A Comparison of the Mean $CTDI_{vol}$ and DLP Values for Adult Abdominal CT Examination for MTRH, Eldoret Hospital, St. Luke's Hospital and Mediheal Hospital: A Retrospective Study

Edward Ouma*, Rose Kittony, Elias Onditi

Department of Radiology and Imaging. Moi University School of Medicine, Kenya.

DOI: https://doi.org/10.51244/IJRSI.2023.10408

Received: 18 March 2023; Revised: 03 April 2023; Accepted: 06 April 2023; Published: 10 May 2023

Abstract:

Background: Advances in Computed Tomography (CT) have facilitated widespread use of medical imaging while increasing patient lifetime exposure to ionizing radiation. In Kenya we use the international DRLs as our point of reference and so far, no regional protocols for abdominal CT scan have been adopted. This study endeavors to form a basis for dose reference levels protocols for abdominal CT scan in Uasin Gishu County.

Objective: To compare the mean $CTDI_{vol}$ and DLP values for adult abdominal CT examination for MTRH, Eldoret Hospital, St. Luke's Hospital and Mediheal Hospital.

Methods: This was a retrospective review of CT scans of 700 adult patients conducted in Uasin Gishu healthcare system at MTRH, Eldoret Hospital, Mediheal Hospital and St. Luke's Hospital in a period of 1 year in the year 2021 using systematic and consecutive sampling. The Volumetric CT-dose index ($CTDI_{vol}$) and dose length product (DLP) length from CT abdominal scans for the adults were collected from the various CT scans dose tracking software's.

Results: The mean age of patients who underwent CT abdominal scans was 52 years with majority being females at 53 %. The mean $CTDI_{vol}$ was 81. (SD=22.2) and the mean DLP values was 1699.1 (SD=1053.1). Comparison by scan model demonstrated the median for the Total DLP and for the $CTDI_{vol}$ significantly differed by the model with the median for the Neusoft model being highest at 2538 mGy.cm and 10.3mGy respectively while those for the Siemens were the lowest for the two markers at 1318.5 mGy.cm for the DLP and 5.39mGy respectively. These findings were statistically significant with a p value of < 0.001. Comparison by the type of facility showed that the median DLP and $CTDI_{vol}$ values were significantly higher in the public facilities at 1668.8mGy.cm and 6.3mGy respectively when compared to private facilities at 1282.4mGy.cm and 5.9mGy with a p value of <0.001. The Local Dose reference level (LDRL) was set as the median value for $CTDI_{VOL}$ and DLP at 6.1mGy and 1465 mGy.cm respectively.

Conclusions: The LDRLs for the patients undergoing abdominal CT examination in Uasin Gishu healthcare system were markedly lower than the regional and the international values for the same abdominal CT examination.

Keywords: CTDI: DLP: Radiology and Imaging: MTRH

I. Introduction

The rapid innovations and technology have led to new imaging modalities like magnetic resonance imaging, positron emission tomography scan and computer tomography (CT). As a result, image-guided minimally invasive interventions have emerged as advances that can be used in place of traditional invasive approaches.[1].

Current surveys have shown growing dependency rate on imaging procedures for diagnostic and medical therapies since they have remarkably shown improvement on quality of health care services. Due to choice and frequency of imaging modality, there has been an increase in radiation burden to the patient's body during examinations and medical procedures, in regards to absorbed radiations.[2]. The number of X-rays that gets absorbed when radiation is passed through the body contributes to the patient's effective dose. Millisievert(mSv) is the scientific unit of measurement for the whole-body radiation dose, (effective dose). Other radiation dose measurement units include Rad(rad), Rem(rem), Roentgen, Sievert and Gray (ICRP, 2007).In order to evaluate the risk of radiation to the entire body, effective dose takes into account how sensitive different tissues are to radiation [3]. Hence, it allows the radiologist to compare the risks or possible side effects such as the chance of developing cancer later in life to common, daily sources of exposure such as natural background radiation [3].

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) report (2010) have indicated that medical exposures constitute more than 99% of the total radiation dose burden to the global population from the anthropogenic activities [2].

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue IV April 2023

Advanced imaging modalities like computed tomography and interventional therapeutic procedures have the potential for deterministic effects (epilation and erythema) or could lead to non-threshold stochastic effects (leukemia and hereditary disease) due to their high dose radiation [2]. In the developed countries International Commission on Radiological Protection (ICRP)introduced a concept called Diagnostic Reference levels (DRL) with the objective of providing a reference level for the radiation dose for standard radiographic and CT examinations without compromising quality. This has resulted to significant decline in human radiation exposure. Radiation doses used to perform similar CT studies of diagnostic quality should remain within a relatively narrow range. However, multinational and national surveys indicate that this is not the case; large variability in dose levels exists[2]. In the United Kingdom and US, CT procedures contribute to 67 % of the collective effective radiation due medical procedures. In Kenya as computed tomography (CT) technology evolves, many new applications have emerged, leading to high numbers of CT scans performed. Today CT is a major contributor (80%) to patient radiation exposure [2]. CT abdomen is one of the commonest examinations done and its international approximate effective dose is 8mSv. Related studies have been done in Kenya and it has collectively looked at the effective dose burden of the entire body organs [2]. This study aimed to establish the examination frequency and associated radiation dosages to patients specifically undergoing examination of CT abdomen at Moi Teaching and Referral Hospital, Eldoret Hospital and Mediheal Hospital in Eldoret. As a result, provided a basis for setting regional DRLs.

