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Evaluation of Tube Current Modulation Profile on CT Image of 128 slices CT Scanner using The Borobudur Phantom

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ABSTRACT

The purpose of this study is to evaluate the tube current profile of Siemens 128 slice CT scanner with tube current modulation (TCM) technique using the Borobudur phantom. Borobudur phantom was made from acrylic which has four different diameters of 8, 16, 24, and 32 cm. It was filled with distilled water. The phantom was scanned using a Siemens Somatom 128 slice CT Scanner. The CT scanner took a topogram image first to estimate the attenuation level of each diameter of the phantom. The phantom was scanned using tube voltage and quality reference variations. After the axial images of the phantom were obtained, the tube current information was extracted from digital imaging and communications in medicine (DICOM) header in each dataset using through IndoQCT software. It is found that as the phantom diameter increases, the tube current also increases. For variation of quality reference, the increasing value of quality reference will increase the tube current value. The results show that the tube current profile in the tube voltage variation shows insignificant changes with a statistical test p-value of 0.752. From this study, we conclude that TCM can be evaluated using Borobudur phantom and IndoQCT software.

Keywords: CT, Siemens, Step wedge, Tube Current Modulation

I. INTRODUCTION

Computed tomography (CT) is one of the medical imaging modalities widely used for diagnostic examinations, screening, and treatment planning system [1,2]. However, CT has a relatively high radiation dose compared to other imaging modalities. As the use of CT increases worldwide, it rises concern about the potential carcinogenic in the future [3-5]. To minimize this negative impact, various techniques were developed to reduce the dose, one of them is the tube current modulation (TCM) technique [6].

When using TCM, the tube current changes dynamically based on the attenuation region of the object being scanned. It is noted that the tube current is proportional to the number of X-ray photons and proportional to the dose received by the patient. The tube current decreases in areas having low attenuation levels, and the tube current increases in areas having high attenuation levels. Using TCM radiation dose can be reduced down to 10 - 60% [7,8]. TCM will optimize the radiation dose to the patient by adjusting the tube current along angular, longitudinal, or both directions [9,10]. However, the implementation of tube current modulation can vary according to the scanner model, manufacturer, and each manufacturer has a different name [11,12]. The name of TCM technique on the GE CT Scanner is SmartmA, on Siemens is Care Dose4D, on Toshiba is SureExposure, and on Philips is DoseRight. TCM have a principle that produces some degree of constant noise in the image of the body having different size and attenuation by using a dynamic tube current within a predetermined minimum and maximum range. Although TCM from each manufacturer has a different name, the principle of TCM is the same [13,14].

The implementation of TCM needs to be evaluated by characterizing TCM in terms of tube current as a function of attenuation [15]. Several studies have been conducted to evaluate tube current profiles using both cylindrical polymethyl methacrylate (PMMA) phantoms and elliptical phantoms. Merzan et al has conducted a study to evaluate the impact of scan settings on TCM using an elliptical phantom with three different sizes (25, 30, 35 cm). In the study, it was reported that the GE, Toshiba, and Philips manufacturers of CT scanners at low tube voltages produced high tube currents. However, for the Siemens CT scan manufacturer tube current modulation is not too affected by variations in tube voltage [16]. However, this study has the disadvantage that the size of the phantom cannot represent the body size of children. McKenney et al has also conducted research to determine the relationship between image quality parameters of various CT scan manufacturer using phantoms made of PMMA which has five different diameters. From the study, it was also reported that the tube current profile increased with increasing phantom diameter and quality reference. The increase in tube current is also very dependent on the predetermined noise level setting [17]. However, the availability of cylindrical PMMA phantoms is currently expensive and quite limited, especially in developing countries.

One alternative phantom that can be used is to use an in-house step wedge water cylindrical phantom with a case from acrylic. Acrylic was chosen because it has a density that is almost close to water and easy to find [18]. Previously, acrylic has been applied as the basic material in the manufacture of square-step wedge phantoms for the measurement of water equivalent diameter and size-specific dose estimate. However, the in-house step wedge water phantom has the disadvantage that the shape of the phantom is square. Until now in Indonesia, it has never been developed of step wedge water cylindrical phantom for tube current profile evaluation. By using a cylindrical step wedge water phantom that has a variety of diameters, it provides the advantage that in one-time scanning we can get tube current profiles of various diameter sizes. This study aims to evaluate the tube current profile of Siemens 128 slice CT scan on in-house step wedge water cylindrical phantom with tube current modulation technique with image level variation on Borobudur phantom.

