Atom Indonesia Vol. 51 No. ..... (2025) .....-....

Atom Indonesia

Journal homepage: http://atomindonesia.brin.go.id

Determination of Typical Values for Pediatric Head CT Scan at Universitas Andalas Hospital

R. Fardela[1*], R. Delvihardini[1], I. B. G. P. Pratama[2], D. Milvita[1], A. Oktavia[3]

[1]*Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Andalas, Padang 25166, Indonesia*
[2]*Nuclear Energy Regulatory Agency (BAPETEN), Jalan Gajah Mada No. 8, Central Jakarta Pusat 10120, Indonesia*
[3]*Department of Radiology, Universitas Andalas Hospital, Padang 25166, Indonesia*

ARTICLE INFO

Article history:
Received 22 August 2024
Received in revised form 21 December 2024
Accepted 26 January 2025

Keywords:

CT Scan
$CTDI_{Vol}$
DLP
Typical value

ABSTRACT

The utilization of X-rays in the Computed Tomography Scaner (CT scan) modality has proliferated for diagnostic purposes. CT scans deliver higher doses than other modalities, consequently protecting patients from excessive radiation doses is necessary by increasing optimization efforts in patients, especially pediatric patients. This research aims to determine the typical value and analyze the correlation of age, body mass, and exposure factor (mAs) to Computed Tomography Dose Index Volume ($CTDI_{Vol}$) and Dose Length Product (DLP). The typical dose value was obtained from the median value (Q_2) using data derived from pediatric patients undergoing a head CT scan with a total of 33 patients at Universitas Andalas Hospital, with a correlation determined using a linearity test. The results obtained were the typical value for $CTDI_{Vol}$ of 31.1 mGy and DLP of 793.3 mGy.cm. There is a moderate correlation between age and $CTDI_{Vol}$ and DLP values, a high correlation between body mass and $CTDI_{Vol}$ and DLP values, and a very high correlation between the exposure factor (mAs) and $CTDI_{Vol}$ and DLP values.

INTRODUCTION

X-rays can be utilized in medicine, namely radiotherapy and diagnostic radiology [1-3]. The development of imaging technology is also increasing, including X-rays in diagnostic radiology and Computed Tomography Scanner (CT Scan) [4-7]. A CT Scan is a tool or modality used as diagnostic support through modern tomography and computerization techniques to produce cross-sectional images of the body and detect body anatomy [8-10]. CT scans are used for head, chest, and abdomen examinations. However, the head is the most common part performed in the examination of CT scan. The head has a denser structure than other parts of the body’s and a sensitive organ, the brain [11].

CT scans can potentially deliver larger radiation doses than general radiography because they can provide more accurate information and considerable costs during examination. High radiation doses can increase the risk of radiation hazards that can damage tissue cells and body genetics [12-18]. Therefore, it is necessary to protect patients from excessive radiation doses that are not needed by patients, especially pediatric patients. Moreover, children's body tissues have greater radiosensitivity compared to adults, which has the potential for carcinogenic effects [19-23]. Radiation protection aims to protect patients from excessive radiation exposure. Radiation exposure consists of occupational, public, and medical exposure. Occupational and public exposure apply the principles of justification, optimization, and limitation. Medical exposure only applies to the principles of justification and optimization, while the limitation principle does not apply because there is no dose limit value for

[*]Corresponding author.
E-mail address: ramacosfardela@sci.unand.ac.id
DOI: https://doi.org/10.55981/aij.2025.1517

patients. Optimization efforts are made so that patients can receive the lowest possible amount of radiation dose for diagnostic purposes without reducing image quality by considering social and economic factors [24-27]. Optimization efforts can be made by determining the typical value at the hospital. The dose value on a CT Scan can be identified by the Computed Tomography Dose Index Volume ($CTDI_{Vol}$) and Dose Length Product (DLP) indicators, which can be seen on the CT Scan console screen [28].

