International Journal on Advanced Science Engineering Information Technology

Vol.15 (2025) No. 3
ISSN: 2088-5334

Evaluation of the Typical Dose Values in Patients Undergoing CT Scan Examinations at Andalas University Hospital

Ramacos Fardela [a,*], Rani Delvihardini [a], Ida Bagus Gede Putra Pratama [b], Dian Milvita [a], Amel Oktavia [c]

[a] *Department of Physics, Faculty of Mathematics and Natural Sciences, Andalas University, Padang, Indonesia*
[b] *Nuclear Energy Regulatory Agency, Jakarta, Indonesia*
[c] *Radiology Installation of Andalas University Hospital, Padang, Indonesia*
*Corresponding author: *ramacosfardela@sci.unand.ac.id*

***Abstract*—In the medical field, X-rays are used in diagnostic radiology and radiotherapy. The Computed Tomography Scanner (CT scan) is a diagnostic radiology modality that employs X-rays. It is crucial to protect patients from excessive radiation exposure by optimizing measures, as CT scans deliver higher doses than other modalities. This study aims to determine, compare, and evaluate typical dose values at Andalas University (Unand) Hospital with Sumatra Regional, National, and several other countries' Diagnostic Reference Levels (DRLs). It also examines the correlation between Dose Length Product (DLP) and Computed Tomography Dose Index Volume ($CTDI_{Vol}$) concerning exposure parameters (mAs). Data from 225 adult patients undergoing non-contrast CT scans of the head, chest, abdomen, and contrast-enhanced abdomen at Unand Hospital were used to determine typical dose values from the median (Q2). The findings indicate that non-contrast head CT scans at Unand Hospital yielded the highest $CTDI_{Vol}$ and DLP values. The non-contrast abdominal CT scan had the lowest DLP value, while the contrast-enhanced abdominal CT scan had the lowest $CTDI_{Vol}$ value. The non-contrast head and contrast-enhanced abdominal CT scans exceeded Sumatra Regional and National DRLs, while the typical dose value for non-contrast abdominal CT scans at Unand Hospital did not exceed these DRLs. The hospital's typical $CTDI_{Vol}$ value is relatively lower, whereas the DLP is relatively higher compared to DRL values of several countries. The study shows a strong correlation between $CTDI_{Vol}$ and DLP values with tube current.**

***Keywords*— CT scan; $CTDI_{Vol}$; DLP; typical dose values.**

Manuscript received 14 Nov. 2024; revised 2 Mar. 2023; accepted 17 May 2025. Date of publication 30 Jun. 2025.

I. INTRODUCTION

The medical field is one of the many domains in which X-rays find extensive application. X-rays are utilized in the medical disciplines of radiotherapy and diagnostic radiology [1]–[3]. One of the diagnostic radiology modalities that employs X-rays for diagnostic purposes is the Computed Tomography Scanner (CT Scan) [4]–[7]. CT scans impose a greater radiation dosage compared to other modalities. Therefore, it is crucial to safeguard patients from excessive radiation doses during CT scan examinations to mitigate the potential radiation dangers that may harm tissue cells and the body's genetic material [8]–[11]. To mitigate or prevent the consequences of radiation exposure, radiation protection is implemented. The components of radiation exposure include occupational, medical, and public exposure. Justification, optimization, and limitations are all applicable in both public and work exposure. In medical exposure, the principles of justification and optimization are the sole applicable principles, as the principle of limitation is not applicable due to the absence of dosage limits for patients [12]–[16].

Optimization in diagnostic radiology refers to the deliberate measures used to minimize the radiation dose absorbed by the patient for diagnostic purposes, while maintaining picture quality and taking into account social and economic consequences [17]–[19]. Optimization can be implemented by using Diagnostic Reference Level (DRL) evaluation. DRL is a measure that indicates the implementation of radiation protection optimization, as expressed in radiation doses, with the objective of protecting patients from exposure to excessive and unnecessary radiation doses during diagnostic and interventional radiology examinations [20]–[22]. A typical dose value is one of the DRL components. This value is derived from the distribution of hospital data for a single modality, which is characterized by the same type of examination, age group, and body mass.

Using the CT Dose Index Volume ($CTDI_{Vol}$) and Dose Length Product (DLP) indicators displayed on the CT Scan console monitor screen, the dose value in the CT Scan modality can be determined [23], [24].

Costa et al. [24] conducted related research on the statistical analysis of typical values for adult chest and abdomen-pelvis CT examinations . The findings of this research were that the radiation dose varied between hospitals and patients, contingent upon the CT scanner technology and the protocol employed. Because of the increased technical parameters necessary to produce high-quality images, patients with a higher body mass typically receive larger radiation doses. The research conducted by Amalia et al. [25] in the Cipto Mangunkusumo Hospital showed that the DRLs values for CT scan modalities were generally within the internationally recommended range . However, there were several types of examinations that indicated a higher dose. Jannah et al. [26] conducted research on the determination of the diagnostic reference level (DRL) in Samarinda hospitals. The research findings indicated that the majority of the DRLs values set for CT scans at Samarinda hospitals were higher than the DRLs values that were implemented nationally and internationally. Tan et al. [27] explored the potential for dose reduction in specific clinical scenarios without compromising diagnostic quality by conducting research on CT head diagnostic reference levels based on indication-based protocols. The results of their study revealed that several DRLs values were lower than national and international DRLs.

