International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137

Volume –06, Issue – 06, June 2021, PP – 17-22

# Patient Doses Based on the Acceptable Quality Dose on Thoracic CT Examination

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**Abstract:** Optimization of radiation dose is very important in protecting patients against the dangers of x-ray radiation. Optimization of the dose should be able to provide image quality that is acceptable to radiologists for diagnostic purposes with the lowest possible doses. The optimization tool in computed tomography scanner (CT scan) is known as the diagnostic reference level (DRL). However, the use of DRL has limitations since the dose received by the patient is not according to their needs. The DRL is obtained from 75% of the patient dose distribution with a standard size of 70 kg. Therefore, DRL does not fully meet the requirements for optimizing radiation dose. This study aims to determine the dose optimization based on the acceptable quality dose (AQD) in thoracic CT examination. This study involved 80 patients who had undergone a thorax examination using a contrast agent. All images in this study were obtained with digital imaging and communication in medicine (DICOM) format. The results of the analysis in this study stated that the patient dose based on the estimated value using the AQD principle in this study showed that the mean CTDIvol and DLP values were smaller than those using the Indonesian DRL principle. The values indicated in the application of the AQD principle and not applied, respectively, were 8.92 mGy and 9.75 mGy for the patient's weight range of 41-50 kg. 8.82 mGy and 9.72 mGy for the patient weight range of 51-60 kg. 8.99 mGy and 9.90 mGy for the patient weight range 61-70 kg. 7.74 mGy and 8.68 mGy for the weight range of patients 61-70 kg. The results of this study indicate that the use of the AQD principle can also cover the shortcomings of the DRL principle because the AQD principle also takes into account optimization parameters such as image quality. The image parameters in AQD are based on the X-ray attenuation function that represents the patient's dimensions and tissue quality in the form of SSDE values.

**Keyword:** Acceptable Quality Dose, CT Thorax, SSDE

## I. Introduction

Computed tomography (CT) scanners are an x-ray based modality that has many advantages. CT has a good level of accuracy and sensitivity to diagnose abnormalities in patients [1, 2]. In addition, examination using a CT does not take a long time [3]. Thus, CT is widely used for various types of examinations such as cancer screening [4–6]. The time used for the CT examination at the exam stage (1) single slice all 13 seconds, (2) single slice modern 10 minutes 13 seconds, (3) dual slice 11 minutes 52 seconds, (4) 4 slice 10 minutes 10 seconds, (5) 16 slice 9 minutes 07 seconds, and (6) 128 slice 5 minutes 33 seconds [7]. However, in general, the x-ray based modality potentially has a radiation impact on the patient. Therefore, studies related to radiation dose on CT are continuously carried out. The development of radiation dose on CT is carried out to accurately and efficiently calculate the dose received by the patient.

Many efforts have been conducted for dose optimizations [7]. A diagnostic reference level (DRL) was developed as one optimization tool so that the dose received by patients can be achieved at the lowest possible dose without scarifying image quality. In Indonesia, the DRL for CT has been set by the Nuclear Energy Supervisory Agency (BAPETEN) for various types of protocols [8]. However, along with the development of CT technology, the established DRLs have several weaknesses. (1) If there is a possibility of DRL as a dose limit that cannot be exceeded so that it poses harm to patients who require a higher dose than DRL to obtain an acceptable image. (2) DRL is built from certain technologies, so when the technology changes, DRL must also be updated. And (3) DRL as a reference dose is obtained from those based on the average value. Therefore, the dose received by each individual may be different. So that the use of DRL is sometimes less effective and affects the quality of the resulting image [9, 10]. Therefore, the deficiency in DRL was corrected with the development of the concept of diagnostic reference ranges (DRR).

DRR is a quality improvement tool based on a dose range in a patient distribution with optimal image quality. The DRR provides an estimate of the minimum dose limit which is the 25th percentile of the patient distribution and the approximate maximum dose limit which is the 75th percentile of the patient distribution. The estimated minimum dose limit is used as a signal when the dose is below the estimated minimum dose limit which can cause interference with image interpretation. The estimated maximum dose limit is used as a dose limit when the dose given to the patient is excessive. In determining the DRR, the required image quality is the minimum image quality based on subjective judgments by humans. The distribution of patients is based on body width. The disadvantage of the DRR is that it is not clear whether the 25th percentile always represents an estimate of the minimum dose limit or not [10]

Therefore, another metric is needed which is more effective and can be used to determine image quality. Where the image quality in question is an image that can be diagnosed by a radiologist. So that the radiological image can provide accurate information regarding the results of examinations using CT. The new concept was introduced by Madan Rehani in 2011 to overcome the deficiency of DRL. The metric is called the acceptable quality dose (AQD). The main concept of AQD is based on an image that is acceptable for diagnosis. Furthermore, several parameters are also used to determine AQD values including body weight [8] and body mass index (BMI) [9]. Subsequently, Kharita in 2018 reported that the concept of AQD can have the opportunity to be used as a standard for optimizing dosage. This is because the AQD concept provides an assessment of image quality with an appropriate dose of the image being assessed [11]. By using the AQD magnitude, it is hoped that the patient will receive a proper dose based on the patient's weight. Thus, this study aimed to determine patient dose based on AQD values on the chest examination.