A. Study Objective

To compare the mean $CTDI_{vol}$ and DLP values for adult abdominal CT examination for MTRH, Eldoret Hospital, St. Luke's Hospital and Mediheal Hospital.

II. Methodology

A. Study Design

The study involved a retrospective review of CT scans from adult patients who underwent abdominal scans, in the past 6 months from the study period 2021. Retrospective analysis was utilized due to the disadvantages of prospective reviews as concerns time and resource constraints.

B. Study Area

Moi Teaching and Referral Hospital is the second largest National Teaching and Referral Hospital (level 6 Public Hospital) in the country. It is located in Eldoret town, Uasin Gishu county. It serves residents of Western Kenya Region, parts of Eastern Uganda and Southern Sudan. It has an imaging and radiology department equipped with 3 functional CT scanners. It performs an average of 40 general CT scan examinations per day. Eldoret hospital is the oldest private healthcare giver since its inception in 1975 as a nursing home to a fully-fledged hospital with multi-disciplinary specialties' that include imaging department with a CT scan. It does around 8 CT scans a day. It is situated in Eldoret town Uasin Gishu county. Mediheal is a private hospital also located in Eldoret town, it has a modern imaging department with a functional CT scan. It carries out 10 CT scans in a day. St. Luke's as well is a private hospital with a fully-fledged imaging department with an operating CT scan doing averagely 12 CT scans per day. It is also serving the population of Eldoret and Western Kenya Region.

C. Study Population

The study population involved CT scans of adult patients who underwent abdominal scan.

D. Eligibility Criteria

i) Inclusion Criteria: Standard abdominal CT scans both contrast and non-contrast enhanced from adult patients.

ii) Exclusion Criteria: Incomplete standard abdominal CT scan dosimetry

E. Sampling Frame

The principal researcher obtained data from the registry at the CT department of the various facilities included in the survey entailing abdominal CT scans dosimetry for the adult population. In the year 2020, 2100abdominal CT scans for the adults were done at MTRH. For the three private hospitals combined, 369 adult abdominal CT scans in the year 2020 were performed. Hence a total of 2469 CT scans for the 4 hospitals were done in the year 2020.

F. Sample Size

The study sample size was calculated based on the standard formula for estimating mean.

i) Formula:

$n = z^2\sigma^2/ d^2$ where n is the sample size andσ^2 is the variance for the population.

ii) Workings:

$1.96^2 * 74^2 / 5^2 = 842$, n=842

Based on the formula, the sample size of the study was 842 adult patients who underwent abdominal CT scans from the respective hospitals. And the distribution is as shown in table I below.

Table I. Showing Sampling Frame of Patient CT scans

Facility	population	sample size
MTRH (public)	1000	692
Private	150	150
Total	1150	842

G. Sampling Technique

Systematic and Consecutive sampling technique was used to obtain data in the various respective CT scans dose tracking software's from the hospitals. Consecutive sampling was applied to the 3 private facilities. While systematic sampling using the interval K was used in MTRH.

i) Workings:

K=1000/692~2 where K= interval, k ~2

Hence selected the initial point randomly from the given list of the sample database then at every 2nd interval chose the data as the sample until the list is exhausted.

H. Equipment, Protocols and Procedure

The CT equipment's available and functional in the respective hospitals under study are as shown in Table II

Table II. Showing the various CT available in the Hospitals under Research

Facility	**Brand**	**Model name**	**Slices**
MTRH	Neusoft	Neusoft	128
	Siemens	Siemens Somatom. P	32
	Philips	Philips Ingenuity	64
Eldoret Hospital	Siemens	Siemens somatom .E	16
Mediheal	Siemens	Siemens Go-up	64
St. Luke's Hospital	Philips	Philips, MX	16

Table III. Siemens Scanner and Protocols

SIEMENS	**Emotion 16**	**Perspective 32**	**go-up 64**
Scan type	Spiral	Spiral	Spiral
Detector configuration	16 x 1.2 mm	32 x 1.2 mm 64 x 0.6 mm	64 × 0.6 mm (32 x 0.6 mm = 19.2 mm
Rotation Time (s)	0.5	0.5	0.5
Pitch	1.5	1.4	1.4
Tube voltage(Kv)	120	120	120
Quality ref. mAsCD	200	200	200
CARE kV	-	-	-

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue IV April 2023

CARE Dose4D	ON	ON	ON
RECON 1			
Slice (mm)	5	5.0	5.0
Slice increment (mm)	5	5.0	5.0
RECON 2			
Slice (mm)	1.0	1.0	1.0
Slice increment (mm)	0.7	0.7	0.7

