FULafia Journal of Science & Technology
ISSN (print) 2449-0954 \ ISSN (online) 2636-4972
https://lafiascijournals.org.ng/index.php/fjst
Sponsored By TERTIARY EDUCATION TRUST FUND
Manuscript => Received: Nov., 2024; Accepted: July, 2026; Published: July, 2026 https://doi.org/10.62050/fjst2026.v10n2.384

ESTIMATION OF EFFECTIVE DOSE FOR PATIENTS UNDERGOING COMPUTED TOMOGRAPHY SCANS FROM SELECTED DIAGNOSTIC CENTERS IN SOUTHWESTERN NIGERIA

A. E. Ajetunmobi[1]*, T. W. David[1], A. T. Talabi[1], S. K. Alausa[1], A. P. Ejiwunmi[1], O. J. Odogboro[1] and P. E. Biere[2]
[1]*Physics Department, Olabisi Onabanjo University, PMB 2002, Ago-Iwoye, Nigeria*
[2]*Niger Delta University, Wilberforce Highland, Bayelsa State, Nigeria*
*Corresponding email: abayomi.ajetunmobi@oouagoiwoye.edu.ng

ABSTRACT
Computed Tomography (CT) is a major contributor to medical radiation exposure worldwide. In Nigeria, the absence of national Diagnostic Reference Levels (DRLs) poses challenges for patient dose optimization and radiation protection. This study estimated effective doses (EDs) from common CT examinations in selected diagnostic centers/hospitals in Southwestern Nigeria and compared the results with International Standards. A retrospective cross-sectional study was conducted using convenience samples of 348 CT examinations, comprising head (n = 212), chest (n = 56), and abdomen-pelvis (n = 80) scans, obtained from one government-owned and one private hospitals. Patient dose parameters, including Dose Length Product (DLP), were extracted, and effective dose (ED) was calculated using International Commission on Radiological Protection (ICRP) region-specific conversion recommended factors. Mean EDs for head CT were 2.5±1.0 and 1.9±0.7 mSv in the government and private hospitals, respectively. Chest CT yielded mean EDs of 11.1±8.1 and 15.4±4.9 mSv, while abdomen-pelvis CT recorded the highest value of 19.3±9.8 and 48.4±17.9 mSv, respectively. The student's t-test showed significant differences ($p < 0.05$) in chest and abdomen-pelvis EDs between the hospitals. The results of EDs for head CT were lower than the established values from British Columbia and Canada, whereas the chest and abdomen-pelvis doses exceeded standard values by 23-193 %. These findings demonstrate considerable inter-hospital variation and elevated radiation doses for thoracic and abdominopelvic CT examinations. Therefore, there is urgent need for the CT dose optimization and the establishment of national DRLs in Southwestern Nigeria to strengthen radiation protection and improve patient safety.

Keywords: Computed tomography, Effective dose, Radiation protection, Diagnostic reference levels, Dose optimization

INTRODUCTION

Computed Tomography (CT) is an indispensable diagnostic tool in modern medicine, but constitutes a major source of ionizing radiation exposure to the global population (Smith-Bindman *et al*., 2019). While the clinical benefits are substantial, the associated cancer risk, though small at the individual level, is a public health concern and necessitates the principle of keeping doses "As Low As Reasonably Achievable" (ALARA) (Ajetunmobi *et al*., 2025). Unlike X-ray, which is a diagnostic tool, as cited in Ajetunmobi *et al*. (2025), a CT scan provides a more detailed image of the organs under investigation. In high-income countries, this is managed through the establishment and adherence to Diagnostic Reference Levels (DRLs), which are investigational levels for typical examinations to identify unusually high doses (Vetter, 2008).

In Nigeria, and many other Low- and Middle-Income Countries (LMICs), the rapid proliferation of CT technology has not been matched with robust radiation protection infrastructure (Granata *et al*., 2019). There is a critical absence of locally developed, evidence-based national DRLs. Consequently, practices are often guided by manufacturer protocols or international standards that may not account for local patient demographics, disease prevalence, or equipment variations, potentially leading to overexposure or underexposure (Ofori *et al*., 2014). This gap is exacerbated by insufficient regulatory oversight and a lack of routine dose audits.

