

Determination of the Diagnostic Reference Level (DRL) in Samarinda Hospitals

R. Jannah, R. Munir, E. R. Putri*

¹Department of Physics, Faculty of Sciences and Mathematics, Mulawarman University, Samarinda 75123, Indonesia

ARTICLE INFO

Article history:

Received 28 December 2022

Received in revised form 7 August 2023

Accepted 7 August 2023

Keywords:

Abdomen

CT scan

Diagnostic reference level (DRL)

Head

Thorax

ABSTRACT

The diagnostic reference level (DRL) is a form of investigative level used as a tool to help optimize protection to radiation exposure for diagnostic and interventional procedures. The purpose of this study was to determine the local DRL values for the examination of the abdomen, thorax, and head at radiology installations. The modality used was 128-slice CT scan. The numbers of patients whose data were used were 200 for abdominal examinations, 160 for thoracic examinations, and 100 for head examinations. Overall, the total patient whose data was used was 460. Data processing in this study was carried out with a quantitative analysis technique, namely descriptive statistics. This analysis technique used secondary data obtained from the results of recaptures or archival books for examination of the abdomen, thorax, and head. Data processing was carried out with a measure of diversity through the calculation of the third quartile in the data distribution. It was assumed that 75 % of patients performed examinations with a common diagnosis. The results of these calculations are visualized in the form of graphs of the relationship of computed tomography dose index volume (CTDIvol) with the number of patients and a graph of the relationship of dose length product (DLP) with the number of patients. In the abdominal examination, a CTDIvol of 12 mGy and a DLP of 1545.5 mGy·cm. In the thoracic examination, a CTDIvol of 11 mGy and a DLP of 903 mGy·cm were obtained. For the head examination, a CTDIvol of 34.25mGy and a DLP of 2190.25 mGy·cm were obtained. The conclusion obtained from this study is that the DRLs are relatively low, but they still need to be optimized by medical physicists.

© 2023 Atom Indonesia. All rights reserved

INTRODUCTION

The high value of the use of radiation in the health sector means that there are many modalities of ionizing radiation sources used to carry out certain examinations. The CT scan modality is one of the modalities that is widely used in the patient diagnostic process, but exposes the patient to a high radiation dose. The use of these modalities must be monitored to ensure radiation protection and the safety of workers, patients, and the public. To achieve it, radiation officers must use the diagnostic reference level (DRL) when carrying out diagnostic examinations [1].

The magnitude of the radiation hazard caused by the use of radiation results in the need to determine the maximum dose received by the patient in order to reduce the negative effects of radiation

use [2]. To reduce the dose given to patients, optimization is needed to comply with the ALARA principle (as low as reasonably achievable). The purpose of this principle is to be able to provide the minimum possible radiation dose with the maximum possible results [3]. To attain this aim, every nuclear installation or radiation source must be equipped with an adequate safety system.

Based on the recommendations from the International Commission on Radiological Protection (ICRP) Publication 135, the implementation of optimization should be carried out in collaboration between stakeholders and measuring bodies [4]. DRL is an effective way to improve optimization. Review or improvement of examination procedures must be carried out by the hospital team so that the dose given is low. Medical physicists, radiographers, and radiation protection officers are obliged to increase optimization if the DRL is exceeded [4].

*Corresponding author.

