Analysis of Diagnostic Reference Level (DRL) and Effective Dose Values based on Age and Gender in Head CT Scan Examinations

Evelin Trivena Samaliwu[1], Gregoria Illya[1]*

[1]Department of Physics, Faculty of Science, Computer, and Mathematics, Matana University, Tangerang, Banten, Indonesia

Corresponding author: evelintriv@gmail.com, *gregoria.illya@matanauniversity.ac.id

Received: 24th May 2026; Revised: 21th July 2026; Accepted: 06th November 2026

Abstract – *Computed Tomography (CT) examinations involve relatively high radiation doses, making radiation dose optimization essential. This study aimed to evaluate local Diagnostic Reference Level (DRL) values and Effective Dose in non-contrast head CT examinations based on patient age and gender. A total of 270 patient datasets were retrospectively analyzed using a 256-slice Philips iCT scanner operated at 120 kV and 400 mAs. Local DRL values were determined using the third quartile (Q3) of CTDIvol and DLP distributions. The results showed that DLP values were slightly higher in the ≥15 years group (1234.40 mGy·cm) than in the 5–14 years group (1212.68 mGy·cm). Male patients also demonstrated higher DLP values (1243.30 mGy·cm) compared to female patients (1223.10 mGy·cm), while CTDIvol remained constant at 53.34 mGy across all groups. The mean Effective Dose for adult patients was 2.15 ± 0.18 mSv in males and 2.12 ± 0.17 mSv in females. Statistical analysis showed no significant difference in DLP values based on age (p = 0.09), but a significant difference based on gender (p = 0.015). No significant difference was found in Effective Dose between adult male and female patients (p = 0.081). All dose parameters were below the national DRL limits established by BAPETEN, indicating that the non-contrast head CT protocol at Hospital X complies with radiation protection optimization principles and national safety standards.*

Keywords: *Effective dose; Diagnostic Reference Level (DRL); CT scan; CTDIvol; DLP*

1. Introduction

Medical imaging technologies such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI), and mammography have significantly improved diagnostic accuracy in modern healthcare [1]. Among these modalities, CT scanning is widely used because it can rapidly produce detailed anatomical images. However, CT examinations involve relatively high doses of ionizing radiation compared with other diagnostic imaging techniques, raising concerns regarding radiation exposure risks for patients and healthcare personnel [2, 3].

Several technical parameters, including tube current (mAs) and tube voltage (kV), directly influence patient radiation dose during CT examinations [4]. Therefore, optimization principles such as ALARA (*As Low as Reasonably Achievable*) are essential to minimize radiation exposure while maintaining adequate image quality. To support radiation dose optimization, the International Commission on Radiological Protection (ICRP) introduced the concept of Diagnostic Reference Level (DRL), which is commonly assessed using the Volume CT Dose Index (CTDIvol) and Dose Length Product (DLP) [5, 6].

In Indonesia, national DRL values have been established through the Indonesian Diagnostic Reference Level (IDRL) issued by BAPETEN in 2021 as part of the national radiation protection optimization strategy [7]. In addition to CTDIvol and DLP, Effective Dose is also an important parameter because it reflects the biological risk associated with radiation exposure by considering organ radiosensitivity [8].

Patient characteristics such as age, gender, and anatomical size may contribute to variations in radiation dose during CT examinations. Therefore, evaluation of radiation dose distribution based on patient demographics is important to ensure that imaging protocols remain optimized and consistent with radiation

safety standards. Recent head CT studies also show that dose distributions may vary with patient sex, anatomical characteristics, scan length, and clinical protocol [9, 10].

Based on this background, the present study aimed to evaluate local DRL values and Effective Dose in non-contrast head CT examinations according to patient age and gender. This study is expected to contribute to radiation dose monitoring and optimization efforts in diagnostic radiology.

2. Methodology

This study employed a quantitative retrospective design to evaluate local DRL values and Effective Dose in non-contrast head CT examinations. Patient dose reports were collected and analyzed to determine CTDIvol, DLP, and Effective Dose values. Age and sex were also evaluated as potential factors influencing radiation dose parameters.

The examinations were performed using a 256-slice Philips iCT scanner operated at a fixed tube voltage of 120 kV and tube current of 400 mAs. A total of 270 patient datasets from non-contrast head CT examinations were included in this study. Patients were categorized according to gender and age group.