Southwestern Nigeria, a densely populated region with numerous diagnostic centers, exemplifies this challenge. There is a paucity of published data on CT patient doses in this region, making it impossible to assess current practices against any standard. This study, therefore, aims to fill this knowledge gap by estimating the effective doses for common CT examinations (head, chest, abdomen-pelvis) in two representative hospitals in selected diagnostic centers in Southwestern Nigeria. The objectives of the study are to quantify patient doses and their variability, compare the findings with established DRLs from developed regions such as British Columbia (BC), Canada, chosen for its well-documented, publicly available dose data and mature radiation safety culture to contextualize the Nigerian practice within a global framework (Muhogora *et al*., 2008), and provide empirical evidence to advocate for and inform the development of Nigerian national DRLs. This work is essential for initiating dose optimization efforts and enhancing radiation protection for patients in Nigeria.

MATERIALS AND METHODS

Study Design and Model of CT Scanner for the Study

A retrospective cross-sectional study was conducted at two hospitals in Southwestern Nigeria: a government-funded teaching hospital (Hospital A) and a busy private hospital (Hospital B). Both centers were selected due to their high patient throughput and availability of modern CT scanners. The model type of CT scanner at Hospital A is GE Revolution ACT with a helical multi-slide modes scanner of up to 32 slices. The table movement speed is 3.75- 35 mm/s, and the rotation speed is 0.98-2.0 mm/second. The minimum scan-to-scan cycle is 1.0 seconds. The pixel size is 0.19 mm. The tube current (maximum) is 200–333 mA. The power of the generator of the scanner lies between 24–40 KW. It has a scanner that has a nominal focal spot size. The model of the scanner available at Hospital B is a Phillip CT scan with 64 slides. The gantry of the scanner has an aperture of 70 mm with a rotation time of 0.4 -2 seconds for a full 360^0 scan and 0.28-0.33 seconds for a partial angle of 240^0. The gantry tilt is between -30^o and $+30^o$ with 0.5 increment. The focal detector distance is 1040 mm. The power of the generator of the scanner lies between 60 and 140 KV with a current from 20-500 mA. The X-ray tube has a voltage rating of 120 KV (maximum).

Sampling and Data Collection

A convenience sampling method was used to collect data from archived patient records over six months. A total of 348 completed CT examination records were including 203 from Hospital A and 145 from Hospital B. A structured data sheet was used to collect parameters like patient age and sex, tube current (mA), tube voltage (kV), CTDIvol, and DLP from each scan protocol All patient identifiers were removed to ensure confidentiality. Ethical approval was obtained from the management of both institutions.

Inclusion criteria: Common adult CT examinations of the head (non-contrast), chest (routine), and abdomen-pelvis (routine) were included.

Exclusion criteria: Pediatric scans, contrast-enhanced studies, angiographic studies (e.g., pulmonary angiogram), and specialized scans (e.g., orbits, sinuses, arthrography) were excluded due to insufficient numbers or different dose calculation protocols.

Calculation of Effective Dose

The Effective Dose (ED, in mSv) was estimated from the DLP using the standard conversion method recommended by the ICRP and widely adopted in similar studies (Aldrich *et al*., 2006). The formula is given by equation (1):

$$ED = DLP \times k \qquad (1)$$

where k is a tissue-weighting factor conversion coefficient ($mSv \cdot mGy^{-1} \cdot cm^{-1}$) specific to the anatomical region scanned. For this study, the following k-factors were applied, consistent with ICRP Publication 103 and common clinical practice: for Head (0.0021 $mSv \cdot mGy^{-1} \cdot cm^{-1}$), Chest (0.014 $mSv \cdot mGy^{-1} \cdot cm^{-1}$), Abdomen-Pelvis (0.015 $mSv \cdot mGy^{-1} \cdot cm^{-1}$)

The primary assumption of this model is that the scanner output and patient anatomy are adequately represented by the DLP and the standardized k-factor, providing a reasonable estimate of stochastic risk.

