RADIATION SKIN DOSES TO PATIENTS UNDERGOING ABDOMINAL COMPUTED TOMOGRAPHIC EXAMINATIONS

BY

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DECLARATION

This dissertation is my original work and has not been presented at any other university for similar or any other degree award.

Signed: .....

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This dissertation has been submitted for examination with our approval as university supervisors.

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DEDICATION

This work is dedicated to my son Andrew who was born just after I finished part one of my Master's degree course and to my sister Josephine and brother Protas who died almost at the same time in 1999.

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Special thanks go to my supervisors Prof. Tole and Dr. De Sousa for their input into this project in terms of guidance and enrichment of the literature content.
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Thanks to Shem Juma of Sylicon Computer Services, his dedication saw me through the computer hassles.

I thank my sons, Andrew and Arnold and my daughter Audrey for the evening smiles they gave me whenever I returned home.

Finally I thank my wife, Mrs. Jane Umara for the love and moral support that she gave me during this particular period in my career.

TABLE OF CONTENTS

FIGURES

TABLES

ABBREVIATIONS AND TERMINOLOGIES

Radiation:

Emissions and diffusions of energy in the form of electromagnetic wave or particles charged or uncharged electrically

X-ray:

Invisible highly penetrating electromagnetic radiations of short wavelength in the range of 10^{-7} to 10^{-11} cm.

Exposure:

Measures quantity of electrical charges produced in unit mass of air by ionizing electromagnetic radiation. Units are coulomb per kilogram. Unit of roentgen IR = $2.58X10^{-4}$ C/KG.

Absorbed Dose:

(J/kg or Gray), is the energy imparted by ionizing radiation per unit mass of specified material.

Effective Dose (E):

Assesses the total stochastic health detriment by summing up equivalent doses in all the tissues and organs of the body weighted for organ sensitivity. Units are in Sievert (100 rem)

Stochastic Risk

Radiation effect for which the probability of occurrence but not the severity of effects depends on dose.

Deterministic Risk

Radiation effect for which the severity of biological effect depend upon dose.

KV (Kilo Voltage)

This is a unit of electrical potential difference between electrodes of an X-ray tube. It determines the quality (penetrating power) and also the intensity of the X-ray.

Milliampere

Is a thousandth of an ampere. A unit of an electrical current, which passes through the X-ray tube.

mAs (Milli-Ampere Seconds)

Is a product of current and duration of flow in seconds.

CT: Computerized Tomography.

MRI: Magnetic Resonance Imaging.

TL: Thermo-luminescence. These materials when irradiated are capable of storing the radiation energy, which they release in the form of light when a thermal stimulus is applied.

LiF: Lithium Fluoride, a thermoluminiscent material used in radiation dosimetry. Z Value = 8.2

TLD: Thermoluminiscent Dosimeters.

PMT: Photo-multiplier Tube.

Pitch: Is the table movement divided by CT Slice thickness during one X-Ray tube rotation

S.D: Standard Deviation

ICRP: International Commission on Radiological Protection.

NRPB: National Radiological Protection Board (U.K)

KNH: Kenyatta National Hospital

MITC: Medical Imaging and Therapeutic Centre

ABSTRACT

Background

Radiation is always a medical concern as it may induce cancer and hereditary defects. The use of CT has increased rapidly in the past decade due to the increased medical diagnostic applications of this imaging modality. This has resulted in an increasing medical radiation burden associated with CT. Doses should therefore be kept as low as reasonably achievable in line with the ALARA principle.

Objective: The main objective of the study was to generate baseline data in patients' radiation skin doses during abdominal CT scan examination and to assess the associated risks to certain critical organs.

Study Design: The study was comparative and cross sectional.

Study Setting: The study was conducted at MITC and involved eighty-one patients who presented for CT scan examinations of the abdomen between September 2002 and March 2003.
Subject/Patients: Eighty-one patients presented for abdominal CT examinations. Thirty-five patients underwent conventional CT examination at MP Shah while thirty-six patients underwent spiral CT examination at MITC. Ten patients were assessed for radiation skin dose during topogram examination at MP Shah.

Method: Radiation doses were measured by use of Thermolumiscent Dosimeters (Lithium Fluoride), which were placed before the CT scan examination on the skin corresponding to the Thyroid gland, Liver, Breasts and Testis. The amount of radiation absorbed by the dosimeters was determined by reading their light output in the Thermoluminiscent Dosimeter Reader at the Department of Diagnostic radiology (U.O.N).

The dosimeters were earlier calibrated using cobalt-60 radiation to determine their response to a certain uniform amount of radiation.

Results: Dose calculations for each region e.g. liver, breast, thyroid, and testis were done for each patient. Data was entered into a microcomputer using SPSS/PC data entry programme. Geometric means for radiation dose to the various skin sites were calculated. The results showed that mean dose was highest for liver (sequential CT- **88.8mGy**, spiral CT-**92.8mGy**), followed by Breast (sequential-**9.89mGy**, Spiral-**10mGy**), Thyroid (sequential-**2.85mGy**, Spiral-**2.52mGy**) and was lowest for the Testis (sequential-**1.23mGy**, Spiral-**1.33mGy**). Results also showed that there was no significant difference in skin doses delivered during conventional and spiral CT examination. The dose delivered by Topogram examination relative to the multi-slice examination were insignificant to the liver, breast, and thyroid while it was significant to the testis denoting that the topogram contributed to most of the testis skin dose.

Conclusion

There was no significant difference in skin doses at sequential or spiral CT examinations. The skin doses in this study were generally below radiation dose levels required to induce deterministic effects like causing temporary or permanent sterility of the testis. The choice of whether to use spiral or conventional CT should therefore rely on clinical considerations rather than on dose.

OBJECTIVES OF THE STUDY

Main objective

To generate baseline data on patients' radiation doses during abdominal CT scan examination and to assess the associated risks to certain critical organs, there being no other data on the same study in the East African region.

Specific Objectives

i) To determine skin radiation doses at anatomical sites corresponding to the thyroid glands, breasts, liver and testis.
ii) To determine the significance of scatter radiation to the thyroid gland and testis during multislice CT examination of the abdomen.
iii) To assess the contribution of the topogram to the amount of radiation received by the thyroid and testis.

Benefits Expected from the Study

Results from the study are expected: -

- To help establish the magnitude of radiation doses during CT examinations of the abdomen, from the scanner at MITC and MP Shah Hospital.
- To give additional information on radiation doses during CT scans of the abdomen.
- To give recommendations for radiation protection in patients undergoing CT abdominal examinations.

Rationale of the Study

The need for the study is as follows:

1. To establish a data base in our set up
2. Give information on radiation doses to patients during CT examinations of the abdomen to the referring clinician, the radiologist and the radiographer performing the examinations. This may help in redesigning CT techniques and protocols to reduce patients' absorbed dose.
3. Submission to an institutional review board e.g. Radiation Protection Board – for radiation protection purposes and quality control.

HYPOTHESIS

There is no difference in skin doses to patients undergoing conventional and those undergoing spiral CT abdominal examinations.

Inclusion criteria: All patients who were referred for CT examination of the abdomen and gave consent.

Exclusion criteria

i) Included all patients referred for CT examination other than the abdomen
ii) Included those referred for CT abdomen but who refused to give a signed consent.

ETHICAL CONSIDERATION

Medical professional ethics were adhered to, in all patients. All patients referred for abdominal CT examinations were identified by their hospital numbers. The procedure was explained to patients and their consent sought before starting. The authority to conduct the study was secured from the administrator of Medical Imaging and Therapeutic Centre and MP Shah Hospital. A request to conduct this study was submitted together with a copy of study protocol to the Ethical and Research Committee of Kenyatta National and Referral Hospital and approval was granted.

INTRODUCTION AND LITERATURE REVIEW

Computerized axial tomography (CT) is a technique of diagnostic roentgenology developed by Godfrey N. Hounsfield of EMI limited of England in 1973 **(1)**. CT is able to provide axial tomographic images of sections of the head and other parts of the body. CT images represent the spatial distribution of the attenuation of X-rays in the tissues examined. It yields transverse sections that provide a third dimension display of the distribution of x-ray attenuation within the body without superimposition of body structures. CT has the ability to detect minute differences in tissue x-ray attenuation and provides highly accurate quantitative information about the x-ray attenuation properties of tissues imaged and is therefore important for diagnostic purposes. CT has therefore become a primary imaging technique and is used today for the evaluation of organs and musculo-skeletal system. It also finds specialized use in CT angiography, pulmonary embolism detection and interventional procedures. In the USA there has been an increase in CT examinations from (2.8million) in 1981 to (28 million) in 1995.

CT Scan Equipment

Principle of operation

CT utilizes a series of projections taken at different angles and gives cross-sectional images. The x-ray is produced in the x-ray tube and is then collimated. The beam passes through the patient and is again collimated (pre-detector collimation). The radiation energy causes fluorescence in scintillation or xenon gas detector. A photo-multiplier tube that is connected to an electronic circuit picks up the light from the detectors. This information is then sent to a cathode ray oscilloscope monitor. It is from these attenuations that the tomographic section is reconstructed by computer-applied algorithm. There is optimization of CT data acquisition such that the profiles obtained are capable of eliciting differences in x-ray attenuations of a half percent. In conventional radiography the contrast perceptibility is limited to about two percent due to scattered radiation and film screen combination noise. Spatial resolution for CT (1-2mm) is however poor compared to conventional radiography (0.1-0.3mm)

Image reconstruction

Profiles are recorded in a digital form by a computer system. From the data acquired the CT system reconstructs the image of the section through application of a suitable algorithm. The commonly used method is known as filtered back projection reconstruction method. It represents the projection of the image into a two dimensional image. Computerized Tomography is able to remove the artefactual contribution of the object to the image and yield a quantitative representation of the object. The negative values of the filtered profiles are subtracted from the positive values so as to remove the unwanted contribution, thus restoring the true appearance of the object. The technique is based on mathematical considerations **(2)**.

Developments in CT Technology

Computerized tomography has undergone technological development from first generation to fourth generation spiral scanners with improved efficiency in terms of scan time, radiation dose and image quality. Reduction of scan time (tube rotation time) has been achieved from five minutes in first generation scanners to less than one second in spiral CT systems **(2&4)**. The generational evolution of CT scanners is depicted in Fig 1.

First generation scanners

This technology has x-ray tube and detector opposite each other with the subject between them. Two narrow beams of x-ray, each detected by a scintillation detector, simultaneously provide two sections of the subject. The x-ray tube and detector performed translatory and rotary movement. It involved 240 exposures while performing translatory movements, followed by one-degree angular tilt. Overall, 240x180 exposures were made. Scan time for one section took about 5 minutes **(2)**.