E-mail address: erlinda.putri@fmipa.unmul.ac.id

DOI: <https://doi.org/10.55981/aij.2023.1285>

The work reported at [5] has established an institutional DRL at Cipto Mangunkusumo Hospital, Jakarta, Indonesia, and provided practical tools in diagnostic radiology and nuclear medicine. Researchers in [6] have conducted DRL assignments for computed tomography in Egypt whose results are compared with DRLs from several studies in other countries. In addition, the research reported in [7] also performed DRL analysis for head procedures in pediatric patients whose results were compared with DRL values in adult patients. There were also those who calculated DRL on the CT modality in Ireland and the results were compared with international DRLs [8]. The research conducted by [9] was to evaluate the impact of factors affecting CT radiation dose whose results may facilitate the modification of CT imaging procedures after local DRLs is very high compared to national DRLs. Activities conducted in [10] included DRL designations in Japanese children hospitals whose results were compared to other countries. The work reported in [11] renewed the Australian national DRL, which was lower in yield and similar to that of other DRLs in developed countries. Reference [12] also determined DRLs in the United States whose results correspond to the data of other countries. The research in [13] performed cloud-based CT dose monitoring using DICOM-SR and analyzed national DRLs whose results allowed for automatic comparison of national DRLs. The last study conducted [14] determined DRL based on clinical indications of the results of a European survey whose results were used as a feasibility report on the determination of DRL in Europe.

In this work, the authors wanted to conduct a study of local DRLs in several hospitals in Samarinda, East Kalimantan province, Indonesia. The 128-slice CT scan modality at Samarinda hospitals does not yet have a radiation dose reference that is diagnostic. The presence of excessive doses can induce stochastic and deterministic effects. The radiation effects of CT scans are of particular concern for patient safety in radiology. This effect can be minimized by limiting or referring to the value of the dose given to the patient, which is called the diagnostic reference level (DRL). DRL consists of local DRLs, regional DRLs, and national DRLs. Currently, Samarinda hospitals have not set a local DRL and have not used the Si-INTAN application; therefore, research data will be collected manually.

Therefore, this research needed to be carried out to determine the local DRL value on the 128-slice CT scan modality in 2022. The foci of the research were the types of examination that were

mostly carried out in Samarinda hospitals, namely diagnostic examinations of the abdomen, thorax, and head. The local DRL values were obtained from secondary data taken from CT scan examination of 128 radiology patients with various diagnoses on examination of the abdomen, thorax, and head. Data processing was done by calculating the third quartile value and comparing it with the I-DRL value issued by BAPETEN. In addition, the DRL values that had been obtained were also compared with the ones from other countries such as Malaysia, the Netherlands, Canada, and the US.

METHODOLOGY

This study was designed to determine the diagnostic reference level for 128-slice CT scan at the radiology installations of Samarinda hospitals. The data taken was in the form of computed tomography dose index volume (CTDIvol) and dose length product (DLP) values on the abdomen, thorax, and head. A total of 460 data points were collected, consisting of data from 200 abdominal examination patients, 160 thorax examination patients, and 100 head examinations. The age range for all examinees was 18-65 years. The patients' body weights were in the range of 31 kg-90 kg. The research method used was the descriptive statistical method, namely statistics used to analyze data by describing or describing the data that had been collected as it was without making generally accepted conclusions or generalizations. This secondary data was taken from patients who underwent examinations from September 2021 to February 2022. The patient dose data used was data that was entered manually. The data which had been collected was then processed and analyzed by determining the third quartile (Q3) value or percentile 75 of the distribution of the DRL quantity results. This third quartile value was used as the DRL value. The data was also modeled with the Sma4Win software package to obtain CTDIvol and DLP graphs.

This research project was performed according to the following procedure. In the first step, observations were made on patients by examining the abdomen, thorax, and head using the CT scan modality. The position of the patient for abdominal examination was supine (lying on one's back) with both arms on the right and left sides of the body or crossed on the chest. The patient's position for thoracic examination was supine on the examination table with one's head in the gantry first. The position of the patient for examination of the head should be supine with the

chin slightly tucked into the chest. Patients were given contrast by injection in certain parts in order to obtain a clearer image. In the second step, kV, mAs, CTDIvol, and DLP values were recorded for each patient for each type of examination. The kV and mAs values used for all inspections were 120 kV and 200 mAs. In the third step, data grouping of CTDIvol and DLP values was carried out according to the type of examination performed. In the fourth step, the DRL value was calculated as the third quartile (75th percentile) of the dose value in an examination according to Eq. (1) to find the Q3 position from the distribution of patient dose data.

$$n_{q3} = \frac{3(n+1)}{4} \tag{1}$$

In addition, the Q3 value was obtained from Eq. (2).

$$x_{q3} = x_{a3} + \frac{1}{4} (x_{b,3} - x_{a,3}) \tag{2}$$

In the fifth step, a graph of the CTDIvol and DLP values was made against the number of patients at a predetermined time range for each examination. Finally, in the sixth step, a comparison of local DRLs with national/regional DRLs was carried out. This value indicated the local DRL of Samarinda hospitals in 2022.