According to conducted research, hospitals should establish a typical dose value for CT scan patients in order to enhance optimization efforts and minimize the radiation dose received by the patient. This will help safeguard patients from unnecessary and excessive radiation doses that are not justified for diagnostic reasons. The typical dose value is a quantification of the radiation dosage received in a hospital setting. It serves as a diagnostic tool to determine if it surpasses the recommended value established by Indonesia Nuclear Energy Regulatory Agency (BAPETEN) and thus allows for the provision of a more suitable dose based on the medical requirements of the patient. In accordance with medical requirements, radiographers and medical physicists can modify the exposure factor (mAs) and provide radiation doses suitable for the patient's age and body mass. Further investigation is required to establish, to compare, and to assess the typical dose levels in accordance with the regional, national and several countries' DRL values. Additionally, the relationship between exposure factors (mAs) and the values of $CTDI_{Vol}$ and DLP must be examined. An analysis of linearity can be used to establish this correlation.

II. Materials and Method

A. Materials

A CT scan using the Philips Ingenuity CT type equipment, as evidenced by Figure. 1.

B. Method

The research was conducted at the Radiology Installation of Andalas University Hospital adopting a retrospective approach. Specifically, dosage data was gathered from 225 patients who had a CT scan utilizing the Philips Ingenuity CT type equipment. Figure 2 depicts the research phases involved in determining, comparing, and assessing typical dose values with Sumatra Regional, national, and other countries Diagnostic Reference Level (DRL) values. Furthermore, the correlation between exposure factors (mAs) and $CTDI_{Vol}$ and DLP values is also analyzed.

Fig. 1 Computed Tomography (CT-scan) Imaging Modalities at Andalas University Hospital

The median value (Q_2) of the distribution of hospital patient dose data is used to determine typical dose values. The $CTDI_{Vol}$ and DLP values are inputted, sorted, and subsequently processed to determine the Q2 value for each examination. The exposure factor consists of voltage (kV) and time current strength (mAs). The Radiology Installation at Unand Hospital employs a consistent and unchanging voltage of 120 kV for each examination. The exposure factor correlation was assessed solely in terms of the time current amplitude (mAs). The distribution of radiation dose values, the comparison of typical dose values to the DRL of Sumatra Regional, National, and several countries, as well as the correlation of exposure factor (mAs) to $CTDI_{Vol}$ and DLP, are processed and presented in a graphical format. Statistical and linearity tests are implemented to process correlation data. Testing can be conducted by utilizing the coefficient of determination (R^2 or R-Square), which is designed to determine the extent of the influence of two variables. The coefficient of determination is a value that falls within the range of 0 to 1. Table 1 illustrates interpretation of the correlation coefficient [28].

TABLE I
Interpretation of Correlation Coefficient Values

No	Correlation coefficient	Interpretation
1	0.80-1.00	Very High
2	0.60-0.80	High
3	0.40-0.60	Moderate
4	0.20-0.40	Low
5	0.00-0.20	Very Low

The Q_2 values are obtained by employing Equation (1) and Equation (2) for even data and odd data, respectively.

$$Q2 = \frac{(\frac{n}{2})\text{term} + \left((\frac{n}{2})+1\right)\text{term}}{2} \quad (1)$$

$$Q2 = (\frac{n+1}{2})\text{term} \quad (2)$$

n is the number of data, (n/2) term is the value of the $(n/2)^{th}$ data, (n/2+1) term is the value of the $(n/2+1)^{th}$ data, (n+1)/2 term is the value of the $(n+1)/2^{th}$ data.