Research was conducted by Alzimami et al. (2021) regarding the evaluation of pediatric radiation doses in computed tomography procedures in the Kingdom of Saudi Arabia. This research was conducted using chest, abdomen, and pelvis examinations. As a result, some hospitals provided higher than average doses, while others provided lower ones. Doses in some CT procedures exceeded the internationally recommended DRLs. This suggests the need for adjustments and optimization of protocols in local health facilities [29]. In another report by Muhammad et al. (2021), the study analyzed the radiation dose exposure from computed tomography examination of thorax-abdomen-pelvic regions among the pediatric population. This research was conducted on chest, abdomen, and abdomen-pelvis examinations. As a result, some procedures showed higher radiation doses compared to the recommended DRLs. Some of the influencing factors are CT machine protocol settings, operator experience, and institutional policies [30].

Moreover, Rawashdeh et al. (2023) researched dose reference levels in pediatric CT: Age and size-specific dose estimation. This research was conducted using head, chest, and abdomen-pelvis examinations. As a result, children were at risk of receiving higher doses than needed, as standardized protocols are often designed for adults [31].

While in Ireland, Lyons et al. (2024) reported on the expansion of typical values for pediatric patients and comparison with published DRLs. This research was conducted using chest, abdomen, and pelvis examinations. As a result, doses in some age categories and procedures were higher or lower compared to the international DRLs, indicating the need for local adjustments [32].

Based on the prior studies that have been conducted, hospitals need to have a typical value for pediatric CT scan head examination patients in order to increase optimization efforts to keep the radiation dose received by patients as low as possible and protect pediatric patients from excessive radiation. The typical value is a description of the hospital radiation dose that is used as a testing tool and evaluated to be able to provide a more appropriate dose according to the patient's medical needs. The typical value is obtained from the value of the hospital radiation dose data distribution. Radiographers and medical physicists can provide radiation doses that are appropriate to the age and body mass of the patient and can adjust the exposure factor (mAs) according to medical needs. Research to determine the correlation between age, body mass, and exposure factor (mAs) to $CTDI_{Vol}$ and DLP values also needs to be done. This correlation can be determined using the linearity test.

METHODOLOGY

The research was conducted at the Radiology Installation of the Universitas Andalas Hospital using a retrospective approach, namely collecting dose data on pediatric patients who underwent CT Scan head with Philips Ingenuity CT tool type. The data collected were 33 patient data. Fig. 1 shows the stages of the research to determine the typical value and the correlation of age, body mass, and exposure factor (mAs) to $CTDI_{Vol}$ and DLP values.

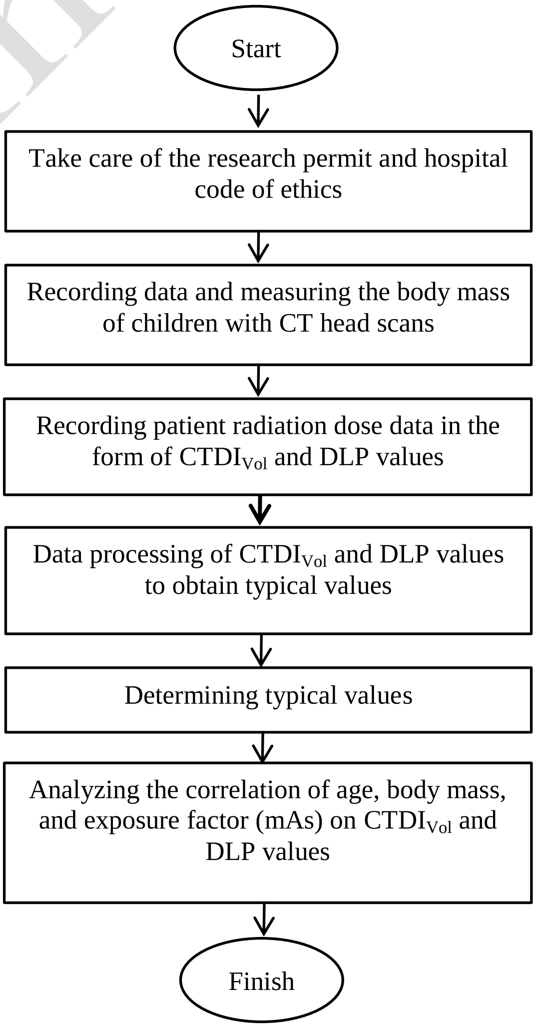


Fig. 1. Research stages.

