**ADDIS ABABA UNIVERSITY**

**COLLEGE OF HEALTH SCIENCES**

**SCHOOL OF GRADUATE STUDIES**

**DEPARTMENT OF RADIOLOGY**


# A SURVEY OF ROUTINE ABDOMINAL/PELVIC COMPUTED TOMOGRAPHY PROTOCOLS AND RADIATION DOSES IN TIKUR ANBESSA SPECIALIZED HOSPITAL, ADDIS ABABA UNIVERSITY, ADDIS ABABA, ETHIOPIA


**BY: GEBRETSADIK ZEGEYE (MD, RADIOLOGY RESIDENT)**


**THESIS SUBMITTED TO DEPARTMENT OF RADIOLOGY, COLLEGE OF HEALTH SCIENCE, ADDIS ABABA UNIVERSITY IN PREPARATION FOR PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR SPECIALITY CERTIFICATE IN RADIOLOGY**

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**ADDIS ABABA, ETHIOPIA**

**ADDIS ABABA UNIVERSITY**

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THIS THESIS IS ACCEPTED IN ITS PRESENT FORM AS SATISFYING THESIS REQUIREMENT FOR THE STUDY OF SPECIALITY CERTEFICATE IN RADIOLOGY.

APPROVED BY THE EXAMINING BOARD

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## LIST OF ABBREVIATIONS AND ACRONYMS

AAPAM------------American Association of Physicists in Medicine

ACR-----------------Americal College of Radiology

CT ------------------Computed Tomography

CTDIvol-------------Volume Computed Tomography Dose Index

DLP------------------Dose Length Product

E --------------------Effective Dose

ICRP-----------------International Commission on Radiological Protection

IQR------------------Interquartile Range

k----------------------Tissue weighting factor

kVp------------------Tube voltage peak in kilovolt

mAs------------------Tube current-time product in milliampere second

mGy-----------------Milligray

mm-------------------Millimeter

mSv------------------Millisilvert

NDRL---------------National Dose Reference Level

NQF-----------------National Quality Forum

P75-------------------$75^{th}$ Percentile

SPR-------------------Society of Pediatric Radiology

SPSS-----------------Statistical Package for Social Science

TASH----------------Tikur Anbessa Specialized Hospital

UK-------------------United Kingdom

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## ABSTRACT

**Background:** The use of CT in medicine is now firmly established and represents one of the most important radiological procedures performed worldwide. CT is a major source of radiation exposure and provides a substantial proportion of the collective dose from medical exposure.

**Objective:** To investigate routine abdominal/pelvic CT radiation doses in Tikur Anbessa Specialized Hospital (TASH), Ethiopia in 2018.

**Method:** A hospital-based retrospective cross-sectional study was conducted from February 1, 2019 to April 30, 2019, at TASH. The study was conducted among all abdominopelvic CT scans performed in TASH in 2018. After counting the total abdominal/pelvic CT scans, a systematic random sampling method (taking every $K^{th}$) was employed to select study subjects from the image registry (medweband workstation) which contain all performed CT scans. Data were collected from a total of 348 abdominal/pelvic CT scans using a structured data collection format by the principal investigator. Finally, data were entered into EpiData version 3.1 and exported to SPSS version 24 software for analyses. Text, tables, and graphs were used to present descriptive data, and analysis was processed.

**Result:** The mean CTDIvol values of pediatric abdominopelvic CT scans for ages <1yr , 1-5yr, 5-10yr and 10-15yr, respectively, were 6mGy (IQR, 3-7mGy), 4.9mGy (IQR, 3.3-6.8mGy), 4.4mGy (IQR, 4.2-4.6mGy), 4.7mGy (IQR, 3.3-5.1mGy). In adult abdominopelvic CT scans, the mean CTDIvol value was 11mGy (IQR, 7–14 mGy) while the mean DLP for single phase, multi-phase and all examinations, respectively, were 593mGy.cm (IQR, 252-1579 mGy.cm), 1759 mGy.cm (IQR, 978-2268 mGy.cm), and 1180 mGy.cm (IQR, 473-1557 mGy.cm) and the mean effective doses for single-phase, multiphase, and all examinations, respectively, were 8.9 mSv (IQR 5.3-10.8), 26.2 mSv (IQR, 14.3-32.7 mSv), and 17.6 mSv (IQR, 7.1-23.2 mSv). Radiation doses of multiphase examinations were approximately two to three times that of the single-phase examinations. Pediatric radiation doses were 20-25% of those of adults. The mean CTDIvol dose values of our hospital procedures are lower or comparable to those reported internationally except for the two younger age group pediatric patients, which have higher values than other DRLs. Additionally, the DLP and effective doses are considerably higher than those reported international DRLs in comparison to the CTDIvol.

**Conclusion:** Higher doses are primarily due to the consistent problem of poor scan length collimation all ages and both higher tube voltage and longer scanning length in the two younger age group pediatric patients. Thus, the scanning length should be reduced to the needed minimum for the examination in all ages and lower tube voltages shoud be used in the two younger age group pediatricpatients.

# CHAPTER 1. INTRODUCTION

## 1.1. BACKGROUND

Computed tomography (CT) scanning has become very popular in medicine. Recent technical advances, as well as faster scan time, improved spatial resolution, and advanced multiplanar reconstruction techniques have hyperbolic the utility of CT for virtually every anatomic abnormality. Concomitantly, a rise in defensive medicine and an ownership interest in CT centers by referring physicians have resulted in an exceedingly dramatic increase in utilization [1, 2].

Similar CT studies of diagnostic quality should have a relatively narrow range of radiation doses. However, national and multinational surveys indicate that this is not the case; large variability in dose levels exists [3, 4]. Therefore, the International Commission on Radiological Protection (ICRP) introduced the concept of the diagnostic reference level (DRL), based on the seventy-fifth percentile (P75) with the target of providing a reference level for the radiation dose for standard CT examinations [5, 6].

Dose variations in CT are mainly because of different scanner types/manufacturers and different scanning protocols (kVp, mAs), also because of variations within the elite length of the region to be scanned, tube rotation speed, helical pitch, collimation, filtration, patient weight, etc. Increasing pitch and decreasing mAs and beam energy has the lowest dose radiation with higher imaging quality at diagnostic levels [7, 8].

The use of Diagnostic Reference Levels (DRLs) has been planned as an associate optimization tool because it identifies high dose practices wherever dose-reduction techniques would have the best impact and to generate triggers to optimize radiation doses per the ALARA (As Low As Reasonably Achievable) principles [9, 10]. National diagnostic reference levels are set at the 75 percentile (P75) of dose distribution from a survey conducted across a broad user base employing a specified dose measurement protocol and phantom. Reference values can also be established at an institution practice level, and these are referred to as local DRLs (LDRLs). These values should be reviewed more frequently than national DRLs, allowing greater local control and therefore increased opportunity for management and optimisation of doses. Because of the smaller sample sizes in a local survey, LDRLs are usually calculated from the mean of the local dose distribution rather than from the third quartile. when doses are assessed from a patient survey at a practice level, minimum recommended number of patients should be 10. DRLs are expressed in terms of Computed Tomography Dose Index (CTDI), dose length product (DLP) and effective dose (E) [6, 9, 10].

CTDI is the primary dose measurement in CT which measures average absorbed doses along the z-axis from serious of contiguous irradiation per axial CT scan. It has also numerous variant measurement parameters like CTDIvol that measures the average dose within the scan volume over x,y,z direction to a standardized phantom in cm. However, it has limitations. For example, it hardly represents the dose for objects of substantially different sizes, shapes, or attenuation, like the human body. Further, it does not indicate the entire energy deposited into the scan volume [11].

