ASSESSMENT OF AVERAGE RADIATION DOSE FOR ABDOMINAL COMPUTED TOMOGRAPHY EXAMINATIONS IN AMINU KANO TEACHING HOSPITAL, KANO

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ABSTRACT
The demand for abdominal Computed Tomography (CT) scans has dramatically increased over the years due to its higher sensitivity in ruling out a wide range medical conditions as compared to other imaging modalities. However, this patronage is associated with high effective dose and hence attributable to the risk of radiation-induced injuries. Establishing an acceptable radiation dose level and designing a protocol of maintaining dose level within that range is a sure optimization practice that is recommended by most national and international radiation monitoring bodies. The study aims to assess the average radiation dose received by patients undergoing abdominal CT examinations in Radiology unit of AKTH Kano, Nigeria. Dose survey of 100 adult abdominal CT scans in Radiology department of AKTH from June-October 2018. CTDIvol and DLP were simply obtained from the CT machine as displayed on the console and recorded into an adapted IAEA survey form. Effective dose was estimated by multiplying DLP by the conversion factor, k-value for abdomen (0.015mSv/mGy.cm). A total of 100 patient's radiation dose summary comprising 57 (57%) of females and 43 (43%) males with a mean age of 46 years. Determined 75th percentile CTDIvol, DLP and effective doses for abdominal CT were found to be 12 mGy, 2225.25 mGy.cm and 33.38 mSv respectively. The CTDIvol value was lower than most local and international established studies. The DLP and effective doses of the present study were significantly higher than other studies and calls for review of existing protocol to optimize practice.
Keywords: Abdominal CT, DRL, Effective dose,

INTRODUCTION

Rapid adaptation of Computed Tomography (CT) in clinical practice increased over the years compared to all other diagnostic imaging modalities due to the advent of multi-slice CT (MSCT) (Zira *et al.,* 2017). Currently, CT has the advantage of acquiring image of the entire abdomen and pelvis in a single comprehensive study. The sensitivity of CT in detecting intra-abdominal injury exceeds 90% (Webb *et al.,* 2015). With improvements in detector technology, specialized multiphasic imaging is frequently used for studying the liver, pancreas, and kidneys as well as in many abdominal CT angiography (CTA) protocols (Romans 2011). These protocols are useful diagnostic and surgical planning tools with great reduction in invasiveness and cost. Images are acquired faster than the conventional catheter angiography (Webb *et al.,* 2015). The assessment of the intramural and extra-intestinal components of gastro-intestinal are better demonstrated with the MSCT (Webb *et al.,* 2015). The demonstration of direct tumor extension to intra-abdominal organs and distant metastases, especially to the liver. The staging of gastric and colon carcinoma, in planning and managing treatment, and in detecting tumor recurrence are some of the remarkable capabilities of MDCT (Eisenberg & Johnson, 2016). All these capabilities make excessive doses in CT not readily identified through image quality effects as in conventional radiography.

Obviously, despite all these remarkable capabilities and accurate outcome in diagnostic radiology, CT directly comes with higher radiation doses to patients (Khosravi *et al.,* 2014). Hence, the risk of carcinogenesis and other forms of radiation sickness is increased (Foley *et al.,* 2012).

