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Breast Radiation Doses and Cancer Risk From Female Chest CT Scans in Palestine

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Breast Radiation Doses and Cancer Risk From Female Chest CT Scans in Palestine

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Dedication

I dedicate this humble effort to My Father, Mother, Wife, Family and Friends who support me to complete my thesis work

Declaration

I certify that the thesis submitted for the degree of master is the result of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not be submitted for a higher degree to any other university or institution.

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Abstract

The use of Computed Tomography (CT scans) in medical diagnosis delivers radiation doses to patients higher than those from conventional medical imaging. Lack of optimized protocols could be an additional source of increased radiation dose to patients. CT scans account for about 20 % of the total medical X-ray procedures performed in the world wide. Chest CT scan is one of the most frequent procedures.

In Palestine, currently there are about 28 CT scanners, 24 of them in the West Bank, 4 Scanners in Gaza Strip. In the case of female patients, chest CT scan will deliver a considerably high dose to a radiosensitive breast. This work aims at the assessment of breast dose and associated lifetime attributable risk LAR from chest CT scans performed on 200 female patients in 10 Palestinian hospitals in the West Bank and Gaza Strip.

Dose estimation was performed theoretically using commercially available software based on Monte Carlo simulation of the human body with tissue equivalent phantoms of all ages and sizes. used BEIR VII Phase 2 modeling to accurately assessment internal organ dose lifetime attributable cancer risk (LAR).

All relevant input data were collected in a data base including patients such as data age, weight, and body mass index BMI; and data on CT scanners such as Computed Tomography Dose Index CTDI, Dose Length Product DLP, mAs, and kVp. It was found that the radiation dose resulting from the same exam varies widely between different hospitals, depending on the parameters used and the type of scanner.

For all patients, the effective dose from chest CT scan per exam varies from 3 to 14.7 mSv with a mean of 7 mSv, while the breast dose varies from 6.5 to 17.5 mGy per procedure, with a mean of 15 mGy. The patient's radiation lifetime attributable breast cancer risk LAR estimated in Palestine in younger female is 0.00042 % or 1 in 2645 for 15 - 39 years and in older female is 0.00014 % or 1 in 10,473 for 40 - 60 years, The International commission on radiological protection recommendation **(**ICRP) does should not exceed 45 mGy, and the lifetime attributable breast cancer risk for younger and older female patients should not exceed 0.00865% and 0.00160%, respectively.

Results indicate that radiation dose to glandular breast tissue generally decreases with the use of suitable exposure scanning parameters.

Contents

Item **Page No**

Declaration i
Acknowledgements ii
Abstract iii
List of Tablets vii
List of Figures vii
List of Abbreviations and Units x
Chapter One: **Introduction** 1
1.1 Historical Background 1
1.2 Radiation dose for CT scan and related risks 2
1.3 CT scan situation in Palestine 4
1.4 Problems statement 5
1.5 Objectives 6
Chapter Two: **Theoretical Background**: 7
2.1 Principles of Computed Tomography 7
2.1.1 CT scan Gantry: 8
2.1.2 X -ray Tube, Collimation and Filtration: 9
2.1.3 Detectors: 10
2.1.4 Data Acquisition System (DAS): 12
2.1.5 CT scan Table : 13
2.1.6 Power Distribution Unit: 13
2.2.1 CT scan imaging technique: 13
2.2.2 Chest CT scans examination: 15
2.3 Radiation Quantities and Units 16
2.3.1 Radiation Quantities: 16
2.3.2 Radiation Units: 16
2.3.3 Exposure: 17
2.3.4 Absorbed dose: 17
2.3.5 Dose Equivalent: 18

2.3.6 Effective Dose: 19
2.3.7 Computed Tomography Dose Index: 20
2.3.8 Computed Tomography Dose Length Product: 21
2.4 Breast radiation sensitivity: 22
2.5 Cancer Risk Assessment 24
2.6 Literature review 25
2.6.1 Previous studies: 25
Chapter Three: **Materials and Methods**: 32
3.1 Collect, Survey data processing and analysis 32
3.2 Data collection 32
3.3 CT scan Machines 35
3.4 CT Scan dose measurements 37
3.5 Breast organ dose estimation 39
3.6 Effective dose estimation 40
3.7 Monte Carlo Simulation Software 41
3.8 Breast cancer risk assessment 43
3.9 BEIR VII Risk Modeling 44
Chapter Four: **Results and discussion**: 46
4.1 Chest CT scans parameters and absorption dose 46
4.2 $CTDI_{vol}$ for female Chest CT scans in different hospitals in Palestine 49
4.3 DLP for female Chest CT scans in different hospitals in Palestine 50
4.4 Relationship between BMI and Effective dose for female Chest CT scan in different hospitals in Palestine 52
4.5 Relationship between $CTDI_{vol}$ and Effective dose for female Chest CT scans in different hospitals in Palestine 54
4.6 Effective dose for female Chest CT scan in different hospitals in Palestine 55
4.7 Breast dose for female Chest CT scan in different hospitals in Palestine 57
4.8 Effective and breast doses for female Chest CT scan in Palestine 58
4.9 CT scan radiation doses between Palestine and other internationals 59
4.9.1 Comparison between $CTDI_{vol}$, DLP and Effective Dose for female Chest CT scan in Palestine and other countries: 59
4.9.2 Comparison between breast doses for female Chest CT scan in Palestine and Reference values of the International commission on radiological protection 60 (ICRP 60) 63
4.10 Risk Assessment Calculations 65

4.10.1 Lifetime attributable breast cancer risk for female Chest CT scan in different hospitals in Palestine:..... 65
4.10.1.1 Age, Female Gender and Cancer Risk..... 66
4.10.2 Effective and breast doses and lifetime attributable breast cancer risks in Palestine:..... 73
4.10.3 Breast cancer risk assessment for female underwent Chest CT scans in different ages in Palestine..... 74
4.10.4 Breast cancer risk assessment for female underwent Chest CT scans in Palestine and comparison with ICRP Recommendations:..... 76
4.10.5 Breast Cancer Risk assessment for female underwent Chest CT scans in different hospitals in Palestine..... 77
4.10.6 Breast cancer risk assessment for female underwent Chest CT scans in Palestine:..... 78
Chapter Five: **Conclusion and Recommendations**:..... 80
5.1 Conclusion..... 80
5.2 Recommendations..... 81
References..... 82
Appendices..... 91
Appendix A..... 91
Appendix B..... 92
Appendix..... 93
Appendix D..... 104
الملخص:..... 123

List of Tablets

No.	Table Title	Page
1.1	Global average relative frequency and collective dose of various types of diagnostic X-ray procedures (all ages, both gender)	2
2.1	The evolution of typical values for high performance CT machines	15
2.2	Radiation Weighting factors	19
2.3	Weighting Factors as defined in ICRP 26, 60 and 103	23
2.4	Terminology used to describe risks from radiation exposure	24
3.1	The values of patient's demographic data during CT scan exam used by each hospital in Palestine	33
3.2	Patient demographic data and exposure parameters during CT scan exam used by each hospital	34
3.3	Specifications of CT scanners used each hospital in Palestine	35
3.4	TABLE 12D-1 lifetime attributable risk of breast cancer incidence (BEIR VII Phase 2, 2006)	45
4.1	$CTDI_{Vol,}$ DLP and Pitch for patient during Chest CT scan used by each hospital	47
4.2	Effective doses and Breast organ doses for female Chest CT scan	48
4.3	Effective dose, Breast organ dose in Palestine	59
4.4	Breast doses in Palestine and Reference values of the International commission on radiation protection 60	63
4.5	Breast Organ doses for female Chest CT scan in Palestine and other countries	64
4.6	Mean effective dose, breast dose and radiation related breast cancer risks for female patients age in Palestine	73
4.7	lifetime attributable breast cancer risk for female patients age (15 – 29, 30 – 39, 40 – 49, 50 – 59, 60 – 69 and 70 - 79) years for Chest CT scan in ten hospitals in Palestine	74
4.8	mean lifetime attributable breast cancer risk for young and old female patients for Chest CT scan in ten hospitals in Palestine and ICRP Recommendations.	76

List of Figures

No.	Figure Title	Page
2.1	CT scanner Gantry	8
2.2	Image acquisitions in CT scan	10
2.3	Scintillation and xenon gas detector image acquisition in CT scan	11
2.4	The scanning techniques used in the first four generations of CT scanners	14
2.5	Radiation quantities	16
2.6	Absorbed Dose	18
2.7	Computed Tomography Dose Index	21
2.8	Dose Length Product	22
3.1	Distribution of the CT scan mode in this study	37
3.2	Phantom models in Monte Carlo Simulation	39
3.3	Screenshot shows example of radiation report generated by modern MDCT and sent to PACS as separate series, Total dose length product is displayed in mGy.cm and $CTDI_{vol}$ is displayed in mGy	41
3.4	Monte Carlo Simulation software	43
4.1	$CTDI_{vol}$ in different hospitals in Palestine	49
4.2	DLP values in ten hospitals in Palestine	51
4.3	correlation between BMI and Effective dose for female patient underwent Chest CT examination in ten hospitals in Palestine	52
4.4	correlation between $CTDI_{vol}$ (mGy) and Effective dose (mSv) for female patient underwent Chest CT scan in all hospitals	54
4.5	mean value of effective dose for female Chest CT scan in different hospitals in Palestine	56
4.6	mean values of breast dose for female CT scan in different hospitals in Palestine	57
4.7	comparison between $CTDI_{vol}$ in Palestine and other countries for	60

No.	Figure Title	Page
	female Chest CT scan	
4.8	comparison between DLP in Palestine and other countries for female Chest CT scan.	61
4.9	comparison between Effective doses in Palestine and other countries for female Chest CT examination	62
4.10	Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital one in Palestine	67
4.11	Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital two in Palestine	67
4.12	Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital three in Palestine	68
4.13	Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital four in Palestine	68
4.14	Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital five in Palestine	69
4.15	Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital six in Palestine	69
4.16	Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital seven in Palestine	70
4.17	Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital eight in Palestine	70
4.18	Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital nine in Palestine	71
4.19	Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital ten in Palestine	71
4.20	lifetime attributable breast risk of cancer incidence for female chest CT scan in Palestine	72
4.21	Attributable breast cancer risk incidence for Chest CT scan in different hospitals in Palestine	77

List of Abbreviations and Units

CT = computed tomography

ICRP = International Commission on Radiological Protection

DAS = data acquisition system

R = roentgen

H = dose equivalent

D = absorbed dose

Q = quality factor

WT = weighting factor

CTDI = Computed Tomography Dose Index

DLP = dose length product

CTDIvol ~ Computed Tomography Dose Index Volume

AEC = automatic exposure controls

TCM = Tube Current Modulation

LAR = lifetime attributable risk

ALARA Principle = as low as reasonable achievable

DRLs = dose reference levels

PACS = picture archiving and communication system

BMI = Body mass index

mAs = milli ampere second

kVp = Kilo volte peak

mSv = milli Sievert

Gy = grey

Sv = Sievert

mGy = milli grey

C/kg = coulomb per kilogram

mGy.cm = milli grey multiplied by centimeter

kg/cm^2 = Kilogram per Squarecentimeter

S. = Second

Chapter One:

Introduction

Medical Computed Tomography
and Radiation Exposure Definition

1.1 Historical Background

Computed tomography CT scan is an imaging technique which produces a digital tomographic image from diagnostic X-ray. The basic principle of CT scan involve digitizing an image received from a slit scan projection of the patient's body and then back projecting the image thought mathematical algorithms (Julian Simpson, 1999).

The invention of CT scan has been credited to Godfrey N. Hounsfield for his work in 1970-71, although preliminary work was done by Oldendrof in 1961 and Alan Cormack in 1963, they won a nopel price 1979 for their work to develop this type of modality of imaging technique, and all three based their work on the investigations of the Austrian mathematician J.Radon, who proved in 1917 (Julian Simpson, 1999).

Modern CT scan units are capable of diverse modes (helical and spiral) much more complex than simple axial scanning. Since the introduction of helical CT scan in 1990, the technology of CT scanners has changed extremely. The development of multi slice systems

in 1998 has accelerated the implementation of many new CT scan examinations (Julian Simpson, 1999).

The number of slices, acquired per axial rotation has increased, with 16, 64, 128 and 256-slice systems now available. In these days, a larger detector arrays and axial coverage per rotation will be commercially available, with results from a 512-slice scanner having already, increased use of multiphase exams, vascular and cardiac exams, perfusion imaging, and screening exams primarily the heart, chest, and colon, but also self-referred whole body screening exams. (Julian Simpson, 1999).

1.2 Radiation dose for CT scan and related risks

The CT scan imaging plays a necessary role in modern medicine, its rapid adoption has resulted in a dramatic increase in the average medical radiation exposure because this technique gives high radiation dose to patients in comparison with other images modalities based on ionizing radiation. For example, one Chest CT scan examination gives radiation more than 400 times the dose delivered by a conventional Chest X-ray examination (Keith J. Strauss and Marilyn J. Goske, 2010).

CT scan represents only 20 % of the total number of medical X-ray procedures in the worldwide. This high dose procedure contributes as 43 % of the annual collective doses from all medical X-ray examinations to the population see Table 1.1. As compared with the previous United Nations scientific committee (UNSCEAR) report six years, see Table 1.1, the collective dose has grown to a factor of about 2.5 (Keith J. Strauss and Marilyn J. Goske, 2010).

Table 1.1: Global average relative frequency and collective dose of various types of diagnostic X-ray procedures (all ages, both gender) (UNSCEAR, 2010)

X-ray examination	Relative frequency (%)	Collective dose (%)
Chest examinations (PA, lateral, others)	40	13.3
Limb and joint	8.4	<1
Skull	3.2	4.2
Abdomen, pelvis, hip	5.2	4.5
Spine	7.4	4.2
Fluoroscopic studies	4.8	14.5
Mammography	3.6	<1

X-ray examination	Relative frequency (%)	Collective dose (%)
Computed tomography	**6.3**	**43.2**
Angiography fluoroscopy-guided interventional procedures	<1	6.1
Other X-ray medical imaging procedures	3	11
Dental procedures	13	<1

Patients have benefited from the rapid diagnoses made possible by CT scan and from its value for monitoring chronic disease. However, there is an increasing concern regarding the risks of this exposure to radiation. It is well established that radiation can be harmful and has both stochastic and deterministic effects (such as hair loss, skin burns, and cell death, which are dose dependent but do not occur below a threshold of 150-200 mSv) (Keith J. Strauss and Marilyn J. Goske, 2010).

It is difficult to assess a safe level of radiation exposure. The typical estimated dose associated with proper use of CT scan is in the range of 2-10 mSv, in which deterministic effects are not normally a concern the induction of cancer by radiation is a probabilistic (stochastic) effect, not a deterministic effect. That is, higher radiation doses are associated with a higher likelihood of carcinogenesis, but even low doses of radiation could potentially induce carcinogenesis (Radiology Rounds, 2003).

Why do CT scan use high radiation dose? That use of many photons series of exposures rather than the single exposure of conventional projection radiography, and the loss of self-regulation inherent in conventional radiography afforded by the use of film (P Dawson, 2004). The reason for this lies in the interposition technique used to reconstruct the image. To reconstruct the highest slice, this factor may contribute up to 10 % increase in the effective dose (Claire Louise chappie, 2008).

CT scan risk is determined using either direct measures of dose, such as organ dose, or a weighted measure of radiation dose taking into account various organ doses and sensitivities (effective dose). The risk of radiation induced malignancies from a single CT scan exposure is difficult to assess. Optimization of CT scan procedures is also important to secure a dose as low as reasonable achievable (ALARA Principle) (Claire Louise chappie, 2008).

The international commission on radiation units and measurements (ICRU) states that to "assess the risk from stochastic and deterministic effects from medical X-ray imaging, it is necessary to know the organ or tissue doses, the dose distribution and the age and gender of the patients, the quantities and units to be used in medical x-ray imaging as well as methods for patient dose estimation and measurements are given in ICRU report 74", the unit is the gray (Gy) (Dan E. Ware, MD Walter Huda, 1999). CT scan doses may be estimated from computed tomography dose index (CTDI) and Dose length product (DLP) (P Dawson, 2004). Doses can also be measured directly by placing thermoluminiscent dosimeters (TLD) or diodes on the patients during the procedures, and indirectly by using simulation software such as used in this study; Monte Carlo Simulation Software (Dan E. Ware, MD Walter Huda, 1999).

The investigation of effective doses and organ doses to individual patients can be done by taking into account the individual technique factors, as well as the physical size of the patients underwent CT scan procedures (Dan E. Ware, MD Walter Huda, 1999). A comparison of the selected technique factors and the corresponding patient doses will help to determine whether these CT scan radiation doses to patients are as low as reasonably achievable (ALARA Principle), as required by the international commission on radiological protection (ICRP, 2007).

1.3 CT scan situation in Palestine

Radiation protection knowledge in Palestine is weak, radiologists and radiographers in Palestine don’t have a clear strategy about the use of medical radiation. So this study comes to put plan on how to use new statistical approaches and procedure to estimate effective dose and organ dose for medical examination in Palestine. In special consideration, estimation of female Chest CT scans dose and assessment of radiation breast cancer risk.

According to Palestinian Health Ministry annual report, Palestinian population is estimate to about 4, 485,400 people at the end of 2013. The population is divided between the West Bank about 2.8 million (61.4%) and about 1.7 million (38.6 %) in Gaza Strip (PHIC, 2013).

The hospital count in Palestine is about 80 hospitals and 96 medical center are locate in the West Bank (63 %) and these hospitals have about 844 beds (PHIC, 2013), Currently there are about 28 CT scan in Palestine, The 24 CT scanners in the West Bank, and 4 CT Scanners in Gaza strip in 2015. Nearly approximately 88,200 CT scan examinations in West Bank in 2015. According to the General Administration of health policy and planning (Palestinian Health Information Center, 2015), this constitutes about 70 % of all medical CT scan procedures performed in Palestine hospitals government, In addition, it remains about 30 % of CT in private hospitals.

Accordingly, the total CT scan examination in Palestine approximately 110.000 CT scans examinations (Palestinian Medical Engendering Units, 2015).

Despite the fact of the many benefits of CT scan, the risks from CT scan ionization is increasing and cause many effects and syndrome, stochastic effect such as cancer from CT scan. Cancer is considered the second death causative in Palestine for about 13.3%, and it is increasing annually for noticed (PHIC, 2013).

1.4 Problems statement

This research is interested to study of medical radiation exposure in Palestine, which should be taken to give the diagnostic information in the best way with minimum x-ray dose. Increased use of this high dose procedure has been of great concern globally because of the high possibility of inducing undesired health effects, such as induction of cancer in patients. The radiation dose must be known to estimate the patient's potential risk from radiation and to weight the risk against the benefits of scanning. In addition, most radiation regulatory agencies require the measurement or estimation of radiation dose to the patient from medical x-ray units.

The ICRP has thus warned against CT scan in report 87 stating that: "The absorbed dose to tissue from CT scan (10 to 100 mGy) can often approach or exceed the levels known to increase the probability of cancer" (Keith J. Strauss and Marilyn J. Goske, 2010).

The aim of this study is to analyze the factors that affect in medical radiation doses and estimate the Chest effective dose and Breast organ dose by Monte Carlo simulation software, and to calculate breast cancer risk from Chest CT scan by the Seventy Biological

effects of Ionizing Radiation Committee Phase Two (BEIR VII Phase 2) to calculate Lifetime attributable breast cancer risk in Chest CT scan.

1.5 Objectives

The objectives of this study are to find out the effective dose, breast organ dose and cancer risk from Chest CT scan from in the West bank and Gaza strip of Palestine; in order to get appropriate recommendations to limit it's cancer risk and to decrease its breast organ absorption radiation.

The study will try to achieve the following objectives:

- Investigate doses from Chest CT scan examinations of female patients and to compare the doses with international standards as provided in dose reference levels (DRLs).

- Measure and evaluate the organ and effective dose in female patients during breast organs CT scanning by Chest CT scan software.

- Calculate and assess the lifetime attributable cancer risk in female patients during breast CT scanning by Chest CT scan model.

- Establishing Chest dose reference levels (DRLs) for each facility as a part of quality assurance program.

- Improve the radiological techniques to assure that radiation dose to female patient comply with the as low as reasonable achievable (ALARA principles).

- Provide a protocol for the optimal exposure factors that can give dose without exceeding dose reference levels (DRLs) with high image quality.

Chapter Two:

Theoretical Background:

2.1 Principles of Computed Tomography

The CT scanner is a device using an X-ray source which can be used to give precise information on the attenuation properties of a thin sectional volume of the body.

The general structure of CT scan equipment can be divided in three principle elements:

1. The Data Acquisition and Transfer system, which encompasses the gantry, the patient's table, the power distribution unit and the data transfer unit (Cattin, 2010).

2. The computing system is installed in separate room, making it possible for the operator (Radiographer) to control the acquisition process, introducing patient data and selecting several acquisition parameters such as the kVp , mA values the protocol is going to use (Cattin, 2010). Also there is another operator's console for editing and post processing is also necessary, so it possible to analyze and review previous exam data, without interfering with the current examinations taking place (Cattin, 2010).

3. The image reconstruction system: receives the X-ray transmission data information from the data transfer unit, in a digital format. This gathered data is then corrected using reconstruction algorithms and later stored (Cattin, 2010), Figure 2.1 shows CT scanners.

2.1.1 CT scan Gantry:

Moveable frame that contains the x-ray tube including collimators and filters, detectors, data acquisition system (DAS), rotational components including slip ring systems and all associated electronics such as gantry angulation motors and 6 positioning laser lights (Bushong, Stewart, 1993). A CT scan gantry can be angled up to 30 degrees toward a forward or backward position. Gantry angulation is determined by the manufacturer and varies among CT scan systems. The opening through which a patient passes is referred to as the gantry aperture. Gantry aperture diameters generally range from 50-85 cm. Lasers or high intensity lights are included within or mounted on the gantry. The lasers or high intensity lights serve as anatomical positioning guides that reference the center of the axial, coronal, and sagittal planes (Bushong, Stewart, 1993), Figure 2.1 shows CT scan gantry.

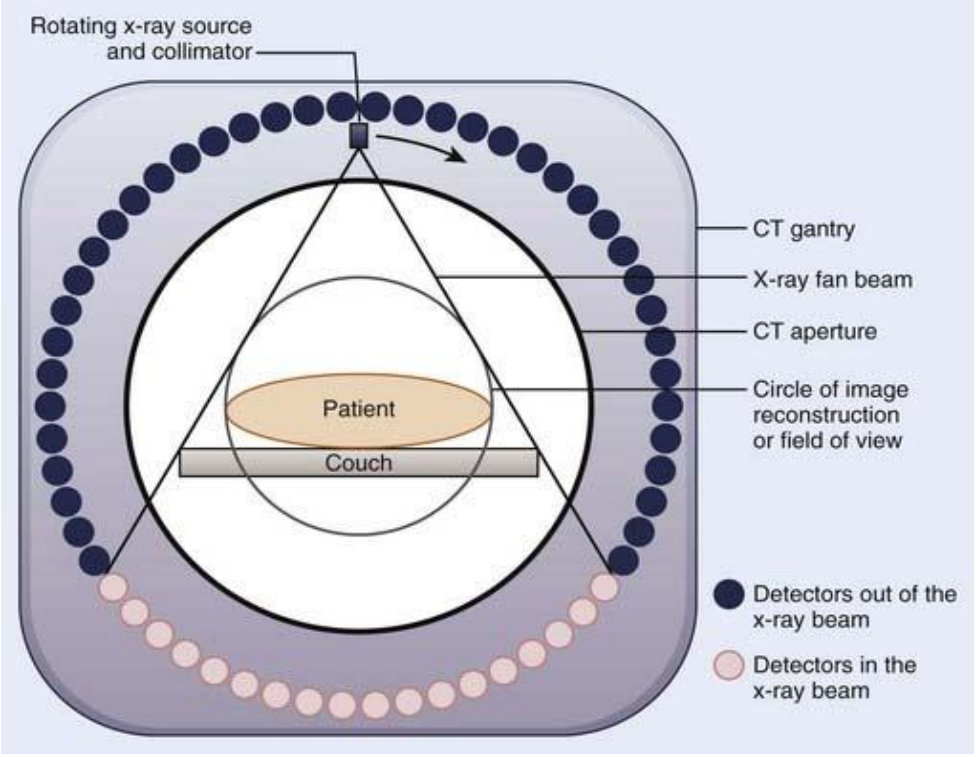

Figure 2.1: CT scanner Gantry

2.1.2 X -ray Tube, Collimation and Filtration:

CT scan procedures facilitate the use of large exposure factors, (high mA and kVp values) and short exposure times. CT scan systems produce x-radiation continuously or in short millisecond pulses. CT scan x-ray tubes must possess a high heat capacity which is the amount of heat that a tube can store without operational damage to the tube. CT scan systems utilize x-ray tubes that have a heat capacity of approximately 3.5 to 5 million heat units (MHU). Many CT scan x-ray tubes utilize a combination of oil and air cooling systems to eliminate heat and maintain continuous operational capabilities (Bushong, Stewart, 1993). A CT scan x-ray tube anode has a large diameter with a graphite backing. The large diameter backed with graphite allows the anode to absorb and dissipate large amounts of heat. CT scan tubes utilize a bigger filament than conventional radiography x-ray tubes. The use of a bigger filament increases the size of the effective focal spot decreasing the anode or target angle decreases the size of the effective focal spot. CT scan tubes employ a target angle approximately between 7 and 10 degrees. The decreased anode or target angle 7 also helps elevate some of the effects caused by the heel effect. CT scan can compensate any loss of resolution due the use of larger focal spot sizes by employing resolution enhancement algorithms such as bone or sharp algorithms, targeting techniques, and decreasing section thickness (Bushong, Stewart, 1993).