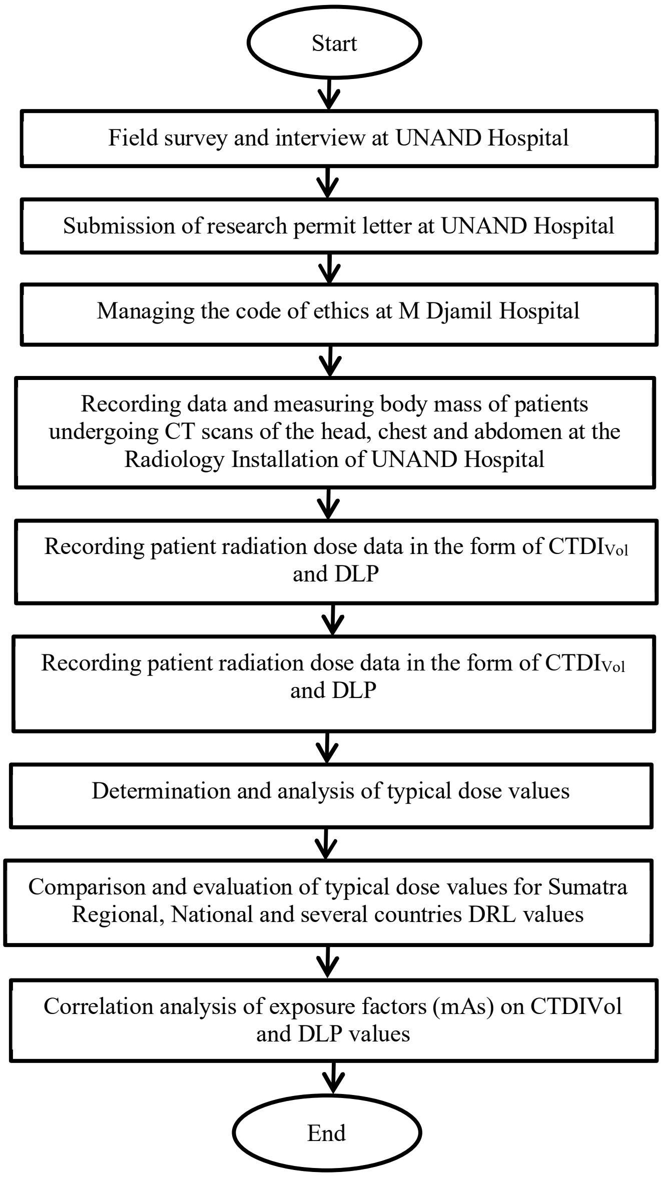


Fig. 2 Research stages

III. Results and Discussion

A. Determination of Typical Dose values for Patients with Head, Chest and Abdomen CT Examinations

According to the research conducted at the Radiology Installation of Unand Hospital, 225 patient data were collected for non-contrast CT scans of the cranium, non-contrast chest, non-contrast abdomen, and contrast abdomen. The data were organized into four categories: 114 patient data on non-contrast head CT scans, 13 patient data on non-contrast chest CT scans, 43 patient data on non-contrast abdominal CT scans, and 55 patient data on contrast abdominal CT scans. Figure. 3 and Figure. 4 illustrate the distribution of $CTDI_{Vol}$ and DLP values for each examination.

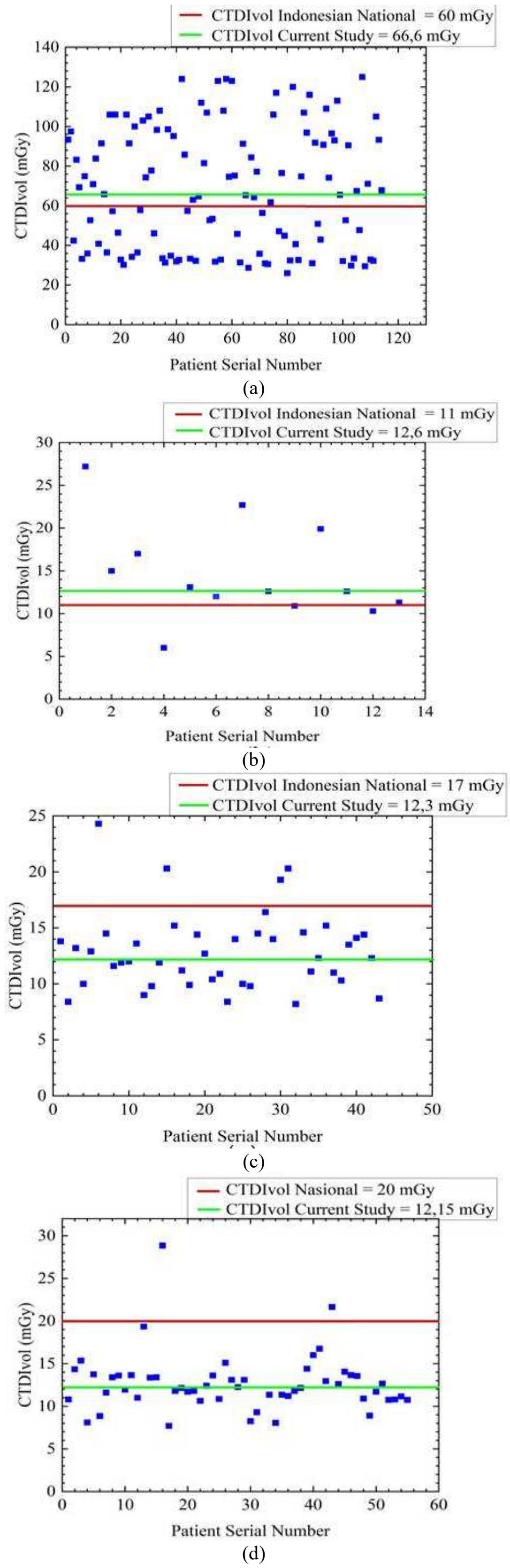


Fig. 3 Distribution of $CTDI_{Vol}$ on CT Scan examination:(a) non-contrast head section; (b) non-contrast chest section; (c) non-contrast abdomen section; (d) contrast abdomen section

