FAMPO
FEDERATION OF AFRICAN MEDICAL PHYSICS ORGANIZATIONS

African Journal of Medical Physics
2020; 3(1): 23-28. doi: 10.

Research Paper

# Assessment of Dose to Patients Undergoing Computed Tomography Procedures at Selected Diagnostic Centers in Kano, Nigeria

Abdullahi A. Hassan [1,✉], Umar Ibrahim[2], Taofeeq A. Ige [3,7], Joseph Dlama Zira[4], Bello A. Aisha[5], Rilwan Usman[6]

1. National Agency for Science and Engineering Infrastructure, Idu Industrial Area, Garki, Abuja-Nigeria,
2. Department of Physics, Nasarawa State University Keffi, Nasarawa State, Nigeria.
3. Department of Medical Physics, National Hospital, Abuja, Nigeria.
4. Department of Medical Radiography, Bayero University, Kano, Kano State, Nigeria.
5. Department of Physics, Federal University of Lafia, Nasarawa State, Nigeria.
6. Department of Physics, Nigerian Army University, Biu, Borno State, Nigeria.
7. Department of Physics, University of Abuja, Abuja, Nigeria.

✉ Corresponding author: Mr. Abdullahi Hassan Abdullahi, National Agency for Science and Engineering Infrastructure, Idu Industrial Area, Garki, Abuja-Nigeria. Tel: +2348032175792; E-mail: abdallahdkd@gmail.com


ISSN 2643-5977

Received: 2019.09.02; Accepted: 2020.09.02; Published: 2020.09.10

## Abstract

Radiation dose levels for adult most common Computed Tomography (CT) examinations namely brain, chest and abdomen CT scans were studied. Radiation dose reports, scan parameters and demographic information were surveyed for a period of three - months. Ethical approvals were obtained from the research ethics committee of Ministry of Health and the studied centers. Data were randomly collected using a simple random technique from 131 adult patients with weights 70 ± 3kg. The General Electric 8 and 16-slice and 160-slice Toshiba CT scanners were used in the study. The data were analyzed using SPSS (version 20.0 Chicago) statistical software. The results indicated that the $CTDI_w$ and DLP values were (62.5 mGy and 2946mGy*cm), (9.9mGy and 663.3 mGy*cm) and (13.5 mGy and 1397 mGy*cm) for brain CT, chest CT and abdominal CT scans respectively. The study shows that the $CTDI_w$ values are relatively similar to those reported in established work by the European Commission. However, the DLP values are comparably higher than those of the European Commission. This revealed that there is need for robust and sustained optimization program so as to reduce patient doses without affecting diagnostic image quality.

Keywords: Computed Tomography; Head; Chest; Abdomen; Dose Reference levels; Scanning parameter.

## Introduction

Radiation dose surveys from medical imaging examinations provide valuable information about human health and play an important role in helping the physicians to make accurate diagnosis [1]. The medical physicists have become more concerned recently about the somatic and genetic hazards associated with radiation exposure and absorbed dose to patients during CT scan examination [2]. Radiological examination utilizing X-rays remain the most commonly used ionizing radiation in the field of medicine, responsible as the most substantial man-made source of radiation exposure to the world population [3]. Computed Tomography (CT) was introduced into clinical practice in 1972 and revolutionized x-ray imaging by providing high quality images which reproduced transverse cross sections of the body [4].The initial potential of the imaging modality has been realized by rapid technological developments, resulting in the continuing expansion of CT practices. As a result, the numbers of examinations are increasing; to the extent that CT has made a substantial impact on not only patients care but also patients and population exposure to medical X-rays. It was estimated that more than 62 million CT scans per year are currently obtained in the United States [5]. Today, it accounts for up to 40% of the resultant collective dose from diagnostic radiology in some countries of the European Union (EU).In Nigeria, dose escalation of CT procedures is generally reported in most local surveys due to, lack of guidance levels for routine examinations [6]. Special measures are therefore required to ensure optimization of performance in CT, and of patients' protection [4].