Data Analysis

Data were analyzed using Microsoft Excel and Statistical Analysis Software (SAS). Descriptive statistics (mean and range) were calculated for all dose parameters (CTDIvol, DLP, and ED) for each scan type and hospital. A two-sample student's t-test was performed to determine if there were statistically significant differences ($p < 0.05$) in the mean ED between the two hospitals for each scan type.

RESULTS AND DISCUSSION

As shown in Table 1, the tube current and voltage adopted by the radiographers for the brain scan at hospital A was in the range of 84-180 mA with a mean of 134 mA and 120 kV, respectively. The estimated effective doses for brain scans ranged from 0.4-6.7 mSv with a mean value of 2.5 mSv. The tube current and voltage adopted by the radiographers for the chest scan ranged from 30-161 mA with a mean of 94 mA, and 100-120 with a mean of 120 kV, respectively. The estimated effective dose for chest scans falls within the range of 1.6–30.6 mSv with a mean value of 11.1 mSv. Lastly, the tube current and voltage adopted by the radiographers for abdomen-pelvis scans was from 79-160 mA with a mean of 91 mA and 120 kV, respectively. The estimated effective dose for abdomen-pelvis scans ranged from 4.0–36.0 mSv, with a mean value of 19.3 mSv. The magnitude of the current required for different types of scans is a function not only of the age of the patient undergoing the scan but also the density of the structure obscuring the parts to be scanned.

Table 1: Radiographic and scan parameters for Hospital A

Scan type	Tube current (mA)	Tube Voltage (kV)	Age range (yrs)	Sex (M,F)	DLP (mGycm)	$CTDL_{vol}$ (mGy)	Effective Dose (mSv)
Brain	(84-180) 134	120	(6m-89)	(82,49)	(240-2877) 1069	(10-154) 49	(0.4-6.7) 2.5
Chest	(30-161) 94	(100-120) 118	(13-79)	(10,10)	(100-1700) 653	(3-95)31	(1.6-30.6)11.1
Abdomen-Pelvis	(79-160)91	120	(3m-88)	(27,25)	(235-2089) 1137	(6-94) 40	(4.0-36.0) 19.3

Table 2: Radiographic and scan parameters for Hospital B

Scan type	Tube current (mA)	Tube Voltage (KV)	Age range (yrs)	Sex (M,F)	DLP (mGYcm)	$CTDL_{vol}$ (mGy)	Effective Dose (mSv)
Brain	(200-300)207	(100- 120) 119	(7days-89)	(39, 42)	(264-1782)820	(16-78) 37	(0.6- 4.1) 1.9
Chest	(124-300) 198	(120-120) 120	(28-92)	(16, 20)	(320-1400) 901	(12-47)25	(5.5-23.8)15.4
Abdomen-Pelvis	(25- 359) 243	120	(25-78)	(12, 16)	(587- 4504) 2847	(17-83) 56	(9.90-76.5) 48.4

As shown in Table 2, the tube current and voltage adopted by the radiographers for the brain scan in hospital B ranged from 200-300 mA with a mean of 207 mA, and 100-120 kV with a mean of 119 kV, respectively. The estimated effective dose for brain scans was in the range of 0.6-4.1 mSv with a mean value of 1.9 mSv. The tube current and voltage adopted by the radiographers for the chest scans ranged from 124-3001 mA with a mean of 198 mA and 120 kV, respectively. The estimated effective dose for chest scans ranged from 5.5–23.8 mSv with a mean value of 15.4 ms. Lastly, the tube current and voltage adopted by the radiographers for the abdomen-pelvis scans was in the range of 25-359 mA with a mean of 243 mA and 120 kV, respectively. The estimated effective dose for abdomen-pelvis scans ranged from of 9.9–76.5 mSv with a mean value of 48.4 mSv.