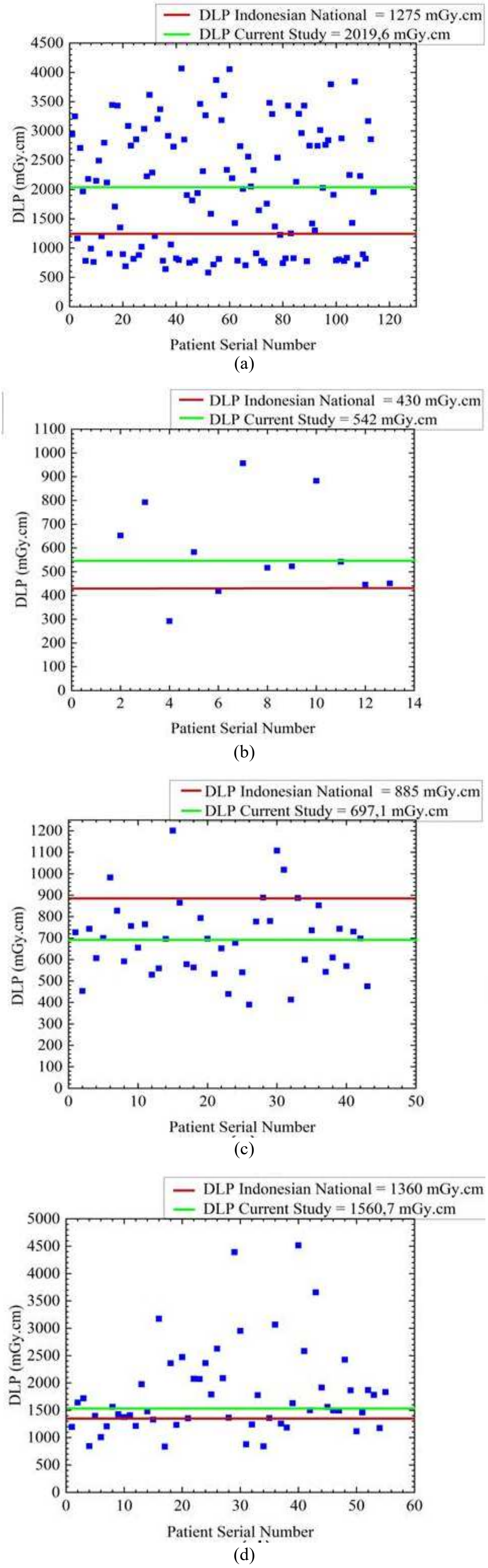


Fig. 4 DLP distribution on CT scan (a) non-contrast head (b) non-contrast chest (c) non-contrast abdomen (d) contrast abdomen

The data distribution of patient radiation dose values at Unand Hospital for each examination of the $CTDI_{Vol}$ and DLP values is depicted in Fig. 3 and Fig. 4. The red straight line in the image represents the National DRL value recommended by BAPETEN. According to Figure 2, the National DRL line was primarily crossed by the distribution of $CTDI_{Vol}$ value data on non-contrast CT scans of the head and thorax, while only a small number of contrast and non-contrast media CT scans of the abdomen crossed the National DRL line. The National DRL line is only minimally crossed by the distribution of DLP value data on non-contrast abdominal CT scans, as evidenced by Fig. 4. Conversely, the line is crossed by a relatively high number of other examinations.

The median value (Q_2) was subsequently calculated and analyzed to determine the typical dose value, as determined by the data distribution. Appendix C displays the Q_2 values that were obtained. Additional dose data (minimum 20 patient data) is still required for obtaining more accurate non-contrast chest CT scan data. Equation (1) was employed to calculate typical dose values for even data, while Equation (2) was used for odd data, based on patient dose data from CT scans at the Unand Hospital Radiology Installation. Table 2 displays the typical dose values for $CTDI_{Vol}$ and DLP for each examination.

TABLE II
RESULTS OF TYPICAL DOSE VALUES CALCULATION FOR EACH EXAMINATION TYPE

No	Type of examination	$CTDI_{Vol}$ Unand Hospital (mGy)	DLP Unand Hospital (mGy.cm)
1	CT Head non-contrast	66.6	2019.6
2	CT Abdomen non-contrast	12.3	697.1
3	CT Abdomen contrast	12.15	1560.7

The highest $CTDI_{Vol}$ and DLP values at Unand Hospital are for non-contrast head CT scans, as indicated in Table 2. The contrast abdominal CT scan gave the lowest $CTDI_{Vol}$ value, while the non-contrast abdominal CT scan yielded the lowest DLP value.

B. The Comparison and Evaluation of Typical Dosage Values in Relation to DRL Values of Regional Sumatera, National, and Several Other Countries.

The results of the typical dose values obtained during the CT scan examination at Unand Hospital were compared to the DRL values of Regional Sumatra, National, and several countries, as illustrated in Table 3. The 2021 Executive Summary of the National Diagnostic Reference Level (DRL) Study Results Report was used to evaluate the typical dose values for DRL of Regional Sumatra. The typical dose values for National DRL were evaluated in accordance with Decree of the Head of BAPETEN Number: 1211/K/V/2021. Comparisons were also made between the typical dose levels at Unand Hospital and the DRL values of Japan, United Kingdom (UK), and Malaysia.

The $CTDI_{Vol}$ value of Unand Hospital for non-contrast abdominal CT scan and contrast abdominal CT Scan examinations is lower than the Sumatra Regional and National DRLs, as demonstrated in Table 3. Conversely, the non-contrast head CT Scan examination has a higher $CTDI_{Vol}$

value than the Sumatra Regional DRL and National DRL. The DLP value of Unand Hospital in non-contrast abdominal CT scan examinations is lower than the Sumatra Regional DRL and National DRL, whereas other CT scan examinations are relatively higher than the Sumatra Regional DRL and National DRL.

From Table 3, it is evident that the Q2 $CTDI_{Vol}$ value for the CT Scan head examination at Unand Hospital is significantly higher than that of the Sumatra Regional and National DRLs. Consequently, medical physicists are required to assess the radiation dose that the patient received. Scanning procedures, worker skills, and the utilization of modality features are all potential evaluations. The intense time current (mAs) may be the cause of the higher CTDIVol value for the Unand Hospital [29].

TABLE III
EVALUATION OF TYPICAL DOSE VALUES FOR EACH EXAMINATION TYPE

No	Type of examination	Typical dose values (current study) (2024)		Sumatera Regional DRL (2021)		National DRL (2021)	
		$CTDI_{Vol}$	DLP	$CTDI_{Vol}$	DLP	$CTDI_{Vol}$	DLP
1	CT Head non-contrast	66.6	2019.6	61.8	1317	60	1275
2	CT Abdomen non-contrast	12.3	697.1	15.2	980	17	885
3	CT Abdomen contrast	12.15	1560.7	19.3	1197	20	1360

The $CTDI_{Vol}$ value increases as the time current strength (mAs) increases. The tube voltage influences the quality of the X-rays, whereas the time current strength influences the quantity or number of X-rays produced [30] Consequently, the time current strength has a greater impact than the tube voltage. The increased DLP value of Unand Hospital may be attributed to variations in the number of sequences in the examination and the duration of the scan [31]. The duration of the scan is contingent upon the patient's body measurement at the time of exposure and their medical requirements for the examination procedure. This is consistent with the findings of [32], who discovered that the DLP value increased as a result of the scan duration used in testing with an extended phantom. The abdominal CT scan examination with contrast media consisted of two, three, and four sequences, while the non-contrast media examination consisted of only one sequence. The DLP value is influenced by the number of examination sequences; the higher the number of sequences, the greater the DLP value and the higher the radiation dose required. To prevent unnecessary radiation exposure, radiographers and medical physicists can employ scanning protocols that are customized to the specific requirements of patients and implement more efficient scanning techniques.