CT is associated with relatively high radiation doses, with a corresponding increased risk of carcinogenesis [8]. Therefore, the use of CT requires strict adherence to the tenets of radiation protection, justification and optimization to ensure that the risk to patients does not outweigh the benefit gained from the technique [9]. One of the optimization methods is the establishment of diagnostic reference levels [9]. Periodic national reviews and surveys concerning frequency and dose for medical X-ray procedures in the UK, conducted over the last 35 years by Public Health England (PHE) and previously by the National Radiological Protection Board [10] and the Health Protection Agency [11], have provided unique insight into the national trends in population exposure [12]. These surveys have also formed the basis for setting local reference doses as a quality improvement tool in the promotion of the optimization of patient's protection. Such radiation dose data is similar in purpose to national diagnostic reference levels, DRLs [13, 14].

The two basic principles of radiation protection for medical exposure as recommended by ICRP are justification of practice and optimization of protection, including the consideration of diagnostic reference levels. The emphasis is to keep the dose to the patient as low as reasonably achievable (ALARA), consistent with clinical requirements. Justification is the first step in radiation protection and thus, no diagnostic exposure is justifiable without a valid clinical indication. The optimization of patients' protection in computed tomography requires the application of examination-specific scan protocols tailored to patient age or size, region of imaging and clinical indication in order to ensure that the dose to each patient is as low as reasonably achievable for the clinical purpose of the examination [14].

The study aimed to conduct a CT dose survey in Kano State, Nigeria with the intent on establishing a local diagnostic reference level (LDRL).

## Materials and Methods

The study was quantitative and retrospectively carried out in four months at three centers performing CT scan procedures in Kano metropolis, Kano State, Nigeria. For anonymity, the centers were coded as Centre A, B and C. Ethical clearance was sought and obtained from Kano State Ministry of Health and the three studied centers. Data collection sheet used was adopted from the tested and validated International Atomic Energy Agency survey form for establishing reference levels. A total of 131 patients with various CT examinations which included the head chest and abdomen CT scans were obtained in this study corresponding to 60, 26 and 45 samples for each CT examination procedure respectively. Information recorded included the scan parameters (kV, mAs, slice thickness, pitch); radiation dose data (CTDI and DLP) and patient demographic information (age, gender and weight). Details of the different CT scanners such as detector configuration, year of manufacture, make and model were also documented.

The data were analyzed using SPSS (version 20.0 Chicago) software. Descriptive and inferential statistics were performed. The reference level based on CTDI and DLP was established at the level of median of 3$^{rd}$ quartile value. A p value of 0.05 at 95% confidence interval was accepted as level of significance.

Inferential statistical analysis was employed to measure the significance (whether any difference between two samples is due to chance or a real effect of a test result). It is represented using p values [15, 16].

Comparison was made between the measured doses and reported data from European countries where there are established DRLs. Statistically significant results of dose values between CT centers were determined using chi-square and student t-test at 0.05 level of significance.

## Results and Discussion

The information obtained from the three hospitals was used to determine the patient characteristics, scan parameters and radiation dose report as presented in Table 2. The doses obtained are required for establishing the local diagnostic reference level (LDRLs) for patients undergoing brain, chest and abdomen CT scan examinations in Kano, Nigeria. The mean kV values for head CT in Centers (B) and (C) were the same but different from those of Center (A). Chest CT had the same kV values in both Centers (A) and (B) but there were no available data for chest CT in Center (C) during the study period. In the abdomen, the kV values were entirely different for all the three study centers. The mean mA values were the same for all the examinations in Center (C) and different in Center (B) while, the CT machine in center (A) had mAs instead of mA and the values were different. It was observed that such variation could be attributed to different types of scanners.