Second-generation scanners

In this design the beam of x-ray is fan shaped with an angle of ten degrees. The beam is detected by a series of scintillation detectors, typically about thirty and the source of radiation and detectors scan across the patient in approximately a second. The gantry is then rotated about ten degrees and the operation is repeated. Total scan time is approximately 20 seconds making it 15 times faster than first generation scanners.

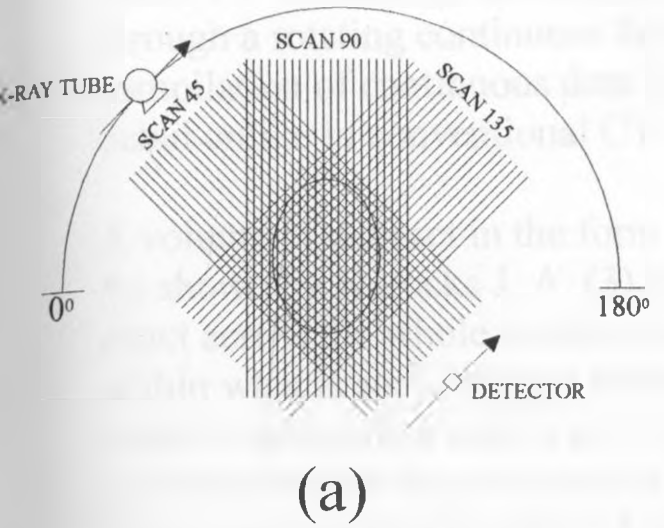
Third generation scanners

This technology had wider fan beam systems (30 degrees) with no translatory but continuous rotary movement of the tube and detector. With this technology the scan time was reduced to about 5 seconds per section **(2)**.

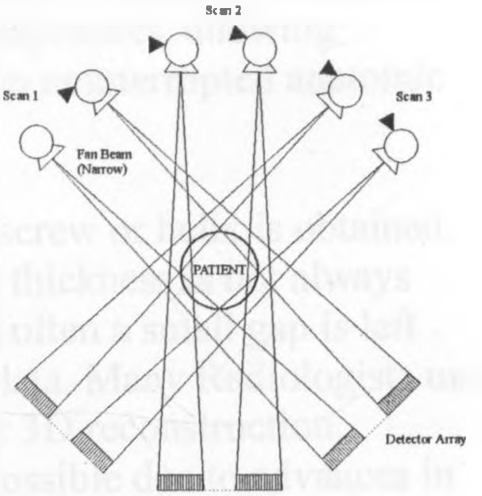
Fourth generation scanners

This technology has fan shaped beam with annular array detectors that remain stationary. The x-ray tube performs rotational motion inside the detector ring. Scan time for one section was about one second

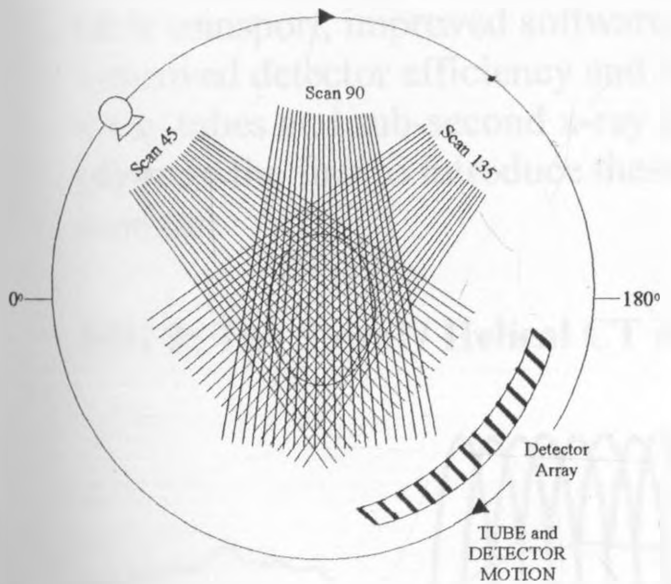
FIG 1: Diagrams showing First To Fourth Generation Scanners (Clinical radiology: 2001; 56:302-309) (5).



(a)



(b)



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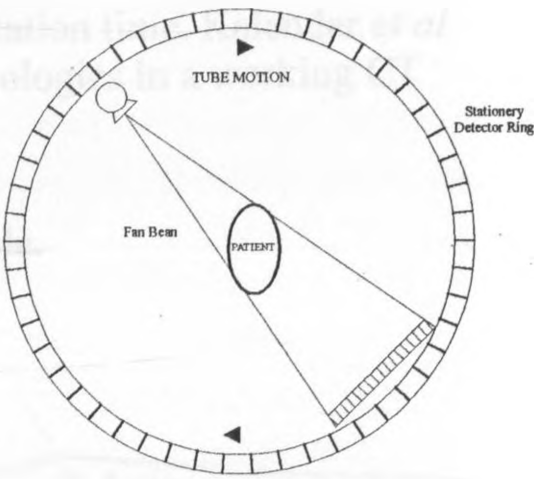


(d)

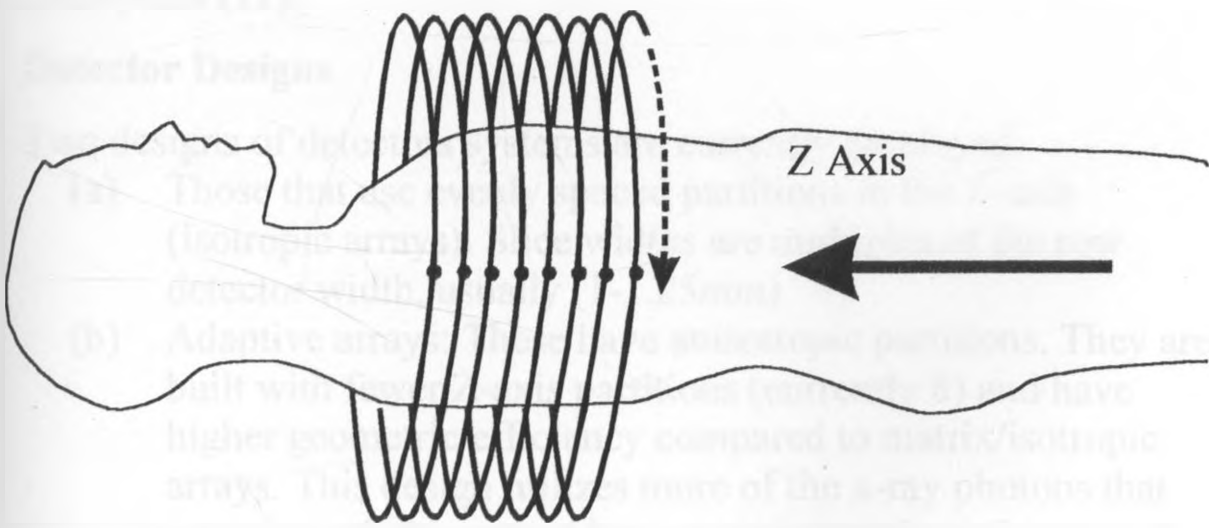
a-first generation scanner
b-second generation scanner
c-third generation scanner
d-fourth generation scanner

Volume (Spiral, Helical) CT technology.

Spiral CT technology involves continuous movement of the patient through a rotating continuous fan beam exposures, allowing compilation of continuous data that has an uninterrupted anatomic detail unlike in conventional CT.

A volume of data set in the form of corkscrew or helix is obtained. As shown by Horocks J. A. **(3)**, the slice thickness is not always exact across the whole cross-section and often a small gap is left within what is supposedly a volumetric data. Many Radiologists use a small overlap when data is to be used for 3D reconstruction. Continuous data acquisition was made possible due to advances in CT technology that introduced slip – ring technology, precise patient table transport, improved software reconstructing algorithms, improved detector efficiency and introduction of higher heat capacity x-ray tubes and sub-second x-ray tube rotation time. Kalender *et al* **(4)** were the first to introduce these technologies in a working CT scanner.

FIG 2: The Spiral / Helical CT Principle.



Spiral CT with advanced detector designs (multi-slice technology)

Major advances have occurred in detector technology with the introduction of ceramic detectors, which have higher x-ray photon detection efficiency **(5)**. This has enabled high quality imaging with reduced radiation burden. By using a beam, which is fanned in the patient's z-direction (patient's axis) to include two contiguous detectors, the scan time is halved if the other parameters remain the same (acquiring two slices per tube rotation). Currently available systems enable acquisition of 4 up to 16 slices at a time. This has led to faster data acquisition and consequently the liver can be scanned with 5mm collimators in less than 6 seconds.

Hu *et al* **(6)** have shown in studies in commercial CT scanners that a two to three times increase in volume acquisition rate as compared with a single slice system is fully compatible with comparable image quality. Any further increase in acquisition speed leads to loss in image detail. The real speed advantage of these systems lies in their ability to obtain more volume studies at high resolution during a single breath hold. Multi-slice CT today is comparable to magnetic resonance imaging in many areas of clinical studies e.g. detection of aneurysms **(11)**.

Detector Designs

Two designs of detectors systems are currently employed

(a) Those that use evenly spaced partitions in the Z-axis (isotropic arrays). Slice widths are multiples of the row detector width, usually (1-1.25mm)

(b) Adaptive arrays: These have anisotropic partitions. They are built with fewer Z-axis partitions (currently 8) and have higher geometric efficiency compared to matrix/isotropic arrays. This design utilizes more of the x-ray photons that pass through the patient hence increasing the efficiency of the multiple detector system.

The detector geometry (5)

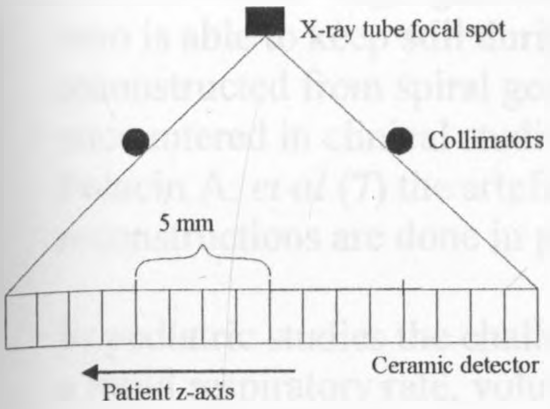


FIG 3: Matrix Detectors (Isotropic Array with 16 Partitions)

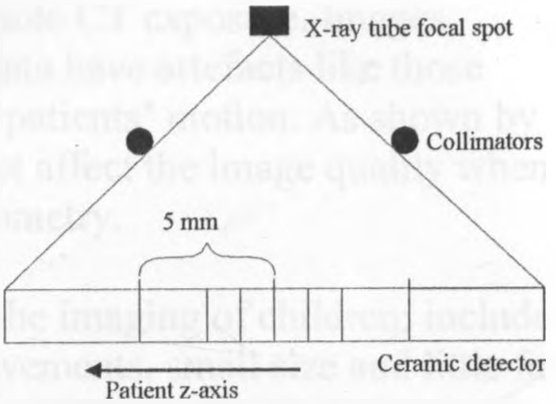


FIG 4: Anisotropic Array with 8 Partitions

Pre-patient collimators and the electronic combination of signals from partitioned detectors allow multi slice acquisition.