Unand Hospital's CT Scan modality is equipped with a variety of features, including Iterative Reconstruction (IR), which is capable of reducing the radiation dose. Nevertheless, the radiation dosage administered to patients at Unand Hospital remains substantial and surpasses the DRL recommended by BAPETEN. It is advised that radiographers and medical physicists consider exposure factors according to the patient's body mass and scanning duration during exposure, as indicated by the results.

Table 3 provides a graphical representation of the $CTDI_{Vol}$ and DLP values for each examination type at Unand Hospital in comparison to the DRLs of Japan, United Kingdom (UK), and Malaysia. Figure 5 and 6 illustrate this comparison.

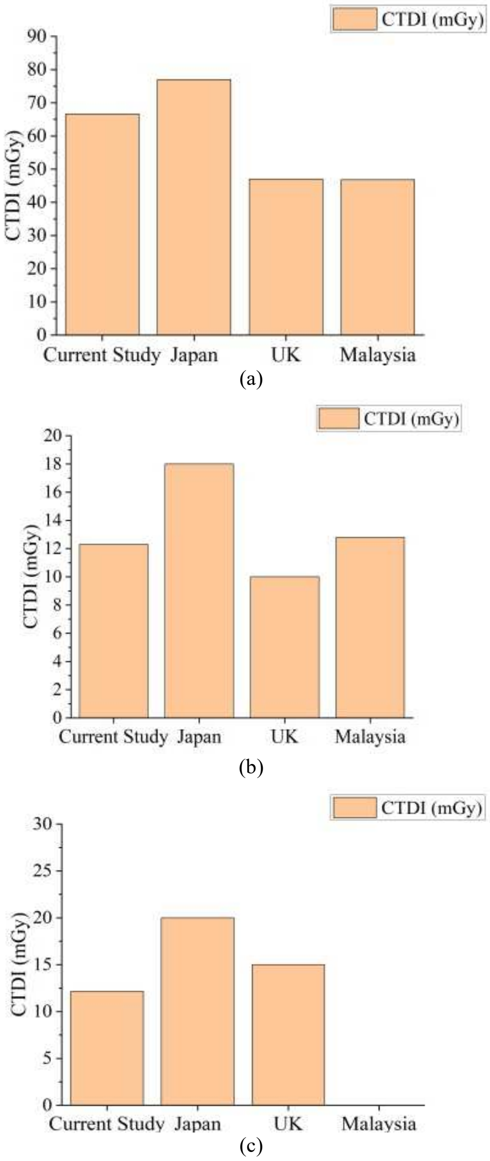
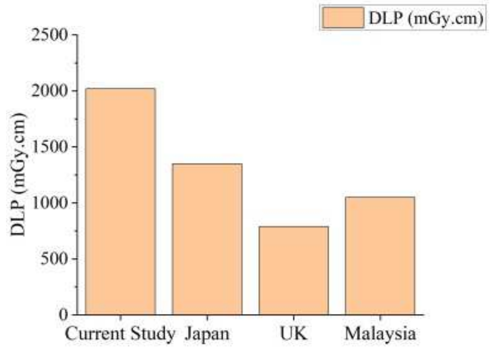


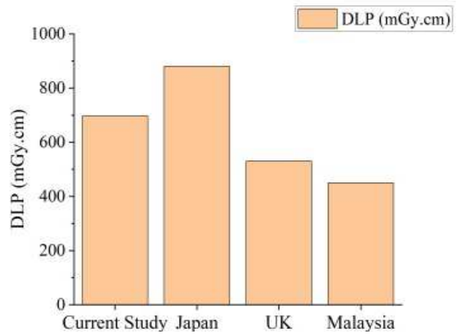
Fig. 5 Comparison of Unand Hospital $CTDI_{Vol}$ to several countries (a) non-contrast head section (b) non-contrast abdomen section (c) contrast abdomen section

Figure 5 and 6 present a comparison of the standardized dosage values at Unand Hospital with the comparatively lower $CTDI_{Vol}$ values and the comparatively higher DLP values of DRL in Japan, the UK, and Malaysia. The DRL value of the UK is comparatively lower than that of Unand Hospital and some Asian countries. Such variations might arise from disparities in scanning methodologies, equipment, and scanning processes. Located in Europe, the United Kingdom has a human physical size that surpasses that of several Asian countries. Anatomical dimensions of humans encompass both body mass and body height.

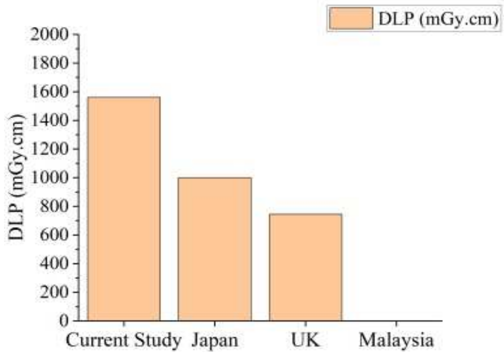
Additional factors contributing to high DRL readings include the duration of the scan and the patient's body size as determined by medical requirements during the examination. Therefore, the DRL value for smaller human physical sizes in numerous Asian nations should be minimized compared to the UK in order to enhance the optimization of patient radiation exposure through the use of improved scanning techniques, technologies, and protocols [33].



