Journal of
Physiotherapy & Physical Rehabilitation

Research Article Open Access

Evaluation of Radiation Doses in Adult Patients of Routine Computed Tomography Examination in Maiduguri, Borno State, Nigeria

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Abstract

Volume computed tomography dose index (CTDIvol) and the dose length product (DLP) represents an average doses within a scan dose for a standardized CTDI measurement. They are the useful indicators of the dose measurements for a specific examination protocol. In each case dose evaluations were extracted retrospectively and manually from the operating console. CT examination and radiation doses were determined using the General electric (GE) Bright speed 16-slice scanner. Results are presented in terms of the volume computed tomography dose index (CTDIvol) and dose length product (DLP) for head, Chest and abdomen. The 16-slice capacity and tube potential uniform (120 kVp) was used in the centre while tube current was within a narrow range (200-250 mA). The 75th percentile of adult CTDIvol for head, chest and abdomen are 85 mGy, 13.34 mGy and 13.29 mGy respectively and the corresponding DLP values 1437.47 mGy*cm, 417.49 and 656.02 mGy*m. The finding shows a considerably high CTDIvol and DLP values for adult head comparable to the recommendations of the European Commission, thus optimization is required.

Keywords: Radiation exposure; Computed tomography; Maiduguri; Borno State

Introduction

CT uses x-ray procedure to selectively obtain anatomical image details, where small dose of ionizing radiation is used in x-ray technique. Recent research shows that low doses radiation equivalent to three CT scans, which are considered safe, but give cancer-capable cells a competitive advantage over normal cells in healthy tissue. In medicine ionizing radiation is the process of depositing energy inform of heat to a given medium (matter) which changes the state and condition of the medium at such CT produces its images either for diagnostic or therapeutic purposes [1]. In diagnostic radiology, dose monitoring is carried out to reassure exposures are within the reference limits and the established optimization of the radiation protection of the patients [2, 3]. Since CT uses a very high ionizing radiation dose compare to that of x-ray cannot be ignore without measuring the amount of radiation dose received by the patients undergoing CT examination [4]. Ever since the invention of computed tomography in 1972, CT had evolve in terms of high image quality for viewing physiological part of the patient body with a higher absorbed radiation dose that comes from it [5]. Though CT consist of scanner that revolve about a fixed point taking different two dimensional (2D) images at different location in different direction at different angles, however when these two dimensional images taken at different angles placed on a computer, the resultant image is three dimensional (3D) image that can reveal the presence of injuries and disease for either therapeutic or diagnostic purposes (Via Radiology, 2015). Furthermore in the last two decades CT could not take diagnostic or therapeutic images for thoracic within a shortest possible time but in recent years the same type of examination can be achieved within a second with a high resolution, this makes it more reliable and easy for physician to treat the patients very fast [6]. In recent years the image quality from CT has become more pronounce to a certain extent that the number of CT is on increase day by day, as the number of CT keeps increasing the amount of ionizing radiation dose also increases. However the increase of radiation dose is directly proportional to the risk associated with CT examination especially carcinogenic [7]. With the high risk involve in CT examination, pediatrics patient are at highest risk of cancer stimulation as a result of high ionizing radiation while pediatrics are radiosensitive compare to adult patients that have mature body composition and evidence shows that the rate at which death is occurring in pediatric due to cancer is as a result of exposure of head and abdomen to ionizing radiation from the CT in clinical practice of US, Where CT examination are carried out annually for more than six-hundred thousand on pediatrics patients [8]. The computed tomography dose index free-in-air (CTDIair) and the single scan dose profile (SSDP) was evaluated in 128 slice CT scanner using thermoluminescent dosimeters, TLD-100 and found that the changes of tube potential have influenced the CTDIair values and CT dose profiles [9].

The amount of radiation dose received by the patients during CT examination which induce cancer risk varies from one CT centre to another [10]. However these cancer risk and dose variation need to be optimize since patients and personnel are at risk to optimize and reduce the level of dose variation, the International Commission on Radiation Protection (ICRP) introduced the idea of diagnostic reference levels (DRLs) [11]. This research work investigates and assesses the radiation doses in adult patients under-going routine computed tomography examinations in Federal Neuro-Psychiatric Hospital Maiduguri, Nigeria.

Materials and Methods

The General Electric (GE) 16-slice (Figure 1) CT procedure for adult patients undergoing a routine CT scan is designed in chronological

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Received: July 09, 2019; **Accepted:** October 01, 2019; **Published:** October 08, 2019

Citation: Ngaram SM, Mohammed IB (2019) Evaluation of Radiation Doses in Adult Patients of Routine Computed Tomography Examination in Maiduguri, Borno State, Nigeria. Physiother Rehabil 3: 174.