Table 1 presents the patient distribution based on gender, while Table 2 shows the patient distribution according to age group.

Table 1. Patient distribution by gender [11].

Type of Examination	Gender	Number of Patients
Non-contrast head CT scan	Male	133
	Female	137
	Total	270

Table 2. Patient distribution by age [11].

Type of Examination	Age (years)	Number of Patients
Non-contrast head CT scan	5-14	26
	≥ 15	244
	Total	270

To evaluate the influence of age and gender on radiation exposure, the calculation of Effective Dose and DRL values was performed based on Table 1 and Table 2. Statistical analysis included the calculation of standard deviation to determine the data distribution relative to the mean. Subsequently, an independent t-test was used to assess whether significant differences existed between two data groups based on gender and age categories. A significance value (p-value) greater than 0.05 indicated acceptance of the null hypothesis (no significant difference), while a p-value less than 0.05 indicated acceptance of the alternative hypothesis (a significant difference exists). This analysis is expected to provide deeper insights into the factors influencing increases or decreases in Effective Dose and DRL values, and to serve as a basis for optimizing patient radiation protection.

For examinations containing more than one CTDIvol value, the average CTDIvol was used for analysis. Local DRL values were determined using the third quartile (Q3 or 75th percentile) of CTDIvol and DLP distributions. Effective Dose was calculated by multiplying DLP by the head-specific conversion factor (k) of 0.0018 mSv/mGy·cm. The obtained DRL values were compared with the national DRL reference values established by BAPETEN Regulation Number 1211 of 2021, namely 60 mGy for CTDIvol and 1275 mGy·cm for DLP [7].

Statistical analysis included calculation of the mean and standard deviation, followed by independent t-tests to evaluate differences between groups. A p-value < 0.05 was considered statistically significant.

3. Results and Discussion

Radiation dose optimization is a fundamental aspect of diagnostic radiology to ensure patient safety while maintaining adequate image quality. In CT examinations, parameters such as CTDIvol and DLP are commonly used to evaluate radiation exposure and establish Diagnostic Reference Levels (DRLs). DRLs function as practical benchmarks for identifying whether radiation doses applied during imaging procedures remain within acceptable limits and comply with radiation protection standards [12-14].

In this study, DRL values and Effective Dose were evaluated based on patient age and gender in non-contrast head CT examinations performed at Hospital X. The analysis included comparisons of CTDIvol, DLP, and Effective Dose values to determine whether patient demographic factors influenced radiation exposure. The obtained values were also compared with the Indonesian DRL standards established by BAPETEN.

3.1 Comparison of DRL values based on age

The comparison of DRL values based on patient age is summarized in Table 3, while the graphical distributions of DLP and CTDIvol values are presented in Figure 1 and Figure 2, respectively.

Table 3. DRL values by age group [11].

No.	Age Range (years)	DLP (mGy.cm)	P-value DLP (< 0,05)	CTDIvol (mGy)
1	5-14	1212,68	0,09	53,34
2	≥15	1234,4		53,34

Table 3 shows that the DLP value for the ≥15 years group was slightly higher than that of the 5–14 years group. Adult patients demonstrated a DLP value of 1234.40 mGy·cm, whereas pediatric patients showed a value of 1212.68 mGy·cm. Although the difference was relatively small, the trend indicates that radiation exposure tends to increase with patient age. This increase is primarily associated with differences in anatomical dimensions and scan length between pediatric and adult patients. Larger anatomical coverage in adult patients generally requires longer scan lengths, thereby increasing the DLP value.

The independent t-test analysis demonstrated that the difference in DLP values between the two age groups was not statistically significant ($p = 0.09$). This suggests that, despite the observed increase in DLP values among adult patients, the variation was insufficient to indicate a significant age-dependent difference in radiation exposure under the applied scanning protocol. The relatively small variation may also reflect the use of standardized scanning parameters for all patients.

The CTDIvol value remained constant at 53.34 mGy across both age groups. Since CTDIvol primarily represents the radiation dose delivered per slice and depends mainly on scanner settings rather than patient anatomy, the use of fixed tube voltage and tube current parameters resulted in uniform CTDIvol values. Therefore, variations in patient radiation dose were more strongly reflected by DLP rather than CTDIvol.

