EFFECTIVE DOSE ESTIMATION AND CANCER RISK ASSESSMENT DUE TO SOME SELECTED CT EXAMINATIONS AT SWEDEN GHANA MEDICAL CENTRE (SGMC)

BY

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DECLARATION

Student's Declaration:

I hereby declare that, with exception of references to other people's work which have duly been acknowledged, this work is the result of my own original research undertaken under supervision, and either in whole or in part has not been presented for any other degree at another university elsewhere.

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Supervisors' Declaration:

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with guidelines on supervision of thesis laid down by the University of Ghana.

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DEDICATION

I dedicate this work to my parents Mr. and Mrs. Akyea-Larbi and my two siblings Mr. Kwadwo Akyea-Larbi and Ms. Esther Mintah-Larbi and also to my wife Mrs. Antiana Akyea-Larbi for their continuous financial support, love, care and prayers throughout this research.

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ABSTRACT

In this study, the effective dose and its associated cancer risk were estimated for adult patients undergoing the five most common types of CT examinations (head, neck, chest, abdomen and pelvis) at Sweden Ghana Medical Centre (SGMC) in the Greater Accra Region of Ghana. Two main methods were employed in the study: patients' data collection and phantom measurement to verify the patient data. The effective doses were estimated using the dose length product (DLP) from the control console of the CT machine and the anatomic region specific conversion factors. The lifetime attributable risk of cancer incidence and cancer mortality for each patient for a particular examination were both determined from the effective dose, age and sex of each patient with the help of BEIR VII report. The effective doses were all within the range of typical effective doses (1-10mSv) for CT examinations. The abdominal scan recorded the highest mean effective dose of 7.01 mSv with the minimum effective dose of 1.00 mSv and maximum effective dose of 24.46 mSv. The average risk for all the examinations was observed to be low (1 in 10 000 to 1 in 1000). The average lifetime attributable risk of cancer incidence was 0.049% (1 in 2041) and in the range of 0.004% (1 in 25000) and 0.267% (1 in 375). For the lifetime attributable risk of cancer mortality, the average was also 0.030% (1 in 3333) in the range of 0.003% (1 in 33333) and 0.124% (1 in 807).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

CT	Computed Tomography
RPB	Radiation Protection Board
ALARA	As Low as Reasonably Achievable
DDREF	Dose and Dose Rate Effectiveness Factor
ICRP	International Commission on Radiological Protection
LNT	Linear Non-Threshold
LSS	Life Span Study
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
NCRP	National Council on Radiological Protection
BEIR VII	Biological Effects on Ionizing Radiation
NRC	National Research Council
FDA	Food and Drug Administration
ACR	American College of Radiology
IAEA	International Atomic Energy Agency
SNR	Signal to Noise Ratio
ACR	American College of Radiology
NRPB	National Radiological Protection Board
EPA	Environmental Protection Agency
CAT	Computerized Axial Tomography
LET	Linear Energy Transfer
DLP	Dose Length Product
MDCT	Multi Detector Computed Tomography
ImPACT	Imaging Performance Assessment of CT
CTDI	Computerized Tomography Dose Index
SGMC	Sweden Ghana Medical Centre
LAR	Lifetime Attributable Risk
AP	Antero-Posterior
AEC	Automatic Exposure Control

LIST OF SYMBOLS AND CONSTANT

D	Dose
E	Effective dose
e	Age since exposure
F (D)	Function determining the dose dependency of the cancer risk
g (β)	Excess risk function for a specific cancer that depends upon gender, age of the individual, age at exposure and time since exposure
f (d)	Function of effective dose
s	Sex
t	Time since exposure
W_R	Radiation weighting factor
W_T	Tissue weighting factor
α	Modifying function of relative risk
β	Modifying function of absolute risk
λ (d)	Total fatal cancer risk
λ_o	Absolute age specific cancer risk to unexposed population
i	Individual
3D	3 Dimensional
2D	2 Dimensional
Gy	Gray
kg	Kilogram
J	Joule
KVp	Kilovolts peak
mAs	milliamperes per second

CHAPTER ONE

INTRODUCTION

This chapter gives the background, research objectives and relevance of the research study.

1.1 BACKGROUND

Computed tomography (CT) is used to create cross-sectional slices of the body. This imaging technique uses x-rays and complex computers. It was also formerly known to as CAT scan (Computerized Axial Tomography). Each image provides comprehensive anatomy of the body at the particular location or slice. This technology took medicine and diagnosis into an advanced stage as the images provided exceptionally high detail of body structures including soft tissue, brain, organs, bones and blood vessels. It provides information that doctors can use to help diagnose medical conditions. Since the introduction of CT into clinical practice in the early 1970's there has been a world-wide proliferation of scanners, with the number in clinical operation rising steadily. As at December 2013, the number of CT scanners in operation in Ghana stood at 17 [1]. By projection, the number of CT scanners is expected to be over 22 at present. Therefore, the dose levels delivered in CT examinations should be known in order to enable estimation of potential radiation hazards.

Notwithstanding the undoubted benefits of CT in healthcare, growth of this diagnostic technique took place initially without full appreciation of the relatively high patient doses involved. Patient doses from CT examinations are comparatively higher than doses from other imaging techniques that use ionizing radiation. The collective radiation doses from

CT are therefore in constant increase. The risk is proportional to the amount of dose from CT. Knowledge of an individual organ absorbed dose permits the determination of the probability of inducing deterministic effects such as skin burns or epilation and any corresponding stochastic risks of carcinogenesis, and genetic effects [2, 3]. In addition, the dose to the conceptus of a pregnant patient quantifies any possible detrimental effect in the irradiated embryo or foetus [4]. At the relatively low radiation doses normally encountered in diagnostic radiology, deterministic effects are extremely unlikely [5]. The considerable radiation dose delivered to shallow radiosensitive organs like the eye lens, thyroid and breast which are irradiated during radiological procedures of the head and chest are of great interest.

The effective dose is currently deemed to be the best available dose descriptor for quantifying stochastic risks in diagnostic radiology [5]. The effective dose takes into account the dose and the relative radio sensitivity of all irradiated organs and may be converted into a corresponding estimate of detriment (i.e., carcinogenesis and genetic effects) if proper account is taken of the age and gender of an exposed individual. Patients undergoing CT examinations can range from neonates to oversized adults. Radiation doses in CT, however, are generally measured in anthropomorphic physical acrylic phantoms designed to simulate a head or body. Having the understanding of organ doses it would be simple to recognize the organs at greatest radiation risk, which need urgent protective measures [5].

The information available and exhibited for a CT scan among others is the computed tomography dose index ($CTDI_{vol}$) and the dose length product (DLP). These displayed

parameters are radiation machine output metrics rather than patient specific dose information [6].

The CTDI is computed from a weighted average of the external doses and middle line dose that is given to a 16 cm or 32 cm homogenous plastic phantom. After scanning an adult patient, the displayed $CTDI_{vol}$, which is computed by the CT scanner, shows the weighted average dose that cylindrical phantom of 32 cm diameter would had received assuming it had been scanned with the similar radiographic parameters as the patient. The DLP is computed from the product of the scan length and the weighted average of the dose [6].

There are a various ways to assure that CT examination provides maximum benefit/risk ratio to the patient [7]. The identified ways are:

1) A physician should make sure that, it is necessary and proper before proposing that a patient must have a CT scan. Radiologists must be skilled to identify the most suitable imaging study for a given patient's conditions at any given time.

2) In certain situations, other imaging techniques such as ultrasound (US) and magnetic resonance imaging (MRI) which uses non- ionizing radiation can be used in place of CT. On the other hand, not all CT examinations can be substituted with US or MRI.

3) Patients below 30 years are more radiosensitive than grown-up patients over 40 years, and this piece of information should be well thought-out when a CT scan is recommended [7].

Every medical test has risks as well as advantages, and CT is no special. When diagnostic CT is used properly, images from CT can provide adequate diagnostic information which may progress patient care and patient results. Before the introduction of CT, investigative surgery was a comparatively common procedure, even with its significant risk and associated pain. CT does not include pain and allows physicians to have a look through the patient's internal anatomy. The diagnostic information from the CT procedure in many cases provides physicians with detail knowledge which can lead to most favourable treatment strategies [7].

1.2 STATEMENT OF THE PROBLEM

The level of radiation doses delivered during CT examinations has been of major concern to medical physicists, radiologists and radiation protection experts over the years. With development in technology, advanced CT systems which produce several multiple image slices in a rapid scan have been produced in an attempt to increase image detail. This has in turn resulted in increased radiation exposure to patients in recent times, and hence there is a need to constantly assess the radiation output from CT scanners and the resultant radiation doses in medical examinations. The radiation exposure to patients undergoing CT examinations is determined by two factors: equipment-related factors, i.e. the design of the scanner with respect to dose efficiency, and application-related factors, i.e. the way in which the radiologist or the radiographer makes use of the scanner. The possibility of radiation to cause stochastic or deterministic effects necessitates that its delivery in medical practice be kept as low as reasonably achievable. Therefore it is expedient that the effective doses of patients should be known to estimate the cancer risk

in order to protect patients undergoing CT examinations and also to serve as a guide and awareness to radiologist, radiographers and all medical staffs in charge of patients.

1.3 OBJECTIVES

The main objective of this research is to determine the effective doses received by selected anatomical region of patients undergoing CT examinations at SGMC and compare them with reference levels (International standards) in order to be able to assess the associated risk. This is expected to be achieved by:

1. Performing a comprehensive quality assurance program for CT systems.
2. Reviewing the significance of the radiation dose associated with computed tomography and the factors affecting CT scanner dose efficiency.

Also to make appropriate recommendations to the; (i) Hospital Authorities (ii) Medical Physicist and (iii) the Regulatory Authority

1.4 RELEVANCE AND JUSTIFICATION

In diagnostic radiology for that matter CT, there are two fundamental reasons for measuring or estimating radiation doses to patients. Firstly, measurements make available a means for setting and checking standards of good practice as a help to the optimization of patient protection. Secondly estimation of the absorbed dose to tissues and organs in the patient are needed to determine the risks so that diagnostic techniques can be properly justified and cases of accidental over exposure thoroughly investigated. This research will help to ensure that CT is practiced accurately and that minimum amount of radiation is used to obtain the diagnostic information for which the CT scan was ordered. The main

focus of this research will be on improving radiation safety standards for the protection of patients at SGMC [7].

1.5 SCOPE AND LIMITATION

This work was carried out at the Sweden Ghana Medical Centre (SGMC). It was limited to CT scan procedures and the radiation doses delivered to patients undergoing CT scan. The body parts that were considered in this study include head, thorax, abdomen and pelvis. The study was performed using data from January 2013 to December 2014 for patients' undergoing CT examinations of the head, neck, chest, abdomen and pelvis and verification measurements from a head and body phantom.

1.6 ORGANIZATION OF THESIS

The thesis would be in the chronological order of five chapters. Chapter one is an introduction to the research that provides an overview of the current state of knowledge relevant to the study. Chapter two also reviews existing literature relevant to the research problem. Chapter three focuses on the experimental, methodology and calculations framework for the study. The results obtained are presented and discussed in chapter four. Chapter five gives the conclusions of the study and appropriate recommendations.

CHAPTER TWO

LITERATURE REVIEW

This chapter reviews, the literature pertaining to computed tomography, radiation dosimetry in CT examinations and various techniques or methodologies used by various committees in the estimation of cancer risk and optimization of patient protection.

2.1 BASIC PRINCIPLES OF CT

In computed tomography, a patient lies on a motorized table which moves through the machine. The machine is composed of an x-ray source and x-ray detector.

The density of the tissue passed by an x-ray can be measured from the estimation of the attenuation coefficient. Thus, computed tomography depends on this basic theory. CT then allows the reconstruction of the density of the body, by two dimensional sections which is perpendicular to the axis of the acquisition system.

Information from the x-ray detectors basically represent a sequence of x-ray images acquired from various positions around the patient. The images are sent to a computer, which reconstructs them into 2 or 3-dimensional images representing a slice of the body in any preferred plane.

Several computers are used to manage the complete CT system. The main computer "host computer" arranges the operation of the entire system. Other computers are also available to reconstruct the CT data into an image. Figure 2.1 shows a schematic diagram of a patient in a CT machine.

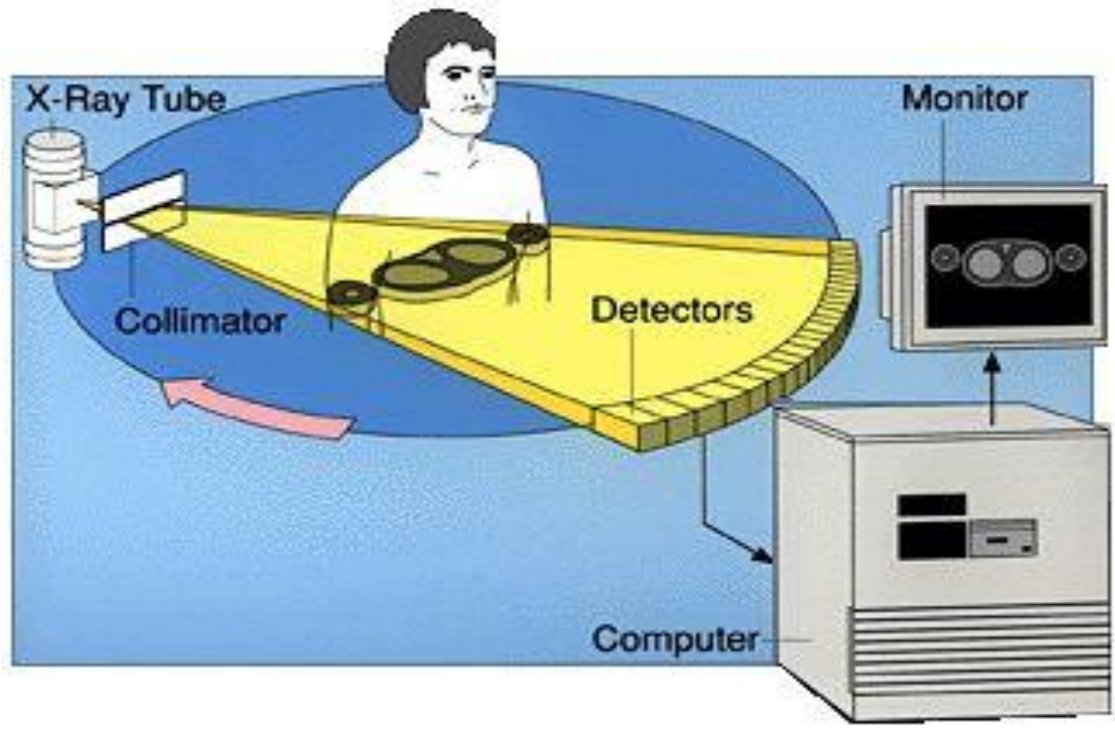

Figure 2.1: Diagram of a patient, detector, and image reconstruction computer and display monitor [8].

2.2 RADIATION DOSE IN CT

In spite of a general consent that computed tomography (CT) benefits when used for proper indications, alarms have been raised regarding the probable risk of cancer from CT due to the rapid increased use of CT in medicine.

To keep radiation dose as low as reasonably achievable, two main principles must be followed:

1. CT exams must be properly justified for clinical need.
2. All technical aspects of each CT examination must be optimized.

2.3 RADIATION QUANTITIES AND UNITS IN CT

2.3.1 ABSORBED DOSE

In radiation biology, clinical radiology, and radiological protection the absorbed dose, D, is the basic physical dose quantity, and it is used for all types of ionizing radiation and any irradiation geometry.

This is the energy absorbed per unit mass at a given point. The absorbed dose, *D*, is the quotient d$\bar{\mathcal{E}}$ by d*m*, where d$\bar{\mathcal{E}}$ is the mean energy D imparted to matter of mass d*m*. This is given mathematically as:

$$D = \frac{d\bar{\varepsilon}}{dm} \tag{2.1}$$

The unit is the joule per kilogram (J/kg) and is given the special name gray (Gy). A dose of one gray is equivalent to a unit of energy (joule) deposited in a kilogram of a substance. The conventional unit is rad [9].

1 Gy = 100 rad or 1 rad = 10 mGy

Absorbed dose essentially describes how much energy from ionizing radiation has been absorbed in a small volume centered at a point. It does not describe where those radiation doses are absorbed or reflect the relative radiosensitivity or risk of detriment to those tissues being irradiated.

2.3.2 RADIATION WEIGHTING FACTORS

The probability of stochastic effects is found to depend, not only on the absorbed dose, but also on the kind of energy and the type of the radiation causing the dose. This is taken into account by weighting the absorbed dose by a factor related to the quality of the radiation. In the past, this weighting factor has been applied to the absorbed dose at a point and called the quality factor, *Q*. The weighted absorbed dose was called the dose equivalent, H.

2.3.3 ORGAN DOSE

The organ dose quantity is defined in relation to the probability of stochastic effects mostly cancer induction as the absorbed dose averaged over an organ. It is the quotient of the total energy imparted to the organ and the total mass of the organ. The unit D_T is the joule per kilogram and is given the special name gray (Gy) [9]. Thus:

$$D\mathrm{T} = \frac{\varepsilon_\mathrm{T}}{m\mathrm{T}} \qquad (2.2)$$

Where ε_T is the total energy imparted in a tissue or organ and m_T *is* the mass of the tissue or organ. For example, m_T may range from less than 10 g for the ovaries to over 70kg for the whole body.

2.3.4 EQUIVALENT DOSE

In radiological protection, equivalent dose is the absorbed dose averaged over a tissue or organ and weighted for the radiation quality that is of interest. The equivalent dose, H_T, to an organ or tissue, for a single type of radiation, R is the product of a radiation weighting factor, W_R, for radiation R and the organ dose, D_T. This is given mathematically as:

$$H_T = \sum_R W_R D_{T,R} \qquad (2.3)$$

Where $D_{T,R}$ is the absorbed dose averaged over the tissue or organ T, due to radiation R. The radiation weighting factor takes account of the relative biological effectiveness of the incident radiation in producing stochastic effects. This correction factor is numerically 1 for x-rays. The unit of equivalent dose is the joule per kilogram (J/kg) with the special name sievert (Sv) [10].

2.3.5 TISSUE WEIGHTING FACTORS AND EFFECTIVE DOSE

Effective dose takes into account where the radiation dose is being absorbed or which tissue has absorbed that radiation dose. It attempts to reflect the equivalent whole-body dose that results in a stochastic health risk. It takes the nature of each organ, the type of radiation and the tissues being irradiated into account.

The relationship between the probability of stochastic effects and equivalent dose is found also to depend on the organ or tissue irradiated. It is therefore appropriate to define a further quantity, derived from equivalent dose, to indicate the combination of various doses to some different tissues in a way which is possible to correlate well with the total of the stochastic effects. The quantity most appropriate for assessing the risk of cancer damage from a CT procedure is the effective dose (E) [11]. The factor by which the equivalent dose in tissue or organ T is weighted is called the tissue weighting factor, W_T which represents the relative contribution of that organ or tissue to the total detriment due to these effects resulting from uniform irradiation of the whole body. This is given mathematically as:

$$E = \sum_T W_T H_T \qquad (2.4)$$

Where H_T is the equivalent dose in tissue or organ T and W_T *is* the weighting factor for tissue T. The effective dose can also be expressed as the sum of the doubly weighted absorbed dose in all the tissues and organs of the body.

It is desirable that a uniform equivalent dose over the whole body should be give an effective dose numerically equal to that uniform equivalent dose. This is achieved by normalizing the sum of the tissue weighting factors to unity. The values of the radiation weighting factor depend on the type and energy of the radiation and are independent of the tissue or organ. Different tissues and organs have different radiation sensitivities. For example, bone marrow is much more radiosensitive than muscle or nerve tissue. Similarly, the values of the tissue weighting factor are chosen to be independent of the type and energy of the radiation incident on the body. This simplification may be no more

than approximations to the true biological situation, but they make it possible to define a radiation field outside the body in dosimetric terms without the need to specify the target organ. How much a particular organ contributes to effective dose depends on its relative sensitivity for radiation-induced effects, as represented by the tissue-weighting factor attributed to the organ [12]:

1) 0.08 for gonads;
2) 0.12 for each of lungs, colon, red bone marrow, breast and stomach wall;
3) 0.04 for each of urinary bladder, liver, thyroid and oesophagus;
4) 0.01 for each of bone surface, brain, salivary glands and skin;
5) 0.12 for the 'remainder'

The 'remainder' which is of a group of additional organs and tissues with a lower sensitivity for radiation induced effects for which the average dose must be used: small intestine, pancreas, thymus, spleen, muscle tissue, adrenals, kidneys, and uterus. The sum of all tissue-weighting factors W_T is equal to 1 [12].

Both equivalent dose and effective dose are quantities intended for use in radiological protection, including the assessment of risks in general terms. They provide a basis for estimating the probability of stochastic effects only for absorbed doses well below the thresholds for deterministic effects.

Effective dose cannot as such be measured directly in vivo. Measurements in anthropomorphic phantoms with thermo luminescent dosimeters' (TLD) are very time-consuming and therefore not suitable for every day practice. Effective dose, on the other hand, can be assessed in various ways by using conversion factors. It is satisfactory to

multiply the dose-length product (DLP) with mean conversion factors, depending on which body region was scanned and whether the scan was made in head or body scanning mode. Hence:

$$E = DLP \times f_{mean} \quad (2.5)$$

Where f_{mean} is the generic mean conversion factor for DLP to effective dose in mSv/mGy.cm

Table 2.1 shows the conversion factors from DLP to effective dose provided by the European Guidelines on Quality Criteria for Computed Tomography Report 16262 [13].

Table 2.1: Body region and corresponding conversion factors

Region of Body	**E/DLP Conversion factor mSv/mGy.cm**
Head	0.0023
Neck	0.0054
Chest/Thorax	0.017
Abdomen	0.015
Pelvis	0.019

Estimates of the effective dose from a diagnostic CT procedure can vary by a factor of 10 or more depending on the type of CT procedure, patient size and the CT system and its operating technique [13].

There are three aspects of radiation dose in CT that are unique in comparison to x-ray projection imaging [14]. First, because a single CT image is acquired in a highly collimated manner, the volume of tissue that is irradiated by the primary x-ray beam is substantially small compared with, for example the average chest radiograph. Secondly, the volume of tissue irradiated, is exposed to the x-ray beam from almost all angles during the rotational acquisition, and this more evenly distributes the radiation dose to the tissues in the beam. In radiography, the tissue irradiated by the entrance beam experiences exponentially more dose than the tissue near the exit surface of the patient. Finally, CT acquisition requires a high signal to noise ratio (SNR) to achieve high contrast resolution, and therefore the radiation dose to the slice volume is much higher because the techniques used (kV and mAs) are higher. As a rough comparison, a typical posterior-anterior (PA) chest radiograph may be acquired with the use of 120 kV and 5 mAs whereas a thoracic CT image is typically acquired at 120 kV and 200 mAs. The radiation dose for a particular study depends on multiple factors: volume scanned, patient build, number and type of scan sequences, and desired resolution and image quality. In addition, two helical CT scanning parameters that can be adjusted easily and that have a profound effect on radiation dose are tube current and pitch. [15] The effective doses from diagnostic CT procedures are typically estimated to be in the range of 1 to 10 mSv [15]. This range is not much less than the lowest doses of 5 to 20 mSv received by some of the Japanese survivors of the atomic bombs.