In CT collimation of the x-ray beam includes tube collimators, a set of pre patient collimators and post patient or pre detector collimators. Some CT scan systems utilize this type of collimation system while other does not. The tube or source collimators are located in the x-ray tube and determine the section thickness that will be utilized for a particular CT scanning procedure. A second set of collimators located directly below the tube collimators maintain the width of the beam as it travels toward the patient. A final set of collimators called post-patient or pre-detector collimators are located below the patient and above the detector (Bushong, Stewart, 1993) Figure 2.2 shows image acquisitions in CT scan.

The primary responsibilities of this set of collimators are to insure proper beam width at the detector and reduce the number of scattered photons that may enter a detector. There are two types of filtration utilized in CT scan. Mathematical filters such as bone or soft tissue algorithms are included into the CT scan reconstruction process to enhance

resolution of a particular anatomical region of interest. Inherent tube filtration and filters made of Aluminum or Teflon are utilized in CT scan to shape the beam intensity by filtering out low energy photons that contribute to the production of scatter. Special filters called "bow-tie" filters absorb low energy photons before reaching the patient. Heavy filtration of the x-ray beam results in a more uniform beam. The more uniform the beam, the more accurate the attenuation values or CT scan numbers are for the scanned anatomical region (Bushong, Stewart, 1993) Figure 2.2 shows Image acquisitions in CT scan.

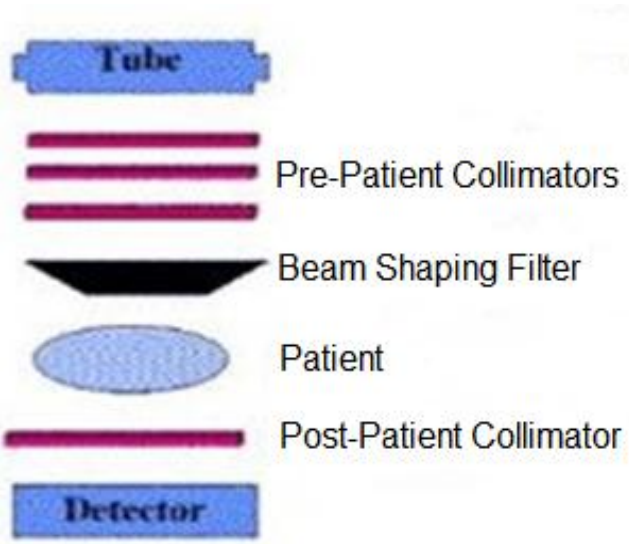

Figure 2.2: Image acquisitions in CT scan.

2.1.3 Detectors:

When the x-ray beam travels through the patient, it is attenuated by the anatomical structures it passes through. The image receptors that are utilized in CT scan are referred to as detectors. The CT scan process essentially relies on collecting attenuated photon energy and converting it to an electrical signal, which will then be converted to a digital signal for computer reconstruction (Wolbarst, Anthony B, 1993). The two types of detectors utilized in CT scan systems are scintillation or solid state and xenon gas detectors Figure 2.3 shows scintillation and xenon gas detector image acquisition in CT scan. Scintillation detectors utilize a crystal that fluoresces when struck by an x-ray photon which produces light

energy. A photodiode is attached to the scintillation portion of the detector. The photodiode transforms the light energy into electrical or analog energy. The most frequently used scintillation crystals are made of Bismuth Germinate (Bi4Ge3012) and Cadmium Tungstate (CdW 04) Figure 2.3 shows scintillation and xenon gas detector image acquisition in CT scan (Wolbarst, Anthony B, 1993).

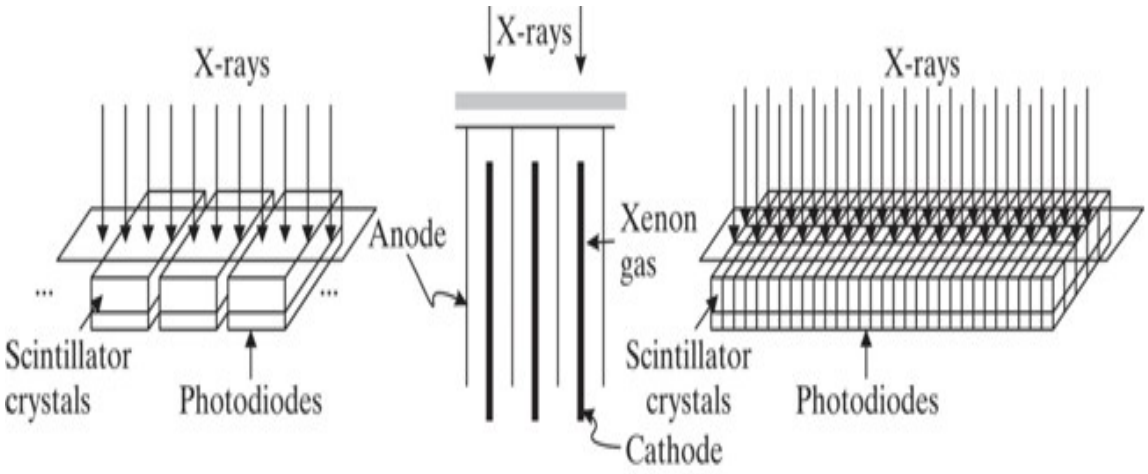

Figure 2.3: Scintillation and xenon gas detector image acquisition in CT scan

The second type of detector utilized for CT scan imaging system is a gas detector. The gas detector is usually constructed utilizing a chamber made of a ceramic material with long thin ionization plates usually made of Tungsten submersed in xenon gas. The long thin tungsten plates act as electron collection plates. When attenuated photons interact with the charged plates and the xenon gas ionization occurs. The ionization of ions produces an electrical current. Xenon gas is the element of choice because of its ability to remain stable under extreme amounts of pressure. The term detector refers to a single element or a single type of detector used in a CT scan system. The term detector array is used to 9 describe the total number of detectors that a CT scan system utilizes for collecting attenuated information (Wolbarst, Anthony B, 1993).

The path that an x-ray beam travels from the tube to a single detector is referred to as a ray after the x-ray beam passes through the object being scanned, the detector samples the

beams intensity. The detector reads each ray and measures the resultant beam attenuation. The attenuation measurement of each ray is termed a ray sum. A complete set of ray sums is referred to as a view or projection. It takes many views to create a computed tomography image (Morgan, Carlisle L, 1983).

The more photons collected, the stronger and more accurate the detector signal. This is essential for accurate image reconstruction. The dynamic range determines the ability of a detector to detect and differentiate a wide range of x-ray intensities. Dynamic range of a detector describes the range of x-ray exposures at the detector to which the system can respond without saturation and produce satisfactory gray-scale images. CT scan systems have the ability to respond to 1,000,000 x-ray intensities at approximately 1,100 views per second (Morgan, Carlisle L, 1983).

2.1.4 Data Acquisition System (DAS):

Once the detector generates the analog or electrical signal it is directed to the data acquisition system (DAS). The analog signal generated by the detector is a weak signal and must be amplified to further be analyzed. Amplifying the electrical signal is one of the tasks performed by the data acquisition system (DAS) (Seeram, Euclid, 1994). The DAS is located in the gantry right after or above the detector system. In some modern CT scan scanning systems the signal amplification occurs within the detector itself. Before the projection or raw data, which is currently in the form of an electrical or analog signal, goes to the computer it must be converted to digital information.

The computer does not understand analog signals therefore; the information must be converted to digital information. This task is accomplished by an analog to digital converter which is an essential component of the DAS.

The digital signal is transferred to an array processor. The array processor solves the statistical information using algorithmic calculations essential for mathematical reconstruction of a CT scan image. An array processor is a specialized high speed computer designed to execute mathematical algorithms for the purpose of reconstruction (Berland, Lincoln L, 1987), the array processor solves reconstruction mathematics faster than a standard microprocessor. It is important to note that special algorithms may require several seconds to several minutes for a standard microprocessor to compute. Recently,

processors that compute CT scan reconstruction mathematics faster than an array processor have been utilized to solve reconstruction mathematics essential to the development of CT scan fluoroscopy. The term image or reconstruction generator is used to describe this type of computer (Berland, Lincoln L, 1987).

2.1.5 CT scan Table :

CT scan tables or couches should be made with a material that will not cause artifacts when scanned. Many CT scan tables or couches are made of a Carbon fiber material. Various attachments are available for different types of scanning procedures. Attachments for direct coronal scanning and therapy planning are commonly used in many CT scan departments (Bushong, Stewart, 1993).

2.1.6 Power Distribution Unit:

The power Distribution unit supplies power to the gantry, the patient's table and the computers of the Computing System (Bushong, Stewart, 1993).

2.2.1 CT scan imaging technique:

Early machines had an x-ray tube and detector that moved in precise alignment on opposite sides of the patient to make each pass. The size of these machines allowed only heads to be scanned. After one pass, the gantry containing the tube and detector was 11 rotated 1° and the next pass was taken. After data for 180 passes were recorded, the image was reconstructed. A complete scan took about 4 minutes. CT scan units use an array of detectors and a fan shaped beam that covers the whole width of the patient. The scan time is reduced to a few seconds. Figure 2.4 shows the early evolution of the scanning techniques (Glassberg, 2013).

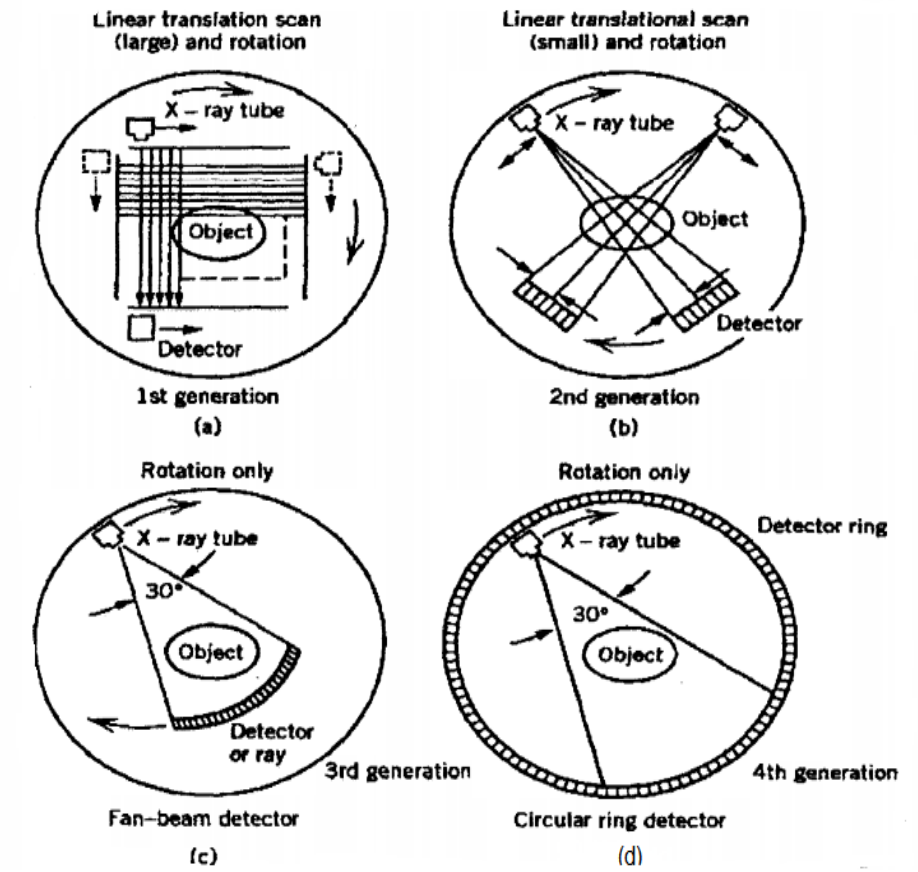

Figure 2.4: The scanning techniques used in the first four generations of CT scanners.

CT scan machines all of the electrical connections are made through slip rings. This allows continuous rotation of the gantry and scanning in a spiral as the patient moves through the machine (Glassberg, 2013). Interpolation in the direction of the axis of rotation (the z axis) is used to perform the reconstruction for a particular value of z. This is called spiral CT scan or helical CT scan. Array detectors are now used to fill in the space between the spirals. Table 2.1 shows how scanners have improved since they were first introduced. Spiral CT provides p(x, y, z), and the images can be displayed in three dimensions (Glassberg, 2013).

Table 2.1: The evolution of typical values for high performance CT machines (Glassberg, 2013).

Feature	1972	1980	1990	2000
Minimum scan time	300 s	5-10 s	1-2 s	0.3-1 s
Data per 360 ° scan	57.6 kB	1 MB	2 MB	42 MB
Data per spiral scan	-	-	24-48 MB	200-500 MB
Image matrix	80 x 80	256 x 256	512 x 512	512 x 512
Power (kW)	2	10	40	60
Slice thickness (mm)	13	2-10	1-10	0.5-5
Spatial resolution (Line pair cm-1)	3	8-12	10-15	12-25

2.2.2 Chest CT scans examination:

CT scanning of the Chest uses special equipment to obtain multiple cross sectional images of the organs and tissues of the Chest CT scan produces images that are far more detailed than a conventional Chest x-ray. CT scan is especially useful because it can simultaneously show many different types of tissue including the lungs, heart, bones, soft tissues, muscle and blood vessels (Glassberg, 2013), Using a variety of techniques, including adjusting the radiation dose based on patient size and new software technology, a growing fraction of the population is exposed to low dose ionizing radiation from CT scan. Data extrapolated from atomic bomb survivors and other populations exposed to low dose ionizing radiation suggest that CT scan associated radiation may increase an individual lifetime risk of developing cancer. Because this topic has recently attracted the attention of both the scientific community and the general public, it has become increasingly important for physicians to understand the cancer risk associated with CT scan (Sarma A et al, 2012).

2.3 Radiation Quantities and Units

2.3.1 Radiation Quantities:

There are many different physical quantities that can be used to express the amount of radiation delivered to a human body. Generally, there are advantages and applications as well as disadvantages and limitations for each of the quantities. There are two types of radiation quantities: those that express the concentration of radiation at some point, or to a specific tissue or organ, and there are also quantities that express the total radiation delivered to a body (Perry Sprawls, May 1993) Figure 2.5 shows radiation quantities.

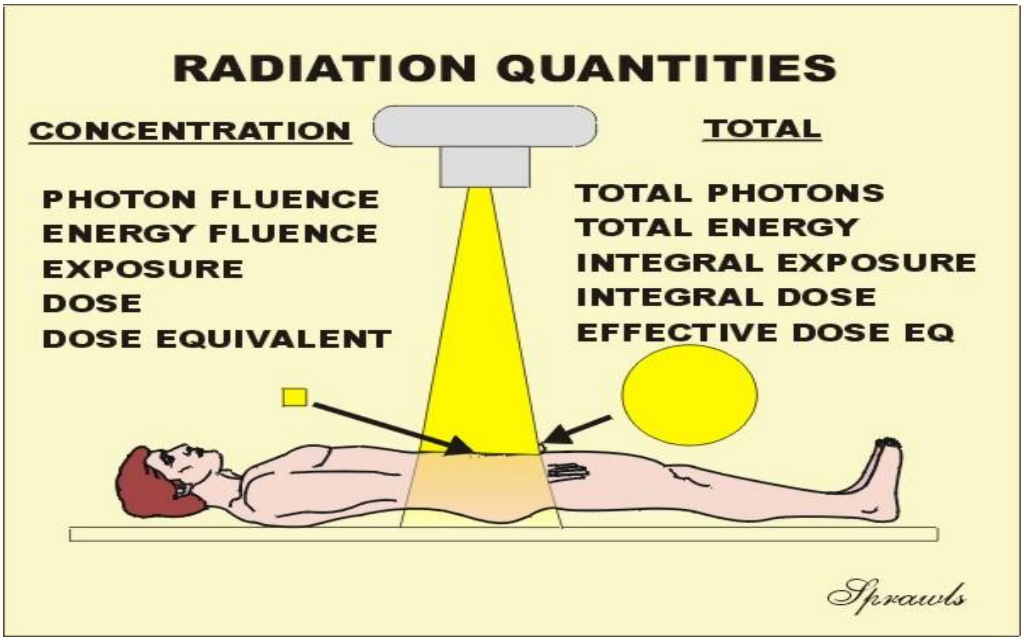

Figure 2.5: Radiation quantities

2.3.2 Radiation Units:

Throughout the course of history there have been many different systems of units developed to express the values of the various physical quantities. In more recent times the metric system has gradually replaced some of the other more traditional or classic systems, It his is also true for the units used for many of our radiation quantities (Perry Sprawls, May 1993).

2.3.3 Exposure:

Exposure is the quantity most commonly used to express the amount of radiation delivered to a point. The conventional unit for exposure is the roentgen (R). and the SI unit is the coulomb per kilogram of air (C/kg):

$$1\ R = 2.58 \times 10^{-4}\ C/kg$$

$$1\ C/kg = 3876\ R$$

The specific effect used to measure exposure is the ionization in air produced by the radiation. Exposure is generally measured by placing a small volume of air at the point of measurement and then measuring the amount of ionization produced within the air. Exposure is a quantity of radiation concentration. For specific photon energy, exposure is proportional to photon concentration (Perry Sprawls, May 1993).

2.3.4 Absorbed dose:

Absorbed dose is the quantity that expresses the concentration of radiation energy absorbed at a specific point within the body tissue. Since an x-ray beam is attenuated by absorption as it passes through the body, all tissues within the beam will not absorb the same dose Figure 2.6 shows absorbed Dose. The absorbed dose will be much greater for the tissues near the entrance surface than for those deeper within the body. Absorbed dose is defined as the quantity of radiation energy absorbed per unit mass of tissue (Perry Sprawls, May 1993). The conventional unit for absorbed dose is the rad. which is equivalent to 100 ergs of absorbed energy per (g) of tissue. The SI unit is the gray (Gy), which is equivalent to the absorption of (1J) of radiation energy per (kg) of tissue. The relationship between the two units is:

$$1\ rad = 100\ erg/g = 0.01\ J/kg = 0.01\ Gy$$

$$1\ Gy = 100\ rad$$

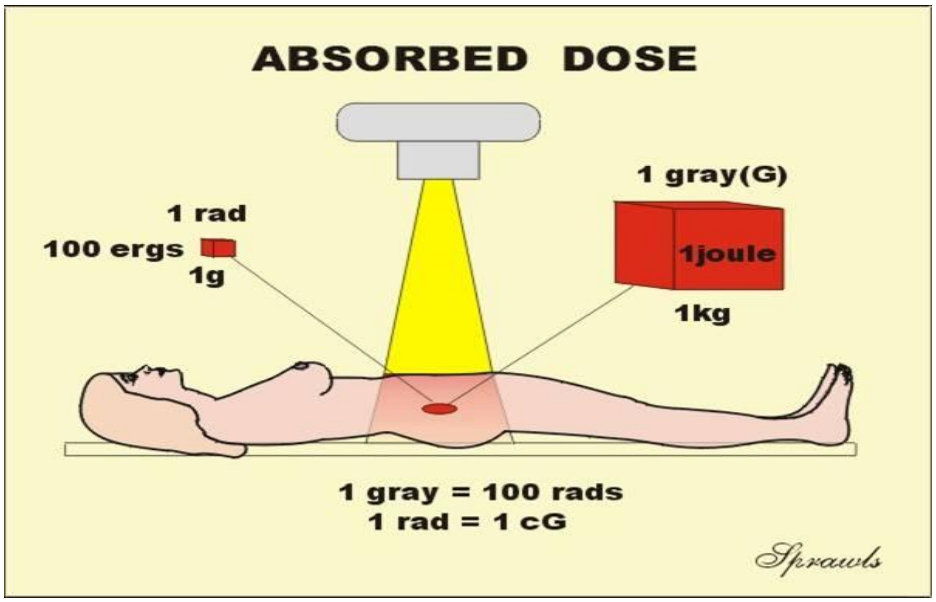

Figure 2.6: Absorbed Dose

2.3.5 Dose Equivalent:

Dose equivalent (H) is the quantity commonly used to express the biological impact of radiation on persons receiving occupational or environmental exposures. Personnel exposure in a clinical facility is often determined and recorded as a dose equivalent. Dose equivalent is proportional to the absorbed dose (D). the quality factor (Q) and other modifying factors (N) of the specific type of radiation. Most radiations encountered in diagnostic procedures (x-ray, gamma, and beta) have quality and modifying factor values of l. Therefore, the dose equivalent is numerically equal to the absorbed dose. Some radiation types consisting of large (relative to electrons) particles have quality factor values greater than 1 see table 2.2 (Perry Sprawls, 1993). The conventional unit for dose equivalent is the rem, and the SI unit is the sievert (Sv). When the quality factor is 1, the different relationships between dose equivalent (H) and absorbed dose (D) are:

$$H(rem) = D(rad)$$

$$H(Sv) = D(Gy)$$

Dose equivalent values can be converted from one system of units to the other by:

$$1\ Sv = 100\ rem.$$

Table 2.2: Radiation Weighting factors.

Radiation Type and Energy Range	Radiation Weighting Factor, WR
X and γ rays, all energies	1
Electrons positrons and muons, all energies	1
Neutrons:	
< 10 keV	5
10 keV to 100 keV	10
> 100 keV to 2 MeV	20
> 2 MeV to 20 MeV	10
> 20 MeV	5
Protons, (other than recoil protons) and energy > 2 MeV	2-5
α particles, fission fragments, heavy nuclei	20

2.3.6 Effective Dose:

Effective dose is becoming a very useful radiation quantity for expressing relative risk to humans, both patients and other personnel. It is actually a simple and very logical concept. It takes into account the specific organs and areas of the body that are exposed. The point is that all parts of the body and organs are not equally sensitive to the possible adverse effects of radiation, such as cancer induction and mutations (Perry Sprawls, 1993). For the

purpose of determining effective dose, the different areas and organs have been assigned tissue weighting factor (W_T) values.

If more than one area has been exposed, then the total body effective dose is just the sum of the effective doses for each exposed area. It is as simple as that. There is often a need to compare the amount of radiation received by patients for different types of x-ray procedures (Perry Sprawls, May 1993).

2.3.7 Computed Tomography Dose Index:

The Computed Tomography Dose Index, CTDI, is the special dose quantity that is used extensively to express absorbed dose in CT scan. Figure 2.7 shows Computed Tomography Dose Index. In CT scan, the x-ray beam is rotated around the patient and passes through from all sides. This gives a relatively uniform distribution of absorbed dose within each slice. A dose value determined at the center of the slice is usually considered a good indicator of tissue dose and can be used to compare imaging techniques and for dose management purposes (Perry Sprawls, May 1993).

One of the complicating factors in determining CT scan dose is that the tissue in a slice is exposed to two sources of radiation. One is the direct beam and the other is the scattered radiation from adjacent slices in the typical multiple slice imaging procedure. It is the contribution from the scattered radiation that is very difficult to measure. Values for the CTDI are determined by a measuring protocol that makes a reasonable estimate of the dose contribution from scatter.