Figure 1 illustrates the comparison of DLP values between pediatric and adult patients. The orange horizontal line represents the national DRL limit established by BAPETEN for non-contrast head CT examinations (1275 mGy·cm). Both age groups demonstrated DLP values below this threshold, indicating that the CT examination protocol applied at Hospital X complied with national radiation safety standards. The slightly higher DLP value observed in adult patients is consistent with the larger anatomical scan coverage typically required in adult examinations.

The findings of this study are consistent with previous reports indicating that pediatric patients generally receive lower DLP values because of smaller anatomical dimensions and reduced irradiated tissue volume [15-17]. Shorter scan lengths in pediatric patients contribute directly to reduced DLP values, even when fixed exposure parameters are used.

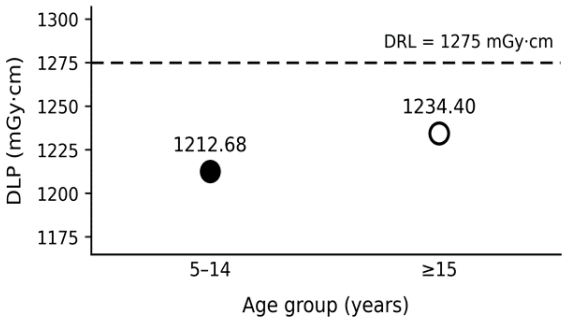

Figure 1. DLP values by age group relative to the BAPETEN DRL Limit [11].

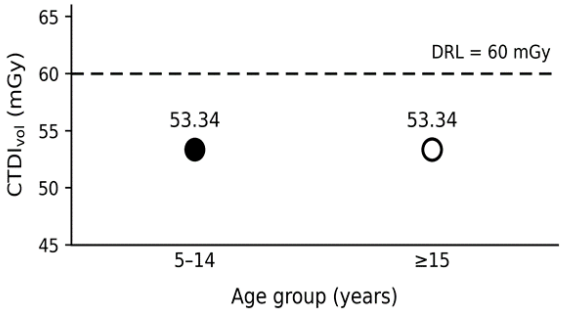

Figure 2. CTDIvol values by age group relative to the BAPETEN DRL limit [11].

Figure 2 shows that CTDIvol values were identical in both age groups and remained below the BAPETEN DRL limit of 60 mGy. This result demonstrates that the CT scanner produced consistent radiation output per slice regardless of patient age. The absence of CTDIvol variation further supports the conclusion that DLP is a more sensitive parameter for evaluating total patient radiation exposure in examinations using fixed scanning protocols.

Overall, the age-based analysis demonstrated that all DRL parameters remained within recommended national limits. Although adult patients tended to receive slightly higher radiation doses, the values were still considered safe and clinically acceptable according to BAPETEN standards.

3.2 Comparison of DRL values based on gender

The comparison of DRL values based on patient gender is presented in Table 4, while the graphical distributions of DLP and CTDIvol values are shown in Figure 3 and 4, respectively.

Table 4. DRL values by gender [11].

No	Gender	DLP (mGy.cm)	P-value DLP (< 0,05)	CTDIvol (mGy)
1	Male	1243,3	0,015	53,34
2	Female	1223,1		53,34

Table 4 demonstrates that male patients received higher DLP values compared with female patients. The DLP value for male patients was 1243.30 mGy·cm, while female patients showed a lower value of 1223.10 mGy·cm. This difference indicates that patient gender may influence the total radiation dose received during non-contrast head CT examinations.

The independent t-test analysis revealed a statistically significant difference in DLP values between male and female patients ($p = 0.015$). This result suggests that gender-related anatomical differences contributed to variations in scan length and overall radiation exposure. Male patients generally possess larger anatomical dimensions and greater head size, which may require slightly longer scan coverage and consequently higher DLP values.

Despite the difference observed in DLP values, CTDIvol remained constant at 53.34 mGy for both male and female patients. This finding confirms that CTDIvol was primarily determined by the scanner operating parameters rather than by patient characteristics. Since fixed tube current and tube voltage settings were used throughout all examinations, the scanner produced consistent radiation output per slice across all patients.