II. METHODS AND MATERIAL

A. In-house step wedge water cylindrical phantom

This study used an in-house step wedge water cylindrical phantom with a case from acrylic material. The phantom has four different diameters of 8, 16, 24, and 32 cm integrated into one with the height of each diameter being 6 cm. A valve was installed on the side of the phantom at the largest diameter to fill the water. Since the phantom looks similar to a stepped pyramid, we call this phantom the Borobudur phantom, as shown in Figure 1a. The phantom was positioned lying down with the help of a support, as shown in Figure 1b.

B. Data Acquisition

We scanned the borobudur phantom using Siemens Somatom Definition AS+ with the scanning parameters shown in Table 1. Before axial scanning, we took topogram images to estimate the attenuation level of the phantom diameter.

(a) (b) (c)

Figure 1. Borobudur phantom (a) Schematic Borobudur phantom (b) Photograph of the phantom (c) Photograph of the phantom on CT scanner table.

Table 1. Scan Parameters

Scan Parameter	Tube voltage variation	Quality reference variation
Tube voltage (kVp)	80 ,100, 120, 140	120
Tube current (mA)	TCM	TCM
Quality reference (mAs)	210	170, 190, 210, 230, 250
Scan mode	Helical	Helical
Pitch	1	1
FOV (mm)	371	371
Slice thickness (mm)	5	5

The topogram of the phantom can be seen in Figure 2. We conducted two types of scans, i.e., tube voltage variation and quality reference variation. As for the quality reference variation, we did it for the Siemens CT specific settings. Quality reference is a parameter entered by the user to determine the level of image quality required. Quality reference is set equal to the effective mAs that produces the desired image quality on a standard-sized patient. All images will be saved in Digital Imaging and Communications in Medicine (DICOM) format.

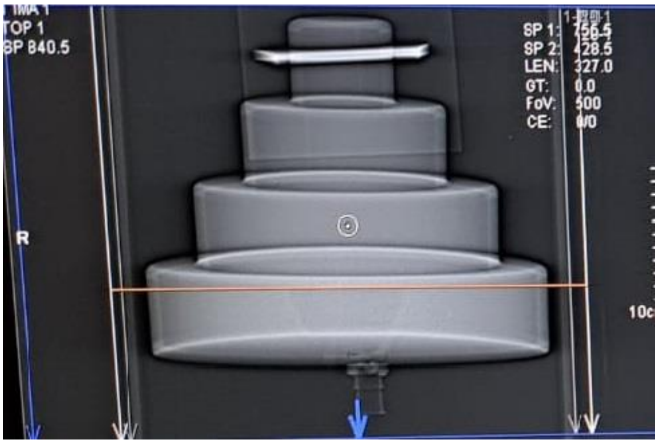


Figure 2. Topogram of Borobudur phantom.

C. **Analysis of tube current profile in Borobudur phantom**

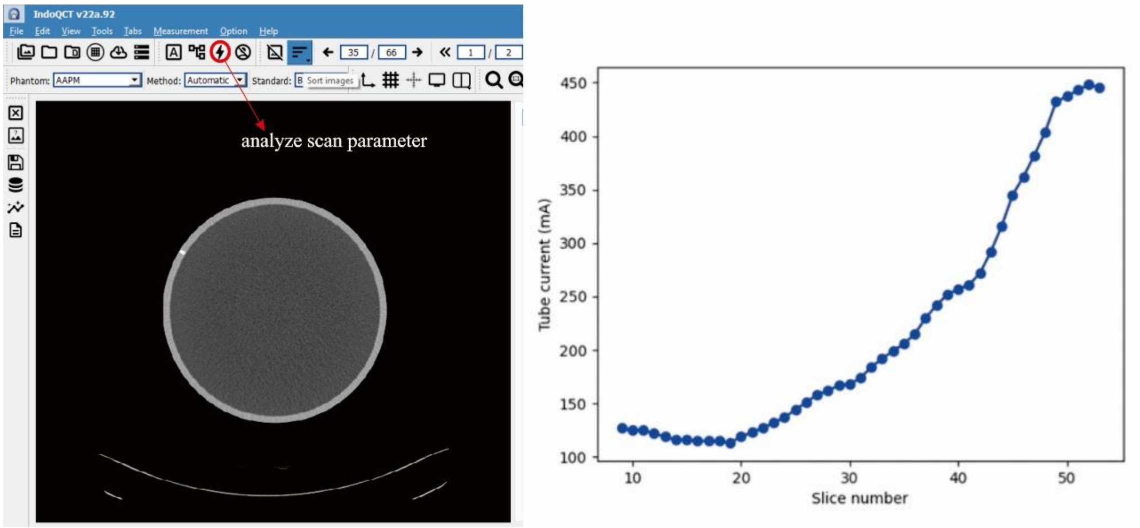
We extracted the tube current profile on the Borobudur phantom using IndoQCT software [19]. After the axial image of the phantom is obtained, the first step was to read the image with IndoQCT. The image read by IndoQCT assigned to a variable called ds. This variable is a DICOM dataset class that contain header. For accessing the tube current information, the tag description "XRayTubeCurrent", as we used in Equation (1).