The other dose metric used is DLP which reflects the total energy absorbed (and thus the potential biological effect) attributable to the complete scan acquisition. DLP (mGy.cm) is a product of CTDIvol (mGy) and irradiated scan length (cm) [11].

For body CT examinations, almost all scanners today display patient dose descriptors (CTDIvol and DLP) that relate to the large 32 cm dosimeter body phantom regardless of the pediatric body size and small 16cm dosimeter for head and neck. CT users should be aware that this metric underestimates patient dose in pediatric CT and that this has consequences on the accuracy of patient dose registration [7].

Effective dose (E) is an important dose quantity related to the probability of health detriment due to stochastic effects, which depends on the patient's sex and age at exposure, and which takes account of the relative radiosensitivity of the various organs in the scanned region. E is a derived quantity and can be utilized for comparison purposes between studies. A practical approach for assessing E is to use the DLP value, displayed on the console after the examination, using age and region-specific conversion coefficients (E/DLP) which are considered independent of CT scanner type and manufacturer ($E=k \times DLP$) [12].

Recording of the radiation dose (CTDIvol, DLP) for every CT study by a dose-tracking system allows knowing whether the doses are below or above the P75 of the national DRLs. When needed, dose optimization to obtain CTDIvol and DLP values below the P75 will be undertaken (adapting mAs, kVp, and use of iterative reconstruction) [13].

The strategy for the present survey ideally involved the calculation of values of CTDIvol and DLP for each sequence. This was accomplished on the basis of the scan settings and scanner-specific CTDI coefficients as part of its CT patient dosimetry calculator.

## 1.2. STATEMENT OF THE PROBLEM

CT is a valuable tool in diagnostic radiology. The number of CT scans being performed annually is unceasingly increasing. More than two-thirds of all medical radiation can now be attributed to CT, with the majority resulting from examinations of the Head, chest and abdominopelvic [3, 4].

CT scanning is a relatively high-dose procedure, and many patients have to undergo multiple scans [3,4]. The use of CT in private and governmental health institutions in Ethiopia is on increase. Thus, a compelling need to teach, understand, and use; detailed information regarding CT dose has also increased.

The doses delivered from a common CT scan can lead to an increased risk of radiation evoked carcinogenesis, particularly in children [14] thus methods that minimize radiation dose are mandatory. National, international regulatory authorities and research groups investigate ways for reducing patient exposure and optimizing scanning protocols [9, 11]. Justification and optimization, as well as the development of reference dose values, are particularly important, especially in pediatrics, given the contribution of CT scanning to population dose [15]. Applying optimized technical parameters can decrease radiation exposure by up to 65% [16].

## 1.3. SIGNIFICANCE OF THE STUDY

With the increasing use of CT scanning, concerns about radiation exposure have been growing in recent decades. Several studies have been conducted to estimate these radiation exposure levels, but to my best knowledge no survey of CT radiation dose had previously been conducted in Ethiopia with regard to the age and sex distribution of patients receiving CT scans, what type of scan or how much radiation dose they receive.

This study provides a summary of scanning parameters and radiation doses of adults and pediatric abdominopelvic CT scans based on the number of consecutive scans performed at Tikur Anbessa specialized hospital. The measurements, organized according to patient age and number of phases, offer practical data that other CT imaging facilities can use as a starting point for assessing their own doses when more detailed and protocol-specific targets are not available. Furthermore, my data can contribute to the creation of radiation dose benchmarks by oversight and health care quality organizations.

Facilities can use these summary data in two ways. First, they can compare their scanning parameters and dose distributions to our reported values to determine whether their doses are within this attainable range. If distributions are considerably higher (e.g., if medians are higher than our 75th percentiles), the institutions could review protocols and scanner settings. Second, in the absence of broadly accepted diagnostic reference levels, these summary data can contribute to the creation of meaningful reference levels in Ethiopia.

In addition, a technologist setting scanner parameters for a patient could compare prescan CTDIvol and DLP values reported by the scanner with our summary data. If the planned scan would lead to doses higher than our 75th percentile or even higher than the 50th percentile, depending on how aggressively an institution wants to optimize doses, with no clear clinical or patient-specific indications to exceed this level, a radiologist or physicist could be consulted to determine whether altering scanning parameters might be possible.

Although my present survey is conducted from a single facility and a single body region, it represents the first survey of the radiation exposure of pediatric and adult CT scans in Ethiopia.

# CHAPTER 2. LITERATURE REVIEW

Many works of literature show that there are wide variations in radiation doses because of the use of different imaging protocols and the intrinsic differences among makes and models of CT scanners [17-19].

According to the 2000 report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the age distribution of patients having CT scans in countries with a relatively high level of medical care (other than the United States), For body CT, 3% were done on patients aged 0–15 years, 24% in patients aged 16-40 years and 73% in those aged over 40 years. This data also indicated that there is a male/female ratio of 51/49 for body CT examinations [20].

Many articles done in 2001 pointed out that using adult CT protocols for pediatric patients resulted in estimated radiation doses to the smallest children as much as three times that of an adult [8, 14, 21].

According to a 2003 UK survey of CT doses, the mean radiation doses CTDIvol value from the abdominal scan in adults was 12mGy (IQR, 9.8-14 mGy) while the mean DLP was in the range of 292-539 mGy.cm depending on the number of phases. The mean effective dose was also in the range of 4.4-8.1mSv [6].

In 2oo8 age-based diagnostic reference level (DRL) of pediatric doses on CT scanning on abdomen was surveyed in Switzerland in 10 centers. The scanning parameters used were a number of series, kilovoltage, tube current, rotation time, reconstruction slice thickness and pitch, volume CT dose index (CTDIvol) and dose length product (DLP). The covered ages were 0-15 years with 4 groups (<1, 1-5, 5-10, 10-15). The result shows a great vary of CTDI and DLP in different centers with the proposed DRLs for abdomen in terms of CTDIvol is 16 mGy, and in terms of DLP is 500 mGy.cm [22].

According to 2011 summarized doses from 42 published studies, the median effective dose in the abdomen scan in adults was 7.9 mSv (1.4–31.2 mSv) while the median DLP was 464 mGy.cm (58–2537 mGy.cm) [19].

In a study done in 2011 ionizing radiation in abdominal CT, the mean effective dose per patient for the entire patient population was 25.8 (24.2, 27.5) mSv (range: 3.5–144 mSv) with a mean effective dose per CT phase of 14.1 (13.6, 14.7) mSv (range: 2.1–71.0 mSv) [1].

Another study conducted in 2012 by Stamm from a broad review of diagnostic reference levels (set at the 75th percentile), reported reference levels for the DLP of 534–1629 mGy.cm in the abdominal scan of adults [23].

In one study done in 2015 from Five University of California Medical Centers, the median radiation dose in adults for abdominal scans was 12 mGy (IQR, 8–17 mGy). The median DLPs for single-phase, multiphase, and all examinations, respectively, were 580 mGy.cm (IQR 360–860 mGy.cm), 1220 mGy.cm (IQR, 850–1790 mGy.cm), and 960 mGy.cm (IQR, 600–1460 mGy.cm) while the median effective doses for single-phase, multiphase, and all examinations, respectively, were 10 mSv (IQR, 6–16 mSv), 22 mSv (IQR, 15–32mSv), and 17 mSv (IQR, 11–26 mSv). Effective doses and DLPs for multiphase examinations were approximately twice those for single-phase examinations. In children, median radiation doses were substantially lower than those in adults, approximately 25% of those adults. The median CTDIvol value in children for abdominal scans was 4mGy (IQR, 2–5 mGy). Most examinations in children were single phase, with the median DLP of 140 mGy (IQR, 90-230 mGy) [24].