(a)



(b)



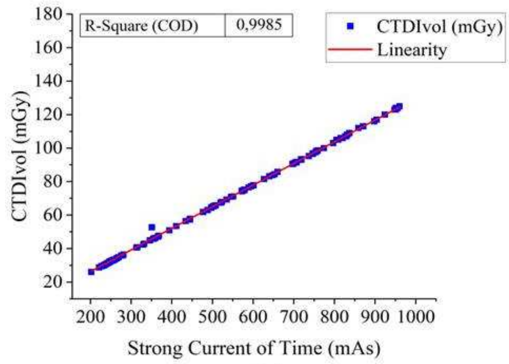
(c)

Fig. 6 Comparison Unand Hospital DLP with that of several other countries (a) non-contrast head section (b) non-contrast abdomen section (c) contrast abdomen section

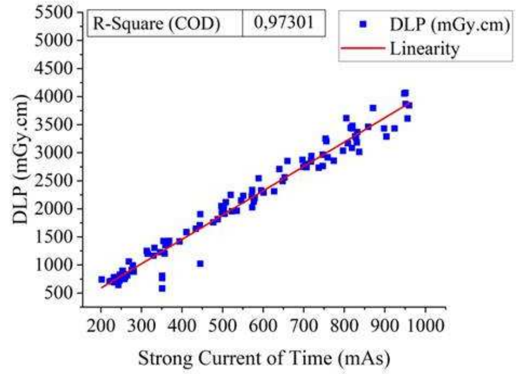
C. Correlation Analysis of Exposure Factors (mAs) on $CTDI_{Vol}$ and DLP Values

Figures 7 and 8 illustrate the correlation between current strength and time (mAs) with $CTDI_{Vol}$ and DLP on non-contrast CT scans of the cranium, non-contrast chest, and non-contrast abdomen, respectively. The correlation between mAs and $CTDI_{Vol}$ and DLP on each CT Scan examination, as shown in Figure. 7 and Figure. 8, exhibits a coefficient of determination (R^2) value ranging from 0.8 to 0.9. This correlation is very high, approaching 1. Therefore, there exists a substantial relationship between current strength and the duration of the associated dose.

These findings are relevant to the research conducted by Shirazu et al. [33] which determined that the delivery of radiation doses was influenced by the current strength (mAs) over time. The flow of electrons released by the filament toward the X-ray tube influences the intensity of the time current (mAs) [32]. The patient's radiation dose is directly proportional to the quantity of electrons present, as the production of X-rays increases [29].

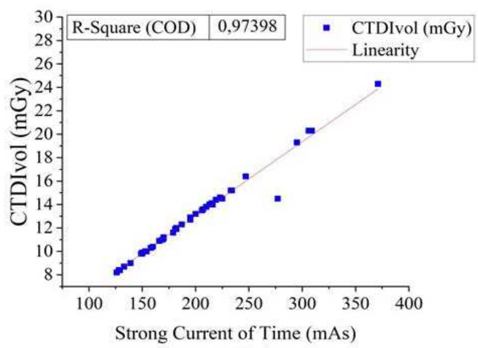


(a)

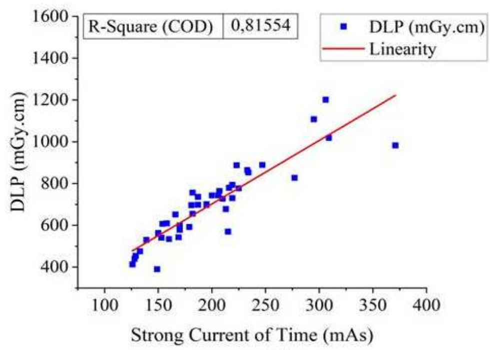


(b)

Fig. 7 (a) Correlation of mAs with $CTDI_{Vol}$ on a non-contrast head CT scan (b) Correlation of mAs with DLP on a non-contrast head CT scan



(a)



(b)

Fig. 8 (a) Correlation of mAs with $CTDI_{Vol}$ on a non-contrast abdominal CT scan (b) Correlation of mAs with DLP on a non-contrast abdominal CT scan

Lyons et al. [34] conducted an additional study that confirmed the earlier claim, namely that the patients mAs have an impact on the radiation exposure. The patient receives a reduced radiation dose as a result of the reduced number of X-rays generated, which is due to the smaller mAs value. Unand Hospital"s CT Scan aircraft is equipped with a variety of features, including IR techniques, which enable the CT scan to autonomously determine the time current strength parameters. This was previously explained. Radiographers and medical physicists must prioritize the precision of radiation dose determination by accurately measuring the length of radiation.

IV. Conclusion

According to the research conducted, the typical radiation dose values for non-contrast CT scans of the cranium, non-contrast abdomen, and contrast abdomen for $CTDI_{Vol}$ and DLP values are (66.6; 12.3; and 12.15) mGy and (2019.6; 697.1; and 1560.7) mGy.cm. In comparison to the Sumatra Regional DRL and National DRL, the typical radiation dose value for the Unand Hospital $CTDI_{Vol}$ is lower for the non-contrast abdominal and contrast abdominal CT scans, while the non-contrast head and non-contrast CT scans for the thorax are higher. In contrast to the Sumatra Regional DRL and National DRL, the DLP value of Unand Hospital is lower in non-contrast abdominal CT scans, while other CT scans are relatively higher. The DRL value of the Unand Hospital is relatively higher than the DRL of several countries, while the typical radiation dose value for the $CTDI_{Vol}$ value is relatively lower. The higher standard dosage values require further evaluation. The $CTDI_{Vol}$ and DLP values were also found to be significantly correlated with the time current strength (mAs).