A particular radiation dose will depend on the size of the body part examined, the type of procedure, and the type of CT equipment and its operation. Due to the expansion

application of CT, there is an emergent need for radiation dose reduction to avoid a reversal of the risk-benefit ratio associated with this imaging modality [16].

Ionizing radiation enhances the risk of certain kinds of cancer more than others. The bone marrow and the thyroid gland are more sensitive to radiation. Leukemia, a type of cancer that occurs in the bone marrow, is the most common radiation-induced cancer. Leukemia may emerge as early as some years after radiation exposure.

2.4 CT DOSE DESCRIPTORS

The main dose descriptors used in CT are the computed tomography dose index ($CTDI_{vol}$) and the dose length product (DLP).

In a clinical setting, it would be helpful to be able to estimate the effective dose before the CT examination. This has been made possible by the availability on the CT scanners of data derived from measurements made in head and body phantoms. These data are shown on the scanners as the CT dose index ($CTDI_{vol}$) and dose-length product (DLP) and the DLP can be used to calculate effective dose in a reference subject.

2.4.1 COMPUTED TOMOGRAPHY DOSE INDEX (CTDI)

The computed tomography dose index (CTDI) is the fundamental CT dose descriptor. CTDI is defined by the following equation:

$$CTDI = \frac{1}{T}\int_{-\infty}^{+\infty} D(z)dz \qquad (2.6)$$

T is the nominal slice thickness and $D(z)$ is the dose profile along a line parallel to the z-axis.

Computed tomography dose index (CTDI) integrates the radiation dose imparted within and beyond a single slice. It is measured using a specially designed pencil ionization chamber with an active length of 100 mm both in free air at the centre of rotation ($CTDI_{air}$) and within cylindrical polymethyl methacrylate (PMMA) phantoms of 16 and 32 cm in diameter, simulating the head and body of a patient, respectively. $CTDI_c$ and $CTDI_p$ are defined respectively as the CTDI values measured with a pencil chamber dosimeter positioned within the centre and in the periphery of the PMMA phantom. $CTDI_p$ can thus be considered as a good approximation of the entrance surface dose (ESD) [17].

$CTDI_w$ is used for approximating the average dose over a single slice in order to account for variations in dose values between the centre and the periphery of the slice. It is defined by the following equation [17, 18]:

$$CTDI_w = \frac{1}{3}CTDI_c + \frac{2}{3}CTDI_p \quad (2.7)$$

$CTDI_p$ is the average of the four $CTDI_p$ values measured in the periphery of the phantom and the $CTDI_c$ is the measured CTDI at the center of the phantom.

Modern CT scanners provide two dose parameters that both became available by the scanner manufacturers around 2001: the Volume CTDI ($CTDI_{vol}$) measured in mGy, and the dose-length product (DLP) measured in mGycm. $CTDI_{vol}$ is a measure of the average dose within the scan volume to a standardized phantom. The total amount of radiation

delivered to a standardized phantom is represented by the DLP, which is the product of $CTDI_{vol}$ and the scan length. Organ doses in CT are well below the threshold for the induction of deterministic effects (e.g., erythema, epilation). Patient radiation risks in CT are therefore those related to carcinogenesis.

$CTDI_{vol}$ is introduced to determine the radiation dose in one tube rotation in multi-detector row scanners and allows for variations in exposure in the z-direction when the pitch (pitch is the ratio of table feed in one rotation to slice collimation) is not equal to 1 ($CTDI_{vol}$ = $CTDI_w$/pitch). In the case of a single slice spiral system, $CTDI_{vol}$ is equal to $CTDI_w$ [17,18].

2.4.2 DOSE-LENGTH PRODUCT (DLP)

Dose length product (DLP) is used to calculate the dose for a series of slices or a complete examination and is defined by the following equation [17, 18];

$$DLP = \sum_{i}^{N} CTDI_w T.N \qquad (2.8)$$

Where i represents each one of the individual, N scans of the examination that covers a length T of patient anatomy. Certain manufacturers of CT machines display the DLP and $CTDI_{vol}$ values in each patient examination [17,18]. To better represent the overall energy delivered by a given scan protocol, the absorbed dose can be integrated along the scan length to compute the dose length product (DLP), where DLP (mGycm) = $CTDI_{vol}$ (mGy) x scan length (cm). DLP is convenient index for the total dose. The DLP reflects the total energy absorbed (and thus the potential biological effect) attributable to the complete scan acquisition. Thus, an abdomen-only CT exam might have the same $CTDI_{vol}$ as an abdomen/pelvis CT exam, but the latter exam would have a greater DLP,

proportional to the greater *z*-extent of the scan volume. In helical CT, data interpolation between two points must be performed for all projection angles. Thus, the images at the very beginning and end of a helical scan require data from *z*-axis projections beyond the defined "scan" boundaries (i.e., the beginning and end of the anatomic range over which images are desired). This increase in DLP due to the additional rotation(s) required for the helical interpolation algorithm is often referred to as "over ranging". For MDCT scanners, the number of additional rotations is strongly pitch dependent, with a typical increase in irradiation length of 1.5 times the total nominal beam width. The implications of over ranging with regard to the DLP depend on the length of the imaged body region. For helical scans that are short relative to the total beam width, the dose efficiency (with regard to over ranging) will decrease. For the same anatomic coverage, it is generally more dose efficient to use a single helical scan than multiple [19].

2.5 DOSE REDUCTION TECHNIQUES

The use of CT is assumed to be justified in each individual case. There is considerable room for effective dose reduction through elimination of unjustified examinations [20]. Where the examinations are justified, the main opportunity for dose saving arises from optimization of examinations and techniques. The principle of optimization should be applied on an individual so as to achieve image quality sufficient with the minimum dose to the patient. Intuition suggests that it would be reasonable to expect to use more radiation to get a satisfactory image on larger patients and less radiation dose on smaller patients. A recent review of dose reduction in CT imaging [21] points out that dose reduction should not be at the cost of poorer imaging, so that 'appropriate' imaging

parameters might be a better term. In addition, in recent years many papers have shown that adequate diagnostic information can be obtained at lower doses [22,24]. Increasing dose in CT results in images with less noise and fewer streak artefacts, although not necessarily with greater diagnostic information. Thus, in view of the major impact of CT on doses from medical radiation, there has been increasing concern in recent years over the need to minimize doses from CT, particularly since it is believed that image quality sometimes exceeds the clinical requirements for adequate diagnosis. International Commission on Radiological Protection (ICRP) noted and reiterated that technical and clinical developments in CT have not led to reductions in patient dose per examination, and that there was a clear need for optimization of doses [25]. International Commission on Radiological Protection (ICRP) recommended specific protocols with lower exposure factors (mAs) for paediatric examinations and stated that anatomically based automatic exposure control would be a helpful improvement in CT equipment for managing dose.

A recent Japanese survey shows an increasing use of dose reduction techniques in routine clinical practice, particularly the use of automatic exposure control techniques [26]. Scanning techniques that have been evaluated for dose reduction include those that can be modified based on patient size and study indications such as tube current, gantry rotation time, pitch, tube potential, scan coverage, radiographic shields, automatic exposure control techniques, and noise reduction filters. Vendors have also developed several techniques for dose reduction, which include improved detector geometry, automatic exposure control, noise reduction filters, metal artefacts reduction algorithms, beam shaping filters, projection adaptive space filters, and pre-patient beam collimators [27].

Many traditional CT systems used the same exposure settings for each scan type, for example, in every abdominal scan, regardless of patient size. At its extreme the same settings were used for both adult and paediatric scans. Where this is the case more radiation than is necessary to provide an acceptable image is being used. In the last few years, all manufacturers have incorporated automated patient size, longitudinal and rotational automatic exposure control (AEC) systems to deal with this issue [28]. The aim of AEC is to use the optimal radiation level for patients to attain sufficient image quality for a given diagnostic task. For smaller patients, less tube current, and therefore fewer doses, is enough to obtain the desired image quality. For larger patients, to ensure sufficient image quality, the radiation dose must be increased.

These techniques have demonstrated dose reductions of typically 15–65% [28,30]. They should be used wisely, with a thorough understanding of their principles.

2.6 IMAGE QUALITY AND DOSE

In a CT scanner, two of the most commonly used image quality parameters are spatial resolution and low contrast resolution. Spatial resolution is, in practice, determined almost entirely by the number of rays in each projection, and the spacing of the detectors. In the absence of artefacts, low contrast resolution is determined solely by noise. However, noise depends on most aspects of the CT image in non-linear ways [31]. Image noise is affected by mA, scan time, kVp, patient size, and pitch in multislice CT, slice thickness, and reconstruction algorithm. The first five affect both image noise and patient dose; but slice thickness and reconstruction algorithm affect only noise. The only parameter that is not in the control of the scanning staff is the patient size or weight.

That patient size is an important determinant of noise and has been known for some time, and attempts have been made to modify scan parameters to reduce the variation of noise with patient size [32–34]. One extreme of size variation is the paediatric patient; in the USA, the Food and Drugs Administration (FDA) issued a warning in 2001 concerning the radiation exposure of children from CT examinations [35].

In addition some recent studies have attempted to adjust dose with a body weight protocol [36].

2.7 CT SCANNING

Dose and image quality in CT generally depend on the choice of technique factors that are used to perform a chest CT examination. The most important of the parameters that are under the control of the CT operator are; x-ray tube voltage, tube current/exposure time and pitch ratio.

2.7.1 X-RAY TUBE VOLTAGE

The choice of x-ray tube voltage (kV) in CT scanning ranges from 80 to 140 kV. Increasing the x-ray tube voltage will increase the amount of radiation used in the exam, and hence increase the average photon energy. As a result, high voltages reduce image contrast, as well as reducing the amount of noise (mottle) and increasing patient dose. In addition, use of high tube voltage values may also reduce artifacts, such as beam hardening.

2.7.2 TUBE CURRENT/EXPOSURE TIME

The product of the x-ray tube current milliampere (mA) and scan time (s) is known as the milliampere-seconds (mAs), which is a measure of the amount of radiation that is used to generate any radiographic or CT image. Because pediatric patients are smaller, and therefore easier to penetrate, the CT mAs used to scan pediatric patients is generally reduced relative to those used for adults.

If the milliampere-seconds value is reduced by 50%, the radiation dose will be reduced by the same amount. Depending on the requirements of the clinical application, this reduction may be readily accepted; in other cases, this type of reduction in milliampere-seconds may compromise the diagnostic quality of the imaging examination.

2.7.3 PITCH RATIO

In helical CT, the pitch ratio (P) is given by the table increment distance per 360° rotation of the x-ray tube divided by the x-ray beam width. A pitch of 1 corresponds to performing axial scans with contiguous slices. For a fixed scan length, increasing the pitch will spread the radiation energy over a larger patient volume, decreasing patient doses, and vice versa.

The radiation dose is inversely proportional to pitch when all other factors are held constant. Therefore, increasing pitch is one consistent way to reduce radiation dose. The trade-off in increasing pitch is an increase in effective section thickness, which results in increased volume averaging, which in turn may reduce the image signal (contrast

between some object and background). The ability to use this type of dose reduction again depends on the clinical application.

2.8 CONCEPT OF RISK

The word risk has several different meanings. In technical contexts it is used quantitatively, but without any general agreement on its definition. Sometimes it is used to mean the probability of a defined adverse outcome, but it is also widely used as a combination of that probability and some measure of the severity of the outcome. In all activities involving radiation, the quantification of and the perception of risks have been recognized as important issues. A major difficulty in managing risks has been to satisfy the concerns of individuals, communities and society. The basic approach in risk management has been to justify activities or practices by the benefits provided and to do all that is reasonable to reduce the risks. Risk assessment has been defined by the National Research Council (NRC) of USA as "the characterization of the potential adverse health effects of human exposures to environmental hazards" [37, 38]. An assessment of the risks from all types of hazards, including radiological hazards requires all or some of the following components:

i. Hazard identification which is investigated to determine whether a particular hazard has a corresponding health effect;
ii. Dose-response assessment, in which the relation between the magnitude of the dose and the probability that the health effect will occur is determined;

iii. Exposure or dose assessment, which is the determination of the extent to which human will be exposed to the hazard; and,

iv. Risk characterization, which describes the nature and magnitude including uncertainties surrounding that risk.

It is the last component of risk characterization that integrates the results of the previous three components into a risk model that includes one or more quantities estimates.

2.9 RISKS ASSOCIATED WITH LOW DOSES OF RADIATION

Depending on the machine settings, the organ being studied typically receives an average radiation dose of 15 millisieverts (mSv) (in an adult) for a single CT scan. At these doses, the most likely (although might be small) risk is for radiation-induced carcinogenesis [39]. Most of the quantitative information that is available regarding the risks of radiation-induced cancer appears from studies of survivors of the atomic bombs explosion in Japan in 1945 [40]. Data from cohorts of these survivors are generally used as the basis for predicting radiation-related risks in a population. It is possible because the cohorts are large and have been thoroughly studied over a period time. There was a major increase in the overall risk of cancer in the subgroup of atomic-bomb survivors who received low doses of radiation, ranging from 5 to 150 mSv. The mean dose in this subgroup was about 40 mSv, which approximates the relevant organ dose from a typical CT study involving two or three scans in an adult [41,42]. 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 who were exposed to an average dose of approximately 20 mSv (a typical organ dose from a single CT scan for an adult) [37,38].

Summing it up, 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.

2.10 BEIR VII RISK ASSESSMENT MODEL

BEIR report VII develops the most current and comprehensive risk estimates for cancer and other health effects from exposure to low-level ionizing radiation. It is the first publication of its kind to include detailed estimates for both cancer incidence and cancer mortality. Since completion of the 1990 report, additional evidence has emerged from studies of the Hiroshima and Nagasaki atomic bomb survivors suggesting that other health effects, such as cardiovascular disease and stroke, can result from radiation exposure. Additional information is also available from radiation worker studies, medical radiation exposures, and populations with environmental exposures. Although the cancer risk estimates have not changed greatly since the 1990 report, confidence in the estimates has gone up because of the increase in epidemiologic and biological data available to the committee. Progress has also been made since the 1990 report in areas of science that relate to the estimation of genetic (hereditary) effects of radiation. In the risk assessment by the BEIR VII Committee, cancer risks were based mainly on epidemiological studies and in a large part, on the population of residents from Hiroshima and Nagasaki in 1950, known as the Life Span Study (LSS). The BEIR VII Committee Report estimated risks

for breast cancer, leukemia and other non-leukemia cancers [38]. The assessment for genetic risk relied on animal (especially mouse) data to supplement human data. To determine human genetic risk by extrapolating from animal data, three assumptions were made:

1) the amount of genetic damage induced by a given type of radiation under given conditions in the animal species was the same in human germ cells;
2) biological factors such as sex, germ cell stage , and age and physical factors such as the quality of radiation and dose rate similarly affected genetic damage in the animal species and in humans; and
3) the relationship between low-linear energy transfer (LET) radiation and the frequency of genetic effects was linear at low doses.

The risk of radiogenic cancer is modified by age at exposure, time since exposure, sex and linear energy transfer of the radiation. This was reflected in the BEIR VII risk models.

A dose-response relationship is determined by the change in effect (response, the dependent variable) with increasing amounts of radiation (dose, the independent variable). The relationship between dose and response is the primary problem in predicting the health risks of radiation.

The BEIR VII Committee has incorporated a latency period, in which all cancer deaths and persons-years of observation were excluded. Thus, it was assumed that any cancers caused by radiation could only occur after some minimum time has elapsed. The latency

periods used by the BEIR VII Committee were: ten years for cancers other than leukemia and two years for leukemia [43]. After incorporating these latency periods, the relative risk of cancer was assumed to be constant for all ages up to 100 years.

The BEIR VII Committee estimates were about three to five times larger for solid cancers and four to five times larger for leukemia than those reported by the BEIR III Committee [44]. These differences arose mainly from the revised Atomic bomb dosimetry called DS86 and the increased length of follow up of the A-bomb cohort. In BEIR VII, the lifetime number of excess cancer deaths was calculated as the difference between the total number of deaths in an exposed and an unexposed population. In contrast, earlier Committees [44, 45] calculated the number of deaths by applying the difference in cause specific death rates between an exposed and an unexposed population to a hypothetical population at the beginning of each age interval. The total excess was obtained by summing over all age intervals. Because an exposed population has smaller survival probabilities, the method used by the BEIR VII Committee produced fewer excess cancers.

Quantifying excess cancer deaths from radiation is key to projecting risk. When the risk to exposed people exceeds the risk to unexposed people by the same amount at all ages, the effect of the radiation is additive and the mathematical expression for the risk is thus an additive one. This is often called the absolute risk because at all ages the excess risk is constant. When the risk to exposed people exceeds the risk to unexposed people by a constant fraction, the effect of radiation is multiplicative. This is also known as relative risk, because at all ages after irradiation, the relative risk or risk ratio is constant. These

two models are used in projecting risk. The BEIR VII Committee permits the risk to vary as complex functions of time after exposure throughout the individual's life.

Cancer risk projection requires knowledge of several parameters, including relationship between excess cancer risk and relative risk, the latency period or the time from irradiation to the first expression of excess cancer risk, the plateau period or the time from the first expression of excess risk until the excess cancer risk disappears, the age distribution of the exposed population and the baseline pattern of age-specific mortality rate from all causes and from cancers under consideration, the age at irradiation and dose-response function. These parameters are brought together in the cancer risk projection model used by the BEIR VII Committee. The BEIR VII used only the multiplicative method to project the cancer risk. The measure chosen by this Committee was excess lifetime cancer risk, which is the increase in the lifetime probability that a person will die from a specific cancer as a result of a specific irradiation.

In the BEIR VII report, separate lifetime risks are estimated for an exposed population and for an unexposed population. The unexposed population is assumed to be exposed to the same background as the exposed population. The excess cancer risk is simply the difference between the two lifetime risks [43].

The principal finding was that exposure to 100 mSv would result in a solid organ cancer or leukemia developing in 1 person in 100 (0.01/mSv). The BEIR VII assumes a linear non-threshold model for risks associated with radiation exposure. The lifetime risk of cancer from all other causes is 42 in 100 [46].

2.11 RISK MODELS FOR CANCER

Here, the models that allow individual to estimate the lifetime risk of cancer resulting from any specified dose of ionizing radiation are started. A vital task of the BEIR VII committee was to develop "risk models" for estimating the risk that an exposed individual will develop cancer. This task requires expressing the dependence of risk on radiation dose and also on sex and age at exposure. Several national and international organizations have developed models for estimating cancer risk from exposure to low levels of low-LET ionizing radiation. These include the work of the BEIR V committee [37], the International Commission on Radiological Protection [47], the National Council on Radiation Protection and Measurements [48] and the United Nations Scientific Committee on the Effects of Atomic Radiation [49].

Two models were used for describing and calculating radiation-induced cancer risks. The first is the time-constant absolute (or additive) risk projection model which assumes that after some latent period the excess cancer risk is constant. The second is the time-constant relative (or multiplicative) risk projection model which assumes that following administration of a dose of radiation after some latent period the cancer rate rises in a manner proportional to the underlying cancer risk.

Due to the extra years of follow-up in the Japanese bomb survivors, it became clear that the relative risk model fitted the solid cancer data much better than the absolute risk model. For this reason, ICRP and most other scientific committees tend to use the relative risk model rather than the absolute risk model for projecting solid cancer risks to the end of life.

Expressed mathematically, the absolute risk model can be represented as follows:

$$\lambda(d) = \lambda_o + f(d)g(\beta) \qquad (2.9)$$

Where; $\lambda(d)$ represents total fatal cancer risk;

λ_o is the absolute age specific cancer risk to unexposed population;

$f(d)$ is a function of effective dose in sievert; and,

$g(\beta)$ is the excess risk function for a specific cancer that depends upon gender, age of the individual, age at exposure and time since exposure.

Among atomic bomb survivors, the age-specific number of excess cancers induced by radiation increased with attained age, while the risk of radiogenic cancer relative to the background incidence remained relatively constant.

The general expression for calculating the total cancer risk, including natural and radiation- induced, to a population is expressed mathematically as:

$$\lambda(d) = \lambda_o[1 + f(d)g(\beta)] \qquad (2.10)$$

Where $1 + f(d)g(\beta)$ represents the radiation induced fatal cancer risk and the dose-response function, $f(d)$ depends on the type of cancer involved [38].

CHAPTER THREE

MATERIALS AND METHODS

Chapter three focuses on the experimental framework for the study, the analysis of data, the calculation of the effective dose and the estimation of cancer risk due to the selected CT examinations.

3.1 MATERIALS

The materials used for this study include:

- 16 Slice CT scanner (Siemens Somatom Emotion, Germany)
- CT dose profiler (RTI Electronics, Sweden)
- Barracuda electrometer (RTI Electronics, Sweden)
- CTDI head and neck phantom (RTI Electronics, Sweden)
- CTDI body phantom (RTI Electronics, Sweden)
- Ocean software (RTI Electronics, Sweden)
- Microsoft excel spreadsheet and access data base tools

3.1.1 SIEMENS SOMATOM EMOTION CT SCANNER

The Somatom Emotion 16 slice by Siemens is a CT scanner with a 16-slice configuration which produces quality images with excellent spatial resolution and using a very small focal spot (0.8×0.5 mm). The scanner has been designed with a 70 cm aperture and a 50 cm scan field and has a patient table that can hold patients up to 440 pounds.

Siemens' fully automated, real-time dose management (CARE Dose4D) reduces dose to a minimum while ensuring that the required image quality is always met. Unlike other dose modulation attempts, CARE Dose4D achieves this through a truly real-time modulation of the tube current during patient scanning enabling dose reduction of up to 68 % [50].

CARE Dose 4D is an automated exposure control, which ensures constant diagnostic image quality over all body regions at the lowest possible dose. CARE Dose 4D combines three different adaptation methods to optimize image quality at the lowest dose level: (i) automatic adaptation of the tube current to the patient size, (ii) automatic adaptation of the tube current to the attenuation of the patient's long axis, the so-called z-axis, (iii) automatic adaptation of the tube current to the angular attenuation profile measured online for each single tube rotation, the so-called angle modulation.

The Siemens Somatom Emotion CT system (Plate 3.1) consists of the following components: (i) Control console, (ii) Scan control box, (iii) Gantry and patient table.

The control console is used to operate and monitor the scans being performed whiles the gantry provides the support and means for rotating the x-ray tube, beam elements and the detectors. The gantry panels (front and rear) are used to activate the laser marker, tilt the gantry and control patient table movements. Selectable x-ray tube voltage values are 80kV, 110kV and 130kV.