Studies have reported about 1.5 – 2% of cancer cases may be caused by higher doses of radiation currently used in CT (Abdulqadir *et al.,* 2016). The Radiological Society of North America (RSNA) in 2012 stated that average radiation dose from abdominal CT examinations is about 10mSv while that for brain is just about 2mSv (Vega, 2014). Radiation dose of 10mSv and above carry higher risks of radiation induced injuries. Unfortunately, this falls within the dose following complex CT examinations of the abdomen and perhaps required urgent action at all levels (Lin, 2010). The International Commission on Radiological Protection (ICRP) in 2012, proposed Optimization of procedure as a sure way of reducing radiation dose. In order to avoid severely inequitable outcomes of this optimization procedure, there should be restrictions on the doses or risks to individuals from a particular source (dose or risk constraints and reference levels) (ICRP, 2012). The recommended optimization tools used is known as the Diagnostic Reference Levels (DRLs) (Abdulqadir *et al.,* 2016). Diagnostic reference levels are established locally, regionally and nationally (Mccollough, 2010). This will ensure dose limits are defined based on peculiarities of individual geographical distributions and the outcomes satisfying the clinicians queries. Conventionally, DRLs are defined in terms of an easily and reproducibly measured dose metric using technique parameters that reflect those used in a clinical practice, CT dose index (CTDI)-based metrics such as weighted CTDI ($CTDI_w$), volume CTDI ($CTDI_{vol}$), and dose length product (DLP) are used in CT (Mccollough, 2010). The aim of this study was to therefore investigate the current radiation dose delivered to patients undergoing abdominal CT scan in Aminu Kano Teaching Hospital (AKTH) using CTDI-based metrics; $CTDI_{vol}$ and DLP values and to derive the estimated effective dose with a view of comparing with other established local and international works.

MATERIALS AND METHODS
This is a retrospective study that was carried out in the CT suit of Radiology Department of Aminu Kano Teaching Hospital (AKTH), Kano State, Northwest Nigeria from June to October 2018.Only adult patients' radiation dose data that are 18 years and above and referred for abdominal CT-scan during the period of study were recruited. Incomplete radiation dose summary for any patient was excluded. Purposive sampling method was adopted. A total of one hundred (100) patients radiation data were recruited. Ethical approval to conduct the study was obtained. The CT scanner installed at the study site is a 160-slice Aquilon Toshiba with 2.7 Al eq. inherent filtration, maximum tube voltage of 140 kVp, maximum tube current of 400mA, 512×512 reconstruction matrices, 203×243×107cm gantry size and 78cm gantry opening. Helical scan mode is used for image acquisition with a slice thickness of 0.5×40 mm and tube rotation time of 0.5 s were used all through the scans. Patients' demographic information and clinical indication for the study was recorded. Scan parameters: kV, mA, scan length, pitch, FOV, scan time, slice thickness, $CTDI_{vol}$ and total DLP values displayed on the console for each patient series were recorded on an adapted IAEA survey form (Nwodo *et al.,* 2018). The mAs value was simply determined by multiplying the mA value with a fixed tube rotation time of 0.5s. Effective dose was calculated by multiplying a conversion factor called k-factor by the DLP value for each patient series. The k-factor is a normalized coefficient found in the European guideline (Nwodo *et al.,* 2018). The k-factor for abdomen is 0.015mSv/mGy.cm. Minimum, maximum and Mean±SD values for $CTDI_{vol,}$ DLP and effective dose were estimated and tabulated. The 25th, 50th and 75th percentiles for $CTDI_{vol}$, DLP and effective dose were also determined and tabulated. The 25th, 50th and 75th percentiles were used to compare with a similar work conducted in Nigeria. The 75th percentile values were used to compare with European commission (EC) recommendations and other established works.

RESULTS
A total of 100 patient's radiation dose summary were recruited into the study comprising of (57) 57% females and (43) 43% males. Their age ranged from 18-83 years with a mean age of 46 years. Commonly requested abdominal CT were routine abdomen (62%) and CT urography (CTU) (32%), while the least examinations were Colonoscopy and CT angiography (CTA) with 2% each. The range and mean ±SD of scan parameters were determined. Tube voltages ranged from 100 - 120 kVp, pitch of 1mm, tube current-time product ranged from 85-220 mAs, with mean± standard deviation (SD) of 166±48 mAs, field of view (FOV) ranged from 206-525 mm with mean±SD of 355±46.8 mm and the scan length ranged from 33-58 cm with mean±SD of 43±5 cm.
The minimum and maximum $CTDI_{vol}$ for abdominal CT was found to be 2mGy and 20mGy respectively with a mean bb±SD of 8.7±4.5mGy.

The minimum and maximum DLP for abdominal CT was determined to be 506mGy.cm and 4996mGy.cm respectively with a mean±SD of 1795.1±1086.9 mGy.cm. The minimum and maximum effective dose was determined to be 8 mSv and 75 mSv respectively with mean ±SD of 26.9±16.3 mSv.