RESULTS AND DISCUSSION

Figure 1 shows a graph of the distribution of CTDIvol values and Fig. 2 shows a graph of the distribution of DLPs on abdomen examination. Figure 3 shows a graph of the distribution of CTDIvols and Fig. 4 shows a graph of the distribution of DLPs on chest examination. Figure 5 shows a graph of the distribution of CTDIvols and Fig. 6 shows a graph of the distribution of DLPs on head examination.

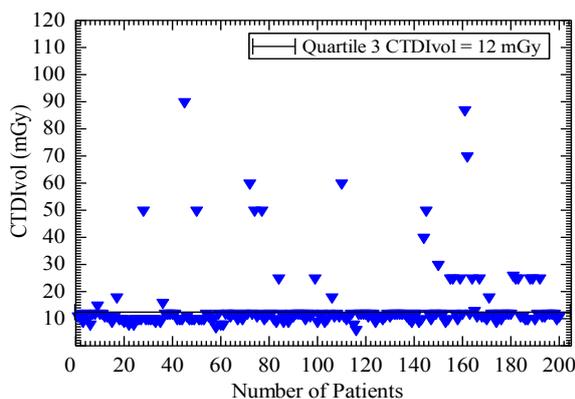


Fig. 1. Distribution of CTDIvol on abdominal examinations.

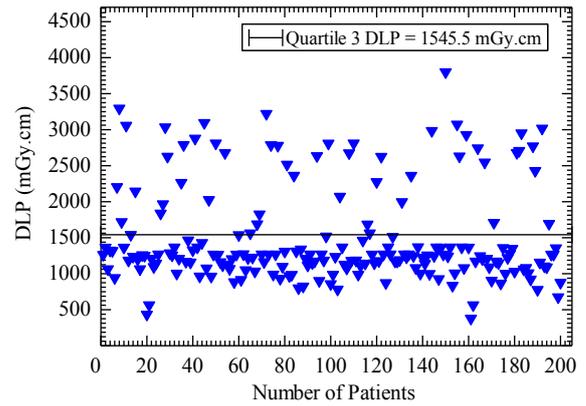


Fig. 2. Distribution of DLP on abdominal examinations.

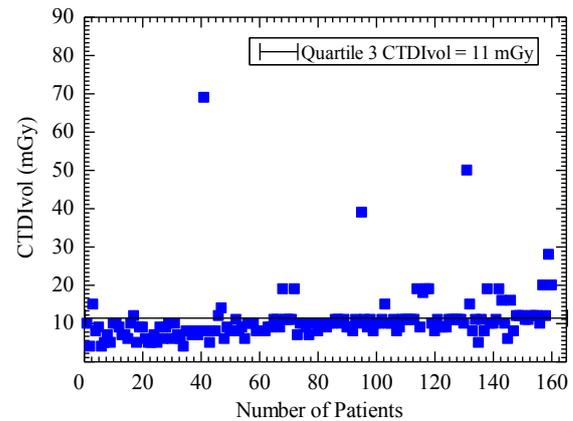


Fig. 3. Distribution of CTDIvol on thoracic examination.

