DIAGNOSTIC REFERENCE LEVELS (DRLS) FOR COMPUTED TOMOGRAPHY (CT) EXAMINATIONS IN NORTH EASTERN NIGERIA

Joseph Dlama Zira,[1] Christian Chukwuemeka Nzotta,[2] Joseph Dimas Skam[3]

[1] Department of Radiology, Abubakar Tafawa Balewa University Teaching Hospital Bauchi, Nigeria
[2] Department of Radiography and Radiological Sciences, Nnamdi Azikiwe University, Nnewi Campus, Anambra State, Nigeria
[3] Department of Radiology, Federal Medical Centre Katsina, Katsina State, Nigeria

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ABSTRACT

BACKGROUND: Diagnostic reference levels (DRLs) for computed tomography (CT)examination is important for dose optimization.The are suggested action levels and reference guide for achieving radiation protection among patients.**OBJECTIVE OF THE STUDY:** To establish DRL for CT examination in north eastern Nigeria and to compare it with other established work. **METHODOLOGY:** Prospective cross-sectional study conducted in two hospitals in north eastern Nigeria. One hundred and eighty subjects were recruited for the study. Computed tomography dose index (CTDIvol), dose length product (DLP) and Scan parameters were obtained. Weight, height and body mass index (BMI) were recorded. Student T-test was used to compare the relationship between the mean CTDIvol obtained in the two centers, Pearson's correlation was used to determine the relationship between the dosimetric and anthropotechnical parameters. Statistical significance was set at P<0.05. **RESULTS:** The DRL values obtained in this work were 67.90 mGy, 18.83 mGy and 19.20 mGy for head CT, Chest CT and CT abdomen respectively. There was no statistical significant relationship (p>0.05) between CTDIvol with thickness, weight, height and BMI for head CT and abdominal CT. However, CTDI for Chest CT show statistical significant relationship (p<0.05) with weight and height. **CONCLUSION:** DRL was higher when compared with internationalvalues.There is need for optimization of radiology practice in North Eastern Nigeria.

Key words: X-rays, computed tomography, diagnostic reference levels, CTDIvol, dose length product, dose, optimization.

Introduction

Medical x-rays are the largest man-made source of public exposure to ionizing radiation and plays an important role in diagnosis and treatment of diseases through x-ray examinations.[1] Although x-ray is a very useful and essential in health care and has numerous advantages.[2] Computed tomography (CT) is an x-ray imaging modality with high radiation dose, ten to hundred times greater than conventional x-rays.[3] Since 1972, the use of CT for medical diagnosis has substantially increased over the past decade compared to all other diagnostic imaging modalities especially with the rapid use of multidetector CTs (MDCT).[4] While there is increasing pressure to depend on the CT for diagnosis, there is lack of specific guidance to perform the CT examination by optimizing image quality with minimum dose to patient.[4]

Diagnostic reference level (DRL) is defined as an investigation level used to identify unusually high radiation doses for radiological examinations.[5,6] They are suggested action levels above which a facility

Correspondence : Mr. Joseph Dlama Zira
Department of Radiology,
Abubakar Tafawa Balewa University Teaching Hospital
Bauchi, Nigeria
Email: josephdlama@gmail.com

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should review its methods and determine if acceptable image quality can be achieved at lower doses.[7] DRLs is an optimization tool to ensure patients are adequately protected and it is deemed to be an important mechanism for the management of patient dose to ensure it is commensurate with the medical purpose of x-ray examination.[8] In the recommendation of international commission of Radiological protection (Report 103), the principle for setting DRLs are enumerated, the local, regional and national objectives is clearly defined, including the degree of the specification of clinical and technical conditions for medical imaging task, the selected value of the DRL is based on the relevant regional, national and local data, the quantity used for the DRLs can be obtained in practical way.[9] The use of diagnostic reference levels has been supported by national and international advisory bodies.[5] These and other organizations have provided guidelines on measuring radiation dose and setting diagnostic reference levels.[10] The concept of investigation levels for diagnostic medical exposures was first proposed by the International Commission of Radiological protection (ICRP) in its 1990 recommendations, and further developed into diagnostic reference levels (DRL) in 1996 in ICRP publication 73.[11] The numerical values of diagnostic reference levels are advisory however; implementation of the DRLs concept may be required by regulatory and professional bodies.[7] Diagnostic reference levels (DRLs) are optimization tools used as special type of dose constraints above which doses must be reviewed and considered above acceptable levels, especially if acceptable image quality can be achieved at lower doses.[12] Optimizing the protection of patients, and maintaining appropriate good practice is a priority for all diagnostic radiological examinations.[12] The definition strongly suggests that DRLs are not dose limits and donot help distinguish between good and poor medical practice.[4] Several studies recorded wide inter and intra-variations in CT doses in centers.[13] Although dose limits may not be exceeded, DRLs may be exceeded if clinically necessary and justifiable. The objective of this study was to establish DRL for CT examination in north eastern Nigeria and to compare it with other established work.