The determined 25th, 50th and 75th percentile $CTDI_{vol}$, DLP and effective doses were determined and presented in table 1.

Table 1: Percentile distribution of radiation doses from Abdominal CT.

Percentile	CTDI$_{vol}$ (mGy)	DLP (mGy.cm)	Effective Dose (mSv)
25th percentile	5	990.75	14.86
50th percentile	7	1449.5	21.74
75th percentile	12	2225.25	33.38

The determined 75th percentiles of CTDI$_{vol}$, DLP (DRL) and effective dose values of the present study were compared with other established DRLs in Nigeria (table 2) and other countries (table 3).

Table 2: Comparison of Radiation Dose (DRLs and effective dose) between Present Study and other reported works in Nigeria.

Radiation Dose values	Present Study	Ogbole & Obed, (2014)	Abdulkadir *et al*. (2016)	Zira *et al.* (2017)	Ekpo *et al.* (2018)	Nwodo *et al.* (2018)
CTDI$_{vol}$ (mGy)	12	37.9	15	19.20	20	24
DLP (mGy.cm)	2225.25	1902	757	1290	1486	963
EFFECTIVE DOSE (mSv)	33.38	22.5	11.9	19.35	22.29	14.4

Table 3: Comparison of radiation dose values (DRLs and effective dose) from this study, Other countries and EC recommendations.

Radiation Dose Values	Present Study (Nig. 2018)	EC (1999)	Ireland 2012	Japan 2015	Nepal 2016	Cameroun 2017	India 2018
CTDI (mGy)	12	35	13	15	30.8	15	13.71
DLP (mGy.cm)	2225.25	780	1120	1800	1180.5	716	2336.4
EFFECTIVE DOSE (mSv)	33.38	11.7	16.8	27	17.7	10.74	35.7

An independent sample t-test was done to check if there's any statistical significant difference between the radiation dose with sex. However, no statistically significant difference was established in CTDI$_{vol}$, DLP and effective dose among sex (p>0.05).

The mean scan length from the present study (43cm) was compared with similar works reported in UK and the National Radiological Protection Board (NRPB) (Abdulkadir *et al.,* 2016) (Figure 1). Furthermore, estimated 25th, 50th and 75th percentiles CTDIvol, DRL and effective dose values from the present study were compared with the works of Ekpo *et al.,* (2018) who proposed a national DRL for Nigeria (Figure 2,3 & 4 respectively).
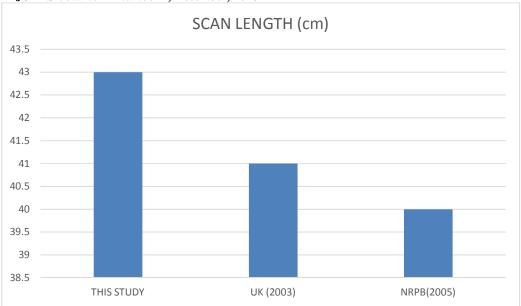
Figure 1: Comparison between scan length from this study, UK and National Radiological Protection Board (NRPB) (Abdulkadir *et al.*, 2016)
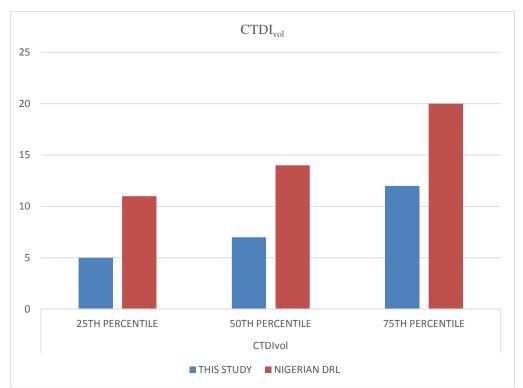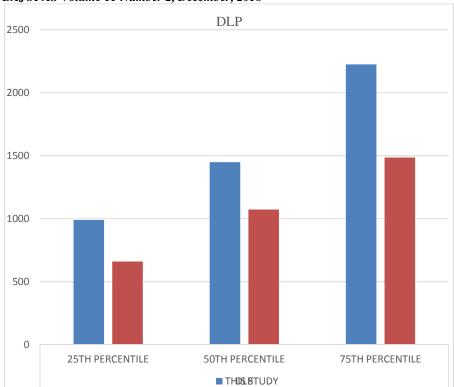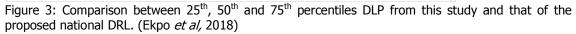