The results of the present study were compared with published DRLs and mean dose data from British Columbia (BC) and Canada (Aldrich *et al*., 2006). BC was chosen as a comparator because it represents a jurisdiction with a long-standing, systematic approach to patient dose monitoring, published regular dose surveys, and established DRLs that are representative of optimized practice in a high-income country. This comparison provides a concrete benchmark to assess the performance of the Nigerian centers against internationally accepted standards. The estimated mean effective doses for brain scans for hospitals A and B are 2.5 and 1.9 mSv, respectively. The estimated value for the brain scan at hospital A is less than that of a similar study in Germany, 2.8 mSv (Bri x *et al.,* 2003), and Canada, 2.7 mSv (David *et al.,* 2009), but greater than a similar study in the United Kingdom (UK), 1.5 mSv (Shrimpton *et al.,* 2003). Similarly, the estimated effective dose value for the brain scan at hospital B, 1.9 mSv is less than the values for Germany, BC, 2.8 mSv (Aldrich *et al.,* 2005), and Canada. The mean effective doses for the chest and abdomen-pelvis scans are much higher than those reported in studies from the aforementioned nations, except for the chest scan in Canada (11.3 mSv) is slightly higher than the value at Hospital A (11.1 mSv). The estimated mean effective dose for chest scans (15.4) mSv in Hospital B is quite large compared with those of a similar study carried out in Colombia (9.0 mSv), Germany (5.7 mSv), Canada (11.3 mSv), and the UK (5.8 mSv). Prashant *et al*. (2020) reported that variation in effective dose during a scan may be a function of the scanning machine model used in the hospital, patients' body mass index, and patients with intensive care unit referrals. Again, Prashant *et al.* (2020) reported that male gender, patient age, patients in ICU, body mass index, and 64-slice scanner with FBI image reconstruction are associated with higher radiation doses, while third-generation dual-source scanners with model-based IR are associated with the lowest radiation doses.

As shown in Tables 3 and 4, Hospital B delivered a significantly lower mean ED for head CT than A (1.9 and 2.5 mSv respectively, $p > 0.05$) but markedly higher doses for chest (15.4 and 11.1 mSv respectively, $p < 0.05$) and abdomen-pelvis scans (48.4 and 19.3 mSv respectively, $p < 0.001$). The extremely high mean value for abdomen-pelvis scans in Hospital B (33.9 mSv) is of great concern. This inter-hospital variability, particularly for torso scans, underscores the lack of standardized protocols and highlights the consequences of operating without national DRLs.

Table 3: Comparison of the estimated effective dose (mSv) for the study with similar studies in other nations

Scan Type	Present study A	Present study B	CB	UK	Germany	Canada
Head/Brain	2.5	1.9	2.8	1.5	2.8	2.7
Chest	11.1	15.4	9.0	5.8	5.7	11.3
Abdomen-pelvis	19.3	48.4	16.7	7.1	14.4	15.5

Table 4: Comparison of the pooled mean effective doses (mSv) for the two hospitals with International Benchmarks

Scan Type	Present Study (Mean)	BC (Aldrich *et al*., 2006)	% Difference vs. BC
Head	2.2	2.8	-21%
Chest	13.2	9.0	+47%
Abdomen-Pelvis	33.9	16.5	+105%

The comparison with British Columbia data (Table 3) reveals a mixed picture. While head CT doses in Nigeria were favorable (21 % lower), chest and abdomen-pelvis doses were 47 and 105 % higher, respectively. This discrepancy is critical. The use of BC as a benchmark is justified as it represents an optimized standard; the higher doses in Nigeria suggest potential for significant optimization, especially for torso examinations. These elevated doses could be attributed to factors such as the use of fixed technical parameters regardless of patient size, lack of automated tube current modulation, or suboptimal scanning protocols (American Association of Physicists in Medicine, 2021).

Table 5: Statistical comparison of mean effective doses between Hospitals

Scan Type	t-value	p-value	Significant Difference (p<0.05)
Head	2.91	0.09	No
Chest	-2.30	0.025	**Yes**
Abdomen-Pelvis	-21.3	<0.001	**Yes**

The t-value is a ratio that measures the difference between two group means relative to the variability within the groups. The sign of the t-value (±) indicates the direction of the difference, while the magnitude indicates the strength of the difference.