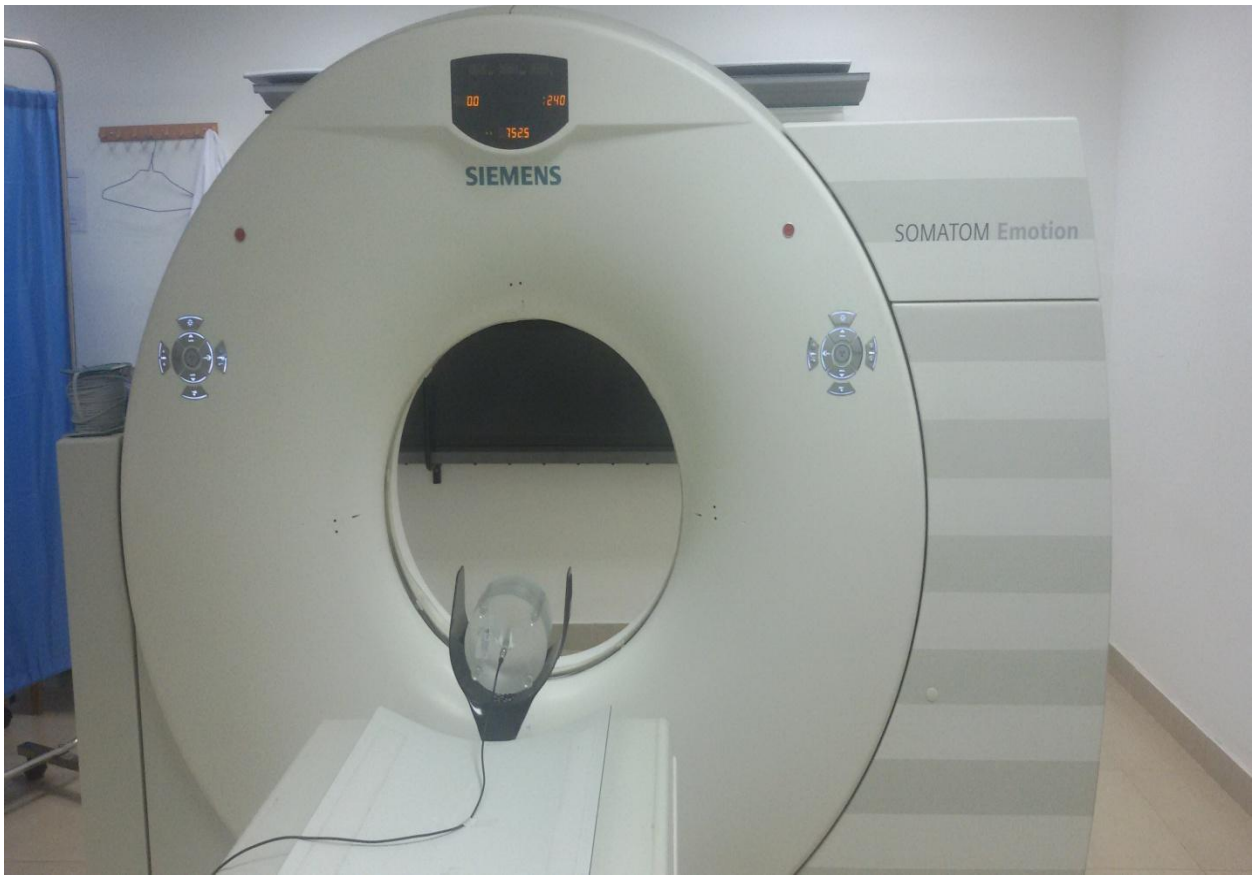

Plate 3.1: Siemens Somatom Emotion CT 16 slice scanner at SGMC

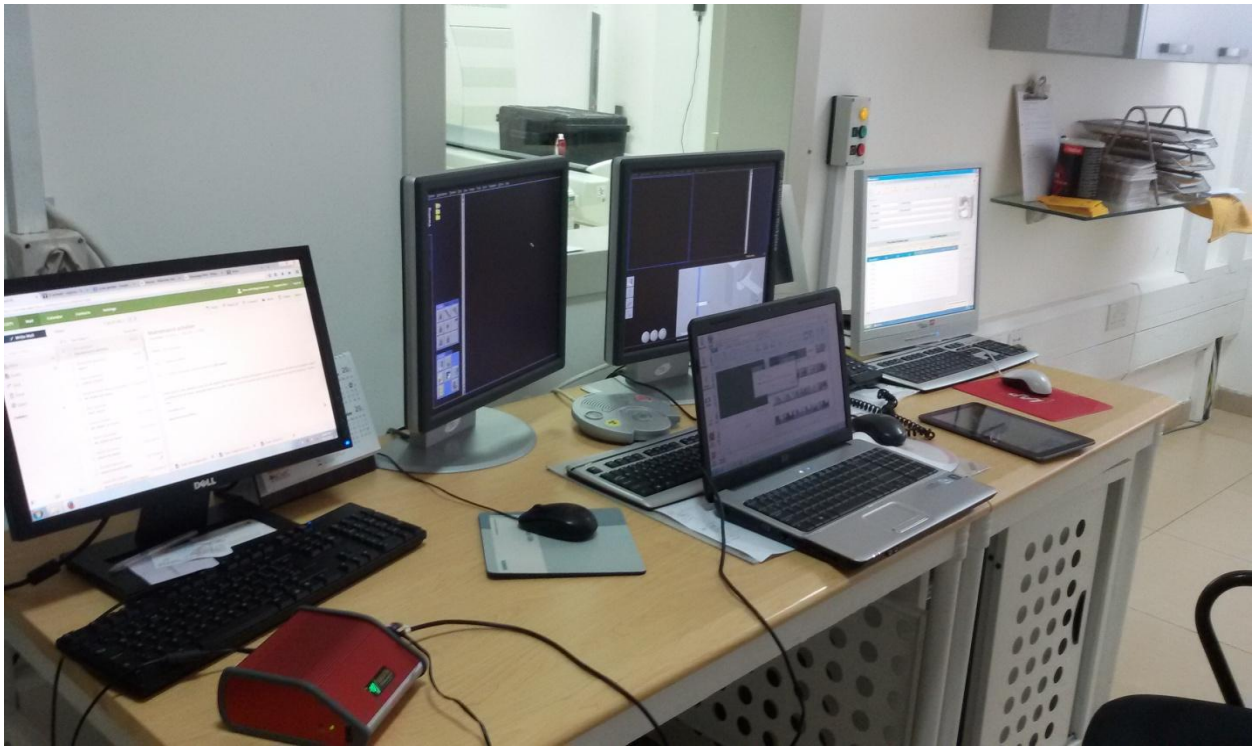

Plate 3.2: Control Console of the Siemens Somatom Emotion CT 16 slice scanner at SGMC

3.1.2 CT DOSE PROFILER

Regular measurements on CT scanners are necessary in order to monitor the doses to patients from the medical examinations. The rapid advancements in CT technology are placing new demands on methods and equipment used for quality assurance. The wide beam widths found in CT scanners with multiple beam apertures make it difficult to use existing CT dose ionization chambers to measure the total dose given to the patient. Using a standard 10 cm CT ionization chamber may result in inaccurate measurements due to underestimation of the dose profile for wide beams. The CT dose profiler (Plate 3.3) was developed to solve this problem.

The dose is measured in every point of the x-ray beam and the total dose profile is acquired regardless of how wide the beam is. There is no limitation of the beam width. This makes it possible to measure without the drawbacks of traditional CT probes.

The CT dose profiler is an advanced point dose probe for evaluation of computed tomography systems and has no limitation when it comes to measuring in wide beams. It is designed to be used with the Barracuda x-ray electrometer (Plate 3.4) and computer running the CT dose profiler software, CT dose profile analyzer which fits into all standard phantoms.

Following parameters can be measured from a single exposure

- $CTDI_{100}$
- Point Dose
- CT dose profile
- $CTDI_{w}$
- $CTDI_{vol}$
- DLP
- Performance of the AEC
- FWHM (Full width at half maximum of the dose profile)
- Geometric efficiency%

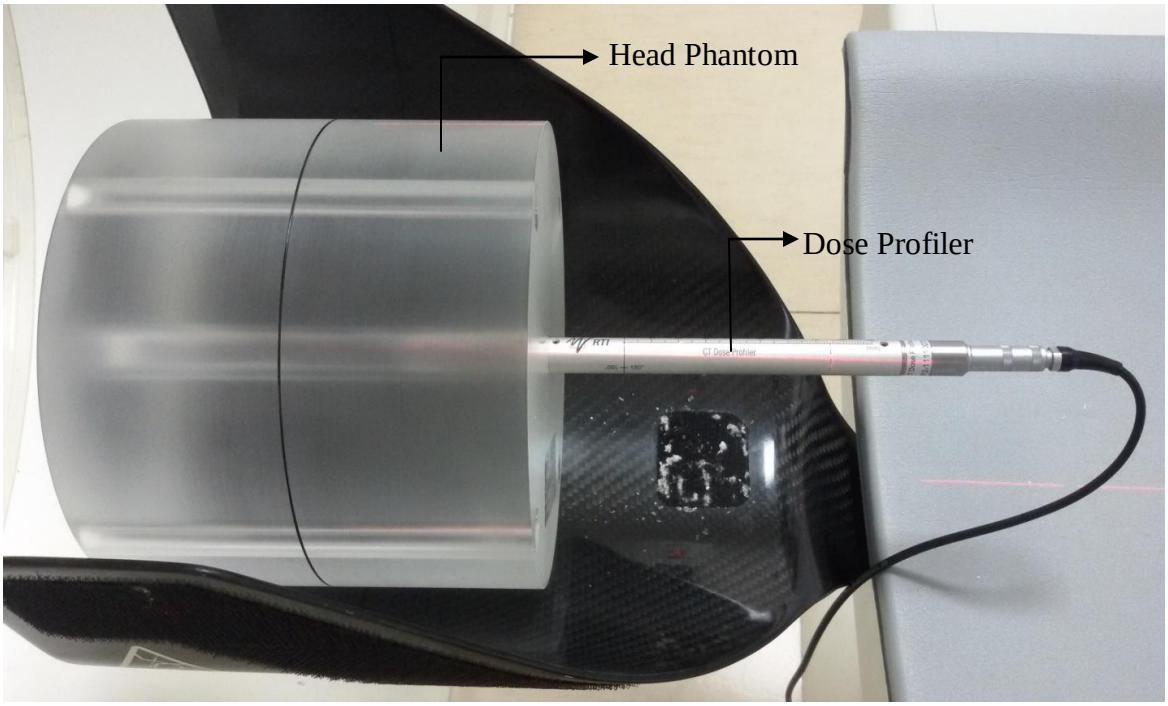

Plate 3.3: CT Dose Profiler inserted in a head phantom

Plate 3.4: RTI Barracuda Electrometer

3.1.3 OCEAN SOFTWARE

Ocean software is quality assurance software from RTI Electronics for the Barracuda, to organize and simplify workflow in CT measurements.

Ocean comes as standard with a new QA system. Ocean Display provides an easy-to-read display that can be used with a simple default template, or one customized to suit specific needs. The wide range of parameters measured by the Barracuda is displayed on a single screen, and these results can be retained in the database for later analysis.

3.2 METHODS

Two main methods were employed in the study: patients' data collection and phantom measurement to validate the patient data.

3.2.1 PATIENTS' DATA COLLECTION

Data was collected from the CT facility at the Sweden Ghana Medical Centre. This facility was chosen because of the significant patient output. Furthermore, since the inception of the facility, there has not been any study on the CT machine and radiation dose received by patients to be specific. The institutional review board at the health centre approved the study. Patient data was compiled from the facility for adult patients for each of the examination types performed in the facility from January 2013 to December 2014 for a total sample size of about 900 examinations. Patient parameters such as age, gender and patient ID were collected when patients undergo the examination for easy identification. Technique factors such as scan length slice thickness, kVp, mAs,

pitch, DLP and $CTDI_{vol}$ were recorded from the control console of the CT machine whiles the patient was on the couch undergoing the examination. Patient exposure parameters were recorded and the data was compiled and analyzed using Microsoft excel.

3.2.2 PHANTOM MEASUREMENT

Standard head and body with phantoms with respective diameters 16 cm and 32 cm were placed on the patient table in succession and positioned exactly in the center of the gantry. A topogram was created and the scan length was determined to be exactly the length of the phantom. The actual protocol in question was loaded. A helical scan was done for the entire phantom, beginning exactly at one edge and stopping exactly at the opposite edge. Measurements were performed with RTI Barracuda electrometer connected to the CT dose profiler. Each measurement was repeated for at least three times to find the average. The phantom (head, neck, chest, abdomen and pelvis) was scanned applying typical scanning protocols of the hospital.

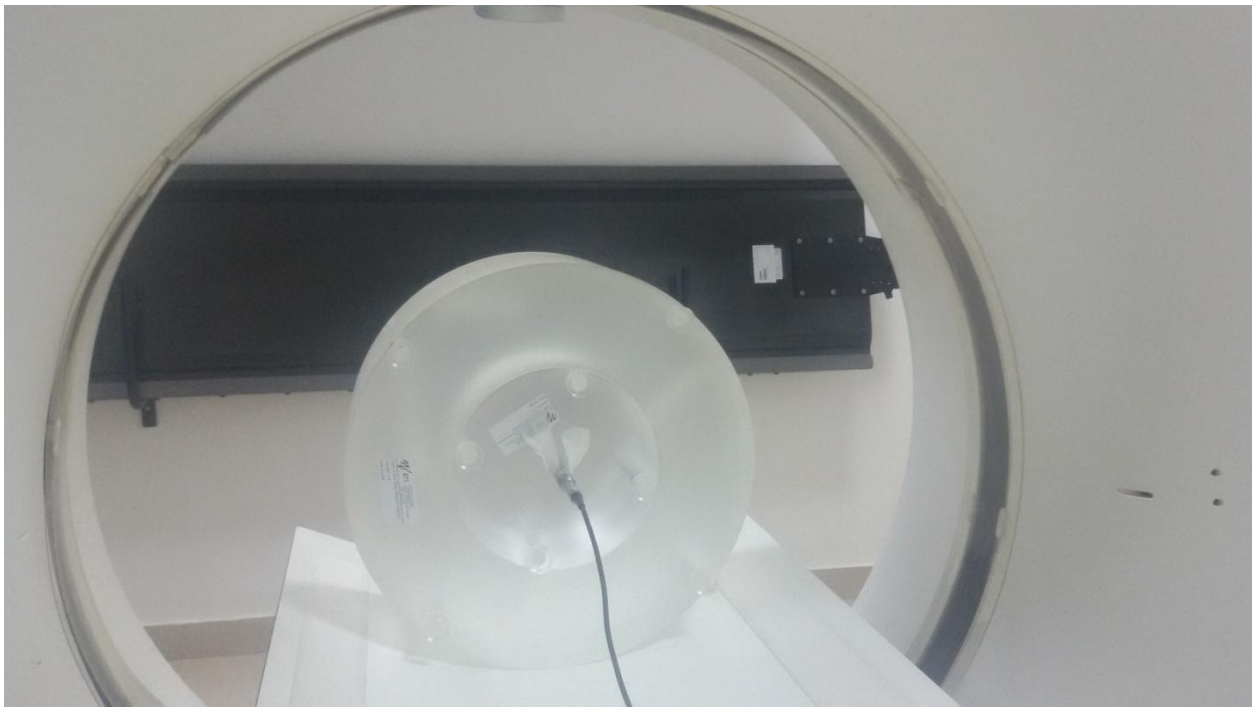

Plate 3.5: Head and body phantom positioned exactly in the center of the gantry

3.3 ESTIMATION OF EFFECTIVE DOSE

It is impractical to directly measure the effective dose of an individual patient even when the radiation emitted by a machine is precisely known. Instead, radiation dose may be quantified using various methods. The effective dose associated with each CT examination was estimated because it is one of the most frequently reported dosimetric quantities [13]. Furthermore, the effective dose allows comparison across the different types of CT studies and between CT doses and other imaging tests, facilitating comparison of CT doses to the most common radiology studies patients undergo. The effective dose accounts for the amount of radiation to the exposed organs and each organ's sensitivity to developing cancer from radiation exposure. Although effective dose

best reflects a patient's overall risk to radiation, organ-specific dose may be more appropriate for estimating lifetime cancer risk for non-uniform doses from CT examinations. For example, if a patient undergoes an imaging study that irradiates only the breast, her risk of cancer from that examination will primarily reflect her increased risk of breast cancer [12]. Effective dose cannot be measured directly but can be estimated from measurable quantities.

The effective dose calculation was done manually using the equation;

$$EffectiveDose = DLP \times k\,(E/DLP) \tag{3.1}$$

Where; DLP is dose length product

$$DLP\,(mGycm) = CTDI_{VOL}\,(mGy) \times Scanlength\,(cm) \tag{3.2}$$

Where; $k(E/DLP)$ is the anatomic region specific conversion factor.

Table 3.1 shows the conversion factors from DLP to effective dose for adult patients as a function of voltage, region, and age for ICRP Publication 103 Recommendations [51].

Table 3.1: Conversion factors from DLP to effective dose for adult patients [51]

Tissue/Organ	**Conversion factor** $k\,(E/DLP)$ **[** $mSv/mGycm$ **]**
Head	0.0019
Neck	0.0052
Chest/Thorax	0.0146
Abdomen	0.0153
Pelvis	0.0129

3.4 RISK ASSESSMENT

The general expression for calculating the total cancer risk, according to BEIR VII [NRC, 2006] including natural and radiation- induced, to a population is expressed mathematically as:

$$\lambda(d) = \lambda_o[1 + f(d)g(\beta)] \qquad (3.5)$$

Where λ_o represents absolute age specific cancer risk to unexposed population with background rate at zero dose. [$1 + f(d)g(\beta)$] represents the radiation induced fatal cancer risk and the dose-response function, $f(d)$ depends on the type of cancer involved which is always a linear or linear quadratic function, i.e., $f(d) = \alpha_1 d$ or $f(d) = \alpha_2 d + \alpha_3 d^2$. In general, the excess risk function, $g(\beta)$ depend upon a number of parameters, for example sex, attained age, age at exposure, and time- since exposure.

One can also write the age specific risk as an additive risk model:

$$\lambda(d) = \lambda_o + f(d)g(\beta) \qquad (3.6)$$

These models give similar results as expected since the function of $g(\beta)$ is allowed to depend on age, time, etc. This will not be the case if $g(\beta)$ were restricted to having a constant value other than for sex and age at exposure. The models were fitted using maximum likelihood, i.e., the values of the unknown parameters which maximize the probability of the observed number of cases (the "likelihood function") are taken as the best estimates, and, where applicable, confidence limits and significance tests are derived from standard large –sample statistical theory.

Biological Effects of Ionizing Radiation (BEIR VII) report presents models to allow one to estimate the lifetime risk of cancer resulting from any specified dose of ionizing radiation and applies these models to sample exposure scenarios for the U.S. population. Models are developed for estimating lifetime risks of cancer incidence and mortality and take account of sex, age at exposure, dose rate, and other factors. Estimates are given for all solid cancers, leukemia, and cancers of several specific sites [40].

The BEIR VII (2006) report provides a method to estimate lifetime attributable risk (LAR) of cancer based on the magnitude of a single radiation exposure and a patient's age at the time of that exposure. The LAR is defined as additional cancer risk above and beyond baseline cancer risk. This can be calculated for specific cancers as well as for all cancers combined [38].

The Tables, B.1 and B.2 which can be found in Appendix B show lifetime risk estimates for cancer incidence for both male and female respectively for specific ages. In Appendix C, Tables C.1 and C.2 show lifetime risk estimates for cancer mortality for both male and female respectively. Estimates are shown for all cancers, leukemia, all solid cancers, and cancer of several specific sites.

The lifetime attributable risk (LAR) of cancer incidence and cancer mortality can be calculated by the following equations respectively;

$$\text{BEIR VII LAR (at specified age at exposure)} = \frac{\text{E(mSv)}}{100} \text{ x } \frac{\text{LAR(Cancer Incidence)}}{100000} \quad \text{and}$$

$$\text{BEIR VII LAR (at specified age at exposure)} = \frac{\text{E(mSv)}}{100} \text{ x } \frac{\text{LAR(Cancer Mortality)}}{100000}$$

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter outlines and discusses the results from the acrylic phantom measurements and patient data collected on estimation of effective dose and application of these results in estimating patient cancer risk due to CT examinations at Sweden Ghana Medical Centre (SGMC).

4.1 PHANTOM MEASUREMENTS

To ensure that the patient data was accurate and appropriate, verification measurements with a phantom was done. CTDI and DLP measurements from the CT console (measured) and the reference reading from the ocean software should be less than ±20% [51]. For better accuracy, deviation of ±10% is set as tolerance. From table 4.1 deviations between measured and reference readings were all found within 10%, which implies a good confidence in the measured data [51]. Hence, the patient data met the acceptance criteria.

Table 4.1: Head and Body Phantom measurements

Phantom	Scan length/ Mm	Dose/ mGy	CTDI ref/mGy	CTDI meas/ mGy	% Diff.	DLP ref/ mGycm	DLP meas/ mGycm	% Diff.	mAs
Head	174	61.68	53.48	56.02	4.53	1011.86	974.8	3.66	200
Head	174	61.68	53.48	52.63	1.59	1011.86	915.8	9.49	200
Head	174	54	53.48	53.15	0.62	1011.86	921.4	8.94	200
Neck	229	55.6	22.03	21.06	4.41	552.37	520.22	5.82	170
Neck	229	57.2	20.53	20.12	1.99	552.37	518.15	6.19	170
Neck	299	53	19.32	19.75	2.18	552.37	521.05	5.67	170
Thorax	223	5.718	7.48	7.35	1.74	178.41	163.6	8.31	60
Thorax	223	5.724	7.48	7.43	0.67	178.41	165.3	7.35	60
Thorax	223	5.721	7.48	7.36	1.61	178.41	165.2	7.41	60
Abdomen	195	7.335	9.63	9.48	1.56	202.74	184.5	8.99	77
Abdomen	195	7.323	9.63	9.43	2.07	202.74	183.3	9.56	77
Abdomen	195	7.327	9.63	9.45	1.87	202.74	184.1	9.19	77
Pelvis	184	9.475	12.51	12.26	1.99	282.5	254.5	9.91	100
Pelvis	184	9.488	12.51	12.22	2.32	282.5	264.8	6.27	100
Pelvis	184	9.479	12.52	12.23	2.32	282.5	255.2	9.66	100

4.2 DISTRIBUTION OF CT EXAMINATION BY BODY PART

The distribution of CT examinations performed at SGMC for the period January 2013-December is shown in Figure 4.1. Radiation dose information was only extracted on the most common type of CT examination and for only adult patients (18 years and older). Examinations performed in association with therapeutic procedure were also eliminated. In all, a total number of 889 adult CT examinations were compiled from the CT facility. Out of the 889 patients scanned, 288 (32.36%) were males and 601 (67.53%) were females; who underwent five different types of CT examinations with the highest being abdomen (52%) followed by chest and thorax (30%), head (13%), pelvis (3%), neck (2%).