According to 2015 National Diagnostic Reference Level Initiative for Computed Tomography Examinations in Kenya, the mode and range kVp, mAs, rotation time (Sec), slice thickness (mm) and pitch abdominal CT, respectively, were 120 (110-120), 160 (70-313), 0.8 (0.4-1), 5 (1-5) and 1 (0.94-2) in pediatric while that of adults, respectively, were 120 (80–140), 100 (61–415), 0.75 (0.4–1.5), 3 (0.5–8) and 0.9 (0.43–2.0) [25].

According to 2017 adult CT-dose levels of regional and national references Benchmarking using a dose-tracking software, the median CTDIvol for CT-abdomen-pelvis scan of adults range from 4.0-10.8mGy with a slight female dominance for CT-abdomen-pelvis: 0.91 [13].

According to the 2018 Nigerian Diagnostic reference levels for common computed tomography (CT) examinations, Patients’ age ranged from 19–90 years, with males and females, almost equally split (53.3% versus 46.7%, respectively). Abdomen/pelvic examinations were performed with 120–140kVp and the tube current-time product varied from 180–300mAs, with many centers performing in automatic mA mode. Gantry rotation time varied from 0.5–2.0s. The CTDIvol for abdomen/pelvic examination ranged from 6.7–204mGy and the DLP varied from 416–4466mGy.cm. The median, 75th and 25th percentiles of CTDIvol, DLP, and effective dose, respectively, were 14mGy, 11mGy, 20 mGy; 1073mGy.cm, 661mGy.cm, 1486 mGy.cm and 16.08 mSv, 9.92 mSv, 22.29mSv [26].

# CHAPTER 3. OBJECTIVES

## 3.1. GENERAL OBJECTIVE

To investigate abdominal/pelvic Computed Tomography radiation doses in Tikur Anbessa Specialized Hospital, 2018.

## 3.2. SPECIFIC OBJECTIVES

To compare adult and pediatric abdominal/pelvic CT radiation doses.

To determine abdominal/pelvic CT radiation dose variations and compare with other studies and national standards.

To determine factors for high CT radiation dose exposure in pediatrics and adults.

# CHAPTER 4. MATERIALS AND METHODS

## 4.1. STUDY AREA

The study was conducted in Tikur Anbessa Specialized Hospital, College of Health Science, Addis Ababa University, Addis Ababa, Ethiopia. TASH is under the administration of Addis Ababa University and located in the nation's capital, Addis Ababa. It is the largest referral and the main teaching hospital in the country. The hospital has around 700 beds and gives diagnostic and treatment services for about 370,000-400,000 patients per year. The Radiology department is one of the many departments in the institution which gives imaging service and academic activities. It has two CT scans (64 and 128 slices), one Magnetic Resonance Image machine (1.5T), 3 X-ray machines and an adult and pediatric ultrasound unit.

## 4.2. STUDY DESIGN AND PERIOD

A Hospital-based retrospective cross-sectional study was conducted from February 1, 2019 – April 30, 2019, to address the specific objectives.

## 4.3. SOURCE POPULATION

All abdominal/pelvic CT scans performed in TASH.

## 4.4. STUDY POPULATION

All abdominal/abdominopelvicc CT scans performed in TASH at any time in 2018.

## 4.5. STUDY UNIT

Each selected abdominal/pelvic CT scan performed in TASH in 2018.

## 4.6. INCLUSION AND EXCLUSION CRITERIA

### 4.6.1. INCLUSION CRITERIA

Abdominal/pelvic CT scans performed in TASH at any time in 2018 with complete degmographic variables and dose report data.

### 4.6.2. EXCLUSION CRITERIA

Abdomin/pelvic CT scans performed with some other body parts at the same time. (E.g. Chest and abdomen)

Abdominopelvic CT scans performed for treatment planning or attenuation corrections have made (interventional procedures and low dose CT).

## 4.7. SAMPLING TECHNIQUE

### 4.7.1. SAMPLE SIZE DETERMINATION

The total abdominopelvic CT scans performed in 2018 are counted from image registry (medweb) which is a simple and complete diagnostic tool with reporting, storage and messaging uses. The total number of abdominopelvic CT scans performed in 2018 was 3,665 which are obtained as a list according to the time at which they are performed. So we have a total population of 3,665 subjects for the study. From this population, we can determine the sample size. In the survey study, it is nearly always safest to stay with a 50% distribution, which is the most conservative. Considering 95% Confidence interval with a 5% margin of error, and employing a single population proportion formula the sample size can be calculated as follows.

The sample size $n = z^2 p(1-p)/d^2$

$Z^2$ = at 95% confidence interval Z value ($\alpha = 0.05$) = 1.96

p = population distribution of the event to be studied 50% (0.5)

d = Margin of error at (5%) (0.05)

$n_0 = (1.96)^2(0.5)(1-0.5)/(0.05)^2 = 384$

USING THE FINITE POPULATION CORRECTION FACTOR

$$n = \frac{n_0 N}{n_0 + (N-1)},\ n = \frac{(384)(3665)}{384 + (3665-1)} = 348$$

So the total sample size will be 348.

### 4.7.2. SAMPLING METHOD

Study Subjects/CT scans are selected using a systematic random sampling method (every $K^{th}$) after calculating the "K" value by dividing the total number of abdominal/abdominopelvic CT scans performed in 2018 to the required sample size.

$$K = \frac{3665}{348} = 10.53$$

The calculated "K" value will be "10". The first subject will be selected randomly by the lottery method and then continued every $10^{th}$ value in a similar pattern until the required number of samples were collected. If the selected "$K^{th}$" case does not fulfill the inclusion criteria, the immediate next case will be used.

## 4.8. DATA COLLECTION PROCEDURES (INSTRUMENT, PERSONNEL, DATA QUALITY CONTROL)

### 4.8.1. DATA COLLECTION INSTRUMENT AND DATA COLLECTOR

The data were collected using a structured data collecting instrument. A structured data collection format was prepared and filled by the principal investigator. The data collecting format has included quantities for assessing CT doses like $CTDI_{vol}$, DLP, and scan parameters like kVp and mAs. The data collecting format also had socio-demographic characteristics like age and sex. All data regarding data collecting format were retrieved from the image registry (medweb or CT workstations).

### 4.8.2. DATA QUALITY CONTROL

Data from each collection format were checked for its completeness, clarity, consistency, and accuracy.

Data were collected by the principal investigator who is well trained to understand and retrieve CT doses and scan parameters.

Onsite supervision was done by the principal investigator during data collection.

## 4.9. STUDY VARIABLES

### 4.9.1. DEPENDENT VARIABLES

Volume Computed Tomography Dose Index (CTDIvol)

Dose Length Product (DLP)

Effective Dose (E)

### 4.9.2. INDEPENDENT VARIABLE

Age

Tube current-time product (mAs)

Tube voltage peak in kilovolts (kVp)

Contrast Usage

Pitch

Collimation

Rotation time

Phantom Type

## 4.10. DATA PROCESSING AND ANALYSIS

Data entry was done with EpiData version 3.1 and exported to SPSS version 24 software for analyses. The data were processed by using descriptive analysis, including frequency distribution, cross-tabulation and summary measures to see the relation between the dependent variable and independent variables. Finally, the results are presented in text, charts, graphs, and tables.