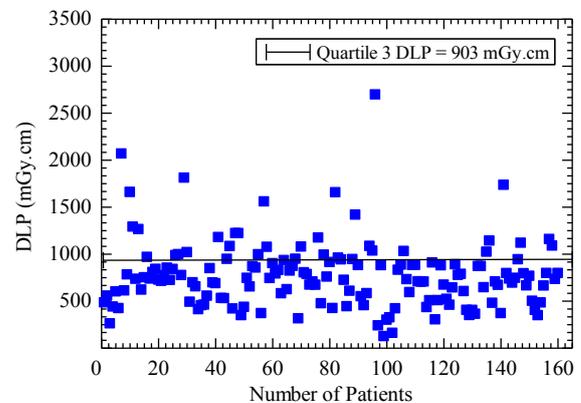


Fig. 4. Distribution of DLP on thoracic examinations.

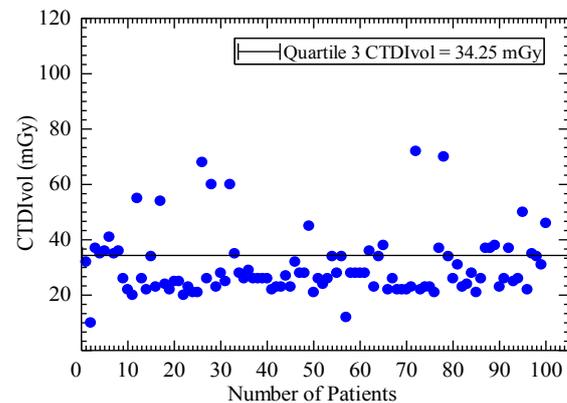


Fig. 5. Distribution of CTDIvol on head examinations.

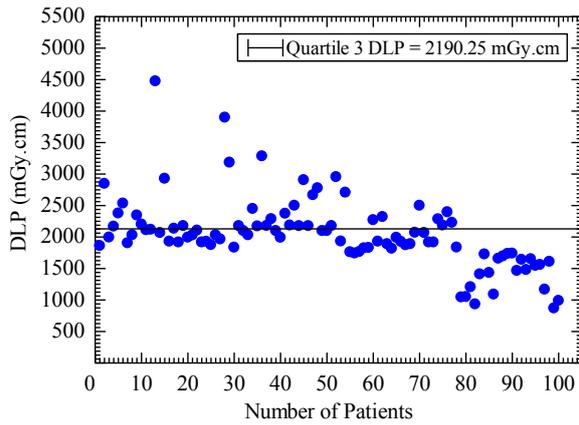


Fig. 6. Distribution of DLP for head examinations.

The use of ionizing radiation has to follow several principles of radiation protection as referred to in Article 20 of BAPETEN Regulation Number 4 of 2022 concerning Radiation Safety in the Use of X-Ray Equipment in Diagnostic and Interventional Radiology which includes justification, dose limitation, and implementation of optimization of radiation protection and safety [15]. To apply some of these radiation protection principles, the DRL is needed.

Based on the results of Q3 data processing for abdominal examination, the CTDIvol was 12 mGy and the DLP was 1545.5 mGy.cm. For thoracic examination, the CTDIvol was 11 mGy and the DLP value was 903 mGy.cm. For head examination, the CTDIvol was 34.25 mGy and the DLP was 2190.25 mGy.cm. The Q3 values can be used as the local DRLs of Samarinda hospitals in 2022. This value can be used as a reference (diagnostic and interventional radiology examinations) at the hospitals. It means that if the DRLs have been determined, then those values can be used as a comparison with the estimated dose received by the patient for the next one to two years. In Figs. 1, 3, 5, and 6, the dose is below the limit values set by BAPETEN. It indicates that the examinations that were carried out at the radiology installation went well. However, if the values obtained exceeds the reference DRL values, then the excess value must be evaluated or investigated what is the cause and corrective action is taken. For example, the procedures or SOPs are improved for exposure factors, so that the excess value will not be repeated in future examinations. Another example is that new technologies in the X-ray modality are reviewed if they have the potential to increase the value of

DRLs. By evaluating and correcting dose findings that exceed the DRL, the patient dose data for the year the DRL is in effect will be mostly below the DRL. In the subsequent period, the dose data for the validity period can be used to determine the next DRL value. It causes the DRL afterwards to be lower than the original DRL. This process is repeated onward.