Figure 1: General Electric (GE) Bright Speed 16-slice CT scanner.

form of axial and helical mode for all type of examination, such as head, chest and abdomen. However, the tube current used for adult was in the range of 135 mAs to 257 mAs with a fixed tube voltage of 120 KV for the whole type of examination that was carried out during this research work with a pitch of 1.375 mm. Single values for DLP and CTDI were noted and recorded.

Dose study

The study was performed at Federal Neuro-Psychiatric Hospital conducting CT procedures located in Maiduguri, Nigeria. A quantitative and retrospective research designed to determine the radiation doses absorbed by the adult patients undergoing CT examination of head, chest and abdomen was adopted. However, the data obtained from the archive of the study centre Federal Neuropsychiatric hospital Maiduguri were numerical values in which the quantitative design is suitable and was conducted retrospectively which ensured numerous valid and reliable data acquired [12, 13]. However, the study populations of this research work consist of adult patients that attended CT examinations of head, chest and abdomen at the study centre. The sheet was designed to extract patient measurement especially on the basis of comparative study such as demographic information, scan parameters and dose parameters. In choosing the sample size for this study 30 patients were randomly selected each for head, chest and abdomen CT scan. However, 20 patients were selected on the minimum of twenty years each from 30 patients that were selected at random for the most three common CT examinations in adult. Thus, Based on the recommendation guideline for sample selection made by the European commission which says a minimum of 10 samples shall be selected for each body part under examination [5]. However, the total samples collected were 60 patients for final analysis in order to standardize the sample size.

Dosimetry in computed tomography

Computed Tomography Dose Index (CTDI): The Dose in CT was first described using the computed tomography dose index (CTDI). However, now the original definition has been changed following the technological improvements of CT. The CTDI is a basic concept to understand dose measurement in CT and is defined by

$$CTDI = \frac{1}{nT}\int_{Z1}^{Z2} D(z)\,dz\,(mGy) \quad (1)$$

Where: D(z) as a function of z, is the outline of the absorbed dose along the z axis, n is the number of slices acquired in a single axial rotation, however the value of n may be less or equal to the maximum number of channels available on the system (64 for a multislice CT detector with 64 rows). T is the nominal thickness of the tomographic section or the Amplitude of the group of detectors used in the case of multislice CT (5 mm acquisition for a 4 × 5 mm) the CTDI can be measured using a 100 mm long pencil ionization chamber either in air ($CTDI_{air}$) or in a cylindrical polymethyl methacrylate (PMMA) phantom simulating the head (head 16 cm in diameter) and the body (body 32 cm in diameter) [14]. However the $CTDI_{air}$ is the quality for each scanner and depends on tube current intensity, voltage, beam collimation, filtration and the geometric characteristics. Since dose sharing in the phantom is generally not uniform, the measurements are acquired in five different positions these position are in the centre and at the four cardinal points, these resulted to introduction of the weighted CTDI ($CTDI_w$) [14].

Weighted Computed Tomography Dose Index (CTDIW): The weighted CTDIw, does not explain the involvement of pitch used during a spiral acquisition which can be written mathematically as

$$CTDI_W = \frac{1}{3}CTDI_{100c} + \frac{2}{3}CTDI_{100p} \quad (2)$$

Where $CTDI_{100c}$ and $CTDI_{100p}$ are measured at the centre and at the periphery of the phantom, respectively, and the index 100 indicates that the CTDI was measured with a 100 mm long ionization chamber. However as a result of that, the volumetric CTDI was introduced to account for the pitch. The $CTDI_{vol}$, is the $CTDI_w$ corrected for pitch [14].

$$CTDI_{vol} = \frac{CTDI_W}{Pitch} \quad (3)$$

However the effective mAs is mAs in one revolution per pitch, the value of the mAs can be read through the console of the computer depending on the type of company manufacture the machine, because some have no indication provisions on their console. Thus, the $CTDI_{vol}$ will not change with pitch; as such a single-slice cannot be acquired but the whole volume. Therefore, the scan length was considered to provide total exposure in complete CT examination.

Dose Length Product (DLP): DLP was introduced as dose descriptor which is referred to as dose length product. DLP is defined as the product of the $CTDI_{vol}$ multiplied by the irradiated scan length (L). The DLP is measured in mGy cm.

