ESTABLISHMENT OF LOCAL DIAGNOSTIC REFERENCE LEVELS (LDRL) FOR ADULT CHEST COMPUTED TOMOGRAPHY EXAMINATION IN A SOUTH-EASTERN STATE OF NIGERIA.

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Abstract

Background: Diagnostic reference levels (DRLs) are indispensable tools and a sub-principle in optimization of radiation dose in the field of Radiography and radiological sciences. It is intended to identify and reduce unnecessary high ionizing radiation dose to patients during radiological examinations such as Chest Computed Tomography (CT) examination.

Objective: To determine local Chest Computed Tomography dose index ($CTDI_{vol}$) and Dose length product (DLP) in the selected CT centers, estimate the Effective dose (ED) for Chest CT examination and compare our results with both stated Nigerian national and international standards.

Materials and Methods: A total of 240 adult subjects referred for chest CT examination from the four considered CT radiodiagnostic centers were surveyed within a period of six months. Data were obtained from different models of CT scanners which included Toshiba Alexium, Brightspeed multidetector CT scanner and Siemens Somerton respectively. Radiation dose were generated from Computed Tomography Dose Index ($CTDI_{vol}$) and Dose Length Product (DLP) from where the effective dose (E) was calculated using the product of chest DLP and the normalized coefficient found in the European guideline. Data were analyzed using SPSS version 20 Chicago software. The mean values for each CT centre were calculated at 75th percentile of DLP and $CTDI_{vol}$ chosen as the basis for DRLs.

Results: The 75^{th} percentile of $CTDI_{vol}$ and DLP were 22 mGy and 800 mGy.cm. The effective dose was 13. 6mSv.

Conclusion: Radiation dose variations across the four CT centres surveyed have revealed the need for urgent dose optimization to narrow down centre-specific and composite DRL values to national and international best practice.

Key Words: Computed Tomography, Diagnostic Reference levels, Dose Optimization, Effective dose.

Introduction

Computed Tomography (CT) examination has globally contributed to more than 63% of ionizing radiation from total medical exposures[1]. In some developed countries such as the United States of America (USA), CT scans constitute only 12% of all radiological investigations which however account for about 50% of the collective radiation dose to the population from medical radiation procedures [2]. The USA effective radiation dose have so far declined by 20% due to increased awareness, regular retraining and education of staff, periodic radiation dose optimization, production of advanced machines with high sensitive detector technology and improved operator performance[2]. It is estimated that over 400 million CT procedures are performed globally with an average frequency of 55 per 1000 (5.5%) subjects [1]. Patient dose variation were reported between interdepartmental and intradepartmental levels [3]. According to researches, more than one percent of patients receives an effective dose of more than 100.0mSv after 5.0 years; and malignant tumors incidence from CT treatments will likely approach two percent [4,5]. Consequently, it became imperative strike a balance by ensuring that radiation dose is well optimized and image quality maintained. The principle of optimization expects that the likelihood of incurring radiation exposures, the number of people exposed and the magnitude of their individual exposure should all be kept as low as reasonably achievable (ALARA principle)[6]. Optimization of patient dose in CT requires the application of examination-specific scan protocols tailored to patient age, size, region of body and clinical indication in order to ensure that the dose to each patient is as low as reasonably achievable (practicable) for the clinical purpose of the CT examination[7]. Currently, the number of chest CT examinations is on the increase due to technological advancement which allow scanning of large area including the radiosensitive organs such as the mammary gland [8].