A pencil shaped dosimeter (ionization chamber) is placed in a phantom. It is then scanned for only one complete slice and the dose value is read. The dosimeter will read the radiation from the direct x-ray beam within the slice plus the scattered radiation coming out of the sides of the slice and reaching the dosimeter (Perry Sprawls, May 1993).

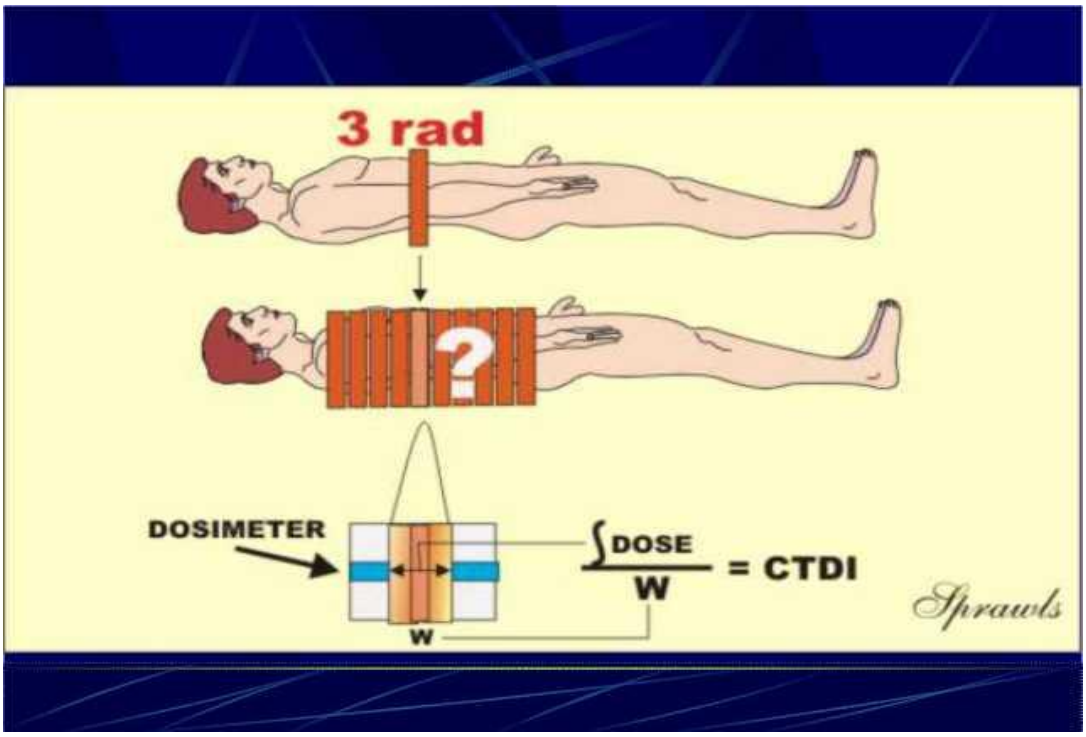

Figure 2.7: Computed Tomography Dose Index.

2.3.8 Computed Tomography Dose Length Product:

The CTDI is the practical quantity for specifying dose in CT scan procedures. The associated quantity for specifying the total radiation to a patient is the dose length product (DLP). The DLP is just the product of the CTDI value and the length of the body area scanned. Figure 2.8 shows Dose Length Product. It has the units of either Gy.cm. It is a useful and practical quantity for comparing the total radiation to a patient for various CT scan procedures. It is not a precise measure of the total radiation or integral dose that is more difficult to determine (Perry Sprawls, May 1993).

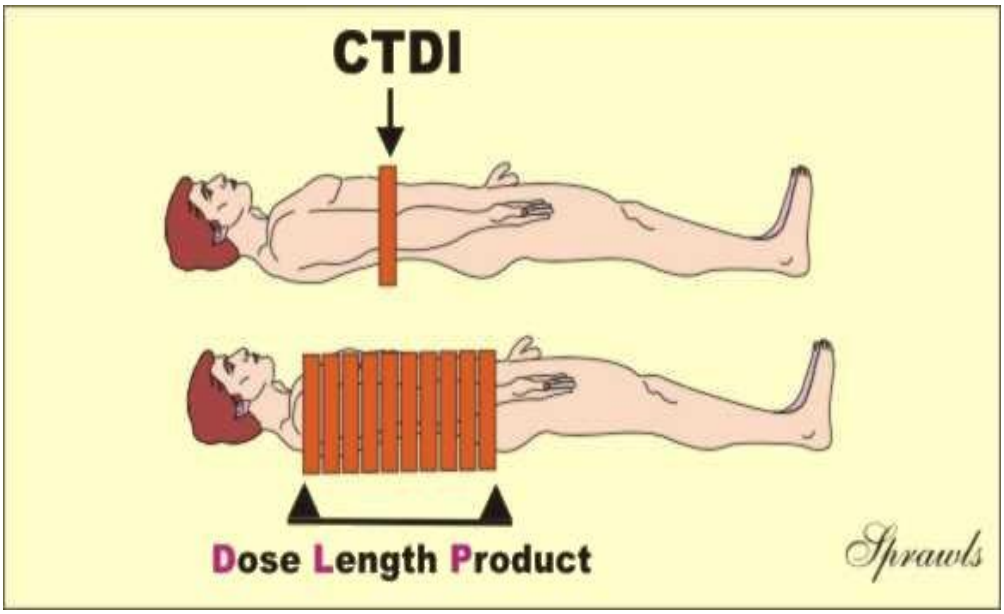

Figure 2.8: Dose Length Product

2.4 Breast radiation sensitivity:

The Breast tissue of young women is one of the most radiation sensitive tissues in a human body. The sensitivity of Breast tissue has been demonstrated in the Japanese atomic bomb survivors (Carmichael A.et al, 2003). Also, a significant increased risk in the incident of Breast carcinoma has been demonstrated in patients who have received substantial cumulative doses to the breast from multiple diagnostic x-ray procedures and from radiation therapy for benign diseases (Carmichael A.et al, 2003).

It has been reported that the delivery of 1 rad to a woman younger than 35 years, can increase the lifetime risk of breast cancer by 13.6% (Yilmaz et al, 2007). For comparison, breast doses from computed tomography and some nuclear medicine studies are greater than 1 rad. The adverse biological effects associated with radiation exposure are classified as either stochastic or deterministic and are largely defined by total dose and dose rate. The potential radiation effect from doses received in computed tomography is stochastic effects due to the magnitude of delivered dose. Stochastic effects are those where the occurrence of the effect is dose dependent (Ries LAG et al, 2004).

"The International Commission on Radiological Protection (ICRP) Special Task Force 2000 reported that the doses from computed tomography often approach or exceed levels that are known to increase the probability of nonfatal and fatal cancers" (ICRP, 2001). In the most recent ICRP publication 103, the breast weighting factor increased from 0.05 to 0.12. Table 2.3 shows the reported values in ICRP publication 60 (ICRP, 1990) and (ICRP, 2007). This is due to recent research showing the increased radiation sensitivity of breast tissue and the fact that breast cancer accounts for about one quarter of the total detriments in females (Tokunaga M et al, 2007).

Table 2.3: Weighting Factors as defined in ICRP 26,60 and 103.

Tissue or Organ	Weighting factors (ICRP 26) 1979	Tissue Weighting Factors (ICRP 60) 1990	Tissue Weighting Factors (ICRP 103) 2007
Bladder	-	0.05	0.04
Bone	0.03	0.01	0.01
Brain	-	-	0.01
Breasts	0.05	0.05	0.12
Colon	-	0.12	0.12
Esophagus	-	0.05	0.04
Liver	-	0.05	0.04
Lungs	0.12	0.12	0.12
Ovaries/testes	0.25	0.2	0.08
Red marrow	0.12	0.12	0.12
Remainder tissues	0.3	0.05	0.12
Salivary glands	-	-	0.01
Skin	-	0.01	0.01
Stomach	-	0.12	0.12
Thyroid	0.03	0.05	0.04
Total	1.00	1.00	1.00

2.5 Cancer Risk Assessment

Due to the high doses received through CT scan and the possibility of excessive radiation exposure, there Health Physics Society recommends that assessment of radiogenic health risks be limited to dose estimate near and above 100 mSv. Such ranges can patient use radiation risk, so as to establish radiation protection measure (Health Physics Society, 1995).

The numerical risks derive directly from the organ doses; the female specific risk coefficient to give the risk assessment. Table 2.4 shows the terminology that could be used to describe risks from radiation exposure (Martine, 2007). Using a variety of mathematical models including linear and non-threshold model, cell killing and cell replacement occurs through radiogenic effects at any dose, and creating an environment favorable for tumor growth, but in high dose the probability is high comparing of low dose, high dose which is define more than 100 mSv and low doses less than 100 mSv (Health Physics Society, 1995).

Table 2.4: Terminology used to describe risks from radiation exposure (Martin, 2007).

Effective dose range (mSv)	Level of risk	Proposed risk	Example of medical exposure
<0.1	1 in 1 million	Negligible	X-ray radiography of Chest, limbs, neck and teeth
0.1 – 1	1 in 100,000	Minimum	X-ray radiography of L.s.spine, Abdomen and Pelvis.
1 – 10	1 in 10,000	Very low	Fluoroscopy, CT scan of Head, Chest and Abdomen and nuclear medicines scans.
10 – 100	1 in 1000	Low	Double CT scan for contrast enhancement, higher dose interventional radiology procedure

2.6 Literature review

2.6.1 Previous studies:

This section presents other related researchers who conducted studies similar to the proponents that will also greatly help in die progress of the study. And it will also help the understanding of the proposition.

A study by (Hurwitz et al, 2006) titled "Radiation Dose to the Female Breast from 16 Multiple detector computed tomography (MDCT) Body Protocols". The study intended to determine the radiation dose to the female breast from current 16-MDCT body examinations. Metal oxide semiconductor field effect transistor (MOSFET) detectors were placed in four quadrants of the breast of a female configured anthropomorphic phantom to determine radiation dose to the breast. Imaging was performed on a 16-MDCT scanner using current clinical protocols designed to assess pulmonary embolus (PE) (140 kVp, 380 mA, and 0.8-sec rotation), appendicitis (140 kVp, 340 mA, and 0.5-sec rotation) and renal calculus (140 kVp, 160 mA, and 0.5-sec rotation). Radiation dose to the breast ranged from 4 to 6 mGy for the PE protocol and up to 1-2 mGy in the inferior aspect of the right breast and lateral aspect of the left breast for the appendicitis protocol. The renal calculus protocol yielded less than 150 mGy absorbed breast dose. Current clinical chest and abdomen protocols result in variable radiation doses to the breast. The magnitude of exposure may have implications for imaging strategies.

A study by (Staley, 2012) with the title "Assessing the use of routine abdominal CT in staging evaluation of patients with primary breast cancer". The purpose of this study was to determine the utility of routine abdominal CT in the staging evaluation of women with newly diagnosed primary breast cancer given no detectable disease beyond the ipsilateral axillary nodes on chest CT. The chest and abdominal CT scans from 440 patients over a 10-year period were reviewed. The presence of definite or possible metastatic disease in the axillary nodes, chest wall, internal mammary nodes, mediastinal nodes, lungs, liver and adrenals were recorded for each patient. Cross tabulation bivariate analysis as well as ache-

square test was performed to characterize the relationship between detection of disease in the chest and disease in the abdomen. Of die 440 patients reviewed, the following were found to have detectable metastatic disease by CT scan: axillary nodes 258 of 440 (56.46%), chest wall 40 of 440 (9.10%), 26 intemalmammary nodes 8 of 440 (1.82%), mediastinal nodes 29 of 440 (6.59%), lung 25 of 440 (5.68%), liver 12 of 437 (2.73%), and adrenals 8 of 440 (1.82%). In total, 81 patients had disease detectable in the chest beyond the ipsilateral axillary nodes, and only 12 patients had detectable disease spread in the abdomen. Of the 359 patients who had a negative chest CT, only 1 patient had detectable or possible metastatic disease spread on abdominal CT, resulting in a99.70% negative predictive value ($p < 0.001$). The routine use of abdominal CT in women with newly diagnosed primary breast cancer and no detectable disease beyond the ipsilateral axillary nodes on staging chest CT scan has little value with a 99.70% negative predictive value. We recommend that if a negative CT scan of the patient's chest yields no detectable disease beyond the axillary nodes, then further CT imaging of the abdomen is of no additional benefit to the patient.

A study by (Lee et al, 2012) by the title "Breast Cancer Risk Estimates Increased with Repeated Prior CT ". The purpose of this study is to estimate increased with repeated CT imagines. They collected CT dose information from 1,656 patients who Underwent CT examinations that exposed the breast to radiation and, using a new automated computational method, estimated the patients' effective radiation dose and the amount of radiation absorbed by the breast. The researchers then estimated the Women imaging-related risk of breast cancer and compared it to their underlying risk of developing breast cancer. Each woman's 10-year imaging- related risk of Developing breast cancer, beginning 10 years after her exposure to imaging and based On her age at exposure, was estimated using die breast-specific radiation data and a Statistical risk model. They found that young women receiving several chest and or Cardiac CTs had the greatest increased risk of developing breast cancer at approximately 20 percent. To lower imaging-related risk of developing breast cancer, imaging providers should analyze the radiation doses associated with each exam, reduce the use of multi-phase protocols and employ dose-reduction software Wherever Possible to minimize exposures.

A study by (Fuji et al, 2009) studied "Radiation dose evaluation in 64-slice CT examinations with adult anthropomorphic phantom". The objective of this study was to evaluate the organ dose and effective dose to patients undergoing routine adult CT examinations with 64-slice CT scanners and to compare the doses with those from 4-, 8- and 16- multislice CT scanners. Patient doses were measured with small (, 7 mm wide) silicon photodiode dosimeters (34 in total), which were implanted at various tissue and organ 27 positions within adult anthropomorphic phantom. Output signals from photodiode dosimeters were read on a personal computer, from which organ and effective doses were computed. For the adult phantom, organ doses and effective doses were 8-35 mGy and 7-18 mSv, respectively, for chest CT. Doses to organs at the boundaries of the scan length were higher for 64- slice CT scanners using large beam widths and/or a large pitch because of the larger extent of over-ranging. The CT dose index (CTDIvol), dose length product (DLP) and the effective dose values using 64-slice CT for the adult phantom was the same as those obtained using 4-, 8- and 16-slice CT. Conversion factors of DLP to the effective dose by International Commission on Radiological Protection l03 were 0.024 mSv. MGy.cm for adult chest CT scans.

A study by (Aldrich JE.et al, 2006) about "Radiation doses to patients receiving computed tomography examinations". The purpose of this study was to estimate the diagnostic reference levels and effective radiation dose to patients from routine computed tomography (CT) examinations. The patient weight, height and computed tomography dose index or dose linear product (DLP) were recorded on study sheets for 1070 patients who were referred for clinically indicated routine CT examinations at 18 radiology departments in British Columbia. Sixteen of the scanners were multidetector row scanners. The average patient dose varied from hospital to hospital. The largest range was found for CT of the abdomen, for which the dose varied from 3.6 to 26.5 (average 10.1) mSv and for chest CT, it was 3.8 to 26 (average 9.3) mSv; Reference dose values were calculated for each exam. These DLP values are as follows: chest, 600 mGy cm and abdomen, 920 mGy cm. Among hospitals, there was considerable variation in the DLP and patient radiation dose for a specific exam. Reference doses and patient doses were higher than those found in similar recent surveys carried out in the United Kingdom and the European Union. Patient doses were similar to those found in a recent survey in Germany.

A study by (Clarke et al, 2000) studied "Application of draft European Commission reference levels to a regional CT dose survey". The method used was to study standard protocols and calculate doses to the NRPB mathematical phantom, so that a direct comparison could be made with other surveys carried out in a similar fashion elsewhere. The surrey addressed the patient radiation dose but not image quality or clinical outcomes. It is estimated that in Northern Ireland the contribution to collective dose to the population 28 from CT is about 4% of that from all medical x-rays, the proposed European Commission reference quantities, weighted CT dose index and dose- length product were computed and their potential use evaluated. A full study of mean values of effective dose per examination revealed the average dose per examination was not significantly different from that found in the 1989 UK surrey, although several procedures gave rise to doses that were high enough to be investigated with a view to justification or reduction. One of the scanners was found to give consistently high doses. It is likely that a revision of the mAs values used on this scanner will produce a significant reduction in patient doses without compromising image quality. When compared with the draft EC reference levels would therefore be useful for continual monitoring of CT dose status, but do not appear to provide as comprehensive an assessment of patient exposure as that given by consideration of effective doses.

A study by (Ngaile et al, 2006) studied Estimation of patient organ dose from CT examinations in Tanzania. The aims of this study are, first, to determine the magnitude of radiation dose received by selected radiosensitive organ of patients undergoing CT examinations and compare them with other studies, and second, to assess how CT scanning protocols in practice affect patient organ dose. Patient organ dose from five common CT examinations were obtained from eight hospitals in Tanzania. The patient organ doses were estimated using measurements of CT dose indexes (CTDI), exposure related parameters, and the Impacts spreadsheet based on NRPB conversion factors. The mea organ dose in this study for the breast (for chest) was 26.1 mGy. This value was mostly comparable to and slightly higher than the values of organ doses reported from the literature for the United Kingdom, Japan, Germany, Norway, and the Netherlands. It was concluded that patient organ doses could be substantially minimized through careful selection of scanning parameters based on clinical indications of study, patient size, and

body region being examined. Additional dose reduction to superficial organs would require the use of shielding materials.

A study by (Origgi et al, 2010) by the title of " Survey of computed tomography techniques and absorbed dose in Italian hospitals" The aim of this study was the production of the first Italian survey of radiation dose in computed tomography (CT) prior to the widespread adoption of multislice CT, in order to have a reference point to facilitate later investigation of dose exposure changes brought by this new CT modality. The collected dose data were compared with diagnostic reference levels (DRLs). The agreement between experimental dose evaluation and Monte Carlo (MC) simulations 29 was investigated. The survey was carried out in 29 Italian hospitals, covered 48 CT scanners and 232 examinations. The dose-length product (DLP) and effective dose (E) values were estimated based on MC simulations for seven clinical protocols using the CT-Dose program. Statistical analysis showed a significant difference (^{p} <0.01) in the DLP between the two methods, with MC values being greater than the experimental ones. The weighted CT dose index, the DLP and E were always below the DRLs set by the European Community. This dose survey gives a good but incomplete picture of the Italian CT dose situation and may be useful as a reference baseline for defining clinical multislice protocols in the near future.

A study by (Livingstone et al, 2010) studied "Radiation doses during chest examinations using dose modulation techniques in multislice CT scanner". The purpose of this study was to evaluate the radiation dose and image quality using a manual protocol and dose modulation techniques in a 6-slice CT scanner. Two hundred and twenty-one patients who underwent contrast-enhanced CT of the chest were included in the study. For the manual protocol settings, constant tube potential (kV) and tube current-time product (mAs) of 140 kV and 120 mAs, respectively, were used. The angular and z-axis dose modulation techniques utilized a constant tube potential of 140 kV; mAs values were automatically selected by the machine. Effective doses were calculated using dose length product (DLP) values and the image quality was assessed using the signal-toniest (SNR) ratio values. Mean effective doses using manual protocol for patients of weights 40-60 kg, 61-80 kg, and 81 kg and above were 8.58mSv, 8.54 mSv, and 9.07 mSv, respectively. Mean effective doses using z-axis dose modulation for patients of weights 40-60 kg, 61-80 kg, and 81 kg and above were 4.95 mSv, 6.87 mSv, and 10.24 mSv, respectively. The SNR at the region

of the liver for patients of body weight of 40- 60 kg was 5.1 H, 6.2 H, and 8.8 H for manual, angular, and z-axis dose modulation, respectively. Dose reduction of up to 15% was achieved using angular dose modulation and of up to 42% using z-axis dose modulation, with acceptable diagnostic image quality compared to the manual protocol.

A study by (Smith-Bindman et al, 2009) studied "radiation dose associated with common CT examinations and the associated lifetime attributable risk of cancer". They sought to estimate the radiation dose associated with common CT studies in clinical practice and quantify the potential cancer risk associated with these examinations. They conducted a retrospective cross sectional study describing radiation dose associated with the 11 most common types of diagnostic CT studies performed on 1119 consecutive adult patients at 4 30 San Francisco Bay Area in situation California. They estimated life time attributable risks of cancer by study types from these measured doses. Radiation doses varied significantly between the different types of CT studies. The overall median effective doses were 31 mSv for a multiphase abdomen and pelvis CT scan. Within each type of CT study effective dose varied significantly within across institutions, with a mean 13- fold variation between the highest and lowest dose for each study type. The estimated number of CT scans that will lead to the development of a cancer varied widely depending on the specific type of CT examination and the patient's age and sex. An estimated 1 in 270 women who underwent CT coronary angiography at age 40 years will develop cancer from that CT scan (1 in 1180 men). For 20 year old patients, the risks were approximately doubled, and for 60 year old patients, they were approximately 50% lower. Radiation doses from commonly performed diagnostic examinations are higher and more variable than generally quoted, highlighting the need for greater standardization across institutions.

A study by (Andrew J. Einstein, MD, PhD et al, 2007) studied " Estimating Risk of Cancer Associated with Radiation Exposure From 64-Slice Computed Tomography Coronary Angiography". Organ doses ranged from 42 to 91 mSv for the lungs and 50 to 80 mSv for the female breast. Lifetime cancer risk estimates for standard cardiac scans varied from 1 in 143 for a 20-year-old woman to 1 in 3261 for an 80-year-old man. Use of simulated electrocardiographically controlled tube current modulation (ECTCM) decreased these risk estimates to 1 in 219 and 1 in 5017, respectively. Estimated cancer risks using ECTCM for

a 60-year-old woman and a 60-year-old man were 1 in 715 and 1 in 1911, respectively. A combined scan of the heart and aorta had higher LARs, up to 1 in 114 for a 20-year-old woman. The highest organs LARs were for lung cancer and, in younger women, breast cancer.

A study by (Rebecca Smith-Bindman, 2009) studied “Radiation Dose Associated With Common Computed Tomography Examinations and the Associated Lifetime Attributable Risk of Cancer". Radiation doses varied significantly between the different types of CT studies. The overall median effective doses ranged from 2 millisieverts (mSv) for a routine head CT scan to 31 mSv for a multiphase abdomen and pelvis CT scan. Within each type of CT study, effective dose varied significantly within and across institutions, with a mean 13-fold variation between the highest and lowest dose for each study type. The estimated number of CT scans that will lead to the development of a cancer varied widely depending on the specific type of CT examination and the patient’s age and sex. An estimated 1 in 270 women who underwent CT coronary angiography at age 40 years will develop cancer from that CT scan (1 in 600 men), compared with an estimated 1 in 8100 women who had a routine head CT scan at the same age (1 in 11 080 men). For 20-year-old patients, the risks were approximately doubled, and for 60-year-old patients, they were approximately 50% lower.

Chapter Three:

Materials and Methods:

3.1 Collect, Survey data processing and analysis

This study intended to estimate the breast dose and effective dose from Chest CT scan examinations. Data was collected from 10 hospitals in Palestine (West Bank and Gaza strip). According to previous experience from literature reviews, effective dose and organ dose have been estimated through several steps, and different models used. Data was collected from May to November 2016.

3.2 Data collection

Data were collected using a sheet for all patients in order to maintain consistency of the information displayed during CT scan examinations (Appendix A).The data used in this study were collected from Departments of Radiology in Palestine. Patient data collected from these hospitals were further classified into two categories.

First, data were collected to study the effects of patient related parameters (e.g., age, gender, height and weight) (Patient phantom), diagnostic purpose of examination, body region and body mass index (BMI) Table 3.1 shows values of patient's data. A total of

approximately 200 female patients under went Chest CT scanning examinations. Doses in this study were measured in different CT scan technologies. Table 3.3 shows hospitals and different scanners and numbers of slices. The results were tabulated in the tables (mean ± standard deviation (SD)) and the range of the readings. The mean and the standard deviation were calculated using excel version 2010.

Secondly, data were collected to investigate the effect of exposure related parameters (gantry tilt, peak voltage (kV), tube current (mA), exposure time, slice thickness, table increment, number of slices, and start and end positions of scans), and $CTDI_w$ and DLP Table 3.2 shows exposure parameters data.

Table 3.1: The values of patient's data during CT scan examinations used each hospital in Palestine.