Table IV. Philips Scanner and Protocols

PHILIPS	**MX 16**	**Ingenuity CT 64**
Scan type	Helical	Helical
Rotation Time (s)	0.75	0.75
Collimation	16 × 1.5 mm	64 × 0.625 mm
Tube voltage(Kv)	120	120
mAs (mAs/slice) @ water equivalent diameter	DoseRight (200 mAs @ 33 cm Reference), ZDOM	DoseRight (200 mAs @ 33 cm Reference), ZDOM
DoseRight ACS	ON	ON
Pitch	1	1
FOV (mm)	350-500	350-500
SP Filter	Yes	Yes
Adaptive Filter	Yes	Yes
Resolution Setting	Standard	Standard
RECON 1		
Type	Axial	Axial
Slice thickness (mm)	5	5
Slice increment (mm)	5	5
RECON 2		
Type	Axial	Axial
Slice thickness(mm)	2	0.9
Slice increment (mm)	1	0.45
RECON 3		
Type	Coronal	coronal
Slice thickness(mm)	3	3
Slice increment (mm)	3	3

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue IV April 2023

Table V. Neusoft Scanner and protocols

NEUSOFT	**NeuViz 128**
Scan type	Helical
Rotation Time (s)	0.5
Collimation	128 x 0.625mm
kVp	120
Reference mAs	150
Pitch	1.4
DFOV (mm)	350-500
Resolution	Standard
Dose Modulation	O-Dose
RECON 1	
Type	Axial
Slice thickness (mm)	5
Slice increment (mm)	5
RECON 2	
Type	Thins for MPR
Slice thickness(mm)	1
Slice increment (mm)	0.5

I. Study Procedure

Information from the respective CT registry was obtained by the Principal Investigator following authorization from the departmental heads. Using a IAEA survey guide that captured the facility name, demographics, scanner model, dosimetry and relevant information pertaining to the study was retrieved, recorded and stored in password protected database. Data from the CT database systems from the Imaging and Radiology department in the respective hospitals were obtained retrospectively for a 6 months' period (2021) using the same type of dose management system. Data compilation, cleaning and analysis was performed.

J. Data collection

For purpose of determining the exposure related parameters on patient doses, typical exposure parameters (e.g., kilovoltage (kV), tube current (mA), exposure time, slice thickness, table increment and number of slices and phantom size) was collected from each hospital participating in the study. In order to consider the variations due to the different scanners from each hospital hence, standard protocols were adhered to as provided by the specific manufactures for the CT scanners and which have been authorized by the International Commission on Radiation Protection (ICRP/IAEA).

Abdominal CT examination protocols for routine or unique indications and other diagnostic tasks as prescribed may vary with each CT scanner machine. The regulatory authorities together with the manufacturers have set standards that are adhered to universally in respect to the CT scan model and for each modality being examined e.g. it is recommended that irrespective of the machine type, a CT phantom of standard diameter 32 in size should be selected when performing body or Abdomen scans (EC 1999). In most multiphase abdominal examination each phase is performed with constant scanner parameter settings which are standardized with every CT scanner model as per the set regulations(ICRP) and each phase multiplies the total patient dose[4]. As a result, the total dose is increased as per the number of phases being performed but the scan parameters remain the same all through the phases for the given CT protocol during the examination. The aim of the researcher was to categorize the scans into a single phase or multiphase where applicable and obtained the respective dosages and compared the variations with the already stipulated guidelines by ICRP/UNSCEAR. The displayed average $CTDI_{vol}$, DLP and Effective dose post scan which are patient specific were the data that were retrieved from the CT database systems.

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue IV April 2023

The data storage in CT scanner systems can be categorized into three; console storage, advanced view workstation (AVW) and Picture Archiving and communication systems (PACs). Console storage is a primary component of the data acquisition systems within the CT set up. It has limited storage capacity and only data for a given limit can be stored for a few days then auto deleted, depending on the scanner models. The advance view workstation can act as secondary temporary integrated storage for a short period of time which when the limited storage capacity has been exhausted it has to be reformatted. PACs is a medical imaging technology that provides economical storage and convenient access to images from multiple modalities. PACs offers unlimited storage capacity it is currently encouraged in busy hospital set ups since it offers long term storage. PAC systems can be institution specific or machine specific for instance at MTRH there is PAXERA and NEUSOFTPACS respectively. The facilities that were involved in this study have PAC systems installed. The PACS offer a better data protection platform since its access controlled and it can have both physical and virtual servers as backups. Sutton et al has indicated that PACS-based dose audit project is proving to be better tools in patient dose modulations and further optimization of CT doses as compared to DRLs which are viewed as more of compliance tools.

