

**ABDOMINAL EXAMINATION IN KNH USING 16 MULTI-SLICE  
CT SCAN: REVIEW OF ALARA PRACTICE IN MANAGING  
PATIENT DOSE**

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# DECLARATION

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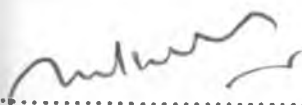
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## **ABBREVIATIONS AND ACRONYMS**

ALARA- As Low As Reasonably Achievable  
Cvol - Volume radiographic exposure  
CT- Computed tomography  
CTDI-Computed tomography dose index  
CTDI100 – Computed tomographic dose measured at 100mm ionization pencil  
CTDIvol- Volumetric computed tomography dose index  
DLP - Dose Length Product  
EC- European Commission  
ERCP- Endoscopic retrograde cysto-pancreatography  
FDA- Food and Drug Administration  
GIT- Gastro-intestinal tract  
HU - Hounsfield units  
IEC- International Electro-technical Commission  
ICRP- International Committee on Radiation Protection  
IV- Intra-venous  
IVC- Inferior vena cava  
IVU - intravenous urography  
KNH- Kenyatta National Hospital  
kVp- Peak kilo-voltage  
LLQ- Left lower quadrant  
LNMP- Last normal menstrual period  
mA- milli-ampere  
mAs- milli-ampere seconds  
mGy – milli-Gray  
mSv- milli-Sievert  
MRI - Magnetic resonance imaging  
MSCT- Multi-slice computed tomography  
NRPB- National Radiation Protection Board  
PMMA- Poly(methyl methacrylate)  
RF- Radio-frequency  
RLQ- Right lower quadrant  
SPSS- Statistical Package for Social Sciences  
SSCT- Spiral Single-Slice Computed Tomography  
TLD- Thermo-luminescent dosimetry  
UNSCEAR- United Nations Scientific Committee on the Effects of Atomic Radiation.  
WHO- World Health Organization  
WL- Window level  
WW- Window width

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## **DEDICATION**

This book is dedicated to my dear Florence, Loise Jr. (Tessie) and Loise Sr.



# ABDOMINAL EXAMINATION IN KNH USING 16 MULTI-SLICE CT SCAN: REVIEW OF ALARA PRACTICE IN MANAGING PATIENT DOSE

## ABSTRACT

**Objective of the study:** To assess the justification of abdominal CT examinations carried out, quantify radiation dose and evaluate the optimization of scanning parameters that contribute to radiation dose determination within the ALARA principle in comparison to international standards.

### Methodology:

Through cross-sectional study, 76 patients aged between 20 and 65 years of age, who were referred for abdominal CT scanning at KNH's department of Diagnostic Radiology were recruited through random sampling between July 2008 and March 2009.

Justification of the CT examinations was studied through perusing the request forms from clinicians for the patients that were being scanned to establish how specific the indications were. The CT diagnostic findings were also analyzed in view of how they offered clinical solutions to the requesting clinician. Association between the specificity of the indication and the CT result was also studied.

Dose quantification was done through estimation of effective dose, E calculated from the dose length product (DLP) displayed on the console during scanning.

Optimization was studied by analyzing the matching of scan protocol with the clinical indication and evaluation of the operator control of scan parameters during the image acquisition process. Patient descriptors including the transverse abdominal width and scanning protocol practices were also interrogated as possible contributors to this relatively high dose.

Data collection was through a structured table and management was done using *Epi Info*, *SPSS* and *MS-Excel* software.

**Results :** 18.4% of the examinations had a non-specific clinical indication and 26.3% of the CT findings did not support a clinical diagnosis.

The average E was five times higher than internationally published guidelines for abdominal scanning and within epidemiological concerns.

39.5% of the examinations were done with mismatched protocols. Specificity of the request and correct protocol matching were positively associated with supporting CT result to the clinical indication.

**Conclusion:** MDCT as a new and useful technology in medical imaging is providing technical challenges to end users that compromise optimization in reducing patient dose, from Kenyatta National Hospital's experience. Local protocol practice was shown not only to have had an impact on the dose but also to have influenced the diagnostic yield of the examinations. Further Quality Assurance practices are needed. This highlighted the fact that in regard to dose reduction, justification for the examination appears to be the main component of ALARA that clinicians and radiologists can take advantage of.

## Chapter One: INTRODUCTION

Since the introduction of x-rays in the late 19<sup>th</sup> century, radiology has evolved into a field of multiple diagnostic tools. This includes both ionizing and non-ionizing radiation. X-rays and gamma rays are ionizing unlike sonography and magnetic resonance imaging (MRI). Application of x-rays is in conventional radiography including fluoroscopic procedures, conventional tomography and computed tomography (CT scan).

CT examinations are increasingly being employed in diagnostic procedures despite their high contribution to the total radiation dose (1). The skewed impact of CT radiation dose can be illustrated in Figure 1. According to UNSCEAR report of 2000, while only 5% of radiological examinations were CT scans, these contributed 34% of the collective radiation dose. The range of application for abdominal CT examinations for diagnostic and even therapeutic value cannot be overemphasized.

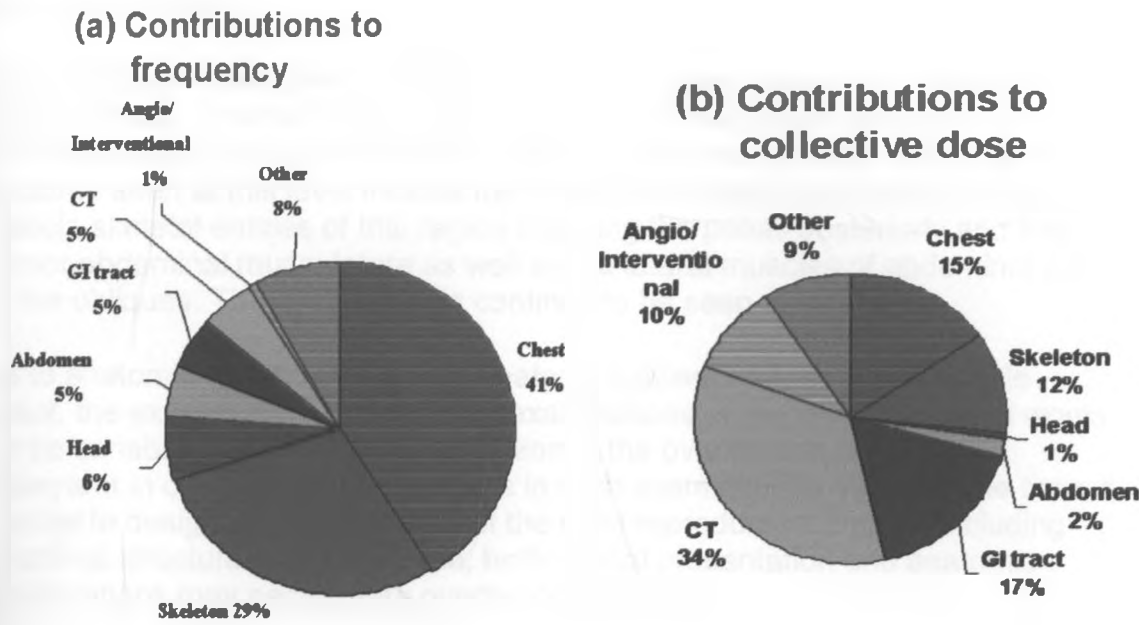
On the other hand, there is clear need to assess ALARA practice in the application of this useful imaging tool especially in the areas of justification and optimization of the procedures. The ALARA principle is one of the important strategies in Radiation Protection. It requires that all justifiable exposures to ionizing radiation be kept As Low As Reasonably Achievable, social and economic factors having been taken into consideration. This is in cognizance of the deleterious biological effect of radiation to the human body because no radiation can be considered safe.

From a single X-ray source and single detector in the first generation, CT systems have been developed to maximize efficiency in reduced time of acquisition and multiple applications including multiplanar and 3-D applications. The seventh generation scanner including the new machine in KNH is a multiple detector array otherwise known as multi-slice detector CT scanner (2). The machine at KNH is a *Philips Brilliance 16* that has all the capabilities of 16-multidetector helical scans (*Philips Co., Netherlands*)

These machines utilize the principles of the helical scanner, whose principle was introduced in 1989, but incorporate multiple rows of detector rings. They can therefore acquire multiple slices per tube rotation, thereby increasing the area of the patient that can be covered in a given time by the X-ray beam. The greater number of rows allows the scanner to acquire more slice images per second. The multislice CT has many potential uses.

The advantages of helical CT over conventional CT in the abdomen are numerous. First, helical CT technology allows more efficient use of the CT scanner including "faster throughput". In addition, patients are provided with improved comfort and safety. With helical CT, image data acquisition can be optimally timed with the administration of the contrast material bolus and

enhancement phases, specifically isolate arterial, portal venous, parenchymal, or delayed phase. The volume of intravenous contrast medium used can also be reduced in some cases. Helical CT also eliminates or minimizes physiologic artifacts and prevents misregistration artifacts. Finally, the use of retrospective region-of-interest placement and overlapping reconstructions in helical CT data postprocessing eliminates or minimizes partial volume artifacts (3,4,5).



**Figure 1: The relativity of (a) CT examination frequency and (b) contribution to collective dose (Source: UNSCEAR 2000)**

Disadvantages of MSCT include occurrence of specific artifacts (multislice artifacts, cone-beam artifacts) and increased contribution to patient dose due to reduced geometric efficiency and more prominent impact of the additional tube rotations necessary before and after data acquisition over the planned scan range (6)

Indications of CT abdominal examination are varied but can be broadly divided into focal or non-focal illnesses. This can also be viewed in terms of the abdominal regions. The abdomen in CT scanning is divided into two anatomic regions namely the upper and lower abdomen. The pelvis is considered as a separate anatomic region entity even though some CT examination protocols for abdomen must of necessity include the same. (7,8, 9)

### 1.1: Brief CT abdominal anatomy review

**Upper abdomen** - This consists of the region between a line drawn transversely at the diaphragmatic level and another at level of the lower costal margins.

Organs located in this region are the liver, spleen, pancreas, gallbladder, adrenal glands and the kidneys with its drainage.

Parts of the gastro-intestinal tract namely the stomach, duodenum, jejunum, ileum and the colon are also included in this anatomic region.

Vascular structures like aorta, inferior vena cava, and portal venous system are also part of the upper abdomen.

All these structures are well outlined by CT scanning depending on inherent or introduced contrast.

**Lower abdomen and pelvic region-** Unlike the upper abdominal region where one gets to see several organs and structures the lower abdominal part below the kidney level and above the pelvic region shows less of those. Much of the structures seen at this level include the bowels, the ureters and the surrounding musculo-skeletal entities of this region including the psoas posteriorly and the anterior abdominal musculature as well as the lateral muscles of abdominal wall like the obliques. The great vessels continue to be seen at this level.

Due to anatomic variations in pelvic anatomy between the male and female patient, the exposure to gonads in CT examinations of the lower abdomen would also be variable at a given level. Radiation to the ovaries can be more inadvertent in comparison to the testes in such examinations. At the same time, it is easier to design appropriate cuts of the male reproductive organs excluding abdominal structures. In the female, both clinical presentation and anatomic considerations may necessitate overlap of exposure.

**Female pelvis-** Computed tomography (CT) remains a valuable technique in the assessment of the female pelvis. Newer high-resolution CT scanners combined with mechanical intravenous contrast medium injectors and thinner sections have substantially improved the imaging of female genital tract anatomy (10)

## 1.2: Protocols in Abdominal CT

CT examinations in the abdomen can be customized to the clinical question focusing on regions and even organ of interest effectively. A glimpse of such a scenario is captured in the description below for applied protocols and indications during abdominal CT examination. The original scan protocols used are based on those recommended by the manufacturers as a starting point for clinical work, but appropriate optimization process requires local clinical input (11).

### **CT Abdomen and Pelvis (CT A/P):**

Patient is scanned from diaphragm to pubic symphysis by 7 mm cuts, usually with oral and i.v. contrast. Indications for CT A/P include abdominal pain, diffuse

pain (acute abdomen or chronic, intractable pain), history of malignancy, abdominal or pelvic mass, suspected abscess and trauma

### **Abdominal CT**

Only CT of the abdomen is performed with oral and intravenous contrast with images extending from dome of diaphragm to iliac crest. The pelvis is not included. This examination is used when only upper abdominal organs are of interest. In general, if the patient has disease that may spread through the peritoneal cavity or by lymphatics (GI tract cancer, lymphoma, infection), then the pelvis should also be performed.