A research permit was obtained, and the hospital's code of ethics was followed to conduct the research. This research adheres to the ethical guidelines outlined in the Code of Ethics No. DP.04.03/D.XVI.XI/613/2023. The studied data were patient sequence number, patient initials, age, body mass, kV, mAs, $CTDI_{Vol}$, and DLP. Typical values were obtained from the median value (Q_2) of the distribution of hospital patient dose data. $CTDI_{Vol}$ and DLP values were entered and sorted. Then, it is processed to obtain Q_2 values. The exposure factor consists of voltage (kV) and current strength time (mAs). The Radiology Installation of Universitas Andalas Hospital used the same fixed voltage for each examination, which was 120 kV. The correlation of the exposure factor was performed only on the current strength time (mAs). The distribution of radiation dose values and the correlation of age, body mass, and exposure factor (mAs) to $CTDI_{Vol}$ and DLP were processed and displayed in graphical form. Correlation data processing was performed using statistical and linearity tests. Testing was evaluated using the coefficient of determination (R^2 or R-squared), which aims to determine how much influence two variables have. The value of the coefficient of determination ranged between 0 and 1. The interpretation of the correlation coefficient value given by [33] can be tabulated in Table 1.

Table 1. Interpretation of correlation coefficient.

No	Correlation Coefficient	Interpretation
1	0.80-1.00	Very high
2	0.60-0.80	High
3	0.40-0.60	High Enough
4	0.20-0.40	Low
5	0.00-0.20	Very low

The median value (Q_2) represents the central value of the patient dose data for those undergoing head CT scan. It is calculated using Eq. (1) for datasets with an even number of values and Eq. (2) for datasets with an odd number of values.

$$Q_2 = \frac{(\frac{n}{2})term + \left((\frac{n}{2})+1\right)term}{2} \quad (1)$$

$$Q_2 = (\frac{n+1}{2})term \quad (2)$$

Where n is the number of data, $(\frac{n}{2})term$ is the value shown in the $(\frac{n}{2})$-th data, $((\frac{n}{2})+1)term$ is the value shown in the $((\frac{n}{2})+1)$ data, and $(\frac{n+1}{2})term$ is the value shown in the $\left(\frac{n+1}{2}\right)$data.

RESULTS AND DISCUSSION

The radiation dose distribution in the form of $CTDI_{Vol}$ and DLP values is presented in Figs. 2 (a) and (b).

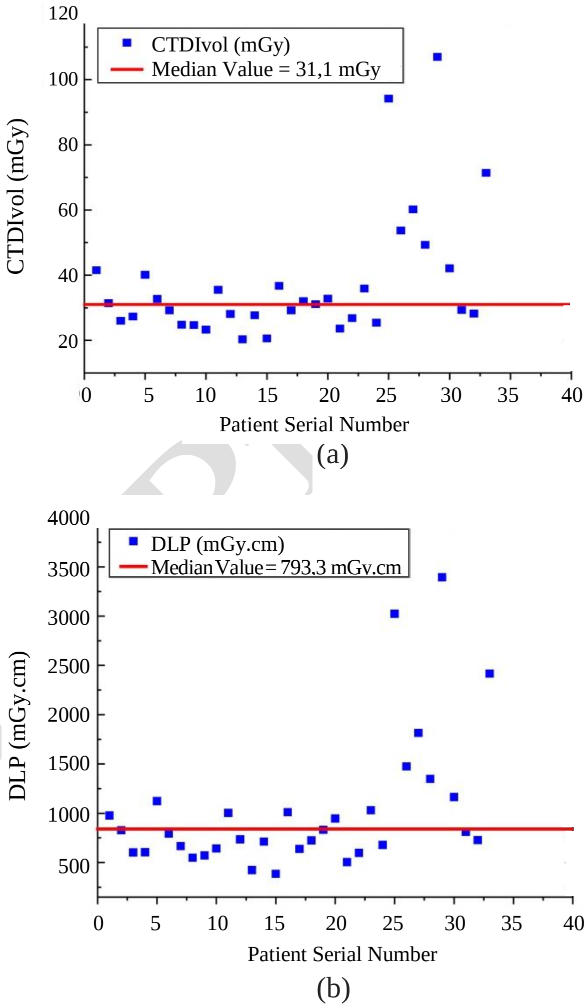


Fig. 2. Radiation dose distribution (a) $CTDI_{Vol}$ (b) DLP.