K. CT Dose Measurements

CT dose is not measured directly on patients. It is measured using standard phantoms and then the measurements are used to estimate patient dosages. The standard phantom for the adult body is 32 cm and adult head is 16cm in diameter. Pediatrics phantom is 16 cm for the body EC (1999). CT dose is measured and reported through different methods, it can be classified into three broad categories: exposure, absorbed dose, and effective dose. In order to accurately determine a patient dose from a CT scan patient size and radiation output must be considered. Basically CTDI or $CTDI_{vol}$ is thought of as a measure of how CT was performed as opposed to the amount dose a patient received. Exposure: is the amount of radiation at a set point in a known amount of air, measured by using an ionization chamber. The measurement of exposure via the ionization chamber is in coulomb per kilogram (Ckg^{-1}) which was previously measured in roentgen(R)[2.] Absorbed dose: it is also referred as the radiation dose; it is the measures of energy absorbed per mass. It is the appropriate parameter to refer to when quantifying how much dose a patient received in CT. It is measured in gray (Gy). Effective dose: the effective dose is the measure of radiation calculated with the radiosensitivity of specific organs taken into account. It also known as equivalent dose and it is measured in Sievert (Sv)

The commonly encountered dose metrics in CT scan are CT dose index (CTDI), CTDIvol, Dose length product (DLP) and Size Specific dose estimate (SDDE)[2]. CTDI is the standardized measure of dose output and it is best used to compare CT scanners. It is measured in mGy and it is not a measure of absorbed dose or effective dose. $CTDI_{vol}$ is a CT dose index that measures radiation per slice of tissue using a reference phantom only taking into account the scanner output and therefore not a measure of absorbed or effective dose. Dose length product (DLP)(mGy*cm) is the product of the $CTDI_{vol}$ and scan length. DLP factors in the length of the scan to show overall dose output and does not take into account the size of the patient and also is not a measure of absorbed dose or effective dose. It is measured in (mGy*cm). Size specific dose estimate (SDDE)[2]: it is the measure of absorbed dose but not effective dose. And it takes into account the patient's size, it is measured in mGy.

According to the EC the major dose indices used when measuring dosages are namely; CTDI, CTDIW, CTDIvol, DLP, Effective dose EC (1999). Theoretically CT dose index (CTDI) is a measure of dose from single slice irradiation, defined as the integral along a line parallel to the axis of rotation (z) of the dose profile, D(z), divided by the nominal slice thickness, t, given[5] by the formula;

$$\mathrm{CTDI}_{\infty} = \frac{1}{t}\int_{-\infty}^{\infty} D1(z)dz.$$

Fig. 1 Formula for CTDI calculation

When measuring the dose radiation, CTDI being the key parameter is obtained from measurement of dose, D(z), along the z-axis made in air using a special pencil-shaped ionization chamber 100mm in length and plastic anthropometrics dosimetry phantoms of standard size diameters (16 and 32). Measurements of CTDI in air (CTDI100, air) and in the cylindrical polymethylmethylacrylate (PMMA) phantoms (CTDI100, phantom) of diameter 32 cm (body) was appropriated for adult abdominal CT scan as recommended by EC guidelines based on the typical patient and exposure related parameters for this study (EC 1999).

In this study, CTDI among other parameters was to be obtained from the displayed CT parameters post exposure specific to the patient for CT Abdominal examination from the various CT scanners of the respective hospitals under the study. Currently Modern CT equipment have advanced dosimetry software and technical capacity to perform dose modulation according to patient size, height or weight which might provide homogenous and optimal effective dosages which are patient specific. Hence there are studies being done to compare whether Size Specific Dose Estimates can be more accurate in estimating patient dosages (AAPM 2014).

The CT scanners under the study have their valid licensure which is renewed annually by the Kenya Nuclear Regulatory Authority (KNRA). KNRA inspects and ensures the CT machines are calibrated to the required legal safe dosimetry standards as required by law and in keeping with the ICRP, IAEA and UNSCEAR.

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue IV April 2023

L. Determination of Reference Dosages

Advances in CT technology has made it possible to carry out digitally dose modulation specific to the patient through standardized software applications installed in the modern scanners and thus display average optimal effective dosage that are patient specific. The CT machines under the study were of current technology and hence the researcher collected the displayed average $CTDI_{vol}$, DLP of post exposure scan of each patient examined and for each specific CT machine for every hospital and estimated the dosages and came up with their mean distributions for comparisons with the international DRLs.

M. Data Analysis

The data analysis process involved cleaning, classification, coding, and tabulation of collected data hence amenable for analysis. The data collected from MTRH, Eldoret Hospital, Mediheal Hospital, St. Luke's Hospital was de-identified and recorded on an access database which was password protected so as to maintain confidentiality. Descriptive statistics of the dose distribution findings across CT scanners surveyed was used to determine mean, minimum and maximum values. Mean values for each facility was calculated, and then rounded 75th percentiles of DLP and $CTDI_{vol}$ was used as a basis for DRLs. To compare doses between scanners of different numbers of detectors, Student's t-test and one-way ANOVA test was used to compare two and more than two groups of scanners, respectively.