### **Pelvic CT Only**

CT of the pelvis is performed with oral and intravenous contrast with imaging extending from iliac crest to the pubic symphysis. It is usually performed in conjunction with abdominal CT, but is sometimes warranted in patients with pelvic pain or specific clinical question involving only the pelvic organs.

### **Triple Phase CT of Liver**

Scanning of liver is performed pre-contrast, during arterial phase of contrast enhancement, and during portal venous phase of contrast enhancement. The abdominal CT is then completed to iliac crest level. If hemangioma is suspected, additional delayed images are obtained to assess for filling in of hemangioma. It is indicated for suspected liver mass (cirrhosis to rule out hepatocellular carcinoma, characterize mass seen by ultrasound) and malignancy with hypervascular metastases (carcinoid, islet cell, thyroid and others). It can also be performed for follow up therapy for liver tumor (alcohol ablation, cryotherapy, RF ablation, resection, embolization).

### **Pancreas Protocols**

Pancreas protocol includes pre-contrast imaging of pancreas to look for calcification or hemorrhage, followed by dynamic contrast enhanced images with thin sections, then completing the abdomen from dome of diaphragm to iliac crest. Triple phase imaging (precontrast, arterial phase, portal venous phase, then abdomen) can be used when looking for neoplasm (adenocarcinoma or islet cell tumor) or vascular complications of pancreatic disease. Water is acceptable oral contrast agent.

### **Renal CT Protocol (Mass, Infection)**

Pre-contrast images of the kidneys are obtained to demonstrate calcifications and density of renal masses, followed by dynamic IV contrast enhanced images with thin sections through the kidneys, extending through the abdomen.

Frequently the pelvis is also imaged to see the entire urinary tract and look for adenopathy. Because scanning is so fast, dynamic images of kidneys show the cortical phase of enhancement, making it useful to obtain a third set of images through the kidneys to better assess the parenchyma. If upper tract transitional cell carcinoma is of concern (history of bladder cancer, filling defect on IVU),

further delayed (5 minute) images of kidneys are needed to see filling defects in opacified collecting system, and the exam is extended into the pelvis with delayed views of the bladder to assess bladder tumor.

### **Helical CT, Renal Stone Protocol**

This is a non-contrast study requiring no patient preparation. Helical CT is performed using 5mm slices from kidneys to pubic symphysis. It is used as a screening study for obstructing calculus in patients with acute flank pain, hematuria, and symptoms of renal colic. This exam is beginning to replace intravenous urography (IVU) in most cases within the developed world. If no stone or obstruction is found to explain patient's symptoms, or if other abnormalities are seen that require further imaging (kidney mass, kidney swelling, possible pyelonephritis), the CT exam may be repeated using a screening CT protocol (with oral and IV contrast) or CT urography.

### **Adrenal CT Protocol**

Thin section, high resolution CT of the adrenal glands is performed without IV contrast to differentiate normal adrenals from adenomas, nodular hyperplasia or malignant lesions. Attenuation measurements (Hounsfield Units) of adrenal masses should be routinely performed and documented in the report, both pre- and post-contrast. An additional contrast enhanced exam through the abdomen may also be performed, especially if there is history of malignancy or the exam demonstrates a mass that does not meet the criteria for benign adenoma (uniformly hypodense mass, HU < 10).

If the primary clinical question is pheochromocytoma or extraadrenal paraganglioma, MRI is recommended instead of CT. If patient has contraindications for MRI (pacemaker, aneurysm clip, others), noncontrast CT is recommended using good oral contrast. There have been reported cases of hypertensive crisis with IV contrast in patients with pheochromocytoma.

## **1.3: Contrast media in abdominal CT imaging**

Contrast employed can be positive or negative. Positive contrast is made of high atomic number elements like barium and iodine while negative is from low atomic number material like water or air.

For most abdominal and pelvic CT examinations, contrast media is used. This can either be in form of oral or intravenous (i.v.) contrast.

**Oral contrast:** This may be accomplished with positive (barium or iodinated) or with negative contrast using air, CO<sub>2</sub>-producing granules or water. The aim is to outline the gastro-intestinal tract either as the primary region of interest or delineate the same from adjacent soft tissues of more or less similar inherent contrast.

For water-soluble contrast media 2-3% Urografin flavoured with orange juice to disguise taste is given.

Low-density barium (2%w/v) is usually the recommended dose for non-soluble contrast to minimize artifact effects.

Contrast is usually give within an hour before examination and where opacification of the large bowel is needed this can be given at least three hours prior (8)

**I.v. contrast:** vascular outline and structures that have good tissue perfusion is achieved. Soluble iodinated contrast media is used. All the major abdominal organs are studied using this technique after non-contrast survey when function and anatomy is being studied to detect pathology.

Contrast is known to have implications on radiation dose to the patient. Some investigations by their very nature may not require the use of contrast media like where calculi are the clinical suspicion and the radiological confirmation at the same time.

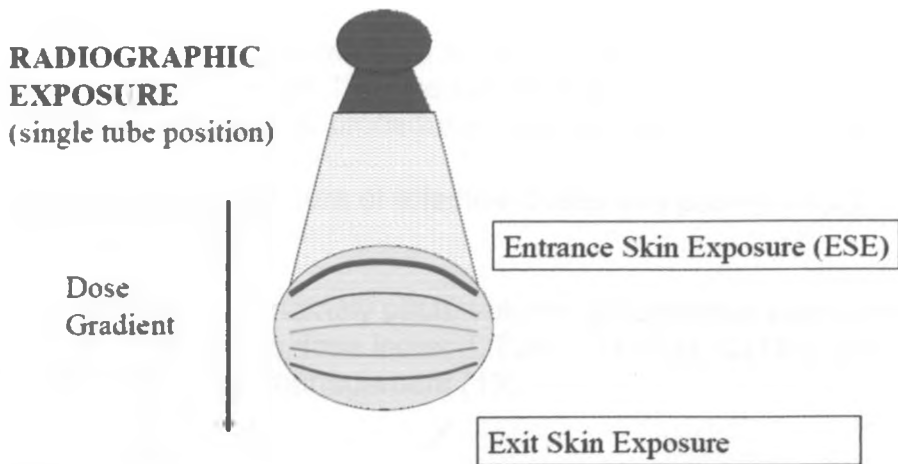
This can be advantageous to the patient as radiation dose is significantly reduced when the question is answered without use of contrast media.

It is valuable to consider the role of contrast medium enhancement prior to commencing the examination. In some cases a single examination following enhancement may be adequate for clinical purposes and initial unenhanced images may therefore be avoided. In multiphase enhancement studies the examination should be limited to the number of phases, which are clinically justified.

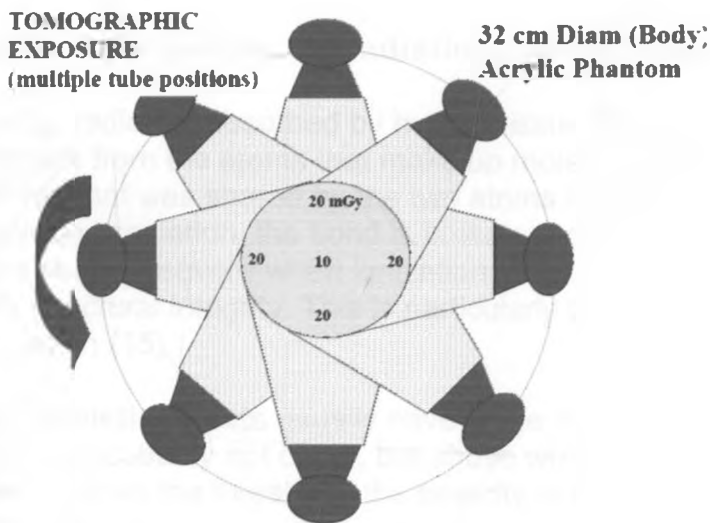
#### **1.4: Calculation and estimation of CT radiation dose**

The conditions of exposure during CT radiation examination are quite different from those encountered during conventional X-ray procedures and specific techniques are necessary in order to allow detailed assessment of patient dose from CT. The unique features about radiation dose from CT examinations include geometry and usage of exposure at multiple points around the patient with typically thin (0.5-20 mm) slices as well as multiple scans (11)

This is schematically presented in the figures 2 and 3.



**Fig 2:** Schematic representation of conventional radiography radiation distribution (Source: Prof. M.F. McNitt-Gray; SCAAPM Presentation. February 25,2005. ([www.mednet.ucla.edu](http://www.mednet.ucla.edu)))



**Fig 3:** Schematic representation of typical dose distribution from CT radiation. (Source: Prof. M.F. McNitt-Gray; SCAAPM Presentation. February 25,2005. (<http://www.mednet.ucla.edu>))

Important definitions in dosimetry and their relevance in CT are described below.

**Absorbed dose in tissue** is the energy deposited in tissue/organ per unit mass. The units of measurement are joules/kilogram (J/kg), Gray (Gy) or Rad.

1 Gy = 100 rads.

It is the basic quantity used for assessing the relative radiation risk to the tissue/organ. (12)



**Effective dose** is a calculated quantity that takes into account the difference in radiosensitivity of tissues. It is used as an index to compare relative radiation risk from different radiological procedures and is expressed in Sv (sievert).

**Collective dose** is the sum of effective doses in a patient population. It is measured in man-Sv.

The following factors, namely pitch, volume radiographic exposure (Cvol), computed tomographic dose index (CTDI), CTDI<sub>100</sub>, CTDI<sub>w</sub> and CTDI<sub>vol</sub> are important in CT dose management (13).

**Pitch** is the distance in millimetres that the table moves during one complete rotation of the X-ray tube, divided by the slice thickness (millimetres). Increasing the pitch by increasing the table speed reduces dose and scanning time, but at the cost of decreased image resolution (14).

### 1.5: Biological effects of radiation dose in human body

Ionizing radiation absorbed by human tissue has enough energy to remove electrons from the atoms that make up molecules of the tissue. When the electron that was shared by the two atoms to form a molecular bond is dislodged by ionizing radiation, the bond is broken and thus, the molecule falls apart. The effect is much severe when ionization occurs at the chromosome level distorting DNA structural integrity. This is particularly the case in actively dividing cell population (15).

**Deterministic effects** usually have some threshold level - below which, the effect will probably not occur, but above which the effect is expected. When the dose is above the threshold, the severity of the effect increases as the dose increases.

**Stochastic effects** are dose independent and can occur at either low or high doses. They are probabilities of effects occurring at low doses by extrapolating the effects of high dose radiation.

**Somatic effects** appear in the exposed person and **hereditary or genetic effects** appear in the future generations of the exposed person as a result of radiation damage to the reproductive cells. Genetic effects are abnormalities that may occur in the future generations of exposed individuals.

### 1.6: ALARA principle and CT imaging practice

It is important to emphasize that ALARA is practised based on technologic and economic considerations (16)

ALARA employs three key strategies of dose management in diagnostic radiology practice namely, justification, optimization and dose limitation. Radiologists and referring clinicians have a critical role in ensuring that patients are not irradiated unjustifiably. Justification is a shared responsibility between clinician and radiologist.

The principle of optimization requires that the radiologist have primary responsibility for ensuring that the examination is carried out conscientiously, effectively, and with good technique. Within this process the radiologist has considerable scope for limiting the radiation dose to the patient.

While there is no set upper limit for medical exposure to patients according to ALARA, the worker at the radiology department has to take precautions to operate within the prescribed dose limits. The standards of shielding, proper equipment handling and personnel dose monitoring need to be observed. Much detail will not be described in this study as the focus is on patient dose.

## **Chapter Two: LITERATURE REVIEW**

### **2.1: Advances in studying radiation dose in relation to CT imaging**

The overwhelming benefits accruing to patients from properly conducted procedures have fostered the widespread practice of medical radiology, with the result that medical radiation exposures is the largest man-made source of radiation exposure for the world's population (17). This is despite the fact that there is far from equitable distribution of medical radiation services in different countries with different levels of health care. According to WHO, in 1993 two thirds of the world's population lacked adequate diagnostic imaging and radiation therapy services (18). From the same report the estimate for the annual per caput dose from diagnostic examinations was 0.3mSv and corresponding average values for countries of the upper and lower health-care levels were 1.1 mSv and 0.05 mSv, respectively. However, population exposures from the diagnostic and therapeutic uses of ionizing radiation are likely to be increasing worldwide, particularly in countries where medical services are in the earlier stages of development (19, 20).