Establishment of diagnostic reference levels (DRLs) was first proposed by the International Commission on Radiation protection in 1996 [9] and saddled with the responsibility of optimizing radiation dose to patients during radiographic procedure and to minimize dose variations within and among healthcare facilities [10,11]. It is simply an essential control mechanism used to shield patients from unnecessary radiation exposure[12.] The dosimetric parameters recommended for monitoring the DRL in CT examination are weighted Computed Tomography Dose Index ($CTDI_{vol}$) and Dose Length Product (DLP), displayed on the CT scanner console at the end of each scan which are measures in 16 and 32cm diameter acrylic phantoms [10]. $CTDI_{vol}$ is a standardized measurement of the radiation output of a CT scanner and fixed. It is independent of the size of patient and scan length. It therefore allows for comparison between other scanners and scan protocols [13]. Also, the DLP is the product of $CTDI_{vol}$ and the scan length, used to quantify the radiation dose received by a patient and therefore a direct estimate of radiation dose received by a patient [10]. DRLs are usually calculated by collection of patient dose data at the 75th percentile point of the dose spread or reported median [10] of $CTDI_{vol}$ and DLP from a survey conducted across a broad user base [14,10]. Because 25% of the population will exceed the DRLs, it should be regarded as an indicator rather than an overexposure of radiation dose. DRLs can be established at local, hospital or center based [14].

The International Atomic Energy Agency (IAEA) mandated every country to establish a radiation regulatory body for radiation protection. Consequently, Nigerian Nuclear Regulatory Authority (NNRA) and National Institute for Radiation Protection and Research (NIRPR) in 1996 and 2005 respectively were established by Act 19 of 1995. These two bodies are responsible for research, regulation and training of Radiation Protection Personnels in Nigeria as well as establishment of national, regional and local diagnostic reference levels. DRLs should be reviewed frequently to guarantee that patient doses are optimized within a justified levels preferably on annual bases [10]. In Anambra state, there is paucity local data base for Chest DRLs and thus there is need for its determination. This study was therefore aimed at determining the local diagnostic reference levels for Chest computed tomography examination in a South-Eastern state of Nigeria.

Materials and Methods.

A retrospective cross-sectional study was conducted in four CT centers in Anambra state, Nigeria for a period of six months. A total of 240 subjects aged from 18 years and above were purposively surveyed. For establishment of Diagnostic Reference levels (DRLs) and in several reviewed literatures, a minimum of 10 subjects for each body region were considered significant [15,16, 17]. Among the CT centres considered for this study, two were Mission-owned hospitals, one was private-owned while one was government-owned hospital. They were coded as A,B,C and D and had different installed models of CT scanners which included Toshiba Alexium, Brightspeed multidetector CT scanner and Siemens Somerton. These centres were selected because they were functional, fully licensed, undergo regular calibration and are authorized to administer ionizing radiation by the Nigerian nuclear Regulatory Authority (NNRA) as at the time of study. Ethical consideration was obtained from the Ministry of Health Anambra state (MH/Awk/M/132/413) and informed consent form the hospitals/ centres under study. Data collection plan was adopted from the International Atomic Energy Survey form which has the following sections: Subject demographic information, Scan parameters and Dosimetric quantities/parameters were collected with the assistance of the CT Radiographers in charge of each of the four centres surveyed. SPSS version 20.0 Chicago was used for data analysis. Statistical significance level among CT centres surveyed were considered at 0.05. Data were calculated to generate the mean values and standard deviation for each CT centre with 75th percentile (third quintile) of DLP and $CTDI_{vol}$ chosen as the basis for establishing local DRLs. Results from this present study were compared with other similar studies both locally and abroad.

.The following steps were taken to determine the local diagnostic reference levels (DRLs) for chest CT examination in this study:

Stage 1

The mean values were used to summarize all the data. This was achieved by adding all the values of $CTDI_{vol}$ and DLP obtained from different centres and dividing the sum by the number of subjects. Comparism of the mean $CTDI_{vol}$ & DLP values for chest CT examination from one center to another were carried to determine whether there was dose variation among the respective CT centres.

Stage 2

The 75th percentile values of the mean $CTDI_{vol}$ and DLP were obtained and used to determine the local Diagnostic Reference Levels. The 75th percentile (third quartile) value was chosen as an appropriate investigation level on the grounds that if 75% of CT units can operate satisfactorily below this dose level, the remaining 25% sho uld to be made aware of their potential less th an optimal performance. The values obtained were compared with other similar studies to ascertain the level of conformance of current practices in Anambra state.