The collected and analyzed data included departmental CT protocols routinely applied to average-sized adult patients (weighing between 60 and 80 kg) for abdominal examination, included scanning parameters, such as detector collimation, slice thickness, tube current, tube potential, tube rotation time, scan range and pitch. Radiation dose recordings, included the displayed CT dose index volume (CTDI vol) and dose length product (DLP). Data was imported into STATA version 16 for analysis.

To answer the objective, the mean and their corresponding deviations for Volumetric CT-dose index ($CTDI_{vol}$), dose length product (DLP) and scan length from the scans from each facility was calculated and presented in a table. Medians and their corresponding interquartile ranges were calculated for each facility. Comparison was made between different models of CT scanners for the respective facilities under survey. The results were presented in tables and figures and recommendations done.

N. Ethical Consideration

Ethical review and approval were obtained from Moi University Institutional Research and Ethics Committee (MU-IREC) and NACOSTI for licensure before proceeding to the field. Permission to carry out the research at Moi Referral and Teaching Hospital, Eldoret Hospital, Mediheal and St. Luke's hospital was sought and duly provided. Since there was no direct involvement of patients there were no consent forms to be addressed.

III. Results

There was a total of 700 Abdominal CT scan that were reviewed in this study and included in the analysis. This represented 83 % of the total sample size of 842 as had been calculated. A target of 100 % could not be achieved at the time of data collection due to routine CT maintenance at the respective study sites. Table 1 shows the characteristics of the reviewed scans as well as the characteristics for the participants whose CT scan were reviewed. We observed that 451 (66.4%) of the reviewed scans were from public facilities and Siemens was the most common scan model 490 (70%). Majority of the scan 560(82.3%) were from CT scan that were manufactured as from 2016. Almost all the scan had a contrast administered 665 (96. 8%).The mean CTDI was 8.1mGy. (SD=22.2) and the mean DLP values was 1699.1 mGy.cm (SD=1053.1)

The mean age of the participants was 52years (SD=17.7) and 376 (53.7%) were females. For almost all the patients 685(98.1%) whose CT scans were reviewed the positioning was H-SP. (Table VI)

Table VI. Descriptive

Variable	Freq (%)
Type of Facility	
Private	249 (35.6%)
Public	451 (64.4%)
Scanmodel	
Neusoft	72 (10.3%)
Philips	138 (19.7%)

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue IV April 2023

Siemens	490 (70.0%)
Year of manufacture	
Missing	19
2007	19 (2.8%)
2013	75 (11.0%)
2014	27 (4.0%)
2016	316 (46.4%)
2017	189 (27.8%)
2018	55 (8.1%)
Contrast administered	
Missing	13
Contrast	665 (96.8%)
Non-contrast	22 (3.2%)
Patient Age	
Missing	3
Mean (SD)	52.227 (17.668)
Range	14.000 - 101.000
Patient Gender	
Female	376 (53.7%)
Male	324 (46.3%)
Patient positioning	
N-Miss	2
Feet First Supine	13 (1.9%)
H-SP	685 (98.1%)

The mean CTDI was 8.1mGy. (SD=22.2) and We observed that the CTDI and DLP values were highly dispersed hence in this analysis instead of comparing the mean the median was compared. Table VIII shows the comparison by scan model it demonstrated the median for the Total DLP and for the CTDI significantly differed by the model with the median for the Neusoft model being highest and those for the Siemens were the lowest for the two markers. When the markers were compared by whether there was contrast or not we observed that there was a statistically significant difference in the DLP values with the median being higher where there was contrast (table 9). However, there was no significant difference in the CTDI values.

Table X shows the comparison by the type of facility we observed that the median DLP and CTDI values were significantly higher in the public facilities when compared to private facilities. The mean DLP values was 1699.1 mGy.cm (SD=1053.1) as shown in Table VII.

Table VII. CTDI and DLP values

	Median (IQR)	Mean (Std)	Range
Total DLP(mGy.cm)	1465.0 (1019.5, 2213.7)	1699.1 (1053.1)	0.0 - 7318.2
CTDI vol (mGy)	6.1 (4.6, 8.4)	8.1 (22.2)	0.0 - 549.3

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue IV April 2023

Table VIII: DLP and CTDI by Scan Model

	NEUSOFT (N=72)	PHILIPS (N=138)	SIEMENS (N=490)	p value
Total DLP(mGy.cm)				< 0.001
Median	2583.8	1785.8	1318.5	
Q1, Q3	2112.1, 3201.5	1155.1, 2799.6	961.5, 1851.0	
CTDI vol(mGy)				< 0.001
Median	10.320	8.470	5.390	
Q1, Q3	9.050, 11.817	6.083, 11.185	4.280, 6.860	

Table IX. DLP and CTDI by Contrast Administration

	Contrast (N=665)	Non-contrast (N=22)	p value
Total DLP (mGy.cm)			0.020
Median	1488.0	680.8	
Q1, Q3	1077.0, 2234.0	251.5, 2124.9	
CTDI vol(mGy)			0.757
Median	6.2	6.5	
Q1, Q3	4.7, 8.4	3.0, 10.8	