Figure 2 depicts the dose data distribution of CT scan head examination children against $CTDI_{Vol}$ (Fig. 2a) and DLP (Fig. 2b) values. In Figure 2, it can be seen that the red colored straight line shows the median value (Q_2) of $CTDI_{Vol}$ and DLP values. Based on the data distribution, calculations are then performed to obtain the median value (Q_2), which is used as a typical value.

Based on patient dose data on CT scan at the Radiology Installation of Universitas Andalas Hospital, the typical value is obtained through calculation using Eq. (1) for even data and Eq. (2) for odd data. The typical value for $CTDI_{Vol}$ was obtained at 31.1 mGy and DLP at 793.3 mGy.cm. Radiographers and medical physicists can pay attention to the radiation dose received by pediatric patients and are expected not to perform repeated irradiation to get good image quality.

The correlation between age and $CTDI_{Vol}$ and DLP values can be seen in Figs. 3 (a) and (b).

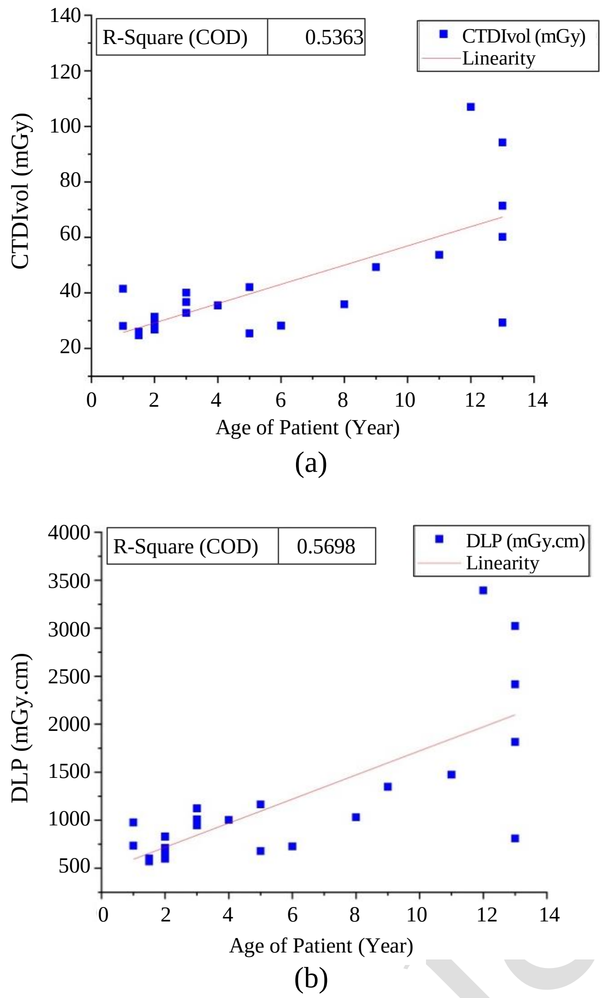


Fig. 3. (a) Correlation of age to $CTDI_{Vol}$ values (b) Correlation of age to DLP values.

Based on Fig. 3, the correlation between age and $CTDI_{Vol}$ and DLP values was carried out using statistical and linearity tests. The results obtained show a sufficient correlation with the coefficient of determination (R^2) of 0.5, so there is a significant correlation. The same results were shown by research [34], which found a correlation between age and $CTDI_{Vol}$ and DLP values. Younger patients (especially infants and toddlers) receive higher radiation doses compared to older children in head CT scans. The typical values serve as dose guidelines for radiographers and medical physicists, helping to ensure pediatric patients receive the lowest possible radiation dose while achieving adequate image quality. The results obtained in this research are similar to research conducted by [35], which found a correlation between age and $CTDI_{Vol}$ and DLP values. The greater the age, the greater the $CTDI_{Vol}$ and DLP values produced. Furthermore, research conducted by [36] also obtained that increasing age gets a greater radiation dose, which is in the same agreement with this present study. The correlation of age with $CTDI_{Vol}$ and DLP values is not always directly proportional. This is obtained from the results of research [33], which found that the increasing age of the patient's radiation dose can also amount to a small amount.