Hospitals	**Age (years)**	**Height (m)**	**Weight (kg)**	**Body Mass Index (BMI)= Weight /(Height)^2 (KG/CM^2)**
(H1)	49 (32-66)	1.69 (1.6-1.8)	75.7 (64-89)	26.5
(H2)	40 (22-66)	1.66 (1.6-1.7)	69.9 (65-75)	25.37
(H3)	50 (30-75)	1.67 (1.55-1.70)	76.33 (55-85)	27.36
(H4)	42 (20-68)	1.73 (1.6-1.85)	84 (60-96)	28.1
(H5)	44 (22-72)	1.69 (1.52-1.84)	72.2 (52-110)	25.28

Hospitals	Age (years)	Height (m)	Weight (kg)	Body Mass Index (BMI)= Weight /(Height)^2 (KG/CM^2)
(H6)	41 (19-75)	1.684 (1.55-1.84)	73.86 (65-90)	26
(H7)	43 (24-62)	1.694 (1.60-1.80)	76 (50-100)	27
(H8)	39 (17-65)	1.655 (1.50-1.80)	81.7 (60-110)	30
(H9)	44 (19-75)	1.71 (1.55-1.80)	76.93 (55-90)	26.6
(H10)	35 (18-60)	1.70 (1.62-1.80)	77.73 (58-95)	27

Table 3.2: Patient data and exposure parameters of CT scan examinations used each hospital.

Hospitals	Numbers of patients	Exposure setting (mAs)	Scan time (second)
(H1)	10	200	4
(H2)	15	200	4
(H3)	15	216	6
(H4)	30	300	20

Hospitals	Numbers of patients	Exposure setting (mAs)	Scan time (second)
(H5)	30	168	4
(H6)	20	200	6
(H7)	20	240	20
(H8)	20	250	21
(H9)	20	200	8
(H10)	20	350	21

3.3 CT scan Machines

Ten CT scan machines were used to collect data during this study. These machines are installed in Ten Hospitals radiological departments Table 3.3 shows ten CT scanners in Palestine. All quality control tests were performed to the machines prior to any data collection.

Table 3.3: Specifications of CT scanners used each hospital in Palestine.

Hospital	Manufacturer	Scanner model/ Scan mode	Field Of View(FOV)/ Detector type
(H1)	Philips Medical systems, manufactured 2013.	Brilliance iCT Big Bore, 128 slices, Spiral and helical modes.	FAD:60cm Detector: Solid State array GOS. (cadmium tungstate)
(H2)	Philips Medical systems, manufactured 2010.	Brilliance iCT Big Bore, 128 slices, Spiral and helical modes.	FAD:60cm Detector: Solid State array GOS. (cadmium tungstate)
(H3)	Philips Medical systems,	Brilliance iCT Big Bore, 128 slices,	FAD:60cm Detector: Solid State array

	manufactured 2013.	Spiral and helical modes.	GOS. (cadmium tungstate)
(H4)	Philips Medical systems, Manufactured 2010.	Multi-slice MX 16 slices, Spiral and helical modes.	FAD:50cm Detector: Solid State GOS.
(H5)	Siemens Medical systems, Manufactured 2012.	SOMATOM Definition AS+, 128 slices, Spiral and helical	FAD:70cm Detector: Stellar.
(H6)	Philips Medical systems, Manufactured 2012.	Brilliance 64 channel with essence technology Spiral and helical Modes.	FAD:50, 25cm Detector: Solid State GOS.
(H7)	Siemens Medical Systems, Manufactured 2010.	Multi-slice MX 16 slices, Spiral and helical modes.	FAD:≤50cm Detector: Stellar.
(H8)	Philips Medical Systems, Manufactured 2010.	Multi-slice MX 16 slices, Spiral and helical Modes.	FAD:50, 25cm Detector: Highlight ceramic matrix.
(H9)	Philips Medical systems, Manufactured 2011.	Brilliance iCT Big Bore, 128 slices, Spiral and helical modes.	FAD:60cm Detector: Highlight ceramic matrix
(H10)	Philips Medical Systems, Manufactured 2010.	Multi-slice MX 16 slices, Spiral and helical Modes.	FAD:50, 25cm Detector: Highlight ceramic matrix.

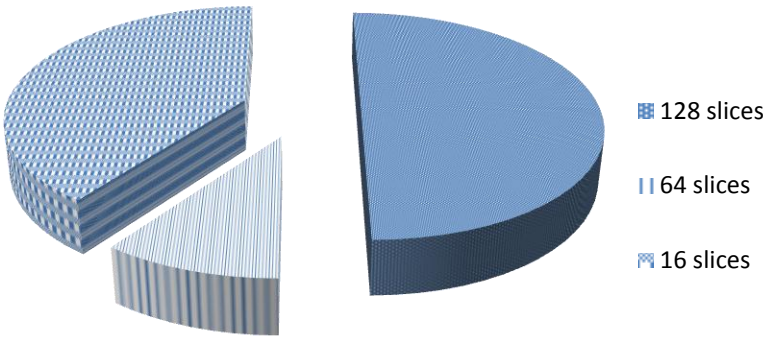

Figure 3.1: Distribution of the CT scan mode in this study.

3.4 CT Scan dose measurements

Dose estimation was carried out Monte Carlo method, by inputting patient individual exposure parameters of kVp and mAs. Patient's age, height and weight were presented per departments. The correlation coefficient which is defined as a measure of the degree of linear relationship between two variables, usually labeled X and Y was used in this study to describe the relation between effective dose against mAs and DLP. Radiation dose indicators $CTDI_{vol}$ and DLP can be obtained from a dose summary page, which includes information about the CT scan examination. $CTDI_{vol}$ allows the comparison of scan protocols or scanners and is useful for obtaining data to compare techniques, but it is not so good for estimating patient dose (Ridely, 2012). DLP is an indicator of the dose imparted to the patient is estimated by multiplying $CTDI_{vol}$ times the scan length. In addition to being affected by the issues associated with $CTDI_{vol}$, DLP can be problematic in a limited scan range (Ridely, 2012).

The CTDI is defined as:

The radiation dose, normalized to beam width, measured from 100 mm length of a pencil ionization chamber.

$$CTDI_{100} = 1/NT \int_{+\infty cm}^{-\infty cm} D(z)dz \qquad mGy \qquad 3.1$$

Where D (z) absorbed dose relative to location along the z axis; N is the number of acquired sections per scan (or the number of data channels used during acquisition) and T

is the nominal width of each acquired section or slice thickness (product of NT is also known as beam collimation).

The normalized average dose to the slice is:

$$CTDI_w = (1/3\ CTDI_{100,\,C} + 2/3\ CTDI_{100,\,P)} \qquad mGy \qquad 3.2$$

Where $CTDI_{100,\,C}$ is center location of the phantom, $CTDI_{100,\,p}$ is average of measurements at four different locations around the periphery of the phantom.

Specific imaging protocols also include the pitch as a factor, thus in Consideration of that factor, another descriptor has been created. The unit is $CTDI_{vol}$ or $CTDI_W$. It is defined as:

$$CTDI_{vol} = CTDI_{w.}\ NT/I \qquad mGy \qquad 3.3$$

Where W and T are defined in equation 3.1and 3.2 and represent the total collimated width of the X-ray beam and (I) is the table increment per rotation for helical scan or spacing between acquisitions for axial scans.

Pitch is one of the parameters in spiral CT scan Pitch is defined as table distance travelled in one 360° rotation over total collimated width of the x-ray beam, while in conventional CT scan it is defined as table increment over slice thickness.

Pitch can be calculated by the equation 3.3:

$$Pitch = I/NT \qquad 3.4$$

Thus equation 3.2 can be rewritten as:

$$CTDI_{vol} = CTDI_W/Pitch \qquad mGy \qquad 3.5$$

In describing the exposure distribution along the z axis another descriptor known as Dose Length Product (DLP) (European Commission 1998) is used as an integral dose quantity. This DLP is created as estimated effective dose value without taking account of tissue weighting factor.

The DLP is expressed in units of Gy.cm and given in the equation below:

$$DLP = CTDI_{vol.}\ Scan\ length \qquad mGy.cm \qquad 3.6$$

3.5 Breast organ dose estimation

The use of the Monte Carlo method for organ doses estimation in CT scan diagnostics used a MIRD V and voxelized patient data. To accomplish this we have modified a general purpose Monte Carlo transport code (MCNP4B) to simulate the CT x-ray source and movement, and then calculate absorbed radiation dose in desired objects (G Jarry et al, 2003). The movement of the source in either axial or spiral modes was modeled explicitly while the CT system components were modeled using published information about x-ray spectra as well as information provided by the manufacturer. Simulations were performed for single axial scans using the head and body computed tomography dose index (CTDI) polymethylmethacrylate phantoms at both central and peripheral positions for all available beam energies and slice thicknesses as seen figure in 3.2 (G Jarry et al, 2003).

Figure 3.2: Phantom models in Monte Carlo Simulation.

This was done by first marking the start and end positions of the scan region and then determining the scan length from the number of slices, the slice thickness, and the table increment. This information was used in the selection of the part of the phantom irradiated in order to improve the correspondence between the organs irradiated in the patient and the phantom (IAEA, 2001).

The organ equivalent dose (mSv) is given by:

$$H_T = \Sigma_R W_R . D_{T,R} \quad 3.7$$

Where $D_{T,\ R}$ is the mean absorbed dose to tissue (T) from radiation (R) and W_R is the radiation weighting factor from the recent ICRP recommendations. Effective dose (E, mSv) is a quantity that has been introduced to give an indication of risk from partial or non-uniform exposure to risk from an equivalent body exposure.

E is given by the following equation:

$$E = \Sigma_T W_T . H_T \quad 3.8$$

Where H_T is the equivalent dose to tissue T and W_T is the weighting factor representing the relative radiation sensitivity of tissue T.

3.6 Effective dose estimation

CT scanners record the radiation exposure as a DLP in mGy.cm. DLP can be multiplied by the appropriate conversion factor to be converted in to effective dose in mSv. The dose length is typically saved on picture archiving and communication system (PACS) within a radiation report that appears as a separate series in the form of a screenshot as soon in Figure 3.2, in the absence of automated or computerized translation of DLP into effective dose equivalent, for use of the Monte Carlo method for effective doses estimation in CT scan (Ridely, 2012).

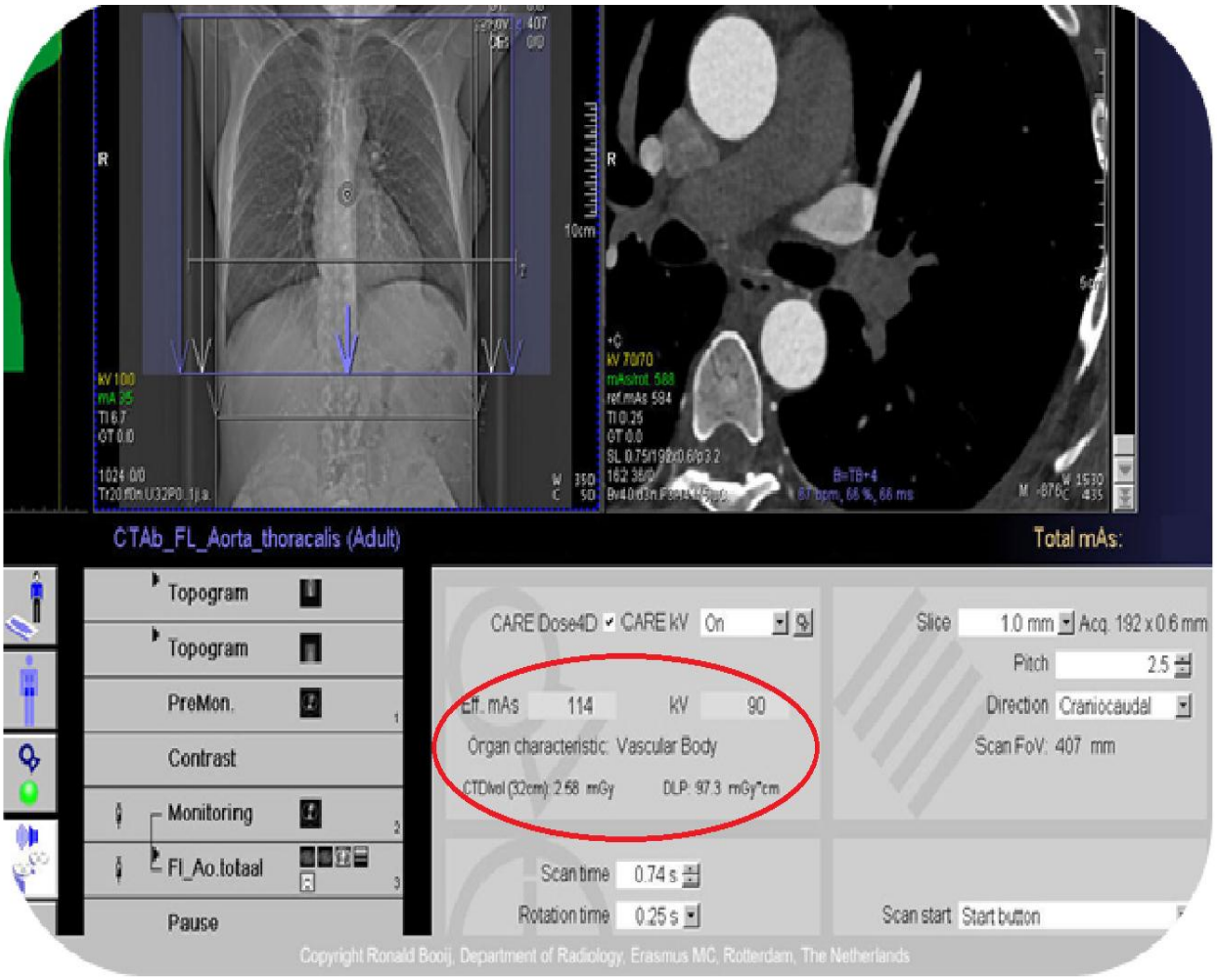

Figure 3.3: Screenshot shows example of radiation report generated by modern MDCT and sent to PACS as separate series, Total dose length product is displayed in mGy.cm and $CTDI_{vol}$ is displayed in mGy.

3.7 Monte Carlo Simulation Software

Virtual Patient incorporation (VPI) is a computer program was founded in 2009 by faculty members from Rensselaer Polytechnic Institute (RPI), in collaboration with the University of Florida (UF), using the VPI technologies developed from nearly 20 years research at RPI and UF in the field of nuclear and radiological engineering. Combining a large collection of anatomically accurate models of patients of various ages and sizes and sophisticated “Monte Carlo” simulation methods originally developed for nuclear weapons research at Los Alamos in the 1940s, VPI is recognized as a world leader in the modeling

of ionizing radiation, radiation safety, and medical occupational radiation dosimeter (Virtual Phantoms Inc.).

Monte Carlo Simulation CT scan uses cutting edge advances on Monte Carlo simulation software to estimate CT doses for the latest CT scanners and International Commission on Radiological Protection (ICRP) (Virtual Phantoms Inc., 2016), recommendations across multiple anatomically realistic patient phantoms for:

- Average (or median) adult patients.
- Children at different ages (newborn, 1, 5, 10, and 15 year old).
- A pregnant female at three gestational stages (3, 6, and 9 month).
- Overweight and obese patients.

The entrance surface dose by direct measurements on patients using TLDs could accurately estimate the dose to this superficial organ not internal organ. There are we used Monte Carlo Simulation to accurately estimate internal Organ dose and Effective dose. Virtual Dose CT scan is sophisticated radiation dose simulation software for radiologists, technologists, and medical physicists. See Figure 3.3 which shows Monte Carlo modeling Simulation radiological software.

Virtual Dose CT scan enables users to assess organ doses, in addition to CTDI and DLP data provided by the CT scanner. It is able to differentiate for individuals outside of the "average" population body habitus. It is ready for use with the latest CT scanners and with recent ICRP-60 and ICRP-103 recommendations on effective dose.

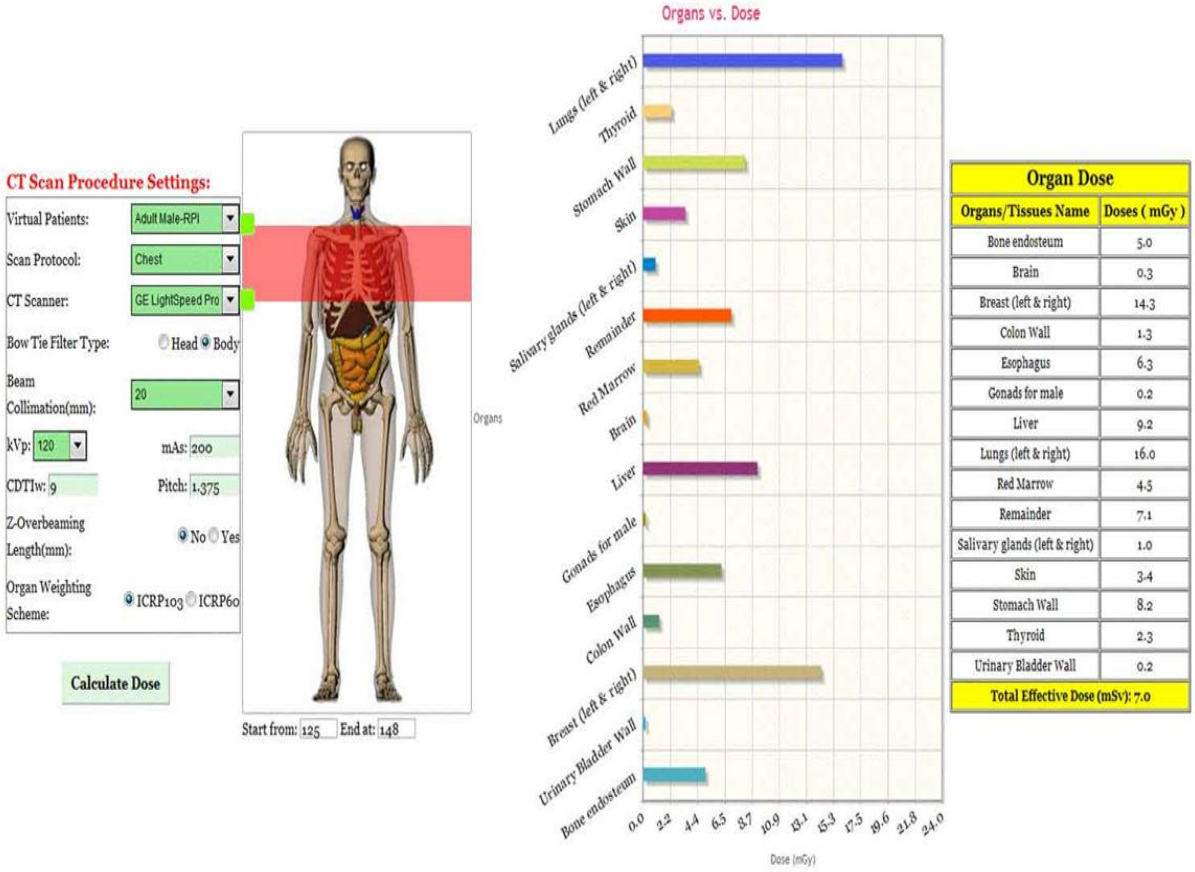

Figure 3.4: Monte Carlo Simulation software.

3.8 Breast cancer risk assessment

The risk (R_T) of developing cancer in a particular organ (T) following after irradiation was estimated by multiplying the mean organ equivalent (H_T) dose with the risk coefficients (F_T) obtained from ICRP.

$$R_T = H_T \,.\, F_T \qquad 3.9$$

The overall lifetime mortality risk (R) per procedure resulting from cancer / heritable was determined by multiplying the effective dose (E) by the risk factor (F). The risk of genetic

effects in future generations was obtained by multiplying the mean dose to the ovaries by the risk factor (ICRP, 1991).

$$R = E.F = \Sigma R_T \qquad 3.10$$

3.9 BEIR VII Risk Modeling

The Seventy Biological effects of Ionizing Radiation Committee Phase Two (BEIR VII Phase 2) committee was convened in 1998, after a Phase 1 committee formed to address the US Environmental Protection Agency's request of the National Academy of Sciences to evaluate the need for a follow up of health effects of low levels of ionizing radiation had concluded that such follow up was necessary.

The 17 member of BEIR VII Phase 2 were composed of international experts in a variety of scientist fields to develop theory and models found solve this problem about "Develop the best possible risk estimates for exposure to low dose, low linear energy transfer radiation in human subjects" (Andrew J. Einstein et al, 2007).

For each age, sex and organ, the estimated lifetime attributable risk (LAR) of cancer incidence from 100 mSv organ equivalent dose was determined using Table 12D-1 see Table 3.4 of the BEIR VII report. If data were not available for a specific age, then linear interpolation was performed from the 2 nearest tabulated ages.

This LAR from a theoretical 100 mSv organ dose was scaled linearly based on the actual organ dose determined in the Monte Carlo simulation. For example, the breast equivalent dose for a 50 year old woman from a standard Chest CT scan is 12 mSv; the LAR of Breast cancer incidence for a 50 year old woman from a 100 mSv Breast dose is 70 cases per 100 000 by the BEIR VII preferred model, so the LAR from a 12 mSv dose is (12/100) x (70/ 100, 000) or 0.008% or 100,000 / (12/100) x 70 = 1 in 6803 (BEIR VII Phase 2, 2006).

Table 3.4: Table 12D-1 lifetime attributable breast cancer risk of incidence (BEIR VII Phase 2, 2006).

Age at Exposure (years) Females	**0**	**5**	**10**	**15**	**20**	**30**	**40**	**50**	**60**	**70**	**80**
Stomach	101	85	72	61	52	36	35	32	27	19	11
Colon	220	187	158	134	114	82	79	73	62	45	23
Liver	28	23	20	16	14	10	10	9	7	5	2
Lung	733	608	504	417	346	242	240	230	201	147	77
Breast	**1171**	**914**	**712**	**553**	**429**	**253**	**141**	**70**	**31**	**12**	**4**
Uterus	50	42	36	30	26	18	16	13	9	5	2
Ovary	104	87	73	60	50	34	31	25	18	11	5
Bladder	212	180	152	129	109	79	78	74	64	47	24
Other	1339	719	523	409	323	207	181	148	109	68	30
Thyroid	634	419	275	178	113	41	14	4	1	0.3	0.0
All solid	4592	3265	2525	1988	1575	1002	824	678	529	358	177
Leukemia	185	112	86	76	71	63	62	62	57	51	37
All cancers	4777	3377	2611	2064	1646	1065	886	740	586	409	214

NOTE: Number of cases per 100,000 persons exposed to a single dose of 0.1 Gy.

Chapter Four:

Results and discussion:

4.1 Chest CT scans parameters and absorption dose

A total of 200 female patients underwent Chest CT examinations in Palestine. Appendix C and Table 4.1 shows DLP and $CTDI_{vol}$ for patients in ten hospitals in Palestine. There are wide variations in patient's doses among different CT scanner, parameters such as ordinary CT scan DLP and $CTDI_{vol}$. The values of DLP range (410 - 1067) mGy.cm and $CTDI_{vol}$ range (3.75 – 16.6) mGy for Chest CT scan in Palestine.

The kVp was the same (120 kVp) for all hospitals; the trend was almost the opposite for mAs product, which a large variation ranging from 168 to 350 mAs for Chest CT scan for different hospitals, and these variation caused for different in CT scanner and focus to isocenter distance among scanners (Radio protective garments, 2013).

The radiation intensity is inversely proportional to the square of the distance between the focus and the patient, this intensity due to shorter distance, and lower the mAs values, while the longer the distance due to higher the mAs values. The scan length (calculated from slice thickness, table increment, and number of slices) varied among scanners (Radio protective garments, 2013).

Table 4.1: means of $CTDI_{vol,}$ DLP and Pitch for patient during Chest CT scan used each hospital.

Hospitals	$CTDI_{VOL}$ (mGy) Per 100 mAs	$CTDI_w$ (mGy) = $CTDI_{VOL}$ x Pitch	Pitch	DLP (mGy.cm)
(H1)	6	6	1	423
(H2)	8	8	1	410
(H3)	7.7	7.7	1	410
(H4)	11	10	0.9	978
(H5)	5.6	5	0.9	427
(H6)	6	6	1	406
(H7)	8	7	0.9	967
(H8)	15	13.5	0.9	1000
(H9)	3.75	3.75	1	407
(H10)	16.6	14.8	0.9	1067

CT examination, patients are exposed to high radiation dose for use of ordinary dose values ($CTDI_{vol}$ and DLP). Comparisons between different parameters are possible with different imaging modalities (Radio protective garments, 2013). Table 4.2 shows the effective doses and breast doses for female underwent Chest CT examinations for range (3 – 14.7) mSv, (6.5 – 28) mGy, respectively, the effective dose variation related to the manufacture model related to number of slices used. The breast organ dose variation related to spot focusing about the $CTDI_{vol}$ parameters factor (Radio protective garments, 2013).