$$\text{tube current} = \text{ds.XRayTubeCurrent} \quad (1)$$

In IndoQCT, we used the “analyze scan parameter” tool to find out the tube current profile in each slice, as shown in Figure 3. The tube current profile from the dataset can be directly exported for further analysis.

III.RESULTS AND DISCUSSION

Example images of the phantom with four different size of 8, 16, 24, 32 cm are shown in Figure 4.



(a) (b)

Figure 3. Tube current measurements for all slices on IndoQCT. (a) Scan parameter analysis button, (b) Example of tube current analysis results from a dataset of phantom images.

A. Tube current profile at tube voltage variation

The tube current profile of the Borobudur phantom four tube voltage variation is shown in Figure 5. The 8 cm diameter is at slice numbers 1 to 9, the 16 cm diameter is at slice numbers 10 to 21, the 24 cm diameter is at slice numbers 22 to 32, and the 32 cm diameter is at slice numbers 33 to 45. Based on Figure 5, the change in tube current is gradual at each phantom diameter. When using tube voltage variation there is no significant changes were observed along the resulting tube current profile. This is evidenced by the statistical test which have a p-value of 0.752.

However, the tube current has an upward trend as the phantom diameter increases, except a few slices at the end of the slices with the largest diameter. This characteristic is observed for all the data under tube voltage variation.

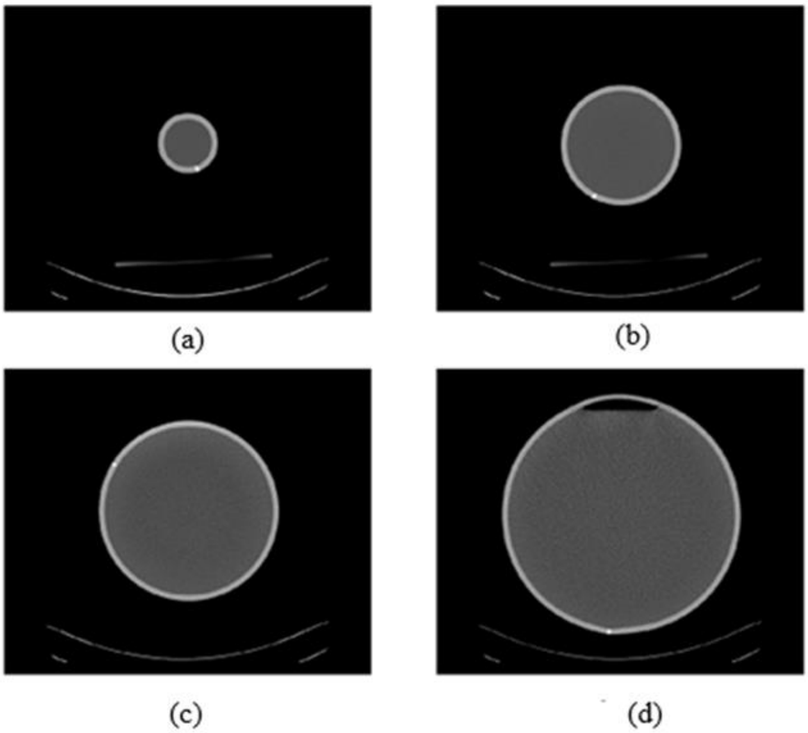


Figure 4. Axial image of Borobudur phantom (a) diameter 8 cm (b) 16 cm (c) 24 cm (d) 32 cm.

