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Study of Radiation Doses in Adult and Paediatric Patients Undergoing Computed Tomography Examination in Nigeria

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Abstract

The use of computed tomography (CT) has increased over the past decades and has resulted in a concurrent increase in medical exposure to ionizing radiation. Several recent studies have examined the link between medical radiation and the risk of cancer, especially in children. Results are presented in terms of the volumetric computed tomography dose index ($CTDI_{vol}$) and dose length product (DLP) for head, chest and abdomen. The 75th percentile of adult $CTDI_{vol}$ 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·cm. However, the paediatric head based on age group 0 - 1 yr, 1 - 5 yrs, 6 - 10 yrs and 11 - 15 years are 28.18 mGy, 32.12 mGy, 32.13 mGy and 28.20 mGy and corresponding DLP values 399.75 mGy·cm, 514.38 mGy·cm, 578.42 mGy·cm and 487.11 mGy·cm respectively and for paediatric abdomen from 1 - 5 years to 11 - 15 years are 3.98 mGy, 4.26 mGy and 5.92 mGy and the corresponding DLP 99.36 mGy·cm, 160.84 and 235.85 mGy·cm. The finding shows considerably high $CTDI_{vol}$ and DLP values for adult head comparable to the international standard thus optimization is required. Reduction in radiation doses for both adult and paediatric patients involve training of staff and optimize CT protocols.

Keywords

Radiation Doses, Computed Tomography, Pediatrics and Adults

1. Introduction

Computed tomography which is referred to as CT in medicine, CT is the highest ionizing radiation exposure that accounts for more than 30% ionizing radiation doses in the United States. However evidence shows that in 2010 about 80 million CT examinations were investigated as a result of outstanding imaging selection and high resolution that brings about details anatomical information [1]. This is suitable for the larger head, chest, abdomen/pelvis and other sensitive organs or soft tissue to be investigated. However in practice CT investigation or examination involves contrast agent pre and post to be administered to the patient in who irradiated volume increases by a factor of more than one [1]. CT uses x-ray procedure to selectively obtain anatomical image details, where small dose of ionizing radiation is used in x-ray technique. In medicine ionizing radiation is the process of depositing energy in form 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 [2]. Since CT uses a very high ionizing radiation dose compared to that of x-ray cannot be ignored without measuring the amount of radiation dose received by the patients undergoing CT examination [3]. Ever since the invention of computed tomography in 1972, CT had evolved in terms of high image quality for viewing physiological part of the patient body with a higher absorbed radiation dose that comes from it [4]. Though CT consists of scanner that revolves 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 [5]. In recent years the image quality from CT has become more pronounced 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 [6]. With the high risk involve in CT examination, pediatrics patients 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 examinations are carried out annually for more than six-hundred thousand on pediatrics patients [7]. With the various dose dependencies in mind, optimization techniques to reduce the dose of the patients, especially in regard to paediatric cases remains a popular focus of efforts (see for instance, [8]). The amount of radiation dose received by the patients during CT examinations which induce cancer risk varies from one CT center to another [9]. However these cancer risk and dose variation need to be optimized 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) [10]. The effect of radiation doses from CT greatly depends upon choice of acquisition parameters, with potential for optimization. This research work investigates the analysis of radiation dose in adult and pediatric patients undergoing computed tomography examination.

2. 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 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 and for paediatric was 170 mAs throughout 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.