$$DLP = CTDI_{vol} \times L \quad (4)$$

The DLP is comprehensive dose descriptor that allows the risk to be evaluated through an estimation of the effective dose using the appropriate conversion factors defined by anatomical region. These conversion factors have been defined in a document of the European Commission [15] and updated after the release of ICRP 103 in 2007 to consider the weighting factors for the different tissues. Thus, the conversion factors for the body region which is measured in mSv mGy-1 cm-1. However, these values are; 0.0024, 0.0053, 0.020, 0.016 and 0.014 for skull, neck, chest, abdomen, and pelvis respectively [16]. However, these advances in CT has account for an estimate of effective dose without the considering the patient's size for optimization protocol [14]. The 100 mm long ionization chamber cannot measure the beam width of the dose outline which has been resulted in underestimation of $CTDI_{vol}$ values which is not suitable for multislice CT. However the commercial phantoms used for CTDI measurement is not long enough to cover the chest of an adult also scattered radiation are not adequately produced, that is why $CTDI_{vol}$ and DLP are no longer suitable and adequate CT dose descriptors. However, the estimations of patient dose for a "standard man" will underestimate the dose received by a pediatric or thin patient and overestimate the dose truly absorbed by an obese subject [14]. However, the Effective doses (E) for these examinations were estimated using the k conversion factor as described in the ICRP publication 103 [11].

$$EDLP = k \times DLP \quad (5)$$

Dose assessment

In the present study two main doses descriptor have been assessed, volumetric computed tomography dose index ($CTDI_{vol}$) and dose length product (DLP) these being the values noted from the display consoles of the CT units included in the present study. Radiation doses from the patients were calculated using equation (3) and (4). $CTDI_{vol}$ and DLP values to the organs by specifying the scanner model, scanner manufacturer and scanning parameters as input. All scanning parameters, including patient characteristics and calculated results, were collected and registered in a Microsoft Excel spreadsheet and transferred to statistical package for social sciences (SPSS) version 23.0 software (IBM Corp. Armonk, NY) for analysis. The mean or average values and standard deviation (SD) of $CTDI_{vol}$ and DLP for head chest and abdomen CT examinations in adult patients were calculated as recommended by the ICRP [11]. The local diagnostic reference levels (LDRLs) for each of these examinations was then calculated based on the 75th percentiles. However, the 75th percentiles are most commonly and recently used as indicator of the DRLs. whilst the 75th percentile DRLs represent the recommended dose values that should not be exceeded. The 50th percentile (median) provides dose levels that facilities should strive towards. The 50th percentile is also reported so that institutions whose median dose values are significantly higher than the 75th percentile would evaluate their scan protocol and settings in order to reduce patient doses [17].

Results

The exposure parameters were presented in Table 1 where, the adult tube voltage (KV) for head, chest and abdomen were fixed at 120 KV (constant) but varies in tube current time for head (140-185) mAs, abdomen (135-257) mAs and 135 mAs fixed for chest. However, the mean mAs for abdomen record the highest and lowest in chest (Table 1). The number of patients each per examination for adult was twenty (20) patients that undergo a routine head, chest and abdomen. In Table 2, the mean age of adult patient for head, chest and abdomen as well as their corresponding standard deviation were presented, the ages range for adult head, chest and abdomen, from 22-73 years, 30-83 years and 17- 75 years. The dose values obtained for head, chest and abdomen in the current study for adult patients shows that the mean $CTDI_{vol}$ (mGy) of adult head, chest and abdoment are 49.48 mGy, 10.85 mGy and 11.24 mGy with their corresponding mean DLP (mGy*cm) values 749.69 mGy*cm, 327.81 mGy*cm and 517.15 mGy*cm, the lowest value of $CTDI_{vol}$ was contributed by chest which was 10.85 mGy when the mAs setting was 135 mAs and the highest value of $CTDI_{vol}$ was also contributed by the head which was 49.48 mGy with 173.75 mAs, this is due to the variation change in tube currents (Table 3). Figure 2 shows display console of CT for GE 16-slice scanner and General Electric (GE) Bright Speed 16-slice CT scanner. (Table 1, 2, 3, 4 and Figure 2 and 3).

CT Examination	Tube Voltage (KV)	mAs (Mean ± SD)
Head	120	173.75 ± 19.99
Chest	120	135 ± 00
Abdomen	120	207 ± 44.98

Table 1: Result of measured CT exposure parameters for organ dose measurement of adult patients.

CT Examination	Number of Patient per CT Examination	Age (Mean ± SD)
Head	20	47.70 ± 16.28
Chest	20	46.15 ± 14.10
Abdomen	20	55.28 ± 16.95

Table 2: Result of patient's characteristics for adult patients.

Center	Region	$CTDI_{vol}$ (mGy) Mean ± SD	DLP (mGy*cm) Mean ± SD
FNPHM	Head	49.48 ± 27.83	749.69 ± 490.90
	Chest	10.85 ± 4.05	327.81 ± 117.83
	Abdomen	11.24 ± 2.67	517.15 ± 153.86

Table 3: Measured CTDIvol (mGy) and DLP (mGy*cm) dose values from the study center for adult patients.