Materials and Methods

Method

The study is prospective cross sectional study carried out in Radiology departments of two referral Hospitals located in North Eastern part of Nigeria. One hundred and eighty (180) patients were recruited for the study. The data in this study were collected from October 2015 to January 2016. The centers were chosen because they met the eligibility criteria for the study; having the imaging modalities for the study (CT machine) and Nigerian Nuclear Regulatory Authority's Requirement for Authorization and Practice (Licensing) involving ionizing radiation. Most common CT examinations head, chest and abdominal CT were selected. Individual patients CT machine generated CTDIvol in mGy and DLP in mGy.cm and scan parameter data such as kV,mA, scan time , pitch, and slice thickness for thirty patients in each examination in the two centers. Patient's weight was taken using ZT WHO scale for weight in (kg) and height (m2). Standard sized patients weighing 70 ±10kg were recruited for the study.

Machine Specifications

Computed tomography machine: Both machines were manufactured by Neurosoft medical systems Philips in the year 2010 and 2013 for hospitals A and B respectively. They have kVp and mAs range of 30-120 and 30-500 for hospital A and 40-140 and 22-400 for hospital B respectively. All the equipment's were multislide design with rotating gantry, anode target of tungsten-Rhenium alloy and ring detectors.

Ethical Clearance

In line with Helsinki declaration (1964), ethical approval was obtained from the research ethics committee of each hospital under study. Informed consent form interpreted in Hausa language was filled by each (volunteer, Patient) participant in compliance with the Human Research Ethics Guidelines for patients who donot understand English Language. The first author/ researcher also underwent web based training by National Health Institute on Research Ethics United States involving human subject for adequate knowledge on research procedures and guidelines involving human subjects.

Dose Determination

In CTdosimetry, CTDIvol is considered as the dose descriptor. It was obtained using the formular below.[14,15,16]

$$CTDIvol = \frac{CTDIw}{pitch} \text{ (mGy) (1)}$$

Where CTDIw is the weighted computed tomography dose index. Pitch- is the ratio between table increment per rotation and beam width.

Another reference quantity is the dose length product (DLP) that expresses total dose in a complete examination:

$$DLP = CTDIw \times N \times T \text{ (mGy.cm)} \quad (2)$$

Where N is the number of slices and T is the slice thickness. If the examination is performed in helical mode, DLP is calculated.[14]

$$DLP = CTDIvol \times L \text{ (mGy.cm)} \quad (3)$$

Where L= scan length

Data Analysis

Data was obtained and saved on a computer Microsoft excel spread sheet and categorized for each examination. It was independently checked by a statistician and two senior radiographers. Statistical Package for Social Sciences (SPSS) version 21.0 was used to analyze the mean and standard deviation of the anthropometric variables, technical parameters and radiation dose received. Seventy fifth (75th) percentile or (3rd quartile) value of the total mean of the examinations and or procedures were obtained at 95% confidence interval. Using Kolmogorov- Smirnov to test for normality of data distribution it was verified that, for 95% of confidence level, there was a normal distribution. Therefore, we used a parametric test that was suitable for the set of data and analysis. Pearson's correlation was used to determine the relationship between CTDIvol, DLP and anthropotechnical parameters while students t-test was used to compare the mean CTDIvol for the two hospitals. Statistical significance was set at $p<0.05$.

Resutls

(Tab. 1) shows mean and standard deviation of volumetric computed tomography dose index (CTDIvol) and DRL for CT for head, chest and abdomen.

The mean CTDI for hospital A is 57.26 ± 12.50 mGy, 13.94 ± 4.48 mGy and 13.92 ± 5.57 mGy for head CT, chest CT and CT Abdomen respectively. The mean CTDI for hospital B is 44.08 ± 9.95 mGy, 10.64 ± 4.78m Gy and 10.92 ± 5.57 mGy for head CT, chest CT and CT Abdomen respectively. The total mean CTDI for hospitals is 57.25 ± 2.50 mGy, 12.58 ± 4.20 mGy and 12.24 ± 4.28 mGy for head, chest and Abdomen respectively. The mean and standard deviation of dose length product are 958.52 ± 6.3, 659.10 ± 1.30 and 1290.07 ± 1.71 for CT head, CT chest and CT abdomen respectively.