2.1. Sample Size

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. However, ten (10) paediatric patients were also selected each for head and abdomen as a result of limitation of the patients. 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 [11]. However, the samples selected for paediatrics were grouped based on age (0 - 1 year, 1 - 5 years, 6 - 10 years and 11 - 15 years). Thus, there was no patient for chest at the study centre as of the time I was collecting the data as well as 0 - 1 year for

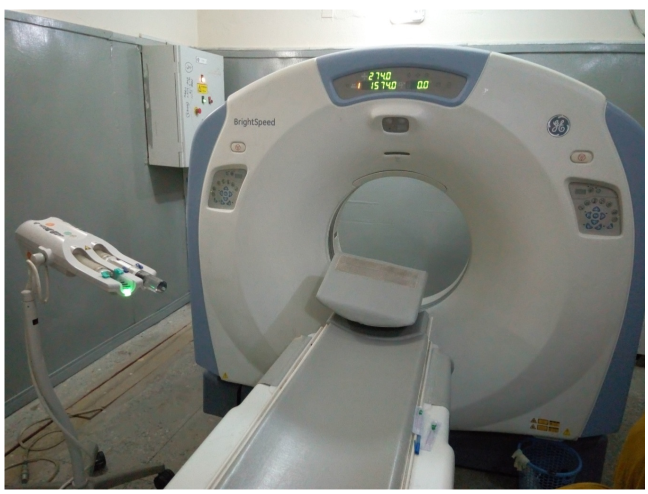

Figure 1. General Electric (GE) bright speed 16-slice CT scanner.

abdomen CT scan. However, the total samples collected were 130 patients for final analysis in order to standardize the sample size.

2.2. Inclusion Criteria

- Both adult and paediatric patients were included.
- Only those came for a routine CT examination of head, chest and abdomen in both adult and paediatric patients were regard as valid samples.
- Only 17 years of age and above for adult patients were considered.
- Adult patients weighing ±73 kg were considered for this work [1] [11] [12].
- CT scanner that was calibrated by the Nigerian Nuclear Regulatory Authority (NNRA) [1] [13].

2.3. Exclusion Criteria

- Adult Patients with below the age of 17 years were not included.
- Adult patients with weight below or above the specified limit mention above [12].
- A non-routine CT examination for both adult and paediatric.

2.4. Dose Survey

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

$$\mathrm{CTDI} = \frac{1}{nT}\int_{Z1}^{Z2} D(z)\,\mathrm{d}z\,(\mathrm{mGy}) \tag{1}$$

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) [10]. 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 center and at the four cardinal points, these resulted to introduction of the weighted CTDI (CTDI_w) [10].

The weighted CTDI_w, does not explain the involvement of pitch used during a spiral acquisition which can be written mathematically as

$$\text{CTDIw} = \frac{1}{3}\text{CTDI}_{100c} + \frac{2}{3}\text{CTDI}_{100p} \quad (2)$$

where $\text{CTDI}_{100,c}$ and $\text{CTDI}_{100,p}$ are measured at the center 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 CTDIw corrected for pitch [10].

$$\text{CTDI}_{vol} = \frac{\text{CTDIw}}{\text{Pitch}} \quad (3)$$

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.

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.

$$\text{DLP} = \text{CTDI}_{vol} \times L \quad (4)$$

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 [14] 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 are measured in mSv $\text{mGy}^{-1}\cdot\text{cm}^{-1}$. However, these values are: 0.0024, 0.0053, 0.020, 0.016 and 0.014 for skull, neck, chest, abdomen, and pelvis respectively [15].

2.5. Dose Assessment

A quantitative and retrospective research designed to determine the radiation dose absorbed by the adult and pediatric patients undergoing CT examination of head, chest and abdomen was adopted. However, the data obtained from the archive of the study center 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 [1] [16]. However, the study populations of this research work consist of adult and pediatric patients that attended CT examinations of head, chest and abdomen at the study center. The sheet was designed to extract patient measurement especially on the basis of comparative study such as demographic information, scan parameters and dose parameters.

Dose data such as CTDI_{vol} and their corresponding DLP were extracted from patients' digital examination folders stored in the archive. However these dose values were read through the console of the display computer monitor and recorded on the data captured sheet for both adult and paediatric patients that have undergo the three common CT examinations (head, chest and abdomen) performed under the existing protocols in Federal Neuropsychiatric Hospital Maiduguri.

