The comparison of Size-Specific Dose Estimate (SSDE) in chest CT examination calculated based on volumetric CT Dose Index (CTDI\textsubscript{vol}) reference phantom and Dose Length Product (DLP)

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Abstract. The radiation dose of X-ray radiation exposure that comes from a CT scan is not easy to determine, because a CT scan uses several beams of X-ray radiation for one scan. In addition, the X-ray exposure dose on the CT scan is not the sum of the X-ray radiation exposure doses from each beam. Therefore, the Size-SpecificDoseEstimate (SSDE) parameter is used, which means as the estimated radiation exposure dose received by the patient. The SSDE value is a function of the CTDI\textsubscript{vol} which is determined from the reference phantom or from the derived Dose Length Product (DLP) values. The CTDI\textsubscript{vol} value determined from the reference phantom has the same value for the weight interval of the patient, so that the patient gets the same dose of X-ray exposure even though the body size is different. The CTDI\textsubscript{vol} value determined by Dose Length Product (DLP) depends on the lateral length of the patient's body. Because the lateral body length of each patient is different, the CTDI\textsubscript{vol} value will be different, so the SSDE value will vary more. The results showed different SSDE values for each patient according to body mass index.

1. Introduction

CT scan is a diagnostic instrument that is generally used to see a clearer picture of abnormalities in internal organs. Usually a CT scan examination is used after conventional X-ray examination. Diagnostic examination with a CT scan will produce clearer images of the organs, because a CT scan uses several X-ray sources simultaneously. As a result, the radiation dose received by the patient becomes larger [1-3]. Therefore, determination of the value of radiation dose on CT scan examination is focused on the probability of stochastic effects that can occur, such as developing cancer [4].

Calculating the dose on a CT scan is not as simple as conventional X-ray diagnostics, because many X-rays sources are used in one scan. The dose of a CT scan is not the sum of the dose of each X-ray used. CT scan uses several types of doses, such as the effective dose that can be determined from the Dose Length Product (DLP), Computed Tomography Dose Index (CTDI) which is the total radiation dose for one scan, and Size-SpecificDoseEstimate (SSDE) which is the estimated radiation exposure dose received by the patient.

Setting of CTDI\textsubscript{vol} Value indicator at CT scan instrument is determined through measurements using the reference phantom [5]. This reference phantom can be assumed has a size near with patient size to estimate the absorbed dose. So the CTDI\textsubscript{vol} value is adjusted to the CTDI\textsubscript{vol} value of the reference phantom, using an assumption that the patient's size approaching the phantom size. As a result, the radiation dose obtained by a patient with a body size that is approximately closer to that of the phantom, receives the same radiation dose, although this appears imprecise. Another parameter that is associated
with a more accurate patient-received dose is Size-SpecificDoseEstimate (SSDE). This SSDE value is the multiplication of CTDI\_vol with a constant that depends on the length of the lateral and anterior-posterior (AP) \cite{5}. For the lateral length, it is easy to determine because it is the width of the chest, but determining the length of the AP is not easy. One way that can be done is to get the CTDI\_vol value through the DLP value, as in the following equation \cite{4}:

\[ \text{DLP} \, (\text{mGy-cm}) = \text{CTDI}\_\text{vol} \times L \] \hspace{1cm} (1)

where \( L \) is the scan length. DLP is a parameter indicated on the CT scan screen, which is used to obtain the effective dose value \cite{4-6}.

Considering the description above, the aim of this study is to evaluate the comparison of the SSDE value obtained through CTDI\_vol which is obtained from the reference phantom, with the SSDE value obtained through CTDI\_vol which is derived from DLP.

2. Materials and methods

This study uses secondary data from one of the hospitals in the city of Makassar. The CT scan machine used is the Hitachi CT-wo-50. The parameters used were patient data and CT scan data. Patient data were taken from medical records including age, weight, and height, while CT scan data included CTDI\_vol, DLP, scan length, lateral and anterior-posterior (AP) length.

The phantom CTDI\_vol value is obtained from the normalized CTDI measurement results using the 32 cm PMMA phantom as a reference, while the CTDI\_vol value derived from DLP is calculated using equation (1). The SSDE value is determined using the equation as listed in AAPM Report 204: \cite{5}

\[ \text{SSDE} \, (\text{mGy}) = f_{32} \times \text{CTDI}\_\text{vol} \] \hspace{1cm} (2)

where \( f_{32} \) is the conversion constant used in a phantom with a size of 32 cm in diameter of PMMA phantom for CTDI\_vol as a function of the lateral length and AP.

3. Results and discussion

The sample data used in this study were secondary data from hospital. The data were from 100 people with ages ranging from 18 years to 88 years who performed chest CT examinations. The highest number of samples who performed chest examinations were 48 people aged between 51 years and 70 years, while the lowest number were samples who were young or less than 30 years old (Table 1).

| Table 1. Sample characteristics |
|-------------------------------|
| Age (Years) | Body Mass Index (kg/m\(^2\)) | Category | Number of samples |
|-----------------|-------------------|---------|------------------|
| < 30            | 4                 | Under weight | 37               |
| 31 - 50         | 28                | Normal weight | 47               |
| 51 - 70         | 48                | Over weight  | 13               |
| > 70            | 20                | Obese       | 3                |

According to the weight category, the sample that performs a chest CT scan is generally in the normal weight category. Three samples were included in the obese and 37 samples were included in the underweight category.