After the introduction of single-slice spiral CT (SSCT) into clinical practice in 1989 (20), the next considerable advance was the development of multi-slice spiral CT (MSCT) systems a few years ago. The resulting improvement in scanner performance has increased the clinical efficacy of CT procedures and offered promising new applications in diagnostic imaging (22, 23, 24, 25). On the other hand, data from various national surveys have confirmed the growing impact of CT as a major source of patient and man-made population exposure (20).

Various studies on MSCT dosimetry have identified higher radiation doses than with use of conventional single slice CT. In conventional CT scanning, patient exposure is restricted to a thin slice of the body during each rotation of the x-ray tube with the possibility of an inter-slice gap. However, in spiral CT and more so in multi-slice CT the cumulative radiation dose from each complete investigation can be relatively high and gives rise to concern (26).

Studies in the UK, suggested as an initial trend broadly increasing levels of exposure per examination; the overall mean doses per CT examination from regional surveys in Wales (1994) and Northern Ireland (1996) were 20% and 5% higher, respectively, than the level observed in a national survey for the UK in 1989, before the introduction and application of spiral and multislice CT technology (27). On the basis of equivalent scanning parameters, doses from spiral scanning are broadly similar to those from serial scanning, although increases by 10-30% tend to occur with multislice detector-array scanners (28).

The levels of the dose for patients undergoing a CT procedure depend in principle on the required image quality and on the extent of the body region to be

scanned to meet the specific clinical objectives. In practice, however, numerous factors relating to both the CT scanner and the procedures in use have an influence on the imaging process and thus on patient exposure. Since the effect of these factors on radiation exposure is very complex, many of those who have to deal with CT in both hospitals and private practices are in general not capable of estimating the relevant quantity for risk assessment—the effective dose—related to the various CT protocols used in their facility and of optimizing scan protocols towards dose reduction (29)

To overcome this problem, different software packages for dose calculation in CT have been developed (30, 31, 32) based on Monte-Carlo data published by the National Radiological Protection Board (NRPB) in the United Kingdom (33) or the Research Center for Environment and Health (GSF) in Germany (34). Some of these software packages have widespread applicability to nearly all existing SSCT and MSCT scanners. The Monte Carlo method is a computational model in which physical quantities are calculated by simulating the transport of X-ray photons. This attempts to model the shape of a human being and its internal organs in order to calculate absorbed radiation doses. By the use of appropriate software, the organ doses and effective dose for complete CT procedures may be assessed from the input values of scanner model, CTDI (mGy/mAs), and the exposure parameters (mAs, slice thickness, total scan length). These simulations have been in use since the early 1970's for use in radionuclide medicine and conventional X-ray examinations until Jones and Shrimpton in 1991 expanded such calculations to CT examinations, providing conversion coefficients between the CTDI free in air at the axis of rotation and organ doses per slice (33).

CTDI calculations have been derived from gradual research and evaluation of dosimetric factors from which Monte Carlo methods spring forth and they are described sequentially in the next few paragraphs.

#### **Volume radiographic exposure (Cvol)**

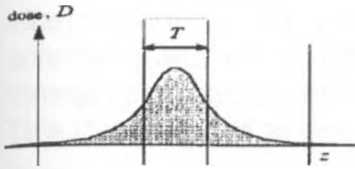
In helical scanning, volume radiographic exposure describes the overall average exposure over the total volume scanned. It is measured in mAs. (35)

$$C_{vol} = \frac{C}{CT \text{ pitch factor}} \quad (\text{mAs})$$

C = Current time product in mAs

#### **Computed tomographic dose index (CTDI)**

The principal dosimetric quantity used in CT is the computed tomographic dose index. (CTDI, mGy). This is defined as the integral of the dose profile along a line Z perpendicular to the tomographic plane of the dose profile (D(z)) for a single axial scan, divided by the product of the number of tomographic sections N and the nominal section thickness T (36)



where:

$D(z)$  is the dose profile along a line  $z$  perpendicular to the tomographic plane, where dose is reported as absorbed dose to air (mGy);

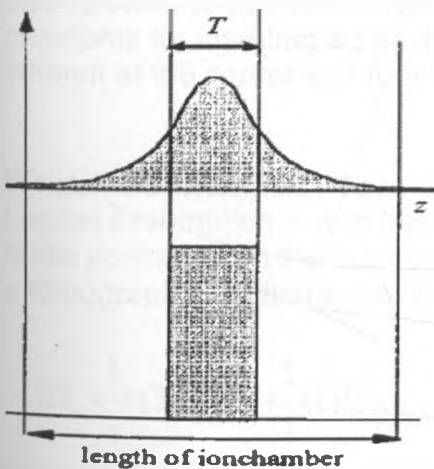
$N$  is the number of tomographic sections produced simultaneously in a typically a  $360^\circ$  rotation of the x-ray tube;

$T$  is the corresponding nominal tomographic section thickness (mm)

$$CTDI = \int_{-\infty}^{+\infty} \frac{D(z)}{N \times T} dz \quad (\text{mGy})$$

The CTDI may be assessed free in air or in phantoms, and the measurements may be done with TLDs or ionization chambers. The Food and Drug Administration (FDA) in the United States recommends that the measurements be done in the centre and periphery of cylindrical phantoms of 16 cm and 32 cm diameter, respectively. Because of the scattered radiation in the phantom, the total integration length must be defined. According to FDA, the dose is to be integrated over 14 slice thicknesses, which implies that the total integration length depends on the slice thickness. (37)

This approach was adopted by the International Electro-technical Commission (IEC) in 1994, but was not very practical, so the predominant method is now to apply a fixed integration length of 100 mm for all measurements. The measurements are done with a pencil shaped ionisation chamber of 10 cm length. The method is illustrated in Figure 4 below.



**Fig. 4:** The length of the ionization chamber must include the slice thickness of interest,  $T$ . It is now standard practice to use ionization chambers of  $T$  as 100mm.

In literature, there is however, still some confusion concerning the definition and interpretation of the various quantities found for single- and multi-slice CT-scanners (38). This is basically caused by the definition of the nominal tomographic section thickness,  $T$ , and the number of tomographic sections,  $N$ . This therefore led to derivation of another quantitative measure,  $CTDI_{100}$  (34)

### $CTDI_{100}$

$CTDI_{100}$  is defined according to the equation:

$$CTDI_{100} = \int_{-50mm}^{+50mm} \frac{D(z)}{N \times T} dz \quad (\text{mGy})$$

In practice, a convenient assessment of CTDI can be made using a pencil ionization chamber with an active length of 100mm so as to provide a measurement of  $CTDI_{100}$  expressed in terms of absorbed dose to air (mGy). Such measurements may be carried out free-in-air on, or parallel with, the rotation of the scanner ( $CTDI_{100}(\text{air})$ , or in abbreviation  $CTDI_{\text{air}}$ ), or at the centre ( $CTDI_{100}(\text{center})$ ) and 10mm below the surface ( $CTDI_{100}(\text{peripheral})$ ) of standard CT dosimetry phantoms; in practice  $CTDI_{100}(\text{peripheral})$  is determined as the average of four values of  $CTDI_{100}$  measured at evenly distributed positions around the dosimetry phantom.

$CTDI_{\text{air}}$  is the  $CTDI_{100}(\text{air})$  measured at the iso-centre (center-of-rotation) of the scanner in the absence of a phantom and patient support.

For the phantom measurements two homogeneous cylindrical phantoms with diameters of 160mm for the head and 320mm for the body are used. The height of the cylinders is at least 140mm and the material is *Poly(methyl methacrylate)* also referred to as PMMA. Holes with matching PMMA plugs are available in the phantoms for inserting a pencil ionisation chamber with an active length of 100mm at the center and four equally spaced peripheral positions.

### Weighted $CTDI_{100}$ ( $CTDI_w$ )

Logical assumption is that dose in a particular phantom decreases linearly with radial position from the surface to the center. Therefore the average CTDI within a tomographic section is the weighted  $CTDI_{100}$  or  $CTDI_w$ .

$$CTDI_w = \frac{1}{3} \times CTDI_{100(\text{center})} + \frac{2}{3} \times CTDI_{100(\text{peripheral})} \quad (\text{mGy})$$

(Kalender: MSCT Dosimetry)

### $CTDI_{\text{vol}}$

$CTDI_{\text{vol}}$  describes the average dose over the total volume scanned in a sequential or helical sequence.

$$CTDI_{vol} = \frac{CTDI_w}{CT \text{ pitch factor}} \quad (\text{mGy})$$

While CTDI and CTDI<sub>w</sub> are machine specific, CTDI<sub>vol</sub> is examination specific. (Kalender: MSCT Dosimetry)

### **Dose length product (DLP)**

Monitoring of the dose-length-product (DLP, mGy.cm) provides control over the volume of irradiation and the overall exposure for an examination. The DLP depends on the CTDI<sub>vol</sub> and the length of the exposed range.

$$DLP = CTDI_{vol} \times L \quad (\text{mGy cm})$$

Where:

L is the scan length (cm) limited by the outer margins of the scan range (irrespective of the pitch). For a helical scan sequence, this is the total scan length that is exposed during raw data acquisition, including any additional rotations at either end of programmed scan length that are necessary for data interpolation.

Estimates of DLP for an examination may be derived from the equation above with knowledge of the appropriate CTDI<sub>vol</sub> (or CTDI<sub>w</sub>) for the scanner and details of the particular scanning protocol used.

Most modern MSCT scanners show values of DLP on the user interface in compliance with IEC standards (15). In the case of examinations involving separate scanning sequences in which different technique parameters might be applied (such as slice thickness or radiographic exposure, for example), the total DLP should be determined for the entire procedure as the sum of the contributions from each of the serial or helical sequence.

### **Effective dose**

Effective dose is a risk descriptor to the harmful effects of radiation. An estimate of effective dose can easily be derived from DLP using effective dose conversion coefficient. As explained above DLP is displayed in most modern MSCT scanners.

The European quality criteria for CT includes proposed reference levels for both CTDI<sub>w</sub> and DLP for various CT procedures. The relation between DLP and effective dose is shown to be about the same for a variety of scanners, and conversion factors between the two quantities are supplied as shown in the table below. This means that effective dose may be broadly estimated from the DLP values using these factors.

Region of body	Normalised effective dose, E/DLP (mSv mGy <sup>-1</sup> cm <sup>-1</sup> )
Head	0.0023
Neck	0.0054 *)
Chest	0.019
Abdomen	0.017
Pelvis	0.017
Legs	0.0008 **)

\*) Conversion factor from previous document on CT Quality Criteria (CT study group 2000).

\*\*\*) Calculated with CT Dose (version 0.6.7) National Board of Health, National Institute of Radiation Hygiene, Denmark).

**Table 1: Conversion factors for CT doses**

The conversion coefficient is also known as E<sub>DLP</sub> and is region specific. Therefore, effective dose, E can be derived using the equation,

$$E = E_{DLP} \times DLP \quad (\text{mSv})$$

(Kalender: MSCT Dosimetry)

With the agreeable system whereby modern MSCT scanners display values of CTDI<sub>vol</sub> and DLP as well as the other factors of exposure including pitch and scan length, current teaching has recommended the use of the displayed parameters to estimate the effective dose (39, 40).

Further studies have been conducted to verify the accuracy of Monte Carlo model techniques. This has been done using phantoms that simulate the human body. Brix et al in 2003 (29) carried out such a study. The phantom measurements and model calculations performed in this study for a variety of scanners validated the reliability and accurateness in both approaches. For modern scanners the values of CTDI<sub>vol</sub> and DLP are provided on the operator console when ordering the examination, and should be put down as a part of the patient's journal. Dose surveys may simply be performed by collecting such information (41).

The need for practical dosimetry is now legalized in European countries, which happen to be the main source of our CT machines, the new 16-slice multidetector at KNH included.

There is also general consensus concerning CT dose descriptors such as CTDI, CTDI<sub>w</sub>, CTDI<sub>vol</sub> and DLP.