Clinical applications of Spiral CT

Spiral CT has the advantage of speed and therefore reduced scan time. However to get good images it requires a co-operative patient who is able to keep still during the whole CT exposure. Images reconstructed from spiral geometric data have artefacts like those encountered in clinical studies due to patients' motion. As shown by Polacin A. *et al* **(7)** the artefacts do not affect the image quality when reconstructions are done in planar geometry.

In pediatric studies the challenges in the imaging of children; include a rapid respiratory rate, voluntary movements, small size and little fat to provide intrinsic contrast. This may affect the image quality and repeat scanning is often required especially when conventional CT is used. Spiral CT is the method of choice to reduce motional blurr, radiation dose and the risk associated with prolonged sedation to children.

Studies by Geoffre D. *et al* **(8)** have demonstrated the role of spiral CT in vascular studies. Spiral CT reliably demonstrated second to fourth order aortic branch anatomy in good comparison with arteriography. Major aortic branches (renal, splenic and hepatic arteries) were clearly demonstrated to the hilum of the organ in all patients, with the exception of those vessels with high-grade stenoses.

The diagnosis of pulmonary embolism is often made with the use of radio- nuclide ventilation perfusion scans and pulmonary angiograms. However CT angiography has gained ground in pulmonary emboli detection and is now the imaging procedure of choice. While the ultimate patients' outcome is uncertain, the CT diagnosis of pulmonary emboli appears accurate and affects patients' care **(9)**.

Avian R. *et al* **(10)** conducted a hospital-based study to analyse the cost effectiveness of various diagnostic strategies (Spiral CT An giography, Conventional Pulmonary Angiography, Perfusion and Ventilation Scintigraphy, Ultra-Sound and D-dimer assay) in the diagnosis of suspected pulmonary embolism.

A single diagnostic test or combinations of up to five sequential diagnostic tests were implemented followed by anti-coagulant treatment when indicated. Three outcome parameters were assessed e.g., the mortality and morbidity at three months and the average realistic costs of diagnosis and therapy for pulmonary embolism. The marginal cost-effectiveness was determined by comparing the outcome of strategy with a no treatment strategy of zero cost. Results showed that with mortality as the primary outcome parameter the best strategies all made use of Spiral CT angiography. When preference was determined on the basis of cost per life saved, the best strategies again all contained Spiral CT angiography.

Helical CT, both, with and without the use of multi-planar reconstructions as demonstrated by Leslie E. Quint *et al* **(11)**, enabled highly accurate differentiation among diseases of the thoracic aorta e.g. aneurysms, dissections and ruptured aneurysm and predicted surgical planning for patients.

Limited spiral CT with colonic contrast material was able to demonstrate 64 true positive, two false negative, 128 true-negative, one false-positive and four indeterminate in a study to evaluate suspected appendicitis in children **(12)**. Spiral multi-detector CT has facilitated donor selection and surgical planning in potential donors being evaluated for living adult right lobe liver transplantation in studies by Mary T. *et al* **(13)**. Of the 40 potential donors, 15 patients (37.5%) were excluded on the basis of CT findings with most exclusion due to portal vein anomalies.

CT fluoroscopy with a slip-ring helical CT scanner modified by adding a high speed array processor to increase the speed of the image reconstruction has become important in biopsy and drainage procedures. It has been used to guide intra-cranial, chest, and abdominal and pelvic biopsy procedures. Radiation exposure is however high and remains a concern (mean patients dose 74cGy) **(14)**.

Surveys of CT use

Computed Tomography (CT) has been shown to have wide applications. It has made an enormous contribution to the diagnosis and treatment of disease. The use of CT has therefore increased rapidly in the past two decades, fuelled in part by the development of helical CT. This has resulted in an increasing medical radiation burden associated with CT examinations. By their nature CT examinations contribute disproportionately to the collective diagnostic radiation dose to the population.

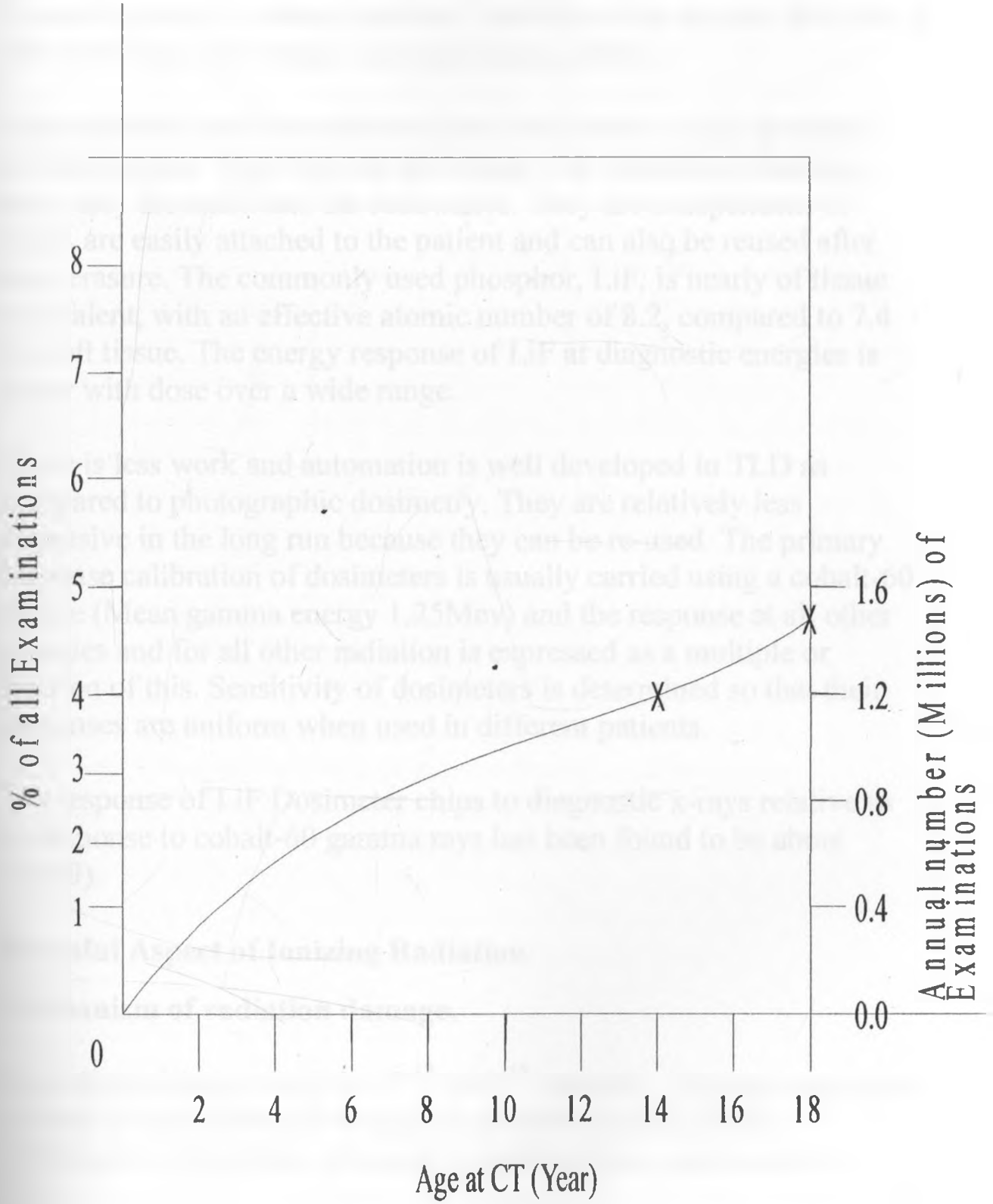
In the United Kingdom for example studies estimated CT examination to account for about 2.4% of all radiological examinations but account for 20% of the annual collective doses from medical X-Rays **(15 & 16)**.

Later studies performed by Shrimptom and *et al* in Britain have estimated that approximately 4% of diagnostic radiology procedures are CT examinations, but their contribution to the collective dose is approximately 40 % **(17)**.

Table 1 shows a breakdown of the number of CT examinations by age at examination based on the results of a 1989 British survey **(15)**. In this survey a million CT examinations were performed on children under the age of 15 years (4% of CT examinations).

In the United States the estimated annual number of CT examinations rose approximately ten fold from 2.8 million in 1981 **(18)** to 28 million in 1995 **(19)**.

TABLE 1: CT Examinations Frequency (British Survey 1989) (15).



Radiation Dosimetry

Quantities used to evaluate patients' radiation dose include skin dose, effective dose, and energy imparted among others.

Most methods use Thermoluminiscent Dosimeters to get absorbed radiation doses. They have an advantage over ionization chambers since they are small and un-obstructive. They are independent of leads, are easily attached to the patient and can also be reused after dose erasure. The commonly used phosphor, LiF, is nearly of tissue equivalent, with an effective atomic number of 8.2, compared to 7.4 for soft tissue. The energy response of LiF at diagnostic energies is linear with dose over a wide range.

There is less work and automation is well developed in TLD as compared to photographic dosimetry. They are relatively less expensive in the long run because they can be re-used. The primary response calibration of dosimeters is usually carried using a cobalt-60 source (Mean gamma energy 1.25Mev) and the response at all other energies and for all other radiation is expressed as a multiple or fraction of this. Sensitivity of dosimeters is determined so that their responses are uniform when used in different patients.

The response of LiF Dosimeter chips to diagnostic x-rays relative to its response to cobalt-60 gamma rays has been found to be about 1.3(**20**).

Harmful Aspect of Ionizing Radiation

Mechanism of radiation damage.

Immediate changes occur in 10^{-17} to10^{-15} seconds. Damage occurs as a result of ionization and excitation of atoms and molecules.
Two theories have been advanced to explain these mechanisms: -

Direct action of radiation

There is a sensitive volume in a cell or macromolecule (the target) which if inactivated leads to cell death, mutation or other biological effect. Energy of ionization is taken directly by target. Site of anatomical lesion e.g. chromosome break is also site of primary ionization responsible for damage.

Indirect action

Microscopic deposition of radiation energy leads to ionization and excitation of atoms and molecules. Radio-chemical reactions produce highly reactive chemical species (free radicals in tissue water). The free radical attacks DNA resulting in molecular damage/mutation and cell death. Radicals commonly produced are electrons, hydroxyl group, hydrogen and hydrogen peroxide. Radicals attack DNA and RNA. Radio- sensitivity in cells depends on type of cell, radiation dose, dose rate, position in a cell cycle, oxygen tension and cellular repair **(21)**.