Reference

[1] K. C. Eze *et al.*, 'Diagnostic reference levels (DRLs) for chest radiography, non-contrast head computed tomography and mammography examinations in Nigeria: review of national data', *Chinese J. Acad. Radiol.*, vol. 5, no. 2, pp. 99–106, 2022, doi:10.1007/s42058-022-00097-3.

[2] R. Fardela, D. Milvita, L. A. Rasyada, M. Almuhayar, F. Diyona, and A. Mousa, 'Radiation Dose Evaluation for Radiotherapy Workers at Unand Hospital Using Four-Element Thermoluminescence Dosimetry', *J. Ilm. Pendidik. Fis. Al-Biruni*, vol. 12, no. 2, p. 143, 2023, doi: 10.24042/jipfalbiruni.v12i2.18101.

[3] R. Fardela, D. Milvita, M. Almuhayar, D. Mardiansyah, L. A. Rasyada, and L. M. Hakim, 'Classification of Thoracic X-Ray Images of COVID-19 Patients Using the Convolutional Neutral Network (CNN) Method', *J. Comput. Sci.*, vol. 20, no. 4, pp. 357–364, 2024, doi:10.3844/jcssp.2024.357.364.

[4] M. Rawashdeh, C. Saade, D. S. Al Mousa, M. Abdelrahman, P. Kumar, and M. McEntee, 'A new approach to dose reference levels in pediatric CT: Age and size-specific dose estimation', *Radiat. Phys. Chem.*, vol. 205, no. November 2022, p. 110698, 2023, doi:10.1016/j.radphyschem.2022.110698.

[5] D. Joseph Zira *et al.*, 'Clinical indication-based diagnostic reference levels for paediatric head computed tomography examinations in Kano Metropolis, northwestern Nigeria', *Radiography*, vol. 27, no. 2, pp. 617–621, 2021, doi: 10.1016/j.radi.2020.11.021.

[6] O. A. Bawazeer, 'Assessment of diagnostic reference levels awareness and knowledge amongst CT radiographers in Saudi Arabia', *J. Radiat. Res. Appl. Sci.*, vol. 15, no. 2, pp. 98–105, 2022, doi:10.1016/j.jrras.2022.05.009.

[7] E. Gyan, C. Subaar, G. Edusei, and L. Antwi Nyarko, 'Paediatric computed tomography diagnostic reference levels in Africa: A systematic review', *J. Med. Radiat. Sci.*, pp. 1–9, 2024, doi:10.1002/jmrs.824.

[8] M. H. Kharita *et al.*, 'Relation between age and CT radiation doses: Dose trends in 705 pediatric head CT', *Eur. J. Radiol.*, vol. 130, no. May, p. 109138, 2020, doi: 10.1016/j.ejrad.2020.109138.

[9] Y. Inoue, H. Itoh, A. Waga, R. Sasa, and K. Mitsui, 'Radiation Dose Management in Pediatric Brain CT According to Age and Weight as Continuous Variables', *Tomography*, vol. 8, no. 2, pp. 985–998, 2022, doi: 10.3390/tomography8020079.

[10] A. Arriaga, C. Gonçalves, P. Teles, J. Santos, P. Simãozinho, and P. Sousa, 'Establishment of local diagnostic reference levels for abdomen and chest radiographies in the region of Algarve, Portugal', *Eur. J. Radiol.*, vol. 170, no. December 2023, 2024, doi:10.1016/j.ejrad.2023.111248.

[11] H. Osman *et al.*, 'Evaluation of CT dose and establishment of local DRLs for abdomen and pelvis examinations in hospitals in Taif City, Saudi Arabia', *Radiat. Phys. Chem.*, vol. 202, no. May 2022, p. 110206, 2023, doi: 10.1016/j.radphyschem.2022.110206.

[12] F. Yang and L. Gao, 'Age-based diagnostic reference levels and achievable doses for paediatric CT: a survey in Shanghai, China', *J. Radiol. Prot.*, vol. 44, no. 2, 2024, doi: 10.1088/1361-6498/ad3ce5.

[13] Y. Inoue, H. Itoh, K. Nagahara, H. Hata, and K. Mitsui, 'Relationships of Radiation Dose Indices with Body Size Indices in Adult Body Computed Tomography', *Tomography*, vol. 9, no. 4, pp. 1381–1392, 2023, doi: 10.3390/tomography9040110.

[14] M. K. Saeed and Y. Almalki, 'Assessment of computed tomography radiation doses for paediatric head and chest examinations using paediatric phantoms of three different ages', *Radiography*, vol. 27, no. 2, pp. 332–339, 2021, doi: 10.1016/j.radi.2020.09.007.

[15] N. A. Muhammad, A. Sabarudin, N. Ismail, and M. K. A. Karim, 'A systematic review and meta-analysis of radiation dose exposure from computed tomography examination of thorax-abdomen-pelvic regions among paediatric population', *Radiat. Phys. Chem.*, vol. 179, no. August 2020, p. 109148, 2021, doi:10.1016/j.radphyschem.2020.109148.

