text{periphery}}
\]  

Equation (1) shows the calculation for CTDI weighted values. Each hole of CTDI phantom was scanned to obtain the value of CTDI weighted.

3. Results

![Figure 1. CTDI dose against mAs at 120 kV for care dose setting for head phantom](image-url)
3.1 Care Dose

*CTDI* dose against mAs (in figure 2) shows that not too much different, even changing the pitch. Abdomen caredose for pediatric patients by using Care Dose (used in hospitals) was not too much different. Scan time 2.49 by the rotation time 0.5 and slice thickness 5mm.

![CTDI Dose versus Effective Current](image)

**Figure 2.** *CTDI* dose against mAs in 120 kV for manual setting.

A Mann Whitney U Test revealed no significant difference between Care dose 80kV (Md= 16.06, n=4) and manual setting at 80 kV (Md=0.6437, n=4), U=8, z= 0 p=1, r=0 (figure 3). This would be considered as large effect. This because the tube current used for care dose were 85 to 200, while tube current used for manual setting were 10-30 mAs. This shows that it was not suitable to choose lowest manual setting because the dose will absorbed into the pediatric patient’s body. Whereas for 120 kV Care dose shows (Md= 16.06, n=4) and manual setting for 120 kV shows (Md=2.261, n=4), U=8, z= -2.309, p=0.21, r=-1.15, this would considered as small effect where the value of r shows less than 0.1 from Cohen (1988) criteria, while in between care dose energy 120 kV and 80 kV both have the same value of median while in between 120 kV and 80 kV both have different values of median 2.2610 and 0.6437. It has 1.61735 differences.

For a second finding, a Mann Whitney U test shows that pitch values of care dose 120 kV were: pitch 1.4 (Md= 16.06, n=4), 1.45 (Md=16.03) and 1.5 Pitch (Md=16.01). This shows that using pitch 1.4, 1.45 or 1.50 still considered for 120 kV. Besides that, by using manual setting where the energy chooses 80 kV; pitch 1.4 (Md=2.261) 1.45 (Md=2.282) and 1.5 (Md=2.2865). These shows that pitch 1.4 used to have a large difference compared to pitch 1.45 and 1.5.
4. Discussion
Choosing pitch value > 1 decreased patient dose and image quality. However, pitch value < 1 results in better image quality, but a higher patient dose. Using 1.5 pitch still considered either in manual setting or caremode compared to choosing 1.4 and 1.45 pitch values since the median values were small difference. However, choosing 80 kV with pitch 1.5 is better compared to choosing 120 kV for 1.5 pitch value for the pediatric patient. These because the values choice of pitch affect both image quality and patient dose. [12][11]. From this study it is shown that the radiation dose in pediatric head CT examination varies with tube voltage and other CT imaging parameters. The tube current plays an important role in determining the optimal radiation dose in pediatric head phantom.

5. Conclusion
This study shows that the radiation dose is reduced significantly with the use of low tube voltage in pediatric head CT imaging. The use of AEC mode offers the best service with lowest radiation exposure to pediatric patients.

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