## 4.11. ETHICAL CONSIDERATION

Data collection was started after getting permission from the ethical review committee of the Department of Radiology, TASH, Addis Ababa University.

## 4.12. OPERATIONAL DEFINITIONS

Volume Computed Tomography Dose Index (CTDIvol): a standardized measure of the radiation output of a CT scanner through a slice of an appropriate phantom.

Dose length product (DLP): a measure of CT tube radiation output/exposure for the length of scan.

Effective dose (E): the radiation dose that must be delivered to the whole body to yield the same biological consequences (specific for cancer induction only) as the dose actually received by the exposed organs.

National diagnostic reference level (NDRL): the third quartile value of measured national patient dose distributions for a specific procedure.

Local diagnostic reference level (LDRL): the mean value of patient dose for sampled patients at a specific CT facility or hospital radiological practice.

# CHAPTER 5. RESULT

## 5.1. SOCIO-DEMOGRAPHIC CHARACTERISTICS

From a total of 3665 abdominal/abdominopelvicc CT scans with a calculated sample size of 348 abdominopelvic CT scans are reviewed. The age of participants ranges from 2months to 82yrs with a mean age of 5.4yrs in pediatric and a mean age of 46.9yrs in adults. The proportion of males and females is almost equal (50.6% versus 49.4% respectively). 50(14.4%) of them are pediatrics and 298(85.6%) are adults [Table 1].

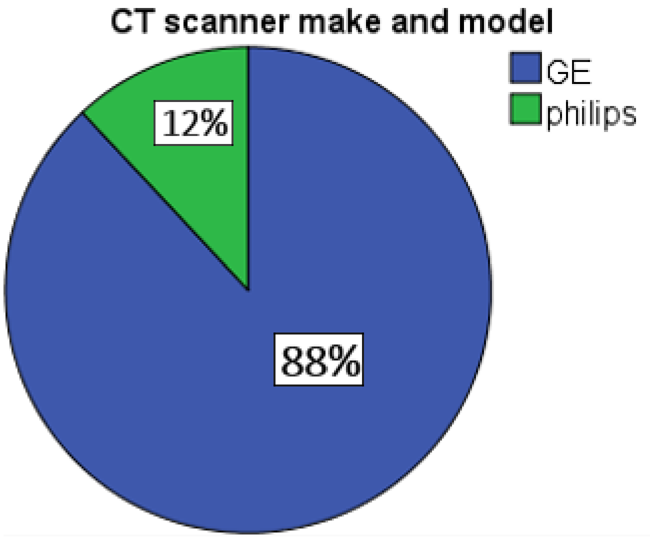
Table 1: Sociodemographic characteristics of patients who had undergone abdominopelvic CT in Tikur Anbessa Specialized Hospital, Ethiopia, 2018.

| Age Group | Sex of Participant | | Total | Percent | |
|---|---|---|---|---|---|
| | Male | Female | | | |
| <1 | 4 | 7 | 11 | 3.2 | 14.4 |
| 1-5 | 11 | 8 | 19 | 5.5 | |
| 5-10 | 6 | 6 | 12 | 3.4 | |
| 10-15 | 5 | 3 | 8 | 2.3 | |
| ≥15 | 150 | 148 | 298 | 85.6 | 85.6 |
| Total | 176 (50.6%) | 172 (49.4%) | 348 | 100.0% | |

## 5.2. EXPOSURE FACTORS/SCANNING PARAMETER CHARACTERISTICS

The majority of patients (88%) were scanned with GE Medical Systems, Optima CT660 CT scan machine (64 slices) while the remaining were scanned with Philips, Ingenuity CT scan machine (128 slices) [Figure 1].

Figure 1: Diagram showing the frequency distribution of CT scanner make and model used for abdominopelvic CT scanning in Tikur Anbessa Specialized Hospital, Ethiopia, 2018.




Abdominopelvic examinations were performed with a tube voltage of 120 kV (98.9 % of patients) and 100kV (1.1% patients) and the tube current-time product (mAs) ~100mAS in pediatrics and varied from 80–290mAs in adults. All adult examinations were performed in automatic mA mode (mean range varying from 50.5mA to 498.5mA) while most pediatric examinations (86%) were performed in fixed mA (ranging from 50mA to 120mA). Gantry rotation time varied from 0.4-0.9seconds. Almost all scans performed with GE scanner have a slice thickness of 5mm while those performed using Philips scanners have slice thickness varying from 0.8mm to 3mm. Almost all scans performed with GE scanner have a pitch factor of 0.98 in adults and 1.38 in pediatric patients while those performed using Philips scanners have a pitch factor of 0.89 in adults and 1.1 in pediatric patients [Table 2 and 3].

The total scan length in pediatric patients varies from 138.91mm to 560.57mm while that of adults varies from 274.95mm to 635.57mm with a mean of 530.57mm. Most examinations (77.1%) in pediatric were single-phase post-contrast scans while the remaining were multiphase scans. Half (50.3%) of examinations in adults were multiphasic scans with the majority having three and above phase scans [Tables 3].

Table 2: Range (Mean) of clinically used exposure factors during abdominopelvic CT scanning in Tikur Anbessa Specialized Hospital, Ethiopia, 2018.

| Age Group | No. of Examinations | mAs Range (Mode) | mA Range (Mode) | Automatic Tube current modulation (%) | Rotation Time (sec) Range (Mode) | Slice thickness (mm) Range (Mode) | Pitch Range (Mode) | Contrast medium Use Yes/No(%) |
|---|---|---|---|---|---|---|---|---|
| Pediatrics | 50 | 24-202(55) | 50.0-288.3(110.0) | 14% | 0.4-0.8(0.5) | 2.0-5.0(5.0) | 0.98-1.38(1.38) | 99%/1% |
| Adults | 298 | 35-292(106) | 50.5-498.5(152.5) | 100% | 0.5-0.9(0.7) | 0.8-6(5) | 0.89-1.38(0.98) | 98%/2% |

Table 3: Cross-tabulation of Tube voltage used and scan length * age of study participants of abdominal/abdominopelvic CT in Tikur Anbessa Specialized Hospital, Ethiopia, 2018.

| Age group | kVp (kV) | | Scan Length (cm) |
|---|---|---|---|
| | 100 | 120 | Mean (IQR) |
| <1 | 2 | 9 | 31(26-32) |
| 1-5 | 1 | 18 | 30(29-33) |
| 5-10 | 0 | 12 | 37(30-43) |
| 10-15 | 0 | 8 | 42(32-46) |
| >15 | 1 | 297 | 53 (50-56) |
| Total | 4 (1.1%) | 344 (98.9%) | |

## 5.3. DOSE PARAMETER CHARACTERISTICS

The mean CTDIvol values of pediatric abdominopelvic CT scans for ages <1yr , 1-5yr, 5-10yr and 10-15yr, respectively, were 6mGy (IQR, 3-7mGy), 4.9mGy (IQR, 3.3-6.8mGy), 4.4mGy (IQR, 4.2-4.6mGy), 4.7mGy (IQR, 3.3-5.1mGy) [Table 4].

The mean CTDIvol value of that of adult abdominopelvic CT scans was 11mGy (IQR, 7–14 mGy) while the mean DLP for single phase, multi-phase and all examinations, respectively, were 593mGy.cm (IQR, 252-1579 mGy.cm), 1759 mGy.cm (IQR, 978-2268 mGy.cm), and 1180 mGy.cm (IQR, 473-1557 mGy.cm) while the mean effective doses for single-phase, multiphase, and all examinations, respectively, were 8.9 mSv (IQR 5.3-10.8), 26.2 mSv (IQR, 14.3-32.7 mSv), and 17.6 mSv (IQR, 7.1-23.2 mSv) [Table 4].