Radiation dose to the patients from the three centers was expressed in terms of CTDIw, DLP and third quartile values. From this data we can see that CT examinations in Center (C) indicated the lowest mean values of CTDIw and DLP for brain CT (19.8 ±18.1 mGy) and (487.4±193.2mGy*cm). The highest value of CTDIw and DLP was noted at Center (A) for brain CT examination with a value of 64.3 ±2.9 mGy and 2987.1 ± 425.0mGy*cm respectively. Center (A) had the lowest CTDIw and high DLP mean value for chest CT (8.5 ± 1.3 mGy) and (620.7 ± 318.4 mGy*cm) respectively. The highest mean values of CTDIw and DLP for abdomen CT were noted at Centre (B) 11.8 ±2.4 mGy and 1297.9 ± 482.1 mGy*cm and lowest at Center (C) with 6.4 ± 1.9mGy and 571.9 ± 120.9 mGy*cm.

Comparing the results of CTDIw, DLP and the third quartile values with the facilities in Table 1, most of the high values were obtained from scanner with 160 slice detector configurations. It was observed that there was significant variation in the measured scan parameters in the three centers which attributed to difference in the size of the patients, scanned area, scan mode and the tube current (mA) and tube current time product (mAs). This variation and its attribution could agree with the research findings reported in previous studies [7, 12, 17, 18]. Furthermore, the variation of the type of CT equipment to the hospital specification for mean CTDIw and DLP led to higher dose of brain CT than other CT examinations [17].

The third quartile values obtained in this study for brain, chest and abdomen CT, with respective values of 62.5mGy and 2946mGy*cm, 9.9mGy and 663.3mGy*cm, 13.5mGy and 1397 mGy*cm were compared with Diagnostic Reference Level (DRLs) of European Union (2014) survey. The third quartile radiation dose values obtained from the European Union (2014) for brain CT, chest CT and abdomen CT with respective values of 60mGy and 1000mGy*cm, 10mGy and 600mGy*cm, 35mGy and 800mGy*cm, were comparably nearer in term of CTDIw while the DLP was below the values of the present study, except for the CTDIw value of abdomen CT that was higher than the present finding. However, the DLP obtained in this study for abdomen CT was higher than the one in European Union [18].

**Table 1.** Details of facilities, specifications and year of installation

| CT Center | Manufacturer | Brand/Model | CT Scanner Detector Configuration | Year of manufacture | Year of installation |
|---|---|---|---|---|---|
| Center A | Toshiba | Toshiba aquilion | 160-slice | 2015 | 2015 |
| Center B | General Electric (GE) | GE Brivo CT 385 | 16-slice | 2015 | 2015 |
| Center C | General Electric (GE) | Speed C4000 | 8-slice | 2001 | 2010 |

**Table 2.** Measured $CTDI_w$(mGy) and DLP (mGy*cm) with 75th Percentile values

| Region | $CTDI_w$ (mGy) | | DLP (mGy*cm) | | 75th Percentile |
|---|---|---|---|---|---|
| | Mean ± | SD | Mean ± | SD | (Median value) |
| Head | 44.7 | 20.9 | 1538.6 | 1122.7 | 62.5<br>2946 |
| Chest | 8.9 | 2.3 | 593.3 | 205.1 | 9.9<br>663.3 |
| Abdomen | 9.6 | 4.7 | 1076.2 | 845.1 | 13.5<br>1397 |