Figure 3 illustrates the comparison of DLP values by gender relative to the BAPETEN DRL limit. Figure 3 illustrates the DLP distribution according to patient gender. The red horizontal line indicates the BAPETEN DRL limit of 1275 mGy·cm. Both male and female groups showed DLP values below the national DRL threshold, indicating compliance with radiation protection standards. Nevertheless, male patients demonstrated slightly higher DLP values than female patients. This finding is consistent with previous studies reporting that body size, organ dimensions, and anatomical coverage influence radiation dose parameters in CT imaging [6, 9, 10, 18].

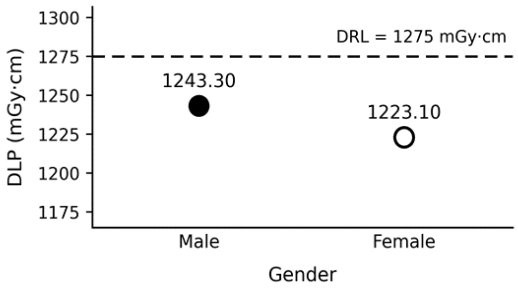

Figure 3. DLP Values by Gender Relative to the BAPETEN DRL Limit [11]

The difference in DLP values also highlights the importance of considering patient anatomy during CT dose optimization. Although fixed scanning parameters provide consistent image acquisition, patient-specific factors such as body dimensions may still influence total radiation exposure through variations in scan length.

Figure 4 demonstrates that CTDIvol values remained identical for male and female patients and were below the BAPETEN DRL limit of 60 mGy. The consistency of CTDIvol values is strongly associated with the use of fixed exposure parameters (400 mAs and 120 kV) during all examinations. Similar findings have been reported in previous studies using fixed tube current protocols, where CTDIvol values remained nearly constant across different patient groups [19, 20]. Because CTDIvol values showed minimal variation, DLP was considered a more representative parameter for evaluating patient radiation exposure in this study. DLP incorporates both radiation output and scan length, thereby providing a more comprehensive estimate of the total radiation dose received by the patient.

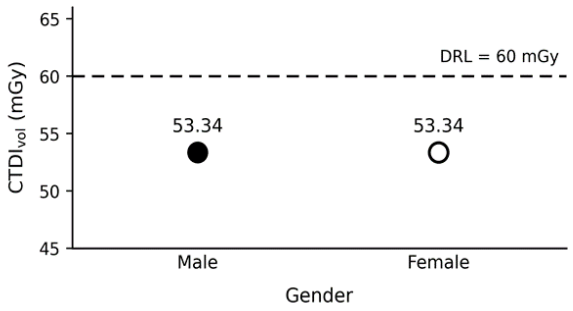

Figure 4. CTDIvol values by gender relative to the BAPETEN DRL limit [11].

3.3 Effective dose comparison based on gender

The comparison of effective dose values in adult patients (≥ 15 years) is summarized in Table 5, while the graphical comparison is presented in Figure 5.

Table 5. Effective dose by gender in adult patients [11].

No.	Gender	Mean Effective Dose (mSv)	P-value Effective Dose (< 0,05)
1	Male	2,15 ± 0,18	0,081
2	Female	2,12 ± 0,17	

Table 5 shows that male patients received a slightly higher mean Effective Dose than female patients. Male patients demonstrated an average Effective Dose of 2.15 ± 0.18 mSv, while female patients showed a value of 2.12 ± 0.17 mSv. Although the difference was relatively small, the trend corresponded to the higher DLP values observed in male patients.

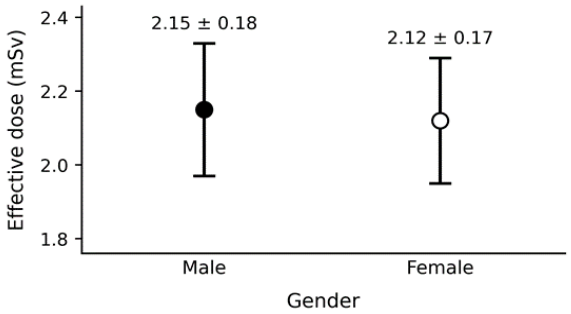

Figure 5. Mean effective dose by gender in adult patients [11].