Radiation doses of multiphase examinations were approximately two to three times that of the single-phase examinations. Pediatric radiation doses were 20-25% of those of adults [Table 4].

Table 4: Radiation Dose Metrics in pediatrics and adult abdominopelvic CT in Tikur Anbessa Specialized Hospital, Ethiopia, 2018.

| Age Category | No. of Exam | CTDIvol (mGy) | | | | DLP (mGy.cm) | | | | Effective Dose (mSv) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LDR L/M | 25th | 50th | 75th | LDR L/Mean | 25th | 50th | 75th | LDR L/Mean | 25th | 50th | 75th |
| **Pediatrics** | | | | | | | | | | | | | |
| <1yr | 11 | 6 | 3 | 3.1 | 7 | 456 | 99 | 120 | 192 | 10.2 | 4.1 | 5.9 | 8.8 |
| 1-5yrs | 19 | 4.8 | 3.3 | 3.3 | 6.8 | 167 | 102 | 123 | 171 | 4.0 | 3.0 | 3.7 | 4.5 |
| 5-10 yrs. | 12 | 4.4 | 4.2 | 4.4 | 4.6 | 238 | 139 | 173 | 285 | 4.7 | 2.8 | 3.5 | 5.7 |
| 10-15yrs | 8 | 4.7 | 3.9 | 4.4 | 5.1 | 376 | 139 | 201 | 427 | 3.7 | 2.1 | 3.0 | 6.4 |
| Single | 40 | | | | | 214 | 102 | 128 | 263 | 4.0 | 3.0 | 3.7 | 4.1 |
| Multi | 10 | | | | | 629 | 172 | 215 | 676 | 11.6 | 3.4 | 6.4 | 13.2 |
| All | 50 | 5 | 3 | 4 | 6 | 309 | 111 | 139 | 369 | 5.6 | 3.0 | 3.7 | 6.6 |
| **Adults** | | | | | | | | | | | | | |
| Single | 147 | | | | | 593 | 359 | 481 | 723 | 8.9 | 5.4 | 7.3 | 10.8 |
| Multi | 151 | | | | | 1759 | 978 | 1548 | 2268 | 26.2 | 14.3 | 22.8 | 32.7 |
| All | 298 | 11 | 7 | 9 | 14 | 1180 | 473 | 882 | 1557 | 17.6 | 7.1 | 13.2 | 23.2 |

# CHAPTER 6. DISCUSSION

## 6.1. Exposure Factors

The tube voltage (varying between 100 and 120kVp with modal value of 120kVp) in adults, the rotation time (varying between 0.4 and 0.8sec with modal values of 0.5sec in children and varying between 0.5 and 0.9sec with modal values of 0.7sec in adults), use of helical scanning, slice thickness and pitch correspond to the trends seen in most countries [Kenya, 2016 [24]; Nigeria, 2018 [26]; Switzerland, 2010 [28] and Egypt, 2016 [32]]. The use of higher tube voltage (120kVp) in the two younger age group pediatric patients in our practice is unlike the standard recommendations [11] and other international practices. The use of contrast is 98% in this study unlike the Egyptian study [32] which is 100%. The possible explanations are individual considerations for the follow up of patients with established diagnoses and requests that are not reviewed by the radiology residents/radiologists in emergency patients especially emergency physicians order non-contrast abdominal CT for trauma patients. The tube current to time product (mAs) values of this study is lower or comparable with other African and European pactices [24, 26, 32] with a variation of 2-21% in adults and by up to 35% in children. [Table 6].

Table 5: Comparison of Exposure/Scanning parameters of pediatric and adult abdominopelvic CT in Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia, 2018, with international practices in ( Nigeria, 2018 [26]; Kenya, 2016 [24]; Egypt, 2016 [32]; Switzerland, 2010 [28]).

| Country<br>Age Group | kVp (kV),<br>Range (Mode) | mAs,<br>Range (Mode) | Rotation Time (sec),<br>Range (Mode) | Slice thickness (mm),<br>Range (Mode) | Pitch,<br>Range (Mode) | Contrast medium Use Yes/No(%) |
|---|---|---|---|---|---|---|
| Current Study (Ethiopia) | | | | | | |
| Pediatrics | 100-120(120) | 24-202(55) | 0.4-0.8(0.5) | 2.0-5.0(5.0) | 0.98-1.38(1.38) | 98%/2% |
| Adults | 100-120(120) | 35-292(106) | 0.5-0.9(0.7) | 0.8-6(5) | 0.89-1.38(0.98) | 98%/2% |
| Kenya 2016 [24] | | | | | | |
| Pediatrics | 110-120(120) | 70-313(160) | 0.4-19(.8) | 1-5(5) | 0.94-2(1) | |
| Adults | 80–140(120) | 61–415(100) | 0.4-1.5(0.75) | 0.5-8(3) | 0.43-2.0(0.9) | |
| Nigeria 2018 [26] | | | | | | |
| Adults | 120-140(120) | 180-300 | 0.5-2.0 | | | |
| Egypt 2016 [32] | | | | | | |
| Adults | 100–135 (120 | 100–430 (100) | 0.28–1.0 (1.0) | | 0.2–1.5 (1.0) | Yes (100%) |
| Switzerland 2010 [28] | | | | | | |
| Adults | 120-140(120) | 75-424(165) | | | (0.93–1.38)<br>1.07 | |

The scan lengths used in our practice are higher than other international practices [Table 6] with a variation of 19-45% in adults and 5%-37% in pediatric. The possible explanation is scanners/technologists are collimating the scan length to the needed minimum for the examination (e.g. the abdomen/pelvis should be scanned from top of liver to either iliac crest or pubic symphysis, depending on clinical indications)

Table 6: Comparison of Scan length of pediatric and adult abdominopelvic CT in Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia, 2018, with international practices and recommendations (German, 2006 [36]; Switzerland, 2010 [28] and Aliasgharzadeh A et al. 2018, Iran [38]

| Age group | Scan Length (cm) | | | |
|---|---|---|---|---|
| | Current study (Ethiopia), Mean(IQR)/Variation | Germany, 2006, P75 | Switzerland 2010, P75 | Aliasgharzadeh A et al. 2018, Iran |
| <1 | 31(26-32)/37.6% | 20 | | |
| 1-5 | 30(29-33)/6.3% | 28.1 | | |
| 5-10 | 37(30-43)/16% | 31.6 | | |
| 10-15 | 42(32-46)/5% | 40 | | |
| >15 | 53 (50-56)/19-45% | - | 41(38-45) | 29.4(24.6-33) |

## 6.2. Dose Indices and DRLs

In all adults and the two older age group pediatric abdominopelvic CT examinations at TASH, the mean CTDIvol values (11mGy in adults, 4.4mGy in 5-10yrs and 4.7mGy in10-15yrs) are lower than most international DRLs by a variation of 11% to 127.3% in adults, 9% to 68% in 5-10yrs and 109% to 115% in 10-15yrs. [Figure 2 and 5]. This implies that the protocol settings for the adults and two older age group pediatric abdominopelvic scans at the TASH are well optimised and reflect current international practice.