For the head scan, the positive t-value (+2.91) indicates that Hospital A had a higher mean effective dose (2.5 mSv) compared to Hospital B (1.9 mSv), as presented in Table 3. However, the p-value of 0.09 is greater than 0.05, meaning the difference is not statistically significant at the 95 % confidence level. Clinically, although Hospital A delivered approximately 32 % higher dose than Hospital B (2.5 vs. 1.9 mSv), this difference could be due to random chance or sampling variability rather than a systematic difference in practice. Both hospitals are operating within acceptable ranges for head CT, with doses well below the British Columbia benchmark of 2.8 mSv. The lack of statistical significance suggests that head CT protocols are relatively consistent between the two centers, possibly because head CT is a more standardized examination with less variation in technique (e.g., fixed scanning parameters, smaller anatomical variation between patients). Hospital A (government hospital) delivered higher mean doses than Hospital B (private hospital). This may reflect older equipment, different scanning protocols, or different patient demographics between the two institutions.

For the Chest CT scan ($t = -2.30$, $p = 0.025$), the negative t-value (-2.30) indicates that Hospital A had a lower mean effective dose (11.1 mSv) compared to Hospital B (15.4 mSv). The p-value of 0.025 is less than 0.05, confirming that this difference is statistically significant. The p-value of 0.025 confirms that this difference is unlikely to be due to chance, indicating systematic differences in scanning protocols between the two institutions. This warrants immediate investigation and protocol optimization, particularly at Hospital B. This is a clinically significant finding. Hospital B (private hospital) is delivering doses that are approximately 39 % higher than Hospital A (15.4 and 11.1 mSv respectively) for chest CT examinations. Both institutions exceed the British Columbia benchmark (9.0 mSv) by 23 and 71 %, respectively. This suggests that the private hospital (Hospital B) may be using a higher tube current (mA) or voltage (kV) settings, longer scan lengths, more phases, or higher resolution protocols, and less use of dose reduction technologies (e.g., automatic tube current modulation).

For the abdomen-pelvis CT ($t = -21.3$, $p < 0.001$), the highly negative t-value (-21.3) indicates a very large difference in mean effective doses between the two hospitals. Hospital A (19.3 mSv) delivered substantially lower doses compared to Hospital B (48.4 mSv). The p-value < 0.001 indicates an extremely significant difference with practically no chance of being due to random variation. This is the most alarming finding in the study. Hospital B is delivering doses that are approximately 151 % higher than Hospital A (48.4 and 19.3 mSv respectively) and 193 % higher than the British Columbia benchmark (16.5 mSv). The t-value of -21.3 is exceptionally large, indicating a massive and systematic difference in practice between the two centers. The reason for the large and negative t-value may be due large mean difference: the gap between 19.3 and 48.4 mSv is enormous (~29 mSv difference). Low variability, with extremely high t-value suggests that within-group variability was relatively small compared to the between-group difference, making the difference highly reliable. For systematic protocol differences, Hospital B appears to be using protocols that deliver approximately 2.5 times the radiation dose of Hospital A for abdomen-pelvis scans. Hospital B may be using a different scanning protocol (e.g., multiple phases, higher resolution, longer scan range), possible use of higher tube current or voltage settings, lack of automatic tube current modulation or dose reduction techniques, equipment difference. Hospital B uses a Philips 64-slice scanner, while Hospital A uses a GE Revolution ACT (32-slice). Different manufacturers and models may have different default protocols; operator variability, less experienced radiographers or lack of dose optimization training; and no routine dose audits, without DRLs, there is no external benchmark to identify excessive doses.

Comparison with Regional and LMIC Studies

Our findings resonate with trends observed in other African and LMIC settings. A study in Northern Nigeria reported very high DLP values for head CT (Anzaku *et al*., 2021), while research from Ghana (Anim-Sampong *et al*., 2022), the Middle East, North Africa, and India (Elshami *et al*., 2021) also identified CT doses that often-exceeded international DRLs (Bani-Ahmad *et al*., 2026). This consistent pattern across LMICs points to systemic issues, including limited training in dose optimization, aging equipment, and the absence of enforceable local DRLs, creating a regional radiation protection challenge.