3. Results and Discussion

The exposure parameters were presented in (Table 1) below 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). Thus, the tube voltage for all paediatric age group in head were fixed at 120 KV compared to adult patients and the corresponding paeditric 170 mAs which is slightly less compared to adult head as you can see in Table 1 and Table 2.

However, the paediatric abdomen based on age group recorded 170 mAs mean tube current time which is less than that of adult that mean value 207 mAs. But both the adult and paediatric patients recorded the same tube voltage of 120 KV (Table 1 and Table 3). 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 (Table 4). However the mean $CTDI_{vol}$ (mGy) for paediatric head based on age group 0 - 1 year (19.39 mGy), 1 - 5 years (27.78 mGy), 6 - 10 years (30.95 mGy) and 11 - 15 years (20.99 mGy) is less than that of adult head value (49.48 mGy) and related DLP values for adult 749.69 mGy·cm higher than paediatric patients based on age group (248.39, 492.35, 524.90 and 366.38) mGy·cm (Table 4 and Table 5). However, the $CTDI_{vol}$ and DLP in paediatric increase as the age increases but decreased significantly towards the 11 - 15 years (Table 5 and Table 6). Technical factors might be the contributors to high doses and dose variation Optimization and selection of parameter ought to reduce dose variation. This finding is of paramount importance in regards to the optimization

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

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

Table 2. Result of measured CT exposure parameters for organ dose measurement of pediatric head.

Age Group	0 - 1 Year	1 - 5 Years	6 - 10 Years	11 - 15 Years
Tube Voltage (KV)	120	120	120	120
mAs (Mean ± SD)	170 ± 00	170 ± 00	170 ± 00	170 ± 00

Table 3. Result of measured CT exposure parameters for organ dose measurement of pediatric abdomen.

Age Group	0 - 1 Year	1 - 5 Years	6 - 10 Years	11 - 15 Years
Tube Voltage (KV)	120	120	120	120
mAs (Mean ± SD)	170 ± 00	170 ± 00	170 ± 00	170 ± 00

Table 4. Measured $CTDI_{vol}$ (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
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 5. Measured $CTDI_{vol}$ (mGy) and DLP (mGy·cm) values from the study center for pediatric head.

Age Group	0 - 1 Year	1 - 5 Years	6 - 10 Years	11 - 15 Years
$CTDI_{vol}$ (mGy) Mean ± SD	19.39 ± 8.64	27.78 ± 11.09	30.95 ± 1.90	20.99 ± 11.59
DLP (mGy·cm) Mean ± SD	248.39 ± 148.73	492.35 ± 138.13	524.90 ± 86.38	366.38 ± 155.49

Table 6. Measured $CTDI_{vol}$ (mGy) and DLP (mGy·cm) values from the study center for pediatric abdomen.

Age Group	0 - 1 Year	1 - 5 Years	6 - 10 Years	11 - 15 Years
$CTDI_{vol}$ (mGy) Mean ± SD	NA	3.29 ± 0.79	4.09 ± 0.44	4.82 ± 0.91
DLP (mGy·cm) Mean ± SD	NA	85.25 ± 17.54	148.34 ± 25.84	203.00 ± 34.20

NA = Not Available.

process of our current practice. We find that lowering tube potential and utilizing a larger slice collimation are the most applicable methods for significantly reducing radiation dose to the patients without degrading the acquired image quality.

4. Conclusion

The $CTDI_{vol}$ and DLP dose values should not be exceeded when radiology departments operate under normal diagnostic and technical practice [11] [13]. 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. Technical factors might be the contributors to high doses and dose variation optimization and selection of parameter ought to reduce dose variation. Paediatric patients with age group 11 - 15 years in terms of $CTDI_{vol}$ and DLP dose values are lower considerably compared to the 6 - 10 years age group. Retraining of staff should help reduce and optimize CT protocols for paediatric patients.

Highlights

- We study radiation doses received by both adult and paediatric patients from CT scan examination.
- Data obtained were compared with some international diagnostic reference levels.
- Doses from CT were influenced by CT parameter, scanning techniques and patient characteristics.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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