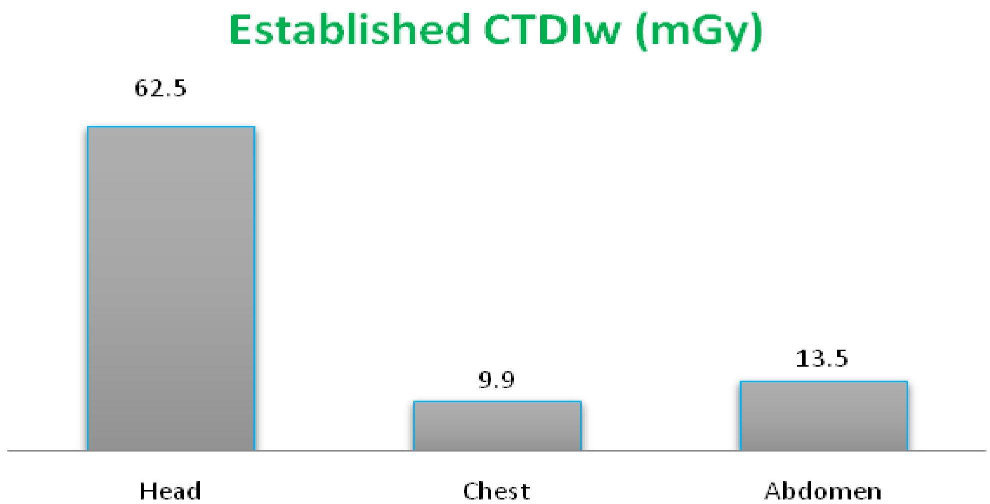


Figure 1. **Established DRLs in terms of CTDIw (mGy) values**

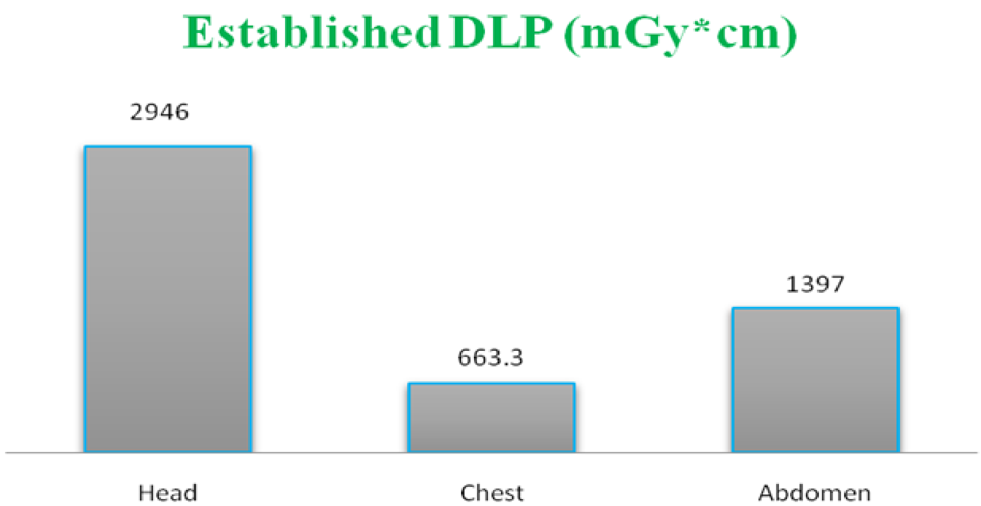


Figure 2. **Established DRLs in terms of DLP (mGy*cm) values**

**Table 3.** Comparison of DRLs of CTDIw (mGy) and DLP (mGy*cm) with the international values

| Region | This study (2019) | European Commission | Portugal | Australia |
|---|---|---|---|---|
| Author | | European Union, 2014 | Santos *et al.* (2014) | ARPANSA 2013 |
| Head | 62.5 | 60 | 75 | 47 |
| | 2946 | 1000 | 1010 | 527 |
| Chest | 9.9 | 10 | 14 | 9.5 |
| | 663.3 | 600 | 470 | 447 |
| Abdomen | 13.5 | 35 | 18 | 10.9 |
| | 1397 | 800 | 800 | 696 |

Therefore, the scan parameters and the protocols used were the main contributors to this higher output particularly, tube current and tube potential.

Measurements of patient dose undergoing CT examinations can be done directly on patients through the measurement of weighted CT Dose Index (CTDI) and Dose Length Product (DLP). CTDI is a measure of dose from a single slice of irradiation. It is also, a fundamental radiation dose parameter that increases dose awareness, and dose optimization in a CT examination [20]. CTDI represents the integral under the radiation dose profile in the z-axis of a single slice scanner that would produce one tomographic image per tube rotation [20, 21].