Center	Region	$CTDI_{vol}$ (mGy) Mean ± SD	DLP (mGy*cm) Mean ± SD	75th Percentile	
				$CTDI_{vol}$ (mGy)	DLP (mGy*cm)
FNPHM	Head	49.48 ± 27.83	749.69 ± 490.90	85.82	1437.47
	Chest	10.85 ± 4.05	327.81 ± 117.83	13.34	417.49
	Abdomen	11.24 ± 2.67	517.15 ± 153.86	13.29	656.02

Table 4: Establishing local diagnostic reference level for adult.

Figure 2: Display CT scanner Monitor for GE 16-slice scanner (archive).

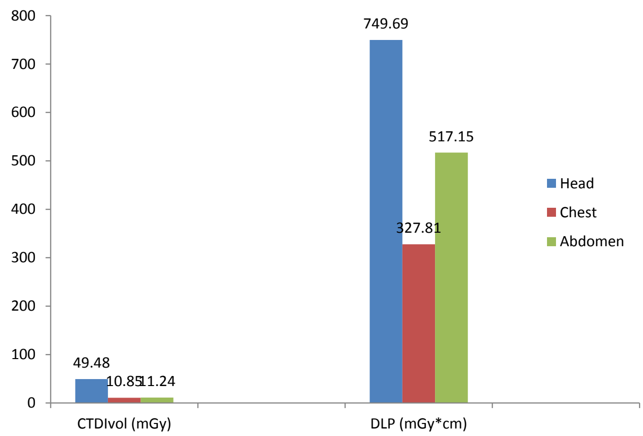

Figure 3: Adult patients 75th percentile $CTDI_{vol}$ dose.

Discussion

The patient's characteristics, technology, and examination protocol affect DRLs [11]. Thus, ICRP recommended the DRLs to be established taking these factors into consideration, that local or regional DRLs should equal the national benchmark (ICRP, 2007). The current study provides the local DRLs for a routine head, chest and abdomen CT scan. Findings reveal dose in adult patients at the study centre. The dose variations in adult head exist in wide range (Table 4). Figure 3 shows that the 75th percentile $CTDI_{vol}$ dose reported in this current study was (85.82 mGy) which is significantly higher compared to European Commission and ICRP (60 mGy) and the United State (62 mGy) as well as the DLP values is higher (1437.74 mGy*cm) compared to European Commission and ICRP (1050 mGy*cm) and lower compared to Kenya

Country 75th Percentile	Head		Chest		Abdomen	
	$CTDI_{vol}$ (mGy)	DLP (mGy*cm)	$CTDI_{vol}$ (mGy)	DLP (mGy*cm)	$CTDI_{vol}$ (mGy)	DLP (mGy*cm)
Current Study (Nigeria)	85.82	1437.47	13.34	417.49	13.29	656.02
United State 2015	62	1120	17	610	17	860
European Union 2014	60	1050	30	650	35	780
Egypt 2016	30	1360	22	420	31	1425
Canada 2017	83.4	1098	13.7	483	23	806
Kenya 2016	61	1612	19	895	20	1842
ICRP 2007	60	1050	30	650	35	780

Table 5: Comparison of new DRLs obtained in terms of $CTDI_{vol}$ (mGy) and DLP (mGy*cm) with established international DRLs for adult patients.

with the highest DLP (1612 mGy*cm). This may be as a result of technological factors and protocol employed in the current study centre that needs to be optimized to meet the benched mark established or recommended by the ICRP and European Commission.

However, the $CTDI_{vol}$ and DLP reported for a CT chest were (13.34 mGy) and (417.49 mGy*cm) is comparable with Canada (13.7 mGy), (483 mGy8cm) and India (12 mGy) (456 mGy*cm). But lower compared to European commission and ICRP (30 mGy), (650 mGy*cm) and that of the United State (17 mGy) and (610 mGy*cm). The abdominal $CTDI_{vol}$ and DLP values were also reported in this study, (13.29 mGy) and (656.02 mGy*cm) is significantly lower compared to the United State (17 mGy), (860 mGy*cm) and European Union also recommended by ICRP (35 mGy) and (780 mGy*cm) as you can see in Table 5.

Conclusion

CT uses a very high ionizing radiation dose compare to that of x-ray which cannot be ignore without measuring the amount of radiation dose received by the patients, which is limited to study dose descriptors variation. The exposure to ionizing radiation dose from CT is now a serious problem to an extent that the problem might not be entirely ascertain, since dose varies among CT centres across the country. However, the idea of establishing local dose reference level (LDRLs) will help to optimized and address the burden of high doses. However, the 75th percentile of $CTDI_{vol}$ and DLP dose values for routine chest and abdomen are comparable to those reported internationally in the literature; the $CTDI_{vol}$ and DLP dose values for head are considerably higher.

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