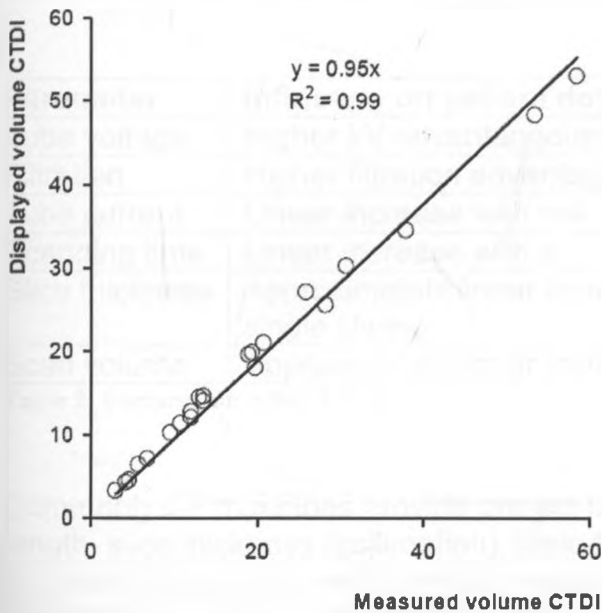
However accurate effective dose measurements can be done by use of phantoms and instituted mathematical software such as Monte Carlo techniques. Such software are made available for example a CT dose calculator based on this approach is now provided by the CT evaluation center "Impact" at St. George's Hospital, London. The dose calculator is based on Microsoft Excel, and may be downloaded from their website <http://www.impactscan.org/index.htm>



.The NRPB Monte Carlo dataset (NRPB-SR-250) must be available in the same file folder to make the programme work (41,42).

In 2003, a concerted action by European Working Group on CT dosimetry developed a database and also made comparison studies on the displayed dose on console and the measured dose. CTDIvol was used as the standard variable for comparison.

The measurements were taken from all the major CT machines in Europe like GE Lightspeed, Philips Aura, Siemens: Somatom AR Star and Somatom Plus-4 and Toshiba Aquilion-16. The correlation between the two variables is as shown in figure 5.



**Fig 5: Good correlation seen between measured CTDIvol and displayed CTDIvol in several CT machines in Europe in 2003. (Source: EC 2004 CT Quality Criteria: MSCT Dosimetry – [http://www.msct.eu/PDF\\_FILES/Appendix%20MSCT%20Dosimetry.pdf](http://www.msct.eu/PDF_FILES/Appendix%20MSCT%20Dosimetry.pdf))**

From the high correlation coefficient in the study as illustrated in figure 5 above, the case for using displayed dose descriptors on the user interface of a CT machine becomes strengthened. This is practical in estimation of patient doses during a given examination.

In a setting like KNH where phantoms are not available but where dose descriptors are displayed on the console of the new MSCT machine, CTDIvol and DLP can be used to estimate effective dose to the patient.

## 2.2: Determinants of Radiation Dose in CT Examinations

A number of national surveys have indicated widespread variation in the radiation dose to patients for any particular radiological examination (43,44).

Balancing the image quality and patient radiation dose in CT imaging is a delicate act. In conventional radiography, higher exposure leads to increased darkening of the image, whereas in CT that is not the case and this can result in selection of unnecessarily high exposure factors (45,46).

Studies have also been carried out to determine the factors that influence patient dose during CT examination. These are summarized in the table below (28).

Parameter	Influence on patient dose
Tube voltage	Higher kV advantageous (for constant image noise)
Filtration	Higher filtration advantageous
Tube current	Linear increase with mA
Scanning time	Linear increase with s
Slice thickness	Approximately linear increase in dose with thickness (valid for single slices)
Scan volume	Approximately linear increase in dose with volume

Table 2: Factors that affect CT dose

Commonly CT machines provide pre-set factors such as tube current (mA), scan length, slice thickness (collimation), table feed per 360°, pitch and applied potential (kVp). However the settings should be tailored for each patient according to body part and patient build. Protocols should be designed to include patient parameters.

### Role of mA and mAs

The mAs is the single most important factor for managing patient dose. mAs should vary with patient size and body part. The mA controls the x-ray intensity (the number of x ray photons per unit time). The intensity is directly proportional to mA. One of the factors influencing the choice of mAs in CT practice is the signal-to-noise ratio.

In a study carried out in 1990 a low dose CT technique of the thorax was described whereby scans of acceptable diagnostic quality were obtained with an

mAs setting that was only 20% of that used for standard practice (46,47). A study under simulated conditions using phantoms demonstrated that there is no decrease in detection of simulated plaques, nodes and effusions in a chest phantom when mA is reduced by 80%, typically from 400 to 80 mA (48). It is possible to perform spiral CT of the maxilla and mandible with a radiation dose similar to that used for conventional panoramic radiography (49,50).

There are definite problems in achieving low doses in areas of low contrast in the body like the abdomen. Noise becomes a limiting factor in such circumstances. It is a common practice to use the same mAs whenever abdomen and pelvis are to be scanned. Substantial dose reduction, without any recognisable deterioration in diagnostic image quality, may be achieved if pelvic CT is performed at almost a third of the mAs for abdomen region (51). The rationale behind reducing the mAs for imaging of the pelvis relative to the abdomen is that the abdomen contains organs like the liver, where resolution is very important, whereas the pelvis does not have similar structures, but rather bones, bladder and opacified bowel. This means that there is more inherent contrast within the pelvis than in the abdomen.

#### **Smart technique:**

Recently attempts have been made to develop the so-called "*smart technique*"(52) with the principal idea being to change technical factors during a 360° rotation according to the actual object attenuation, instead of keeping tube current constant for all projection angles as is usual practice today (53). If this is implemented by the manufacturers, it will contribute in a large measure to reduction in patient dose and reduce the need for subjective adjustment of mA, Kalender concludes in his publication of 1999. This has now been realized by leading manufacturers including *Philips*.

#### **Scan length**

This controls the volume of patient irradiated. Unfortunately, with the advent of fast scanners, there is a tendency to increase the scan length so much that examinations of the thorax, abdomen and pelvis in one setting are becoming much more common (23). Practice may soon include head-to-pelvis examinations (particularly for rapid assessment of patients with massive trauma). It is essential to draw the attention of referring clinicians and radiologists to the dose consequences of such practices and efforts must be made to restrict the areas of examination to those clinically essential.

#### **Collimation, table speed and pitch**

In conventional CT, the latter two factors are absent. In spiral CT, all three factors have to be considered together. They are inter-linked in such a way that discussion of one in isolation is irrelevant. For example, pitch is table feed (mm) in one rotation relative to collimation (slice thickness and interslice separation). If the pitch is taken as 1, it can be achieved by 10 mm/rotation for 10-mm collimation. If the rotation time is one second for 360°, the table speed becomes

10 mm/sec. If one alters the collimation to 5 mm without changing table speed, the pitch becomes 2. If the pitch is to be retained as 1, the table speed has to be adjusted to 5mm/sec.

There are two ways by which pitch can be increased: increase table travel speed or decrease collimation. These methods have different effects

Increasing table travel speed for a given collimation and hence higher pitch is associated with lower radiation dose (due to lower effective exposure time) and predictably decreased detection of lesions like small pulmonary nodules.

Decreasing collimation (for a given table speed) results in unchanged scan time, decreased radiation dose, decreased signal-to-noise ratio and, depending upon the signal-to- noise ratio consideration, potentially superior detection of small pulmonary nodules (48).

Increasing the pitch reduces the radiation dose, while changing the collimation has little effect on dose. For a given collimation, increasing the table speed (increasing the pitch) reduces the radiation dose by a factor,  $1/\text{pitch}$ . For example, going from 10 mm and pitch of 1 (10 mm/s) to 10 mm and pitch of 2 (20 mm/s) reduces the radiation dose by 50% according to the study by Naidich et al (48).

Studies aimed at high quality 3-D reconstruction led to the conclusion that there is no indication to apply a pitch smaller than one. Most scanners provide high-quality diagnostic images with a pitch of 1.5–1.6. An increased pitch of 2 is necessary in cases requiring narrow collimation and significant patient coverage, for example in evaluation of ureteral colic and vascular disease (54)

### **Role of combination of factors**

KVp is normally not changed from patient to patient for a particular type of study, even though many machines make it possible to change the setting and it may be desirable to do so. Assuming that scan length and slice thickness have been judiciously chosen as per clinical need, we are left with mA, table feed/rotation and pitch. It has been noted that combined reduction of both kVp and mA has significant impact on radiation dose.

However, consideration has to be given to ensuring image quality is sustained with dose reduction in mind.

### **Shielding of superficial organs**

Conventionally organ shielding has not been practised in CT. However, increased doses in CT have generated interest in this area. Shielding is particularly relevant in children. Use of shielding should not be an excuse to raise exposure parameters. Breast, thyroid, lens of the eye and gonads are seldom the organ of interest in a CT examination, although they incidentally are often in the

beam. Bismuth or Lead can be used depending on ease of manufacturing, versatility, fit and cost.

When the gonads are within the direct CT beam shielding may be considered if they are not the organ of clinical concern and if shielding will not compromise the examination by producing significant artifacts or by directly obscuring a contiguous area of clinical interest. Shielding of the ovaries is difficult because their exact location is usually not clear and the expected pathology is often nearby. This has practical implications for CT examinations of the abdomen.

**Partial Rotation**

A major positive research product in some modern CT scanners is the capability of performing an angular rotation of 270°. This has major application in head scanning whereby if the frontal 90° is omitted, minimal dose is received by the eyes (56).

Therefore it is evident that there is great sharing of responsibilities to ensure dose reduction between the user and manufacturer as illustrated in table 3.

<b>Measures for the user</b>	<b>Measures for the manufacturer</b>
Checking the indication and limiting the scanned volume	Increasing the prefiltration of the radiation spectrum
Adapting the scanning parameters to the patient cross-section	Attenuation-dependent tube current modulation
Pronounced reduction of mAs values for children	Low-dose scanning protocols for children and special indications
Use of spiral CT with pitch factors >1 and calculation of overlapping images in-stead of acquiring overlapping single scans	Automatic exposure control for conventional CT and spiral CT
Adequate selection of image reconstruction parameters	Noise-reducing image reconstruction procedures
Use of z-filtering with multi-slice CT systems	Further development of algorithms for z-filtering and adaptive filtering

**Table 3: Roles of manufacturer and user in ALARA practice**

Kenyatta National Hospital's CT machine model is *Philip's Brilliance 16* and the manufacturer proclaims meeting the above requirements.

### **2.3: Potential risk of carcinogenesis from CT examinations.**

Although most of the quantitative estimates of the radiation-induced cancer risk are derived from analyses of atomic-bomb survivors, there are other supporting studies, including a recent large-scale study of 400,000 radiation workers in the nuclear industry (57), who were exposed to an average dose of approximately 20 mSv (a typical organ dose from a single CT scan for an adult). A significant association was reported between the radiation dose and mortality from cancer in this cohort (with a significant increase in the risk of cancer among workers who received doses between 5 and 150 mSv)

There is direct evidence from epidemiologic studies that the organ doses corresponding to a common CT study (two or three scans, resulting in a dose in the range of 30 to 90 mSv) result in an increased risk of cancer. The evidence is reasonably convincing for adults and very convincing for children.

### **2.4: Justification in ALARA**

Studying the area of justification can be complicated but a rather objective though indirect way of doing it is by assessing the indications against results of the examination. A study carried out by Brown *et al* found out that in non-traumatic abdominal examinations, 44% of the CT results supported the indication, 13% suggested an alternative diagnosis (non-supportive), 41% were negative, and 3% were indeterminate (58). This model of studying justification can be borrowed to other departments.

Part of the issue is that physicians often view CT studies in the same light as other radiologic procedures, even though radiation doses are typically much higher with CT than with other radiologic procedures. A survey involving radiologists and emergency-room physicians in the UK, revealed that about 75% of the entire group significantly underestimated the radiation dose from a CT scan, and 53% of radiologists and 91% of emergency-room physicians did not believe that CT scans increased the lifetime risk of cancer (59). Therefore, the International Commission on Radiation Protection (ICRP) has given weighty consideration to the subject of justification of radiographic exposures and came up with the following recommendations as discussed in the following paragraphs (44).