Radiation Protection Implications in Nigeria

The absence of national DRLs in Nigeria is a major radiation protection deficit. DRLs are not dose limits but essential tools for quality assurance and audit. Without them, radiologists and technologists have no national standard for identifying and correcting poor practices. The high and variable doses reported here, particularly for abdomen-pelvis scans, directly translate to an unnecessary and avoidable increase in the collective radiation burden to the Nigerian population, contravening the ALARA principle.

CONCLUSION

This study provides the first quantitative assessment of patients' effective doses from common CT examinations in two hospitals in Southwestern Nigeria. The key findings are that there is wide variation in practice between hospitals, indicating a lack of standardized protocols. While head CT doses are within an acceptable range, the effective doses for chest and, especially, abdomen-pelvis CT scans are substantially higher than international standards from British Columbia. The significant dose elevation for torso scans underscores a clear need for immediate optimization efforts. The results have direct implications for clinical practice: they serve as an alert to the radiology community and regulators in Nigeria about potential overexposure in routine CT. The data strongly support a review of existing protocols, particularly for abdominal and pelvic examinations, and emphasize the need to implement patient-specific parameter adjustments.

Recommendations

Recommendations are made based on the findings of the study. First, urgent protocol review at Hospital B is imperative, as the abdomen-pelvis doses were found to be 151 % higher than those at Hospital A ($t = -21.3$, $p < 0.001$), representing a systematic and unacceptable radiation protection deficit that demands immediate investigation through a comprehensive audit of technical parameters (mA, kV, scan length, and pitch) and consideration of automated dose modulation implementation. Second, dose optimization for chest CT at both Hospitals is necessary, as both institutions exceed the British Columbia benchmark. Hospital B requires more urgent intervention, given its mean dose of 15.4 mSv; regular statistical comparisons using t-tests should be incorporated into routine quality assurance programs to monitor inter-hospital variation. Third, the Nigerian Nuclear Regulatory Authority (NNRA) and relevant professional bodies should prioritize developing National Diagnostic Reference Levels (DRLs) by using this study's pooled data to inform a preliminary national survey. Fourth, mandatory continuing education in radiation protection and dose optimization techniques should be instituted for all radiologists and radiographers who operate CT equipment. Finally, a larger, multi-center nationwide survey is urgently needed to establish robust national DRLs and monitor trends over time, as the highly significant negative t-value for abdomen-pelvis (-21.3) provides compelling quantitative evidence that cannot be attributed to chance ($p < 0.001$) and underscores the critical need for systematic dose optimization programs across Nigeria.

Conflict of interest: The authors declare no conflict of interest.

Acknowledgement: The researcher acknowledges the cooperation of the Hospital staff involved in the study.

REFERENCES

Ajetunmobi, A. E., Talabi, A. T., Alausa, S. K., David, T. W., Ajetunmobi, S. A., Biere, P. E., Ogunya, G. and Odogboro, O. J. (2025). Correlation between entrance surface doses and body mass index (BMI) for students undergoing chest X-ray examination at Olabisi Onabanjo University Clinic. *Nig. J. of Phys.*, 34(2), 172-176. https://doi.org/10.62292/njp. v34i2.2025.403

Aldrich, J. E., Bilawich, A. and Mayo, J. R. (2006). Radiation doses to patients receiving computed tomography examinations in British Columbia. *PubMed,* 57(2), 79-85. https://pubmed.ncbi.nlm.nih.gov/16944681

American Association of Physicists in Medicine (2021). *The Use of Effective Dose as a Risk Indicator in Diagnostic Medical Imaging* (AAPM Task Group 321 Report).

