Atom Indonesia

Correlations Between Body Weight and Size-Specific Dose Estimate on Thoracic Computed Tomography Examination

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ABSTRACT

The dose received by a patient on CT examination is expressed in size-specific dose estimates (SSDE) which is a function of the patient diameter, x-ray attenuation, and scanner output (volume computed tomography dose index, CTDIvol). Patient diameter and x-ray attenuation are represented as water equivalent diameter (Dw). We conducted the research to analyze the relationships between body weight and Dw, CTDIvol, and size-specific dose estimates (SSDE) in contrast-enhanced thorax examinations. We used images from 100 patients (50 women and 50 men patients) whose weight range from 2.8 kg to 80 kg. The values of Dw, CTDIvol, and SSDE were automatically calculated from axial CT images using the IndoseCT software. Statistical analysis showed that the patient's body weight correlates linearly with the Dw. The linearity coefficient (R^2) values for body weight and Dw is 0.43 (women) and 0.55 (men). However, weight was independent of the patient dose in terms of CTDIvol and SSDE. This was because the CT system used tube current modulation (TCM), which automatically adapted the tube current to patient size, resulting in a relatively constant dose regardless of the patient size (Dw).

INTRODUCTION

Computed tomography (CT) is an X-ray-based modality used as a supporting tool in performing diagnostics. CT image has good sensitivity and specificity [1]. It means that CT can be used as a tool to correctly identify patients with disease and those who do not have one. Since the scanning time of CT is extremely short [2], it is very practical to be used for examinations such as head cancers, neck, and thorax [3,4]. However, in general, X-ray-based CT examinations resulted in a relatively high radiation dose with a potential to cause cancer in the future. Therefore, in CT examinations, there is a predetermined protocol so that the dose received by the patient is as low as possible, consistent with images of sufficient quality to make diagnosis.

The dose received by patients in a CT examination is currently based on the size-specific dose estimate (SSDE) [5,6]. SSDE value is critical in determining diagnostic reference level (DRL) [7], acceptable quality dose (AQD) [8,9], and organ dose [10,11]. Currently, SSDE based on the water equivalent diameter (Dw) can be automatically determined through axial images or topogram images using software such as IndoseCT [12]. However, not everyone can get an access to the software.

Several studies mentioned that both Dw and SSDE have a good correlation with body size and body mass index (BMI) [13,14]. The correlation between BMI with Dw and SSDE is better than the correlation between body weight with Dw and SSDE [14]. However, the relationships between Dw and BMI or weight were observed only for Taiwanese or American patients [13,14]. Until now, to the best of our knowledge, there are no data on relationships

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between Dw and BMI or body weight for Indonesian patients. This study was conducted to analyze the correlation between body weight with Dw and SSDE for Indonesians. It is expected that everyone of interest can access SSDE through the patient's weight.

METHODOLOGY

This study involved 100 patients consisting of 50 women and 50 men with a weight range of 2.8 kg to 80 kg who had undergone a thoracic examination at Dr. Kariadi Hospital, Semarang, Central Java, Indonesia. The CT scanner was a Siemens Sensation 64. The image used in this study is an image generated from examination using a contrast agent. The scanning protocol was the routine thorax, i.e. a voltage of 120 kV (children and adults), tube currents of 45 mA for children and 100 mA for adults, a pitch factor of 1.4, and a total collimation width of 19.2 mm.

CTDI$_{vol}$ value

CTDI$_{vol}$ values were obtained from CTDI$_w$ as indicated in Eq. (1).

$$CTDI_{vol} = \frac{CTDI_w}{pitch} \qquad (1)$$

the CTDI$_{vol}$ dose is the output dose of the device or CT scanner. Its value in this study was obtained from the Digital Imaging and Communications in Medicine (DICOM) dose report.