Table 4.2: shows means Effective doses and breast doses for female Chest CT scan.

Hospitals	Effective dose (mSv)	Breast Dose (mGy)
(H1)	6.5	13.6
(H2)	7	13
(H3)	8	14
(H4)	8.8	22
(H5)	4.6	8.6
(H6)	5.4	12.4
(H7)	6.5	15
(H8)	14.7	28
(H9)	3	6.5
(H10)	8.5	17.5

Table 4.2 shows values of effective and breast doses in ten hospitals in Palestine, the H9, H5, H1, H2 and H3 are low values of effective and breast doses because they are used the same CT scanner manufacture model is 128 slices, the H6 CT scanner is 64 slices, and the H8, H10, H4 and H7 are high values of effective and breast doses because they are used the same CT scanner manufacture model is 16 slices.

4.2 $CTDI_{vol}$ for female Chest CT scans in different hospitals in Palestine

The breast and effective doses cannot be determined without the knowledge of $CTDI_{vol}$ parameter; the values of $CTDI_{vol}$ for female patients underwent Chest CT scans in ten hospitals in Palestine are presented in Figures 4.1.

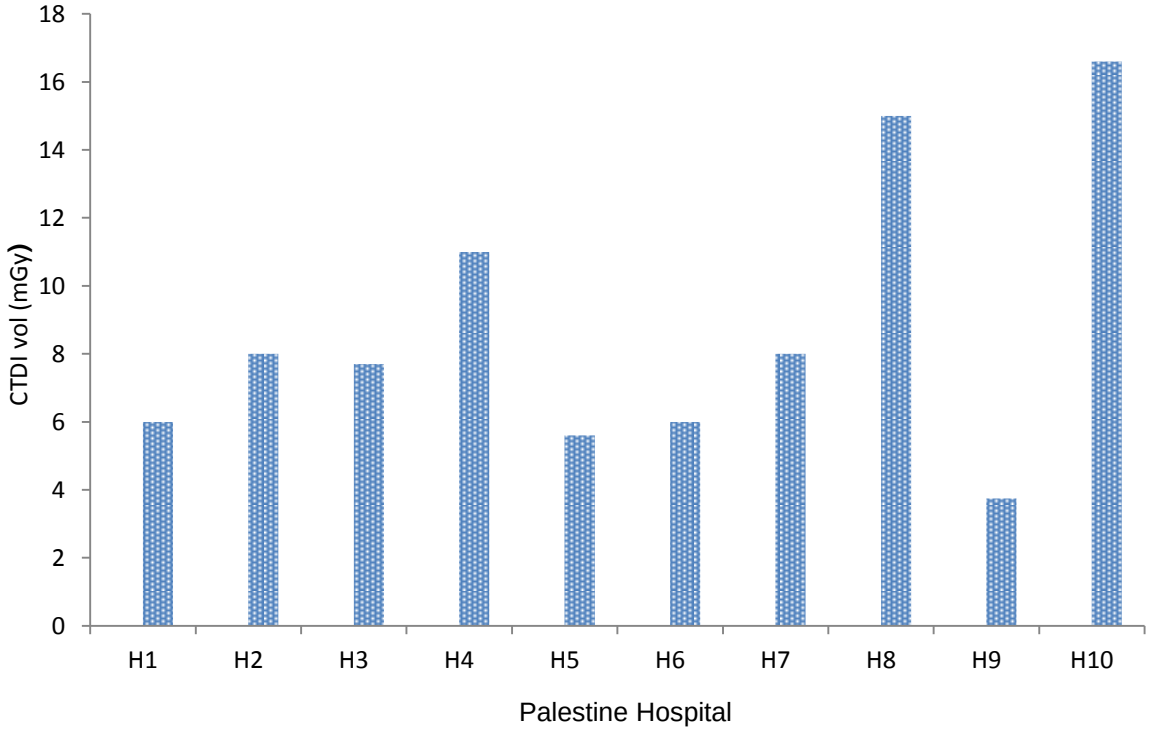

Figure 4.1: $CTDI_{vol}$ in different hospitals in Palestine.

Figure 4.1 shows $CTDI_{vol}$ in different hospitals for female Chest CT scans in Palestine. Have a variation in $CTDI_{vol}$ because there are a different in scanner manufacture models and software version (Hurwitz et al, 2006).

The amount of radiation in CT examinations is based on a unique dose metric $CTDI_{vol}$, the $CTDI_{vol}$ is obtained by using a 100-mm-long pencil-shaped ionization chamber in one of two phantom sizes (16 or 32 cm in diameter). Most manufacturers use a 32-cm phantom to calculate $CTDI_{vol}$ for chest CT examinations (Huda W et al, 2010).

The relatively high values shows for H10, H8, H4 and H7 are used manufacture scanner is 16 slices and probably a function of their short focus to axial distance, the scanner with the shorter distance between the x-ray tube focal spot and the isocenter of the gantry aperture can produce more radiation exposure than the long geometry scanner.

On the other hand, the variation of source to detector distance among scanners affects the image quality (Hurwitz et al, 2006), and due to image noise in Chest CT scan, inversely proportional to the square root of the number of photons received by the detector, whereas the number of photons (dose) is inversely proportional to the squared distance between the source of the radiation and the detector (Hurwitz et al, 2006).

As a result, if all other scanning parameters are held constant. The difference in the case of H10 and H9 is probably the result of the use of different CT scanners and used different parameters such as $CTDI_{vol}$, by use different slice thickness and pitch, whereas using thin slices to the same scan length, pitch will increase to have decrease $CTDI_{vol}$. Figure 4.1 is evident the effect of slice thickness on $CTDI_{vol}$ (Hurwitz et al, 2006).

4.3 DLP for female Chest CT scans in different hospitals in Palestine

Another important parameter is DLP to determine effective and breast doses for female Chest CT scans in ten hospitals in Palestine are presented in Figure 4.2.

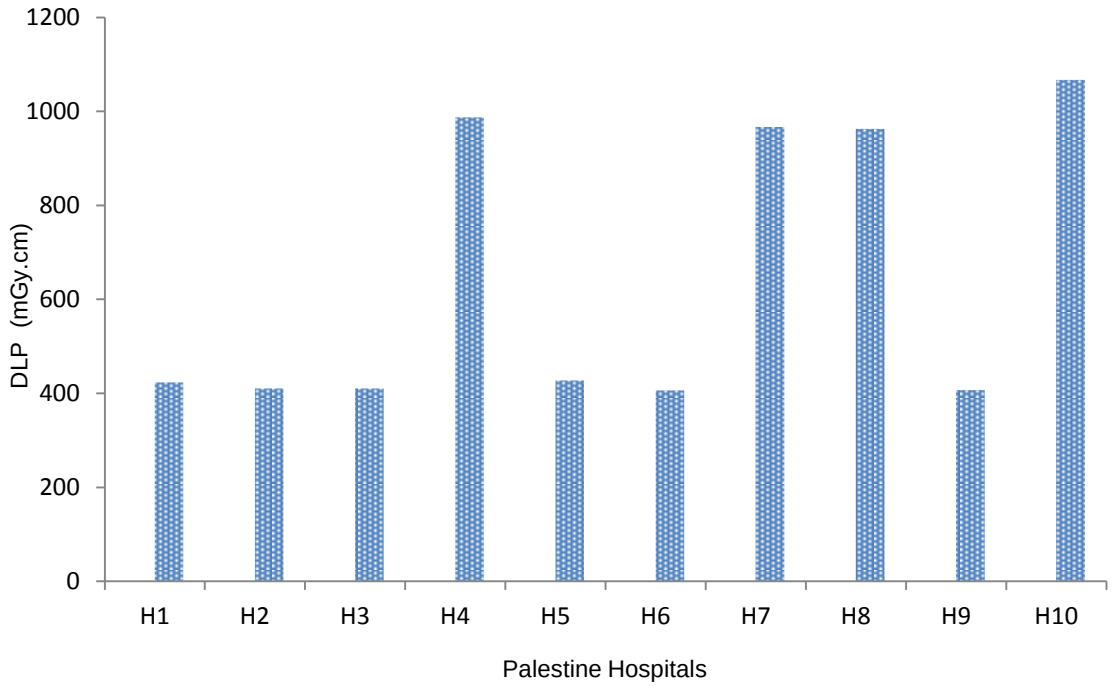

Figure 4.2: DLP values in ten hospitals in Palestine.

Figure 4.2 shows DLP in different hospitals for female Chest CT scans in Palestine. Have a variation in DLP because there are a different in scanner manufacture models and software version for used different mAs and kVp parameters (Hurwitz et al, 2006).

DLP is the total amount of radiation incident on the patient, product of the $CTDI_{vol}$ and scan length cm and is measured in mGy.cm. The DLP is the second dose metric that is accounts for both radiation intensity ($CTDI_{vol}$) and scan length in the CT examination. Indicate the total amount of radiation (intensity × scan length) used to perform the CT examination and are quantified in a cylindrical phantom of a specified size 16 or 32 cm in diameter (Huda W et al, 2010).

The values of DLP relatively high values in H10, H4, H7 and H8 for his values is 1067, 987, 967 and 963 mGy.cm, respectively, to compare with low values in H9, H6, and H3 for his values is 407, 406 and 410 mGy.cm, respectively. With different manufacture models and number of slices, correctly, with the length of the irradiated body section, there is most likely variation values of the $CTDI_{vol}$ and variation scan length for z-axis. (Hurwitz et al, 2006).

In most cases this procedure involves a repeated scan of the same scan length. Variations as also observed elsewhere were largely caused by different scanning parameters such as slice thickness, number of slices, mAs, kVp and pitch) and larger scanning regions (Shrimpton PC, et al, 1991).

4.4 Relationship between BMI and Effective dose for female Chest CT scan in different hospitals in Palestine

Patients' biological features are considered of an important exposure technical determinant factors. The BMI is an attempt to quantify the amount of tissue mass (muscle, fat, and bone) in an individual, and then categorize that person as underweight, normal weight, overweight, or obese based on that value. The body mass index (BMI) patients are exposed highly.

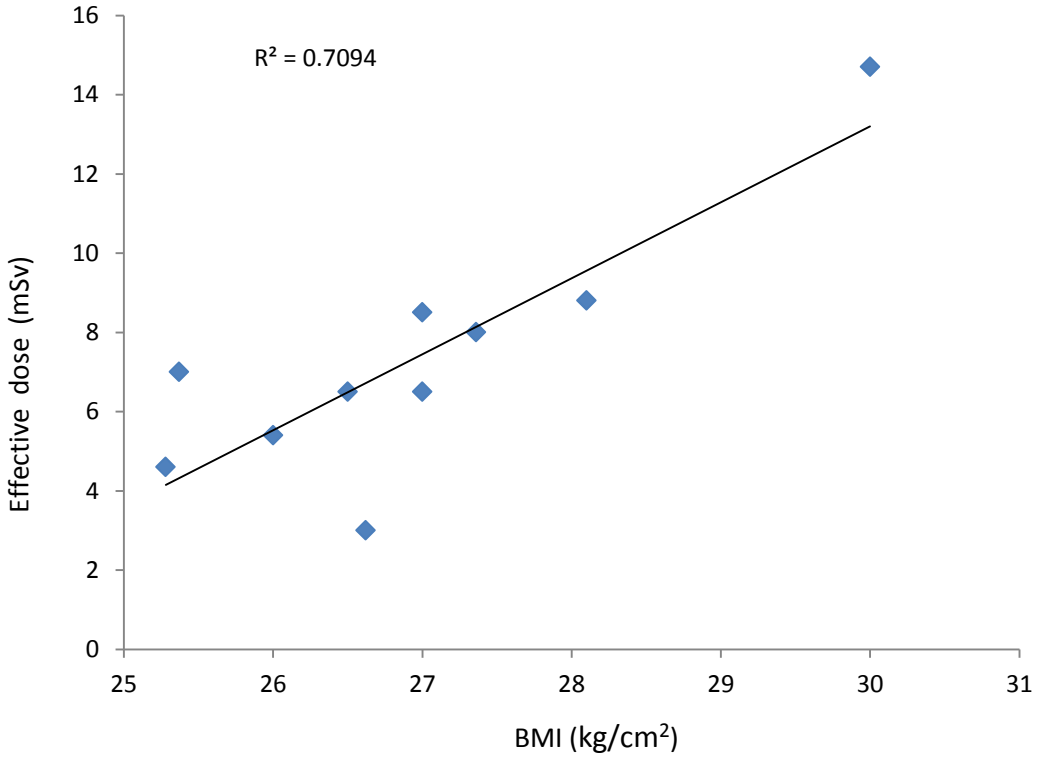

Figure 4.3: correlation between BMI and Effective dose for female patient underwent Chest CT examination in ten hospitals in Palestine.

Figure 4.3 shows the correlation between the effective dose and the BMI for female underwent CT scan, the squared correlation coefficient (r^2) = 0.709, which show a linear relationship between ten hospitals in Palestine. The BMI ($kg.cm^2$) was obtained for each patient to analyze effective dose variations relative to body size, the goal of using height and weight was to obtain an estimate of the effect of patient dimensions on effective dose from Chest CT scan protocols. To estimate the effective dose for the CT scans whole body (Chest). The coefficient of determination, R^2, was used to describe the variability in the calculated effective dose explained by the linear regression (DHHS, 2006).

Strong positive relationship between BMI and effective dose for different hospitals in Palestine, to increase BMI is increase effective dose.

Relationship between BMI and Effective dose important to describe and determinate the effective dose in human body (Smith Bindman, 2009). BMI points are different values of effective dose depending of on the CT scan manufacturer model such as 16, 64 and 128 slices and put parameters without considering patient weight (Rebecca Smith-Bindman et al, 2011)

4.5 Relationship between $CTDI_{vol}$ and Effective dose for female Chest CT scans in different hospitals in Palestine

The volume CTDI ($CTDI_{vol}$), defined as $CTDI_w$ divided by the beam pitch factor.

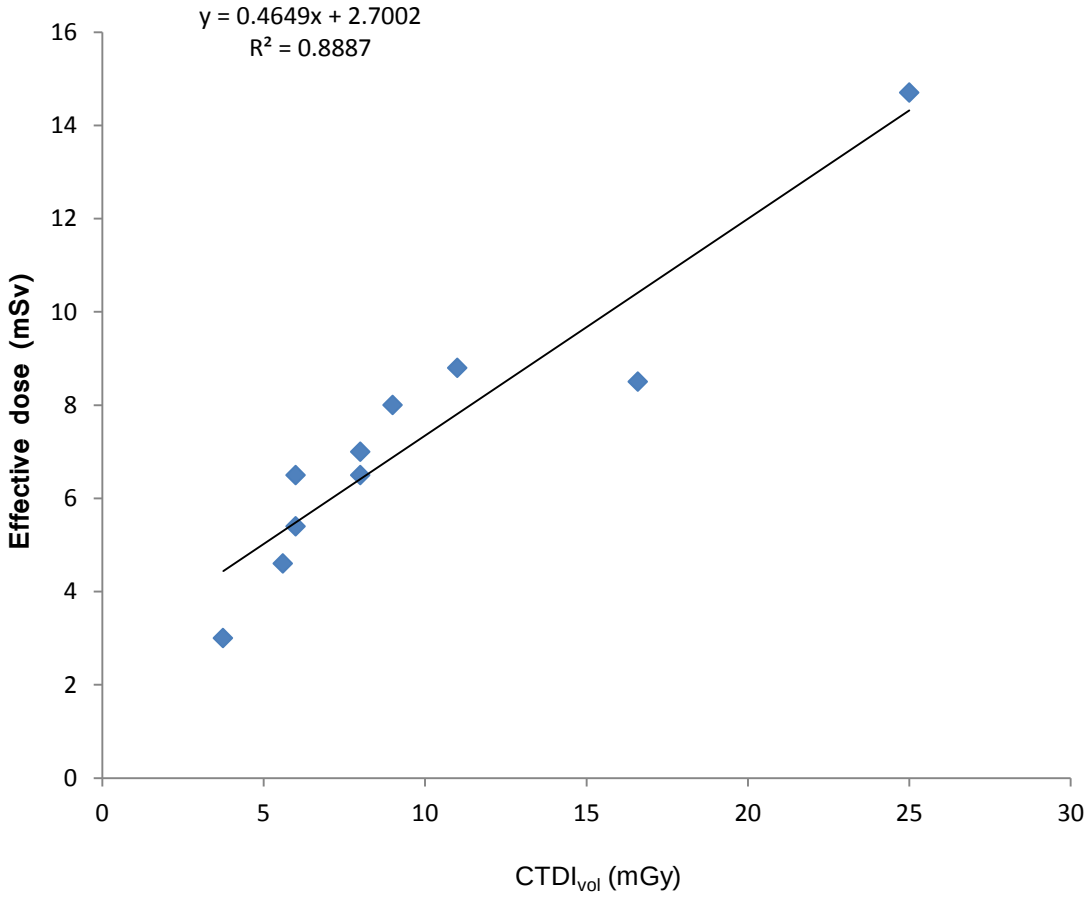

Figure 4.4: correlation between $CTDI_{vol}$ (mGy) and Effective dose (mSv) for female patient underwent Chest CT scan in all hospitals.

Figure 4.4 shows the correlation between $CTDI_{vol}$ (mGy) and effective doses (mSv), the squared correlation coefficient (r^2) = 0.88, which show that strong positive correlation, variability in patient's effective doses can be related to mAs and the effective dose as a functional of $CTDI_{vol}$ for difference CT scanners. The $CTDI_{vol}$ of CT scans most important parameter to optimize different hospitals in Palestine.

High values of $CTDI_{vol}$ gave high values of effective dose, any change of $CTDI_{vol}$ value leads to a change in effective dose value which means that the relation is ascending.

Variations in CTDI with identical radiographic techniques (such as kilovolt peak and milliampere second) result from differences in CT scan tube design, tube filtration, and beam shaping (bow tie) filters.

CT scan and acquisition parameters such as $CTDI_{vol}$ are "fixed" and independent of patient size and scan length. The $CTDI_{vol}$ does not quantify how much radiation any specific patient receives, but indicates the intensity of the radiation being directed at that patient. When the same amount of radiation is directed to a young female and an oversized adult, the resultant breast dose and effective dose are substantially higher in the younger female than in the older female. At constant techniques, doses are lower in large patients, because the CT scan beam is attenuated to a greater extent in large patients than in small patients (Walter Huda, 2011).

4.6 Effective dose for female Chest CT scan in different hospitals in Palestine

Effective dose estimated by Monte Carlo Simulation for female Chest CT examinations in different hospitals in Palestine. Figure 4.5 mean effective dose for female Chest CT examination in different hospitals in Palestine.

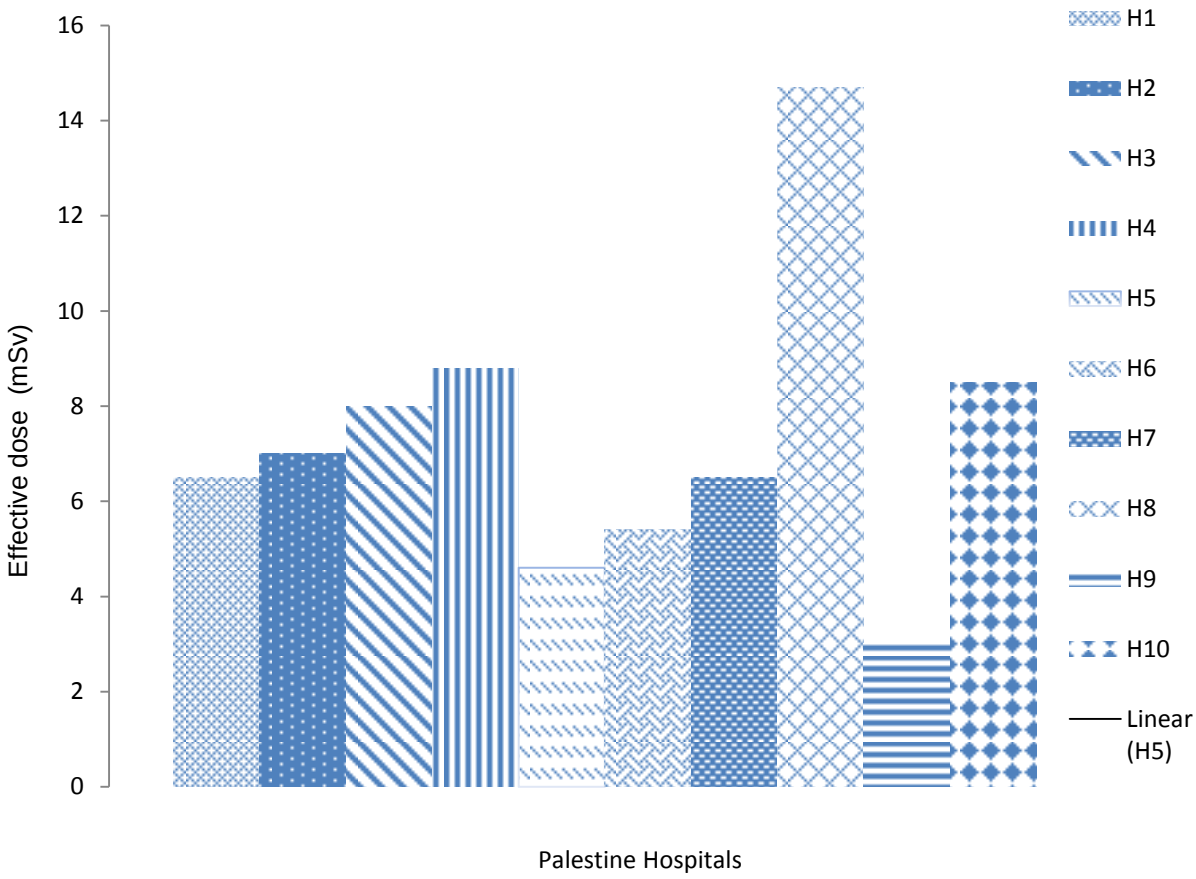

Figure 4.5: mean value of effective dose for female Chest CT scan in different hospitals in Palestine.

The variation of effective doses in Figure 4.5 is about 3 - 14.7 mSv the H8, H4 and H10 high values effective doses 14.7, 8.8 and 85 mSv, respectively, and low values in H9, H5 and H6, there are 3, 4.6 and 5.4 mSv, respectively, for all Chest CT scans which is an indication that different scanner manufacture models such as single slice 16 slices and multi slice 64 and 128 slices and parameters such as mAs, scan length, and Pitch, hospitals have a significant influence on breast dose determination (Hurwitz et al, 2006).

The effective doses from diagnostic CT examination 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. These survivors, who are estimated to have experienced doses only slightly larger than those encountered in CT scan, have demonstrated a small but increased radiation related excess relative risk for cancer mortality (BEIR VII Phase 2).

In Palestine the range is 3 to 14.7 mSv, this range is suitable with BEIR VII Phase 2, except H8 used high parameters such as mAs and kVp, so the effective dose is high, high than the highest of value for BEIR VII Phase 2.

4.7 Breast dose for female Chest CT scan in different hospitals in Palestine

Breast dose estimated by Monte Carlo Simulation for female Chest CT examinations in different hospitals in Palestine. Figure 4.6 shows mean breast dose in different hospitals in Palestine.