Table 1 shows the results of calculating the CTDIvol and DLP values for the third quartile values on abdominal, thoracic, and head examinations from Samarinda hospitals. The corresponding official CTDIvol and DLP values from BAPETEN are also shown.

Table 1. Comparison of CTDIvol and DLP values for examination of the abdomen, thorax and head

Procedure	Samarinda Hospitals		BAPETEN [15]	
	CTDIvol (mGy)	DLP (mGy.cm)	CTDIvol (mGy)	DLP (mGy.cm)
Abdomen	12	1545.5	20	1360
Thorax	11	903	16	810
Head	34.25	2190.25	60	2500

When compared with the DRL value expressed in the official CTDIvol and DLP values set by BAPETEN, the DRL value from Samarinda hospitals is fairly good with a low dose value. This is because the CTDIvol value is considered low or below the official CTDIvol value set by BAPETEN. However, the third quartile DLP value for abdominal and thorax examination at the Samarinda hospitals was high or above the ideal DLP value set by BAPETEN. This happened due to several factors, including the many abnormalities of various types of cancer in patients undergoing abdominal examinations, differences in the brands of the instruments used, the clinical condition of the patients undergoing the examination, the patients' weights, and the scan lengths or widths of the irradiation fields given. In this study, the weight parameter has an influence on the CTDIvol and DLP values.

Table 2 shows the DRL for adult CT examinations compared to the DRLs of Malaysia [16], the Netherlands [17], Canada [18], and the US [19]. The DRL values for CT examination in this study for abdominal, thoracic, and head CT are higher than the results of Malaysian, Dutch, Canadian, and US studies.

Table 2. DRLs for adult CT examination compared to other studies.

Procedure	This study		Malaysia [16]		Netherlands [17]		Canada [18]		USA [19]	
	CTDIvol (mGy)	DLP (mGy.cm)	CTDIvol (mGy)	DLP (mGy.cm)	CTDIvol (mGy)	DLP (mGy.cm)	CTDIvol (mGy)	DLP (mGy.cm)	CTDIvol (mGy)	DLP (mGy.cm)
Abdomen	12	1545.5	12.8	450	-	-	18	874	16	781
Thorax	11	903	21.3	420	-	346	14	521	12	445
Head	34.25	2190.25	46.8	1050	-	936	79	1302	57	962

Based on Table 1, at Samarinda hospitals, unlike the result for abdominal and thoracic examinations, head examinations exhibited DLP values below the DLP values set by BAPETEN because the head generally has a narrow irradiation field or scan length not as wide as abdominal and thorax examinations. For abdominal and thoracic examinations, Samarinda hospitals attained higher DLPs than recommended by BAPETEN. Based on the results of this study, it is suggested that medical physicists at Samarinda hospitals have to find a solution to reduce the abdominal and thoracic DLP to below BAPETEN standards. The choice of the type of examination of the abdomen, thorax, and head was carried out because the CT scan modality has a high potential for radiation exposure to patients and the number of procedures for abdominal examinations is the most numerous among types of examinations. From the results of the study, the value of the CTDI_{vol} dose at the Samarinda hospitals is lower than BAPETEN's. However, the DLP value from Samarinda hospitals is higher than BAPETEN's. It means that the examinations carried out for them comply with radiation protection protocols. DLP values that exceed the limits given by BAPETEN can be caused by differences in the size of the irradiation area. However, efforts still need to be made to optimize protection through DRL.

Based on Table 1 and Table 2, it is also shown that the hospitals are only in the early stages of stepping into optimization efforts, namely by setting the local DRL value for the first time. Thus, the DRL value is only in the implementation stage. It can be stated that the local DRL value is an initial picture or portrait of the medical exposure that occurs.