Harmful aspects of radiation were recognized shortly after the discovery of X-Ray in 1895. Evidence for harmful effects of radiation has been obtained from the study of Japanese atomic bomb survivors. The study findings provided the most reliable data on radiation effects e.g. somatic effects such as cancer induction, developmental abnormalities and hereditary effects, which are expressed in the descendants of the exposed person. Radiation effects were classified into either deterministic or stochastic effects. ***Deterministic Effects***: Have a threshold dose above which the severity of the effects is related to dose. Examples are: -

I. Development of cataracts in the eye
II. Erythema of the skin
III. Skin burns and loss of hair
IV. Impaired fertility

TABLE 2: Threshold Doses for Some Deterministic Effects in the More Radiosensitive Human Tissues According To the ICRP 1991 Report. (22)

Human tissues and effects	Threshold total Equivalent dose for Acute exposure (Sv)	Annual dose rate Sv/year
TESTES		
Temporary sterility	0.15	0.4
Permanent sterility	3.5-6.0	>0.4
OVARIES		
Sterility	2.5-2.0	>0.2
LENS		
Detectable Opacities	0.5-2.0	>0.15
Visual Impairment	5.0	>0.15

1 Sievert = 100rems

Since threshold doses for deterministic effects are quite low in some organs, low dose limits are therefore needed to protect these particular organs.

Stochastic Effects: There is no threshold dose below which radiation induced effects will not occur. The probability of the occurrence of stochastic effects is a function of the radiation dose but the severity of these conditions is not dose related. Examples of stochastic effects are cancer induction and most of hereditary effects. Stochastic effects cannot be completely prevented however much you lower the radiation dose. No amount of radiation is therefore considered absolutely safe and the ALARA principle of keeping doses as low as reasonably achievable was recommended.

Risk co-efficient has been derived for: -

a) Somatic effects i.e. risk of inducing fatal and non-fatal cancer.
b) Hereditary effects
c) In Utero exposure i.e. risks of fetal death, growth abnormalities, mental retardation and childhood cancers.

In 1977 the ICRP in its publication article 26 gave for radiation protection purposes, risk of fatal Leukaemia at 0.2×10^{-2}/Sv based on a ratio of about one leukaemia, relative to five cases of non-leukaemia cancer **(23).**

The risk of death due to radiation induced stomach cancer from a 1-Gy dose is about two excess cases per year per10000 exposed individuals and is second only to leukaemia as a cause of death by specific radiation induced cancers among the Japanese atomic bomb survivors **(24).**

A study of about 1600 children exposed in utero at Hiroshima and Nagasaki to various doses at various developmental stages confirmed about 30 of them to develop clinical severe mental retardation. The mental retardation was not observed before 8 weeks from conception but was maximum between 8 and 15 weeks. The incident of mental retardation as function of dose was reported to be linear without a thresh hold at 8 to 15 weeks, with a risk co-efficient of 0.4 per gray. The incident is a bout 4 times lower at 16-25 week **(25).**

The UNSCEAR committee attempted to derive quantitative risk estimates for a number of radiation induced effects in utero (Mortality, Induction of Malformations, Mental Retardation, Tumours and Leukaemia) and to attribute risk to the periods of pregnancy. They concluded that for the small doses likely to be encountered in practice, the overall risk is relatively small (no more than 0.002 for the live born at 0.01 gray) in relation to the natural incidence of malformations in non-irradiated individuals, which is in the order of 0.06 in the human species **(25).**

The predominant risk to patients undergoing abdominal CT is the induction of cancer. The best estimate currently in use for general population is five percent risk per Sievert **(22).** An effective dose of 6mSv for abdominal CT examination thus corresponds to a nominal cancer fatality risk of approximately 3 in 10000 patients.

Radiation Dose during CT Examinations

With the advent of spiral/helical systems various arguments were advanced that the improvement in technology could be associated with reduced radiation dose to patients, but CT both in the old and new forms still undoubtedly represented a significant radiation burden.

McCrohan JL, etal **(26)** and Mini RL, etal **(27)** have respectively estimated the typical surface radiation dose to adults from multiple adjacent CT slices as 30 – 70 mGy (3.0 – 7.0 rad) per head scan series and 20 – 50 mGy (2.0 – 5.0 rad) for each abdominal series. For standard measurements with phantoms, the head radiation dose is nearly uniform; the body radiation dose is essentially uniform over the surface and decreases to about half at the centre **(26 – 27)**. The radiation received by a patient undergoing any type of diagnostic radiology examination is best quantified by the effective dose **(28)**.

In a study by Ware DE. *etal* **(29)** to determine the radiation effective dose to adult and pediatric patients undergoing abdominal computed tomographic (CT) examinations at 120kvp and approximately 7mm slice thickness for all size of patients, results showed mean values (±SD) of **energy imparted** were 72.1 mJ ±24.4 for children, 183.5mJ ±44.8 for young adults and 234.7mJ ±89.4 for adults. The corresponding mean values of patient **effective dose** were 6.1 mSv ± 1.4 for children, 4.4 mSv ±1.0 for young adults and 3.9mSv ±1.1 for adults. Findings revealed that doses (**energy imparted**) were a factor of three higher in adults than children, but corresponding patient effective doses were 50% higher in child than adult. Findings also demonstrated that effective radiation doses to patients from abdominal CT to be at the upper end of patient doses encountered in diagnostic radiology. Doses to patients from abdominal CT examinations are comparable to those in nuclear medicine (2 – 10mSv), barium examination (3-7mSv), and excretory urography (2.5-5.0mSv) and are markedly higher than those associated with chest radiography (0.02-0.05mSv), skull examinations (0.1-0.2mSv), or abdominal radiographic examinations (0.5-1.5mSv) **(28)**.

Van Unnik JG *et al* **(30)** did a survey of CT techniques and absorbed doses in various Dutch hospitals to make an inventory of the radiation dose from CT in the Netherlands and to relate the dose to the way CT was performed. Details were obtained from approximately 3000 CT examinations carried out in 22 hospitals (22 CT scanners). The mean effective doses from brain CT were 0.8-5mSv, from lumbar spine CT 2-12 mSv, from chest CT 6-18mSv, and from abdominal CT 6-24 mSv.

In a study done to compare radiation dose and resolving power of commercial CT scanner **(31)**, findings demonstrated a uniform improvement in image quality with newer CT machines at generally lower radiation doses than observed in 1977. High contrast resolving power improved by 31% from an average of 2.0 to 1.3mm with reduction of average skin dose from 2.2 rad (0.022Gy) to 1.5 rad (0.015Gy)
The findings are summarized in Table 3.

TABLE 3: Skin Dose and Resolving Power with 66 Cm Phantom (31).

CT Model (Year)	Average Quadrant Skin Dose Rad	Gy	High contrast 12%) Resolving power (mm)
General electric 8800 (1980)	0.5	0.005	1.25
EMI 7070 (1979)	1.0	0.01	1.00
Pfizer 0450 (1979)	4.6	0.046	1.50
Technicare Delta 2020 1980	2.2	0.022	1.25
Elscint Excel 905 (1980)	0.8	0.008	1.50-1.75
Picker Synerview 600 (1980)	1.0	0.01	1.25
Siemens Somatom 2 (1980)	0.6	0.006	1.50
Mean:	**1.5**	**0.015**	**1.38**
General Electric CT/T7800 (1977)	0.5	0.005	2.25
EMI, CT 500 (1977)	3.1	0.031	2.25
Pfizer 200 FS (1977)	2.3	0.023	2.00
Ohio Nuclear Delta 50 FS (1977)	1.0	0.01	2.00
Ohio Nuclear Delta 50 (1977)	1.8	0.018	2.00
Varian CT ((1977)	4.3	0.043	1.75
Mean:	**2.3**	**0.022**	**2.00**

Golin U. *et al* **(32)** by using Somaton plus S. Spiral CT systems was able to demonstrate doses to various organ systems with different standard protocols. The dose from abdominal CT was 24mSv to liver, 19.4mSv to ovary, 15.3mSv to lungs, and 6.4mSv to testis and 26.6mSv to skin. The doses are illustrated in table 4.

TABLE 4: Radiation Doses for Standard Protocols on a Typical Spiral CT System

	Cranial CT	Chest CT	Abdominal CT	Lumbar CT
Orbit	4.8	-	-	-
Parotid	28.8	-	-	-
Thyroid	1.4	3.5	-	-
Lung	-	22.1	15.3	-
Liver	-	4.3	24.1	4.4
Ovary	-	-	19.4	10.7
Testis	-	-	6.4	1.9
Skin	-	19.0	26.6	-
Typical Effective dose	2.3	8.0	10.0	10.0

All Values in mSv.

Becker CR, *et al* **(33)** did a study to compare radiation exposure applied by different types of CT scanners for the investigation of the chest and the abdomen. Estimation of the dose in air in the system axis of the scanner, the CT dose index (CTDI) and the effective dose was done for electron beam Tomography (EBT) and two Conventional CT scanners (sequence, SEQ; spiral, SCT). For EBT, dose in system axis for investigation of the abdomen was above 50 mGy. Effective dose for investigation of the chest and abdomen was higher with EBT (11 and 26 mSv, respectively) than with conventional CT (SEQ, 4 and 20mSv; SCT, 2 and 7mSv). The effective dose for a biphasic investigation (liver 5 mSv, kidney 4mSv) was below, for a triphasic investigation (liver 7 mSv) and above the effective dose of the investigation of the abdomen (6 mSv). With spiral CT, effective dose is lower than with EBT and conventional CT.

Dr. Changale H.B in his study of skin doses during CT scan of the Para nasal sinuses also found skin doses to be lower during spiral CT **(34)**. Evaluation of the ability of thin overlying bisthmuth in radio-protective shielding to reduce x-ray dose to radiosensitive superficial organs during diagnostic computed Tomography (CT) has been done by KD Hopper *et al* **(35)**. A prototype and then a final manufactured radio protective brassiere was constructed and tested during diagnostic chest CT. Preliminary studies were also performed to evaluate shielding of the thyroid, orbit and testis. Result showed that the use of bisthmuth radio protective latex reduced by 55% the radiation dose to the breast from an average 2.2rad (0.022Gy) to 1.0rad (0.010Gy) ($P < 0.001$). Preliminary tests of shielding other superficial radiosensitive organs frequently included at diagnostic CT (Eyes, thyroid gland, and testis) were performed with same thickness of overlying bisthmuth with similar results. Radiation to the thyroid gland was reduced by 60% (from 0.0573 to 0.0229Gy) and radiation to the eye and testes was reduced by 40% (from 0.0256 to 0.0154Gy) and 51% (from 0.0463 to 0.0229Gy), respectively. The diagnostic quality of the CT image was however not affected.