Calculation of Dw and SSDE

In general, the value of D$_w$ can be calculated based on the average Hounsfield unit (HU) from the value of the region of interest (ROI) and the area of the ROI (A$_{ROI}$) using Eq. (2) [15-17]. The SSDE value was the product of CTDIvol and a size conversion factor (CF(Dw)) (see Eq. (3)).

$$Dw = 2\sqrt{\left[\frac{1}{1000}\overline{HU} + 1\right]\frac{A_{ROI}}{\pi}} \qquad (2)$$

$$SSDE = CTDI_{vol} \, x \, CF(Dw) \qquad (3)$$

The Dw and SSDE values were automatically calculated from the axial images using the IndoseCT 20.b software [18].

Correlations

The relationships between body weight and D$_w$, body weight and CTDI$_{vol}$, and body weight and SSDE were conducted using regression analysis with OriginPro 9.0. Comparisons between men and women patients were also performed.

RESULTS AND DISCUSSION

Relationship between body weight and D$_w$

Figure 1 presents the relationship between body weight and D$_w$ for all the patients. Based on Fig.1, it can be seen that the linear relationship between body weight and D$_w$ is obtained with a value of $R^2 = 0.51$, which is considered moderately sufficient to imply linearity [19]. Previous study for Americans, as a comparison, reported that the relationship between body weight and D$_w$ had a weak correlation ($R^2 = 0.47$) or moderate correlation ($R^2 = 0.69$) [14].
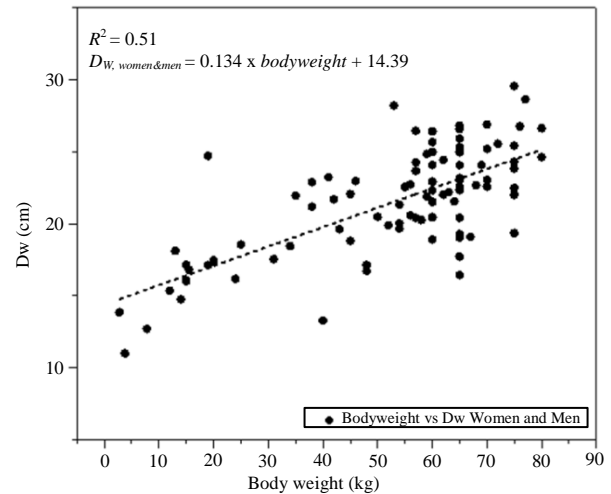

Fig. 1. Relationship between body weight and Dw for a combination of women and men patients.

The relationships between body weight and D$_w$ for women and men patients are separately displayed in Fig. 2. It shows linear relationships between body weight and D$_w$ for both women ($R^2 = 0.43$) and men ($R^2 = 0.55$). These are not significantly different. But, R^2 for women is lower than that for men. It indicates that the anatomy of the thorax of women and men is different. For women patients, the presence of mammae definetly affects the diameter of the patient.
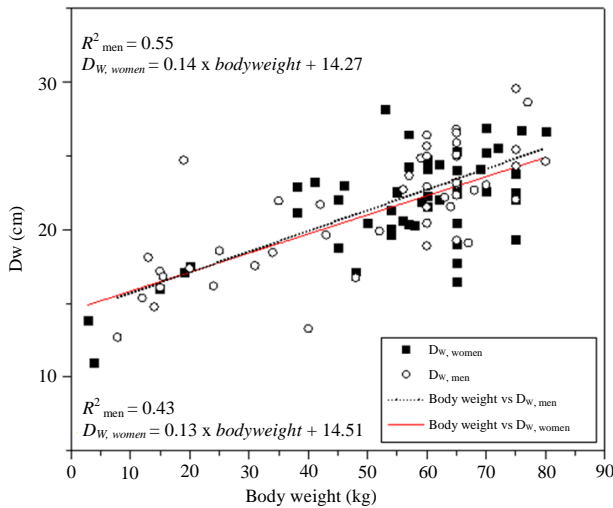
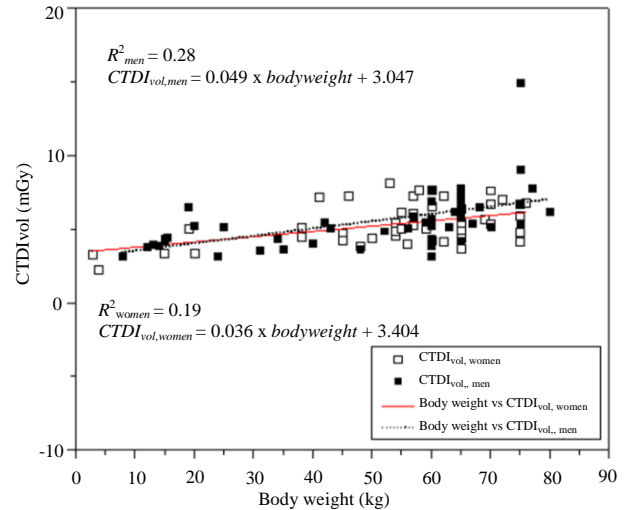**Fig. 2.** The relationships between body weight and Dw separately between women and men patients.