In the two younger age group pediatric abdominopelvic CT examinations at TASH, the mean CTDIvol values are higher than most international DRLs by a variation of 17-35% in <1yr and 2% in 1-5yrs of age group [Figure 5]. The possible explanation for this high CTDIvol values are the persistent use of 120kVp instead of 80kVp which was used in other practices.

The adult mean DLP values of this study are higher than national DRL values of NFQ, 2014 [27]; ACR-AAPAM-SPR, 2018 [39] and Switzerland, 2010 [28], variation of 24.6-46.4% but lower than the national DRL values of US 2015 [25] and Nigeria 2015 [28], by a variation of 23.7-36% [Figure 3]. The adult mean effective dose (E) values of this study are higher than the DRL values of NFQ 2014 [27] by a variation of 15% and lower than the national DRL values of Nigeria, 2015 [28] and US, 2015 [25] by a variation of 26.7-47.7% [Figure 4]. The dose saving achieved through the selection of protocol settings, evident in the CTDIvol values in our institution, appears to be offset to when assessed with the DLP and effective dose values. The possible explanation for the higher DLP and effective dose as compared to CTDIvol in our study may be due to the use of higher scanning length in our institution as DLP is a product of CTDIvol and scan length.

The under 1yrs old pediatric mean DLP and effective dose values in our institution are significantly higher than the international DRL values of German, 2006 [36] and others with a variation of 50-80% [Table 5 and 6]. The possible explanations for the higher doses for this age group in our institution may be due to the persistent use of both higher tube voltage (120kVp) and longer scanning length. Poor correlation of patient age (which is used during scanning ) with weight can also contribut for this.

Figure 2: Comparison of the mean CTDIvol values of adult abdominopelvic CT in Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia, 2018, with international diagnostic reference levels in (NFQ, 2014 [27]; US, 2015 [25]; Nigeria, 2018 [26]; Switzerland, 2010 [28] and ACR-AAPAM-SPR, 2018 [39])

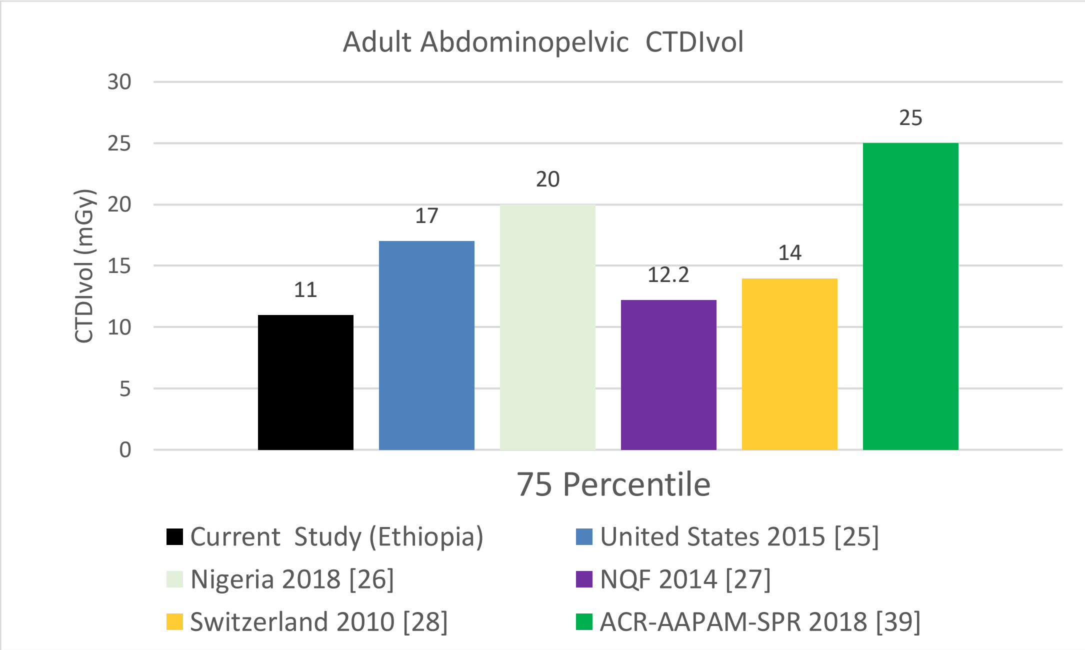



Figure 3: Comparison of the mean DLP values of adult abdominopelvic CT in Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia, 2018, with international diagnostic reference levels in (NFQ, 2014 [27]; US, 2015 [25]; Nigeria, 2018 [26]; Switzerland, 2010 [28] and ACR-AAPAM-SPR, 2018 [39])

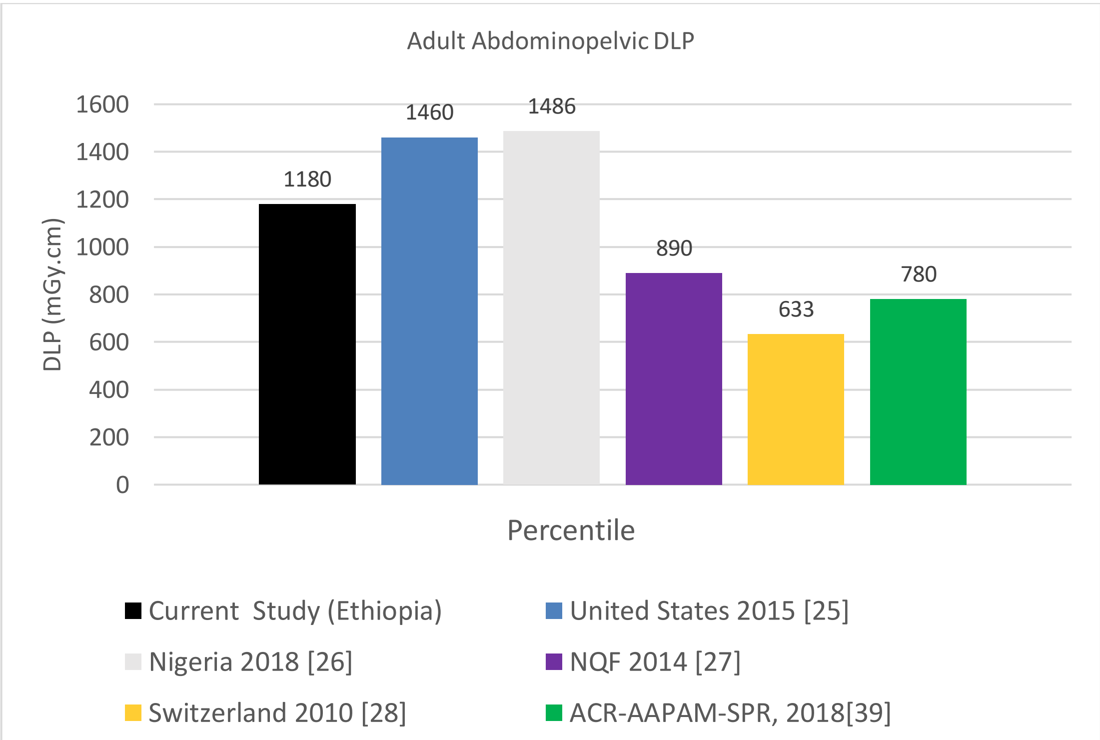


Figure 4: Comparison of the mean effective dose values of adult abdominopelvic CT in Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia, 2018, with international diagnostic reference levels in (NFQ, 2014 [27]; US, 2015 [25] and Nigeria, 2018 [26]).