Mathematically, CTDI is equal to the integral of the dose profile along a line perpendicular to the tomographic plane for a single slice, divided by the nominal slice thickness. CTDI is the primary dose measurement concept in CT, and it is mathematically express as:

$$\boldsymbol{CTDI} = \frac{\boldsymbol{1}}{\boldsymbol{NT}} \int_{-\infty}^{\infty} \boldsymbol{D}(\boldsymbol{z}) \boldsymbol{dz} \qquad (1)$$

where $\boldsymbol{D}(\boldsymbol{z})$ =the radiation dose profile along the z-axis, $\boldsymbol{N}$ =the number of tomographic sections imaged in a single axial scan.This is equal to the number of data channels used in a particular scan. The value of N may be less than or equal to the maximum number of data channels available on the system, and $\boldsymbol{T}$ = the width of the tomographic section along the z-axis imaged by one data channel.

CTDI represents the average absorbed dose, along the z-axis, from a series of contagious irradiations. It is measured from one axial CT scan (one rotation of the X-ray tube), and is calculated by dividing the integrated absorbed dose by the nominal total beam collimation [22].

DLP indicates most closely the radiation dose for a specific CT examination, and its numeric value is affected by variances in patient anatomy (the value of DLP is higher for taller patients because of their height). So, the $CTDI_w$ is more useful in designing CT imaging protocols and comparing radiation doses among different protocols [20]. The DLP is directly related to the patient (stochastic) risk, and may be used to set reference values for a given type of CT examination to help ensure patient doses at CT are as low as reasonably achievable [23].

## Conclusions

In this study, the patients radiation dose from most common CT examinations (brain CT, chest CT and Abdomen CT ) at three hospitals in Kano metropolis, Kano State, Nigeria were presented in terms of CTDIw, DLP with their third quartile dose values. The study has established a basis for Local Diagnostic Reference Level for routine head, chest and abdomen CT scan in Kano State for the purpose of dose optimization which can be further consolidated as more CT machines are available and functional. However, variation of $CTDI_w$ and DLP for the same procedure was observed from one center to another. This is due to the application of different scan protocols at each center. With patient characteristics random variations, and scan parameters specifically the scan range, it may be concluded that size of the patients influenced the results in this study. Hence, it is important to create awareness among physicists/radiologist/radiographers to continuously monitor CT equipment performance through appropriate quality control programs. Finally, it is expected that future studies will further consolidate the currently obtained LDRL's with the availability of more CT machines in the metropolis and perhaps the entire Kano State which has the second largest population in the country. This will further propel the establishment of national diagnostic reference levels to assess CT doses across the country.

## Abbreviations

CT: Computed tomography; CTDI: CT Dose Index; LDRL: Local diagnostic reference level; DLP: Dose length product.

## Author Contributions

All authors contributed equally to this study and gave their final approval.

## Competing Interests

The authors have declared that no competing interest exists.

## References

[1] Zira, J. D., Salisu, A. Y., Sani, U. M., Chukwuemeka, N. C., Tunde, J. J., Skam, J. D., Mundi, A., Ibrahim, U., Hassan, W.E., Boboin, N.F. & Silas, M. A. (2019) Entrance Surface Dose Determination for Common Adult Radiography Examination in Selected Tertiary Hospitals in North Eastern Nigeria. *African Journal of Medical Physics*, 2(1):38-43

[2] Alumuku, L., Iortile, J. T., & Agba, E. H. (2014). Testicular Doses of Patients Undergoing Radiological Examination of the Chest at Federal Medical Centre Makurdi, Nigeria. *International Journal of Advances in Life Science and Technology*, *1*(1), 1-5.