Requests for a CT examination should be generated only by properly qualified medical practitioners. The radiologist should be appropriately trained and skilled in computed tomography and radiation protection, and with adequate knowledge

concerning alternative techniques. A fundamental principle of radiation protection is that of justification, under which no investigation is undertaken unless the radiation dose is deemed to be justified by the potential clinical benefit to the patient. Also to be considered in the justification process are the availability of resources and cost.

Clinical guidelines advising which examinations are appropriate and acceptable should be available to clinicians and radiologists. Ideally these will be agreed at national level but where they are not, local guidelines are often developed within an institution. Where possible, clinically relevant examinations should be obtained with the lowest achievable radiation dose to the patient consistent with obtaining the diagnostic information. In CT, this requires consideration of whether the required information could be obtained by conventional radiography, ultrasound or magnetic resonance imaging (MRI) without unduly hindering clinical management.

Where CT is deemed to be justifiable clinically, consideration must be given to tailoring the examination to diagnostic needs of the patient. This is good practice and constitutes one of the most important protection roles of the radiologist. CT scanning in pregnancy often raises concern. CT scanning of pregnant females is not contra-indicated, particularly in emergency situations. For computed tomography scans with uterus in the field of view, the absorbed doses to the fetus are typically about 40 mGy. Fortunately, the primary radiation beam on CT scanners is very tightly collimated and can be precisely controlled relative to location by using scout view (topogram). As with other examinations it may be possible to limit the scanning to the anatomical area of interest (ICRP 84). As mentioned earlier, CT examinations of the abdomen or pelvis in a pregnant female should be carefully justified.

As in all x-ray procedures, CT examinations should not be repeated without clinical justification and should be limited to the area of pathology under request. Unjustifiable repetition of exposure may occur if the referring clinician or radiologist is unaware of the existence or results of previous examinations. The risk of repetitive examinations increases when patients are transferred between institutions. For this reason, a record of previous investigation should be available to all those generating or carrying out examination requests. The clinician who has knowledge that a previous examination exists has a responsibility to communicate this to the radiologist.

CT examinations for research purposes that do not have clinical justification at the level of immediate benefit to the person undergoing the examination should be subject to critical evaluation since the doses are significantly higher than conventional radiography.

## **2.5: Optimization**

Once the indications and justification of CT examination of the abdomen have been passed, the radiologist has the ultimate challenge to optimize the examination in view of diagnostic accuracy, image quality and patient dose.

Urban et al in 2000 published an article that guided clinicians on improving diagnostic accuracy during abdominal CT examination (60). The publication avers that tailoring the examination to the working clinical diagnosis by optimizing constituent factors like timing of acquisition, contrast material used, means and rate of contrast material administration, collimation and pitch can markedly improve diagnostic accuracy. Furthermore, failure to tailor the examination can greatly reduce the ability to accurately and confidently detect disease.

Communication between the radiologist, the patient, and the referring physician is essential for narrowing the differential diagnosis into a working diagnosis prior to scanning. Otherwise, routine helical scan protocols are suggested for studying non-localized abdominal pain in acute setting in which case this should be the exception rather than the rule.

The employment of contrast is a particular area that has elicited research interest. Single acquisitions performed during either the arterial phase (beginning 20–30 seconds following intravenous injection of contrast material) or the portal venous phase (beginning 70–90 seconds after injection) have been proven adequate in most patients. Occasionally, images should be acquired during both phases, especially for dedicated contrast material–enhanced evaluation of the liver or kidneys. Delayed images (acquired beginning 4 minutes after injection) are also helpful in cases of suspected pyelonephritis or in the work-up of suspected pelvic disease, when opacification of the bladder may be desired (61). Details of the common protocols in abdominal CT examination have been highlighted in the introduction section. A lot of work is still going on to improve on effective protocols and it necessitates the practising radiologist to keep abreast with current best practice in optimization.

An examination that does not have clear-cut working differential diagnosis, properly planned protocols including judicious use of contrast media and scan parameters can easily lead to poor diagnostic yield and unnecessary radiation dose to the patient. In addition repeat examination under such circumstances is definitely undesirable.

## **2.6: Practical assessment of ALARA**

From what is highlighted in the foregoing literature, salient variables can be taken for evaluation of ALARA practice in a multi-slice CT unit like the one at KNH.

These are

1. Justification
  - Analysis of indications and scan results.



## 2. Optimization

- Matching of indication with examination protocol
- Pitch factor
- Scan length
- Dosimetry- CTDIvol, DLP and effective dose (E).

## **Chapter Three: JUSTIFICATION OF STUDY**

Kenyatta National Hospital acquired a new 16 multi-slice CT scanner model in late 2007 that has undoubtedly and positively influenced patient management outcomes. On the flipside the positive revolution may mask the reality of high radiation dose to the patient. Published literature has revealed misconceptions about the radiation dose from helical CT scanners. The fact is that short scan time with helical CT scan does not translate to reduced radiation dose. In fact the converse has been shown to be true. It is therefore important to update both clinicians and radiologists on knowledge of this new useful tool and direct practice to optimization of patient dose management to its best.

**Research Question:** How does ALARA practice in patient care using 16-multislice CT scan for abdominal examinations at KNH compare with established international standards?

## **Chapter Four: OBJECTIVES OF THE STUDY**

**4.1: General Objective:** To assess justification of CT abdominal examinations carried out, quantify the radiation dose and evaluate the optimization of scanning parameters that contribute to radiation dose determination within the ALARA principle in comparison to international standards.

### **4.2: Specific Objectives:**

1. To assess justification of CT abdominal examinations in KNH in view of their indications and results
2. To estimate the patient dose from the examinations and variability with patient size
3. To evaluate the technical contributors to patient dose including matched protocols and operator scan settings
4. To compare the results with internationally published data in light of ALARA.

## **Chapter Five: STUDY METHODOLOGY**

### **5.1: Study design**

This was a cross-sectional survey carried out at KNH between July 2008 and March 2009.

### **5.2: Study Area**

Kenyatta National Hospital's Department of Diagnostic Radiology. KNH situated in Nairobi, Kenya is the largest referral hospital in East and Central Africa region. The Radiology Department is located on the ground floor of the hospital next to the Accident and Emergency department. The department serves the hospital's patients, both in and outpatient categories, as well as private patients referred from other medical institutions.

The CT scan unit of KNH can arguably be considered as the busiest in Kenya with between 25 and 30 patients scanned in a day. Out of this number at least three or four undergo abdominal examinations.

### **5.3: Study population and sample**

Patients referred for abdominal CT scan KNH aged between 20 and 65 years both male and female constituted the study population.

The study sample was drawn from the study population through random sampling.

### **5.4: Data collection**

This was done using a data collection tool that reflected the patient's journal of indications, outcome of study and dosimetric parameters.

The researcher filled in these details during the scanning procedure and after analysis of the radiological report following review by a qualified consultant radiologist.

The variables included were:

- 1) Matched data of indication as per request form and results of CT examination
- 2) Abdominal girth of the patient measured at the umbilical level
- 3) Matched indication and protocol
- 4) Scan length
- 5) Pitch
- 6) mAs
- 7) CTDIvol
- 8) DLP
- 9) Calculated E

The dosimetric parameters were read off the machine and effective dose calculated using the formula demonstrated on page 16. The data collection form is attached in the appendices section.

#### **5.5: Sampling technique**

Random sampling method was applied.

#### **5.6: Sample size determination (n)**

Based on a study conducted in the United States to compare CT radiation outputs, a mean mGy/mAs value of 0.229 at 120 kv with a standard deviation of 0.105 and standard error of sample mean as 0.011 (62). KNH's tube voltage for abdominal CT is 120 kv similar to the one in the above quoted study.

Fixing  $\alpha = 0.05$  and  $\beta = 0.8$  for a two sided tail test,  $n = 16 \sigma^2/d^2$ ,  
Where  $\sigma$  is known population mean and  $d$  is known significant difference in radiation output,

$$\text{Therefore } n > \frac{16 \times (0.229)^2}{(0.105)^2}$$

> 76 patients

#### **5.7: Inclusion and exclusion criteria**

Patients between the age of 20 and 65 who had been specifically referred for abdominal CT scan examination for non-traumatic indications were included for the study. This included both male and female patients that were non-pregnant, evidenced by LNMP, successful contraceptive method and biochemistry if doubtful.

Pregnant mothers were excluded from the study as well as patients with trauma and those who fall out of the above age bracket.

Less than 20 years of age would be considered within the actively growing and therefore CT usage is normally guarded.

Patients with trauma have a standard protocol that is strictly adhered to and therefore operator practice was expected to be non-variable.

#### **5.8: Data processing and analysis**

Sorting out of the data and analysis was done using "Epi Info", SPSS statistical softwares and MS-Excel spreadsheet.

Test of significance was determined in consultation with a biostatistician after data collection.

## **Chapter Six: ETHICAL CONSIDERATIONS**

There was no direct contact with the patient but only the scan parameters. The abdominal girth was calculated electronically from the CT console. However, consent was still sought from the patients who participated in the study. The patient's identity was never revealed anywhere during the study and their right to confidentiality and respect was maintained.

No additional or invasive technique was employed to the patient. The requested examination was done within the standard protocol by the CT operator. No modifications were done that may have increased the patient's radiation dose or compromised the diagnostic quality of the scan. The study sought to benefit the patients' population by seeking to promote best practice in radiation dose management and improved diagnostic yield from CT examination.

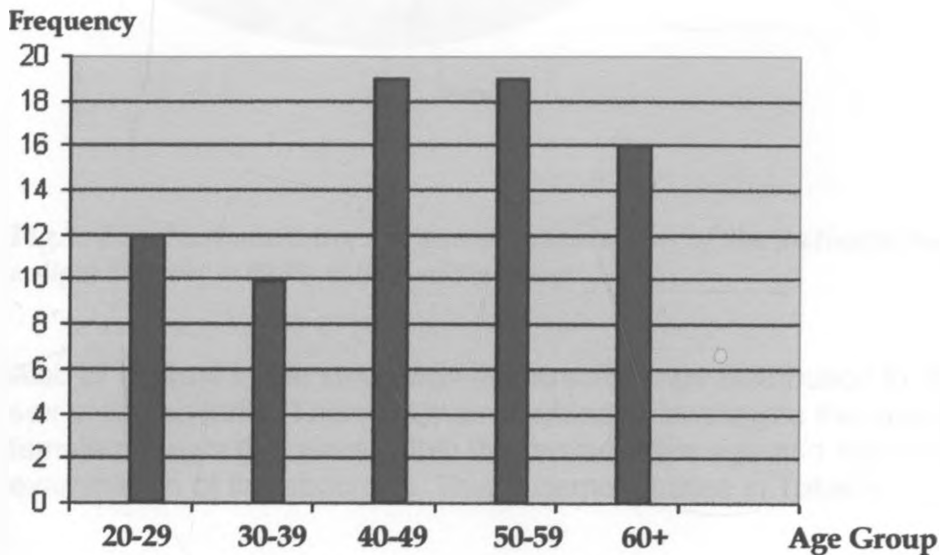
The study received the approval of the Kenyatta National Hospital / University of Nairobi Ethical Review Committee.

Attached in the appendices is the consent form in both English and Swahili languages.

## Chapter Seven: RESULTS

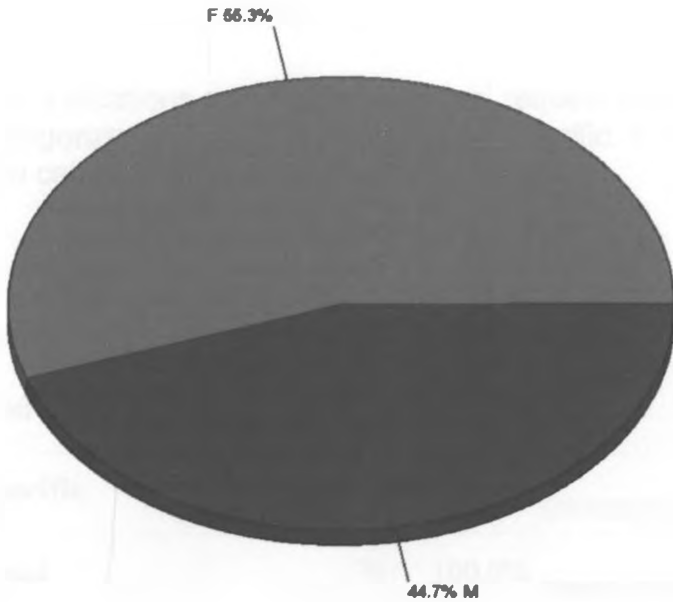
### 7.1. Biodata

The study sought to classify the patients into age groups of 10 years and the distribution pattern plotted as shown in figure 6. The majority of patients (71.1%) were 40 years of age and over.