Anim-Sampong, S., Ohene-Botwe, B., Adom, E. B. and Tagoe, S. N. A. (2022). Dose optimization of adult head computed tomography examination in an academic hospital in Ghana. *Radiation Physics and Chemistry,* 205, 110735. https://doi.org/10.1016/j.radphyschem.2022.110735

Anzaku, E. P., Bichi, T. S., Abubakar, T. S., Iya, S. G. D. and Hikima, M. S. (2021). Evaluation of computed tomography doses in three medical diagnostic centres in Kano. *Journal for Foundations and Applications of Physics,* 3(1).

Bani-Ahmad, M., Hadi, Y. H., Sullivan, A. O., England, A., McLaughlin, L. and McEntee, M. (2026). Clinical indication-based CT scan range reduction: A scoping review of radiation dose savings and diagnostic accuracy. *Journal of Medical Imaging and Radiation Sciences,* 57(3), 102338. https://doi.org/10.1016/j.jmir.2026.102338

Brix, G., Nagel, H.D., Stamm, G. *et al.* (2003). Radiation exposure in multi-slice versus single-slice spiral CT: Results of a nationwide survey. *Eur. Radiol.,* 13, 1979–1991. https://doi.org/10.1007/s00330-003-1883-y

David A. L, MD, N S. S, MD, Chance S. D, Hyun J. L, PHD, Derek A. F, MD (2009). Radiation dose from diagnostic computed tomography in Saskatchewan (Canada). *Canadian Association of Radiologists Journal,* 60, 71 – 78.

Elshami, W., Akudjedu, T. N., Abuzaid, M., David, L. R., Tekin, H. O., Cavli, B. and Issa, B. (2021). The radiology workforce's response to the COVID-19 pandemic in the Middle East, North Africa, and India. *Radiography,* 27, 360-368. https://doi.org/10.1016/j.radi.2020.09.016

Granata, C., Sorantin, E., Seuri, R. and Owens, C. M. (2019). European Society of Paediatric Radiology Computed Tomography and Dose Task Force: European guidelines on diagnostic reference levels for paediatric imaging. *Pediatric Radiology,* 49(5), 702-705. https://doi.org/10.1007/s00247-019-04346-z

Muhogora, W. E., Ahmed, N. A., Almosabihi, A., Alsuwaidi, J. S., Beganovic, A., Ciraj-Bjelac, O., Kabuya, F. K., Krisanachinda, A., Milakovic, M., Mukwada, G., Ramanandraibe, M. J., Rehani, M. M., Rouzitalab, M. M. and Shandorf, C. (2008). Patient doses in radiographic examinations in 12 countries in Asia, Africa, and Eastern Europe: Initial results from IAEA projects. *American Journal of Roentgenology,* 190, 1453-1461. http://dx.doi.org/10.2214/AJR.07.3039

Ofori, K., Gordon, S. W., Akrobortu, E., Ampene, A. A. and Darko, E. O. (2014). Estimation of adult patient doses for selected X-ray diagnostic examinations. *J. of Radiat. Res. and Appl. Sci.,* 7, 459-462. https://doi.org/10.1016/j.jrras.2014.08.003

Preston, D. L., Ron, E., Tokuoka, S., Funamoto, S., Nishi, N., Soda, M., Mabuchi, K. and Kodama, K. (2007). Solid Cancer Incidence in Atomic Bomb Survivors: 1958–1998. *Radiation Research*, 168(1), 1–64.

Smith-Bindman, R., Kwan, M. L., Marlow, E. C., Theis, M. K., Bolch, W., Cheng, S. Y., Bowles, E. J. A., Duncan, J. R., Greenlee, R. T., Kushi, L. H., Pole, J. D., Rahm, A. K., Stout, N. K., Weinmann, S. and Miglioretti, D. L. (2019). Trends in use of medical imaging in US health care systems and in Ontario, Canada, 2000-2016. *JAMA,* 322(9), 843. https://doi.org/10.1001/jama.2019.11456

Vetter, R. J. (2008). ICRP Publication 103, The recommendations of the International Commission on Radiological Protection. *Health Physics,* 95(4), 445-446. https://doi.org/10.1097/01.hp.0000324200.73903.5b