Figure 2: Comparison between 25th, 50th and 75th percentiles CTDI$_{vol}$ from this study and that of the proposed national DRL. (Ekpo *et al,* 2018)

Figure 3: Comparison between 25th, 50th and 75th percentiles DLP from this study and that of the proposed national DRL. (Ekpo *et al,* 2018)
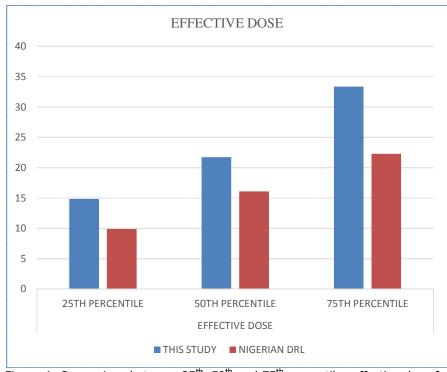

Figure 4: Comparison between 25th, 50th and 75th percentiles effective dose from this study and that of the proposed national DRL. (Ekpo *et al,* 2018)

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DISCUSSION
A maximum tube voltage of 120 kVp was determined in the present study. This is in line with similar works of Moifo *et al*, in 2017. However, Ekpo *et al*, in (2018) reported a higher value of maximum tube voltage of 140 kVp. Regarding tube current-time, the 166 mAs obtained in the present is far less than most similar works reported in the literature (Zira *et al.*, 2017; Abdulqadir *et al.*, 2016; Nwodo *et al.*, 2018; Ekpo *et al.*, 2018; Ogbole & Obed, 2014). Treier *et al.*, (2010) reported 224mAs, Sadri *et al.*, (2013) reported 179 mAs, Khosravi *et al.*, (2014) reported 190 mAs, Abdulkadir, (2015) reported 200 mAs, Moifo *et al.*, (2017) reported 246 mAs and Ekpo *et al.*, (2018) reported as high as 300 mAs for image acquisition. The variation in these exposure factors between the present and other study may obviously be due to equipment and protocol differences. While the present study was a single centre study, Ekpo *et al.*, (2018) adopted a multi-centre approach, thus incorporating other protocols from older machines as against the present study where the equipment was simply installed just 4 years ago. In addition, selection kVp and mAs in the present study site were performed solely by Radiographers and were based on patients' size, age, anatomical region and clinical indication. This may be suggesting a commendable level of optimization in the study site, thus, a measure canvassed by the NRPB, ICRP and EC (Zira *et al.*, 2017; Foley *et al.*, 2012; Abdulqadir *et al.*, 2016; Ekpo *et al.*, 2018; Ogbole and Obed, 2014, Sadri *et al.*, 2013; Abdulqadir, 2015). Similarly, estimated mean scan length of the present study is found to be slightly higher than UK and NRPB recommendations (Abdulqadir *et al.*, 2016). The slight variation may be attributed to body habitus, race and geographical differences between British and Nigerian population.

A maximum pitch factor of 1mm was the pitch setting during helical acquisition of all abdominal CT scans in the study. This is similar with the work of Moifo *et al.*, (2017) but lower than the works of Treier *et al.*, (2010); Sadri *et al.*, (2013) and Abdulkadir, (2015) where they reported a pitch value of 1.38mm, 1.8mm and 1.5mm respectively. Pitch in multi-slice CT is inversely proportional to radiation dose (Abdulkadir, 2015). The use of lower pitch at the present study site may be attributable to local protocol. Optimizing exposure factors will definitely affect image quality, and in an attempt to compensate for this may have warranted the setting of lower pitch value.