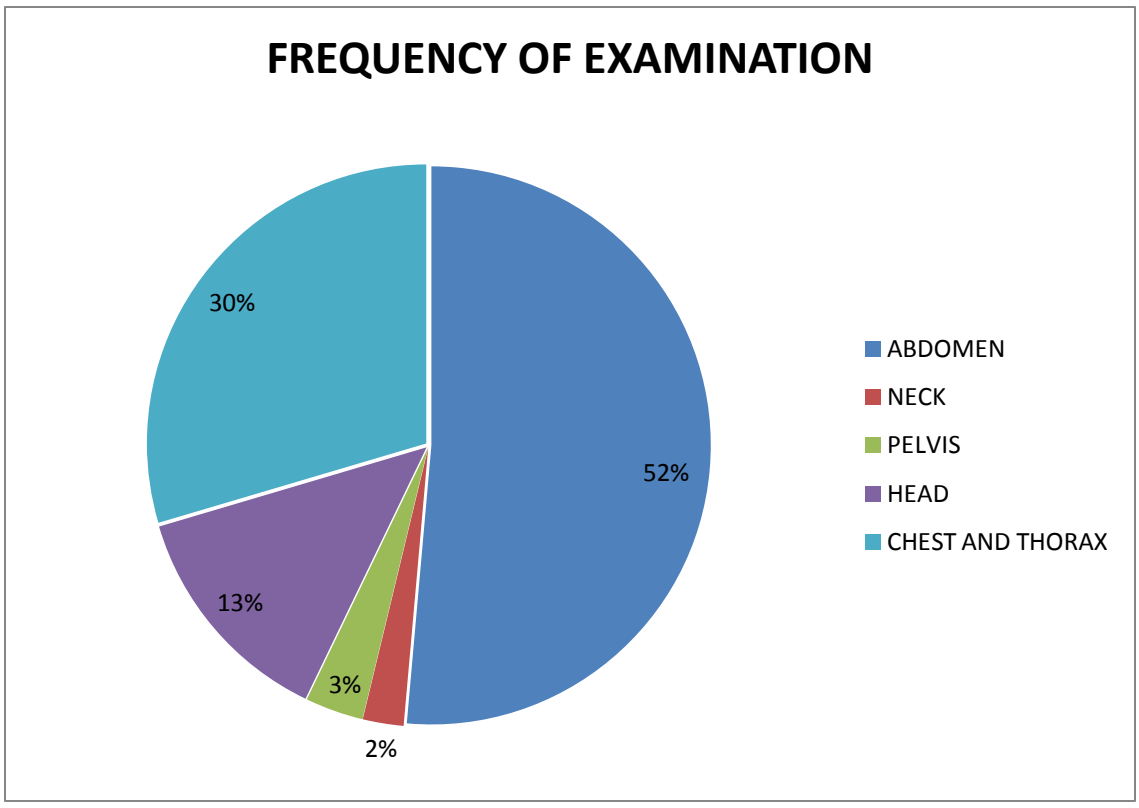

Figure 4.1: Frequency of CT examinations

4.3 DISTRIBUTION OF CT EXAMINATION BY AGE

The various CT examinations performed by age distribution at SGMC is as shown in figure 4.2**.** The most dominant age group for female reported cases was 38-47 with 144 scans, followed by age group 48-57, 58-67, 28-37, 68-77, 18-27, 78-87 and 88-97. The mean age for females was 50 years, and the minimum and maximum ages were 19 and 92 years respectively. Two patients had the maximum age (92 years) and thirteen patients had the minimum age (19 years). The minimum age group mostly underwent thorax and abdomen scan.

For the males, the most dominant age group recorded was 48-57 with 60 scans followed by 28-37, 38-47, 68-77, 58-67, 18-27, 78-87 and 88-97. The mean age for male was 49 years and the minimum and maximum ages were 18 and 90 years respectively. One patient had the maximum age (90 years) and three patients had the minimum age (18 years).

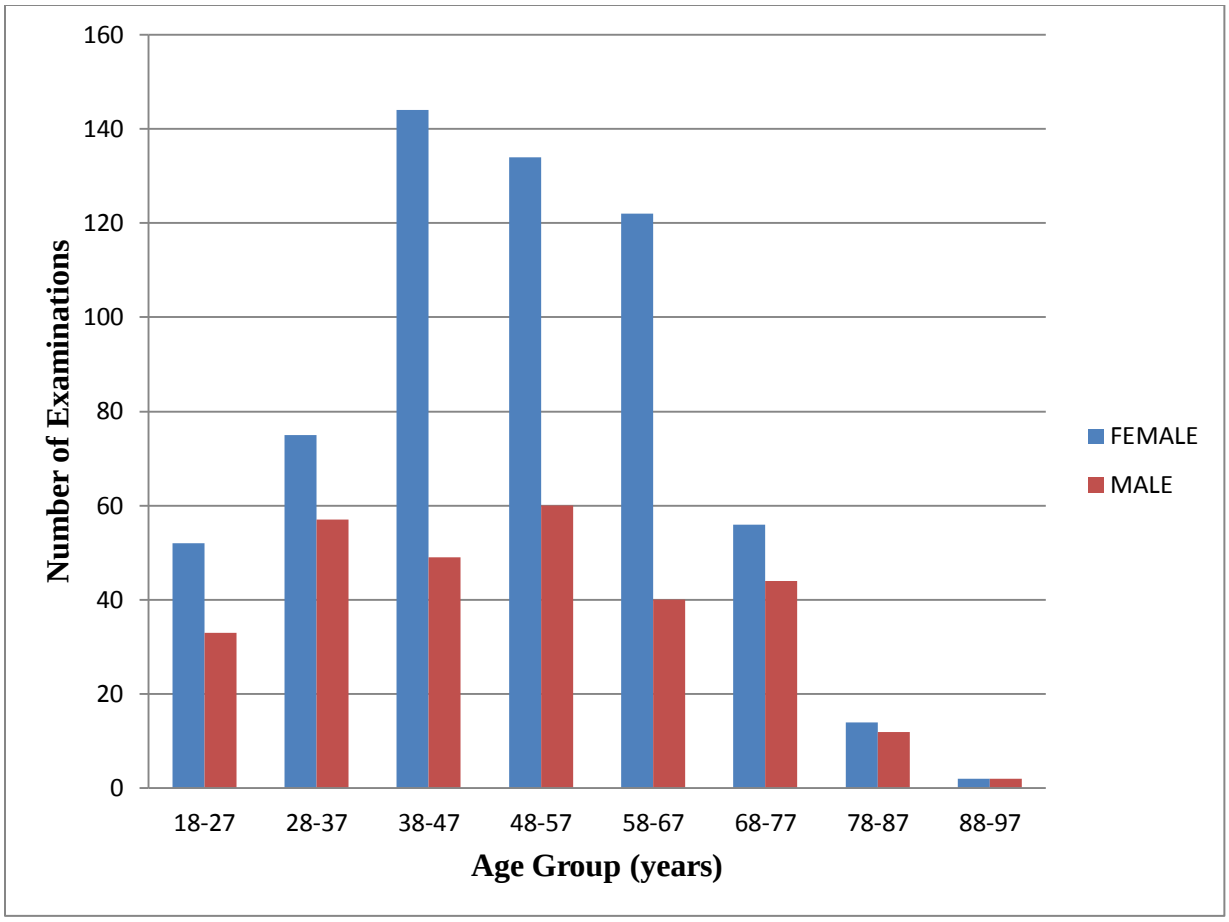

Figure 4.2: Age distribution of patients for CT examination

4.4 $CTDI_{vol}$ AND DLP

The average $CTDI_{vol}$ value for the head was 57.48 mGy and the average DLP was 1073.81 mGycm. The minimum and maximum values for the DLP were 103.72 mGycm and 2321.06 mGycm respectively. The minimum and the maximum values for the $CTDI_{vol}$ were 4.21 mGy and 71.82 mGy respectively.

For neck scans the average $CTDI_{vol}$ value was 20.47 mGy with the minimum and maximum values being 9.97 mGy and 38.26 mGy respectively and the average DLP

value was 495.7 mGycm with the minimum and maximum values being 243.57 mGycm and 953.16 mGycm respectively.

For chest and thorax scans, the average for $CTDI_{vol}$ was 7.35 mGy and 305.13 mGycm as an average for DLP. The minimum $CTDI_{vol}$ value was 3.37 mGy and the maximum $CTDI_{vol}$ was 19.24 mGy. The minimum and maximum DLP values were 87.46 mGycm and 783.94 mGycm respectively.

For abdominal scans, which were the most frequent examination patients underwent the average values for the $CTDI_{vol}$ and DLP were 9.55 mGy and 458.13 mGycm respectively. The minimum and maximum values for the DLP are 65.56 mGycm 1598.70 mGycm respectively. The minimum and the maximum values for the $CTDI_{vol}$ are 3.18 mGy and 25.55 mGy respectively.

For pelvis scans, the average values for $CTDI_{vol}$ and DLP were 12.14 mGy and 373.41 mGycm respectively. The minimum and maximum $CTDI_{vol}$ values were 4.49 mGy and 20.11 mGy. The DLP the minimum and maximum values were 111.31 mGycm and 870.22 mGycm respectively.

Table 4.2 shows the averages in the $CTDI_{vol}$ and DLP with averages of other parameters. The tube current recorded was 130 kV for all the scans.

It was observed that the values for the $CTDI_{vol}$ and the DLP were all within or below the diagnostic reference levels (DRL) in CT as compared to DRL of the European commission (EC) and the American College of Radiology (ACR) [52]. The DRL

provides an appropriate standard of protection to patients against the harmful effects of radiation without reducing the diagnostic efficacy of the examination.

Table 4.2: Average parameters and effective dose based on anatomic coverage region

	MEAN VALUES					
Body Region	**Tube charge per rotation (mAs)**	**Scan length (mm)**	**Pitch**	**CTDI(vol) (mGy)**	**DLP (mGycm)**	**Estimated Effective Dose(mSv)**
Head	217.47	176.41	0.59	57.42	1073.81	2.04
Neck	163.62	229.64	0.74	20.47	495.7	2.58
Chest/Thorax	64.57	407.88	0.8	7.35	305.13	4.45
Abdomen	78.48	448.32	0.79	9.55	458.13	7.01
Pelvis	108.17	299.7	0.89	12.14	373.41	4.82

4.5 EFFECTIVE DOSE COMPARISON

For scans of the head, the effective dose varied from 0.20 mSv to 4.41 mSv with the mean effective dose being 2.04 mSv. For neck scans, the effective dose varied from 1.27 mSv to 4.96 mSv with 2.58 mSv as the mean effective dose. For chest scans, the mean effective dose was 4.45 mSv and varied from 1.28 mSv to 11.45 mSv. For abdomen scans, a routine CT scan had mean effective dose of 7.01 mSv with the minimum effective dose of 1.00 mSv and maximum effective dose of 24.46 mSv. For pelvis scans, the mean effective dose were 4.82 mSv and its minimum and maximum effective dose were 1.44 mSv and 11.23 mSv respectively. The summary of the mean effective doses can be seen in Table 4.2.

Table 4.3: Average effective dose for different CT examinations [52]

Adult Effective Doses for Various CT Procedures		
Examination	**Average Effective Dose (mSv)**	**Values Reported in Literature (mSv)**
Head	2	0.9-4.0
Neck	3	…
Chest	7	4.0-18.0
Abdomen	8	3.5-25
Pelvis	6	3.3-10

The effective doses from diagnostic CT procedures are typically estimated to be in the range of 1 to 10 mSv. This range is not much less than the lowest doses of 5 to 20 mSv received by some of the Japanese survivors of the atomic bombs explosions [52].

Comparing Tables 4.2 and 4.3, it can be seen that the estimated effective doses received by patients undergoing various CT procedures at SGMC were all within the European commission (EC) and the American College of Radiology (ACR) reference levels.

4.6 HEAD CT EXAMINATIONS

Computed tomography scan of the head provides comprehensive information on head injuries, brain tumors, stroke and other brain diseases like stroke and symptoms of damage to part of the brain, such as vision problems, muscle weakness, numbness and tingling, hearing loss, speaking difficulties, or swallowing problems. It also gives detail information on the skull, sinus and the eye sockets.

Out of the total 118 head examinations at SGMC during the period of the study, majority of the examinations were for brain scan with few being sinus and inner ear scans. With this, 47.54% were female and 52.54% being male, indicating more male head CT examinations in comparison to females. Figure 4.3 shows the distribution of head scans with age groups. Average tube voltage used for the head scans was estimated to be 130 kVp and the corresponding average current was 217.47 mAs. Slice thicknesses of acquired head scans varied between 3 mm and 4mm and the average scan length was 176.41 mm. This is shown in Table A.1 in Appendix A.

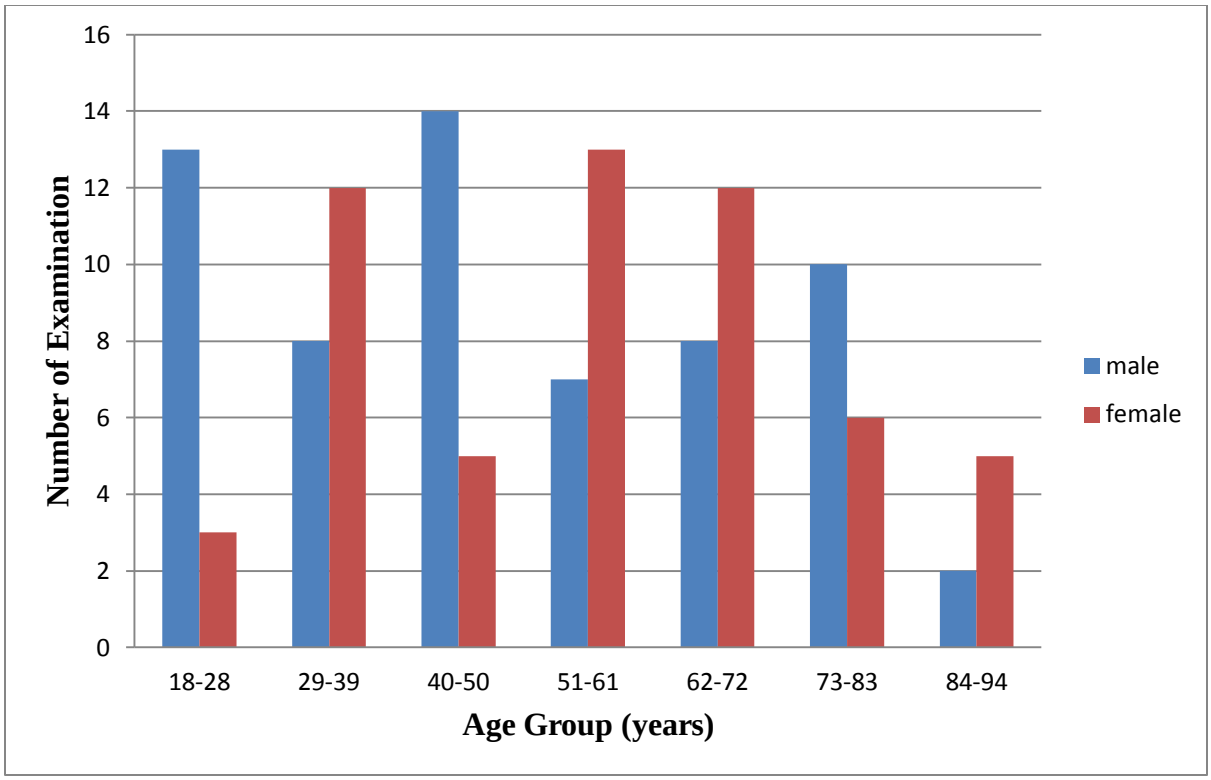

Figure 4.3: Distribution of head CT scans with respect to age group

4.7 NECK CT EXAMINATIONS

The neck computed tomography examination gives detail information on the soft tissues of the neck, including the muscles, adenoids, throat, tonsils, thyroid, and other glands. The upper spinal cord and also blood vessels can also be seen.

The neck examinations were a total of 21, out of which 52.4% were male and 47.6% were female. Figure 4.4 shows the distribution of neck CT scan with respect to age group. Less neck CT scans could imply relatively less need of CT imaging modality for neck diseases. Slice thickness for this study ranged between 3 mm and 4 mm, with mean scan length was 229.63 mm A constant tube voltage of 130 kVp and an average tube current of 163.62 mAs were recorded. This is shown in Table A.2 in Appendix A.

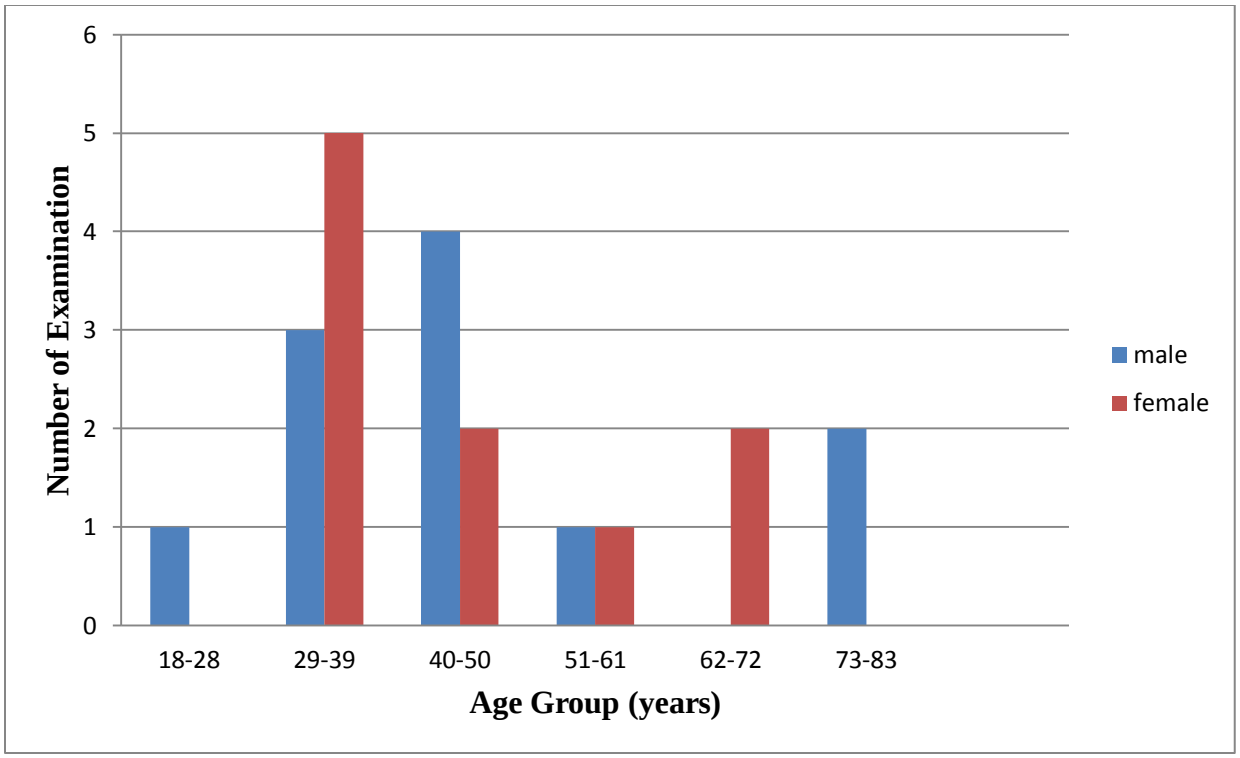

Figure 4.4: Distribution of neck CT scans with respect to age group

4.8 CHEST CT EXAMINATIONS:

Chest (thorax) CT examination provides detailed information of problems with the heart, lungs, aorta, and many other tissues or organs in the chest region. It can also identify common chest problems like infections and lung cancer.

There were 263 CT examinations of the chest and out of this number 73.4% were females and 26.6% were males. Figure 4.5 shows the distribution of chest CT scans with respect to age group. The average tube voltage was estimated to be 130 kVp. Minimum tube current recorded was 26 mAs and maximum tube current recorded was 707 mAs, which gave an average of 64.57 mAs. The slice thickness varied between 3mm and 4mm. The mean scan length was 407.88 mm. This is shown in Table A.3 in Appendix A.

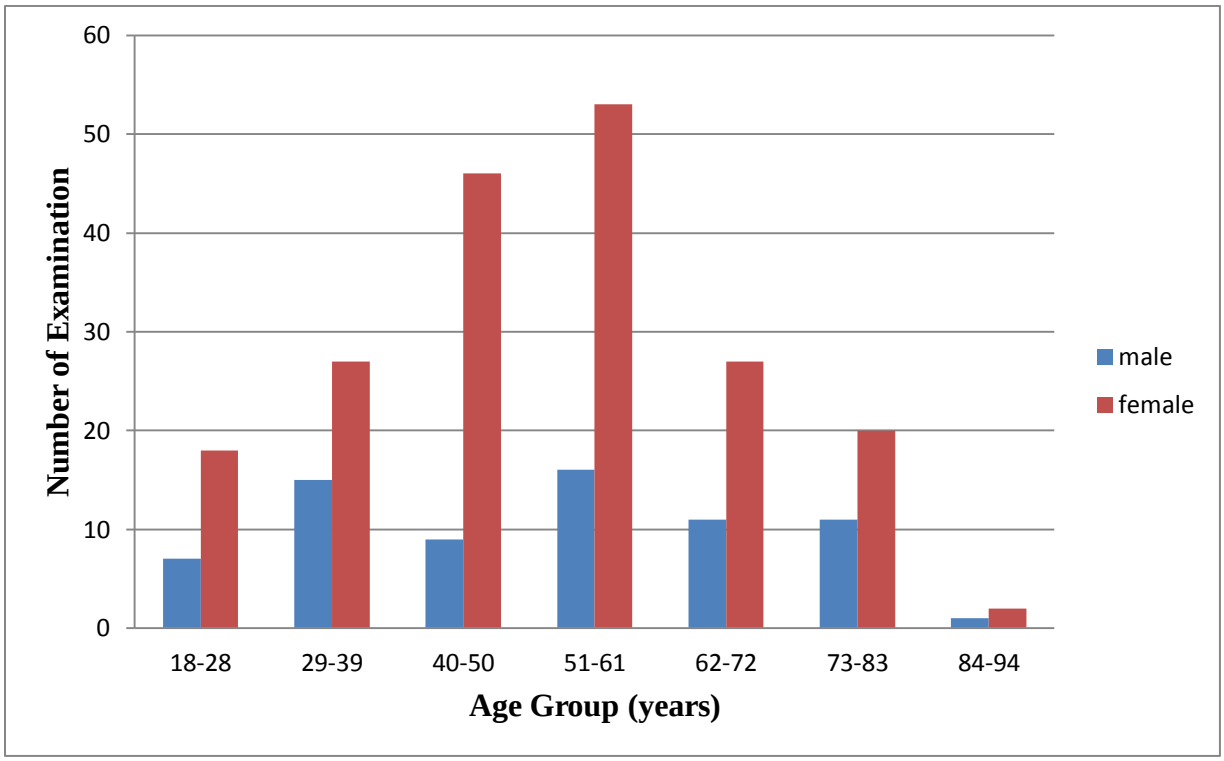

Figure 4.5: Distribution of chest CT scan with respect to age group

4.9 ABDOMEN CT EXAMINATIONS

Abdominal CT scan gives comprehensive information about the abdominal organs like the liver, spleen, kidneys, pancreas, and the gastrointestinal tract. Abdominal CT scan are conducted to verify abnormalities seen in other imaging modalities like ultrasound.

Abdominal scan is the most frequent CT examination recorded at the SGMC. The abdomen houses a lot of tissues and organs which are susceptible to varying degenerative diseases such as cancers, and hence a lot of patients report to hospitals with abdominal diseases. The total number of abdomen examinations was 457, with 70.7% as females and 29.3% as males. Figure 4.6 shows the distribution of the abdomen CT scans with the various age groups. The average tube voltage was 130 kVp, average tube current was 78.84 mAs, and mean scan length was 448.32 mm. Slice thicknesses for the CT images were 3 mm and 4 mm. This is shown in Table A.4 in Appendix A.