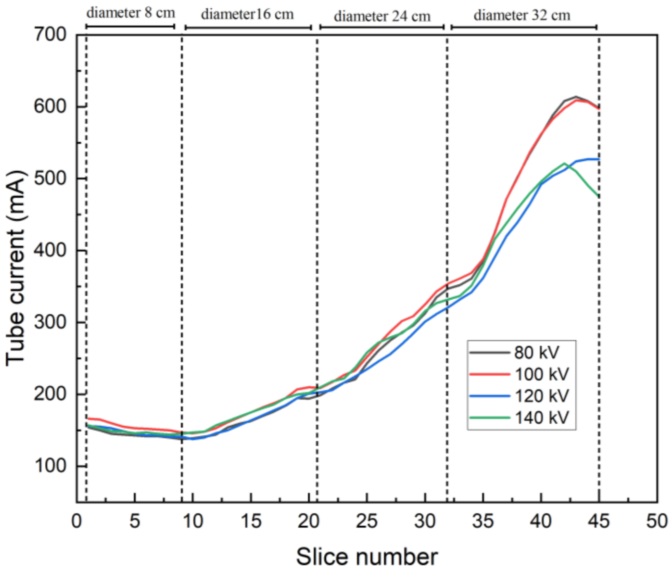


Figure 5. Tube current profile in Borobudur phantom with tube voltage variation at quality reference of 210 mAs.

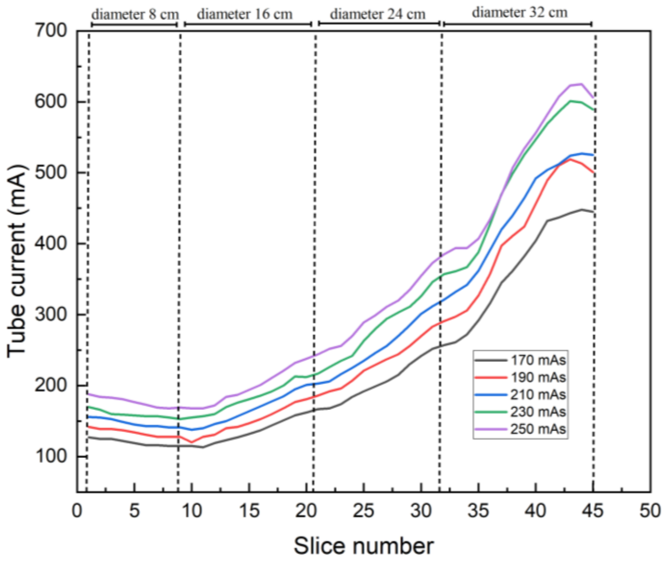


Figure 6. Tube current profile on Borobudur phantom with variation of quality reference at tube voltage of 120 kV.

B. Tube current profile at quality reference variation

The tube current profile of the Borobudur phantom for quality reference variation is shown in Figure 6. Based on Figure 6, the change in tube current is gradual at each phantom diameter It can also be seen that a low-quality reference will result in a higher tube current value.

Tube current is one of the crucial exposure factors because it leads to the amount of radiation dose delivered during the scanning. If the tube current is reduced by half, the dose will be reduced by 50%. One of the technologies that can be used to reduce the dose in CT is TCM technique. One alternative phantom that can be used is the Borobudur phantom.

In this study, we evaluated the tube current profile of the borobudur phantom with two variations: tube voltage variation and quality reference variation. It is found that there is no significant change in tube current when using tube voltage variations (p = 0,752). It is printed out that if the phantom diameter increases, then the tube current tends to increase gradually. This is because when passing through an object, X-rays will experience attenuation. The attenuation coefficient of a material will increase as the thickness of the medium increases [21]. This motivates us to design phantoms with various diameter sizes, which is to simulate different levels of attenuation. The larger the diameter of the phantom, the higher the attenuation level.

To stabilize the noise on all slices of various diameter sizes, the system automatically compensates the tube current. It is found that there is significant change in tube current when using quality reference (p = 0.001). The higher the quality reference value will improve image quality. To improve the image quality, the tube current will automatically increase.

This paper presents an evaluation of TCM using the Borobudur phantom dataset which has several diameter sizes. Our findings can provide enough insight into the changes in tube current when passing through different object sizes. However, the data we collected only came from a single scanner. To understand and analyze this phenomenon more comprehensively, further analysis of different types of scanners is needed. Through processing data from various scanners, TCM can be characterized depending on the vendor and scanner type.

IV. CONCLUSION

Measurement of tube current profile with tube voltage variation and quality reference of Borobudur phantom has been developed. In the tube voltage variation, the tube current value is not significantly different, but the tube current value increases as the phantom diameter increases. Through statistical tests, a p-value of 0.752 was obtained, which indicates that the tube current value in the tube voltage variation is not significantly different. In the quality reference variation, the higher the quality reference value, the higher the tube current value. The statistical test resulted in a p-value of 0.001, which indicates that the tube current value at the quality reference variation has a significant difference. The results obtained provide an overview of the changes in tube current (especially in Siemens manufacturer CT scanners) when passing through different object sizes.

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