## II. Materials and Methods

### 1. Patient and image information

This study involved 80 patients.The patients were divided into four weight groups, namely 41 – 50 kg (7 patients), 51 – 60 kg (28 patients), 61 – 70 kg (29 patients), and 71 – 80 kg (14 patients). All patients underwent a thoracic examination at Dr. Kariadi Hospital, Semarang, Central Java, Indonesia during the period of January 2019 to June 2020. The thoracic examination was performed using a Siemens Sensation 64 CT scanner.A contrast agent was administered in these examinations. The scanning protocol was the routine thorax, i.e. a tube voltage of 120 kV, tube currents of 100 mA, a pitch factor of 1.4, and a total collimation width of 19.2 mm.

### 2. Patient data collection

The images of 80 patients were collected. The image quality assessment was carried out by radiologists. The assessment was based on the clarity of the presence or absence of various types of lesions on ground-glass opacities, paratracheal lymph nodes, pulmonary nodules, and pleural effusions. These sections indicate that the results of the thoracic examination may indicate lung cancer [13–16].

Image quality assessment aims to determine whether the thoracic examination image can be accepted by radiologists or not. Image quality assessment in this study is based on the image quality assessment criteria (IQSC) [16]. The IQSC score consists of five criteria, from zero (0) to four (4). Based on these five criteria, the image that serves as the AQD value is the image that has a score of three (3) which means it is acceptable. Of the 80 patient images that have been analyzed by radiologists, there are only 70 patient images with a score of 3 (acceptable). Next, dose parameters such as CTDIvol value, a product of dose length (DLP), water equivalent diameter (Dw), and estimated dose-specific size (SSDE), were identified.

### 3. CTDIvol value

The mathematical equation used to measure the CTDI value is shown in the equation (1) [17].

$$CTDI = \frac{1}{Nh_{col}} \int_{z=-\infty}^{+\infty} D(z)\, dz \quad (1)$$

$Nh_{col}$ is the nominal beam collimation and D(z) is the dose located along the z-axis. In clinical practice, the dose profile was integrated from -50 mm to +50 mm. Hence the distance to the total accumulated dose is 100 mm. Therefore the CTDI is often called as $CTDI_{100}$ (equation 2).

$$CTDI_{100} = \frac{1}{Nh_{col}} \int_{z=-50}^{+50} D(z)\, dz \quad (2)$$

In addition, the value of $CTDI_{100}$ center and peripherals can be combined into one called weighted CTDI (CTDIw):

$$CTDI_w = \frac{1}{3} CTDI_{100}^{center} + \frac{2}{3} CTDI_{100}^{periphery} \quad (3)$$

In the helical scans, $CTDI_{vol}$ is defined as in equation (3).

$$CTDI_{vol} = \frac{CTDI_w}{pitch} \quad (4)$$

The pitch is a characterization of the speed of movement of the table feed per 360°

## 4. Calculation of DLP, Dw and SSDE

The DLP, Dw, and SSDE values in this study were automatically calculated using indoseCT R2015a software [18]. DLP is a representation of all absorbed energy or the CTDIvol value for the entire scan or scan length. Thus, the equation to determine the DLP is as seen in equation (5) [19].

$$DLP\ (mGy - cm) = CTDI_{vol}\,(mGy)x\ scan\ lenght\ (cm) \quad (5)$$

Meanwhile, the Dw is the diameter of patient taking into account the geometrical and radiological (attenuation) size. In general, the equation for determining the value of Dw is as seen in equation (6). Meanwhile, the SSDE value is the multiplication of the CTDIvol value and a size conversion factor (CF). The equation for the SSDE value is as seen in equation (7) [20].

$$D_W = 2\sqrt{\left[\frac{1}{1000}\overline{HU} + 1\right]\frac{A_{ROI}}{\pi}} \quad (6)$$

$$SSDE = CTDI_{vol}\ x\ CF(Dw) \quad (7)$$

Fig. 1 shows the indoseCT software. Calculations using this software were carried out by inputting the image from the DICOM format. The CTDIvol, Dw, and SSDE values are automatically obtained.