Stage 3

Effective dose for chest C.T examination in Anambra state was calculated by multiplying the composite 75th percentile of the DLP values for chest C.T scans by the normalized coefficient found in the European guideline (0.017 mSv.mGy¯1) for chest CT [9].

Stage 4

The dosimetric parameter ($CTDI_{vol}$ and DLP) values and age were correlated to ascertain if there was any statistical significance.

Results

Table 1: Age, Gender and Number of Subjects

As shown in Table 1, two hundred and forty (240) subjects which were made up of one hundred and twenty-one (50.4 %) male and one hundred and nineteen (49.6 %) female were surveyed in the study. Their ages ranged between 18 – 80 years.

CT Centres	Frequency		Total	Range (Age)	Mean ± SD (Age)
	Male	Female			
Centre A	30	30	60	18 - 80	51 ± 16.4
Centre B	33	27	60	18 - 79	45 ± 16.3
Centre C	31	29	60	19 - 80	54 ± 16.2
Centre D	27	33	60	25 - 79	50 ± 14.3
Composite values.	121	119	240	18 - 80	50 ± 16.1

Table 2: Range and mean of the computed tomography dose index (CTDI).
Table 2 shows the range and mean of the CTDI. Chest had a CTDI ranging from 4.5– 139.0 mGy and mean value of 17.6 ±14.8 mGy.

Variables	**Chest** (mGy)	
	Range	Mean
Centre A	7.0 – 38.0	17.8 ± 8.0
Centre B	4.5 – 34.0	13.8 ± 8.5
Centre C	5.3 – 139.0	23.3 ± 25.0
Centre D	11 – 41.0	22.4 ± 8.2
Composite values	4.5 – 139.0	17.6 ± 14.8

Table 3: Range and Mean of the Dose Length Product (DLP).
Shown in Table 3 is the composite and centre-specific range and mean of the DLP.
Centre A had DLP of 562.7 ± 137.8 mGy-cm while centre B had the highest of 928.5 ± 257.2mGy-cm.

Variables	**Chest DLP (mGy-cm)**	
	Range	Mean
Centre A	288 - 816	562.7 ± 137.8
Centre B	214 -1580	928.5 ± 257.2
Centre C	203 - 966	659.3 ± 183.7
Centre D	441 - 900	657 ± 125.0
Composite values.	203 -1580	714.3 ± 327.5

Table 4: The 75th percentile of the $CTDI_{vol}$.
Table 4 shows the specific 75th percentile of the $CTDI_{vol}$. The 75th percentile of the $CTDI_{vol}$ ranged between 19.0 – 27.6 mGy and composite 75th percentile was 22 mGy.

Variables	**Chest**	
	Mean	75th percentile
Centre A	17.8 ± 8.0	23.5
Centre B	13.8 ± 8.5	19.0
Centre C	23.3 ± 25.0	24.3
Centre D	22.4 ± 8.2	27.6
Composite values.	17.6 ± 14.8	22.0

Table 5: The 75th percentile of the DLP.

Table 5 shows the 75th percentile of the DLP. The centre with the least and highest values were A (672.7 mGy-cm) and D (823.3 mGy-cm) respectively. Composite DLP was 800 mGy-cm

Variables	**Chest (mGy-cm)**	
	Mean	75th percentile
Centre A	562.7 ± 137.8	672.7
Centre B	928.5 ± 257.2	823.3
Centre C	659.3 ± 183.7	802.0
Centre D	657 ± 125.0	741.4
Composite value	714.3 ± 327.5	800.0

Table 6: The 75th percentile of the $CTDI_{vol}$ and DLP according to gender

Table 6 gives the 75th percentile of the $CTDI_{vol}$ and DLP in both gender. The composite $CTDI_{vol}$ recorded a higher value in female (25.0 mGy) than male (24.0 mGy). For the DLP in female values (747.0 mGy-cm) were higher than male (740.0mGy-cm).