The correlation of body mass to $CTDI_{Vol}$ and DLP values is provided in Figs. 4 (a) and (b).

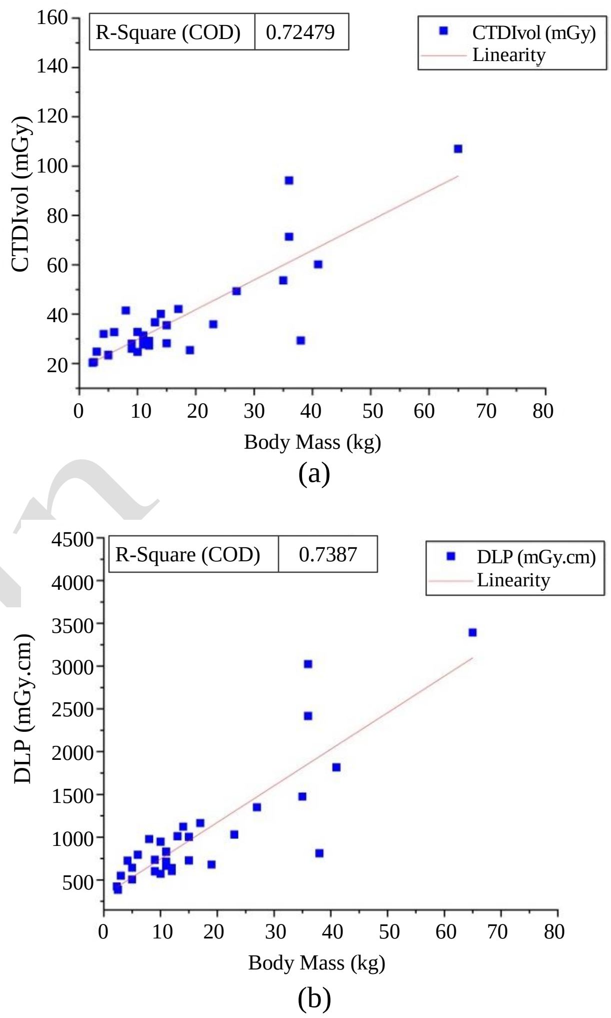
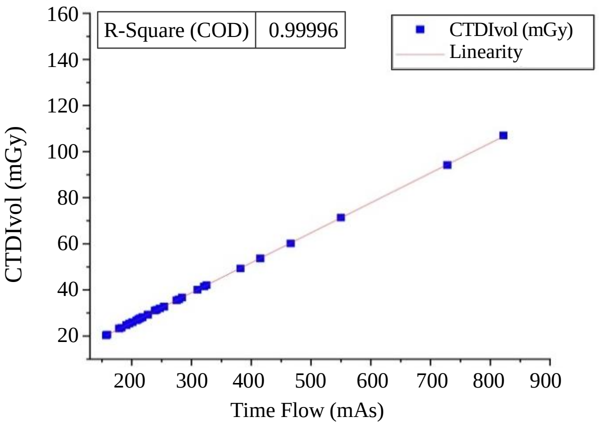


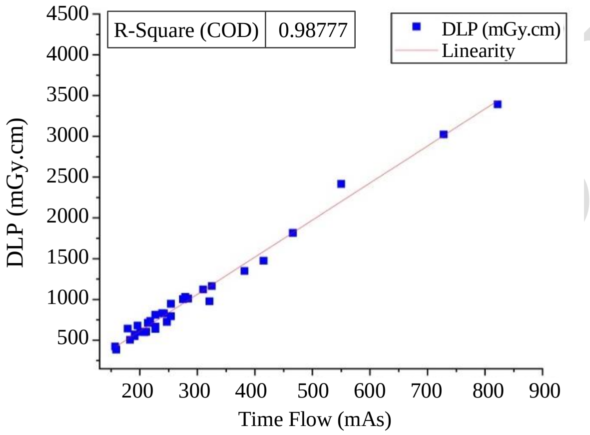
Fig. 4. (a) Correlation of body mass to $CTDI_{Vol}$ values (b) Correlation of body mass to DLP values.