[3] Karim, M. K. A., Hashim, S., Sabarudin, A., Bradley, D. A., & Bahruddin, N. A. (2016). Evaluating organ dose and radiation risk of routine CT examinations in Johor Malaysia. *Sains Malaysiana*, *45*(4), 567-73.

[4] Bongartz, G., Golding, S. J., Jurik, A. G., Leonardi, M., van Meerten, E. V. P., Gelejins, J., Jessen, K. A., Panzer, W., Shrimpton, P. C., Tosi, G. (2014). European Guidelines on Quality Criteria for Computed Tomography.

[5] Brenner, D. J., & Hall, E. J. (2007). Computed tomography—an increasing source of radiation exposure. *New England Journal of Medicine*, *357*(22), 2277-2284.

[6] Oyedokun, O. S., Arogunjo, A. M., Fatukasi, J. I., & Egberongbe, A. A. (2020). Diagnostic Reference Level of Computed Tomography Examinations and Need for Dose Optimization in Ondo State, Nigeria. *Iranian Journal of Medical Physics*, *17*(4), 266-272.

[7] Foley, S. J., McEntee, M. F., & Rainford, L. A. (2012). Establishment of CT diagnostic reference levels in Ireland. *The British journal of radiology*, *85*(1018), 1390-1397.

[8] Australian radiation protection. "CT Radiation Dose Optimisation Program". 2008.

[9] European Commission (1999). "Guidance on diagnostic reference levels (DRLs)

for medical Exposures". *Radiation Protection*, 5, 1–26. Retrieved from: http://scholar.google.com.

[10] National Radiological Protection Board, UK. 2005.

[11] Health Protection Agency, UK, 2013.

[12] Shrimpton, P., Hillier, M., Meeson, S., & Golding, S. (2014). Public Health England-Doses from computed tomography (CT) examinations in the UK–2011 Review.

[13] ICRP Publication 60, 1990 Recommendations of the International Commission on Radiological Protection. *Annals*, 21:1-3, 1991.

[14] Mundi, A., Hammed, S., Dlama, J., Abdul-Jamiu, A., Peter, E., Itopa, R., & Goriya, K. (2015) Diagnostic Reference Level for Adult Brain Computed Tomography Scans: A Case Study of a Tertiary Health Care Center in Nigeria. *IOSR Journal of Dental and Medical Sciences* 14(1):66-75.

[15] Willis, J. (2004). *Data analysis and presentation skills: an introduction for the life and medical sciences*. John Wiley & Sons.

[16] Garba, I., Engel-Hills, P., Davidson, F., & Tabari, A. M. (2015). Computed tomography dose index for head CT in northern Nigeria. *Radiation protection dosimetry*, *165*(1-4), 98-101.

[17] Abdulkadir, M. K., Schandorf, C., & Hasford, F. (2016) Determination of Computed Tomography Diagnostic Reference Levels in North-Central Nigeria. *The Pacific Journal of Science and Technology*, 17 (2), 341-349

[18] European Union. "Radiation protection No 180 Diagnostic Reference Levels in Thirty-six European Countries, 73". 2014.

[19] Lewis, M. A., & Edyvean, S. (2005). Patient dose reduction in CT. *The British journal of radiology*, *78*(934), 880-883.

[20] Morin, R. L., Gerber, T. C., & McCollough, C. H. (2003). Radiation dose in computed tomography of the heart. *Circulation*, *107*(6), 917-922.

[21] IAEA. "Dosimetry in Diagnostic Radiology an International Code of Practice. Technical Reports Series No.457 International Atomic Energy Agency, 2007.

[22] [American Association of Physicist in Medicine Report No 96. "Measurement, Reporting and Management of Radiation Dose in CT produced by task group 23. Available at: http//www.aapm/pubs/reports/rpt 96", 2008.

[23] Huda, W., Ogden, K. M., & Khorasani, M. R. (2008). Converting dose-length product to effective dose at CT. *Radiology*, *248*(3), 995-1003.