Fig. 4. Relationships between body weight and CTDIvol separately between women and men patients.

Correlation between body weight and CTDIvol

Figure 3 shows a linear relationship between body weight and CTDIvol for all 100 patients with $R^2 = 0.25$. The relationships between body weight and $CTDI_{vol}$ for men and women patients shown separately are provided in Fig. 4. The R^2 are 0.28 and 0.19 for men and women patients, respectively, which is not a significant difference. Value of $R^2 < 0.5$ indicate that the relationship between two variables is weak [19]. This is due to the effect of using tube current modulation (TCM) techniques [20]. TCM is a technique to automatically adjust the tube current based on the size of the patient, so that the radiation dose was not increased for small patient size [21,22].
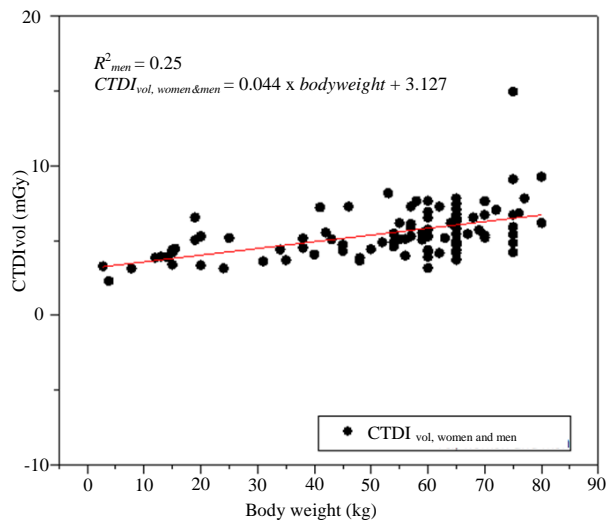
The relationship between weight and SSDE

Figure 5 shows the relationship between body weight and SSDE for all 100 patients with $R^2 = 0.095$. The relationships between body weight and SSDE for men and women patients in a separate line are shown in Fig. 6. The correlations between body weight and SSDE are with $R^2 = 0.093$ for women and $R^2 = 0.097$ for men, both of which are not significantly different. The correlations between the two show a very weak correlation with $R^2 < 0.1$, indicating that the implementation of TCM was successful. TCM adjusts tube current during CT to provide target image quality across scans as well as for patients of any size [22].
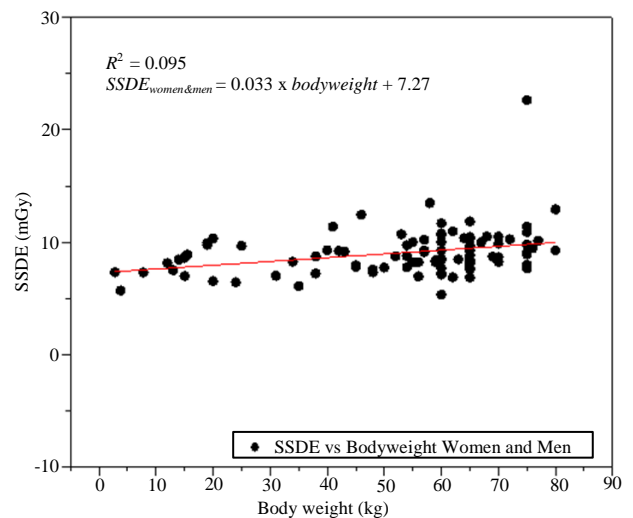