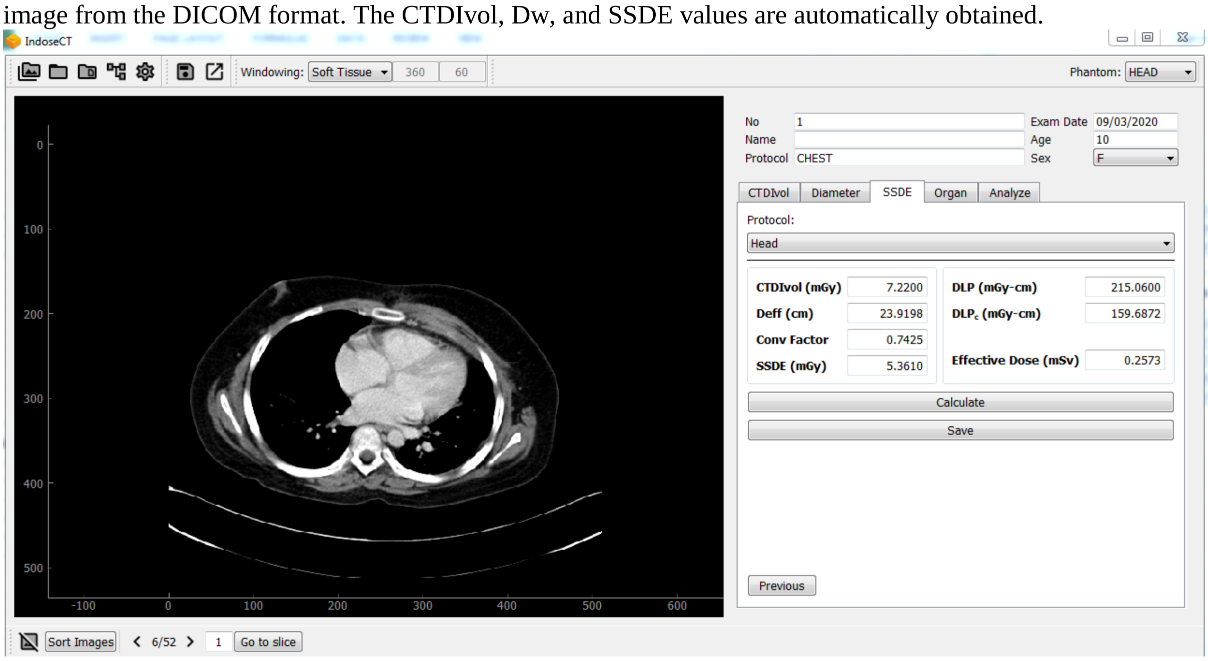


Figure 1. Automatedcalculation the CTDIvol, Dw and SSDE values using the IndoseCT software.

## 5. Calculation of AQD

Before the calculation of AQD, the image quality of the 80 patient images that had been collected was assessed by 3 radiologists. In this study, image assessment is based on image quality assessment criteria which categorize image quality into 5 scores as shown in the table.

Tabel 1. Scoring image based on image quality assessment criteria[16].

| Score | Description |
|---|---|
| 0 | Desired feature not seen in the images |
| 1 | Unacceptable quality |
| 2 | Limited quality (images with high noise) |
| 3 | Adequate quality (the diagnostic interpretation can be achieved from the images) |

  

| | |
|---|---|
| 4 | Higher than needed quality (images with little or no noise, the images are much better for diagnostic interpretation). |

After the assessment of the image using the image quality assessment criteria by the radiologist, an image with a score of 3 is selected which is an adequate image. After that, all images that have a score of 3 are classified based on the patient's weight. Based on these patient classifications, the mean and 75th percentile values of CTDIvol, SSDE, and DLP in each group could be determined. The mean and 75th percentile scores of CTDIvol, SSDE, and DLP are referred to as the AQD.

## III. Result

Images of 70 patients are confirmed as adequate images (score of three) by radiologists. The age range of patients ranged from 10 - 80 years and the patient's body weight was in the range 41 - 80 kg. The data presented included dose data for the thoracic CT examination before the AQD principle was applied (Table 1) and after the AQD principle was applied (Table 2). The DRL values from BAPETEN for Indonesia were tabulated in Table 3.