The established local DRL in the present study was found to be lower than most studies carried out in the different regions across the country (Northwestern Nigeria, North-central Nigeria, North-eastern Nigeria and even national survey). The present study's $CTDI_{vol}$ from this study was found to be lower than all studies that was carried out in Northwestern Nigeria, North-central Nigeria, North-eastern Nigeria and even a national survey (table 3). The lower value may be attributed to the age of CT equipment. The equipment was recently installed; in the year 2015 and couple with the local protocol that optimized exposure factors. Variations exists in DLP among studies carried out across the different geo-political reasons of Nigeria (Zira *et al.*, 2017; Abdulqadir *et al.*, 2016; Nwodo *et al.*, 2018; Ekpo *et al.*, 2018; Ogbole and Obed, 2014). Similarly, DLP from the present study was higher than most of these studies. Abdulkadir *et al.*, (2016) in North-central Nigeria, Zira *et al.*, (2017) in North-eastern Nigeria, Ogbole & Obed, (2014) in South-eastern and Ekpo *et al.*, (2018) (national survey) reported DLPs of 757mGy.cm, 1290mGy.cm, 1902mGy.cm and 1486mGy.cm respectively Nigeria (Zira *et al.*, 2017; Abdulqadir *et al.*, 2016; Nwodo *et al.*, 2018; Ekpo *et al.*, 2018; Ogbole and Obed, 2014). Since, these studies were carried out in different geo-political regions across the country and DLP is a function of length of anatomical region of interest, a possible explanation to these may be the differences in body habitus in each geo-political zone since each zone is dominantly populated by a particular tribe or ethnic group. Furthermore, differences in exposure parameters, radiographic protocol and even calibration of equipment could account for these variations. Hence, the need for standardization of practice is emphasized so as to maximize the potential of optimization is practice.

The estimated effective dose from this study was determined to be 33.38mSv and found to be higher than other studies conducted in the country (Zira *et al.*, 2017; Nwodo *et al.*, 2018; Ogbole and Obed, 2014; Abdulqadir, 2015). This is expected because of the high DLP obtained in the current study since it is derived from the DLP. Nonetheless, the difference is significant and calls for optimization. Differences in practices (protocols) and advancements in technology varies from one country to another and even among centers. Hence, a country or center's DRL cannot be a good factor for generalization.

This justifies the recommendation by the Institute of Physicist and Engineers in Medicine (IPEM) 2004 which states that every country should have or set its DRLs. Therefore, the present study has attempted to establish a local DRL which can form basis for further studies in attempt to establish a National DRL (nDRL) for abdominal CT in Nigeria. Comparison of the 25th, 50th and 75th percentile lDRL values of the present study and the works of Ekpo *et al.,* (2018) who reported a proposed nDRL. The $CTDI_{vol}$ of the present study is consistently lower across all the percentiles. However, DLP and effective dose values from the present study were much higher across the percentiles. Possible reasons may be due to lower pitch factor and longer scan lengths observed in the present study. Further comparison of the present study's DRLs and effective dose with European values indicates that $CTDI_{vol}$ from this study was significantly lower to that of the EC recommendations. However, the DLP and effective doses from this study were much higher than that of the EC recommendation and other European countries except a work in India (table 3). The study recommends a review of protocol to optimize scan length and number of phases in image acquisition.

CONCLUSION
The present study has estimated and proposed a lDRL and estimated effective dose for the study locality being a reference radio-diagnostic centre for Kano and neighboring states. Patient radiation dose level has been assessed. Local protocol indicates proper optimization of exposure factors. Comparisons of lDRL with other similar local, regional, national and international studies showed some variations. The 75th percentile CTDI values of the present study were lower than most reported studies, DLP and effective doses were significantly higher than both local and international studies. A low pitch setting and scan length have been identified as the two causes of the high DLP and effective dose in the study area. Review of protocol to optimize them is highly emphasized. No statistically significant difference exists between the radiation with age.

Declaration of Conflict of Interest
The authors hereby declare that there is no any conflict of interest throughout the work.

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