Table X. DLP and CTDI by Facility Type

	PRIVATE (N=249)	PUBLIC (N=451)	p value
Total DLP (mGy.cm)			< 0.001
Median	1282.4	1668.8	
Q1, Q3	823.8, 1713.0	1140.5, 2459.5	
CTDI vol(mGy)			0.008
Median	5.9	6.2	
Q1, Q3	4.4, 7.730	4.7, 9.5	

IV. Discussion

A total of 700 adult patients who underwent abdominal CT scan from the respective hospitals were enrolled in the study. Participant mean age was 52.227 (17.668) years and ranged from 18 years to 101 years, with more than 53% of the reported examinations belonging to the female patients. The average age of the population gave the impression that currently CT abdominal examination in private and public hospitals in Eldoret is mostly performed on patients that are more advanced in age. Majority of the existing population are young and female, with significant exposure to the probability of radiation risk. Similar finding was also described by Korir et al., (2016) in a study done in Kenya. Likewise, Raksha Erem et al. (2022) reported similar mean age in patients' examinations with an average age of 52 years.

Majority of the CT scans was Siemens model. In the work by [6] on CT scan model characteristics in Sub-Saharan Africa, Siemens model were reported as the popular machines in the region. In this study the earliest CT scan year of manufacturer was 2007 and the most recent year of manufactures for the CT scan were between 2016 to 2018. This suggests that most of the installation of CT scan across the public and private hospital have been made in recent years. Similar observation were made by [7] who suggested that the number of CT scanners in direct medical use in Kenya increased by over 80 % in the past decade (2012-2019). The overall increase in the number of CT scans between 2016 and 2018 can, to a large extent, be attributed to the MES, a public-private

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue IV April 2023

partnership project (PPP) introduced in 2016, that has equally resulted in availability of more imaging modalities in the public sector. Greater investment by the private sector has also played a role in the surge of CT scans in the country [8]. This was a multicenter study and compared to similar studies done Singapore and Nigeria (L Arlany et al.,2022) (Abba et al., 2018).

A. Mean CTDI(w) and DLP Values for Adult Abdominal CT Examination

The findings demonstrated that average $CTDI_{vol}$ and DLP values for abdominal CT were 8.1 mGy and 1699.1 mGy.cm respectively. The $CTDI_{vol}$ was higher than values observed by Wambani et al., (2010). The reason for this difference may in part be explained by the different methods used. The results were calculated using displayed console values as opposed to measured dose values from dosimetry phantom and the average number of slices done for an average adult patient at each facility in the former studies. The dose variations in the measured values are also associated with diverse device protocols, different standard examination techniques, device performance, equipment age and also maintenance and service conditions [10], which could explain the difference in measured valued.

This findings of the study also contradict a much more recent study conducted by Korir et al. (2016) in Kenya that reported lower values. The results can be attributed to study methodology, more so the use of Philips CT model as opposed to this study that had three model of Philips, Siemens and Neusoft. The use of Scanners manufactured by a single company (Philips) in the former study, may have led to substantial homogeneity in the radiation outputs owing to the similar technology and protocol used (Adnan et al.,2018). The high values may also be attributed to the higher exposure factors used and to the possible presence of longer than necessary scan lengths [12]. The current study findings were in support of the high average mean values reported for abdominal CT scan at KNH [13]. In Tanzania by (Muhogora et al.,2009) they also attributed similar findings as the current study and the results were also in near semblance.

B. Comparison of the CTDI(w) and DLP Values for Adult abdominal CT by Type of Facility, Scan Model and Contrast Administration

The findings showed that dose variation of CTDI ($_{vol}$) and DLP values is largely attributable to variation in machine factors, in our case CT model. This is consistent with reported findings by Masjedi et al. (2019) that revealed that CT dose level is affected by the design of the machine. The study findings were also agreeable to the conclusion by [15] that variation in values reported by different CT scanners can vary between 10 and 15%. Dissimilar findings were reported by [16] who established that dose levels are not dependent on the equipment related factor of machine model. The difference in findings can be attributed to a number of institutional factors such radiology technicians given that the study was conducted in government referral hospital while the current study conducted among referral hospital and private hospitals.

The finding of a statistically significant variability in radiation dose for contrast-enhanced CT examinations was confirmed for DLP values. The findings suggest that for contrast-enhanced abdominal CT examination, organ dose volumetric DLP remarkably increased. Results of previous studies [17,18] have attributed the increases in CT dose levels to photoelectric absorption and, more so, the generation of secondary electrons due to absorption of x-rays by contrast agent. A study by Jemal E Dawd et al, demonstrated higher CTDIvol and lower DLP values in non-contrast scans for the abdomen as compared to this study. Significant relationship between $DLP_{contrast}$ and $DLP_{non\text{-}contrast}$, with higher values for contrast has been reported in other studies [19–21].