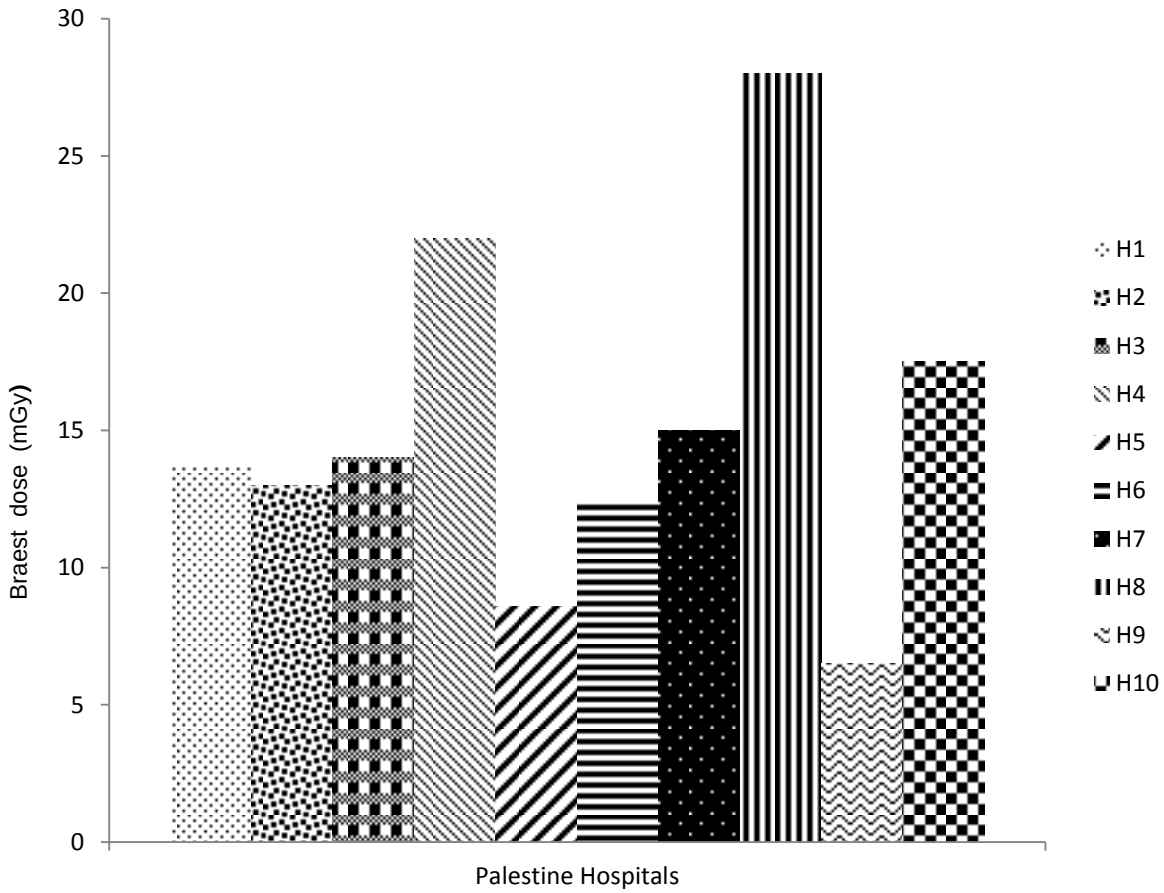

Figure 4.6: mean values of breast dose for female CT scan in different hospitals in Palestine.

Figure 4.6 shows observed wide variation of breast doses is about (6.5 - 28) mGy, the H8, H4, H10 and H7 high values breast doses 28, 22, 17.5 and 15 mGy, respectively, and low values in H1, H2, H3, H5, H6 and H9, there are 13.65, 13, 14, 8.5, 12.4 and 6.5 mGy, respectively, for Chest CT scan in Palestine which is an indication that different manufacture scanners such as single slice 16 slices and multi slice 64 and 128 slices and different parameters such as mAs, scan length, $CTDI_{vol}$, DLP and pitch in different Palestine hospitals have had a significant influence on breast doses (Hurwitz et al, 2006).

CT examination performed for Chest, a quantifiable dose is received by the female breast tissue when positioned in the scanning region. Therefore, the breast dose is higher for Chest CT scan studies as compared to abdomen studies, the probability of cancer due to radiation dose depends on organ dose, age and tissue weighting factor (Hurwitz et al, 2006).

The quantity most relevant for assessing the risk of cancer detriment from a Chest CT examination is the breast dose. Breast dose allows for comparison of the risk estimates associated with breast soft tissue. It also incorporates the radiation sensitivities of the breast in the body. Radiation dose from CT examination varies from patient to patient. The particular radiation dose will depend on the breast size of the Chest CT scan examined, and the type of CT scan and its operation (U.S. Food and Drug Administration).

4.8 Effective and breast doses for female Chest CT scan in Palestine

Radiation dose from CT scan is a subject of concern to radiologists, radiographers, physicians, scientists and patients. Organizations such as the International Atomic Energy Agency (IAEA), the European Society of Radiology (ESR), the U.S. Food and Drug Administration, and the Joint Commission have recommended mean dose for patients not only for estimating potential risk of radiation exposure but also for protocol optimization, standardization, and quality assurance (Natalia Saltybaeva, 2014). It can be used for comparison and mean of dose for different modalities, which is why it is used for this purpose (Natalia Saltybaeva, 2014). Table 4.3 shows means Effective and breast doses in Palestine.

Table 4.3: means effective and breast doses in Palestine.

	Effective dose (mSv)	Breast organ dose (mGy)
In Palestine	7	15

The effective and breast doses in Palestine had have not exceed the international commission such as ICRP and others internationals such as U.K and Germany, and this situation perfect because the Palestinian population patients underwent Chest CT scan should not dangerous for diagnosis and treatment in Palestine hospitals.

4.9 CT scan radiation doses between Palestine and other internationals

4.9.1 Comparison between $CTDI_{vol}$, DLP and Effective Dose for female Chest CT scan in Palestine and other countries:

The measurement $CTDI_{vol}$, DLP and effective doses from CT examinations are comparable to others countries.

Figure 4.7 shows $CTDI_{vol}$ from CT examination in Palestine and other countries.

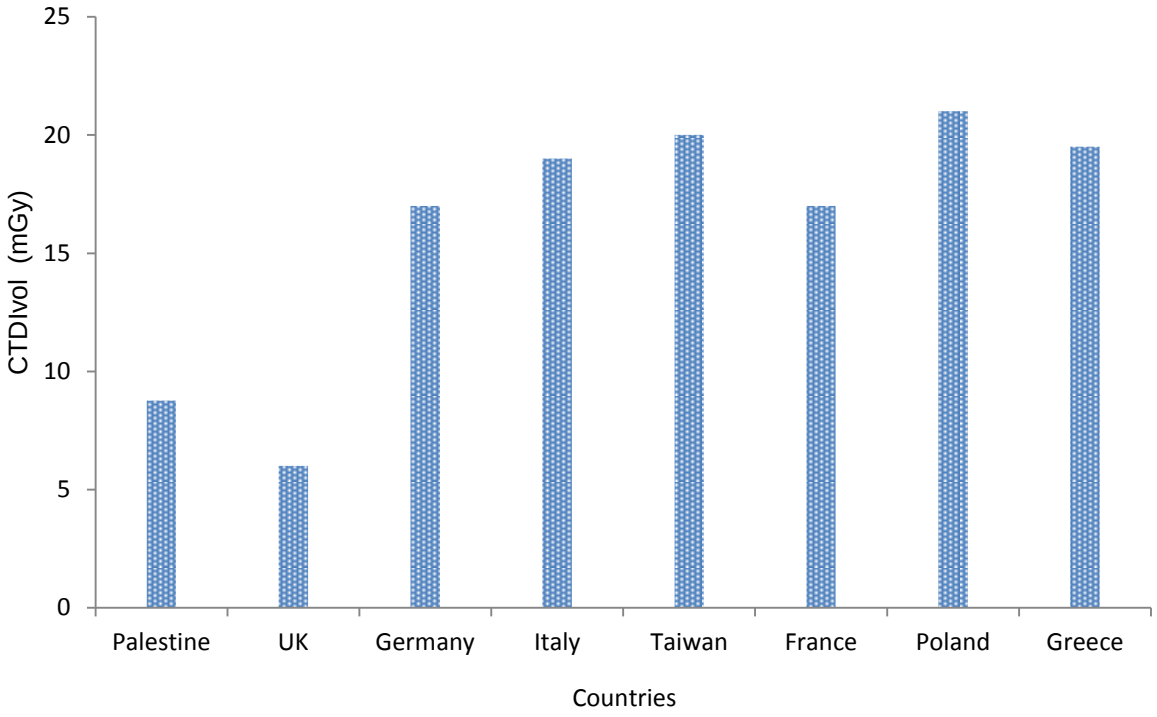

Figure 4.7: comparison between $CTDI_{vol}$ in Palestine and other countries for female Chest CT scan.

Figure 4.7 shows the mean values of $CTDI_{vol}$ in Palestine is about 8.76 mGy and this value low with others countries such as Germany, Italy, Taiwan, France, Poland and Greece, and high value to comparison with United Kingdom could be due to broad range of mAs and pitch employed (ICRP Publication 60, 1991).

Figure 4.8 shows DLP from CT examination in Palestine and other countries.

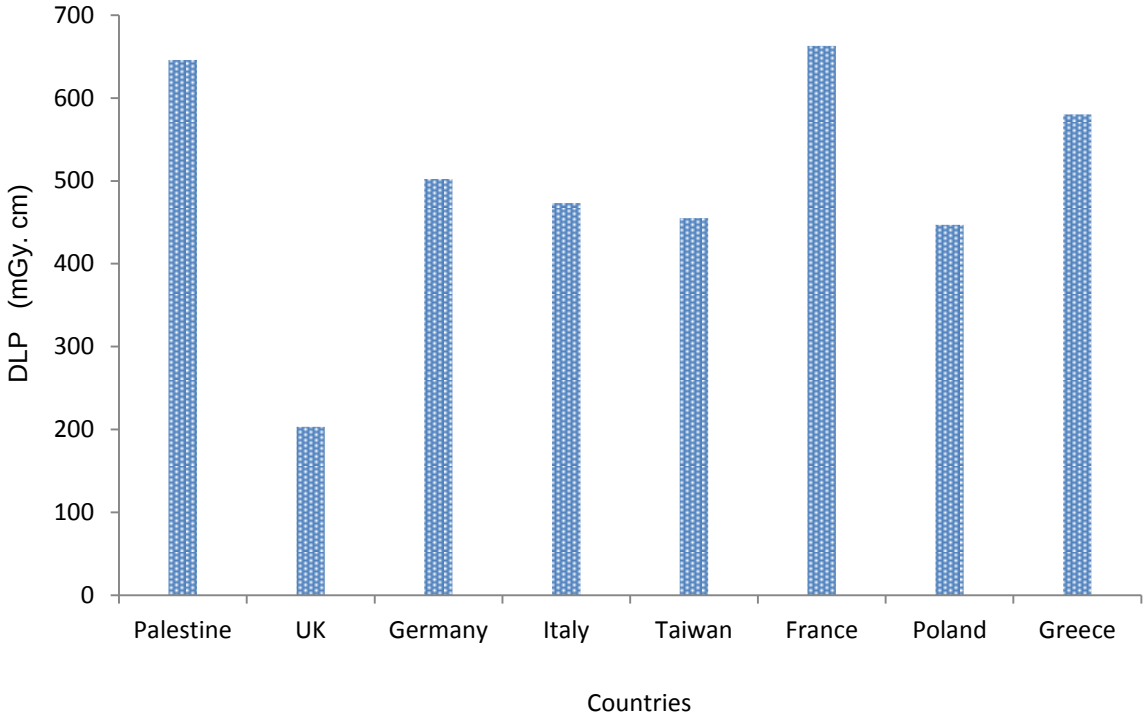

Figure 4.8: comparison between DLP in Palestine and other countries for female Chest CT scan.

Figure 4.8 shows DLP (mGy.cm) from CT examination in Palestine and other countries, the mean values of DLP in Palestine is about 645.8 mGy.cm and this value comparable with France and high with United Kingdom, Taiwan and Poland, Germany, and Greece. This variation related to use manufacture scanners and mAs and scan length values (ICRP Publication 60, 1991).

Figure 4.9 shows Effective dose from Chest CT examination in Palestine and comparison other countries.

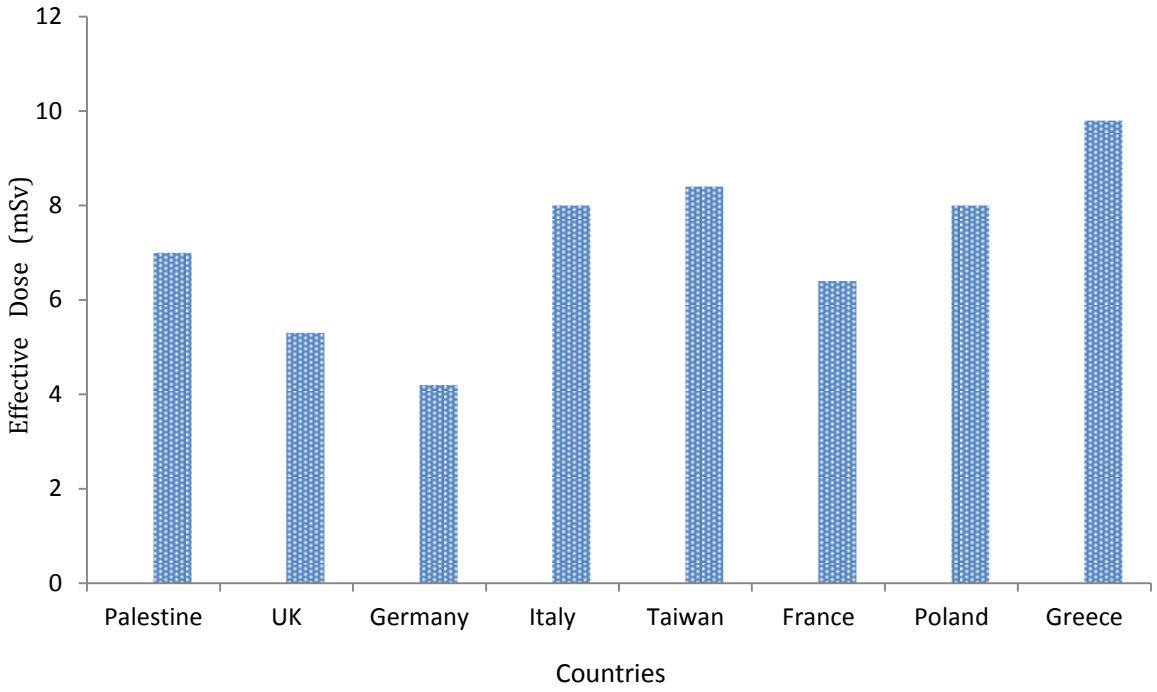

Figure 4.9: comparison between Effective doses in Palestine and other countries for female Chest CT examination.

Figure 4.9 shows effective dose CT examination in Palestine and others countries, the mean value of effective doses in Palestine is about 7 mSv, the Palestine is the highest values to compare with Germany, United Kingdom and France and lower than Italy, Taiwan, Poland and Greece. Reduction effective dose from CT examination can be achieved by reducing the mAs and pitch of the examination protocol, but this requires a careful consideration of the signal to noise in order to avoid significant degradation of image quality and the resulting examination repeats.

4.9.2 Comparison between breast doses for female Chest CT scan in Palestine and Reference values of the International commission on radiological protection 60 (ICRP 60)

Table 4.4: comparison between breast dose in Palestine and Reference value of the International commission on radiological protection 60 (ICRP 60).

Comparison between Palestine and ICRP	Breast doses (mGy)	Reference value of the (ICRP) (mGy)
Breast dose from Chest CT scan mGy	15	Not exceed 45

Table 4.4 shows estimated effective doses from Chest CT examination are comparable than the doses from those others countries. The variation in these doses may be due to differences in manufacture CT scanner and exposure parameters. Female Chest CT examinations appear a low breast dose, ranging from 6.5 to 28 mGy. Table 4.4 shows estimated breast dose from CT examinations in Palestine and comparison with International commission on radiological protection **(**ICRP) breast dose should not exceed 45 mGy (ICRP Publication 60, 1991). Palestine Compared with the ICRP 60 is not should exceed 45 mGy, Therefore, The reason is adopt an effective strategy for the prevention of radiation in hospitals in Palestine (ICRP Publication 60, 1991).

4.9.3 Breast dose for female Chest CT scan in Palestine and other Internationals

Table 4.5: breast doses for female Chest CT scan in Palestine and comparison with others countries.

Comparison between Palestine and other Internationals	Palestine	United Kingdom	Germany	Netherlands	Japan
Breast doses from Chest CT scan mGy	15	21	22	32	16

Assess radiation dose to selected radiosensitive breast organs of female patients underwent in Chest CT examinations in Palestine was investigated. Variations of radiation dose to breast observed in Table 4.5. Different scanning parameters are use among hospitals and variation in scanner design among manufacturer models was responsible for these variations (Hidajat N et al, 1999).

The breast doses in Palestine to comparison with United Kingdom, Germany, Netherlands and Japan has been presented in Table 4.5 (Hidajat N et al, 1999). Conversion factors were mainly attributed to the variation in CT manufacture scanner and parameters such as, kVp, mAs, slice thickness, number of slices, pitch, etc. and types of scanners used. (Hidajat N et al, 1999).

4.10 Risk Assessment Calculations

4.10.1 Lifetime attributable breast cancer risk for female Chest CT scan in different hospitals in Palestine:

Calculated breast absorbed doses can be used for risk assess of medical radiation exposure which can induce cancer. The Committee on the Biological Effects of Ionizing Radiations Phase 2 modeling (BEIR VII Phase 2) estimates the risk factors (BEIR VII Phase 2, 2006).

The BEIR VII has been derived by lifetime risk estimates for cancer incidence and mortality resulting from a single dose of 0.1 Gy at several specific ages. Estimates are shown for all cancer, leukemia, Breast, all solid cancer and cancer of several specific sites (BEIR VII Phase 2, 2006), Average age dependent mortality are used for subsequent assessment of lifetime cancer risk (BEIR VII Phase 2, 2006).

The estimate the lifetime risk of cancer resulting from any specified dose of ionizing radiation and applies, such as CT scan, these models to example exposure scenarios for the U.S. population. Models are developed for estimating lifetime risks of cancer incidence and mortality and take account of gender, age at exposure, dose rate, and other factors. Estimates are given for all solid cancers, leukemia, breast, and cancers of several specific sites. Like previous BEIR reports addressing low LET (linear energy transfer) radiation.

"The risk models are based primarily from data on Japanese atomic bomb survivors. However, the vast literature on both medically exposed persons and nuclear workers exposed at relatively low doses has been reviewed to evaluate whether findings from these studies are compatible with A bomb survivor based models" (BEIR VII Phase 2, 2006).

Risk estimates are subject to several sources of uncertainty due to inherent limitations in epidemiologic data and in our understanding of exactly how radiation exposure increases the risk of cancer. The populations and exposures for which risk estimates are needed nearly always differ from those for whom epidemiologic data are available (BEIR VII Phase 2, 2006).

Appendix D and Figures 4.10, 11, 12, 13, 14, 15, 16, 17, 18 and 19 summarize the risk assessment of different hospitals in Palestine, which depends on the organs equivalent absorbed doses were estimated in this study.

4.10.1.1 Age, Female Gender and Cancer Risk

Estimated risk of cancer incidence attributable for female patients underwent in chest CT scan are shows in appendix D and Figure 4.10, 11, 12, 13, 14, 15, 16, 17, 18 and 19. The Lifetime attributable cancer risk (LAR) for different female patients age, the breast risks were high for female in their young female and decreased to old female markedly as a function of age (Andrew J. Einstein et al, 2007).

Radiosensitivity such as breast has been observed to decrease with age (Andrew J. Einstein et al, 2007). To irradiate along time in CT scan procedure will be development to malignant breast cancer, young female for minimum reaction time from radiation exposure to excess breast cancer risk have been described in Japanese atomic bomb survivors (Land CE, 2003).

The older female patients underwent chest CT scan in Palestine, who were both less radiosensitivity and less likely to development of a radiation attributable breast risk cancer, Figure 4.10, 11, 12, 13, 14, 15, 16, 17, 18 and 19 shows lifetime attributable breast cancer risk in ten hospitals in Palestine.

The Lifetime attributable breast cancer risk (LAR) is:

$$\text{LAR} = \frac{\text{Braest organ dose}}{100\ \text{mSv}} \times \frac{\text{LAR for age patient}}{100{,}000} . \ \%$$

Or

$$\text{LAR} = 1 \ \text{in} \ 100.000 \Big/ \frac{\text{Breast organ dose}}{100\ \text{mSv}} \times \text{LAR for age patient}$$

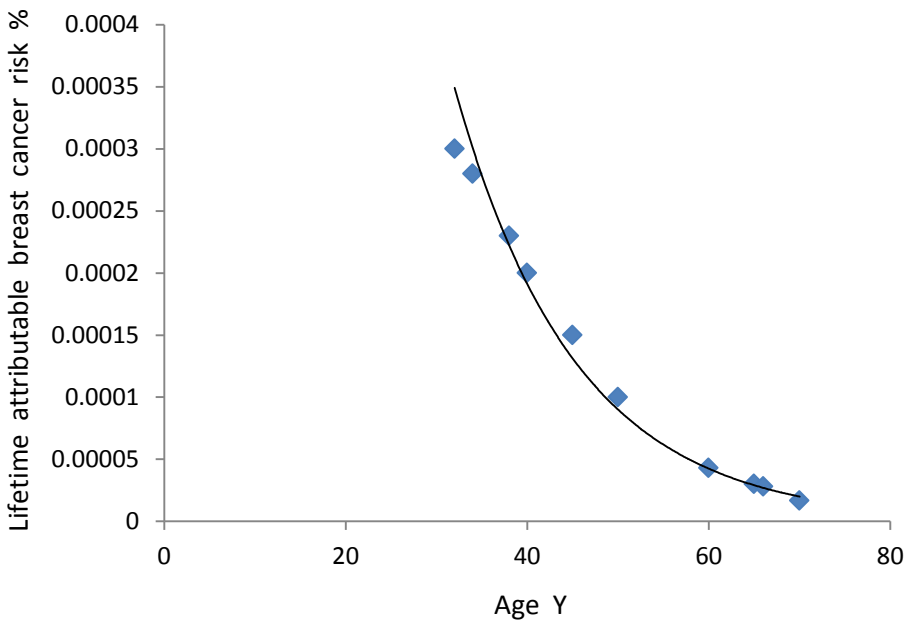

Figure 4.10: Shows Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital one in Palestine

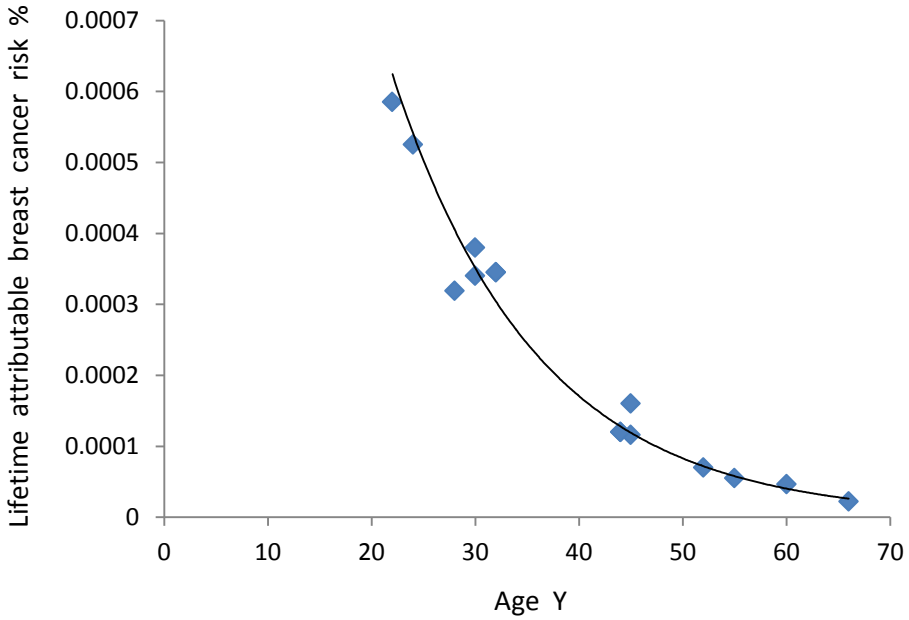

Figure 4.11: Shows Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital two in Palestine