Examination	Mean CTDI (mGy) Hospital A	Mean CTDI (mGy) Hospital B	Mean CTDI (mGy) Both	DLP (mGy.cm)	DRL (mGy)
CT Head	57.26±12.50	44.08±9.95	57.251±2.50	958.52±6.3	67.90
CT Chest	13.94±4.48	10.64±4.78	12.58±4.20	659.10±1.30	18.38
CT Abdomen	13.92±5.57	10.92±5.57	12.24±4.28	1290.07±1.71	19.20

Key: CT- Computed tomography, CTDIvol- Volumetric computed tomography dose index, Dose length product

Table 1: mean doses received and 75 percentile (DRLs) for computed tomography examination

(Tab. 2) shows the relationship between doses and anthropometric parameters for computed tomography examination. There was no statistical significant ($p>0.05$) relationship between computed tomography dose index with thickness, weight, and height BMI for head CT and abdominal CT. However, Chest CT show statistical significant relationship ($p<0.05$) with weight and height.

Examination	FOV (cm) r p	Weight (kg) r p	Height (m^2) r p	BMI (kg/m^2) r p
CT Head	0.051,0.791	-0.149,0.392	0.013,0.943	0.012,0.947
CT Chest	0.123,0.231	-0.365*,0.019	-0.330*,0.035	-0.213,0.182
CT Abdomen	0.534,0.622	-0.236,0.160	-0.033,0.844	-0.041,0.812

**Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed)

Table 2: Relationship between volumetric computed tomography dose index (CTDI vol) and anthropometric parameters for computed tomography examination.

(Tab. 3) shows the T-test comparison of radiation dose and some technical parameters for computed tomography examination between hospital A and B. Detail result from the table shows that when the mean

Examination	Para-meters	Mean±Std (Hospital A)	Mean±Std (Hospital B)	P-value	T-value
CT Head	CTDIvol	57.26±10.00	44.08±10.00	p>0.05	1.614
	DLP	892.48±10.00	958.52±10.00*	P<0.05	8.088
CT Chest	CTDIvol	17.06±5.00	16.22±2.00	p>0.05	1.614
	DLP	655.60±10.00	662.60±10.00	p>0.05	79.481
CT Abdomen	CTDIvol	17.90±5.00	17.52±10.00	p>0.05	0.871
	DLP	1033.20±10.00	1546.94±10.00*	P<0.05	62.920

*= Significant at P<0.05 when compared between Hospital A and Hospital B variables CT- Computed tomography, CTDIvol - Computed tomography volumetric dose index, DLP- Dose length product

Table 3: comparison of patient's radiation dose and technical parameters for computed tomography examination between Hospital A and Hospital B

doses (CTDIvol) and DLP of the hospitals were compared, there was statistical significant relationship (p<0.05) for DLP for CT head and CT abdomen while CTDIvol showed no statistical significant relationship (p>0.05) for CT head, chest and abdomen. DLP for chest CT showed no significant relationship (p>0.05).

(Tab. 4) shows comparison of established diagnostic reference levels for computed tomography examination with that of European commission, United Kingdom and Australia. The DRL for Australian radiation protection and nuclear safety agency (ARPANSA) for CT were 47 mGy, 9.5 mGy and 10.9 mGy for CT head, chest and abdomen respectively. That of European commission was 60 mGy, 30 mGy, and 35 mGy for head CT, chest CT and CT abdomen respectively. Similarly, UK values were 66 mGy, 17 mGy and 19 mGy for CT head, chest and abdomen respectively. The DRL values obtained in this work were 67.90mGy, 18.83 mGy and 19.20 mGy for head CT, Chest CT and CT abdomen respectively.

Examination	ARPANSA DRL(mGy)	EC DRL (mGy)	UK DRL (mGy)	DRL(mGy) This work
CT Head	47	60	66	67.90
CT Chest	9.5	30	17	18.38
CT Abdomen	10.9	35	19	19.20

CT- computed tomography, EC- European commission, UK- United Kingdom
ARPANSA-Australian radiation protection and nuclear safety agency.

Table 4: comparison of DRLs for CT in this work with European Commission, United Kingdom and Australian radiation protection and nuclear safety agency DRLs

Discussion

The study established diagnostic reference levels for CT examination in two selected referral hospitals in North eastern Nigeria. The hospitals studied were divided into two A and B. The hospitals were chosen because they met the inclusion criteria for the study having functional CT machine.