Variables	**CTDI(mGy**	**DLP (mGy)**	**CTDI(mGy**	**DLP (mGy)**
	MALE	FEMALE	MALE	FEMALE
Centre A	21.0	26.5	684.0	675.0
Centre B	18.0	23.6	936.4	823.2
Centre C	24.0	25.0	800.0	864.0
Centre D	30,3	26.3	718.0	743.0
Composite value	24.0	25.0	740.0	747.0

Table 7: Effective dose values for chest C.T in Anambra state.

Table 7 gives the effective dose for chest CT scans in Anambra state. This was calculated by multiplying the composite 75th percentile of the DLP values for C.T scans by the normalized coefficient found in the European guideline (0.017 mSv.mGy¯1) for chest CT (European Commission, 1999 and Nwodo et al., 2018). The effective dose value for chest CT was therefore 13.6 mSv for Anambra state.

BODY REGION	Chest
DLP	800 mGy.cm
Effective Dose	13.6 mSv

Table 8: Comparison of present work with similar publications.

A comparison of the present with other similar publications were shown in Table 7 below. From this work, the $CTDI_{vol}$ for chest (22 mGy) fall apparently within the range found in the literature (10 – 22 mGy). However, the DLP for chest (800 mGy-cm) was higher than the values from the literature (390 – 735 mGy-cm).

Research Study	Location	Chest	
		CTDI (mGy)	DLP(mGy-cm)
Present study, 2023	Anambra (Local)	22	800.0
Diana et al., 2017	Egypt (Local)	22	420
Kam et al., 2020	Australia (Local)	10	390
Saravanakumar, 2014	India (Local)	12	456
Marema et al., 2023	Addis Ababa (Local)	13	635
Muhammad et al., 2016	Ilorin (Local)	10	407
Ernest et al., 2018	Nigeria (National)	17	735

Table 9: Correlation of anthropometric variables with $CTDI_{vol}$ and DLP

Correlation of age with the CTDI and DLP is given in Table 9. Age correlates poorly with the CTDI and DLP. The p-values > 0.05 indicating that the correlations are also statistically not significant.

Variables				
		CTDI	**DLP**	**REMARK**
Age	**R**	-0.024	0.000	Poor correlation
	P	0.792	0.998	Not significant

Discussion

Local diagnostic reference level for chest CT examination for a South-Eastern state of Nigeria was determined using weighted Computed Tomography Dose Index ($CTDI_{vol}$) and Dose Length Product (DLP) at the 75th percentile point of the dose spread or reported median

Four CT centres were purposively selected for the study with a total sample size of 240 adult subjects retrospectively surveyed. They were gender-divided into 121 (50.4%) male and 190 (49.6%) female subjects with age bracket that ranged from18-80 years.

In 2017, the ICRP acknowledged two major principles of radiation protection in clinical and medical applications which include justification of imaging procedures and optimization of radiation exposure during radiological procedures. Justification of imaging procedures and practices indicates that the procedure is necessary and that the overall subjects benefits outweighs the potential risks. Also, optimization refers to keeping radiation dose as low as reasonably achievable, economic and societal factors being taken into consideration without undermining the diagnostic aim [17].

Diagnostic reference level is a tool to ensure that procedures are optimized and remain optimized by continuous improvement of procedures and evaluation of performance of examination[8]

From our study, the 75th percentile of the $CTDI_{vol}$ and DLP for chest CT were 22 mGy and 800 mGy.cm respectively. These values were higher than the values published for adult chest in Australia by approximately 55% for CTDIvol (10 mGy) / approximately 51% for DLP (390 mGy·cm). The values were also higher when compared to the published values for adults in the India by approximately 46% for $CTDI_{vol}$ (12mGy) / approximately 43% for DLP (456mGy·cm) for chest. In Egypt, our result was similar for $CTDI_{vol}$ (22mGy) and approximately higher 48% for DLP (420mGy·cm). In Addis Ababa, Ethiopia when compared to our study, we recorded higher values by approximately 41% for $CTDI_{vol}$ (13mGy) and approximately 21% for DLP (635mGy·cm). In Nigeria, after five years of national dose survey, our local DRL finding were still higher by approximately 49% for $CTDI_{vol}$ (17mGy) and approximately 49% for DLP (735mGy·cm) Similarly in Ilorin, Nigeria, our values were also higher by approximately 49% for $CTDI_{vol}$ (10mGy) and approximately 49% for DLP (407mGy·cm) [18,15, 19, 20, 21, 22].