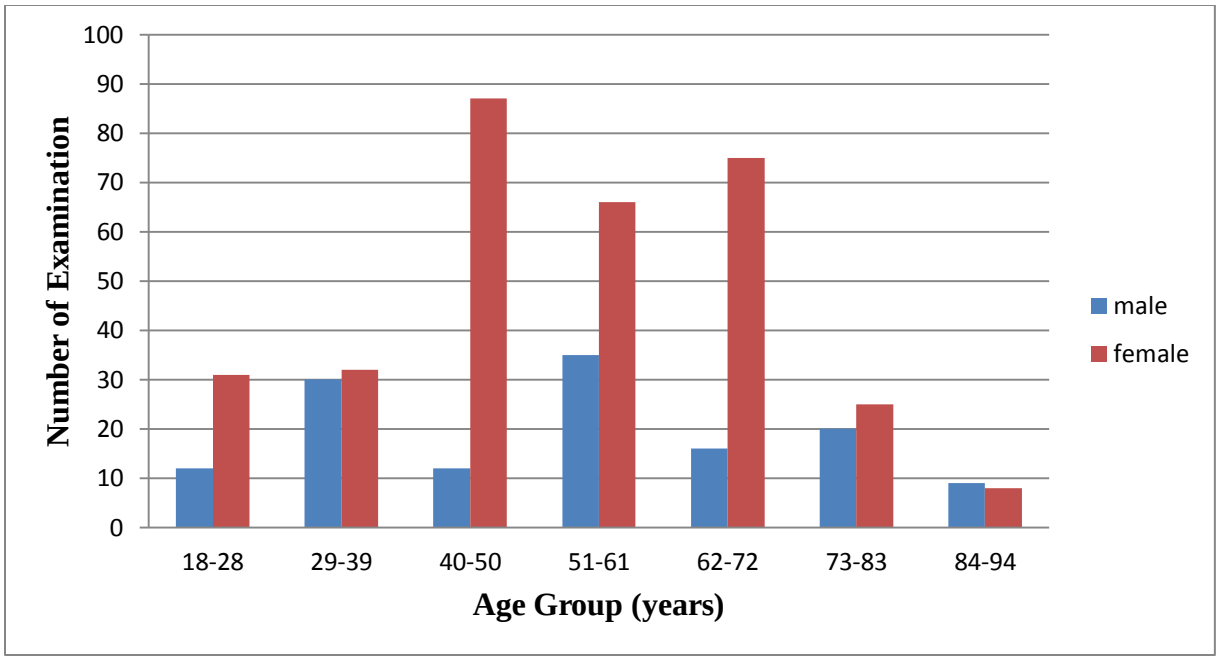

Figure 4.6: Distribution of abdomen CT scans with respect to age group

4.10 PELVIS CT EXAMINATIONS

Pelvis CT scans assesses medical issues with organs or structures in the pelvis. In females, some of the organs are the uterus, ovaries, and fallopian tubes, while in males; organs include the prostate gland and the seminal vesicles.

Thirty (30) pelvic examinations were recorded, out of which 63.3% were females and 36.7% were males. Figure 4.7 shows the distribution of pelvic scans with respect to age group.

The average tube voltage was 130 kVp and mean tube current was 108.17 mAs. The slice thickness was 3mm and only one examination recorded 4 mm. The mean scan length was 211.5 mm and the maximum and minimum values were 487.5 mm and 207.5 mm respectively. This is shown in Table A.5 in Appendix A.

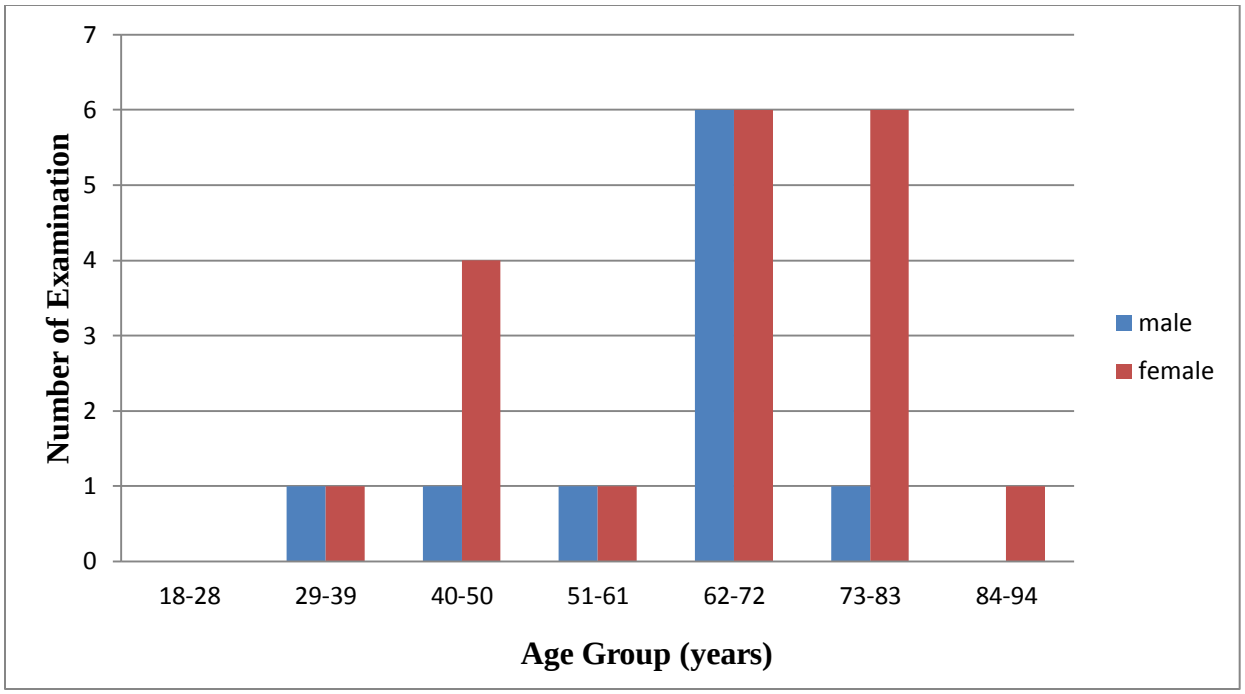

Figure 4.7 Distribution of pelvic scans with respect to age group

4.11 CANCER RISK ASSESSMENT

The lifetime attributable risk (LAR) can be calculated for specific cancers as well as for all cancers combined. All cancers were used to compare all types of CT studies included in this work. Risk may depend on the type of cancer, the magnitude of the dose, the quantity of the radiation, the dose rate, the age and sex of the person exposed. Table 4.4 below gives a summary of the average effective dose and its corresponding lifetime attributable risk of cancer incidence and lifetime attributable risk of cancer mortality. The details are shown in Appendix A.

Table 4.4: Effective dose and Lifetime Attributable Risk

Type of Scan	Population Size	Effective Dose(mSv)		LAR of Cancer Incidence (%)		LAR of Cancer Mortality (%)	
		Averages	Range	Averages	Range	Averages	Range
Head	118	2.04	0.20-4.41	0.019	0.001-0.175	0.008	0.001-0.025
Neck	21	2.58	1.27-4.96	0.018	0.009-0.029	0.018	0.006-0.0970
Chest	263	4.45	1.28-11.45	0.033	0.006-0.131	0.033	0.005-0.060
Abdomen	457	7.01	1.00-24.46	0.049	0.004-0.267	0.030	0.003-0.124
Pelvis	30	4.82	1.44-11.23	0.025	0.005-0.061	0.016	0.004-0.038

From SGMC, the average effective dose for the head was 2.04 mSv in the range of 0.20 mSv and 4.41 mSv. The average lifetime attributable risk (LAR) of cancer incidence was 0.019% or 1 in 5263 in the range of 0.001% (1 in 100000) and 0.175% (1 in 571) compared with a population of 889 patients who underwent CT examinations, indicates that patients were not at risk. For the LAR of cancer mortality, the average was 0.008% (1 in 12500) in the range of 0.001% (1 in 100000) and 0.025% (1 in 4000).

For the neck, the average effective dose was 2.58 mSv in the range of 1.27 mSv and 4.96 mSv. The average LAR of cancer incidence was 0.018% (1 in 5556) and in the range of

0.009% (1 in 11111) and 0.029% (1 in 3448). For the LAR of cancer mortality, the average was also 0.018% or 1 in 5556 in the range of 0.006% (1 in 16667) and 0.097% (1 in 1031).

The average effective dose for the chest was 4.45 mSv in the range of 1.28 mSv and 11.45 mSv. The average LAR of cancer incidence was 0.033% or 1 in 3030 and in the range of 0.006% (1 in 16667) and 0.131% (1 in 764). For the LAR of cancer mortality, the average was also 0.020% or 1 in 5000 in the range of 0.005% (1 in 20000) and 0.060% (1 in 1667).

The average effective dose for the abdomen was 7.01 mSv in the range of 1.00 mSv and 24.46 mSv. The average LAR of cancer incidence was 0.049% or 1 in 2041 and in the range of 0.004% (1 in 25000) and 0.267% (1 in 375). For the LAR of cancer mortality, the average was also 0.030% (1 in 3333) in the range of 0.003% (1 in 33333) and 0.124% (1 in 807).

For the pelvis, the average effective dose was 4.82 mSv in the range of 1.44 mSv and 11.23 mSv. The average LAR of cancer incidence was 0.025% or 1 in 4000 and in the range of 0.005% (1 in 20000) and 0.061% (1 in 1639). For the LAR of cancer mortality, the average was also 0.016% or 1 in 6250 in the range of 0.004% (1 in 25000) and 0.038% (1 in 2632).

Table 4.5 Additional lifetime risk of fatal cancer from examination [53]

Risk Level	**Approximate additional risk of fatal cancer for an adult from examination**
Negligible	less than 1 in 1 000 000
Minimal	1 in 1 000 000 to 1 in 100 000
Very Low	1 in 100 000 to 1 in 10 000
Low	1 in 10 000 to 1 in 1 000
Moderate	1 in 1 000 to 1 in 500

From Table 4.6 above, it was observed that the overall risk ranges between moderate which is 1 in 1000 to 1 in 500 and minimal which is 1 in 1 000 000 to 1 in 100 000. The average risk for all the examinations was observed to be low (1 in 10 000 to 1 in 1000). Considerably, it was observed that a 21 year old female who underwent an abdominal scan recorded the highest value of 0.267% and 0.124% for both cancer incidence and cancer mortality respectively. This could be attributed to the size of the patient or the operation of the equipment. The minimum cancer risk of 0.001% which is almost negligible was recorded by a 92 year old female who underwent a brain scan.

Risks were particularly high for women in their early ages and decreased noticeably as a function of age, whereas estimated risks were considerably lower in men. Radio sensitivity of many organs such as the breast and liver has been observed to decrease with age. Just as there are differences in the risk of cancer among males and females and among different age groups, there are differences in cancer risks among different populations.

Although the risks from the CT examinations were small, it is cumulative and therefore special attention has to be given, especially when repeated examinations are conducted.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

This chapter five elaborates the main conclusions from the study and relevant recommendations for the minimization of patient dose and reduction of probability of cancer induction for patients undergoing CT examinations.

5.1 CONCLUSION

The effective dose accounts for the amount of radiation a patient receives to the exposed organs and each organ's sensitivity to developing cancer from radiation exposure. Although effective dose best reflects a patient's overall risk to radiation, organ-specific dose may be more appropriate for estimating lifetime cancer risk for non-uniform doses from CT examinations. The effective doses of the individual patients from Sweden Ghana Medical Centre were based on the type of examination and the conversion factor from DLP to effective dose. This also determined the cancer risk for each patient. The patient's age and sex were essential elements to assessing the dose a patient receives when undergoing a CT examination. Patient dose calculations were based on the characteristics of 16-slice CT scanner at SGMC.

In this study, the effective dose and cancer risk were estimated for patients undergoing the five most common types of CT examinations (head, neck, chest, abdomen and pelvis) at SGMC in the Greater Accra Region of Ghana.

For abdomen CT examination (52%) was the highest frequency of examination recorded at the facility followed by chest and thorax (30%), head (13%), pelvis (3%), and neck (2%).

The mean age for female was 50 years in the range of 19 to 92 years. The minimum age group mostly underwent thorax and abdomen scan. In the case of males, the mean age was 49 years in the range 18 to 80 years.

Although the risks from the CT examinations were small, continual accumulation of radiation dose has potential of resulting in stochastic effects. Hence necessary radiation safety precautions should be adhered to.

This study found that for a head scan, the average lifetime attributable risk (LAR) of cancer incidence was 0.019% or 1 in 5263 in the range of 0.001% (1 in 100000) and 0.175% (1 in 571) compared with a population of 889 patients who underwent CT examinations, indicates that patients were at a very low risk. For the LAR of cancer mortality, the average was 0.008% or 1 in 12500 in the range of 0.001% (1 in 100 000) and 0.025% (1 in 4000) (estimated using the approach of BEIR VII) varies considerably, depending on age, sex, and protocol. The overall risk ranges between moderate which is 1 in 1000 to 1 in 500 and minimal which is 1 in 1 000 000 to 1 in 100 000.

It can be concluded that the estimated effective doses received by patients undergoing various CT procedures at SGMC were all within the acceptable values (1 to 10 mSv). The average cancer risk for all the examinations was also observed to be low (1 in 10 000 to 1 in 1000).

The approach used in this study has some limitations. The estimates are not based on epidemiological data of actual malignancies in populations of patients receiving CT examinations in Ghana; such data are not available and will not be available for the near future. Rather, these estimates are interpolated based on the lifetime attributable cancer risk models developed in the BEIR VII report.

5.2 RECOMMENDATIONS

5.2.1 SWEDEN GHANA MEDICAL CENTRE

It is recommended that requests for CT scanning must be done only by qualified medical practitioners and justified by both the referring doctor and the radiologist. Establishment of clinical guidelines to advise referring doctors and radiologists about the appropriateness and acceptability of CT examinations helps eliminate inappropriate requests for CT. In addition, CT examinations should not be repeated without clinical justification. Regular training of requesting physicians and CT staff can help in the optimization of scan indications, protocols and radiation dose.

Procedures with no radiation exposure, such as ultrasonography and magnetic resonance imaging (MRI), should be used for appropriate clinical indications where equal or greater diagnostic information can be obtained. Since there are no dose limits for patients undergoing CT examinations and what is deemed to be an acceptable patient dose relies on the professional judgment of the health personnel in charge of the diagnostic procedure; it is important to ensure that imaging protocols are continually reviewed such that the choice of radiographic technique is consistent with ALARA principles. This is

best accomplished with the assistance of a diagnostic medical physicist. Also, repeated scans should be minimized or avoided if possible.

5.2.2 RADIATION PROTECTION BOARD (RPB)

The regulatory authority for radiological procedures should encourage the various facilities to review and implement an effective system of record keeping on patients undergoing CT examinations. The use of dose management software is recommended to aid in dose trend analysis and follow-ups.

5.2.3 MEDICAL PHYSICISTS

It is recommended that medical physicists perform the required quality control and quality assurance test to ensure that the CT machine works effectively to prevent excess radiation dose to patients.

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APPENDICES

APPENDIX A

Table A.1: Patient parameters of head CT Examination at SGMC

Sweden Ghana Medical Centre Ltd, SGMC

Data to be registrated to determine diagnostic standard doses for CT exams

Patient ID	Age (years)	Sex (M/F)	Tube charge per rotation (mAs)	Scan length (mm)	Nominal slice thickness (mm)	$CTDI_{vol}$ values (mGy)	DLP(mGycm)	Estimated Effective Dose (mSv)	LAR of Cancer Incidence (%)	LAR of Cancer Mortality (%)
604	78	M	220	201	4	52.82	1164.11	2.21	0.005	0.004
620	71	M	220	168.5	4	52.82	992.45	1.89	0.006	0.005
724	36	M	240	136	4	63.6	917.74	1.74	0.012	0.007
689	48	M	220	166	4	58.54	1068.94	2.03	0.012	0.007
780	47	M	35	256	3	9.29	134.37	0.26	0.002	0.001
799	78	F	220	256	3	52.82	934.35	1.78	0.005	0.004
533	41	M	220	207.5	3	58.54	1303.69	2.48	0.016	0.009
674	19	M	240	224.5	3	63.6	1524.47	2.90	0.030	0.015
879	69	F	220	159.2	3	58.54	931.96	1.77	0.008	0.006
919	70	F	240	162	3	63.6	1135.88	2.16	0.009	0.007
953	66	F	240	147	3	63.6	1031.58	1.96	0.009	0.007
955	25	F	140	201	3	42	846.72	1.61	0.023	0.010
1015	36	M	270	183.7	3	63.45	1187.78	2.26	0.015	0.009
1114	60	M	240	273.5	3	63.6	1836.11	3.49	0.017	0.011
1121	32	M	240	161	3	63.6	1120.62	2.13	0.014	0.008
891	60	M	240	163	3	63.6	1133.34	2.15	0.011	0.007
1185	78	F	240	151.5	3	63.6	1060.20	2.01	0.005	0.004
1190	39	M	240	156	3	63.6	1088.82	2.07	0.014	0.008
1199	40	F	240	156	3	63.6	1088.82	2.07	0.013	0.010

919	70	F	240	152.5	3	63.6	1066.56	2.03	0.008	0.006
1246	30	F	35	134	3	9.29	139.47	0.26	0.003	0.001
1248	45	M	240	142.5	3	63.6	1002.96	1.91	0.012	0.007
1252	30	F	240	162	3	63.6	1126.98	2.14	0.023	0.012
1344	85	M	270	143.6	3	55.17	824.26	1.57	0.027	0.002
1435	40	F	240	147.5	3	63.6	1034.76	1.97	0.175	0.010
1000	51	F	240	153.5	3	63.6	1072.92	2.04	0.015	0.009
1539	42	F	240	146.5	3	63.6	1028.40	1.95	0.017	0.010
1569	37	M	240	161	3	63.6	1120.62	2.13	0.014	0.008
1578	67	F	220	134	3	58.54	873.42	1.66	0.006	0.006
1586	57	F	270	170.4	3	63.01	1096.42	2.08	0.013	0.009
1654	46	M	240	168.5	3	63.6	1168.32	2.22	0.014	0.008
1491	39	M	35	112	3	9.29	119.04	0.23	0.002	0.001
1663	38	M	240	151	3	63.6	1057.02	2.01	0.013	0.008
424	58	M	240	150.5	3	63.6	1053.84	2.00	0.010	0.007
674	19	M	240	289	3	63.6	1934.68	3.68	0.037	0.019
674	20	M	240	289	3	63.6	1934.68	3.68	0.036	0.019
1011	20	M	270	160.8	3	71.82	965.26	1.83	0.018	0.009
1011	20	M	270	160.8	3	71.82	1172.10	2.23	0.022	0.011
1798	39	M	70	151.5	3	18.57	318.87	0.61	0.004	0.002
1798	39	M	240	152	3	63.6	1063.38	2.02	0.013	0.008
1814	58	M	240	162.5	3	63.6	1130.16	2.15	0.011	0.007
1814	58	M	240	162.5	3	63.6	1130.16	2.15	0.011	0.007
1245	18	M	35	95.5	3	9.29	103.72	0.20	0.002	0.001
1262	70	M	33	174	3	4.21	116.56	0.22	0.001	0.001
1148	28	F	240	344	3	63.4	2279.85	4.33	0.051	0.025
1148	28	F	240	344	3	63.4	2279.85	4.33	0.051	0.025
1851	63	M	240	161	3	63.6	1120.62	2.13	0.095	0.006
1851	63	M	240	161	3	63.6	1120.62	2.13	0.095	0.006

1857	35	M	220	175	3	58.54	1110.51	2.11	0.014	0.008
1857	35	M	220	175	3	58.54	1110.51	2.11	0.014	0.008
1856	39	M	240	164	3	63.6	1139.70	2.17	0.014	0.008
1856	39	M	240	164	3	63.6	1139.70	2.17	0.014	0.008
780	47	M	35	240.5	3	9.29	238.37	0.45	0.003	0.002
780	48	M	35	240.5	3	9.29	238.37	0.45	0.003	0.002
1719	69	F	240	171.5	3	63.6	1187.40	2.26	0.096	0.007
1719	69	F	240	171.5	3	63.6	1187.40	2.26	0.096	0.007
1417	24	M	35	297.5	3	9.29	290.83	0.55	0.047	0.003
1417	24	M	35	297.5	3	9.29	291.30	0.55	0.047	0.003
1753	50	F	114	166	3	63.6	1152.42	2.19	0.016	0.010
1011	20	M	240	149.5	3	63.6	1047.48	1.99	0.019	0.010
774	64	F	240	165	3	63.6	1146.06	2.18	0.011	0.008
774	64	F	240	165	3	63.6	1146.06	2.18	0.011	0.008
1948	55	F	240	147.5	3	63.6	1034.76	1.97	0.013	0.009
1948	55	F	240	151.5	3	63.6	1060.20	2.01	0.013	0.009
1944	64	F	240	167	3	63.6	1158.78	2.20	0.011	0.008
1944	64	F	240	160	3	63.6	1114.26	2.12	0.011	0.008
1954	68	F	240	177.5	3	63.6	1225.55	2.33	0.010	0.008
1790	68	M	240	149	3	63.6	1044.30	1.98	0.007	0.005
1790	68	M	240	149	3	63.6	1044.30	1.98	0.007	0.005
1970	55	F	220	154	3	58.54	990.50	1.88	0.012	0.008
1970	55	F	220	173.7	3	58.54	1016.84	1.93	0.013	0.008
1974	39	F	220	154	3	58.54	990.50	1.88	0.017	0.010
1974	39	F	220	156.5	3	58.54	1005.13	1.91	0.017	0.010
2000	31	F	240	142	3	63.6	999.78	1.90	0.020	0.010
2000	31	F	240	142	3	63.6	999.78	1.90	0.020	0.010
2008	31	F	240	147	3	63.6	1031.58	1.96	0.021	0.011
2008	34	F	240	147.5	3	63.6	1034.76	1.97	0.020	0.010

1996	57	F	240	146	3	63.6	1025.22	1.95	0.012	0.008
1996	57	F	240	146.5	3	63.6	1028.40	1.95	0.012	0.008
693	72	M	240	148.5	3	63.6	1041.12	1.98	0.006	0.005
693	72	M	240	156	3	63.6	1088.82	2.07	0.006	0.005
2057	92	F	240	153	3	63.6	353.61	0.67	0.001	0.001
2057	92	F	240	154	3	63.6	1142.88	2.17	0.005	0.004
1417	24	M	220	329	3	58.54	2014.95	3.83	0.033	0.018
1417	24	M	220	329	3	52.82	1779.44	3.38	0.029	0.016
1176	26	F	240	149	3	63.6	1044.30	1.98	0.016	0.013
1176	26	F	240	152	3	63.6	1063.38	2.02	0.016	0.013
2144	62	F	240	154.5	3	63.6	1079.28	2.05	0.011	0.008
2144	62	F	240	200.5	3	63.6	1371.83	2.61	0.014	0.010
1790	68	M	220	156.5	3	58.54	1005.13	1.91	0.007	0.005
1790	68	M	220	156.5	3	58.54	1005.13	1.91	0.007	0.005
1790	68	M	220	156.5	3	58.54	1005.13	1.91	0.007	0.005
2178	57	F	240	158	3	63.6	1101.54	2.09	0.013	0.009
2178	57	F	240	152	3	63.6	1063.38	2.02	0.013	0.009
2173	63	F	240	177	3	63.6	1222.37	2.32	0.013	0.009
2173	63	F	240	171.5	3	63.6	1187.40	2.26	0.012	0.009
2212	45	M	240	149	3	63.6	1044.30	1.98	0.012	0.007
2212	45	M	240	149	3	63.6	1044.30	1.98	0.012	0.007
1519	34	F	240	151.5	3	63.6	1060.20	2.01	0.020	0.011
1519	34	F	240	147.5	3	63.6	1034.76	1.97	0.020	0.010
1801	70	M	35	97.5	3	9.29	105.58	0.20	0.004	0.001
2244	57	M	240	150	3	63.6	1050.66	2.00	0.010	0.007
2252	56	F	240	157	3	63.6	1095.18	2.08	0.013	0.009
2252	56	F	240	157	3	63.6	1095.18	2.08	0.013	0.009
2255	51	M	240	148	3	63.6	1037.94	1.97	0.011	0.007
2255	51	M	240	154	3	63.6	1076.10	2.04	0.012	0.007