Based on Fig. 4, the correlation of body mass to $CTDI_{Vol}$ and DLP values was carried out using statistical and linearity tests. The results obtained show a high correlation with a coefficient of determination (R^2) of 0.7, so there is a significant correlation. The head has a denser structure compared to other parts. It requires a higher radiation dose to penetrate the body, so the radiation dose absorbed by the patient tends to be greater. This can be caused by the head, which is not affected by fat, and the skull circumference of adult patients [37]. The results obtained are relevant to the results of research [36], which found a correlation between body mass and $CTDI_{Vol}$ and DLP. The more the patient's body mass increases, the greater radiation dose needed to penetrate the body so that the patient absorbs more radiation. Furthermore, research [10] also obtained a correlation between body mass and $CTDI_{Vol}$ and DLP.

The correlation of the exposure factor (mAs) to $CTDI_{Vol}$ and DLP values is demonstrated in Figs. 5 (a) and (b).



(a)



(b)

Fig. 5. (a) Correlation of mAs to $CTDI_{Vol}$ values (b) Correlation of mAs to DLP values.

Based on Fig. 5, the correlation of mAs to $CTDI_{Vol}$ and DLP values was carried out using statistical and linearity tests. The results obtained show a very high correlation with a coefficient of determination (R^2) of 0.9, which is almost close to 1, so there is a significant correlation. These results are relevant to the research conducted by [38], which uses a tube voltage of 120 kV and varying time current strength; the results obtained are that the value of time current strength affects the $CTDI_{Vol}$ value where the greater the time current strength, the greater the $CTDI_{Vol}$ value. Furthermore, the results of research [18] show the correlation of mAs to $CTDI_{Vol}$ and DLP values. The greater the mAs value, the greater the $CTDI_{Vol}$ and DLP values. The strong current time (mAs) is influenced by the flow of electrons released by the filament into the X-ray tube; the more electrons, the more X-rays are produced, so the higher radiation dose is received by the patient [39].

CONCLUSION

Typical values for pediatric patients in head CT scans were obtained. The typical value for $CTDI_{Vol}$ was obtained as 31.1 mGy and DLP as 793.3 mGy.cm. In this research, there was a moderate correlation between age and $CTDI_{Vol}$ and DLP values, a high correlation between body mass and $CTDI_{Vol}$ and DLP values, and a very high correlation between mAs and $CTDI_{Vol}$ and DLP values.

The established typical values can be used as a tool for radiation dose optimization, i.e., as a guideline for radiographers and medical physicists to increase optimization efforts so that radiation doses in pediatric patients can be as low as possible with adequate image quality results. Radiographers and medical physicists can monitor the radiation dose administered to pediatric patients to prevent unnecessary exposure by implementing optimization measures, such as accurately adjusting the scan length and parameters.

ACKNOWLEDGMENT

This research is funded by Universitas Andalas, in accordance with the Undergraduate Thesis Research contract (PSS) Batch I Number: 229/UN16.19/PT.01.03/PSS/2024, the fiscal year 2024. The authors thank Universitas Andalas Hospital, which has facilitated this research.

AUTHOR CONTRIBUTION

R. Delvihardini, I. B. G. P. Pratama, D. Milvita, A. Oktavia, and R. Fardela equally contributed as the main contributors to this paper. All authors read and approved the final version of the paper.

REFERENCES

1. R. Fardela, D. Milvita, L. A. Rasyada *et al.*,. Jurnal Ilmiah Pendidikan Fisika Al-Biruni **12** (2023) 143. (in Indonesian)
2. R. Fardela, D. Milvita, M. Almuhayar *et al.*, J. Comput. Sci. **20** (2024) 357.