*Figure 6: Bar chart demonstrating the age group distribution:* This emphasizes the fact that CT abdominal examinations at KNH were tending to be in the more elderly of the population.

The patients were also categorized according to their sex as demonstrated in the pie chart (Fig.7).



**Fig.7: Pie chart showing the sex representation of the patients: Female patients were a slight majority at 55.3% of the sample group.**

Also of interest in the study was the stratified age distribution in relation to the sex of the patients. This was mainly intended to analyze the population of the female patients that were within the reproductive age and had undergone CT examination of the abdomen. This is demonstrated in Table 4.

Age	Frequency	Percent	
20-29	8	19.0%	
30-39	7	16.7%	
40-49	13	31.0%	
50-59	10	23.8%	
60+	4	9.5%	
<b>Total</b>	<b>42</b>	<b>100.0%</b>	

**Table 4: The age distribution of the female patients. About two thirds of the patients were within pre-menopausal age groups.**



## 7.2. JUSTIFICATION

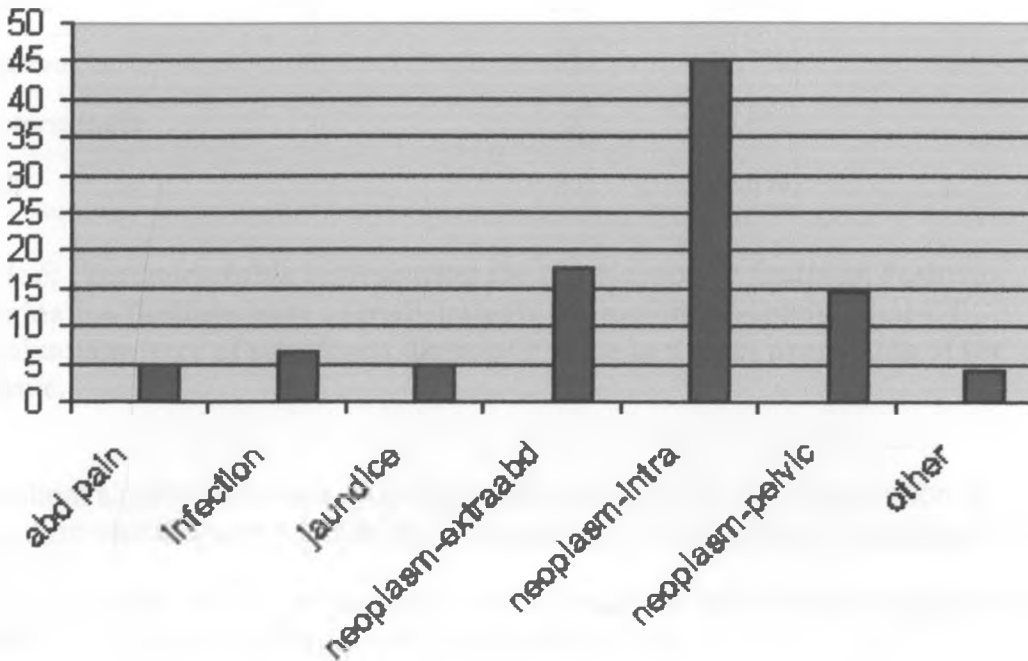
The indications as per the clinicians' request forms for the CT examinations were categorized as either specific or non-specific. The frequency distribution of the two categories is as represented in Table 5.

Indication	Frequency	Percent	
Non-Specific	14	18.4%	
Specific	62	81.6%	
Total	76	100.0%	

**Table 5: Frequency table of specific and non-specific indications: Most of the indications (81.6%) were found to be specific.**

Both the specific and non-specific categories of indications were further sub-categorized (figures 8).

Frequency  
percentage



**Fig 8: Bar chart demonstrating specific indications by category: Already known malignant disease consisted the majority of the indications whereby CT was being used for staging.**

Further, of the 14 patients whose requests were non-specific 71.4% had abdominal pain, which was not well characterized, and the clinician was apparently utilizing CT examination for exploratory purposes.

The CT findings of the examinations were analyzed in relation to their diagnostic yield for each patient. They were categorized as positive, negative or indeterminate. The frequencies of these findings are shown in Table 6.

CT Diagnosis	Frequency	Percent
Positive	56	73.7%
Negative	15	19.7%
Indeterminate	5	6.6%
Total	76	100.0%

**Table 6: Frequency table representing the CT diagnostic findings: Positive examination findings were overwhelmingly the majority implying that CT examinations were of significant diagnostic value in a great proportion of the patients.**

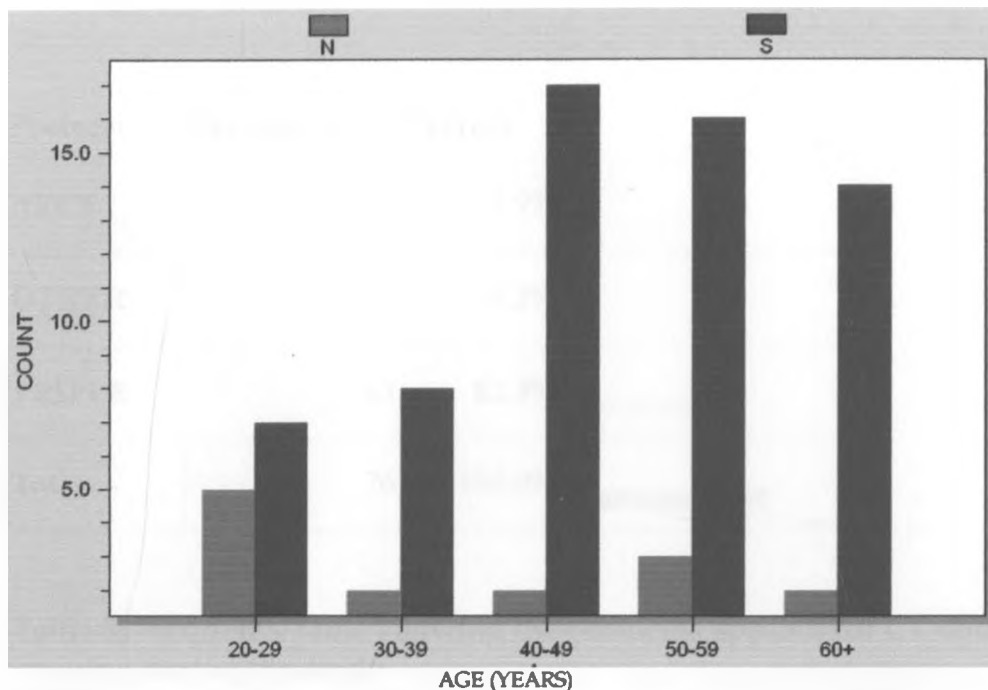
Statistical significance was demonstrated at  $P < 0.05$  on the association of indication variables and those of CT diagnostic findings with Chi-squared value of 25.1653.

Cross-tabulated results of the categorized variables for indications against those for the CT diagnostic findings are produced in Table 7.

Indication	CT Findings			TOTAL
	Indeterminate	Negative	Positive	
<b>Non-Specific</b>	2	9	3	14
Row %	14.3	64.3	21.4	100.0
Col %	40.0	60.0	5.4	18.4
<b>Specific</b>	3	6	53	62
Row %	4.8	9.7	85.5	100.0
Col %	60.0	40.0	94.6	81.6
<b>TOTAL</b>	5	15	56	76
Row %	6.6	19.7	73.7	100.0
Col %	100.0	100.0	100.0	100.0

**Table 7: Cross-tabulation of Indication vs CT findings. An association between the specificity of the indication and the findings from the study is demonstrated. This means for example that a specific indication will more likely provide a concrete solution for the clinician.**

Further, the non-specific and specific indications were stratified according to the age group of the patient. It was demonstrated that the youngest of the groups (20-29 years) had the greatest ratio of non-specific: specific indications. The bar chart in Figure 9 demonstrates this finding.



**Fig 9: Bar charts demonstrating differential comparison of indication (specific/non-specific) by age (N=Non-specific, S= Specific)**

### **7.3.OPTIMIZATION**

The protocols applied were studied. The CT machine had 11 saved protocols that were applicable for abdominal scanning procedures. Only two of those inherent protocols were noted to have been applied. Each protocol has implications in both radiation dose to the patient and diagnostic value for the indicated examination. The most employed was the triple phase protocol at 82.9% (Table 8). Non-contrast protocol was only used in three of the cases. The rest of the patients were subjected to a modification of the triple phase protocol, mainly by acquiring a delayed phase for opacified bladder at the discretion of the operator.

Protocol	Frequency	Percent	
NECT	3	3.9%	
OTHER	10	13.2%	
TRIPLE	63	82.9%	
<b>Total</b>	<b>76</b>	<b>100.0%</b>	

**Table 8: Frequency table showing the protocols applied for CT abdominal imaging during the study.**

In regard to the matching of protocols to clinical indications as per published guidelines, it was found that about 40% of the examinations were performed under mismatched circumstances as demonstrated in Table 9.

Match status	Frequency	Percent	
Yes	46	60.5%	
No	30	39.5%	
<b>Total</b>	<b>76</b>	<b>100.0%</b>	

**Table 9: Frequency table demonstrating the proportions of matched protocols with clinical indication**

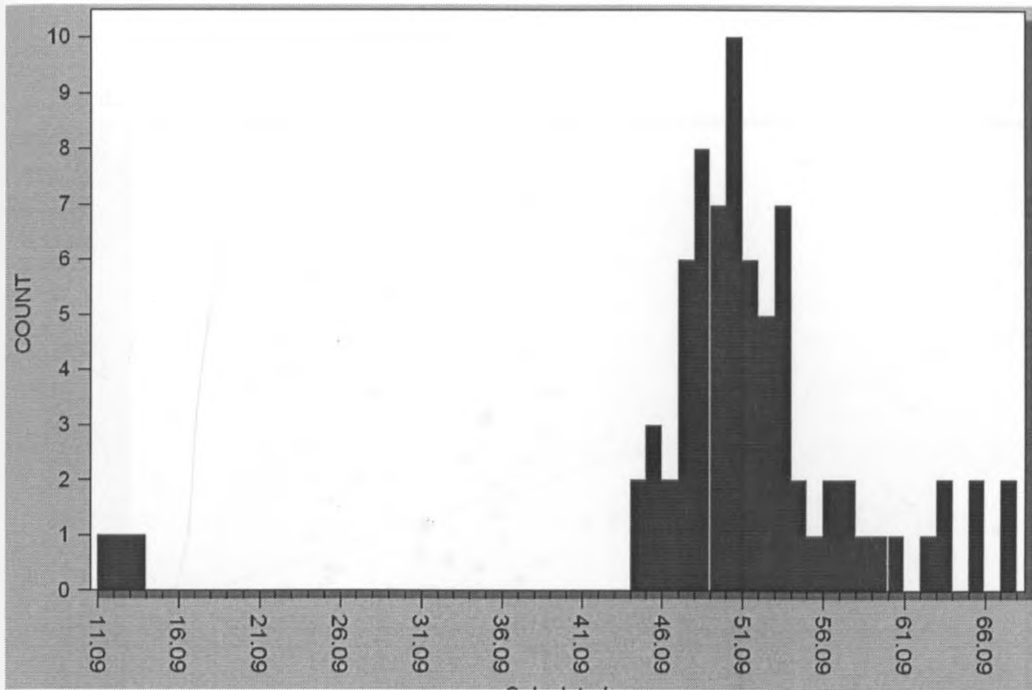
The variables that were categorized for the match status of the examination were cross-tabulated against the ones for the CT findings. Statistical analysis was done using Chi-squared method giving a value of 19.7747 which was significant at  $P < 0.05$ . Of importance to note is that none of the examinations that were properly matched yielded an indeterminate result and positive imaging findings

were recorded in over 90% in this same group. These findings are demonstrated in Table 10.