As we know, a CT scan is used to detect abnormalities in organs in the body using X rays, so that the X rays will pass through the target before arriving at the detector. Thus, the target thickness will affect the X-ray radiation dose used. The target thickness, in this case the patient’s body, can be predicted using the body mass index. The data is easy to get because it can be seen from medical records. On the other
hand, for a chest CT scan, X-ray radiation will fall only on the chest so that only a small area is needed, so the body mass index parameter is not well used. Therefore, other parameters, such as the lateral length and anterior-posterior (AP) length are usually used.

Figure 1. Variation of body mass index and (AP + Lateral)

Figure 2 shows the variation in body weight as represented by the body mass index value, and the patient's body size represented by the sum of the lateral and anterior-posterior values. Figure 2 can illustrate that the variation in body size represented by the summation of lateral and AP is not different from the variation in body mass index. Thus the patient's body size can be represented by summation of lateral and AP [5].

From the observations of chest CT scan examination procedure, the CTDI$_{vol}$ value used in CT scan instrument was the CTDI$_{vol}$ reference phantom of 32 cm in diameter PMMA phantom. The CTDI$_{vol}$ value which is used only two, they are 18 mGy used for patients with underweight categories, and 20 mGy for patients with normal to obese categories.

Figure 2 Comparison of CTDI$_{vol}$ reference phantom and DLP

SSDE is the radiation dose that is estimated to be received by the patient according to the patient's body size. This value can be calculated using equation (2) above. The SSDE value calculated using the CTDI$_{vol}$ from the phantom has a value that is not much different from one patient to another (Figure 3), because there are only two values as mentioned above. On the other hand, the CTDI$_{vol}$ obtained from the derivation of DLP has a varied value, as shown in Figure 3, namely from 20.15 to 25.89 mGy. This value is still in accordance with the value used by the ARC system, which is 12 to 26 mGy. [7]. The
CTDI\textsubscript{vol} obtained from the derivation of DLP is a function of the lateral length of the target, so that the CTDI\textsubscript{vol} value is more appropriate for each target, in this case the patient.

Table 2 shows the difference in the SSDE values from the two calculation methods. The SSDE value using the phantom-based CTDI\textsubscript{vol} value appears to be lower than the SSDE value using the derivation of DLP. Significant differences were seen in patients with less weight than those with normal weight and overweight. This is because the CTDI\textsubscript{vol} value for patients is only differentiated for two categories, which for the underweight category, is 18 or 19 mGy, and for normal and obese using the CTDI\textsubscript{vol} value of 20 mGy. As a result, the dose received by the patient has a wide interval in the underweight patient.

**Table 2. Comparison of SSDE calculated based on CTDI\textsubscript{vol} reference phantom and DLP**

| Weight category | SSDE\textsubscript{reference phantom} (mGy) | SSDE\textsubscript{DLP} (mGy) | Difference (mGy) |
|-----------------|----------------------------------------|----------------------------|-----------------|
|                 | Interval | Average | Interval | Average |                   |
| Under weight    | 18.00 – 37.59 | 24.23 | 35.03 – 43.23 | 35.56 | 12.11            |
| Normal weight   | 30.15 – 38.99 | 33.49 | 30.74 – 46.94 | 37.43 | 5.65             |
| Over weight + Obese | 31.36 – 37.59 | 33.27 | 35.33 – 46.96 | 38.80 | 6.04             |

In contrast to the SSDE value calculated using the CTDI\textsubscript{vol} value, from the derivation of DLP has a different value, but not too large. The SSDE value for the average underweight category sample is 35.56 mGy, for the normal weight category is 37.43 mGy, and for overweight to obese, it is 38.80 mGy. It is reasonable, because the lateral length associated with the smallest area of irradiation in the sample is 22.53 cm for adults, and the largest is 29.32 cm, which is not a big difference.

The radiation dose received by a patient should be different for each person because the body size is different, but in practice, this is difficult to do. On the other hand, it is also a good idea to use phantom as the basis for selecting CTDI\textsubscript{vol} values, although making various phantom sizes is expensive. As a result, the phantom only has two sizes, which is 16 cm for pediatric patients and 32 cm for adult patients, so the dose received by patients is not accurate. On CT scan examination, there are other parameters, namely DLP which is more accurate. This parameter is generally used to determine the effective dose that patients received [1]. The results of this study shown in Table 2 also show the accuracy of using these parameters in determining the dose.

**4. Conclusion**

The radiation dose received by the patient when carrying out a chest examination with a CT scan needs to be known precisely. Radiation dose calculation can be done using the SSDE parameter. The SSDE value determined based on the phantom CTDI\textsubscript{vol} has a big difference in patients with underweight, normal weight and overweight patients. On the other hand, the SSDE value determined based on the CTDI\textsubscript{vol} derived from the DLP has a small difference and is more accurate. This is because the CTDI\textsubscript{vol} calculation based on the lateral length of the patient's chest corresponds to the area of radiation exposure.

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