[16] K. Radaideh, A. Al-Radaideh, R. M. Ramli, A. Saleh, and R. Alshayeb, 'Establishment of national diagnostic dose reference levels (DRLs) for routine computed tomography examinations in Jordan', *Polish J. Med. Phys. Eng.*, vol. 29, no. 1, pp. 26–34, 2023, doi: 10.2478/pjmpe-2023-0003.

[17] K. Alzimami *et al.*, 'Evaluation of pediatric radiation doses in computed tomography procedures in the Kingdom of Saudi Arabia', *Radiat. Phys. Chem.*, vol. 188, no. June, p. 109679, 2021, doi:10.1016/j.radphyschem.2021.109679.

[18] K. M. Aloufi *et al.*, 'Assessing Effective Doses and Proposing DRLs for Pediatric CT Procedures in Madinah (Single Hospital), Saudi Arabia', *Appl. Sci.*, vol. 14, no. 17, 2024, doi: 10.3390/app14177583.

[19] M. M. U. D. Malik, M. Alqahtani, I. Hadadi, A. G. M. AlQhtani, and A. Alqarni, 'An Analysis of Computed Tomography Diagnostic Reference Levels in India Compared to Other Countries', *Diagnostics*, vol. 14, no. 15, pp. 1–16, 2024, doi: 10.3390/diagnostics14151585.

[20] M. Abyar, M. Mahdavi, and G. H. Haddadi, 'Establishing local Diagnostic Reference Level for Adult Patients in Computed Tomography Examination in Kohgiluyeh and Boyer-Ahmad province', *Iran. J. Med. Phys.*, vol. 18, no. 4, pp. 247–254, 2021, doi:10.22038/ijmp.2020.46309.1724.

[21] J. Guðjónsdóttir, S. S. Michelsen, G. Björnsdóttir, and V. K. Guðmundsdóttir, 'CT doses based on clinical indications. New national DRL's in Iceland', *Phys. Medica*, vol. 109, no. March, 2023, doi: 10.1016/j.ejmp.2023.102576.

[22] O. Bwanga and E. Chanda, 'Challenges in Radiation Protection in Healthcare: A Case of Zambia', *EAS J. Radiol. Imaging Technol.*, vol. 2, no. 1, pp. 7–14, 2020, doi: 10.36349/EASJRIT.2020.v02i01.002.

[23] S. Rao *et al.*, 'Systematic Review on Diagnostic Reference Levels for Computed Tomography Examinations in Radiation Therapy Planning', *Diagnostics*, vol. 13, no. 6, pp. 1–13, 2023, doi:10.3390/diagnostics13061072.

[24] P. R. Costa *et al.*, 'Typical values statistical analysis for adult chest and abdomen-pelvis CT examinations', *Radiat. Phys. Chem.*, vol. 221, no. November 2023, 2024, doi: 10.1016/j.radphyschem.2024.111669.

[25] T. Amalia, B. Zulkarnaien, C. Anam, K. Nurcahyo, H. Tussyadiah, and D. E. Pradana, 'The Establishment of Institutional Diagnostic Reference Levels (DRLs) in the Cipto Mangunkusumo Hospital', *Atom Indones.*, vol. 48, no. 2, pp. 159–167, 2022, doi: 10.17146/aij.2022.1131.

[26] R. Jannah, R. Munir, and E. R. Putri, 'Determination of the Diagnostic Reference Level (DRL) in Samarinda Hospitals', *Atom Indones.*, vol. 49, no. 3, pp. 145-150, 2023, doi: 10.55981/aij.2023.1285.

[27] W. S. Tan, S. Foley, and M. L. Ryan, 'Investigating CT head diagnostic reference levels based on indication-based protocols – a

single site study', *Radiography*, vol. 29, no. 4, pp. 786–791, 2023, doi:10.1016/j.radi.2023.05.003.

[28] J. P Guilford, *Fundamental Statistic in Psychology and Education, Third Edition*. Mc Graw-Hill Book Company, 1956.

[29] L. Arlany *et al.*, 'Establishment of CT diagnostic reference levels (DRLs) for a Singapore healthcare cluster', *Radiography*, vol. 29, no. 1, pp. 184–189, 2023, doi: 10.1016/j.radi.2022.11.002.

[30] A. M. Ahmed *et al.*, 'Establishment of a local diagnostic reference level for computed tomography chest and abdomen in two different cities in Saudi Arabia', *Appl. Radiat. Isot.*, vol. 204, no. December 2023, p. 111147, 2024, doi: 10.1016/j.apradiso.2023.111147.

[31] M. Oliveira Bernardo *et al.*, 'Establishing national clinical diagnostic reference levels and achievable doses for CT examinations in Brazil: A prospective study', *Eur. J. Radiol.*, vol. 169, no. August, 2023, doi:10.1016/j.ejrad.2023.111191.

[32] C. Lee *et al.*, 'Organ dose estimation accounting for uncertainty for pediatric and young adult CT scans in the United Kingdom', *Radiat. Prot. Dosimetry*, vol. 184, no. 1, pp. 44–53, 2019, doi:10.1093/rpd/ncy184.

[33] I. Shirazu *et al.*, 'Measurements of CTDI and DLP from CT image data for paediatrics radiological performance evaluation and dose optimisation in Ghana', *Int. J. Sci. Res. Sci. Technol.*, no. December, pp. 162–166, 2018, doi: 10.32628/ijsrst18401134.

[34] A. Lyons *et al.*, 'Expansion of Typical Values for Paediatric Patients in Ireland and Comparison with Published DRLs - Experiences of a Single Institution', *J. Med. Imaging Radiat. Sci.*, vol. 55, no. 3, p. 101421, 2024, doi: 10.1016/j.jmir.2024.04.014.