CT Finding				
Match status	Indeterminate	Negative	Positive	TOTAL
<b>Matched</b>	0	4	42	46
Row %	0.0	8.7	91.3	100.0
Col %	0.0	26.7	75.0	60.5
<b>Non-matched</b>	5	11	14	30
Row %	16.7	36.7	46.7	100.0
Col %	100.0	73.3	25.0	39.5
<b>TOTAL</b>	5	15	56	76
Row %	6.6	19.7	73.7	100.0
Col %	100.0	100.0	100.0	100.0

**Table 10: Cross-tabulation of match status and CT findings.**

The measures of central tendency for calculated effective dose, E, were computed. The mean value was 50.7720 mSv, with a standard deviation of 9.4380 mSv. Median and mode values were at 50.7350 and 49.2800 mSv respectively. The minimum value was 11.0900 and the maximum was 67.8300 mSv. Graphic presentation of the findings of these measures of central tendency are demonstrated in figure 10.



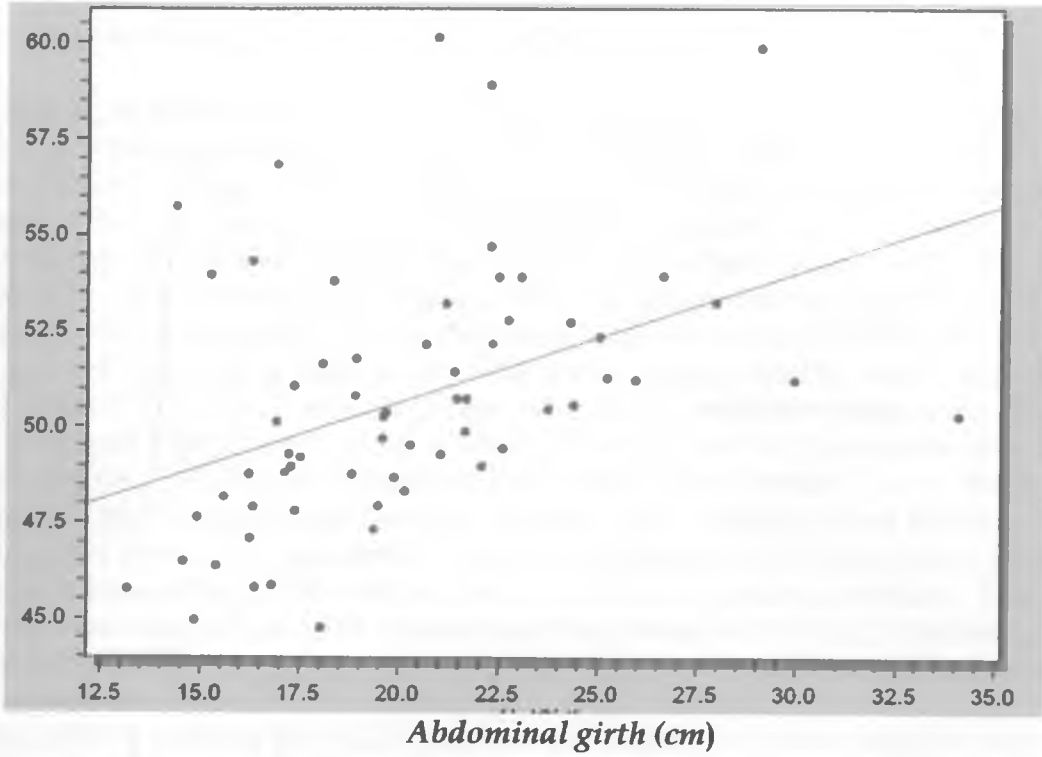
Calculated E

**Fig 10: Measures of central tendency for estimated effective dose , E(mSv)**

Very low positive correlation was demonstrated between the abdominal girth of the patient measured at the umbilical level and the radiation dose received per CT examination.

The Correlation Coefficient,  $r^2$  was 0.18 using Pearson correlation –regression method. This is graphically represented in Figure 11.

***E (mSv)***



**Fig 11: Correlation of patient's abdominal girth with E for similar protocol (triple phase).**



## **Chapter Eight: DISCUSSION**

### **Demographics of patients in the study**

In this study which recruited 76 adult patients with a lower age limit of 20 years, 71.1 % of the patients were aged 40 years and above while 15.8% were less than 30 years of age (Table 4). Still, 46.1% of the patients were aged above 50 years. This gave the impression that currently CT abdominal examination in KNH is mostly performed on patients that are more advanced in age, which was by and large determined by the nature of the indications that the patients presented with, as further discussed below. Fortunately concerns about radiation risk also lessen with advancing patient age. This is even more matched with the gender of the patient (Table 4). Given that in female patients, radiation dose to the gonads is extremely high, there is great concern for women within the reproductive age. From figure 7, 55.3% of the patients in the study were female. Out of the female patients, 66.7% were aged below 50 years of age. Probably other imaging modalities might have answered the clinical questions this proportion of female patients presented within a state of less or no risk of ionizing radiation. The study, however did not seek to establish the correlation of the CT diagnostic findings with other imaging modalities like ultrasound or MRI as this was outside its objectives.

In addition it requires the radiologist and the clinician to further explore each individual request and draw the appropriate conclusions concerning the benefit and radiation risk to the patient and employ alternatives where it is applicable as far as this proportion of patient population is concerned. Cost effectiveness is also to be put into consideration under such circumstances.

### **Matching of protocols with the indications**

The group of patients whose request forms had non-specific indications may appear the minority according to this study but the fact is that such practice if unchecked can grow with time especially in a setting where availability of CT scanner is not an impediment to patient's mode of investigation. It is therefore important for clinicians to recognize the radiation risk against the benefit of the investigation before generating the request form. The request may pass through the radiologist even when it has a non-specific indication for whatever reason and the patient eventually gets scanned. Worse still the CT findings may turn out to be negative. The ALARA principle under such circumstances gets undermined in the sense of poor justification for radiation exposure to the patient.

Once the radiologist passes the clinical request for scanning the onus is on him to match the indication with the appropriate protocol. This not only ensures justifiable radiation dose according to ALARA principle but also enhances the diagnostic yield from the study. The study sought to delve into this issue by assessing the proportion of matched protocols and 39.5% of the examinations

were mismatched as far as the indications were concerned (Table 9). The practice that was noted during the period of this study was that the radiologist (consultant or resident) usually countersigned the clinician's request form before booking for the examination. This is the point at which clear instructions to the technologist should be spelt out concerning the desirable protocol. Or else, the radiologist must of necessity review the patient and the clinician's request just before the start of the examination. For example, cases of obstructive jaundice and pancreatic disease having been given iodinated oral contrast were encountered in this study.

The CT diagnosis is the answer the clinician gets from the scan process and so it is logical to assess the proportion of positive findings. From the study, positive findings were registered in 73.7% of the examinations while indeterminate and negative findings were at 6.6% and 19.7% respectively (Table 6). However a negative or indeterminate finding is not to be condemned at the face value but the principle to emphasize is that a specific clinical question has to be answered. Further, the study demonstrated statistical significance on cross-tabulation of the CT diagnosis with the specificity of the indication at  $p < 0.05$  as shown in Table 7. In the same vein cross-tabulation of match status of protocol against CT diagnostic findings, it was also statistically established that there was an association at  $p < 0.05$ . According to this study, it means that having a specific indication and correct match status for indication and protocol are factors that were strongly associated with a positive CT diagnosis and therefore good practical applications for ALARA as far as justification is concerned (Table 10). The findings thus largely concur with published information by Urban *et al* in 2000 (60) on the need to tailor the examination according to the clinical question.

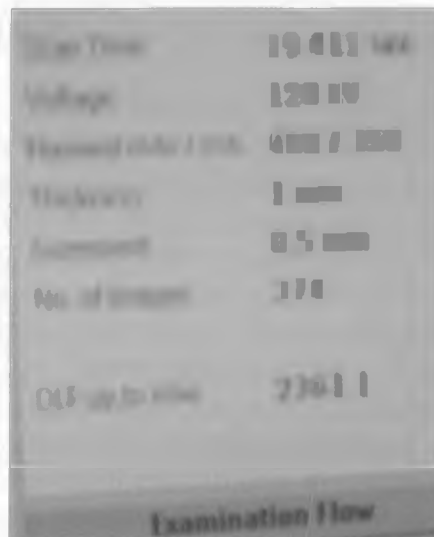
From analyzing the stratified age and specificity of the indication in this study, it was observed that the greatest proportion of non-specific indications were recorded in the less than 30 years age group (Fig.9). It is important to note that this is also the same proportion of the population that is more vulnerable to the harmful effects of radiation. The message to the referring clinician is to as much as possible to avoid CT as a screening tool.

## **Radiation Dose**

ALARA practice cannot be exhaustively assessed without quantification of radiation dose. The final measurement of radiation dose from this study was the estimated effective dose (E). As discussed from the literature review and methodology sections, estimated E was calculated from the displayed dose length product (DLP) on the operator's console during image acquisition with a conversion factor of 0.017 (Table 1, page 16)

The mean effective dose was 50.77 mSv (5.08 rem) as shown in figure 10 under the results section with a standard deviation of 9.44 mSv. Internationally published data puts E for CT abdominal examinations at about 10 mSv as

described under literature review. This means that the mean calculated E from this study stands out at about five times higher than the internationally published data.



**Fig.12: A picture demonstrating displayed DLP on the operator’s console during image acquisition. This particular case was for CT Head examination, which is also the case during abdominal CT imaging whereby a conversion factor of 0.017 is used to estimate the effective dose, E. (Courtesy: KNH Dept of Radiology)**

As discussed under the literature review, the gold standard for calculating radiation dose for CT scan examinations is the use of phantoms for a particular CT machine and for different protocols within the same machine. However modern CT scanners have inherent radiographic film dosimeters next to the patient’s skin during the examination from which DLP is displayed on the operator’s console (Fig 12). These have been globally adopted for estimating E since already published results have given good correlation between displayed and phantom measured radiation doses (Fig 5, page 17). It was therefore practical for the purposes of this study to utilize displayed dose parameters for estimation of E with acceptable reliability of the results. The validity of the results is subject to inherent machine characteristics that largely depend on the manufacturer’s input and in this study *Philips* engineers proclaimed good quality assurance practice.

As the number of helical scanners is constantly increasing in the country, the National Radiation Protection Board (NRPB) must also provide for a database that assesses the correlation of the displayed and measured dose for local scanners. This will go a long way in establishing confidence in the operator when

estimating the radiation dose during a particular examination in accordance with international standards. It would be good practice to avail these readings in the patient's records including on the printed film. Under such circumstances it would be easy for the clinician and the radiologist who are not present during the examination to not the readings.

With validity and reliability of the results thus discussed, the findings of this study as regards the radiation dose need to be examined in the light of ALARA. Recent literature is starting to voice concerns over dose levels greater than 20 mSv (57). This appears to be where KNH is operating around.

The estimated effective dose values gave a very wide range of the readings with outliers on both the lower and higher levels as shown in figure 10. These outliers have to be assessed before considering inherent patient and machine characteristics in view of the examination protocols employed on each patient. The ones on the left indicate cases in which NCECT protocols were used. An interesting protocol was also encountered during the study that included the conventional triple phase study plus a delayed 10 min bladder view and this was responsible for the higher placed outliers. This particular protocol was found to give about 34% higher than the average dose to the patient compared to the standard triple phase examination. Moreover, this is not a preprogrammed protocol within the machine but one that was applied by the operator in view of not a well contrast filled bladder after completion of the standard triple phase protocol. (Fig.13)

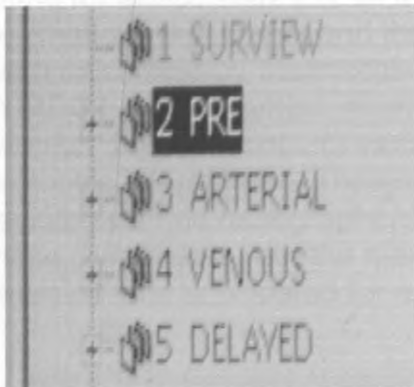
This further means that the operator can manipulate the protocols and this can be to the advantage of the patient in terms of improving the diagnostic value of the images acquired. All this has to be done judiciously and with radiation dose to the patient put into consideration in accordance with ALARA principle. For the patients in this study who underwent this extra phase, there was no justification for it when their CT imaging findings were examined retrospectively.