2260	79	F	240	146.5	3	63.6	1028.40	1.95	0.005	0.004
780	48	M	240	332.5	3	63.6	2211.34	4.20	0.026	0.015
780	48	M	240	332.5	3	63	2211.34	4.20	0.026	0.015
2275	36	F	240	149	3	63.6	1044.30	1.98	0.019	0.010
2275	36	F	240	149	3	63.6	1044.30	1.98	0.019	0.010
2279	62	F	240	168	3	63.6	1165.14	2.21	0.012	0.009
2279	62	F	240	168	3	63.6	1165.14	2.21	0.012	0.009
2288	67	M	240	350.5	3	63.4	2321.06	4.41	0.017	0.012
2293	32	M	240	142	3	63.6	999.78	1.90	0.013	0.007
2293	32	M	240	142	3	63.6	999.78	1.90	0.013	0.007
2297	22	M	240	151.5	3	63.6	1060.20	2.01	0.018	0.010
2297	22	M	240	151	3	63.6	1057.02	2.01	0.018	0.010
	49.24		**217.47**	**176.41**	**3.03**	**57.48**	**1073.81**	**2.04**	**0.019**	**0.008**

Table A.2: Patient parameters of neck CT Examination at SGMC

Sweden Ghana Medical Centre Ltd, SGMC Data to be registrated to determine diagnostic standard doses for CT exams										
Patient ID	**Age (years)**	**Sex (M/F)**	**Tube charge per rotation (mAs)**	**Scan length (mm)**	**Nominal slice thickness (mm)**	**$CTDI_{vol}$ values (mGy)**	**DLP(mGycm)**	**Estimated Effective Dose (mSv)**	**LAR of Cancer Incidence (%)**	**LAR of Cancer Mortality (%)**
655	37	M	167	215.5	4	20.88	486.79	2.53	0.017	0.010
655	37	M	165	215.5	4	20.67	481.33	2.50	0.016	0.009
13	42	M	141	291.5	4	17.61	544.34	2.83	0.018	0.011
1246	30	F	132	200	3	16.52	357.15	1.86	0.020	0.010
1279	57	F	168	216.2	3	21.04	454.86	2.37	0.015	0.010
1380	32	F	180	223	3	22.44	536.80	2.79	0.029	0.015
1463	45	M	248	237	3	31	782.44	4.07	0.025	0.015
826	41	M	174	238	3	21.74	551.22	2.87	0.018	0.011
1481	32	M	167	187	3	20.88	424.34	2.21	0.015	0.084
1495	44	F	206	200	3	25.75	538.69	2.80	0.023	0.014
1518	26	M	150	250.5	3	18.7	498.76	2.59	0.021	0.012
1497	64	F	116	218	3	14.49	339.44	1.77	0.009	0.007
1546	58	F	152	200	3	19.01	411.06	2.14	0.013	0.009
1663	38	M	98	247.5	3	12.31	324.66	1.69	0.011	0.006
1614	52	M	192	258	3	24	657.60	3.42	0.020	0.012
1148	28	F	100	263.7	3	12.47	328.77	1.71	0.020	0.097
1655	43	F	80	268	3	9.97	243.57	1.27	0.011	0.006
1148	28	F	103	213	3	12.94	296.47	1.54	0.018	0.006
1148	28	F	103	213	3	12.94	296.47	1.54	0.018	0.006
1801	70	M	307	233.5	3	38.26	953.16	4.96	0.020	0.016
1801	70	M	287	233.5	3	36.32	901.72	4.69	0.019	0.015
	42.95		**163.62**	**229.64**	**3.14**	**20.47**	**495.70**	**2.58**	**0.018**	**0.018**

Table A.3: Patient parameters of chest CT Examination at SGMC

Sweden Ghana Medical Centre Ltd, SGMC Data to be registrated to determine diagnostic standard doses for CT exams										
Patient ID	**Age (years)**	**Sex (M/F)**	**Tube charge per rotation (mAs)**	**Scan length (mm)**	**Nominal slice thickness (mm)**	**$CTDI_{vol}$ values (mGy)**	**DLP(mGycm)**	**Estimated Effective Dose (mSv)**	**LAR of Cancer Incidence (%)**	**LAR of Cancer Mortality (%)**
408	45	M	46	417.5	4	5.19	232.76	3.40	0.021	0.013
424	57	M	70	215.5	4	8.7	202.36	2.95	0.015	0.010
575	48	F	86	394	4	10.85	446.02	6.51	0.050	0.031
581	65	F	38	387	4	4.77	192.76	2.81	0.014	0.010
535	52	F	56	384	4	7.01	281.36	4.11	0.029	0.019
390	35	F	26	390	4	3.37	137.07	2.00	0.020	0.010
579	59	F	81	388	4	10.19	412.99	6.03	0.036	0.025
600	46	F	35	426	4	4.39	194.78	2.84	0.023	0.014
609	35	F	30	431	4	3.74	167.64	2.45	0.024	0.013
629	72	F	68	383	4	8.6	344.28	5.03	0.019	0.015
635	54	F	42	343.5	4	5.33	192.25	2.81	0.019	0.012
597	53	M	41	446	4	5.14	238.22	3.48	0.019	0.023
655	37	M	42	456	4	5.33	252.21	3.68	0.024	0.014
671	48	F	30	475	4	3.83	188.70	2.76	0.021	0.013
675	44	F	51	420	4	6.45	282.08	4.12	0.034	0.020
361	61	F	35	404	4	4.39	185.11	2.70	0.015	0.011
674	19	M	31	440	4	3.93	179.55	2.62	0.027	0.014
685	41	F	64	399	4	7.21	309.54	4.52	0.039	0.023
695	72	M	53	446	4	6.64	307.52	4.49	0.014	0.010
697	54	M	39	489	4	4.96	250.86	3.66	0.020	0.013
661	52	M	41	503	4	5.14	267.53	3.91	0.022	0.014
699	51	F	114	434	4	14.21	641.29	9.36	0.068	0.043
424	57	M	67	506	4	8.42	440.30	6.43	0.033	0.021
714	51	F	68	491	4	8.6	437.18	6.38	0.046	0.030
751	45	F	85	390	4	9.55	398.86	5.82	0.047	0.028
19	62	M	73	367.5	4	8.21	324.40	4.74	0.022	0.014
765	41	M	79	512	4	8.88	368.64	5.38	0.035	0.020
329	54	F	42	734.1	4	4.78	163.61	2.39	0.016	0.011
791	68	F	88	366	3	11.03	423.70	6.19	0.027	0.021
802	42	F	87	325	3	10.94	373.06	5.45	0.047	0.027
820	75	M	34	395	3	4.3	169.90	2.48	0.006	0.005
825	61	M	58	401.5	3	7.79	304.50	4.45	0.021	0.014

793	60	M	63	378	3	7.95	313.15	4.57	0.022	0.015
714	51	F	72	352	3	9.07	333.78	4.87	0.035	0.023
850	62	M	39	369	3	4.96	190.80	2.79	0.013	0.009
864	56	F	57	389	3	7.2	291.60	4.26	0.028	0.018
674	19	M	37	310.5	3	4.68	144.00	2.10	0.021	0.011
891	60	M	31	462	3	3.39	122.14	1.78	0.008	0.006
899	74	F	67	257.5	3	8.42	229.32	3.35	0.011	0.009
424	57	M	70	378	3	8.88	349.99	5.11	0.027	0.017
919	70	F	43	255	3	5.42	138.30	2.02	0.008	0.006
932	40	F	104	267	3	13	367.83	5.37	0.048	0.027
932	40	F	104	267	3	13	367.83	5.37	0.048	0.027
793	60	M	61	381	3	7.67	292.13	4.27	0.021	0.014
826	40	M	67	387.5	3	8.42	326.10	4.76	0.031	0.018
544	50	F	90	279.5	3	11.31	334.34	4.88	0.036	0.023
968	70	F	80	299	3	8.96	295.47	4.31	0.032	0.014
981	76	F	108	271	3	12.15	366.40	5.35	0.016	0.013
969	70	F	70	296	3	8.04	262.69	3.84	0.016	0.012
983	47	M	70	288.5	3	8.04	256.65	3.75	0.023	0.014
1002	74	F	70	275	3	8.88	258.50	3.77	0.012	0.010
999	68	F	33	269.5	3	4.21	120.13	1.75	0.008	0.006
3	67	M	63	331	3	7.95	275.80	4.03	0.016	0.011
1024	60	F	51	287	3	6.45	195.49	2.85	0.017	0.012
714	51	F	100	329.5	3	12.53	432.91	6.32	0.046	0.029
1061	48	F	35	330	3	4.39	152.06	2.22	0.017	0.009
575	49	F	75	379	3	9.44	373.04	5.45	0.041	0.026
556	49	F	63	378	3	7.95	313.15	4.57	0.035	0.022
810	49	M	52	343	3	6.55	234.98	3.43	0.020	0.012
43	53	F	46	439.5	3	5.8	264.07	3.86	0.027	0.017
983	47	M	73	421	3	9.16	385.79	5.63	0.034	0.021
1151	28	M	59	353	3	7.39	272.58	3.98	0.030	0.016
928	58	F	41	296.5	3	5.14	160.71	2.35	0.014	0.010
1170	44	F	96	378	3	12.06	475.25	6.94	0.057	0.034
1180	52	F	62	385	3	6.95	289.00	4.22	0.030	0.019
424	58	M	76	535	3	9.54	348.12	5.08	0.026	0.017
812	40	F	42	275.5	3	5.24	152.64	2.23	0.020	0.011
1181	55	F	55	456	3	6.92	326.60	4.77	0.032	0.021
255	56	F	142	330.5	3	17.92	619.37	9.04	0.059	0.039
1229	55	F	116	281.5	3	14.49	431.18	6.30	0.042	0.028
1275	50	M	48	273	3	5.45	165.34	2.41	0.014	0.009
1334	56	F	70	341.5	3	8.88	317.57	4.64	0.030	0.020
1106	59	M	62	435	3	7.85	354.24	5.17	0.026	0.017

1058	28	M	43	278	3	5.42	159.45	2.33	0.017	0.009
834	46	M	59	352	3	7.39	271.84	3.97	0.024	0.015
1392	60	F	51	276.5	3	6.45	188.72	2.76	0.016	0.011
1400	52	F	42	280	3	5.33	157.76	2.30	0.016	0.009
1071	45	M	33	357	3	4.21	152.74	2.23	0.014	0.008
1078	26	M	31	329	3	3.93	135.49	1.98	0.016	0.009
1001	43	F	72	329.5	3	9.07	313.37	4.58	0.039	0.023
780	47	M	70	425	3	7.01	298.05	4.35	0.026	0.016
1065	45	F	111	337	3	13.93	491.82	7.18	0.058	0.035
1455	53	M	48	390	3	6.08	246.76	3.60	0.020	0.013
161	53	F	86	394	3	10.85	427.39	6.24	0.043	0.028
1471	48	F	47	390	3	5.89	239.17	3.49	0.027	0.017
1262	70	M	47	417	3	5.89	255.08	3.72	0.013	0.009
864	57	F	55	327	3	6.92	237.34	3.47	0.022	0.015
1613	57	F	35	405	3	4.39	185.02	2.70	0.017	0.012
1103	37	F	45	290.5	3	5.7	174.82	2.55	0.016	0.013
1367	62	F	53	354	3	6.73	249.44	3.64	0.020	0.014
1727	29	M	41	453	3	5.14	241.20	3.52	0.025	0.014
1714	36	F	48	411	3	6.08	259.53	3.79	0.036	0.020
1714	36	F	48	411	3	6.08	259.53	3.79	0.036	0.020
1551	26	F	45	419	3	5.61	244.05	3.56	0.046	0.022
1551	26	F	45	419	3	5.61	244.05	3.56	0.046	0.022
1495	44	F	120	221.5	3	15.35	362.05	5.29	0.044	0.026
1782	19	F	63	639	3	7.95	520.60	7.60	0.131	0.060
1782	19	F	63	639	3	7.95	520.60	7.60	0.131	0.060
1245	18	M	30	429.5	3	3.83	164.66	2.40	0.025	0.013
1245	18	M	30	451	3	3.83	179.04	2.61	0.028	0.014
1818	56	F	50	424	3	6.36	279.77	4.08	0.026	0.018
1818	56	F	52	424	3	6.55	288.00	4.20	0.027	0.018
1832	45	M	70	359	3	8.98	336.62	4.91	0.030	0.018
1262	70	M	40	320.5	3	5.05	169.91	2.48	0.009	0.006
1262	70	M	40	320.5	3	5.05	169.91	2.48	0.009	0.006
897	46	F	33	261	3	4.21	116.56	1.70	0.014	0.008
912	67	M	30	610	3	3.83	239.99	3.50	0.014	0.009
912	67	M	30	610	3	3.83	239.99	3.50	0.014	0.009
1840	57	F	53	611.5	3	6.73	422.46	6.17	0.039	0.026
1840	57	F	52	611.5	3	6.55	410.73	6.00	0.038	0.026
1840	57	F	44	291.5	3	5.52	160.82	2.35	0.015	0.010
1334	56	F	70	252	3	8.98	240.57	3.51	0.023	0.015
1689	47	F	59	435	3	7.39	333.15	4.86	0.038	0.023
1689	47	F	59	435	3	7.39	333.15	4.86	0.038	0.023

897	46	F	57	356.5	3	7.2	268.20	3.92	0.031	0.019
1878	69	F	86	293	3	10.85	335.17	4.89	0.021	0.016
1836	82	F	155	266	3	19.24	541.84	7.91	0.017	0.015
1787	33	F	606	378	3	7.48	294.73	4.30	0.044	0.023
1787	34	F	60	378	3	7.48	294.73	4.30	0.043	0.023
810	49	M	53	378	3	6.64	261.58	3.82	0.023	0.014
810	50	M	54	378	3	6.83	268.94	3.93	0.023	0.014
463	39	F	49	419	3	6.17	268.46	3.92	0.035	0.020
463	39	F	49	419	3	6.17	268.46	3.92	0.035	0.020
1760	29	M	45	345	3	5.61	202.54	2.96	0.021	0.012
1176	26	F	32	456	3	4.11	194.19	2.84	0.037	0.018
1176	26	F	32	456	3	4.11	194.19	2.84	0.037	0.018
1929	46	F	62	378	3	7.85	309.47	4.52	0.035	0.022
1929	46	F	62	378	3	7.85	309.47	4.52	0.035	0.022
1925	65	F	51	433	3	6.45	289.69	4.23	0.021	0.015
1909	65	F	43	447	3	5.42	251.10	3.67	0.018	0.013
1909	65	F	44	447	3	5.52	255.43	3.73	0.019	0.014
1934	76	F	38	424.5	3	4.77	210.07	3.07	0.009	0.007
1934	76	F	37	424.5	3	4.68	205.95	3.01	0.009	0.007
463	39	F	50	411	3	6.26	267.51	3.91	0.035	0.020
463	39	F	50	411	3	6.26	267.51	3.91	0.035	0.020
1975	19	F	39	493	3	4.96	252.25	3.68	0.064	0.029
1975	19	F	39	492	3	4.96	251.76	3.68	0.064	0.029
744	22	F	52	378	3	6.55	257.89	3.77	0.058	0.027
744	24	F	51	378	3	6.45	254.21	3.71	0.052	0.025
1495	44	F	123	480	3	15.43	765.26	11.17	0.092	0.055
1495	44	F	121	480	3	15.15	751.35	10.97	0.091	0.054
1986	36	M	90	579	3	11.22	670.56	9.79	0.065	0.037
1986	36	M	90	579	3	11.22	670.56	9.79	0.065	0.037
1991	75	M	65	443	3	8.23	377.69	5.51	0.014	0.011
1991	75	M	65	443	3	8.23	377.69	5.51	0.014	0.011
1727	29	M	40	429.5	3	5.05	224.95	3.28	0.023	0.013
1727	29	M	41	390.5	3	5.14	209.06	3.05	0.022	0.012
509	70	M	94	427.5	3	11.78	522.52	7.63	0.026	0.019
2008	34	F	240	443.5	3	10.01	459.74	6.71	0.067	0.035
2008	34	F	240	443.5	3	10.01	459.74	6.71	0.067	0.035
2010	25	F	63	448	3	7.95	368.79	5.38	0.073	0.035
2010	25	F	63	448	3	7.95	368.79	5.38	0.073	0.035
1996	57	F	70	479	3	8.98	444.34	6.49	0.041	0.028
1996	57	F	70	508	3	8.98	470.37	6.87	0.043	0.029
2042	44	F	94	395.5	3	11.78	484.82	7.08	0.059	0.035

2042	44	F	94	395.5	3	11.78	484.82	7.08	0.059	0.035
2035	59	F	39	378	3	4.96	195.26	2.85	0.017	0.012
2035	59	F	38	378	3	4.77	187.89	2.74	0.016	0.011
1787	33	F	53	322.5	3	6.73	227.89	3.33	0.034	0.018
1787	34	F	53	322.5	3	6.73	227.89	3.33	0.033	0.018
1367	62	F	57	304	3	7.11	227.41	3.32	0.018	0.013
1367	78	F	57	304	3	7.11	227.41	3.32	0.008	0.007
2011	68	F	42	318	3	5.33	178.02	2.60	0.012	0.009
1843	49	F	39	461	3	4.86	231.93	3.39	0.026	0.016
1843	49	F	39	490	3	4.86	246.03	3.59	0.027	0.017
1843	49	F	35	183	3	4.39	87.46	1.28	0.010	0.006
1176	26	F	34	377	3	4.3	169.04	2.47	0.032	0.016
1176	26	F	32	380.5	3	4.11	163.13	2.38	0.031	0.015
2101	53	F	118	473	3	14.77	722.45	10.55	0.073	0.048
2101	53	F	118	473	3	14.77	722.45	10.55	0.073	0.048
2122	52	M	50	337.5	3	6.36	200.93	2.93	0.017	0.010
2122	52	M	48	337.5	3	6.08	214.85	3.14	0.018	0.011
2121	38	F	34	479	3	4.3	212.91	3.11	0.029	0.016
2121	38	F	34	479	3	4.3	212.91	3.11	0.029	0.016
2132	41	F	64	396	3	8.04	331.31	4.84	0.042	0.024
2132	41	F	64	396	3	8.04	331.31	4.84	0.042	0.024
1944	64	F	77	378	3	9.63	379.47	5.54	0.029	0.021
1944	64	F	75	378	3	9.35	368.42	5.38	0.028	0.020
2142	42	F	86	421	3	10.75	474.22	6.92	0.059	0.035
2142	42	F	86	421	3	10.75	469.91	6.86	0.059	0.034
2111	59	F	39	372	3	4.96	192.29	2.81	0.017	0.012
2111	59	F	39	372	3	4.96	192.29	2.81	0.017	0.012
2144	62	F	47	547	3	5.98	336.92	4.92	0.027	0.019
2144	62	F	47	551	3	5.89	334.01	4.88	0.027	0.019
2143	75	M	38	432.5	3	4.77	213.88	3.12	0.008	0.006
2147	75	F	72	344	3	9.07	326.52	4.77	0.015	0.012
2148	69	F	84	384.5	3	10.47	419.43	6.12	0.026	0.020
2148	69	F	84	384.5	3	9.38	389.51	5.69	0.024	0.019
2152	50	F	32	397	3	4.11	169.92	2.48	0.018	0.012
2152	50	F	32	397	3	4.11	169.92	2.48	0.018	0.012
2150	35	F	70	419	3	8.88	386.42	5.64	0.055	0.030
2150	35	F	70	419	3	8.88	386.42	5.64	0.055	0.030
2154	69	F	62	425	3	7.85	346.78	5.06	0.022	0.017
1103	37	F	46	414.5	3	5.8	249.58	3.64	0.034	0.019
1103	37	F	46	414.5	3	5.8	249.58	3.64	0.034	0.019
363	49	M	41	476.5	3	5.14	253.29	3.70	0.022	0.013

2168	55	F	47	415.5	3	5.98	258.23	3.77	0.025	0.017
2168	55	F	47	415.5	3	5.98	258.23	3.77	0.025	0.017
2178	57	F	58	397	3	7.29	301.22	4.40	0.028	0.019
2178	57	F	58	397	3	7.29	301.22	4.40	0.028	0.019
1925	90	M	58	386	3	7.29	293.20	4.28	0.007	0.007
1660	55	F	35	378	3	4.39	173.16	2.53	0.017	0.011
1660	55	F	35	378	3	4.39	173.16	2.53	0.017	0.011
2182	48	F	66	452.5	3	8.32	389.89	5.69	0.044	0.027
2190	51	M	35	440	3	4.39	200.40	2.93	0.017	0.010
2190	51	M	33	493	3	4.21	214.18	3.13	0.018	0.011
2191	76	F	39	409.5	3	4.36	191.74	2.80	0.008	0.007
2191	76	F	37	409.5	3	4.68	198.93	2.90	0.008	0.007
2173	63	F	35	447.5	3	4.49	208.03	3.04	0.016	0.012
2173	63	F	35	447.5	3	4.49	208.03	3.04	0.016	0.012
2052	45	F	50	410	3	6.26	266.89	3.90	0.032	0.019
2052	45	F	50	410	3	6.26	266.89	3.90	0.032	0.019
1924	51	F	95	426	3	11.88	254.89	3.72	0.027	0.017
1924	51	F	95	426	3	10.64	525.21	7.67	0.056	0.036
1882	44	F	41	418.5	3	5.14	223.46	3.26	0.027	0.016
1882	44	F	41	430	3	5.14	229.37	3.35	0.028	0.016
509	70	M	67	433	3	8.42	377.86	5.52	0.019	0.014
509	70	M	67	433	3	8.42	377.86	5.52	0.019	0.014
2218	40	F	63	395.5	3	7.95	327.06	4.78	0.042	0.024
2218	40	F	63	394	3	7.95	325.87	4.76	0.042	0.024
897	46	F	31	416.5	3	3.93	169.85	2.48	0.020	0.012
897	46	F	32	416.5	3	3.6	161.07	2.35	0.019	0.011
1519	34	F	46	436.5	3	5.8	262.33	3.83	0.038	0.020
1519	34	F	46	436.5	3	5.8	262.33	3.83	0.038	0.020
2222	30	F	50	442	3	6.36	291.22	4.25	0.045	0.023
2222	30	F	52	442	3	6.55	299.78	4.38	0.047	0.024
1548	35	M	59	478	3	7.39	364.92	5.33	0.036	0.020
1548	35	M	59	478	3	7.39	364.92	5.33	0.036	0.020
2227	28	F	47	492	3	5.98	275.88	4.03	0.048	0.024
2227	28	F	50	492	3	4.07	206.73	3.02	0.036	0.018
2229	39	F	82	440	3	10.29	469.03	6.85	0.062	0.035
2229	39	F	82	440	3	10.29	469.03	6.85	0.062	0.035
2224	19	F	53	418	3	6.73	292.19	4.27	0.074	0.034
2224	19	F	53	418	3	6.73	292.19	4.27	0.074	0.034
812	40	F	41	507	3	5.14	268.97	3.93	0.035	0.020
812	40	F	40	562	3	5.05	291.85	4.26	0.038	0.022
2233	28	F	51	477.5	3	6.45	318.40	4.65	0.055	0.027