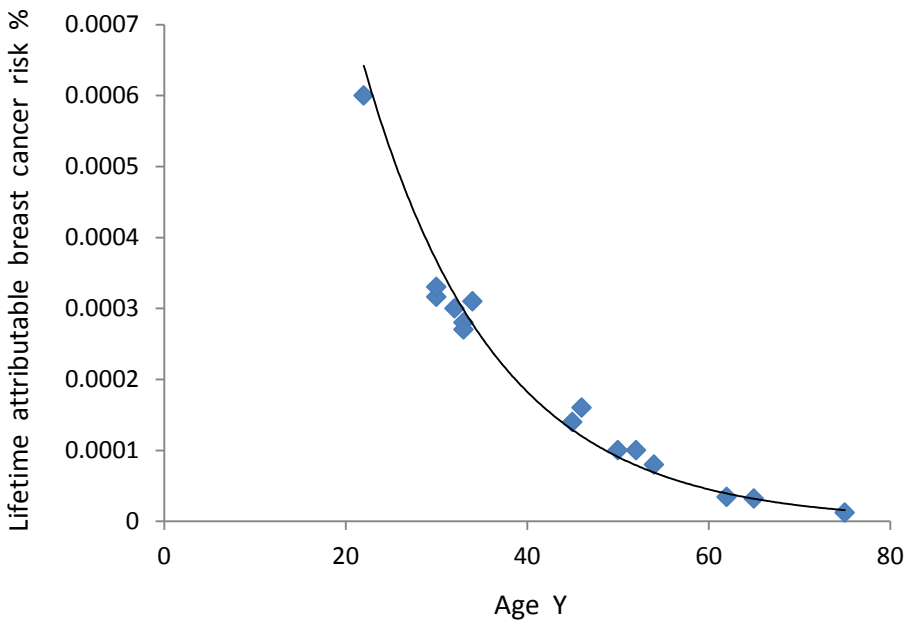

Figure 4.12: Shows Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital three in Palestine

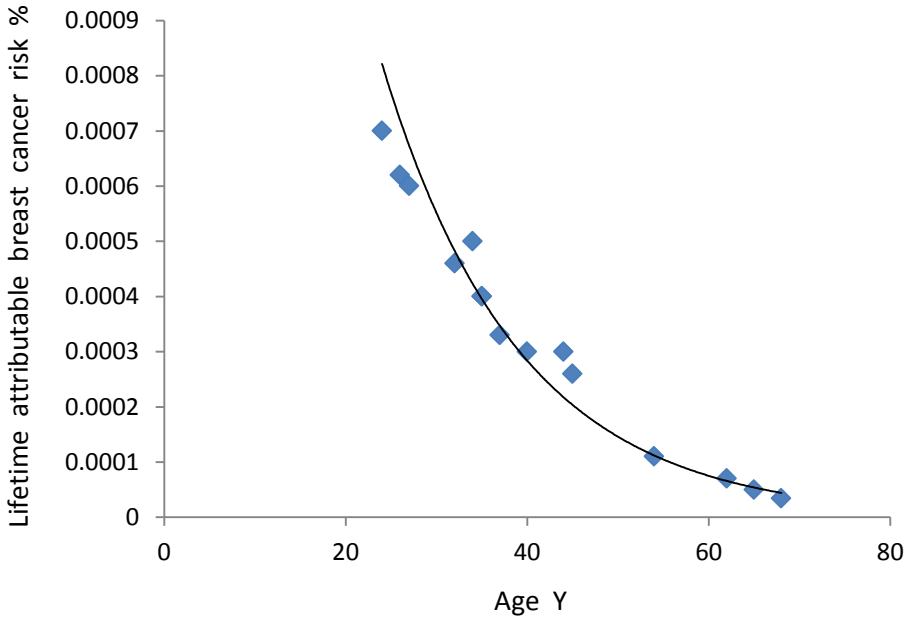

Figure 4.13: Shows Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital four in Palestine

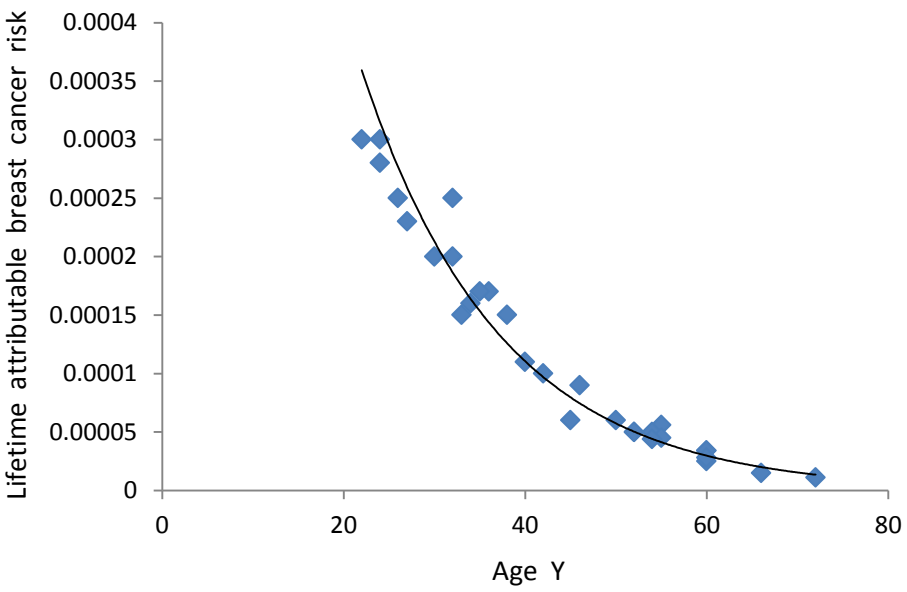

Figure 4.14: Shows Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital five in Palestine

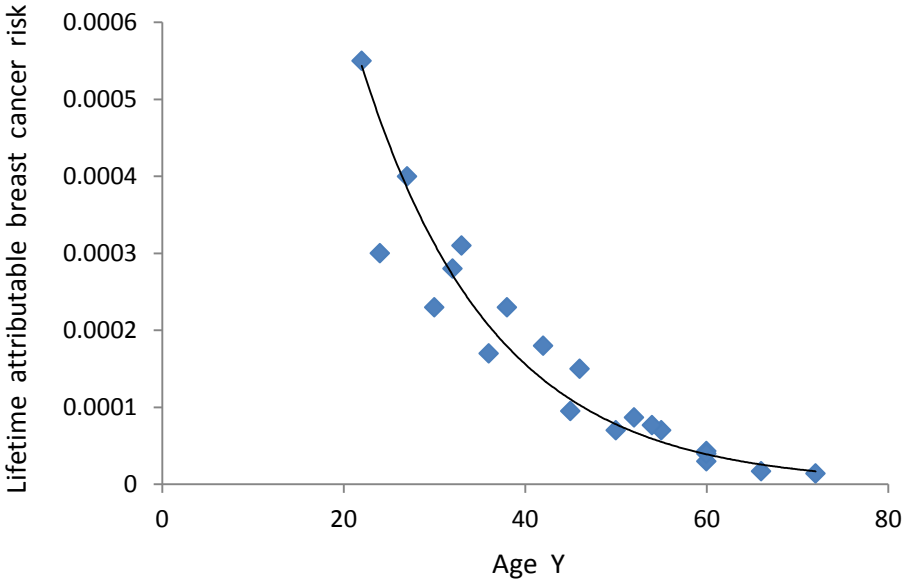

Figure 4.15: Shows Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital six in Palestine

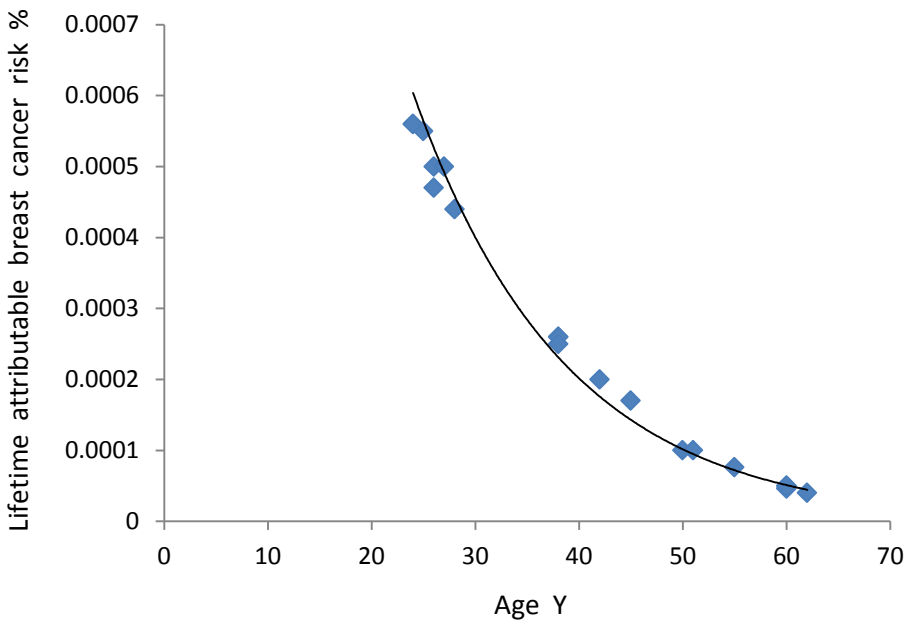

Figure 4.16: Shows Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital seven in Palestine

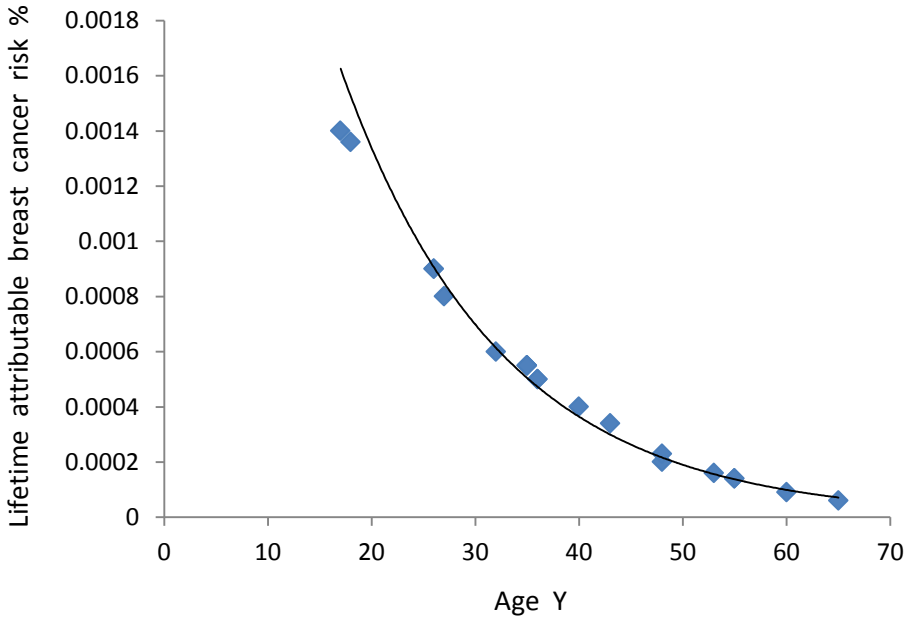

Figure 4.17: Shows Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital eight in Palestine

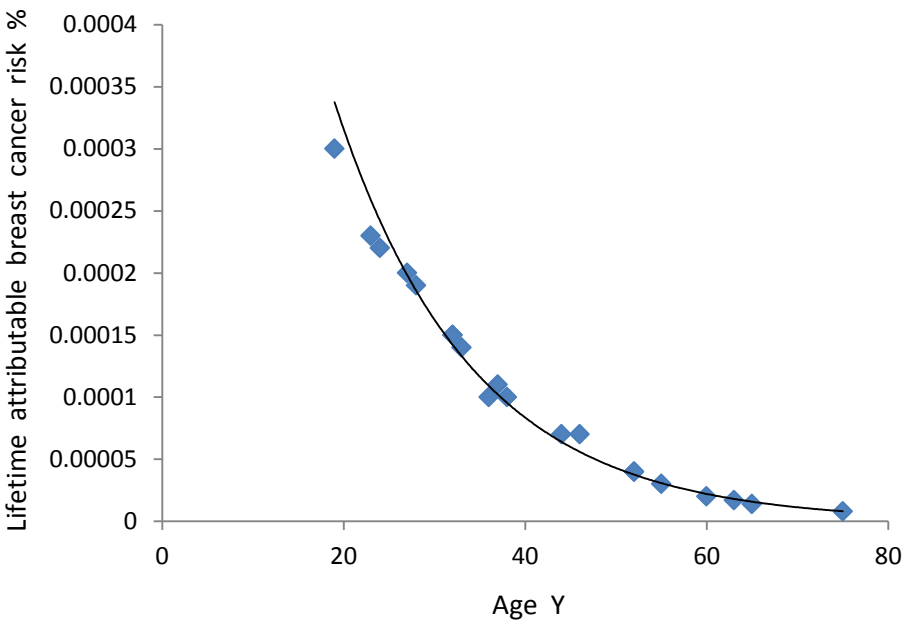

Figure 4.18: Shows Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital nine in Palestine

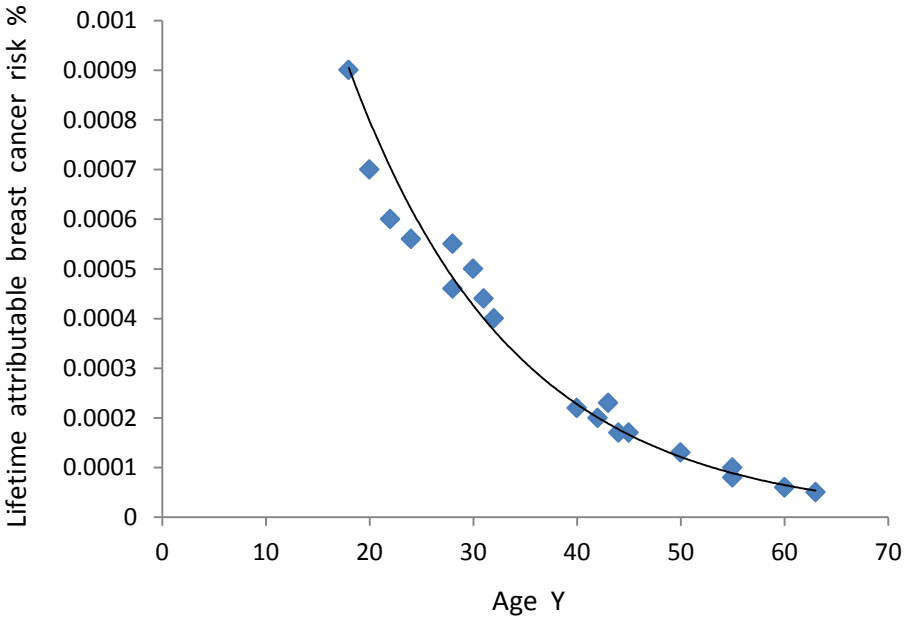

Figure 4.19: Shows Lifetime Attributable Risk of breast Cancer Incidence from female Chest CT scan in hospital ten in Palestine

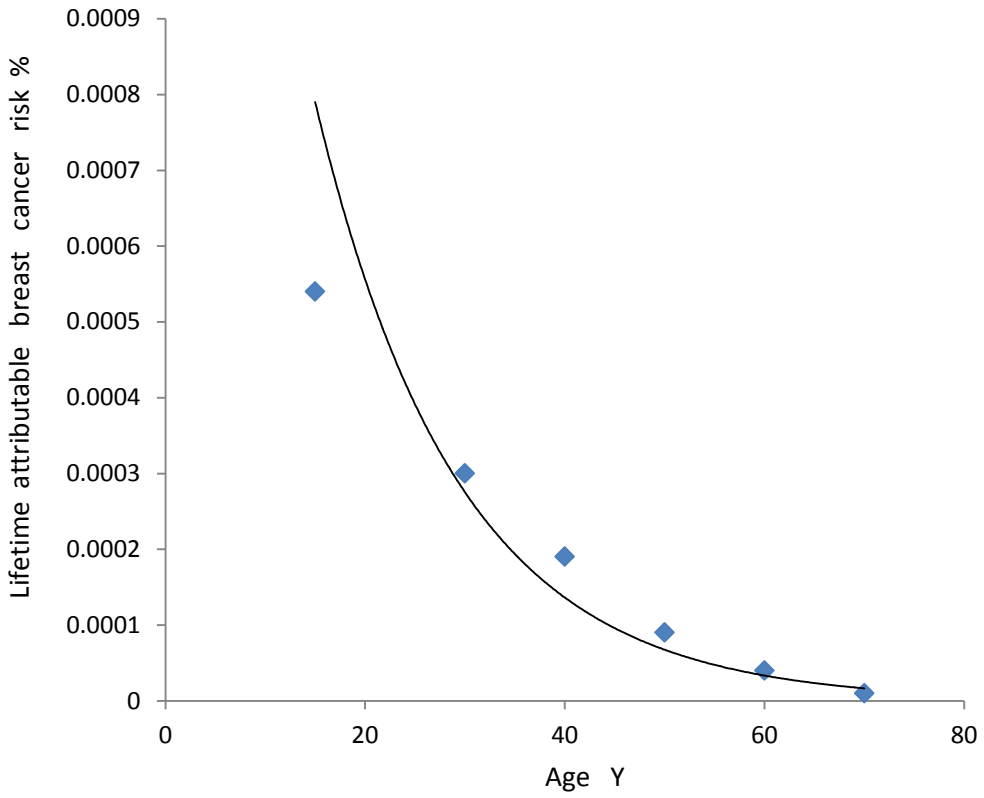

Figure 4.20: Shows lifetime attributable breast risk of cancer incidence for female chest CT scan in Palestine.

Our basic technique is to multiply age dependent lifetime breast cancer incidence risks (per unit dose) by estimated age dependent doses produced by various CT examinations. The age dependence of the cancer incidence risk varies considerably from site to site Figure 4.10, 11, 12, 13, 14, 15, 16, 17, 18 and 19 for a highly inhomogeneous dose distribution, as produced by a CT examination; the age dependence of the overall cancer risk cannot be directly estimates of the total cancer incidence per unit effective dose. Rather, the age dependence of the risks for the various groups of sites shown in Figure 4.20 are each separately calculated by applying appropriate site specific doses to the age and site per breast dependent risks in Figure 4.20 and these site specific risks are then summed to yield the overall age dependent lifetime cancer incidence risk.

4.10.2 Effective and breast doses and lifetime attributable breast cancer risks in Palestine:

To estimate radiation related breast cancer risks, converted each patient's CT scan organ equivalent dose to estimate lifetime attributable breast cancer risk used the standardized BEIR VII.

Table 4.6: shows means effective dose, breast dose and lifetime attributable breast cancer risks for younger and older female patient's ages in Palestine.

	Effective dose (mSv)	Breast dose (mGy)	Lifetime attributable breast cancer risk (%)	
In Palestine	7	15	Young Female (15 – 39)	Old Female (40 – 60)
			0.00042 % 1 in 2645	0.00014 % 1 in 10,473

The risk versus benefit for female patients may justify the potential risks of no imaging or of imaging with a potentially less accurate technique that delivers less of ionizing radiation as soon as possible (Richard T. Griffey and Aaron Sodickson, 2009). And they are important to applicable for every female patient underwent Chest CT scan examination to make best diagnostic.

4.10.3 Breast cancer risk assessment for female underwent Chest CT scans in different ages in Palestine

Table 4.7: Shows Mean lifetime attributable breast cancer risk for female patients ages (15 – 29, 30 – 39, 40 – 49, 50 – 59, 60 – 69 and 70 - 79) years for Chest CT scan in Palestine.

Age Years	lifetime attributable breast cancer risk for female in Palestine %
15 - 29	0.00054 % 1 in 2340
30 - 39	0.0003 % 1 in 2949
40 - 49	0.00019 % 1 in 6534
50 - 59	0.00009 % 1 in 14,412
60 - 69	0.00004 % 1 in 29,159
70 – 79	0.00001 % 1 in 89,415

Table 4.7 shows breast cancer risk for younger and older female for Chest CT scan in ten hospitals in Palestine. CT scan parameters factors and breast sensitivity affect the breast cancer in younger female than older female (Tokunaga M et al, 2007).

Doses from CT scan in the Chest protocol are shows in Table 4.6. Estimated lifetime attributable breast cancer risk to a single and multi CT scan are shows in Figure 4.20. The LAR for a 15 – 39 years young female was 0.00042 % or 1 in 2645. Risks were particularly high for female in their 15 – 39 years and decreased markedly as a function of age. For a 40 – 60 years old female, the LAR was 0.00014 % or 1 in 10,473, and for 70 – 80 years female, the LAR was 0.00001 % or 1 in 89,415.

The lifetime attributable breast cancer risk markedly variable by hospitals and used parameters. The risks reduced with age, so radiation associated cancer risks are particular concern for younger female patients, because the risks of cancer are high among younger patient. Although it is generally assumed that very little CT examination occurs in children and young female.

Age Dependent Doses from CT Examinations

various calculations and measurements are available of the doses produced by a variety of CT examinations under different conditions, the most comprehensive being the results of a 1989 survey of CT practice in Britain, in which organ doses were estimated for 17 CT examinations from more than 100 CT scanners (Shrimpton PC et al, 1991).

Estimated lifetime breast cancer incidence risks from chest CT examinations are somewhat greater for younger women than older women, an effect that is caused by the significantly greater estimated risks per unit dose Table 4.7. The estimated risk for chest CT examinations decreases much more slowly with increasing age at examination.

The doses and risks estimated depend roughly linearly on the exposure settings assumed. The survey data from which the doses were estimated yielded average exposure settings of 168 - 350 mAs and DLP from 410 - 1067 mGy.cm for Chest CT scans.

4.10.4 Breast cancer risk assessment for female underwent Chest CT scans in Palestine and comparison with ICRP Recommendations:

Table 4.8: Shows means lifetime attributable breast cancer risk for younger and older female patients underwent Chest CT scan in Palestine and comparison with ICRP Recommendations (ICRP, 2011).

Age Years	lifetime attributable breast cancer risk for female in Palestine %	lifetime attributable breast cancer risk % ICRP, 2011
Young Female 15 - 39	0.00042 % 1 in 2645	0.00865 %
Old Female 40 - 60	0.00014 % 1 in 10,473	0.00160 %

Table 4.8 shows lifetime attributable breast cancer risk for younger and older female patients underwent Chest CT scan in ten hospitals in Palestine and comparison with ICRP Recommendations in 2011. The lifetime attributable breast cancer for Chest CT scan in Palestine not a fatal cancer at all ages, because the fatal breast cancer according to ICRP is about 1.3 – 2.6 % at same age in the table 4.8 (ICRP, 2007).

4.10.5 Breast Cancer Risk assessment for female underwent Chest CT scans in different hospitals in Palestine

Lifetime attributable breast cancer risk for female patients ages (15 – 70) years for Chest CT scan in different hospitals in Palestine.

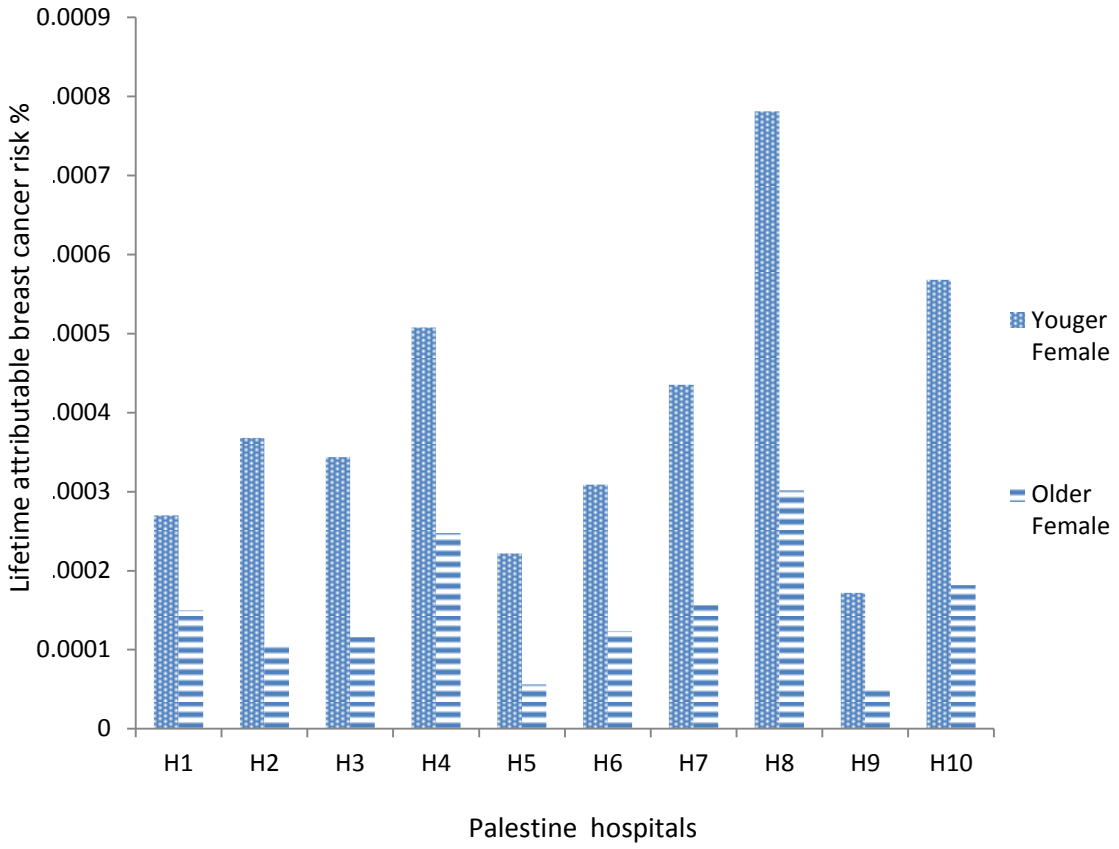

Figure 4.21: Lifetime Attributable breast cancer risk incidence for Chest CT scan in different hospitals in Palestine.