On close scrutiny against published literature on CT radiation dose reduction strategies, the study revealed that there are certain parameters within the preprogrammed protocols that have to be seriously revisited. Of particular interest is pitch and mAs. The preset pitch for the CT machine in this study was invariably lower than 1 as further discussed below. Efforts could have been made at the designing of the protocols to optimize this parameter.

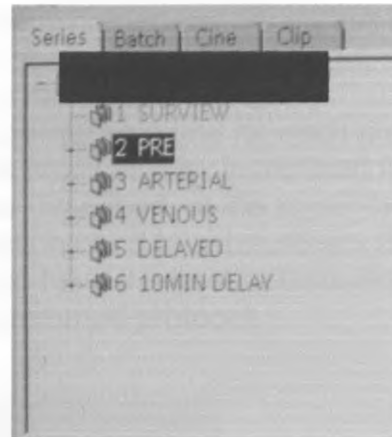
## **Determinants of Radiation Dose**

The study also sought to assess the parameters both patient and machine inherent that are known to influence radiation dose.

Factors that are specific to the machine and were measurable in this study are tube voltage, tube current, mAs, collimation, table speed and pitch. Scan volume is dictated by the clinical indication and is within the operator's capability to easily influence. The patient's size also is documented to influence the radiation dose received.



a



b

**Fig13a): a picture of the displayed triple phase protocol (b): an additional 10 min delay acquisition following triple phase protocol intended to opacify the urinary bladder. This extra acquisition was noted to result in an increased radiation dose of up to 34% compared with the triple phase protocol. (Courtesy: KNH Dept of Radiology)**

In the study sample the mAs applied were constant at 300 for the protocols used except the NCECT whereby the value was at 250. The operator at the moment of acquisition had no capability to adjust the values since these were incorporated within a preprogrammed protocol. The point of departure was therefore choice of appropriate protocol for the operator in ensuring the clinical question is answered within the ALARA principle. Furthermore, comparison of the same protocols with other similar machines for mAs values would be required to establish the performance of the KNH CT scanner in regard to this component of radiation dose determinant. However, the objectives of the study did not include comparing different CT scanners though this is an important point of consideration for any follow up studies as the number of machines in the country increases. This does not construe the fact that it is solely the manufacturer's role to determine mAs for these protocols. For example, the mAs encountered in the CT abdominal examinations at KNH need to be optimized to endeavour at achieving radiation dose reduction. Radiologists and technologists have to bear in mind that in cases whereby mAs are highly set as it is the case with KNH currently, 80% reduction on the same has been documented not to degrade the image diagnostic quality (49,50). Of course, the benefit to the patient needs not

to be overemphasized. At the installation of the CT scanner the institutional radiologists and radiographers need to be involved to determine the optimal mAs for each protocol in accordance with ALARA principle. An article, highlighted in the introduction section, by Crawley *et al* (11) can be used as a guideline by radiologists when inaugurating CT machines within their departments.

Likewise, collimation, table speed and pitch were inbuilt for each protocol and the operator had no influence over them during the image acquisition. Definition of pitch for SSCT is usually straightforward while controversy has bedeviled the same for MDCT (63). For all the examinations carried out during this study, the collimation was 3.0mm and the increment per each rotation was 1.5 mm and the pitch calculated by the machine was displayed as 0.938 (Fig 15)

In MDCT the collimation, pitch and mAs operate as a unit for each protocol and as such did not constitute variables for this study as they were fixed for all the protocols interrogated. Therefore as earlier described, at the onset the radiologists and radiographers in an institution need to exhaustively discuss on these parameters with the manufacturers to have the best optimization for the examinations anticipated for each preprogrammed protocol.

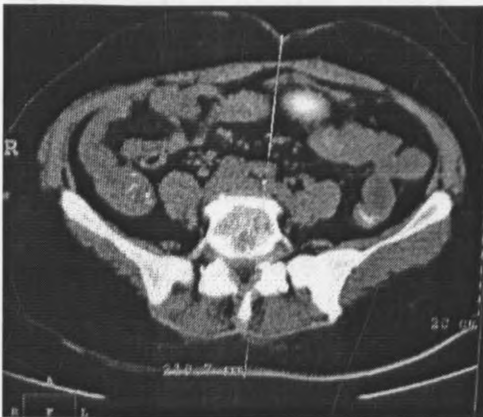
Image Parameters			
Name	[REDACTED]	Gender	M
ID	X 22669 09	Age	27Y
Accession No.	DR. KIBAYA/NJIWE		
Referring Physician	CAS 14404		
Operator Name	NJIWE		
Requested Procedure	ABDOMEN		
Label	PRE	Resolution	STANDARD
Protocol Name	ABDOMEN PRE * 3 I	Collimation	16x1.5 mm
Scan Protocol	Axial Helix	Slice Thickness	3.00 mm
Image Number	2-145	Slice Increment	1.5 mm
Image Date	06 Apr 2009	Pitch	0.938
Image Time	15:40:03.9	Field of View	300.0 mm
Patient Position	Feet First Supine	Voltage	120 KV
View Conversion	RIGHT ON LEFT	mAs	300 mAs/Slice (375 +
Table Position	193.5 mm	Rotation Time	0.75 sec
Table Height	96 mm	SP Filter	Yes
Table Speed	30 mm-sec	Filter	B
Scan Length	445.5 mm	Adaptive Filter	NO
Scan Time	16.19 sec	Image Matrix	512 x 512
		Center X, Y	1.0, 0.0 mm
		Image Zoom	1.00
		CTDIvol	21.1 mGy

**Fig 14:** A picture of the patient's journal of image parameters from which voltage, mAs, slice thickness, increment and pitch can be read for a particular protocol. Note also the CTDI<sub>vol</sub> is displayed. (Courtesy: KNH Dept of Radiology)

As discussed in the literature review section, much emphasis is placed on pitch. Existing evidence shows there is no indication to apply a pitch smaller than one, even in cases where high-resolution 3D reconstruction is required including in vascular studies (54). This therefore produces another challenge for the radiologists and engineers to exhaustively optimize this parameter at the installation stage of the protocols.

When it comes to patient's size and the influence on radiation dose, the study described patient's size as the abdominal girth measured at the umbilical level (Fig 16).

The abdominal girth did not reveal any significant correlation with the radiation dose received by the patient (Fig.12 under results section). This could have had many factors influencing including inherent pathological processes that may have differentially increased the scan volume without necessarily affecting the abdominal girth at the umbilical level. Therefore this means that more conclusive result would be achieved if measurements were done having matched for this confounding factor. Existing literature has already proven the fact that scan volume has direct influence on radiation dose. For globally increased abdominal girth a trend of increased radiation dose could be observed during this study especially in cases involving ascites though only six patients had this condition.



**Fig 15:**Demonstration of abdominal diameter measurement at the umbilical level of a patient using CT image. (Courtesy: KNH Dept of Radiology)

## **Chapter Nine: CONCLUSION**

The results highlighting the specific and non-specific indications for CT scanning indicate that clinicians still need to be more aware of the necessity to justify the radiation risk versus benefit to the patient. A non-specific request tends to increase the probability of an indeterminate or negative CT examination with both patient management and radiation dose ramifications.

For the younger patients and especially women within the reproductive age the proportion exposed to irradiation through abdominal CT scanning needs to be after thorough considerations of how other imaging modalities would fare in answering the clinical question.

Given that over a third of the abdominal CT examinations in this study were done with mismatched protocols, it is important to have radiologists and radiographers getting more involved in the design of protocols and in their application since they not only influence the radiation dose but they also affect the diagnostic yield. A practical example can be drawn from local practice on CT scanning of the abdomen following trauma whereby only post-i.v. contrast acquisition is done, obviously with low dose implications and good diagnostic yield. This study did not include trauma patients though, owing to the fact that no variability on protocol was expected.

The preprogrammed protocols in this study emerged as possible obstacles to achievement of ALARA goals since they had fixed values for Kvp and mAs, which the operators invariably applied during the scanning process. During the period of this study local practice did not include shielding of sensitive organs, which can be described as an oversight as far as ALARA is concerned.

Radiation protection in CT must not become subject to paranoia or a witch-hunt, but equally there is no room for complacency. Both patients and purchasers expect staff to adhere to best practices (64).

Finally, since some of the technical factors affecting radiation in MDCT may be unalterable by the operator during scanning, especially in abdominal imaging, to reduce the dose received by the patient, justification for the examination appears to be the main component of ALARA that clinicians and radiologists can take advantage of.



## **Chapter Ten: RECOMMENDATIONS**

1. Studies of the correlation of CT and other imaging modalities need to be availed locally for most commonly encountered abdominal pathological conditions to enhance the tenet of justification within the ALARA principle.
2. The operator preset protocols must be optimized in regard to mAs and Kvp or else each patient's examination must be customized without necessarily applying a preprogrammed protocol that produces high exposure factors.
3. Shielding practice of sensitive organs must of necessity be embraced locally.
4. Local studies correlating displayed radiation dose on the CT machines with the measured dose need to be carried out in keeping with Quality Assurance practice.
5. Institutional radiologists, technologists, engineers and most importantly NRPB officials must come together during installation of CT machines to optimize the scanning protocols.

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## **INFORMED CONSENT AGREEMENT**

**Title of study: Abdominal Examination in KNH Using 16 Multi-slice CT Scan: Review of ALARA Practice in Managing Patient Dose**

**Institutions:** University of Nairobi and Kenyatta National Hospital

**Principal Investigator:** Dr. Mutala T. Musila- M.MED (DIRM) student.

**Supervisors:** Dr. N.M. Kimani, UoN, DDIRM  
Prof. N. M. Tole, UoN, DDIRM .

**Participation:** Participation in this study is voluntary and without payment. Declination or discontinuation to participate in the study will not have any adverse eventualities on the practitioner.

**Objectives of the study:** To assess the components of ALARA practice in terms of CT abdominal examinations indications and results, the patient dose and the technical determinants of the same in comparison to international standards

**Introduction:** I am seeking to establish the current practice in management of patient dose in harmony with published and evidence based best practice and international standards in Abdominal CT Scanning within KNH.

**Benefits of the study:** The information derived from the study will be shared amongst all the stakeholders including the Departments of Radiology, KNH and University of Nairobi geared towards improved practice in patient dose management during Abdominal CT procedures.

**Procedures to be followed:** Direct observations and measurements from the CT console will be carried out during the process of scanning the patient. No invasive procedures will be carried out. No additional instrumentation will be placed on the patient, only the standard ones for CT scanning.

**Risks of Participation:** No risk is perceivable from participating in this study.

**Assurance of Confidentiality:** Information gathered will in no way bear your identity and will be kept confidential only available to investigator, supervisors and the institution, namely University of Nairobi and KNH.

## KIBALI CHA KUSHIRIKI KATIKA UTAFITI

Jina langu ni Daktari Musila Mutala, mwanatumizi katika chuo cha udaktari, Chuo Kikuu cha Nairobi. Ninalanya utafiti kuhusu kipimo cha nguvu za eksirei zenye kuleta madhara kutokana picha ya CT kwa tumo.

Haki zako zitalindwa. habari utakayotambua ile itaayopatikana kukuhusu. itakuwa siri wakati wote na itatumika katika utafiti huu.

Jina lako halitatumika, bali ile nambari ya matibabu tu ndiyo itaayotumika.

Ni muhimu kuelewa ya kwamba ushiriki ni wakujitolea. sio lazima kushiriki katika huu utafiti, na pia waweza kubadili nia yako walati wowote kuhusu kuendelea kushiriki, bila ya kuathiri huduma zako za kiafya.

Asante sana kwa ushirikiano wako

Mimi .....nimeelezewa kikamilifu kuhusu utafiti huu na nakubali kushiriki.

Sahihi.....

Tarehe.....

Nambari.....

Pia unaweza kuwasiliana na mimi kupitia anwani ituatayo,

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**Appendix 1:**

**Data collection form for assessment of Justification and Optimization**

Participant No.

Age	
Sex	
Indication	
Protocol	
Match status	
Abdominal girth (cm) Umbilical level	
Result	
Scan length	
Pitch	
mAs	
CTDIvol	
DLP	
Calculated E	