2233	28	F	53	477.5	3	6.64	327.63	4.78	0.057	0.028
754	66	F	70	409.5	3	8.88	377.98	5.52	0.026	0.020
754	66	F	707	409.5	3	8.88	377.98	5.52	0.026	0.020
2270	52	F	39	498	3	4.96	246.80	3.60	0.026	0.016
2270	52	F	39	498	3	4.96	246.80	3.60	0.026	0.016
2277	58	F	50	457	3	6.36	300.75	4.39	0.027	0.018
2277	58	F	50	457	3	6.36	300.75	4.39	0.027	0.018
2280	28	F	48	438	3	6.08	275.94	4.03	0.048	0.024
2280	28	F	47	465	3	5.89	283.35	4.14	0.049	0.024
981	76	F	84	426	3	10.47	462.89	6.76	0.020	0.016
1936	28	M	41	440	3	5.14	234.51	3.42	0.025	0.014
1936	28	M	40	509.5	3	5.05	265.34	3.87	0.029	0.016
2142	65	F	67	431	3	8.42	376.18	5.49	0.027	0.020
2142	65	F	67	431	3	8.42	376.18	5.49	0.027	0.020
2130	22	M	38	447	3	4.77	220.80	3.22	0.030	0.016
2130	22	M	38	576	3	4.77	253.70	3.70	0.034	0.018
1189	44	F	62	444	3	7.85	361.31	5.28	0.044	0.026
1189	44	F	65	444	3	8.14	374.21	5.46	0.045	0.027
2286	54	F	133	455	3	16.64	783.94	11.45	0.078	0.051
2286	54	F	130	455	3	16.27	766.32	11.19	0.076	0.050
2096	29	F	104	388	3	13	525.09	7.67	0.086	0.043
2096	29	F	96	445	3	12.06	556.07	8.12	0.091	0.046
1566	19	F	72	425	3	9.07	399.99	5.84	0.101	0.046
1566	19	F	72	425	3	9.07	399.99	5.84	0.101	0.046
1476	28	M	80	430	3	10.1	450.40	6.58	0.049	0.027
1476	28	M	80	430	3	10.1	450.40	6.58	0.049	0.027
	48.44		**64.57**	**407.88**	**3.11**	**7.34**	**305.13**	**4.45**	**0.033**	**0.020**

Table A.4: Patient parameters of abdomen CT Examination at SGMC

Sweden Ghana Medical Centre Ltd, SGMC Data to be registrated to determine diagnostic standard doses for CT exams										
Patient ID	**Age (years)**	**Sex (M/F)**	**Tube charge per rotation (mAs)**	**Scan length (mm)**	**Nominal slice thickness (mm)**	**$CTDI_{vol}$ values (mGy)**	**DLP(mGycm)**	**Estimated Effective Dose (mSv)**	**LAR of Cancer Incidence (%)**	**LAR of Cancer Mortality (%)**
352	65	M	66	440	4	8.32	380.49	5.82	0.024	0.017
45	57	F	126	450	4	15.72	735.25	11.25	0.071	0.048
576	60	F	52	398	4	6.55	271.77	4.16	0.024	0.017
363	49	M	49	519	4	6.17	330.91	5.06	0.030	0.018
500	62	F	46	578	4	5.8	345.06	5.28	0.029	0.021
599	71	M	32	451	4	4.11	192.63	2.95	0.010	0.007
616	81	M	60	484.5	4	7.48	375.30	5.74	0.010	0.009
623	44	M	65	504	4	8.14	424.00	6.49	0.041	0.024
245	33	F	135	446.3	4	16.98	896.84	13.72	0.139	0.073
245	33	F	135	425.7	4	16.98	849.29	12.99	0.131	0.069
638	57	M	48	474	4	6.08	298.55	4.57	0.024	0.015
3	66	M	61	466	4	7.67	370.50	5.67	0.023	0.016
377	46	M	90	555	4	11.31	647.40	9.91	0.061	0.036
689	48	M	60	504	4	7.57	394.76	6.04	0.036	0.022
691	78	M	53	504	4	6.73	357.29	5.47	0.011	0.009
159	26	M	48	487	4	6.08	306.45	4.69	0.038	0.020
715	45	F	101	496	4	12.72	652.63	9.99	0.081	0.049
718	59	F	113	498	4	14.12	727.44	11.13	0.067	0.046
726	67	F	82	494	4	10.29	525.80	8.04	0.037	0.028
731	71	M	125	546	4	15.62	879.47	13.46	0.044	0.032
673	64	F	56	425	4	7.01	310.11	4.74	0.024	0.018
741	57	M	80	516	4	10.01	533.48	8.16	0.042	0.027
690	46	M	63	617.6	4	7.12	363.62	5.56	0.034	0.020
744	22	F	71	431	4	8.98	402.33	6.16	0.094	0.044
371	53	M	47	514	4	5.28	287.45	4.40	0.025	0.015
734	24	F	62	531	4	7.76	425.46	6.51	0.092	0.044
45	57	F	123	581.4	4	13.82	725.90	11.11	0.070	0.047
762	62	F	76	703.3	4	8.55	383.36	5.87	0.032	0.023
764	64	F	62	578.7	4	7.04	372.01	5.69	0.029	0.021
765	41	M	120	560	4	13.57	797.53	12.20	0.078	0.046
763	61	F	68	641	4	8.6	441.49	6.75	0.038	0.027

352	66	M	75	448.5	3	9.35	433.40	6.63	0.027	0.018
790	62	F	62	464	3	7.85	377.02	5.77	0.032	0.023
363	49	M	69	636	3	8.7	566.99	8.67	0.052	0.031
812	40	F	54	613.2	3	6.83	282.60	4.32	0.038	0.022
584	56	F	57	505	3	7.2	363.60	5.56	0.036	0.024
3	67	M	65	556	3	8.14	465.33	7.12	0.028	0.019
805	52	F	45	478	3	5.61	268.18	4.10	0.029	0.019
861	79	F	47	368	3	5.89	226.21	3.46	0.014	0.011
408	46	M	70	477	3	8.79	433.33	6.63	0.041	0.024
681	21	F	43	422	3	5.42	237.54	3.63	0.058	0.027
552	49	M	65	510	3	8.23	432.82	6.62	0.040	0.024
734	25	F	50	459	3	6.26	297.58	4.55	0.062	0.030
980	31	M	116	451	3	14.59	681.21	10.42	0.071	0.040
1052	32	F	94	454	3	11.78	553.74	8.47	0.087	0.045
352	66	M	76	461.5	3	9.54	455.42	6.97	0.028	0.019
1079	78	M	45	475	3	5.7	280.06	4.28	0.009	0.007
763	61	F	68	442.5	3	8.51	390.14	5.97	0.034	0.024
1195	55	F	57	507	3	7.11	371.67	5.69	0.038	0.025
363	77	M	71	499	3	8.98	462.30	7.07	0.016	0.013
808	30	F	50	516	3	6.26	333.29	5.10	0.054	0.028
1303	49	F	53	502	3	6.64	343.90	5.26	0.040	0.025
740	56	F	46	460	3	5.8	275.96	4.22	0.027	0.018
992	57	F	113	521	3	14.12	758.22	11.60	0.073	0.050
1372	37	F	85	509	3	10.66	559.63	8.56	0.080	0.044
1368	34	M	69	526	3	8.7	471.33	7.21	0.048	0.027
897	45	F	61	451	3	7.67	358.07	5.48	0.045	0.027
1386	57	F	70	454	3	8.79	413.11	6.32	0.040	0.027
1028	61	F	93	508	3	11.69	612.47	9.37	0.053	0.037
1501	49	F	71	576.5	3	8.98	531.86	8.14	0.061	0.038
1507	54	M	32	666.5	3	4.11	280.80	4.30	0.024	0.015
1536	53	F	87	603	3	10.94	677.20	10.36	0.072	0.047
992	57	F	134	448.5	3	16.74	777.47	11.90	0.075	0.051
983	48	M	113	726	3	14.12	1047.67	16.03	0.097	0.058
709	52	F	53	600	3	6.73	414.70	6.34	0.045	0.029
1058	28	M	56	492	3	7.01	356.26	5.45	0.041	0.022
363	50	M	72	525	3	9.07	490.69	7.51	0.044	0.027
1029	54	F	48	395.5	3	6.08	250.11	3.83	0.026	0.017
1694	26	F	95	750	3	11.88	909.65	13.92	0.181	0.088
1701	49	M	55	493	3	6.92	352.20	5.39	0.032	0.019
162	52	F	58	471	3	7.29	355.19	5.43	0.039	0.025
1715	36	M	120	513	3	10.85	573.80	8.78	0.058	0.033

1722	47	F	95	468.5	3	11.88	575.36	8.80	0.069	0.042
1376	56	F	137	459	3	17.2	817.00	12.50	0.081	0.054
1726	38	M	62	692	3	7.76	549.48	8.41	0.055	0.032
1726	38	M	62	692	3	7.76	549.48	8.41	0.055	0.032
1028	62	F	75	526	3	9.35	491.84	7.53	0.041	0.029
1028	62	F	75	526	3	9.35	491.84	7.53	0.041	0.029
1028	62	F	65	245	3	8.14	199.31	3.05	0.017	0.012
1665	74	F	65	580.5	3	8.23	490.83	7.51	0.025	0.020
1665	74	F	68	652	3	8.51	568.41	8.70	0.029	0.023
1665	74	F	70	484	3	8.79	439.48	6.72	0.022	0.018
1753	21	F	129	667.5	3	16.08	1099.28	16.82	0.267	0.124
1753	21	F	120	667.5	3	15.05	1029.46	15.75	0.250	0.117
1753	21	F	94	266.5	3	11.82	332.94	5.09	0.081	0.038
1756	58	F	141	667	3	17.7	1208.91	18.50	0.114	0.078
1756	58	F	138	674	3	17.41	1200.17	18.36	0.113	0.077
1756	58	F	149	277.5	3	18.75	548.91	8.40	0.052	0.035
1522	68	F	86	446	3	10.75	496.80	7.60	0.034	0.025
1759	45	F	53	630	3	6.73	434.92	6.65	0.054	0.032
1760	29	M	46	671	3	5.8	398.28	6.09	0.044	0.024
1054	56	F	55	597	3	6.92	424.16	6.49	0.042	0.028
1054	57	M	55	597	3	6.92	424.16	6.49	0.034	0.022
1054	57	F	48	219	3	6.08	142.83	2.19	0.014	0.009
763	61	F	74	618	3	9.26	586.90	8.98	0.051	0.036
763	62	F	74	618	3	9.26	586.90	8.98	0.049	0.035
1495	44	F	136	697	3	17.19	1224.41	18.73	0.155	0.092
1495	45	F	140	528	3	17.55	953.67	14.59	0.119	0.071
1495	45	F	127	298	3	16.11	503.13	7.70	0.063	0.038
1012	67	F	38	612	3	4.77	299.48	4.58	0.021	0.016
1012	67	F	38	612	3	4.77	299.48	4.58	0.021	0.016
1236	46	F	68	660	3	8.51	575.21	8.80	0.070	0.043
1236	46	F	68	721	3	8.15	627.12	9.59	0.077	0.046
1236	46	F	60	562	3	7.57	437.78	6.70	0.053	0.032
991	75	F	116	585	3	14.49	871.06	13.33	0.042	0.034
991	75	F	116	585	3	14.49	871.06	13.33	0.042	0.034
991	75	F	107	238.5	3	13.37	340.30	5.21	0.016	0.013
1787	34	F	92	606	3	11.5	715.38	10.95	0.109	0.058
1787	34	F	94	606	3	11.78	732.83	11.21	0.111	0.059
1787	34	F	79	249	3	9.91	262.66	4.02	0.040	0.021
1786	51	M	76	693.5	3	9.54	676.70	10.35	0.060	0.037
1786	51	M	76	693.5	3	9.54	676.70	10.35	0.060	0.037
1786	51	M	69	318.5	3	8.7	290.88	4.45	0.026	0.016

1809	42	F	91	678.5	3	11.41	792.27	12.12	0.104	0.061
1809	42	F	91	678.5	3	11.41	792.27	12.12	0.104	0.061
1809	42	F	71	287	3	8.98	271.99	4.16	0.036	0.021
1811	22	F	90	622.5	3	11.22	716.45	10.96	0.168	0.079
1811	22	F	90	622.5	3	11.22	716.45	10.96	0.168	0.079
1811	22	F	76	265.5	3	9.54	268.49	4.11	0.063	0.029
930	69	M	78	657	3	9.72	654.47	10.01	0.036	0.026
930	69	M	78	657	3	9.72	654.47	10.01	0.036	0.026
930	69	M	68	257	3	8.51	232.30	3.55	0.013	0.009
1818	56	F	57	229.5	3	7.2	176.76	2.70	0.018	0.012
1711	38	F	116	658	3	14.59	939.40	14.37	0.132	0.074
1711	38	F	116	658	3	14.59	939.40	14.37	0.132	0.074
1711	38	F	107	274	3	13.37	387.77	5.93	0.055	0.030
1830	43	F	103	694	3	12.9	916.18	14.02	0.118	0.069
1830	43	F	103	694	3	12.9	916.18	14.02	0.118	0.069
1838	34	F	69	650	3	8.7	579.16	8.86	0.088	0.047
1838	34	F	69	650	3	8.7	579.16	8.86	0.088	0.047
1838	34	F	53	242	3	6.73	173.70	2.66	0.026	0.014
912	67	M	29	250	3	3.65	91.17	1.39	0.005	0.004
774	64	F	69	600.5	3	8.7	522.20	7.99	0.041	0.030
774	64	F	69	600.5	3	8.7	522.20	7.99	0.041	0.030
774	64	F	60	259.5	3	7.48	194.12	2.97	0.015	0.011
363	49	M	68	497	3	8.6	441.31	6.75	0.040	0.024
363	50	M	71	497	3	8.88	455.70	6.97	0.041	0.025
1334	56	F	78	175	3	8.8	180.87	2.77	0.018	0.012
1334	56	F	92	384	3	11.59	463.79	7.10	0.046	0.031
1833	30	F	86	522	3	10.85	583.56	8.93	0.095	0.048
1833	30	F	86	522	3	10.85	583.56	8.93	0.095	0.048
1833	30	F	75	281	3	9.44	280.49	4.29	0.046	0.023
1732	28	M	85	506	3	10.66	556.44	8.51	0.063	0.035
1732	28	M	86	506	3	10.75	561.32	8.59	0.064	0.035
1732	28	M	84	267	3	10.57	299.02	4.58	0.034	0.019
1854	22	F	77	474	3	9.63	471.93	7.22	0.110	0.052
1854	22	F	75	474	3	9.44	462.76	7.08	0.108	0.051
1864	69	F	84	457	3	10.47	495.36	7.58	0.032	0.025
1864	69	F	84	457	3	10.47	495.36	7.58	0.032	0.025
1863	53	F	45	578	3	5.7	338.81	5.18	0.036	0.023
162	52	F	57	424	3	7.11	312.69	4.78	0.034	0.022
1870	48	F	41	577	3	5.14	304.97	4.67	0.036	0.022
1870	48	F	41	577	3	5.14	304.97	4.67	0.036	0.022
1870	48	F	34	272	3	4.3	123.88	1.90	0.015	0.009

1878	69	F	134	1283.9	3	16.74	1215.16	18.59	0.079	0.061
1878	69	F	123	520	3	15.27	817.81	12.51	0.053	0.041
1697	59	F	65	398	3	8.14	336.76	5.15	0.031	0.021
1697	59	F	65	398	3	8.14	336.76	5.15	0.031	0.021
1836	82	F	131	682	3	16.36	1142.18	17.48	0.037	0.033
1836	82	F	117	474	3	14.7	720.30	11.02	0.024	0.021
730	61	F	49	416	3	6.17	266.61	4.08	0.023	0.016
730	61	F	50	416	3	6.36	274.68	4.20	0.024	0.017
1891	62	M	58	451	3	7.29	340.61	5.21	0.024	0.016
1588	70	F	67	449	3	8.42	391.32	5.99	0.024	0.019
1265	25	F	45	463	3	5.7	273.22	4.18	0.057	0.027
1265	25	F	45	463	3	5.7	273.22	4.18	0.057	0.027
1265	25	F	34	259.5	3	4.3	118.50	1.81	0.025	0.012
1774	64	F	60	299.5	3	7.48	236.01	3.61	0.019	0.013
1774	64	F	60	299.5	3	7.48	236.01	3.61	0.019	0.013
1774	64	F	60	299.5	3	7.48	236.01	3.61	0.019	0.013
1905	33	F	47	403.5	3	5.98	251.05	3.84	0.039	0.020
1905	33	F	47	403.5	3	5.98	251.05	3.84	0.039	0.020
1905	33	F	45	243	3	5.61	145.31	2.22	0.022	0.012
1881	32	M	78	632.5	3	9.72	630.65	9.65	0.065	0.037
1881	32	M	78	632.5	3	9.72	630.65	9.65	0.065	0.037
1881	32	M	68	262.5	3	8.51	236.98	3.63	0.025	0.014
1756	58	F	141	460.5	3	17.67	842.10	12.88	0.079	0.054
1756	58	F	139	460.5	3	17.52	834.31	12.76	0.079	0.054
1756	58	F	139	281	3	17.52	519.89	7.95	0.049	0.033
1911	54	F	77	657	3	9.63	648.18	9.92	0.067	0.044
1911	54	F	77	657	3	9.63	648.18	9.92	0.067	0.044
1914	77	M	57	262	3	7.2	200.16	3.06	0.007	0.006
1914	77	M	57	262	3	7.2	200.16	3.06	0.007	0.006
1054	56	F	44	248	3	5.52	145.65	2.23	0.014	0.010
1054	57	M	43	248	3	5.52	143.18	2.19	0.011	0.007
1790	68	M	48	547	3	6.08	342.19	5.24	0.019	0.014
1790	68	M	48	547	3	6.08	342.19	5.24	0.019	0.014
1753	50	F	240	623	3	14.4	919.30	14.07	0.104	0.066
162	52	F	49	624	3	6.17	394.97	6.04	0.043	0.028
162	53	F	47	624	3	5.98	383.00	5.86	0.041	0.026
1924	51	F	90	459	3	11.31	519.33	7.95	0.058	0.037
1924	51	F	90	459	3	11.31	519.33	7.95	0.058	0.037
1924	51	F	88	292	3	11.03	322.19	4.93	0.036	0.023
1848	43	F	86	638	3	10.85	709.38	10.85	0.091	0.054
1848	43	F	86	638	3	10.85	709.38	10.85	0.091	0.054

1848	43	F	78	220	3	9.72	229.50	3.51	0.030	0.017
1929	46	F	62	205.5	3	7.85	173.98	2.66	0.021	0.013
1931	43	F	60	323.5	3	7.48	253.96	3.89	0.033	0.019
1931	43	F	60	249	3	7.48	198.23	3.03	0.026	0.015
1909	65	F	43	252	3	5.42	145.35	2.22	0.011	0.008
1934	76	F	37	226.5	3	4.68	113.38	1.73	0.005	0.004
1011	20	M	44	642.5	3	5.52	363.29	5.56	0.054	0.028
1011	20	M	44	642.5	3	5.52	363.29	5.56	0.054	0.028
1011	20	M	40	273	3	5.05	145.93	2.23	0.022	0.011
1936	28	M	50	620.5	3	6.36	404.71	6.19	0.046	0.025
1936	28	M	50	620.5	3	6.36	404.71	6.19	0.046	0.025
1936	28	M	52	293.5	3	6.55	202.58	3.10	0.023	0.013
763	61	F	52	412	3	6.55	280.15	4.29	0.024	0.017
763	62	F	50	412	3	6.36	272.14	4.16	0.023	0.016
1522	68	F	95	588.7	3	11.97	647.51	9.91	0.044	0.033
1522	68	F	95	588.7	3	11.97	647.51	9.91	0.044	0.033
1522	68	F	90	308	3	11.31	348.48	5.33	0.024	0.018
1948	55	F	78	436.5	3	9.82	444.27	6.80	0.045	0.030
1948	55	F	78	436.5	3	9.82	444.27	6.80	0.045	0.030
1948	55	F	70	291.5	3	8.98	276.03	4.22	0.028	0.019
1944	64	F	108	389	3	13.56	549.12	8.40	0.043	0.031
1944	64	F	108	389	3	13.56	549.12	8.40	0.043	0.031
463	39	F	46	239.5	3	5.8	148.12	2.27	0.020	0.012
1685	53	F	70	439	3	8.7	395.67	6.05	0.042	0.027
1685	53	F	70	439	3	8.7	395.67	6.05	0.042	0.027
1685	53	F	59	274.5	3	7.39	214.59	3.28	0.023	0.015
1469	29	F	80	664.5	3	10.01	680.85	10.42	0.117	0.059
1469	29	F	80	664.5	3	10.01	680.85	10.42	0.117	0.059
1964	26	F	46	672	3	5.8	398.86	6.10	0.079	0.038
1964	26	F	46	672	3	5.8	398.86	6.10	0.079	0.038
1967	56	M	87	778	3	10.94	868.66	13.29	0.070	0.045
1967	56	M	87	778	3	10.94	868.66	13.29	0.070	0.045
1970	55	F	135	433	3	16.92	759.92	11.63	0.077	0.051
1970	55	F	145	446	3	18.14	838.08	12.82	0.085	0.056
1970	55	F	133	285.5	3	16.64	475.19	7.27	0.048	0.032
1974	39	F	37	385	3	4.68	187.48	2.87	0.026	0.015
1974	39	F	34	378	3	4.3	169.47	2.59	0.023	0.013
1974	39	F	31	200.5	3	3.93	85.03	1.30	0.012	0.007
744	22	F	45	209	3	5.61	126.23	1.93	0.030	0.014
1976	60	F	50	678	3	6.36	441.28	6.75	0.040	0.028
1976	60	F	50	678	3	6.36	441.28	6.75	0.040	0.028

1976	60	F	34	248	3	4.3	113.55	1.74	0.010	0.007
1495	45	F	114	275	3	14.21	413.60	6.33	0.051	0.031
899	74	F	118	557	3	14.77	846.55	12.95	0.043	0.034
899	75	F	118	557	3	14.77	846.55	12.95	0.040	0.033
899	75	F	113	219.5	3	14.13	331.59	5.07	0.016	0.013
1991	75	M	58	271	3	7.29	209.32	3.20	0.008	0.006
1985	43	F	48	615	3	6.08	383.52	5.87	0.049	0.029
1985	43	F	48	615	3	6.08	383.52	5.87	0.049	0.029
1985	43	F	39	247	3	4.86	127.88	1.96	0.016	0.010
810	49	M	51	459	3	6.45	306.47	4.69	0.028	0.017
1573	45	M	77	274.5	3	9.63	279.79	4.28	0.027	0.016
1573	45	M	75	323	3	9.44	320.16	4.90	0.030	0.018
1573	45	M	77	224	3	9.63	231.15	3.54	0.022	0.013
1189	44	F	105	452.5	3	13.18	617.69	9.45	0.078	0.046
1189	44	F	105	452.5	3	13.18	617.69	9.45	0.078	0.046
1189	44	F	76	253.5	3	9.54	257.04	3.93	0.033	0.019
1727	29	M	36	190.5	3	4.58	94.61	1.45	0.010	0.006
509	70	M	94	427.5	3	11.78	522.52	7.99	0.027	0.020
509	70	M	84	208	3	10.57	236.68	3.62	0.012	0.009
2010	25	F	62	241	3	7.96	199.46	3.05	0.041	0.020
2013	28	M	73	508.5	3	9.16	480.63	7.35	0.055	0.030
2013	29	M	71	508.5	3	8.88	465.92	7.13	0.051	0.028
2013	29	M	58	273	3	7.29	210.78	3.22	0.023	0.013
897	46	F	43	259.5	3	5.45	151.24	2.31	0.018	0.011
897	46	F	43	259.5	3	5.45	151.24	2.31	0.018	0.011
897	46	F	41	198.5	3	5.15	111.50	1.71	0.014	0.008
363	49	M	65	493	3	8.14	414.07	6.34	0.038	0.023
363	50	M	65	506	3	8.14	424.65	6.50	0.038	0.023
363	51	M	56	307	3	7.01	226.52	3.47	0.020	0.012
2027	55	F	60	475	3	7.57	371.88	5.69	0.038	0.025
2027	55	F	60	475	3	7.57	371.88	5.69	0.038	0.025
2027	55	F	67	258	3	8.42	230.59	3.53	0.023	0.015
1996	57	F	70	187	3	8.98	182.23	2.79	0.018	0.012
2042	44	F	78	206	3	9.82	217.96	3.33	0.028	0.016
2035	59	F	35	197.5	3	4.39	93.83	1.44	0.009	0.006
2038	62	F	53	397	3	6.64	274.19	4.20	0.023	0.016
2038	62	F	53	397	3	6.64	274.19	4.20	0.023	0.016
2038	62	F	45	199	3	5.7	122.63	1.88	0.010	0.007
693	72	M	82	588	3	10.29	621.26	9.51	0.029	0.022
693	72	M	79	597	3	9.91	607.59	9.30	0.029	0.021
693	72	M	62	187.5	3	7.85	159.84	2.45	0.008	0.006