3. A. J. Garcia-Sanchez, E. A. G. Angosto, P. A. M. Riquelme *et al*., Sensors (Switzerland) **18** (2018) 2.
4. A. M. Ahmed, A. Musa, A. Medani *et al*., Appl. Radiat. Isot. **204** (2024) 111147.
5. D. R. Dance, S. Christofides, A. D. A Maidment *et al*., A Handbook for Teachers and Students: Diagnostic Radiology Physics, International Atomic Energy Agency, Vienna (2014) 1.
6. R. Jannah, R. Munir and E. R. Putri, Atom Indones. **49** (2023) 145.
7. A. L. Wati, C. Anam, A. Nitasari *et al*., Atom Indones. **48** (2022) 61.
8. S. Hussain, I. Mubeen, N. Ullah *et al*., Biomed Res. Int. **2022** (2022) 1.
9. A. Sulieman, A. Elnour, M. Z. Mahmoud *et al*., Radiat. Phys. Chem. **174** (2020) 108963.
10. H. Brat, F. Zanca, S. Montandon *et al*., Eur. Radiol. **29** (2019) 6794.
11. W. S. Tan, S. Foley and M. L Ryan, Radiography **29** (2023) 786.
12. P. R. Costa, J. C. O. Castro, I. P. F. Nunes, *et al*., Radiat. Phys. Chem. **221** (2024) 111669.
13. T. Amalia, B. Zulkarnaien, C. Anam *et al*., Atom Indones. **48** (2022) 159.
14. L. Arlany, H. G. Toh, B. Nazir *et al*., Radiography **29** (2023) 184.
15. A. Arriaga, C. Gonçalves, P. Teles *et al*., Eur. J. Radiol. **170** (2024) 111248.
16. C. C. Yang, Diagnostics **10** (2020) 1.
17. J. Guðjónsdóttir, S. S. Michelsen, G. Björnsdóttir *et al*., Physica. Med. **109** (2023) 102576.
18. W. A. Kalender, Phys. Med. Biol. **59** (2014) R129.
19. A. Aamry, M. Alsufayan, H. Aldossari *et al*., Radiat. Phys. Chem. **172** (2020) 108807.
20. C. Anam, F. Haryanto, R. Widita *et al*., J. Phys: Conf. Ser. **694** (2016) 012030.
21. C. Lee, N. Journy, B. E. Moroz *et al*., Radiat. Prot. Dosim. **184** (2019) 44.
22. M. O. Bernardo, L. Karout, F. Morgado *et al*., Eur. J. Radiol. **169** (2023) 111191.
23. K. Martini, J. W. Moon, M. P. Revel *et al*., Diagn. Interventional Imaging **101** (2020) 269.
24. International Atomic Energy Agency (IAEA), Radiation Protection and Safety of Radiation Sources, Safety Standards for protecting people and the environment, No. GSR Part 3, IAEA, Vienna (2014) 1.
25. R. Latifah, N. Z. Jannah, D. Z. I. Nurdin *et al*., J. Vocat. Heal. Stud. **2** (2019) 127.
26. H. Osman, M. Alosaimi, F. Alghamdi *et al*., Radiat. Phys. Chem. **202** (2023) 110206.
27. S. T. Aldahery, Saudi Pharm. J. **31** (2023) 101820.
28. E. Vañó, D. L. Miller, C. J. Martin *et al*., Diagnostic Reference Levels in Medical Imaging, ICRP Publication 135, Annals of the ICRP **44** (2015) 1.
29. K. Alzimami, A. Sulieman, H. Omer *et al*., Radiat. Phys. Chem. **188** (2021) 109679.
30. N. A. Muhammad, A. Sabarudin, N. Ismail *et al*., Radiat. Phys. Chem. **179** (2021) 109148.
31. M. Rawashdeh, C. Saade, D. S. Al Mousa *et al*., Radiat. Phys. Chem. **205** (2023) 110698.
32. A. Lyons, A. M. Ali, A. England *et al*., J. Med. Imaging Radiat. Sci. **55** (2024) 101421.
33. J. P. Guilford, Fundamental Statistic in Psychology and Education, Third Edition, Mc Graw-Hill Book Company (1956).
34. M. H. Kharita, H. Al-Naemi, C. Arru *et al*., Eur. J. Radiol. **130** (2020) 109138.
35. M. K. Saeed and Y. Almalki, Radiography **27** (2021) 332.
36. F. Yang and L. Gao, J. Radiol. Prot. **44** (2024) 021509.
37. S. O'Neill, R. G. Kavanagh, B. W. Carey *et al*., Eur. Radio. Exp. **2** (2018) 1.
38. S. J. Dewang, B. Abdullah and D. Tahir, J. Phys.: Conf. Ser. **979** (2018) 012078.
39. S. C. Bushong, Radiologic Science for Technologist: Physics, Biology and Protection, Tenth Edition, Elsevier Mosby, St. Louis (2013).