An attempt has also been made to demonstrate the effects of scan parameters on the image quality and radiation dose of CT scanners. Scan parameters were recorded and associated measurements of noise, spatial resolution and the total absorbed dose obtained by using head and body phantoms. The data has demonstrated how recent advances in detector efficiency have significantly reduced the total absorbed dose and how decreasing slice width from 2mm to 1mm increased the absorbed dose value by up to 100% **(36)**. Another study showed that a two-fold reduction in mAs from 400 to 140 (leaving the kilo voltage constant) led to reduction in radiation dose but did not cause a significant change in the subject image quality to affect diagnosis of mediastinal and lung abnormalities e.g. mediastinal adenopathy, lung parenchymal nodes and emphysema **(37)**.

Radiation dose is linearly related to amperage at a fixed kilo voltage. Reduction in amperage leads to reduction in radiation dose. Thus optimal CT tube current is an appropriate balance between image quality and radiation dose. Further reduction in mAs however leads to degradation of image quality due to quantum noise **(38 & 39)**.

MATERIALS AND METHODS

Study Design

This study was comparative and cross sectional.

Study Area: This study was carried out at MP Shah Hospital and Medical Imaging and Therapeutic Centre (MITC) all situated in Nairobi, Kenya. MITC is a privately owned institution and owns both the CT scan units.

Sample Size

The study involved 81 patients who presented for CT scan examination of the abdomen between September 2002 and March 2003 in these centres. Patient selection was random. 35 patients underwent conventional CT examination at MP Shah, 36 patients underwent spiral CT examination at MITC, and 10 patients were assessed during topogram examination at MP Shah.

The CT Equipment (MITC)

The scanner is a Siemens Somatom AR-SP scanner (Siemens, Erlangen, Germany). It has both spiral and sequential capabilities. At this centre, the abdominal CT scans were done in spiral mode. The CT parameters used for all the patients were: 130Kvp, 83mA, 10mm slice thickness and pitch of 1.

CT Equipment (MP Shah)

The unit is a Siemens Somatom ART /Sequential (Siemens Erlangen, Germany). It has sequential mode capabilities only. All the CT scans of abdomen were done in sequential mode. The CT parameters used were 130 kV, 70mA, 10mm slice thickness and pitch of 1.

Preparation of TLD (Thermo-Luminescent Dosimeters)

Lithium Fluoride Thermoluminiscent dosimeters (Harshaw Co) in the form of extruded ribbons and chips were used to measure absorbed radiation doses. Preparation for use involved annealing them completely by placing them in the oven at 400^0C for 1 hour followed by rapid cooling, then 100^0C for 2 hours. After annealing, the dosimeters were grouped into different sizes and physical forms.

Extruded ribbon dosimeters of same length and width but of different thickness (Harshaw Company) were used.

(i) Thicker ones were labelled A (0.125" x 0.125" x 0.015").

(ii) Thinner ones were labelled B (0.063" x 0.125" x 0.015").

Two dosimeters from group A and from group B were separated from the rest and their light output measured in the TLD reader. They were to act as controls for determining the amount of background radiation in the environment.

Calibration of Dosimeters

All dosimeters were irradiated with 60Co radiation in a Perspex phantom to an absorbed dose of 2800 mrad, and the read out was determined on the Toledo 654 TLD Reader (Vinten Co., U.K.) to obtain a calibration. Details of the calculations are presented in Appendix 4.

The TLD Reader Heating System

The TLD Reader was programmed to measure the signal from LiF glow peaks 4&5. Pre-read anneal was achieved by heating at 135^0Cfor 16 seconds, followed by the read at 240^0c for 16 seconds, and a post- read anneal at 300^0C for 16 seconds.

The purpose of the pre-heat is to empty the low temperature traps, which tend to fade rather rapidly, and thus to eliminate any dependence of read out on time after exposure.

Dose measurements during CT scan of abdomen.

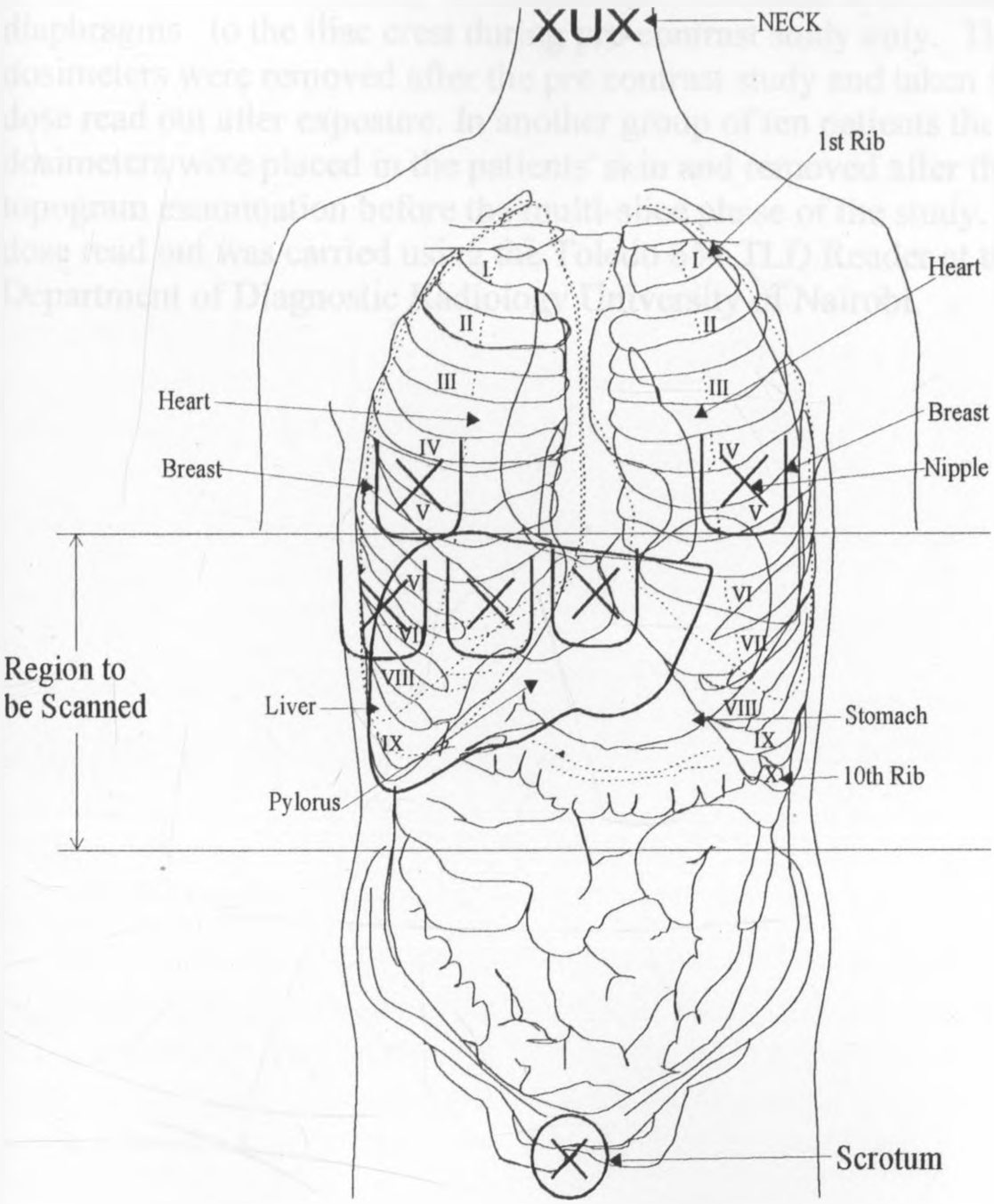
Group A and B dosimeters were used.
Radiation doses to the patient skin and nearby organs were measured by placing Lithium Fluoride dosimeters on the surface of the skin at anatomical sites corresponding to

(a) Thyroid Glands: Either sides of the midline just below the laryngeal prominence in the neck for left and right thyroid lobe.
(b) Left Lobe of Liver: Center of the epigastrium.

(c) Right lobe of the liver:
  (i) In the mid-clavicular line just above the right lower costal margin.
  (ii) Mid-axillary line in line with the one placed in the mid-clavicular line.
(d) Breasts:
  (i) Females: In the middle of the lower quadrant on either breast.
  (ii) Males: placed in the areolar region.
(e) Testis: anterior scrotal skin.

Dosimeter placement sites on the patients' skin are illustrated in Figure 5.

FIG 5: Lithium Floride Dosimeter Placement Sites



X - Dosimeter placement site

The CT scan examination involved the topogram and the multi-slice study. The multi-slice study was taken from the dome of the hemi-diaphragms to the iliac crest during pre-contrast study only. The dosimeters were removed after the pre contrast study and taken for dose read out after exposure. In another group of ten patients the dosimeters were placed in the patients' skin and removed after the topogram examination before the multi-slice phase of the study. The dose read out was carried using the Toledo 654 TLD Reader at the Department of Diagnostic Radiology University of Nairobi.

RESULTS:

Light output of dosimeters placed at various skin sites (Liver, Breast, Thyroid and Scrotum) and the corresponding calculated skin doses during spiral and conventional CT examination of the abdomen are shown in tables 5 to 16.

The mean skin doses at the sites corresponding to the liver, breast, thyroid and testis during abdominal CT examination are tabulated below.

Mean Skin Doses

Multi-Slice CT

ORGAN/TISSUE	SEQUENTIAL CT DOSE (mean value in **mGy**)	SPIRAL CT DOSE (Mean value in **mGy**)
LIVER	**88.8**	**92.8**
BREAST	**9.89**	**10**
THYROID	**2.85**	**2.52**
TESTIS	**1.23**	**1.33**

Mean Skin Doses (Topogram/MP Shah Hospital)

ORGAN/TISSUE	DOSE DELIVERED
LIVER	**109.5mrad (1.1mGy)**
BREAST	**115.5mrad (1.2mGy)**
TESTIS	**122mrad (1.22mGy)**
THYROID	**12.7mrad (0.127mGy)**

The study revealed no significant differences in skin doses during sequential or spiral abdominal CT scanning. The mean skin doses during abdominal CT scanning (Topogram and Multislice study) were highest to the liver followed by the breast, thyroid and lowest for testis. The mean skin doses during topogram examination were lower as compared to the multislice examination.

The multislice study contributed 96.4% of the mean skin dose to the thyroid as compared to 3.6% from the topogram study. The dose to thyroid was therefore as a result of scatter radiation during multislice study.

The topogram study contributed 95.3% of the testicular skin dose as compared to 4.7% from the multislice. The scatter radiation to the testicular skin dose during multislice study was minimal.