(Tab. 1) shows mean and standard deviation of computed tomography dose index (CTDI) and diagnostic reference level for computed tomography for head, chest and abdomen.The mean CTDI for hospital A is 57.26 ± 12.50 mGy, 13.94 ± 4.48 mGy and 13.92 ± 5.57 mGy for head CT, chest CT and CT Abdomen respectively. The mean CTDI for hospital B is 44.08 ± 9.95 mGy, 10.64 ± 4.78 mGy and 10.92 ± 5.57 mGy for head CT, chest CT and CT Abdomen respectively. The total mean CTDI for hospitals which is 57.25 ± 2.50 mGy, 12.58 ± 4.20 mGy and 12.24 ± 4.28 mGy for head, chest and Abdomen respectively. The mean and standard deviation of dose length product are 958.52 ± 6.3, 659.10 ± 1.30 and 1290.07 ± 1.71 for CT head, CT chest and CT abdomen respectively. This investigation revealed an observable changes in CT practices, with a much wider range of studies being performed regularly. This reflects the improved capacity of CT scanners to scan longer distances and at finer resolutions as permitted by helical and multislice technology.[4] The mean computed tomography dose index for head in this study is higher (67.90 mGy) than the study done in Abuja North Central Nigeria by Abdullahiet al.,(2015) (38.08 mGy), Muhammad et al., 2016 with (52.2 mGy) CTDI of head in North central Nigeria.[12,16] Another study by Saravana kumar et al., 2014 recorded findings of head CTDI of 32 mGy.[4] However, the values were lesser than the study in Portugal which presented a value of 65 mGy for head CT.

(Tab. 2) shows the relationship between doses received by patients and anthropometric parameters for computed tomography examination. There was no statistical significant (p>0.05) relationship between computed tomography dose index with thickness, weight, and height BMI head CT and abdominal CT. However, Chest CT show statistical significant relationship (p<0.05) with weight and height.

(Tab. 3) shows the T-test comparism of radiation dose and some technical parameters for computed tomo-

graphy examination between hospital A and B. Detail result from the table shows that when the mean doses (CTDIvol) and DLP of the hospitals were compared there is statistical significant relationship ($p<0.05$) for DLP for CT head and CT abdomen while CTDIvol showed no statistical significant relationship ($p>0.05$) for CT head, chest and abdomen. DLP for chest CT showed no significant relationship ($p>0.05$).

(Tab. 4) shows comparism of established diagnostic reference levels for computed tomography examination with that of European commission, United Kingdom and Australia. The DRL for Australian radiation protection and nuclear safety agency (ARPANSA) for CT were 47 mGy, 9.5 mGy and 10.9 mGy for CT head, chest and abdomen respectively. That of European commission was 60 mGy, 30 mGy, and 35 mGy for head CT, chest CT and CT abdomen respectively. Similarly, UK values were 66 mGy, 17 mGy and 19 mGy for CT head, chest and abdomen respectively. The DRL values obtained in this work were 67.90 mGy, 18.83 mGy and 19.20 mGy for head CT, Chest CT and CT abdomen respectively. The DRL obtained in this study is higher when compared with the reported values for ARPANSA, European commission and United Kingdom[17] and disagrees with the study of Abdullahiet al., 2016 in North central Nigeria with a value of 38.0 mGy lower than European commission.[16] The DRL for head CT obtained in this work is lower than the value obtained in another study in Nigeria with DRL values of 79mGy and 73.5 mGy respectively.[12,16] Although this study may not be a representation of what happens in every hospital but it is an indication that a considerable optimization potential of CT practice through standardization of medical imaging protocols and etiquette. The higher dose received in this study is attributed to variation in technical parameters, clinical procedures, radiographic technique, untimely quality control program and perhaps the condition of the CT machine. The UK study, ARPANSA study and EC study are better means of comparing with this study because their values were obtained from a survey of multi- slice CT scanners. However, result of comparism suggests the need for optimization of doses for more hospitals in Nigeria. The resultant DRL value is based on exposure parameters were found to be lower than the ARPANSA and UK but lesser when compared with EU values for CT chest and Abdomen respectively. Lower DRLs could be due to the fact that hospital and technique vary in their operation and specifications. In some cases authors setting up DRLs do not report on the patient dose influencing factors like added filtration, screen film speed, generator type, use of automatic exposure controls manual method and image receptor technology.

Conclusion

The DRL obtained in this study is higher when compared with the reported values for Australian Radiation Protection and Nuclear Safety Agency, Committee for European commission and United Kingdom.The major contributor to high dose in this present study is attributed to patient size, clinical complexity, sub optimal usage of equipment or equipment problems mainly as a result of the paucity of regular quality control and effective implementation of radiation protection program in our health care facilities. The present work has demonstrated that an efficient and fully integrated radiological dose information system can play an important role, providing data to support radiologist, radiographers, medical physicist, academicians, professional bodies and regulatory bodies in adopting the best strategy in ensuring that radiation dose is kept low. There is need for optimization of our radiology practice in North Eastern Nigeria and most centers in Nigeria.

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