Effective Dose reflects the biological risk associated with radiation exposure because it considers organ radiosensitivity in addition to absorbed dose. In this study, Effective Dose values were calculated using a conversion factor of 0.0018 mSv/mGy·cm, which is commonly applied for adult head CT examinations. The relatively small standard deviations observed in both groups indicate that radiation dose distribution among patients was relatively uniform.

The independent t-test analysis demonstrated no statistically significant difference in Effective Dose between male and female patients ($p = 0.081$). This result indicates that, although male patients tended to receive slightly higher radiation doses, the variation was not sufficient to demonstrate a meaningful difference in biological radiation risk between genders under the applied examination protocol.

Figure 5 illustrates the comparison of mean Effective Dose values between adult male and female patients. Both groups demonstrated Effective Dose values below the equivalent BAPETEN DRL threshold of approximately 2.295 mSv, confirming that the radiation doses delivered during non-contrast head CT examinations at Hospital X remained within safe and acceptable limits.

The slightly higher Effective Dose observed in male patients is likely associated with longer scan lengths and larger anatomical dimensions, which contributed to increased DLP values [13]. Nevertheless, all Effective Dose values remained below the recommended safety threshold, indicating that the CT examination protocol implemented at Hospital X successfully achieved radiation dose optimization while maintaining diagnostic adequacy.

4. Conclusion

This study demonstrated that all third quartile (Q3) values of DLP and CTDIvol in non-contrast head CT examinations were below the national DRL limits established by BAPETEN. The mean Effective Dose values for adult patients also remained within acceptable safety limits. DLP values were slightly higher in the ≥ 15 years age group and in male patients, primarily due to differences in scan length and anatomical dimensions. In contrast, CTDIvol values remained constant across all age and gender groups because fixed scanning parameters were used throughout the examinations. Statistical analysis revealed a significant difference in DLP values between male and female patients, whereas no significant differences were observed between age groups or in Effective Dose values between adult male and female patients. Overall,

the imaging protocols implemented at Hospital X were consistent with radiation protection optimization principles and complied with applicable national safety standards.

References

[1] Filippou, V., & Tsoumpas, C (2018) Recent advances on the development of phantoms using 3D printing for imaging with CT, MRI, PET, SPECT, and ultrasound. Medical Physics, **45** (9). https://doi.org/10.1002/mp.13058.

[2] Siregar, E. S., Sutapa, G. N., & Sudarsana, I. W (2020) Analisis Dosis Radiasi Pasien Pada Pemeriksaan CT Scan Menggunakan Aplikasi Si-INTAN. Buletin Fisika, **21** (2), 53-59.

[3] C Zhou, Xuyang & Liu, Zhengjun (2024) Computerized Tomography. 10.1007/978-981-97-1455-1_4.

[4] Açıkgöz, G (2024) Investigating the Effects of Tube Current and Tube Voltage on Patient Dose in Computed Tomography Examinations with Principial Component Analysis and Cluster Analysis: Phantom Study. Health Physics, **127** (4), 513–519. https://doi.org/10.1097/hp.0000000000001830.

[5] Clerkin, C., Brennan, S., & Mullaney, L. M (2018). Establishment of national diagnostic reference levels (DRLs) for radiotherapy localisation computer tomography of the head and neck. Reports of Practical Oncology & Radiotherapy, **23** (5), 407–412. https://doi.org/10.1016/j.rpor.2018.07.012.

[6] Modlińska, S., Rojek, M., Bielówka, M., & Kufel, J. (2024). Establishing Local Diagnostic Reference Levels for Head Computed Tomography Examinations. Biomedicines, 12(11), 2446. https://doi.org/10.3390/biomedicines12112446.

[7] BAPETEN (2021) Peraturan Kepala BAPETEN No. 1211 Tahun 2021 tentang Penetapan Nilai Tingkat Panduan Diagnostik Indonesia (Indonesian Diagnostic Reference Level) Untuk Modalitas Sinar-X CT Scan Dan Radiografi Umum. Jakarta: BAPETEN.

[8] Ibrahim, A. A., Abdullah, B., & Halide, H (2018) Estimasi Dosis Efektif Pasien Bagian Abdomen dari Hasil Pemeriksaan CT-Scan Merek Siemens SOMATOM. POSITRON, **8** (2), 39. https://doi.org/10.26418/positron.v8i2.25213.