TABLE 5: Light Output of Dosimeter (Digits) and Calculated Skin Absorbed Doses for Liver-Multislice (MP Shah)

NO	SEX	L1 (DIGITS)	GROUP OF DOSIMETER USED	L2 (DIGITS)	GROUP OF DOSIMETER USED	L3 (DIGITS)	GROUP OF DOSIMETER USED	AVERAGE TLD OUTPUT DIGITS	AVERAGE MINUS BACKGROUND	SKIN DOSE CALC RADS
1	F	26159	A	30088	A	18190	A	24812	24712	18.4
2	F	22257	A	26874	A	31360	A	26830	26730	19.9
3	F	17225	B	9628	B	8889	B	11914	11850	14.8
4	M	20805	A	8883	A	8426	A	12704	12604	9.4
5	F	22483	A	17884	A	15257	A	18541	18441	13.7
6	F	17550	A	11242	A	9875	A	12889	12789	9.5
7	M	8234	B	9509	B	8592	B	8798	8678	6.4
8	F	17659	A	17548	A	18907	A	18038	17938	13.3
9	M	11657	B	10153	B	22958	A	14922	14822	11.0
10	F	14000	A	14724	A	14477	A	14400	14300	10.6
11	F	17508	A	22666	A	19767	A	19980	19880	14.8
12	F	12885	B	12888	B	12339	B	12704	12640	15.8
13	F	14516	A	21718	A	18421	A	18217	18117	13.5
14	F	13608	A	18978	A	22068	A	18218	18118	13.5
15	F	6940	A	5202	A	8096	A	6746	6646	4.9
16	F	17257	A	23898	A	23327	A	21494	21394	15.9
17	M	11694	A	21921	A	26981	A	20198	20098	14.9
18	M	19706	A	18885	A	8707	A	15766	15333	11.6
19	F	18676	A	13762	A	19966	A	17468	17368	12.9
20	M	14038	A	16437	A	18323	A	16266	16166	12.0
21	F	13437	A	23091	A	15344	A	17290	17190	12.8
22	M	4763	B	7053	B	10286	B	7367	7303	9.1
23	F	21055	A		A	24210	A	22627	22527	16.7
24	F	21013	A	21013	A	14377	A	18801	18701	13.9
25	M	18948	A	12269	A	26342	A	19186	19066	14.8
26	F	17638	A	12938	A	19097	A	16588	16488	12.2
27	F	11339	A	11890	A	15047	A	12758	12658	9.4
28	M	7926	B	8531	B	11307	B	9254	9090	11.4
29	F	17678	A	11749	A	16828	A	15418	15318	11.4
30	F	20461	A	21140	A	17961	A	19859	19754	14.7
31	F	18285	A	17684	A	12759	A	16242	16142	12
32	M	9754	A	17648	A	23198	A	16866	16767	12.5
33	F	18244	A	14027	A	21855	A	18042	17942	13.3
34	F	18787	A	9568	A	18082	A	15479	15379	11.4
35	M	9451	A	7527	A	8021	A	8332	8232	6.1

TABLE 6: Light Output of Dosimeter and Calculated Skin Absorbed Doses for Liver-Multislice (MITC)

NO	SEX	L1 (DIGITS)	GROUP OF DOSIMETER USED	L2 (DIGITS)	GROUP OF DOSIMETER USED	L3 (DIGITS)	GROUP OF DOSIMETER USED	AVERAGE READ OUT IN DIGITS	AVERAGE MINUS BACKGROUND RADIATION	CALCULATED DOSE mrads
1	M	16210	A	22552	A	15035	A	17932	17832	13248
2	F	12682	A	13423	A	13873	A	13326	13226	9826
3	M	19317	A	20890	A	19127	A	19778	19678	14619
4	M	6909	A	6858	A	9129	A	7632	7532	5595
5	F	20185	A	22720	A	20368	A	21091	20991	15595
6	F	6011	A	10542	A	6264	A	7606	7506	5576
7	M	9029	B	10448	B	11883	B	10450	10386	12982
8	F	10384	A	7449	A	8037	A	8623	8523	6332
9	F	5020	B	5313	B	4518	B	4950	4886	6107
10	F	23857	A	9111	A	19254	A	17407	17307	12858
11	M	10040	A	11469	A	25019	A	15509	15409	11447
12	M	8068	A	6949	A	6945	A	7322	7222	5363
13	F	10415	A	23116	A	10523	A	14685	14585	10836
14	F	25566	A	15477	A	19341	A	20120	20020	14874
15	M	8854	A	6589	A	18698	A	11380	11280	8380
16	F	17901	A	18263	A	10601	A	15588	15488	11506
17	F	26902	A	34036	A	25133	A	28690	28590	21241
18	F	16747	A	21017	A	15682	A	17715	17715	13161
19	M	13184	A	10580	A	24827	A	16194	16094	11957
20	F	22490	A	15224	A	17195	A	18303	18203	13524
21	F	10876	A	9089	A	10671	A	10212	10112	7513
22	F	9678	A	11800	A	18553	A	13344	13244	9839
23	F	13851	A	9933	A	13346	A	12276	12276	9120
24	F	19371	A	24016	A	25400	A	22947	22897	16974
25	M	11829	A	19010	A	12870	A	14570	14470	10750
26	M	28350	A	25314	A	18420	A	24028	23928	17777
27	M	15883	A	11511	A	12300	A	13231	13131	9755
28	F	15553	A	17625	A	19144	A	17440	17340	12883
29	F	32217	A	30862	A	30787	A	31288	31188	23171
30	M	13700	A	13298	A	30723	A	19240	19140	14220
31	M	17730	A	21493	A	13280	A	17501	17401	12928
32	M	25157	A	28099	A	19207	A	24154	24054	17871
33	F	22257	A	26874	A	31360	A	26830	26730	19857
34	F	19578	A	15550	A	15262	A	16797	16697	12405
35	F	15912	A	11383	A	17252	A	14849	14749	10958
36	F	10493	A	15944	A	17127	A	14521	14421	10713

TABLE 7: Light Output of Dosimeter and Calculated Skin Absorbed Doses for Breast-Multislice (MP Shah)

NO	SEX	AGE YRS	BR (DIGITS)	GROUP OF DOSIMETER USED	BL (DIGITS)	GROUP OF DOSIMETER USED	AVERAGE TLD OUTPUTDIGITS	AVERAGE MINUS BACKGROUND	SKIN DOSE CALC mrads
1	F	35	1222	A	1536	A	1379	1279	0950
2	F	8/12	4390	A	5052	A	4721	4621	3433
3	F	80	1550	B	1372	B	1461	1427	1783
4	M	69	1919	B	2245	B	2082	1982	1472
5	F	66	1332	A	2368	A	1850	1750	1300
6	F	50	1721	A	1658	A	1685	1585	1777
7	M	19	1432	A	1093	A	1263	1163	0864
8	F	76	962	B	700	B	831	767	0959
9	M	40	1829	A	1051	A	1440	1340	0995
10	F	40	1188	A	1835	A	1512	1412	1049
11	F	69	2182	A	2298	A	2240	2140	1589
12	F	52	934	B	735	B	844	780	0775
13	F	41	2724	A	2847	A	2786	2686	1996
14	F	32	1900	A	1828	A	1864	1764	1311
15	F	65	935	A	605	A	770	670	0497
16	F	30	3654	A	4075	A	3865	3765	2797
17	M	17	1296	A	1649	A	1447	1373	1020
18	M	40	1699	A	1166	A	1433	1333	0990
19	F	54	490	A	673	A	582	482	0358
20	M	72	754	A	757	A	757	657	0488
21	F	28	1804	A	1890	A	1847	1747	1297
22	M	35	2061	B	2028	B	2045	1981	1472
23	F	54	2100	A	2659	A	2380	2280	1693
24	F	52	2224	A	2211	A	2218	2118	1574
25	M	21	1438	A	2156	A	1797	1697	1260
26	F	68	3110	A	2500	A	2805	2705	2009
27	F	62	2838	B	2700	B	2769	2669	3336
28	M	50	1162	B	706	B	934	834	1043
29	F	45	1755	A	1936	A	1846	1746	1297
30	M	80	2603	A	2744	A	2644	2544	1964
31	F	52	1984	A	1205	A	1594	1499	1110
32	M	50	2632	A	3793	A	3212	3112	2312
33	F	52	2529	A	2676	A	2603	2503	1859
34	M	46	1473	A	1631	A	1552	1452	1079

TABLE 8: Light Output of Dosimeter and Calculated Skin Absorbed Doses for Breast-Multislice (MITC)

No	SEX	AGE YRS	BR (DIGITS)	GROUP OF DOSIMETER USED	BL (DIGITS)	GROUP OF DOSIMETER USED	AVERAGE TLD OUTPUT DIGITS	AVERAGE MINUS BACKGROUND	SKIN DOSE CALC mrads
1	M	67	1069	A	974	A	1021	921	0684
2	F	50	2716	A	3247	A	2981	2881	2140
3	M	50	2567	A	1567	A	2064	1964	1459
4	M	31	2486	A	684	A	722	672	0499
5	F	32	1355	A	988	A	1170	1070	0795
6	F	32	954	A	911	A	933	868	1085
7	M	55	2011	A	1956	A	1984	1844	1400
8	F	12	1837	A	2082	A	1960	1860	1382
9	F	49	920	A	837	A	879	779	0579
10	F	47	1845	A	1141	A	1493	1393	1035
11	M	33	1688	A	1450	A	1569	1469	1091
12	M	46	1261	A	1052	A	1156	1056	0784
13	F	44	1925	A	1543	A	1734	1634	1214
14	F	44	1470	A	1754	A	1612	1512	1123
15	M	59	1816	A	1493	A	1655	1555	1150
16	F	81	3255	A	2699	A	2974	2874	2135
17	F	24/12	6092	A	6230	A	6161	6061	4502
18	F	62	2073	A	2965	A	2519	2419	1797
19	M	74	1443	A	1274	A	1358	1258	0935
20	F	55	923	A	1326	A	1129	1029	764
21	F	7/12	2563	A	2045	A	2304	2204	1637
22	F	46	1530	A	1620	A	1575	1475	1170
23	F	49	659	A	648	A	1307	1243	1554
24	F	47	3684	A	3340	A	3512	3412	2535
25	M	39	2464	A	948	A	1706	1606	1193
26	M	64	1654	A	1800	A	1727	1627	1209
27	M	42	2489	A	3206	A	2847	2747	2041
28	F	37	1057	B	2298	A			1414
29	F	24	1173	B	1828	A			1334
30	M	45	2116	A	1807	A	1962	1862	1383
31	M	45	815	A	738	A	776	712	0890
32	M	42	1789	A	1014	B			1102
33	F	8/12	4390	A	5052	A	4721	4621	3433
34	F	52	1905	A	1725	A	1815	1715	1274
35	F	6	2121	A	2255	A	2188	2088	1551

TABLE 9: Light Output of Dosimeter and Calculated Skin Absorbed Doses for Thyroid-Multislice (MP Shah)