2045	19	F	102	422.5	3	12.81	561.74	8.59	0.149	0.068
2045	19	F	103	422.5	3	12.9	565.84	8.66	0.150	0.069
2045	19	F	95	215.5	3	11.97	277.08	4.24	0.073	0.034
2044	31	F	75	610.5	3	9.35	585.82	8.96	0.094	0.048
2044	31	F	75	610.5	3	9.35	585.82	8.96	0.094	0.048
2044	31	F	52	211.5	3	6.55	148.91	2.28	0.024	0.012
2048	48	F	125	329.5	3	15.62	720.66	11.03	0.085	0.053
872	57	M	86	670	3	10.85	744.09	11.38	0.059	0.038
872	57	M	86	670	3	10.85	744.09	11.38	0.059	0.038
872	57	M	78	230	3	9.72	239.23	3.66	0.019	0.012
2052	45	F	102	614	3	12.81	807.06	12.35	0.100	0.060
2052	45	F	103	614	3	12.9	812.95	12.44	0.101	0.061
2052	45	F	71	196	3	8.98	190.30	2.91	0.024	0.014
132	44	F	36	446	3	4.58	211.68	3.24	0.027	0.016
132	44	F	36	446	3	4.58	211.68	3.24	0.027	0.016
132	44	F	30	174	3	3.83	72.84	1.11	0.009	0.005
1694	26	F	120	611	3	15.15	949.79	14.53	0.189	0.092
1694	26	F	120	611	3	15.15	951.30	14.55	0.189	0.092
1694	26	F	104	206	3	13	288.54	4.41	0.057	0.028
2058	80	F	92	699	3	11.59	829.03	12.68	0.027	0.024
2058	80	F	92	699	3	11.59	829.03	12.68	0.027	0.024
2058	80	F	87	231.5	3	10.94	270.77	4.14	0.009	0.008
2054	80	M	84	713	3	10.57	770.28	11.79	0.021	0.018
2054	80	M	91	819	3	11.41	952.55	14.57	0.025	0.022
2054	80	M	78	232	3	9.82	243.49	3.73	0.006	0.006
1376	78	F	143	469.5	3	17.9	869.04	13.30	0.034	0.029
1376	78	F	135	469.5	3	16.85	816.49	12.49	0.032	0.027
1376	62	F	106	199.5	3	13.31	285.83	4.37	0.024	0.017
2079	31	F	99	652	3	12.44	830.75	12.71	0.133	0.068
2079	31	F	96	652	3	12.1	808.28	12.37	0.129	0.067
2079	31	F	72	208.5	3	9	202.05	3.09	0.032	0.017
1505	40	F	92	400	3	11.5	478.45	7.32	0.065	0.037
1505	40	F	90	400	3	11.22	466.79	7.14	0.063	0.036
1505	40	F	75	219	3	9.35	219.74	3.36	0.030	0.017
2082	60	M	62	670	3	7.85	538.82	8.24	0.040	0.026
2082	60	M	64	670	3	8.04	551.50	8.44	0.041	0.027
2082	60	M	65	218	3	8.14	190.36	2.91	0.014	0.009
2100	60	F	105	574.5	3	13.18	778.54	11.91	0.070	0.049
2100	60	F	105	574.5	3	13.18	778.54	11.91	0.070	0.049
2100	60	F	86	174	3	10.75	204.31	3.13	0.018	0.013
1598	25	M	47	444	3	5.89	270.98	4.15	0.034	0.018

1598	25	M	47	444	3	5.89	270.98	4.15	0.034	0.018
1598	25	M	47	444	3	5.89	270.98	4.15	0.034	0.018
1598	25	M	53	218	3	6.64	155.35	2.38	0.020	0.011
1325	40	F	203	390.5	3	25.55	1037.01	15.87	0.141	0.080
1325	40	F	198	459	3	25.01	1184.00	18.12	0.161	0.092
1325	40	F	184	238	3	23.31	588.23	9.00	0.080	0.046
2101	53	F	121	210.5	3	15.15	343.10	5.25	0.036	0.024
763	61	F	42	232	3	5.33	132.18	2.02	0.011	0.008
763	62	F	42	232	3	5.24	129.86	1.99	0.011	0.008
763	62	F	41	153	3	5.14	86.91	1.33	0.007	0.005
7	47	F	97	421	3	12.16	531.21	8.13	0.064	0.039
7	47	F	97	420	3	12.16	529.99	8.11	0.064	0.039
7	47	F	86	185	3	10.85	218.02	3.34	0.026	0.016
1740	50	F	62	436.5	3	7.85	355.42	5.44	0.040	0.026
1740	50	F	62	436.5	3	7.85	355.42	5.44	0.040	0.026
1740	50	F	59	186.5	3	7.39	149.59	2.29	0.017	0.011
1495	44	F	187	669	3	23.37	1598.70	24.46	0.202	0.120
1495	44	F	181	668	3	22.77	1555.79	23.80	0.197	0.117
1495	45	F	160	222	3	20.09	476.61	7.29	0.059	0.036
2123	47	F	110	634	3	13.84	899.54	13.76	0.108	0.066
2123	47	F	111	634	3	13.9	903.50	13.82	0.108	0.066
2123	47	F	91	203	3	11.4	249.66	3.82	0.030	0.018
2118	60	F	134	618.5	3	16.74	1062.01	16.25	0.095	0.066
2118	60	F	132	618.5	3	16.72	1060.05	16.22	0.095	0.066
2118	60	F	117	172	3	14.75	276.39	4.23	0.025	0.017
2121	38	F	27	173.5	3	3.46	65.56	1.00	0.009	0.005
1756	58	F	131	619	3	16.36	1039.09	15.90	0.098	0.067
1756	58	F	127	619	3	16.01	1016.44	15.55	0.096	0.065
1756	58	F	122	186	3	15.37	310.11	4.74	0.029	0.020
1189	44	F	74	286	3	9.26	279.57	4.28	0.035	0.021
1189	44	F	74	286	3	9.26	279.57	4.28	0.035	0.021
1189	44	F	75	186	3	9.44	200.22	3.06	0.025	0.015
2111	59	F	79	652	3	9.91	662.10	10.13	0.061	0.042
2111	59	F	79	652	3	9.91	662.10	10.13	0.061	0.042
2111	59	F	59	216	3	7.39	171.38	2.62	0.016	0.011
2132	41	F	64	202	3	8.04	175.31	2.68	0.023	0.013
2134	64	F	101	635	3	12.62	821.78	12.57	0.065	0.047
2134	64	F	101	635	3	12.62	821.78	12.57	0.065	0.047
2134	64	F	90	222	3	11.31	269.28	4.12	0.021	0.015
1944	64	F	68	184	3	8.6	172.05	2.63	0.014	0.010
2140	42	F	82	435	3	10.29	463.89	7.10	0.061	0.035

2140	42	F	82	522.5	3	10.29	553.88	8.47	0.073	0.042
2140	42	F	68	215	3	8.6	198.72	3.04	0.026	0.015
2142	42	F	90	216	3	11.22	260.32	3.98	0.034	0.020
2141	57	F	106	696	3	13.28	945.39	14.46	0.091	0.062
2141	57	F	106	696	3	13.28	945.39	14.46	0.091	0.062
2141	57	F	113	266	3	14.12	398.17	6.09	0.039	0.026
2111	59	F	35	196	3	4.49	95.15	1.46	0.009	0.006
2144	62	F	49	238.5	3	6.17	157.06	2.40	0.013	0.009
2148	69	F	78	225.5	3	9.82	237.11	3.63	0.015	0.012
2152	50	F	28	227.5	3	3.55	86.52	1.32	0.010	0.006
2150	35	F	66	241	3	8.32	213.88	3.27	0.032	0.017
1936	28	M	51	416	3	6.45	278.72	4.26	0.032	0.017
1936	28	M	50	546.5	3	6.26	352.40	5.39	0.040	0.022
1936	28	M	53	243	3	6.64	171.95	2.63	0.020	0.011
1103	37	F	42	249.5	3	5.24	139.03	2.13	0.020	0.011
424	57	M	109	811	3	13.65	1129.01	17.27	0.090	0.057
424	57	M	109	839.5	3	13.7	1172.04	17.93	0.093	0.059
424	57	M	115	241.5	3	14.4	370.80	5.67	0.029	0.019
2168	55	F	42	211.5	3	5.24	119.13	1.82	0.012	0.008
2096	70	M	151	735.5	3	18.9	1420.34	21.73	0.075	0.054
2096	70	M	164	738	3	13.15	990.87	15.16	0.052	0.038
2096	70	M	174	254	3	13.92	375.00	5.74	0.020	0.014
2160	28	M	51	618.5	3	6.45	409.38	6.26	0.047	0.025
2160	28	M	51	618.5	3	6.45	409.38	6.26	0.047	0.025
2160	28	M	35	197.5	3	4.49	95.83	1.47	0.011	0.006
2178	57	F	53	200	3	6.73	145.42	2.22	0.014	0.010
1660	55	F	26	194.5	3	3.37	70.86	1.08	0.007	0.005
2190	51	M	29	234	3	3.65	91.17	1.39	0.008	0.005
2013	28	M	90	862	3	11.31	993.39	15.20	0.113	0.062
2013	29	M	90	883	3	11.41	1025.56	15.69	0.112	0.062
2013	29	M	80	274.5	3	10.1	293.37	4.49	0.032	0.018
2191	76	F	30	218	3	3.74	87.52	1.34	0.004	0.003
2195	60	F	54	563.5	3	6.83	395.56	6.05	0.035	0.025
2195	60	F	54	629	3	6.83	440.28	6.74	0.039	0.028
2195	60	F	49	205.5	3	6.17	134.85	2.06	0.012	0.008
2173	63	F	32	240.5	3	4.02	103.13	1.58	0.008	0.006
2052	45	F	47	229	3	5.89	144.33	2.21	0.018	0.011
1924	51	F	92	267	3	10.39	309.17	4.73	0.034	0.022
2211	47	F	147	649.5	3	18.48	1229.71	18.81	0.147	0.090
2211	47	F	138	649.5	3	17.41	1157.51	17.71	0.139	0.085
2211	47	F	132	252.5	3	16.58	443.76	6.79	0.053	0.033

1996	57	F	103	584	3	12.9	774.23	11.85	0.075	0.051
1882	44	F	32	245	3	4.49	117.14	1.79	0.015	0.009
509	70	M	62	274	3	7.85	227.78	3.49	0.012	0.009
2171	82	M	54	718	3	6.83	501.03	7.67	0.013	0.012
2171	82	M	54	739	3	6.83	515.36	7.89	0.014	0.012
2171	82	M	46	219	3	5.8	136.24	2.08	0.004	0.003
2218	40	F	59	241.5	3	7.39	190.22	2.91	0.026	0.015
897	46	F	28	258	3	3.18	91.88	1.41	0.011	0.007
1519	34	F	40	263.5	3	5.05	141.13	2.16	0.021	0.011
2222	30	F	44	280.5	3	5.52	163.58	2.50	0.027	0.014
1548	35	M	60	269	3	7.48	213.19	3.26	0.022	0.012
2227	28	F	50	240	3	4.01	102.64	1.57	0.019	0.009
2229	39	F	82	280	3	10.29	304.46	4.66	0.042	0.024
2224	19	F	50	229	3	6.73	153.49	2.35	0.041	0.019
812	41	F	34	289	3	4.3	131.19	2.01	0.017	0.010
2233	28	F	42	296	3	5.24	163.37	2.50	0.030	0.015
2236	60	M	103	615.5	3	12.9	814.88	12.47	0.061	0.040
2236	60	M	103	615.5	3	12.9	814.88	12.47	0.061	0.040
2236	60	M	75	225.5	3	9.44	228.08	3.49	0.017	0.011
1054	56	F	66	595	3	8.32	508.48	7.78	0.050	0.034
1054	57	M	66	595	3	8.32	508.48	7.78	0.040	0.026
1054	57	F	57	211	3	7.2	163.44	2.50	0.016	0.011
754	66	F	75	247.5	3	9.44	248.85	3.81	0.018	0.013
1847	44	M	134	554	3	16.74	954.05	14.60	0.091	0.054
1847	44	M	128	554	3	16.14	919.12	14.06	0.088	0.052
2255	51	M	79	654.5	3	9.91	664.58	10.17	0.059	0.036
2255	51	M	79	654.5	3	9.91	664.58	10.17	0.059	0.036
2255	51	M	68	241.5	3	8.51	219.11	3.35	0.019	0.012
2230	26	F	65	657	3	8.23	553.78	8.47	0.110	0.053
2230	26	F	67	657	3	8.42	566.37	8.67	0.112	0.055
2230	26	F	71	285.5	3	8.88	267.83	4.10	0.053	0.026
2270	52	F	40	304.6	3	4.52	137.81	2.11	0.015	0.010
2265	62	M	74	642.5	3	9.26	609.58	9.33	0.043	0.028
2265	62	M	72	642.5	3	9.07	597.27	9.14	0.042	0.028
2265	62	M	69	265.5	3	8.7	244.80	3.75	0.017	0.011
2277	58	F	50	219	3	6.36	147.23	2.25	0.014	0.009
2280	28	F	43	205	3	5.42	119.86	1.83	0.022	0.008
1936	28	M	41	450	3	5.14	239.66	3.67	0.027	0.015
2142	65	F	65	248.5	3	8.23	217.65	3.33	0.017	0.012
2130	22	M	35	227	3	4.39	106.79	1.63	0.015	0.008
2284	45	F	82	637.5	3	10.29	672.17	10.28	0.084	0.050

2284	45	F	82	637.5	3	10.29	672.17	10.28	0.084	0.050
2284	45	F	57	219.5	3	7.2	169.56	2.59	0.021	0.013
1588	70	F	71	583	3	8.88	532.10	8.14	0.033	0.026
1588	70	F	71	583	3	8.88	532.10	8.14	0.033	0.026
1588	70	F	51	211.5	3	6.45	146.78	2.25	0.009	0.007
1189	44	F	55	260	3	6.92	190.98	2.92	0.024	0.014
2286	54	F	121	240	3	15.15	387.79	5.93	0.040	0.026
1566	19	F	65	228	3	8.14	198.50	3.04	0.053	0.024
1848	43	F	90	649.5	3	11.22	746.74	11.43	0.096	0.057
1848	43	F	90	649.5	3	11.22	746.74	11.43	0.096	0.057
1848	43	F	80	255	3	10.1	273.67	4.19	0.035	0.021
1848	43	F	95	225	3	11.97	288.45	4.41	0.037	0.022
2297	22	M	42	560	3	5.33	307.00	4.70	0.043	0.023
2297	22	M	37	561	3	4.68	269.77	4.13	0.038	0.020
2297	22	M	31	246	3	3.93	102.89	1.57	0.014	0.008
1476	28	M	73	247.5	3	9.16	241.46	3.69	0.027	0.015
	49.67		**76.84**	**448.32**	**3.07**	**9.55**	**458.13**	**7.01**	**0.04912**	**0.030**

Table A.5: Patient parameters of pelvis CT Examination at SGMC

Sweden Ghana Medical Centre Ltd, SGMC Data to be registrated to determine diagnostic standard doses for CT exams										
Patient ID	**Age (years)**	**Sex M/F**	**Tube charge per rotation (mAs)**	**Scan length (mm)**	**Nominal slice thickness (mm)**	**$CTDI_{vol}$ values (mGy)**	**DLP(m Gycm)**	**Estimated Effective Dose (mSv)**	**LAR of Cancer Incidence (%)**	**LAR of Cancer Mortality (%)**
586	62	M	58	465	4	7.25	351.19	4.53	0.021	0.014
1297	68	F	140	481	3	17.45	870.22	11.23	0.050	0.038
872	57	M	66	353	3	8.33	309.17	3.99	0.021	0.013
2049	60	M	94	337.5	3	11.75	417.71	5.39	0.026	0.017
2049	60	M	94	337.5	3	11.75	417.71	5.39	0.026	0.017
2049	60	M	94	337.5	3	11.75	417.71	5.39	0.026	0.017
1985	43	F	86	274.5	3	10.75	312.38	4.03	0.034	0.020
1985	43	F	84	274.5	3	10.57	306.95	3.96	0.033	0.020
1985	43	F	84	274.5	3	10.57	306.95	3.96	0.033	0.020
1376	78	F	161	224.5	3	20.11	481.93	6.22	0.016	0.013
2079	31	F	128	267.5	3	16	453.60	5.85	0.061	0.032
2082	60	M	64	245	3	8.04	209.88	2.71	0.016	0.009
1739	77	F	65	487.5	3	8.17	412.83	5.33	0.015	0.012
1739	77	F	82	487.5	3	10.29	517.88	6.68	0.018	0.015
1739	77	F	86	247	3	10.85	285.27	3.68	0.010	0.008
2100	60	F	129	207.5	3	16.08	359.46	4.64	0.027	0.019
2123	47	F	132	210.5	3	16.5	373.73	4.82	0.038	0.017
2118	60	F	149	210.5	3	18.81	424.98	5.48	0.032	0.022
1756	58	F	146	213	3	18.38	420.45	5.42	0.033	0.023
2111	59	F	85	216	3	10.66	247.31	3.19	0.019	0.013
2134	64	F	115	222	3	14.4	342.72	4.42	0.023	0.016
2141	57	F	92	219	3	11.5	270.28	3.49	0.022	0.015

424	58	M	375	375	3	12	471.60	6.08	0.038	0.020
2096	70	M	175	304	3	14.02	447.67	5.77	0.020	0.014
1739	77	F	78	469	3	9.83	487.88	6.29	0.017	0.014
2195	60	F	57	258	3	7.11	194.72	2.51	0.015	0.010
2171	82	M	58	291	3	7.29	223.91	2.89	0.005	0.004
1847	44	M	147	258	3	18.58	507.99	6.55	0.041	0.024
1936	28	M	35	232	3	4.49	111.31	1.44	0.011	0.006
1588	70	F	86	211.5	3	10.85	246.76	3.18	0.013	0.010
	59.67		**108.17**	**299.70**	**3.03**	**12.14**	**373.41**	**4.82**	**0.025**	**0.016**

APPENDIX B

Table B.1: Lifetime attributable risk of cancer Incidence (Male adults)

Age at Exposure	All Cancers
18	1059
19	1018
20	977
21	947.9
22	918.8
23	889.7
24	860.6
25	831.5
26	802.4
27	773.3
28	744.2
29	715.1
30	686
31	682.2
32	678.4
33	674.6
34	670.8
35	667
36	663.2
37	659.4
38	655.6
39	651.8
40	648
41	642.3
42	636.6
43	630.9
44	625.2
45	619.5
46	613.8
47	608.1
48	602.4
49	596.7
50	591
51	580.8
52	570.6
53	560.4
54	550.2
55	540
56	529.8
57	519.6
58	509.4

59	499.2
60	489
61	474.4
62	459.8
63	445.2
64	430.6
65	416
66	401.4
67	386.8
68	372.2
69	375.6
70	343
71	326.1
72	309.2
73	292.3
74	275.4
75	258.5
76	241.4
77	224.7
78	207.8
79	190.9
80	174

Table B.2: Lifetime attributable risk of cancer Incidence (Female adults)

Age at Exposure	All Cancers
18	1813.2
19	1729.6
20	1646
21	1587.9
22	1529.8
23	1471.7
24	1413.6
25	1355.5
26	1297.4
27	1239.3
28	1181.2
29	1123.1
30	1065
31	1047.1
32	1029.2
33	1011.3
34	993.4
35	975.5
36	957.6
37	939.7
38	921.8
39	903.9
40	886
41	871.4
42	856.8
43	842.2
44	827.6
45	813
46	798.4
47	783.8
48	769.2
49	754.6
50	740
51	724.6
52	709.2
53	693.8
54	678.4
55	663
56	647.6
57	632.2
58	616.8
59	601.4
60	586

61	568.3
62	550.6
63	532.9
64	515.2
65	497.5
66	479.8
67	462.1
68	444.4
69	426.7
70	409
71	389.5
72	370
73	350.5
74	331
75	311.5
76	292
77	272.5
78	253
79	233.5
80	214

APPENDIX C

Table C.1: Lifetime attributable risk of cancer mortality (Male adults)

Age at Exposure	All Cancers
18	547.8
19	529.4
20	511
21	498
22	485
23	472
24	459
25	446
26	433
27	420
28	407
29	394
30	381
31	380.2
32	380.2
33	379.8
34	379.4
35	379
36	378.6
37	378.2
38	377.8
39	377.4
40	377
41	375.3
42	373.6
43	371.9
44	370.2
45	368.5
46	366.8
47	365.1
48	363.4
49	361.7
50	360
51	355.9
52	351.8
53	347.7
54	343.6
55	339.5
56	335.4
57	331.3
58	327.2

59	323.1
60	319
61	312.1
62	305.2
63	298.3
64	291.4
65	284.5
66	277.6
67	270.7
68	263.8
69	256.9
70	250
71	240.3
72	230.6
73	220.9
74	211.2
75	201.5
76	191.8
77	182.1
78	172.4
79	162.7
80	153

Table C.2: Lifetime attributable risk of cancer mortality (Female adults)

Age at Exposure	All Cancers
18	822.8
19	792.4
20	762
21	740
22	718
23	696
24	674
25	652
26	630
27	608
28	586
29	564
30	542
31	538.5
32	535
33	531.5
34	528
35	524.5
36	521
37	517.5
38	514
39	510.5
40	507
41	503.2
42	499.4
43	495.6
44	491.8
45	488
46	484.2
47	480.4
48	476.6
49	472.8
50	469
51	463
52	457
53	451
54	445
55	439
56	433
57	427
58	421
59	415
60	409

61	399.8
62	390.6
63	381.4
64	372.2
65	363
66	353.8
67	344.6
68	335.4
69	326.2
70	317
71	304.3
72	291.6
73	278.9
74	266.2
75	253.5
76	240.8
77	228.1
78	215.4
79	202.7
80	190