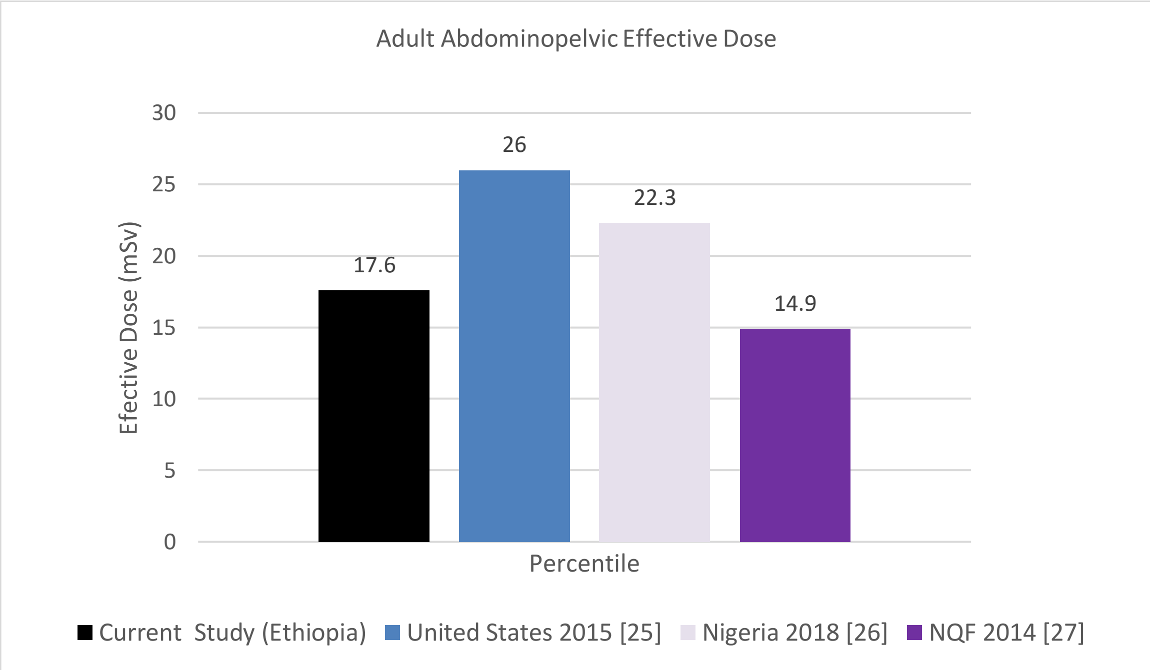



Figure 5: Comparison of the mean CTDIvol values of pediatric abdominopelvic CT in Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia, 2018, with the international DRLs in (Germany, 2006 [36]; ACR-AAPAM-SPR, 2018 [39] and Switzerland, 2008 [35]).

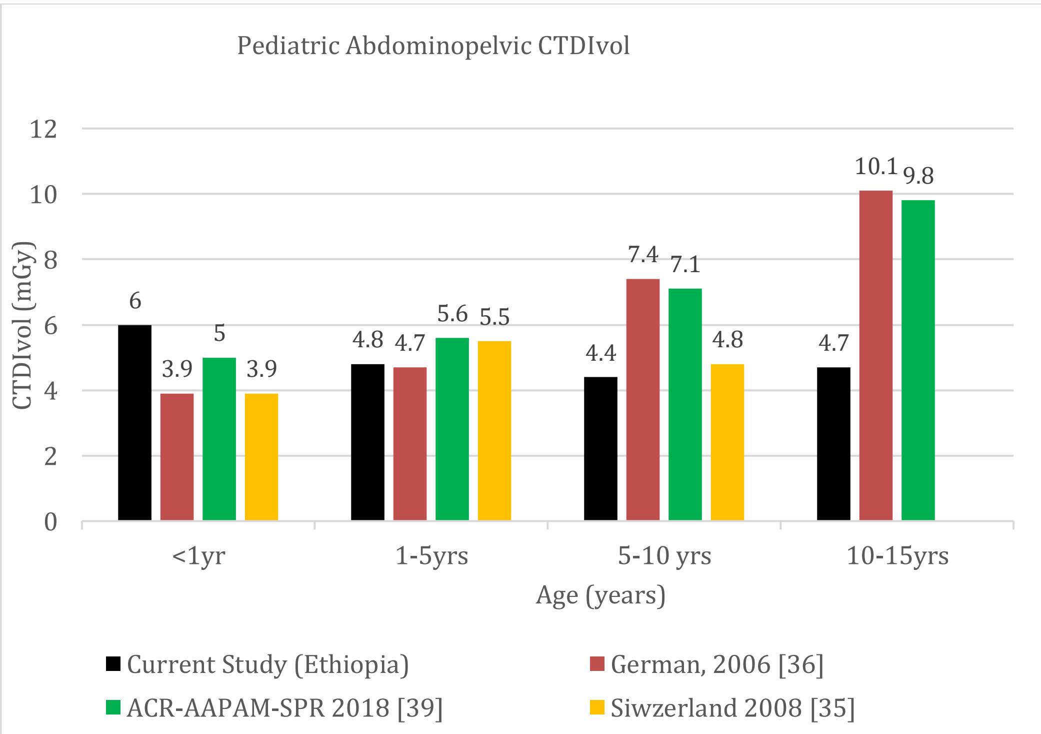


Figure 6: Comparison of the mean DLP values of pediatric abdominopelvic CT in Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia, 2018, with the international diagnostic reference levels in (Germany, 2006 [36]; ACR-AAPAM-SPR, 2018 [39] and Switzerland, 2008 [35]).