The findings showed that relationship between $CTDI_{vol,\ contrast}$ and $CTDI_{vol,\ non\text{-}contrast}$ is not significant. Shofi et al., (2021) reported in their findings that minimal differences between media values of CTDI contrast and non-contrast is due to the use of same protocol scan for routine abdominal scans with and without the use of a contrast agent. Results of [23,24] also confirmed non-significant differences between $CTDI_{vol}$values contrast and non-contrast media.

The median DLP and $CTDI_{vol}$ values were significantly higher in the public facilities when compared to private facilities. Generally, variation in the protocol can affect the radiation dose; therefore, the same scanner in public vs private hospitals might result in doses higher or lower DRLs and $CTDI_{vol}$ (Marema J et al., 2023). Variation in CT protocols is the largest source of dose variation across imaging facilities and is more important than patient factors or machine make and model in explaining this variation across public and private facilities [25]. This study confirmed that variation in CT protocols within organizations is an important barrier to dose optimization (Dina et al.,2017). Yurt et al.(2020) suggests that technical capacity of radiologists in public and private hospitals also account for variations in mean $CTDI_{vol}$ and DLPs. Technical capacity determines how providers or clinical staff chose to set the machine technical parameters which affect dose levels [10,28]

Abba and Ibrahim (2018) reported higher values of $CTDI_{vol}$ and DLPs in public health facilities as opposed to private health facilities. Similarly, Erem et al., (2022) found out that public health facilities had higher mean values for $CTDI_{vol}$ and DLPs when compared to private health facilities. The authors explained that in public health facilities there is the likelihood of having an aging machine or poorly maintained scanner that may yield values outside the accepted standards for effective radiation dose optimization. DLP is directly proportional to scan length hence the higher DLP could be explained by scanning longer region than required

(Manssor et al.,2015). This could be due to fast scanning technique of CTs especially those with higher slices. Lack of support from radiology leaders for dose optimization activities is also likely a contributing factor higher values for CT examinations in sub-Saharan Africa [25]

V. Conclusions

The median for the Total DLP and for the $CTDI_{vol}$ significantly higher in the public facility, Contrast CT and in Neusoft model CT machine than the private facilities. Dose variations could be attributable to contrast enhancement scans and machine related factors. The variations in dose between CT facilities and as well as between identical scanners suggests an opportunity for dose optimization of examinations.

Acknowledgement

We are grateful to MTRH, Mediheal, St. Lukes, and Eldoret hospitals for providing research facilities. We acknowledge the supporting radiology technician and radiologists for making this a success.

i) Conflict of Interest

None

References

1. Fingerle AA, Noël PB. Dose reduction in abdominal CT: The road to submillisievert imaging. Eur Radiol. 2018;28(7):2743-2744. doi:10.1007/s00330-018-5397-z
2. Korir GK, Wambani JS, Korir IK, Tries M, Kidali MM. Frequency and collective dose of medical procedures in Kenya. Health Phys. 2013;105(6):522-533. doi:10.1097/HP.0b013e31829c35f4
3. Muhogora WE, Ahmed NA, Almosabihi A, et al. Patient doses in radiographic examinations in 12 countries in Asia, Africa, and Eastern Europe: Initial results from IAEA projects. Am J Roentgenol. 2008;190(6):1453-1461. doi:10.2214/AJR.07.3039
4. Waszczuk Ł, Guziński M, Garcarek J, Sąsiadek M. Triple-phase abdomen and pelvis computed tomography: Standard unenhanced phase can be replaced with reduced-dose scan. Polish J Radiol. 2018;83:e166-e170. doi:10.5114/pjr.2018.75682
5. Tsai HY, Tung CJ, Huang MH, Wan YL. Analyses and applications of single scan dose profiles in computed tomography. Med Phys. 2003;30(8):1982-1989. doi:10.1118/1.1590315
6. Nikièma Z, Tové KS De, Sombié I, et al. Compliance of Computed Tomography Scan Requests in Sub-Saharan Africa. Open J Radiol. 2016;6(1):125-130. doi:10.4236/ojrad.2016.62019
7. Uushona V, Boadu M, Nyabanda R, Diagne M, Inkoom S, Issahaku S. ESTABLISHMENT OF REGIONAL DIAGNOSTIC REFERENCE LEVELS IN ADULT COMPUTED TOMOGRAPHY FOR FOUR AFRICAN COUNTRIES : A PRELIMINARY SURVEY. Radiat Prot Dosimetry. 2022;198(7):414-422.
8. Gathuru LM, Daniel G, Elias O, Gathuru LM, Onditi GD, Pitcher RD. Analysis of registered radiological equipment in Kenya. Pan Afr Med J. 2021;40(1):1-12.
9. Wambani JS, Korir GK, Onditi EG. A SURVEY OF COMPUTED TOMOGRAPHY IMAGING TECHNIQUES AND PATIENT DOSE IN KENYA. East Afr Med J. 2010;87(10):400-407.
10. Smith-bindman R, Wang Y, Chu P, et al. International variation in radiation dose for computed tomography examinations : prospective cohort study. 2019:1-12. doi:10.1136/bmj.k4931
11. Korir GK, Wambani JS, Korir IK, Tries MA, Boen PK. NATIONAL DIAGNOSTIC REFERENCE LEVEL INITIATIVE FOR COMPUTED TOMOGRAPHY EXAMINATIONS IN KENYA. Radiat Prot Dosimetry. 2016;168(2):242-252.
12. Adam EAS. Estimation of Patient Dose in Abdominal CT Examinations in some Sudanese hospitals. 2016.
13. Musila M. ABDOMINAL EXAMINATION IN KNH USING 16 MULTI-SLICE CT SCAN : REVIEW OF ALARA PRACTICE IN MANAGING PATIENT DOSE. 2009.
14. Masjedi H, Hosein M, Neda Z, Siahpoush K, Kazem S, Ratki R. European trends in radiology : investigating factors affecting the number of examinations and the effective dose. Radiol Med. 2019;21(3):1-10. doi:10.1007/s11547-019-01109-6
15. Nagpal P, Priya S, Eskandari A, et al. Factors Affecting Radiation Dose in Computed Tomography Angiograms for Pulmonary Embolism : A Retrospective Cohort Study. J Clin Imaging Sci. 2020;10(74):1-8. doi:10.25259/JCIS
16. Tayal S, Ali A. Assessment of Effective Dose Received in Various Computed Tomography Protocols and Factors Affecting It. Indian J Nucl Med. 2021;36(2):1-8. doi:10.4103/ijnm.IJNM
17. Geso M, Tabatabaie F, Doyl E, Algithami S. Investigations of CT Dose with Contrast Agent and Its Effects on the CTDI. J Biomed Sci Eng. 2020;13(12):254-266.