Table 2. Dose for thoracic CT examination before AQD principles (scoring) is applied.

| Mean Body Weight (kg) | Number of Patients | Average | | | The 75th Percentile | | |
|---|---|---|---|---|---|---|---|
| | | CTDIvol (mGy) | DLP (mGy-cm) | SSDE (mGy) | CTDIvol (mGy) | DLP (mGy-cm) | SSDE (mGy) |
| 45.33 ( 41 - 50 ) | 9 | 5.11 | 211.37 | 8.94 | 5.52 | 223.98 | 9.20 |
| 57.52 ( 51 - 60 ) | 28 | 5.65 | 241.48 | 9.04 | 6.53 | 273.57 | 10.00 |
| 65.68 ( 61 - 70 ) | 29 | 5.70 | 238.97 | 9.07 | 6.53 | 274.25 | 10.05 |
| 76.07 ( 71 - 80 ) | 14 | 7.24 | 262.43 | 10.71 | 7.62 | 299.53 | 10.73 |

Table 3. Dose for thoracic CT examination after AQD principles (scoring) is applied.

| Mean Body Weight (kg) | Number of Patients | Average | | | The 75th Percentile | | |
|---|---|---|---|---|---|---|---|
| | | CTDIvol (mGy) | DLP (mGy-cm) | SSDE (mGy) | CTDIvol (mGy) | DLP (mGy-cm) | SSDE (mGy) |
| 45.33 ( 41 - 50 ) | 8 | 5.11 | 209.79 | 8.92 | 5.94 | 226.53 | 9.75 |
| 57.52 ( 51 - 60 ) | 23 | 5.88 | 236.39 | 8.82 | 5.88 | 268.32 | 9.72 |
| 65.68 ( 61 - 70 ) | 26 | 5.63 | 235.17 | 8.99 | 6.49 | 268.87 | 9.90 |
| 76.07 ( 71 - 80 ) | 12 | 8.14 | 260.79 | 7.74 | 8.14 | 301.62 | 8.68 |

Based on Tables 1 and 2, it can be seen that the dose on thoracic CT examination increased with the increase of body weight. This is because the CT applies the tube current modulation (TCM) technique which automatically determines doses based on the patient's size and attenuation. The goal of TCM is to achieve image quality that matches the target during scanning [21].

## IV. Discussion

In general, to achieve the appropriate image quality, high doses are required. However, the use of high doses imposes side effects for patients. Therefore, in the examination with an x-ray based modality, the dose is always optimized according to the imaging needs. The objective of the optimization is of course to protect patients from excessive x-ray radiation and to obtain images accepted by radiologists for diagnosis [22]. Optimization of radiation dose can generally be controlled through proper setting of various parameters such as voltage (kVp), tube current (mA), scan length (cm), and beam collimation [23]. However, this optimization must be accomplished by the needs of a radiologist for diagnostic purposes.

In this research, optimization is done by applying the AQD principle. The use of AQD can provide radiation doses according to patient needs. In addition, the principle of AQD can also provide an image quality that is acceptable to radiologists for diagnostic purposes[22–25]. Based on Tables 1 and 2, there are differences in the dose values for each bodyweight group. The dose obtained if the AQD principle is applied, the dose on the CT Scan Thorax has a lower CT dose value than that based on the DRL principle. Table 4 is the DRL value set by BAPETEN in 2018 for the thoracic CT examination.

Table 4.Dose value of thoracic CT examination based on the DRL [25]

| Type of Patients | CTDIvol (mGy) | DLP (mGy.cm) |
|---|---|---|
| Children (5 - 14 year) | 14 | 443 |
| Adult ( $\geq$ 15 year ) | 14 | 759 |

Based on Tables 2 and 3, it can be seen that the CTDIvol for thoracic CT examination using the AQD and DRL principles different. The DRL value represented in CTDIvol for adult patients is 14 (shown in table 3) while the DRL value combined with the concept of AQD in patients with standard size (70kg) is 5,63 (shown in table 3). This indicates that the use of AQD can be used as a reference for dose optimization with adequate image quality. In addition, AQD can be used as a good tool for dose optimization to complement DRL shortages.

The limitations of this study are the limited number of patients and the classification of patients based solely on body weight. In a previous study [9], it was stated that the classification of patients was better based on BMI because the diameter of the patient was not only influenced by the patient's weight but also the patient's height. However, another study [26] stated that both body weight and BMI can represent well the DW value which is then used to calculate SSDE.

## V. Conclusion

Patient dose based on the AQD in the study showed that the mean CTDIvol and DLP values were smaller than those from the Indonesian DRL. The use of the AQD can overcome the shortcomings of the DRL because the AQD also takes into account optimization parameters such as image quality. Image quality parameters in AQD are based on the X-ray attenuation function which presents the patient dimensions and patient tissue density in the form of SSDE values.

## Acknowledgments

This work was funded by Riset Publikasi Internasional Bereputasi Tiggi (RPIBT), Diponegoro University (Contract Numbers: 329-116/UN7.6.1/PP/2021).

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