[9] Tan, W. S., Foley, S., & Ryan, M. L. (2023). Investigating CT head diagnostic reference levels based on indication-based protocols—A single site study. Radiography, 29(4), 786–791. https://doi.org/10.1016/j.radi.2023.05.003.

[10] Alhujaili, S. F., Alshabibi, A. S., Alafer, F., Alrowaili, Z., Salah, H., Sulieman, A., Subahi, M., Al-Raddadi, K., & Abuzaid, M. (2024). Establishment of Local Diagnostic Reference Levels for Head CT Imaging in the Madina Region, Saudi Arabia. Diagnostics, 14(24), 2882. https://doi.org/10.3390/diagnostics14242882.

[11] Samaliwu, E. T (2025) Nilai Diagnostic Reference Level dan Dosis Efektif Computed Tomography Scan Berdasarkan Usia dan Jenis Kelamin pada Pemeriksan Kepala (Skripsi , Universitas Matana). Fakultas Sains Komputer dan Matematika, Universitas Matana, Tangerang, Indonesia.

[12] Sun, Z., Lin, C., Tyan, Y., & Ng Hoong, K (2012) Optimization of chest radiographic imaging parameters: A comparison of image quality and entrance skin dose for digital chest radiography systems. Clinical Imaging, **36** (4), 279-286.

[13] Rama, S (2023) Analisis diagnostic reference level (DRL) modalitas CT-scan untuk jenis pemeriksaan kepala dan abdomen di Rumah Sakit EMC Alam Sutera (Skripsi, Universitas Matana). Fakultas Sains Teknologi dan Matematika, Universitas Matana, Tangerang, Indonesia.

[14] Kanal, K. M., Butler, P. F., Chatfield, M. B., Wells, J., Samei, E., Simanowith, M., Golden, D., Gress, D. A., Burleson, J., Sensakovic, W. F., Strauss, K. J., & Frush, D. (2022). U.S. Diagnostic Reference Levels and Achievable Doses for 10 Pediatric CT Examinations. Radiology, 302(1), 164–174. https://doi.org/10.1148/radiol.2021211241.

[15] Sofiana, L (2013) Estimasi Dosis Efektif Pada Pemeriksaan Multi Slice Ct-scan Kepala Dan Abdomen Berdasarkan Rekomendasi Icrp 103. Brawijaya Physics Student Journal, vol. **1**, no. 1.

[16] Inoue, Y., Itoh, H., Waga, A., Sasa, R., & Mitsui, K. (2022). Radiation Dose Management in Pediatric Brain CT According to Age and Weight as Continuous Variables. Tomography, 8(2), 985–998. https://doi.org/10.3390/tomography8020079.

[17] Ahmad Zaki, B. Q., & Mahmud, M. H. (2025). Local Diagnostic Reference Levels for Paediatric Craniofacial CT and Head CT Procedures. Malaysian Journal of Medicine and Health Sciences, 21(Suppl. 5), 57–62. https://doi.org/10.47836/mjmhs.21.s5.8.

[18] Horuoby, Pricilia & Diartama, Anak & Sukadana, I (2023) Analisis Nilai CTDIvol Dan DLP Pada Pemeriksaan CT Scan Brain Non Kontras Dewasa Untuk Periode Januari – Desember 2022 Di Instalasi Radiologi Rumah Sakit X Jakarta Pusat. Jurnal Rumpun Ilmu Kesehatan. **3.** 280-293. 10.55606/jrik.v3i3.2687.

[19] Noor, J., & Normahayu, I (2014) DOSIS RADIASI DARI TINDAKAN CT-SCAN KEPALA. Journal of Environmental Engineering and Sustainable Technology, **1** (2), 84-91. doi:http://dx.doi.org/10.21776/ub.jeest.2014.001.02.3.

[20] Alhailiy, A., Alkhybari, E., Alghamdi, S., Fisal, N., Aldosari, S., & Albeshan, S. (2023). Reporting Diagnostic Reference Levels for Paediatric Patients Undergoing Brain Computed Tomography. Tomography, 9(6), 2029–2038. https://doi.org/10.3390/tomography9060159.