18. Paolicchi F, Faggioni L, Bastiani L, Molinaro S, Caramella D, Bartolozzi C. Real practice radiation dose and dosimetric impact of radiological staff training in body CT examinations. Insights Imaging. 2013;4(2):239-244. doi:10.1007/s13244-013-0241-0
19. Sahbaee P, Abadi E, Segars WP, Marin D, Nelson RC. The Effect of Contrast Material on Radiation Dose at CT : Med Phys. 2017;283(3):749-757.
20. Cauteren T Van, Silva EH Da, Gompel G Van, et al. The Iodine Dose of Administered Contrast Media Determines the Level of Radiation-Induced DNA Damage during Cardiac CT Scans.; 2018.
21. Mazloumi M, Gompel G Van, Kerseman V, Me J de, Buls N. The presence of contrast agent increases organ radiation dose in contrast-enhanced CT. Eur Radiol. 2021;31(2):7540-7549.
22. Shofi M, Utami N, Sutanto H, Anam C, Laksono MB. Effect of Contrast Agent Administration on Size-Specific Dose Estimates (SSDE) Calculations based on Water Equivalent Diameter in CT Head Examinations. Int J Sci Res Sci Technol. 2021;11(1):1-9.
23. Nitasari A, Anam C, Budi WS, Wati AL, Syarifudin S, Dougherty G. Comparisons of Water-Equivalent Diameter Measured on Images of Abdominal Routine Computed Tomography with and without A Contrast Agent Comparisons of Water-Equivalent Diameter Measured on Images of Abdominal Routine Computed Tomography with and without A. Atom Indones. 2021;47(2):2021. doi:10.17146/aij.2021.1112
24. Tobi AC, Mokobia CE, Ikubor JE, Omojola AD, Ekpo ME, Akpolile AF. Diagnostic Reference Levels for Head and Abdominal Computed Tomography of Adult Patients in Selected States in South-South Nigeria. J Radiat Cancer Res. 2021;12(1):46-52. doi:10.4103/jrcr.jrcr
25. Whitebird RR, Solberg LI, Bergdall AR, López-solano N, Smith-bindman R. Barriers to CT Dose Optimization: The Challenge of Organizational Change. Radiat Prot Dosimetry. 2022;28(3):387-392. doi:10.1016/j.acra.2020.02.016.Barriers
26. Yurt A, Özsoykal ˙Ismail, Kandemir R, Ada E. LOCAL STUDY OF DIAGNOSTIC REFERENCE LEVELS FOR COMPUTED TOMOGRAPHY EXAMINATIONS OF ADULT PATIENTS IN IZMIR ,. Radiat Prot Dosimetry. 2020;13(1):1-6. doi:10.1093/rpd/ncaa121
27. Abba M, Ibrahim S. ASSESSMENT OF AVERAGE RADIATION DOSE FOR ABDOMINAL COMPUTED TOMOGRAPHY EXAMINATIONS IN AMINU KANO TEACHING HOSPITAL , KANO. Bayero J Pure Appl Sci. 2018;11(2):1-8.
28. Erem G, Ameda F, Otike C, et al. Adult Computed Tomography examinations in Uganda : Towards determining the National Diagnostic Reference Levels. BMC Med Imaging. 2022;24(1):1-12. doi:10.1186/s12880-022-00838-x