Fig. 3. Relationship between body weight and CTDIvol for all 100 patients.

Fig. 5. Relationship between weight and SSDE for all 100 patients.

The average values of CTDI$_{vol}$, D$_w$, and SSDE for women, men, and a combination of both are tabulated in Table 1. It shows that the diameter of women is slightly larger (1.35 %) than men, due to the impact of mammae in the women patients. Although TCM was implemented, due to the higher size of women patients, the dose to the women patients was slightly smaller than men patients (2.38 % and 2.91 % for CTDIvol and SSDE, respectively).
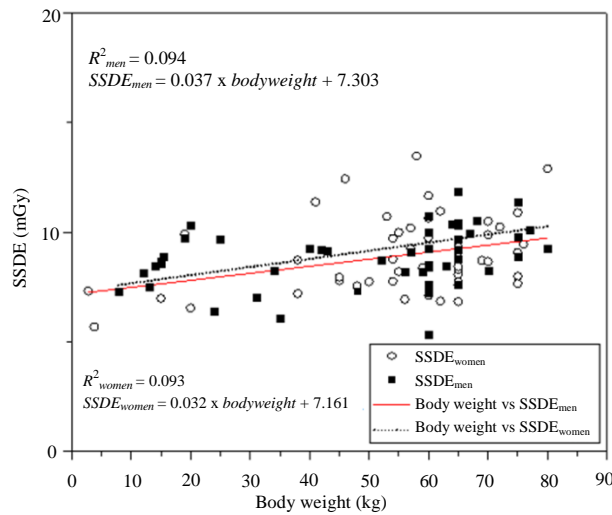

$R^2_{men} = 0.094$
$SSDE_{men} = 0.037 \times bodyweight + 7.303$

$R^2_{women} = 0.093$
$SSDE_{women} = 0.032 \times bodyweight + 7.161$

Fig. 6. The relationships between body weight and SSDE for women and mean patients separately.

Table 1. Average values of CTDI$_{vol}$, D$_w$, and SSDE in chest examination.

Variable	Women	Men	All
	(mean ± standard deviation)		
CTDIvol (mGy)	5.4 ± 1.9	5.6 ± 1.9	5.5 ± 1.7
Dw (cm)	21.6 ± 3.4	21.4 ± 3.9	21.5 ± 3.6
SSDE (mGy)	9.2 ± 2.3	9.2 ± 2.3	9.0 ± 2.0

CONCLUSION

The relationships between body weight and Dw, body weight and CTDIvol, and body weight and SSDE for Indonesian case have been established. There is a linear relationship between weights and Dw with R^2 of about 0.5. However, the relationship between body weight and SSDE has a weak correlation. Thus, body weight cannot be properly used to calculate the SSDE value. Due to the application of tube current modulation (TCM) technique, there was no difference in patient dose (CTDIvol and SSDE) due to patient weight. In this study, there was no significant difference in outcome between male and female patients.

AUTHOR CONTRIBUTION

L. Wati and C. Anam conceived of the idea. L. Wati, A. Nitasari, and S. Syarifudin collected the data. L. Wati and C. Anam wrote the manuscript with the help and input from G. Dougherty. All authors read and approved the manuscript.

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