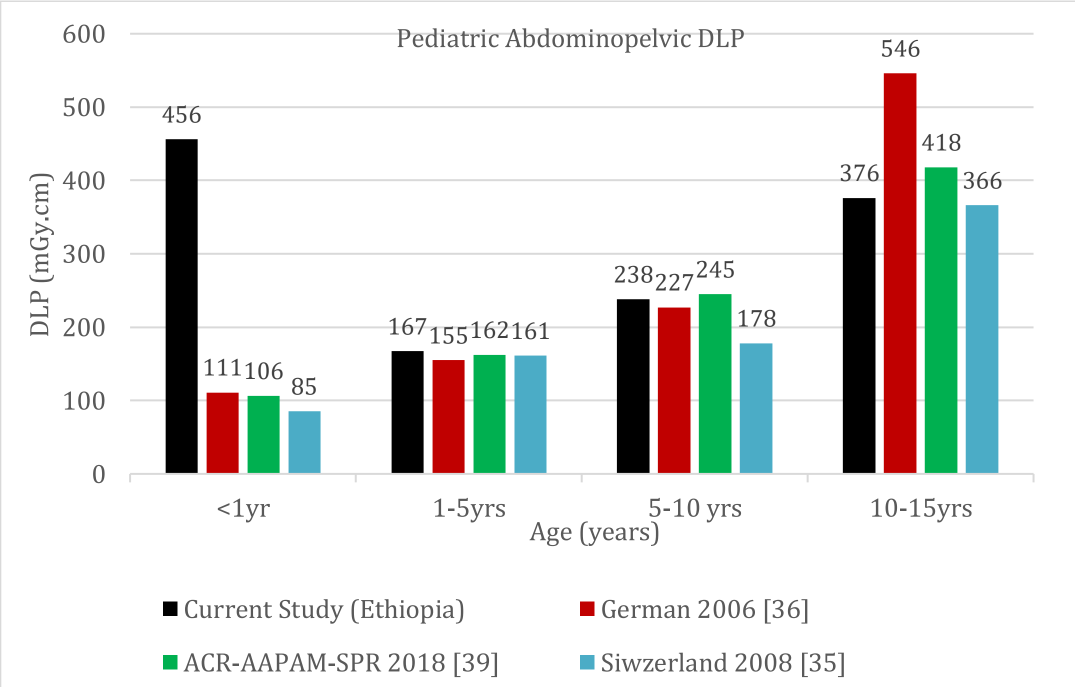
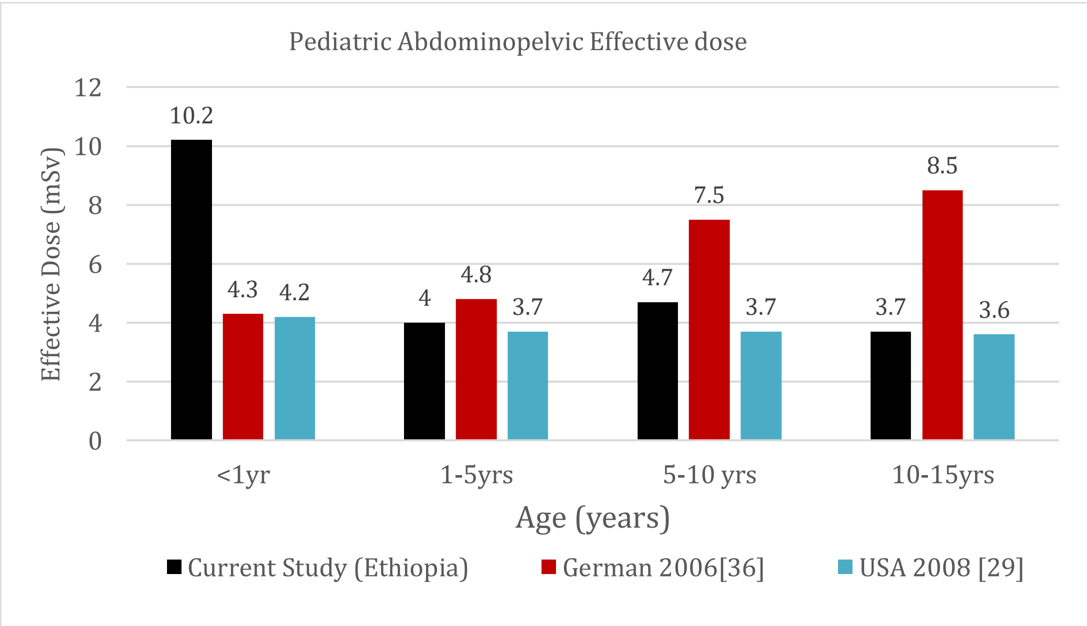



Figure 7: Comparison of the mean effective dose values of pediatric abdominopelvic CT in Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia, 2018, with the international diagnostic reference levels in (Germany, 2006 [36] and USA, 2008 [29]).



# CHAPTER 7. CONCLUSION AND RECOMMENDATION

## 7.1. CONCLUSION

The radiation doses of multiphase abdominopelvic CT examinations are ~2 to 3 times that of the radiation doses of single-phase abdominopelvic CT examinations. The radiation doses of pediatric abdominopelvic examinations are 20-25% of the radiation doses of adult abdominopelvic CT examinations. The practice of proper scanning lenth collimation to the needed minimum for abdominopelvic examination is poor in our institution.

The protocol settings (as evident from low mean CTDIvol dose values) of our facility are well optimized reflecting the use of current international practices for kVp of under 5 yrs, which are higher.

Additionally, the DLP and effective doses of abdominopelvic examination in our institution are higher than those reported international DRLs in comparison to the CTDIvol. Technical factors appear to be significant contributors to these high doses.

## 7.2. RECOMMENDATION

### For Imaging Institutions

Institutions should assess their exposure practices and level of patient doses at a regular bases.

### For Radiologic Technologists

The scanning length should be reduced to the needed minimum for the examination.

The tube voltage should be reduced to the recommended protocol especially in younger pediatric patients

Patient weight should also be put into consideration while scanning in addition to age

### For Ethiopian Radiation Protection Authority

Should take initiative to create awareness about the risk of radiation and update on the optimization methods of radiation doses.

Should take initiative to set a national diagnostic reference level.

### For Further Survey

Regional or National based surveys in collaboration with the Ethiopian radiation protection authority are recommended as it would give the more reliable magnitude of exposure practices and help to put regional or national diagnostic reference levels in Ethiopia

Similar surveys should be conducted in other body parts and used as a template for future studies.

## LIMITATIONS:

This survey data represents only the abdominal/abdominopelvic CT exposure practices and patient radiation doses and therefore does not represent the whole institution`s exposure practices and doses.

This survey data represents only the abdominopelvic CT exposure practices and patient radiation doses of TASH and there fore it does not represent the regional or international practice of Ethiopia as a whole.

Separate sampling of pediatric and adults can not be taken since both of them are found in the medwed labeled as abdomen.

The survey did not collect information relating to the patient's weight, which may also influence the real patient doses

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## ANNEX I: DATA COLLECTION FORMAT

| No | Questions and Filters | Coding Categories | REMARK |
|---|---|---|---|
| PART ONE: SOCIO DEMOGRAPHIC CHARACTERISTICS | | | |
| 101 | Age (years) | | |
| 102 | Sex | 1. Male<br>2. Female | |
| 103 | CT Number | | |
| Part II: EXPOSURE FACTORS/SCANNING PARAMETERS | | | |
| 201 | CT scanner make and model | 1. GE Medical Systems, Optima CT660<br>2. Philips, Ingenuity | |
| 202 | kVp (kV) | | |
| 203 | mAs | 1. mAs________________<br>2. Exposure time (sec)________<br>3. mA_______<br>4. Automatic tube modulation (Yes/No)_____________ | |
| 204 | Rotation Time (sec) | | |
| 205 | Slice thickness (mm) | | |
| 206 | Total Collimation/Scan length (mm) | | |
| 207 | Pitch | | |
| 208 | Phases performed | 1.Single-phase<br>1.1. Non-contrast<br>1.2. Post-contrast<br>2.Multiple phases<br>2.1. Two<br>2.2. Three<br>2.3. Four and above | |
| 209 | Dosimetry Phantom Type | 1. Body 32<br>2. Head 16 | |
| 2010 | Scanning Technique | 1. Helical<br>2. Axial | |
| Part III: CT DOSE PARAMETERS | | | |
| 301 | CTDIvol(mGy) | | |
| 301 | DLP(mGy.cm), Total | | |
| 303 | E (mSv) | To be calculated | |

## ANNEX II: DECLARATION

I, the undersigned, declare that this paper is my original work and has not been presented for postgraduate study in this or another university and that all sources used for this paper have been fully acknowledged.

Name: Gebretsadik Zegeye (MD, Radiology Resident)

Signature: ______________

Date: ______________

Place: Addis Ababa University, College of Health Science, Department of Radiology

This thesis has been submitted with our approval as University advisors

1. Dr. Wondim Getnet (MD, Consultant Body Radiologist)

   Signature: ______________

   Date: ______________

   Place: Addis Ababa University, College of Health Science, Department of Radiology

2. Dr. Seife Teferi (PHD, Medical Physicist)

   Signature:

   Date:

   Place: Addis Ababa University, College of Health Science, Department of Radiology

3. Dr. Daniel Zewdneh (MD, Consultant Pediatric Radiologist)

   Signature: ______________

   Date: ______________

   Place: Addis Ababa University, College of Health Science, Department of Radiology