NO	AGE	TR	GROUP OF DOSIMETER USED	TL	GROUP OF DOSIMETER USED	AVERAGE TLD OUTPUT DIGITS	AVERAGE MINUS BACKGROUND	SKIN DOSE CALC mrads
1	35	545	A	608	A	577	477	0354
2	8M	1337	A	2069	A	1703	1603	1190
3	80	804	B	863	B	833	769	0961
4	69	426	A	509	A	468	368	0273
5	66	846	A	810	A	828	728	0540
6	50	463	A	550	A	507	407	0302
7	19	326	A	331	A	329	229	0170
8	76	426	B	358	B	392	328	0410
9	40	468	A	598	A	533	433	0322
10	40	472	A	567	A	520	420	0312
11	69	591	A	485	A	538	438	0325
12	52	305	B	318	B	312	248	0310
13	41	770	A	903	A	837	737	0547
14	32	639	A	705	A	672	572	0425
15	65	301	A	489	A	395	295	0219
16	30	486	A	524	A	505	405	0300
17	48	354	A	312	A	333	233	0173
18	40	442	A	468	A	445	345	0256
19	54	294	A	295	A	295	195	0142
20	72	661	A	479	A	402	302	0224
21	28	594	A	623	A	569	469	0348
22	35	419	B	419	B	419	353	0443
23	54	639	A	675	A	657	557	0414
24	52	434	A	345	A	390	290	0215
25	21	443	A	384	A	414	314	0233
26	62	389	B	677	B	533	433	0541
27	50	319	B	250	B	285	221	0276
28	45	660	A	1023	A	984	884	0657
29	80	524	A	458	A	491	391	0290
30	52	456	A	359	B		259	0293
31	50	339	B	292	B	316	216	0270
32	52	621	A	537	A	579	479	0356
33	34	452	B	235	B	344	280	0350
35	58	135	A	476	A	306	206	0153
34		559	A	481	A	520	420	0312

TABLE 10: Light Output of Dosimeter and Calculated Skin Absorbed Doses for Thyroid-Multislice (MITC)

No	SEX	AGE YRS	TR (DIGITS)	GROUP OF DOSIMETER USED	TL (DIGITS)	GROUP OF DOSIMETER USED	AVERAGE TLD LIGHT OUTPUT DGITS	AVERAGE MINUS BACKGROUND	SKIN DOSE CALC mrads
1	M	67	336	A	396	A	360	260	0193
2	F	50	687	A	767	A	724	624	0463
3	M	50	887	A	821	A	854	754	0560
4	M	31	342	A	528	A	435	355	0249
5	F	32	345	A	351	A	340	240	0178
6	F	32	381	B	423	B	402	338	0422
7	M	55	648	A	644	A	640	240	0401
8	F	12	857	A	779	A	810	338	0527
9	F	49	386	A	376	A	381	540	0208
10	F	47	647	A	489	A	560	710	0342
11	M	33	551	A	560	A	555	281	0338
12	M	46	674	A	255	A	465	460	0271
13	F	44	1032	A	737	A	885	455	0583
14	F	44	559	A	468	A	513	365	0309
15	M	59	611	A	639	A	625	785	0390
16	F	81	526	A	484	A	505	413	0301
17	F	24/12	2207	A	1698	A	953	525	0377
18	F	62	493	A	497	A	495	405	0286
19	M	74	553	A	485	A	519	419	0311
20	F	55	532	A	531	A	530	430	0319
21	F	7/12	941	A	923	A	932	832	0618
22	F	46	850	A	691	A	770	670	0497
23	F	49	296	B	325	B	310	246	0307
24	F	47	991	A	889	A	940	840	0624
25	M	39	471	A	480	A	475	375	0279
26	M	64	559	A	640	A	599	499	0371
27	M	42	613	A	608	A	610	510	0379
28	F	3	684	B	1258	A			0817
29	F	24	621	B	604	A			0535
30	M	45	524	A	416	A	370	370	0274
31	M	45	255	B	510	A			0272
32	M	42	250	B	311	B	217	217	0271
33	F	8/12	1337	A	2069	A	1603	1603	1190
34	F	52	426	A	426	A	326	326	0242
35	F	52	314	B	320	B	253	253	0316
36	F	6	892	A	997	A	944	844	0627

TABLE 11: Light Output of Dosimeter and Calculated Skin Absorbed Doses for Scrotum-Multislice (MP Shah)

NO	SEX	AGE	TLD LIGHT OUTPUT.	GROUP OF DOSIMETER USED	LIGHT OUTPUT MINUS BACKGROUND	SKIN DOSE CALC mrads
1	M	69	308	A	208	0154
2	M	19	309	A	209	0155
3	M	40	117	A	17	0012
4	M	48	447	A	347	0258
5	M	40	294	A	194	0144
6	M	72	324	A	224	0166
7	M	35	448	B	384	0480
8	M	21	231	A	131	0097
9	M	50	244	A	144	107
10	M	50	195	B	131	0164
11	M	58	565	A	465	0345
12	M		400	A	300	0223

TABLE 12: Light Output of Dosimeter and Calculated Skin Absorbed Doses for Scrotum-Multislice (MITC)

NO	SEX	AGE YEARS	TLD output DIGITS	TLD OUTPUT MINUS BACKGROUND	SKIN DOSE CALC mrads
1	M	67	149	49	036
2	M	50	233	133	098
3	M	31	430	330	245
4	M	55	440	376	470
5	M	33	226	126	093
6	M	46	262	162	189
7	M	59	152	52	038
8	M	74	321	321	193
9	M	39	216	116	2 29
10	M	64	693	593	440
11	M	42	227	127	094
12	M	45	212	148	185
13	M	45	237	183	216
14	M	42	396	332	415

TABLE 13: Light Output of Dosimeter and Calculated Skin Absorbed Doses for Liver-Topogram (MP Shah).

NO	L1-DIGITS	GROUP OF DOSIMETER USED	L2-DIGITS	GROUP OF DOSIMETER USED	L3-DIGITS	GROUP OF DOSIMETER USED	AVERAGE TLD output DIGITS	AVERAGE MINUS BACKGROUND	SKIN DOSE CALC mrads
1	138	A	239	A	490	A	284	184	140
2	438	A	176	A	168	A	258	158	117
3	171	A	282	A	644	A	365	265	197
4	104	A	224	A	602	A	310	210	156
5	149	A	111	A	336	A	199	99	73
6	152	A	237	A	530	A	306	206	153
7	35	A	198	A	378	A	203	103	77
8	552	A	552	A	184	A	429	329	244
9	295	A	438	A	498	A	410	310	230
10	136	B	541	A			338	238	177

TABLE 14: Light Output of Dosimeter and Calculated Skin Absorbed Doses for Breast-Topogram (MP Shah).

NO	BR-DIGITS	GROUP OF DOSIMETER USED	BL-DIGITS	GROUP OF DOSIMETER USED	AVERAGE TLD output DIGITS	SKIN DOSE CALC mrads
1	415	A	219	B		238
2	373	A	253	B		198
3	249	A	284	A	267	198
4	170	A	170	A	170	126
5	224	A	227	A	225	167
6	199	B	256	A		129
7	319	A	223	B		168
8	293	A	134	B		103
9	825	A	564	A	694	515
10	117	A	115	B		25

TABLE 15: Light Output of Dosimeter and Calculated Skin Absorbed Doses for Scrotum-Topogram (MP Shah).

NO	GROUP OF DOSIMETER USED	TLD OUTPUT DIGITS	OUTPUTMINUS BACKGROUND	SKIN DOSE CALC Mrads
1	A	187	87	64
2	A	590	490	364
3	A	209	109	81
4	A	116	16	72
5	A	587	487	361
6	A	511	411	305

TABLE 16: Light Output of Dosimeter and Calculated Skin Absorbed Doses for Thyroid-Topogram (MP Shah).

NO	TR-digits	GROUP OF DOSIMETER USED	TL-digits	GROUP OF DOSIMETER USED	AVERAGE TLD OUTPUT DIGITS	AVERAGE MINUS BACKGROUND	SKIN DOSE CALC mrads
1	107	B	124	B	115	31	38.8
2	64	B	106	B	85	1	1.25
3	112	B	170	B	141	54	675
4	96	B	79	B	875	3.5	4.4
5	92	B	85	B	88.5	4.5	5.6
6	110	B	134	A			25.3
7	154	A	271	B			136.8
8	71	B	119	B	95	11	13.8
9	135	A	177	A	150	50	37.2
10	94	B	112	A			10.7

DATA ANALYSIS

Mean doses for the two types of CT procedure were compared. Geometrical mean was used for comparison due to varied doses between subjects resulting into skew-ness of distribution. Test of significance was calculated using one-way analysis of variance and independent student t-test statistics (F, t-statistics with a 95% confidence interval and 5% level of significance).
Data was entered and managed using SPSS for windows version10.0 on IBM compatible computer system.

DISCUSSION.

There were no significant differences in skin doses during sequential or spiral abdominal CT scanning in this study. For example doses to the skin overlying the liver, breasts, thyroid and testis were as follows; Liver (Conventional – 88.8 mGy, Spiral – 92.8 mGy), Breast (Conventional – 9.89 mGy, Spiral – 10 mGy), Thyroid (Conventional – 2.85 mGy, Spiral – 2.52 mGy) and Testis (Conventional – 1.23 mGy, Spiral – 1.33mGy).

Skin doses during multislice CT was highest to Liver, followed by the Breast, Thyroid and lowest for Testis. The liver being an abdominal organ receives direct CT beam during abdominal scanning and hence got the greatest dose. Dose to skin overlying the breast was lower than liver skin dose but greater than thyroid and testicular skin dose. The breast is anatomically closer and sometimes overlies the upper quadrant of the abdomen and would therefore get higher dose than the thyroid and the testis, which are out of the scan field during abdominal scanning.

Doses during multislice scanning were generally higher than doses during the topogram phase of the study except for the testis where they were almost equal. For example skin doses for liver (Conventional – 88.8 mGy, Spiral – 92.8 mGy and **Topogram** 1.1 mGy), Breast (Conventional – 9.89 mGy, Spiral – 10 mGy and **Topogram** 1.2 mGy), Thyroid (Conventional – 2.85 mGy, Spiral – 2.52 mGy and **Topogram** – 0.127 mGy), Testis (Conventional – 1.23 mGy, Spiral – 1.33 mGy and **Topogram** – 1.22 mGy). Testicular skin dose was low in both the Topogram and Multislice studies but the topogram examinations contributed 95.3% while 4.7% of the dose was from the Multislice examination. The skin dose to the testis during CT abdominal examination is therefore mainly as a result of the topogram and not scatter radiation from the Multislice scans. The testis normally receives direct CT beam during topogram study; however, during Multislice scanning the most inferior slice is taken at the level of the iliac crest well above the normal anatomical location of the testis.

The thyroid gland is not scanned directly during either the multislice or the topogram phase of the study. The dose to the skin overlying the thyroid gland was mainly due to scatter radiation (96.4%) during multislice scanning as the topogram contributed only 3.6% of the skin dose.