These dose variations generated could be as a result of inter-departmental and intra-departmental protocols and technical factors. It can also be attributed to inadequate staff training, variation in patients build up and equipment variation used in different CT centers in Onitsha.

Also our study recorded values lower than those generated in Ibadan, western Nigeria by approximately 3.1% for CTDIvol (22mGy)/approximately 32.7% for DLP (800mGy.cm).

There was obvious radiation dose variation for same chest computed Tomography examination among different CT centres. These variations may be due to CT user's variation in selection of parameters which include kVp, mAs, pitch, patients BMI, quality control practice and manufacturer-specific variations in design of CT equipment used by different facilities.

In other to ascertain the level of compliance of current practices in Anambra state and similar research findings in the literature, further analysis were made.

From our findings, the $CTDI_{vol}$ (22 mGy) fall within the range found in the reviewed literature (10–22 mGy) However, the DLP (800 mGy-cm) was higher than the values found the reviewed literature (390 – 735 mGy-cm) [18,15, 19, 20]. This finding calls for dose audit and optimization in Anambra as well as other State in Nigerian due to high percentage variation between the national dose reference level and our finding.

Comparison between results obtained from different CT centres surveyed in Anambra state and our proposed local DRLs showed remarkable variation across. It was observed that almost 50% of C.T centres surveyed exceeded the DLP set for the local

DRL. Also, 75 % of chest values exceeded the $CTDI_{vol}$ proposed for Anambra state. These observations indicate that there is urgent need for dose audit and optimization in Anambra state, Nigeria.

DLP was converted to effective dose using a normalized coefficient found in the European guideline (0.017 mSv.mGy¯1) for chest CT. The mean effective dose values for chest C.T was 13.6 mSv per scan. This value was higher than value obtained in Egypt (7.14 mSv), Australia (6.63mSv), India (7.75 mSv), Addis Ababa, Ethiopia (10.73 mSv), Ilorin, Nigeria (6.92mSv) and Nigerian National reference level (12.50 mSv) [18, 15, 19, 20].

This indicates urgent need for dose audit and optimization through adjustment of CT. Parameters/ technique and quality assurance.

Age of subject's anthropometric parameter had weak negative correlation with CTDIvol for chest ($r = -0.024$, $p= 0.792$) at p-values > 0.05 level of significance.

Subject's age also showed weak positive correlation with DLP ($r = 0.012$, $p = 0.998$) at p-values > 0.05 level of significance. These indicated that there was no correlations between subject's age and DRLs for Chest Computed tomography examination and statistically insignificant.

Limitations of the study

Data were collected from four C.T centers only due to equipment breakdown in some centres while some centers were not fully licensed and therefore not legally authorized to administer ionizing radiation by the Nigerian nuclear Regulatory Authority (NNRA) as at the time of this research. Weight and height of subjects were not captured by the CT radiographers on their archives, thus, limiting anthropometric statistical correlations with dose. The proposed LDRL is only applicable to the centres that participated in the study.

Conclusion

Local Diagnostic Reference Levels (LDRL) for chest CT scan in Anambra state have been established which were significantly higher than most published results from other countries as well as National and states in Nigeria. From our study, only a few CT center met up with the international recommended reference levels and best of practice.

In spite of the established national reference levels, values from most CT centers in our study were significantly high and were not observing proper dose optimization.

Recommendation

We recommend regular staff retraining, seminars and workshop for CT radiographers on dose optimization and audit in Anambra state on regular bases.

All CT centres/facilities in Anambra state should consider the proposed DRLs as a reference data when conducting their regular audit of as least every three years and imbibe on proper adjustment of their CT dose parameters as well as quality control practice to ameliorate unjustified high radiation dose exposure to the patients.

Disclosures of conflict of interest

The authors declare no conflict of interest during the study.

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Patient (subject) consent for publication

Not required.

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