CONCLUSION

Analysis was carried out for CT scanning in patients who were examined for their abdomens, thoraxes, and heads. It was found that for the abdominal examination, the CTDI_{vol} value was 12 mGy and a DLP value was 1545.5 mGy·cm. For thoracic examination, the CTDI_{vol} value was 11 mGy and the DLP value was 903 mGy·cm. For head examination, the CTDI_{vol} value was 34.25 mGy and the DLP value was 2190.25 mGy·cm. These values can be submitted as local DRL for patients examination of the abdomen, thorax, and head. However, because the DLPs for abdominal and thoracic examinations are higher than the values set by BAPETEN, it is necessary to optimize radiation protection. This effort can be done by reducing the dose or by selecting the correct scan length or the length of the target

examination section for abdominal and thoracic examination procedures.

ACKNOWLEDGMENT

The authors are grateful to Samarinda hospitals, particularly to the employees at radiology installations, for their vital contribution to this research project.

AUTHOR CONTRIBUTION

R. Jannah, R. Munir, and E.R. Putri initiated the research and equally contributed as the main contributors of this paper. All authors read and approved the final version of the paper.

REFERENCES

1. W. Susanto, *CT-SCAN Diagnostic Reference Level (DRL) Determination for Adults Head and Chest Examinations*, Nuclear Safety Seminar Proceeding 2018, Enhanced Radiation Protection Optimization in Nuclear Control Integrated (2018) 1.
2. D. Widyaningsih and H. Sutanto, *Berk. Fis.* **16** (2013) 57. (in Indonesian)
3. L. E. Lubis, *J. Med. Phys. Biophys.* **7** (2020) 22.
4. E. Vañó, D. L. Miller, C. J. Martin *et al.*, *ICRP Publication 135 Diagnostic Reference Levels in Medical Imaging*, *Annals of the ICRP* **46** (2017) 1.
5. T. Amalia, B. Zulkarnaien, C. Anam *et al.*, *Atom Indones.* **48** (2022) 159.
6. D. H. Salama, J. Vassileva, G. Mahdaly *et al.*, *Phys. Med.* **39** (2017) 16.
7. I. B. G. P. Pratama and I. R. Mulia, *Diagnostic Reference Level (DRL) Analysis of CT Scan Modality for Head Procedure on Pediatric Patient*, *AIP Conference Proceedings* **2374** (2021) 020027.
8. S. J. Foley, M. F. McEntee and L. A. Rainford, *Br. J. Radiol.* **85** (2012) 1390.
9. C. C. Yang, *Diagnostics* **10** (2020) 1.
10. R. Imai, O. Miyazaki, T. Horiuchi *et al.*, *Pediatr. Radiol.* **45** (2015) 345.
11. K. L. Lee, T. Beveridge, M. Sanagou *et al.*, *J. Med. Radiat. Sci.* **67** (2020) 5.
12. K. M. Kanal, P. F. Butler, D. Sengupta *et al.*, *Radiol.* **284** (2017) 120.

13. J. Boos, A. Meineke, C. Rubbert *et al.*, *Rofo*. **188** (2016) 288.
14. V. Tsapaki, J. Damilakis, G. Paulo *et al.*, *Eur. Radiol.* **31** (2021) 4459.
15. BAPETEN, Decree of the Head of the Nuclear Energy Regulatory Agency No. 1211/K/V/2021 Year 2021 on the Setting of Indonesian Diagnostic Reference Levels for X-Ray CT Scan and General Radiography Modalities, BAPETEN (2021) (in Indonesian).
16. Ketua Pengarah Kesihatan Malaysia, Malaysian Diagnostic Reference Levels in Medical Imaging (Radiology), Kementerian Kesihatan Malaysia (2013).
17. A. J. van der Molen, A. Schilham, P. Stoop *et al.*, *Insights Imaging* **4** (2013) 383.
18. G. M. Wardlaw and N. Martel, *Med. Phys.* **43** (2016) 4932.
19. P. F. Butler and K. M. Kanal, *J. Am. Coll. Radiol.* **15** (2018) 932.