The skin doses during abdominal CT scanning in this study were generally well below the threshold dose required to induce deterministic effects like causing temporary sterility, skin erythema and Lens cataracts **(22)**.

The skin doses in this study were assessed during the pre intravenous contrast media phase. In most diagnostic studies contrast media is given to opacify blood vessels to improve on delineation of vascular lesions.
This study was limited to the pre-contrast media phase because of the differences in protocols between the two centres regarding post intravenous contrast media study. The skin doses in this study were therefore lower than the actual skin doses in instances where post intravenous scanning was done.

There were variations in skin doses between different subjects. This was attributed to the differences in subject sizes leading to the differences in the number of CT slices required to scan the whole abdomen. Attenuation of X-rays and scatter also depend on tissue thickness and this may lead to dose variations between subjects of different sizes.

In this study there was no significant difference between the skin doses during spiral and during conventional abdominal CT scanning. This was different from studies by other investigators like Becker CR, *etal* **(33)** who found spiral abdominal CT to deliver effective dose of 7 mSv compared to conventional abdominal CT (20 mSv).

Dr. Changale in his Mmed Dissertation **(34)** on doses during CT of paranasal sinuses using the same equipment as the ones used in this study found spiral CT to deliver lower dose compared to

conventional CT. The differences in my study and these studies could have been due to differences in selected parameters e.g. slice thickness, kV, mAs and pitch. Despite no significant difference in skin doses during conventional and Spiral abdominal CT, the spiral CT still had superior clinical advantages. It was more suitable for use in paediatric patients where it had the advantage of reducing the motional blur associated with voluntary movements and hence reduced the need for repeat scanning to get better quality images. The use was therefore accompanied with overall reduction in radiation dose.

Skin doses in this study were almost comparable with findings of McCrohan JL, *etal* **(26)** and Mini RL, *etal* **(27)** who found skin doses to adults from multiple adjacent CT slices as 30 – 70 mGy (3.0 – 7.0 rad) per head scan series and 20 – 50 mGy (2.0 – 5.0 rad) for each abdominal series.
In other studies by Ware DE, *etal* **(29),** Becker CR *etal* **(33)** and Van Unnik JG, *etal* **(30)** who used computerized tomographic dose index (CTDI) and effective dose as a method of estimating dose to various parts during abdominal scanning, the effective dose and effective dose equivalent were found to range between 4 – 24 mSv for CT abdomen. These results differed from the ones in this study due to the differences in radiation quantity assessed. In CT examinations the assessment of equivalent dose to an organ or effective dose to the whole body, presents a better picture of the associated health hazards in comparison to the assessment of skin dose **(28).**

RECOMMENDATIONS

1. **Shielding for patients.**
   Previous studies have shown the usefulness of shielding the radiosensitive organs during CT examinations. During abdominal CT examinations the thyroid, testis and breast can be shielded to reduce the dose. For the thyroid and testis, lead cloth can be used as they are out of the scan field during abdominal CT and would not affect the image. With the breast, radio-transparent materials e.g. bisthmuth can be used as shown in studies by Hopper KD *et al* **(32)**. The study showed that the image quality was not degraded. The breast can also be suspended up in the chest to avoid direct CT beam.

2. **Paediatric protocols.**
   Paediatric protocols should be designed, since radiation dose to children is a special concern. Scanning should be done to the lowest possible mAs that would not affect image quality and will give minimum dose. These protocols can usually be worked between the manufacturers and the radiologists.

3. **Awareness of the need for dose management.**
   There is need to enhance dose information to the clinicians. There was an instance when a CT scan was requested for a neonate as a follow up on abdominal mass previously seen during antenatal obstetric scanning. Ultrasound would have been the first modality of choice in this case. Clinicians should therefore be advised on the use of other imaging modalities like ultrasound, which delivers no radiation when there is no appropriate justification for CT scan as the first modality of choice.

4. **Dose efficiency regarding CT machines.**
   The CT machines should be regularly monitored for radiation doses delivered to patients to ensure that the doses remain low.

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APPENDIX 1: Data Collection Sheet

RADIATION SKIN DOSES TO PATIENTS UNDERGOING ABDOMINAL COMPUTED TOMOGRAPHIC EXAMINATION.

DATA COLLECTION SHEET

CENTRE .....

SCANNER SIEMENS SOMATON AR/SPIRAL/SEQUENTIAL.

DATE.....

Patients hospital No .....Address.....

Age.....Sex.....

CT EXAMINATION REQUESTED: ABDOMEN

INDICATION FOR SCAN

CT PARAMETERS

KVP..... mAs..... SCAN TIME

SLICE THICKNESS..... NO. OF SLICE.....

GT.....

Dosimeter light output Measurements (digits).

Liver.....

Breast.....

Scrotum.....

Thyroid.....

APPENDIX 2: Informed Consent Form.

INFORMED CONSENT FORM

CENTRE: -

I .....OF .....
(ADDRESS)

Patient Hospital No.....

I have agreed to take part in the research in which radiation doses will be monitored on me by placing radiation measurements gadgets (dosimeters) on parts of my body namely the neck, breast, abdomen and scrotum (male) as I undergo CT scan examination, and I have been assured that they will not affect the examination.

Patients Signature.....

Witness.....

APPENDIX 3: Light Output Of Groups A & B Dosimeters.

TABLE 17: GROUP A DOSIMETERS

Response Value	Frequency	Percent	Valid Percent	Cum Percent
3493	1	2.8	2.8	2.8
3593	1	2.8	2.8	5.6
3598	1	2.8	2.8	8.3
3620	1	2.8	2.8	11.1
3629	1	2.8	2.8	13.9
3640	1	2.8	2.8	16.7
3643	1	2.8	2.8	19.4
3647	1	2.8	2.8	22.2
3660	1	2.8	2.8	25.0
3661	1	2.8	2.8	27.8
3666	1	2.8	2.8	30.6
3681	1	2.8	2.8	33.3
3687	1	2.8	2.8	36.1
3736	1	2.8	2.8	38.9
3748	1	2.8	2.8	41.7
3753	1	2.8	2.8	44.4
3762	1	2.8	2.8	47.2
3766	1	2.8	2.8	50.0
3769	2	5.6	5.6	55.6
3777	1	2.8	2.8	58.3
3778	1	2.8	2.8	61.1
3799	2	5.6	5.6	66.7
3806	1	2.8	2.8	69.4
3810	1	2.8	2.8	72.2
3821	1	2.8	2.8	75.0
3877	1	2.8	2.8	77.8
3886	1	2.8	2.8	80.6
3887	1	2.8	2.8	83.3
3888	1	2.8	2.8	86.1
3899	1	2.8	2.8	88.1
3900	1	2.8	2.8	91.7
3940	1	2.8	2.8	94.4
3955	1	2.8	2.8	97.2
4394	1	2.8	2.8	100.0
TOTAL	36	100.0	100.0	

Mean	3770.472	Std err	25.598	Median	3767.500
Mode	3769.000	Std dev	153.590	variance	23589.799
Kurtosis	6.746	S E Kurt	.768	Skewness	1.791
S E Skew	.393	Range	901.000	Minimum	3493.000
Maximum	4394.000	Sum	135737.000		

X Multiple modes exist. The smallest value is shown.

Valid cases 36 Missing cases 0

Set 2 Group B Dosimeters TABLE 6

Value label	Response Value	Frequency	Percent	Valid Percent	Cum Percent
	2006	1	2.8	5.9	5.9
	2074	1	2.8	5.9	11.8
	2094	1	2.8	5.9	17.6
	2133	1	2.8	5.9	23.5
	2190	1	2.8	5.9	29.4
	2198	1	2.8	5.9	35.3
	2222	1	2.8	5.9	41.2
	2246	1	2.8	5.9	47.1
	2258	1	2.8	5.9	52.9
	2267	1	2.8	5.9	58.9
	2279	1	2.8	5.9	64.7
	2310	1	2.8	5.9	70.6
	2329	1	2.8	5.9	76.5
	2353	1	2.8	5.9	82.4
	2387	1	2.8	5.9	88.2
	2393	1	2.8	5.9	94.1
	2477	1	2.8	5.9	100.0
		19	52.8	Missing	
	Total	36	100.0	100.0	

Mean	2248.000	Std err	30.193	Median	2258.000
Mode	2006.000	Std dev	124.490	Variance	15497.750
Kurtosis	.302	S E Kurt	1.063	Skewness	.192
S E Skew	.550	Range	471. 000	Minimum	006.000
Maximum	2477.000	Sum	38216.000		

X Multiple modes exist. The smallest Value is shown,

Valid cases 17 Missing cases 19

APPENDIX 4: Dose Calculations.

GROUP A: the mean light response was 3770.472.
Standard deviation: 153.590.

Variation: $= \frac{153.6 \times 100}{3770.5} = 4\%$

Group B: Mean response was 2248. Standard deviation was 124.490.
Variation was 5.5%.

Response Per mRad
For group A:
3770.4digits/2800mrad
= 1.346digits/mrad

For Group B dosimeters:
2248 digits/2800mrad
0.8digits/mrad.

The light outputs of the dosimeters from group A and B were divided by 1.346 and 0.8 respectively in order to get the skin doses.
To get the final doses the mean doses were further divided by 1.3 to take care of the difference in response of the dosimeters to CT and cobolt-60 radiation.

APPENDIX 5: Geometric Means

LIVER

TYPE1: SEQUENTIAL CT (MP SHAH)
TYPE 2: SPIRAL CT (MITC)

Report

DOSE 1 Rad

TYPE	Mean	N	Std. Deviation	Geometric Mean	F	p
1	12.3028	36	4.3358	11.5377	0.62	0.804
2	12.5286	35	3.2068	12.0637		
Total	12.4141	71	3.7957	11.7941		

BREAST

Type 1: Sequential Scan
Type 2: Spiral CT

Report

DOSE (mrad)

TYPE	Mean	N	Std. Deviation	Geometric Mean	F	p
1	1436.37	35	788.31	1286.76	0.020	0.888
2	1462.00	34	718.18	1302.27		
Total	1449.00	69	749.12	1294.38		

THYROID

Type 1: Sequential Scan
Type 2: spiral Scans

Report

DOSE (mrad)

TYPE	Mean	N	Std. Deviation	Geometric Mean	F	p-value
1	406.86	36	198.58	371.78	0.607	0.438
2	368.74	35	213.46	328.28		
Total	388.07	71	205.47	349.66		

TESTIS

Type 1: Conventional/ Sequential Scans
Type 2: Spiral CT Scans

Report

DOSE (mrad)

Type	M	N	Std. Deviation	G Mean	F	p-value
1	210.07	14	142.79	161.52	0.62	0.804
2	192.08	12	123.18	148.07		
Total	201.77	26	131.76	155.17		