Figure 4.21 shows the high values of breast cancer risk appear in H10, H8, H4 and H7 in Palestine hospitals and low values of breast cancer risk in H9, H5 and H1, and these values not should exceed the ICRP.

The variation related to use different CT scanner manufacture and different scanning parameters such as kVp, mAs, rotation time, focal spot size, scan field of view, slice width and pitch (Hurwitz et al, 2006)

On multi slice scanners such as 64 and 128 and single slice scanners such as 16, the absorbed radiation dose is inversely proportional to pitch, tube current mA, time product and tube potential kV. The dose will be halved if the pitch is doubled. Due to the nature of the reconstruction method used, the pitch on single slice scanners the imaged slice width increases as the pitch increases, noise on single slice scanner constant with changing pitch, and multi slice scanners the imaged slice width to remain constant with pitch. In these conditions the noise will increase as the pitch increases (Kalender WA, 2000).

These factors effect on values organ equivalent dose, and age at exposure for female underwent Chest CT scan in ten hospitals in Palestine, (Tokunaga M et al, 2007).

4.10.6 Breast cancer risk assessment for female underwent Chest CT scans in Palestine:

The breast cancer risk for female Chest CT scan in Palestine was in younger female is 0.00042% or 1 in 2645 for a 15 - 39 years and in older female is 0.00014% or 1 in 10,473 for a 40 - 60 years and these values relatively not high in young and old female in Palestine to compare with ICRP is younger female is 0.00865% and in older female is 0.00160%. The causes for not should increase breast cancer risk related to breast equivalent doses for used CT scanner parameters input on the devices such as CTDIvol and DLP and these factors causes reduced lifetime attributable breast cancer risk in different hospitals in Palestine.

The relationship between radiation induced breast cancer risk and radiation dose is a product of several factors such as age at exposure, latent period (Time after exposure), Hormone level (Tokunaga M et al, 2007). The age of exposure is the most important factor, with younger female than those exposed at an older female (UNSCEAR, 2013). The reason is a need for estrogen stimulation and tissue proliferation in order for radiation damage to occur in breast tissue (Tokunaga M et al, 2007).

A brief description of the breast anatomy is provided in Appendix B. The latent period for radiation induced breast cancer risk to occur is approximately 5 to 10 years this time is longest in younger women and shortest for older women (Ries LAG et al, 2004). The others factors in female patients is the breast lies in the perpendicular field of irradiation (Andrew J. Einstein et al, 2007).

The seventh biologic effects of ionizing radiation report (BEIR VII, 2006) "predicts that for a standardized U.S. population, these age dependent risks combine to produce an average lifetime attributable risk of one radiation induced cancer per 1,000 patients receiving a 10 mSv effective dose approximately half of these cancers are expected to be fatal" (Richard T. Griffey and Aaron Sodickson, 2009).

Chapter Five:

Conclusion and Recommendations:

5.1 Conclusion

This study was an effort to highlight the radiation absorbed doses from CT scan that lead to breast cancer risk. The effective dose from chest CT scan per exam varies from 3 to 14.7 mSv with a mean is 7 mSv, while the breast dose varies from 6.5 to 17.5 mGy per procedure, with a mean is 15 mGy. The patient radiation lifetime attributable breast cancer risk (LAR) estimated for breast female cancer in Palestine for younger female is 0.00042 % or 1 in 2645 for a 15 - 39 years and older female is 0.00014 % or 1 in 10,473 for 40 - 60 years.

The International commission on radiological protection recommendation **(**ICRP) the breast dose should not exceed 45 mGy, and the lifetime attributable breast cancer risk for younger and older female patients should not exceed 0.00865% and 0.00160%, respectively.

The radiation breast dose was not shall high, and the lifetime attributable breast cancer risk for younger and older female patients were not should high risk in Palestine.

5.2 Recommendations

Identification of breast cancer risk factor and development of radiation protection strategies based on CT scan studies can form the basis for developing a comprehensive radiation protection strategy to prevent and reduces breast cancer risk from CT scan in Palestine.

Based on the study finding, the researcher managed to present the following recommendation:

- Radiation dose reduction protocols for Chest from CT scan procedures should be used.
- Young patients should be adequately protected in Palestine from radiation risks.
- A large variation of breast organ and effective doses was observed for different scanner type, protocols and variation in equipment design.
- $CTDI_{vol}$ and DLP in CT dose parameters that can be universally interpreted. CT protocols that specify only kilovolt peak and milliampere second are very poor indicators of patient dose. CT protocols should specify both CTDI and DLP.
- Radiographer should review the manufacturer's preset CTDI and DLP during installation of a new CT scanner. Radiographer should also review these data when protocol modifications are made.
- The radiation dose used to perform the procedure does not exceed the dose necessary to produce an image of adequate diagnostic quality.

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Appendices

Appendix A

Information sheet

No. ( )

date.....

Hospital name.....

Patient data:

Gender…… Height..... Age.....

Weight.....kg……

Clinical indications:

Scan parameter

Start position..... End position…….. Kvp .....

mAs..... Pitch..... Slice thickness..... Number of scan.....

Field of view (FOV)..... Total scan time..... Rotation time.....

Table feed per rotation..... Displayed…….. CTDIvol.....

DLP..... CTDIw.....

Machine information:

CT machine manufacture.....

Model Year of installation.....

Focal axial distance (FAD).....

Detector type.....

Comments.....

Figure 1: Types of CT scan

Appendix B

BREAST ANATOMY

The female breast tissue comprised of glandular, fatty and fibrous tissues. They are located over the pectorals major muscle and are attached to the sternum. The functional parts of the breast include: lobes, lobules, ducts, areola, nipple, fat and blood vessels see Figure 2. Each breast is composed of 15-20 lobes, which are arranged in a circular pattern. The lobes are made up of smaller lobules which are the milk producing glands. During lactation, sensory bulbs located distally on the bulbs respond to hormonal signals from the mother to produce breast milk. The ducts are used as passages for the transportation of breast milk from glandular tissue to the nipple. Fat covers the spaces between the lobules and ducts. During lactation the breast becomes highly lobulated. Newer research in breast anatomy has draws the following conclusions about the breast anatomy: 1) glandular tissue is found closer to the nipple than previous thought, 65% of the glandular tissue is located within 30mm from the base of the nipple 2) the ratio of glandular to fat tissue rises to 2:1 in the lactating breast, compared to 1:1 ratio in no lactating breast.

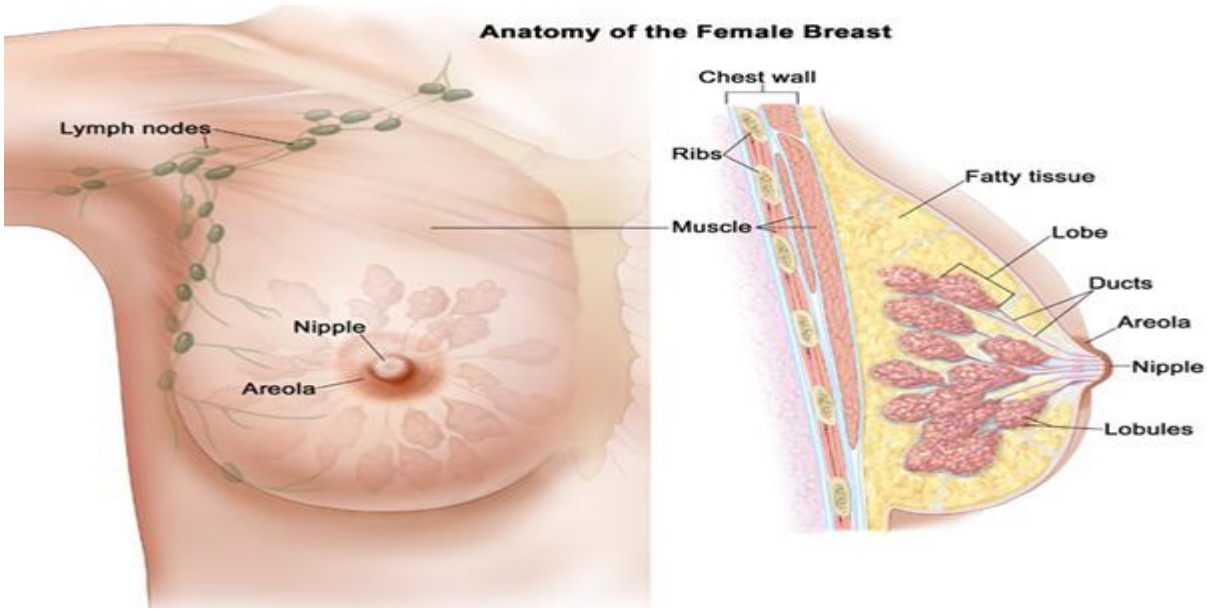

Figure 2: shows Anatomy of the female breast

Appendix C

H1

Table 1: Shows exposure parameters in hospital one in Palestine

Patients number	$CTDI_{VOL}$ (mGy) Per 100 mAs	$CTDI_w$ (mGy) = $CTDI_{VOL}$ x Pitch	Pitch	mAs	DLP (mGy.cm)	Effective dose (mSv)	Breast Dose (mGy)
1	6	6	1	200	425	6.5	13.65
2	6	6	1	200	425	6.5	13.65
3	6	6	1	200	422	6.5	13.65
4	6	6	1	200	422	6.5	13.65
5	6	6	1	200	422	6.5	13.65
6	6	6	1	200	425	6.5	13.65
7	6	6	1	200	422	6.5	13.65
8	6	6	1	200	422	6.5	13.65
9	6	6	1	200	422	6.5	13.65
10	6	6	1	200	425	6.5	13.65
Mean	6	6	1	200	423	6.5	13.65

Table 2: Shows exposure parameters in hospital tow in Palestine

Patients number	$CTDI_{VOL}$ (mGy) Per 100 mAs	$CTDI_w$ (mGy) = $CTDI_{VOL}$ x Pitch	Pitch	mAs	DLP (mGy.cm)	Effective dose (mSv)	Breast Dose (mGy)
1	8	8	1	200	410	5.5	11
2	8	8	1	200	410	6.5	15
3	8	8	1	200	410	6.5	15
4	8	8	1	200	410	5	11
5	8	8	1	200	410	6.5	15
6	8	8	1	200	410	5	11
7	8	8	1	200	410	6.5	15
8	8	8	1	200	410	5	11
9	8	8	1	200	410	6.5	15
10	8	8	1	200	410	5	11
11	8	8	1	200	410	6.5	15
12	8	8	1	200	410	5	11
13	8	8	1	200	410	6.5	15
14	8	8	1	200	410	5	11
15	8	8	1	200	410	6.5	15
Mean	8	8	1	200	410	7	13

H3

Table 3: Shows exposure parameters in hospital three in Palestine

Patients number	$CTDI_{VOL}$ (mGy) Per 100 mAs	$CTDI_w$ (mGy) = $CTDI_{VOL}$ x Pitch	Pitch	mAs	DLP (mGy.cm)	Effective dose (mSv)	Breast Dose (mGy)
1	8	8	1	220	410	7.5	15
2	8	8	1	220	410	7.5	15
3	7	7	1	210	410	6.5	13
4	7	7	1	220	410	6	12.5
5	8	8	1	220	410	7.7	15.5
6	8	8	1	220	410	12.5	15
7	9	9	1	210	410	6.5	13
8	7	7	1	210	410	6	12.5
9	8	8	1	220	410	7.7	15.5
10	8	8	1	220	410	7.5	15
11	8	8	1	210	410	6.5	13
12	7	7	1	210	410	6	12.5
13	8	8	1	220	410	7.7	15.5
14	8	8	1	220	410	7.5	15
15	7	7	1	210	410	6.5	13
Mean	7.7	7.7	1	216	410	8	14

H4

Table 4: Shows exposure parameters in hospital four in Palestine

Patients number	$CTDI_{VOL}$ (mGy) Per 100 mAs	$CTDI_w$ (mGy) = $CTDI_{VOL}$ x Pitch	Pitch	mAs	DLP (mGy.cm)	Effective dose (mSv)	Breast Dose (mGy)
1	10	9	0.9	300	976	8	20
2	11	10	0.9	300	980	9	22
3	12.5	11	0.9	300	976	8	20
4	11.5	10	0.9	300	980	10	25
5	10	9	0.9	300	976	8	20
6	11	10	0.9	300	980	10	25
7	10	9	0.9	300	976	9	20
8	11	10	0.9	300	980	10	25
9	12.5	11	0.9	300	976	8	20
10	11.5	10	0.9	300	980	10	25
11	10	9	0.9	300	976	9	20
12	11	10	0.9	300	980	9	25
13	10	9	0.9	300	976	8	20
14	11	10	0.9	300	980	8	20
15	12.5	11	0.9	300	976	8	20
16	10	9	0.9	300	980	9	22
17	11	10	0.9	300	980	10	25
18	12.5	12.5	0.9	300	976	8	20
19	11.5	10	0.9	300	980	10	25
20	10	9	0.9	300	976	8	20
21	11	10	0.9	300	980	10	25
22	10	9	0.9	300	976	8	20
23	11	10	0.9	300	980	10	25

24	12.5	11	0.9	300	976	8	20
25	11.5	10	0.9	300	980	8	20
26	10	9	0.9	300	976	8	20
27	11	10	0.9	300	980	10	25
28	10	9	0.9	300	980	8	20
29	11	10	0.9	300	976	8	20
30	12.5	11	0.9	300	980	8	20
Mean	11	10	0.9	300	976	8.8	22

H5

Table 5: Shows exposure parameters in hospital five in Palestine

Patients number	$CTDI_{VOL}$ (mGy) Per 100 mAs	$CTDI_w$ (mGy) = $CTDI_{VOL}$ x Pitch	Pitch	mAs	DLP (mGy.cm)	Effective dose (mSv)	Breast Dose (mGy)
1	6	5.4	0.9	155	450	5	10
2	13	11	0.9	197	450	6	11
3	5	4.5	0.9	190	430	4	8
4	5	4.5	0.9	197	450	6	11
5	4	3.6	0.9	190	430	4	6
6	13	11	0.9	150	430	5	9
7	5	4.5	0.9	190	430	5	9
8	5	4.5	0.9	150	430	4	8
9	10	9	0.9	190	430	5	9
10	6	5.4	0.9	150	430	5	8
11	4	3.6	0.9	190	450	4	7
12	6	5.4	0.9	150	400	5	8
13	5	4.5	0.9	150	430	4	8
14	5	4.5	0.9	197	430	5	9

15	4	3.6	0.9	150	400	4	8
16	4	3.6	0.9	150	430	4	9
17	5	4.5	0.9	150	400	4	8
18	6	5.4	0.9	197	450	6	11
19	5	4.5	0.9	150	400	4	8
20	4	3.6	0.9	190	400	4	8
21	5	4.5	0.9	197	430	5	9
22	6	5.4	0.9	150	430	5	8
23	5	4.5	0.9	190	430	5	9
24	4	3.6	0.9	190	430	4	8
25	6	5.4	0.9	150	430	6	11
26	5	4.5	0.9	150	430	4	8
27	5	4.5	0.9	150	400	4	8
28	4	3.6	0.9	150	430	4	9
29	5	4.5	0.9	150	430	4	8
30	5	4.5	0.9	150	430	5	9
Mean	5.6	5	0.9	168	427	4.6	8.6

H6

Table 6: Shows exposure parameters in hospital six in Palestine

Patients number	$CTDI_{VOL}$ (mGy) Per 100 mAs	$CTDI_w$ (mGy) = $CTDI_{VOL}$ x Pitch	Pitch	mAs	DLP (mGy.cm)	Effective dose (mSv)	Breast Dose (mGy)
1	6	6	1	200	400	6	14
2	5	5	1	200	380	5	9
3	8	8	1	200	400	6	14
4	6	6	1	200	400	6	14
5	8	8	1	200	400	4	9
6	6	6	1	200	400	6	14
7	8	8	1	200	400	4	9

8	6	6	1	200	400	6	14
9	6.4	6.4	1	200	420	6	14
10	5	5	1	200	400	4	9
11	6.4	6.4	1	200	420	6	14
12	6	6	1	200	400	6	14
13	6.4	6.4	1	200	420	6	14
14	5	5	1	200	400	5	12
15	6.4	6.4	1	200	420	6	14
16	6	6	1	200	420	6	14
17	5	5	1	200	400	4	9
18	6	6	1	200	420	6	14
19	6	6	1	200	420	6	14
20	5	5	1	200	400	4	9
Mean	6	6	1	200	406	5.4	12.4

H7

Table 7: Shows exposure parameters in hospital seven in Palestine

Patients number	$CTDI_{VOL}$ (mGy) Per 100 mAs	$CTDI_w$ (mGy) = $CTDI_{VOL}$ x Pitch	Pitch	mAs	DLP (mGy.cm)	Effective dose (mSv)	Breast Dose (mGy)
1	8.5	7.6	0.9	245	1000	8	16
2	7.5	6.7	0.9	240	950	6.5	15
3	7.5	6.7	0.9	245	950	6.5	15
4	8.5	7.6	0.9	245	1000	8	16
5	7.5	6.7	0.9	240	950	6.5	15
6	8.5	7.6	0.9	245	1000	8	16
7	7.5	6.7	0.9	240	950	6.5	15
8	7.5	6.7	0.9	240	950	6.5	15
9	8.5	7.6	0.9	245	980	8	16
10	7.5	6.7	0.9	240	950	6.5	15

11	7.5	6.7	0.9	245	950	6.5	15
12	8.5	7.6	0.9	240	1000	8	16
13	7.5	6.7	0.9	245	950	6.5	15
14	8.5	7.6	0.9	240	1000	8	16
15	7.5	6.7	0.9	240	970	6.5	15
16	8.5	7.6	0.9	245	950	8	16
17	7.5	6.7	0.9	240	950	6.5	15
18	8.5	7.6	0.9	245	1000	8	16
19	7.5	6.7	0.9	240	950	6.5	15
20	8.5	7.6	0.9	240	950	8	16
Mean	8	7	0.9	240	967	7	15.4

H8

Table 8: Shows exposure parameters in hospital eight in Palestine

Patients number	$CTDI_{VOL}$ (mGy) Per 100 mAs	$CTDI_w$ (mGy) = $CTDI_{VOL}$ x Pitch	Pitch	mAs	DLP (mGy.cm)	Effective dose (mSv)	Breast Dose (mGy)
1	15	13.5	0.9	250	1000	14.7	28
2	15	13.5	0.9	250	1000	14.7	28
3	15	13.5	0.9	250	1000	14.7	28
4	15	13.5	0.9	250	1000	14.7	28
5	15	13.5	0.9	250	1000	14.7	28
6	15	13.5	0.9	250	1000	14.7	28
7	15	13.5	0.9	250	1000	14.7	28
8	15	13.5	0.9	250	1000	14.7	28
9	15	13.5	0.9	250	1000	14.7	28
10	15	13.5	0.9	250	1000	14.7	28
11	15	13.5	0.9	250	1000	14.7	28
12	15	13.5	0.9	250	1000	14.7	28

13	15	13.5	0.9	250	1000	14.7	28
14	15	13.5	0.9	250	1000	14.7	28
15	15	13.5	0.9	250	1000	14.7	28
16	15	13.5	0.9	250	1000	14.7	28
17	15	13.5	0.9	250	1000	14.7	28
18	15	13.5	0.9	250	1000	14.7	28
19	15	13.5	0.9	250	1000	14.7	28
20	15	13.5	0.9	250	1000	14.7	28
Mean	15	13.5	0.9	250	1000	14.7	28

H9

Table 9: Shows exposure parameters in hospital nine in Palestine

Patients number	$CTDI_{VOL}$ (mGy) Per 100 mAs	$CTDI_w$ (mGy) = $CTDI_{VOL}$ x Pitch	Pitch	mAs	DLP (mGy.cm)	Effective dose (mSv)	Breast Dose (mGy)
1	5	5	1	200	420	3	6.5
2	4	4	1	200	420	3	6.5
3	3	3	1	200	400	3	6.5
4	5	5	1	200	420	3	6.5
5	4	4	1	200	400	3	6.5
6	3	3	1	200	400	3	6.5
7	5	5	1	200	420	3	6.5
8	4	4	1	200	400	3	6.5
9	3	3	1	200	420	3	6.5
10	4	4	1	200	420	3	6.5
11	4	4	1	200	400	3	6.5
12	3	3	1	200	400	3	6.5
13	3	3	1	200	400	3	6.5
14	4	4	1	200	420	3	6.5
15	4	4	1	200	400	3	6.5

16	3	3	1	200	400	3	6.5
17	4	4	1	200	400	3	6.5
18	3	3	1	200	400	3	6.5
19	3	3	1	200	400	3	6.5
20	4	4	1	200	400	3	6.5
Mean	3.75	3.75	1	200	407	3	6.5

H10

Table 10: Shows exposure parameters in hospital ten in Palestine

Patients number	$CTDI_{VOL}$ (mGy) Per 100 mAs	$CTDI_w$ (mGy) = $CTDI_{VOL}$ x Pitch	Pitch	mAs	DLP (mGy.cm)	Effective dose (mSv)	Breast Dose (mGy)
1	16	14.4	0.9	350	1000	8	16
2	17	15.3	0.9	350	1100	9	19
3	16	14.4	0.9	350	1100	8	16
4	16	14.4	0.9	350	1000	9	19
5	17	15.3	0.9	350	1100	8	16
6	17	15.3	0.9	350	1000	9	19
7	16	14.4	0.9	350	1100	8	16
8	17	15.3	0.9	350	1100	9	19
9	16	14.4	0.9	350	1100	8	16
10	17	15.3	0.9	350	1000	9	19
11	16	14.4	0.9	350	1100	8	16
12	17	15.3	0.9	350	1100	9	19
13	16	14.4	0.9	350	1000	8	16
14	17	15.3	0.9	350	1100	9	19
15	16	14.4	0.9	350	1100	8	16
16	17	15.3	0.9	350	1000	9	19
17	16	14.4	0.9	350	1100	8	16

18	17	15.3	0.9	350	1100	9	19
19	16	14.4	0.9	350	1000	8	16
20	17	15.3	0.9	350	1100	9	19
Mean	16.6	14.8	0.9	350	1067	8.5	17.5

Appendix D

H1

Table 1: Shows Lifetime attributable breast cancer risk of age Patients in hospital one in Palestine

Patients number	Age (Y)	Breast equivalent dose (mSv)	lifetime attributable risk (LAR) %
1	65	14	0.00003 % 1 in 33333
2	32	14	0.0003 % 1 in 3125
3	60	14	0.000043 % 1 in 23,255
4	40	14	0.0002 % 1 in 5066
5	50	14	0.0001 % 1 in 10,204
6	45	14	0.00015 % 1 in 6757
7	34	14	0.00028 % 1 in 3571
8	66	14	0.000028 % 1 in 35,714
9	38	14	0.00023 % 1 in 9276
10	70	14	0.0000168 % 1 in 59,532

H2

Table 2: Shows Lifetime attributable breast cancer risk of age Patients in hospital two in Palestine.

Patients number	Age (Y)	Breast organ equivalent dose (mSv)	lifetime attributable risk (LAR) %
1	55	11	0.000055 % 1 in 18,018
2	45	15	0.00016 % 1 in 6329
3	32	15	0.000345 % 1 in 2828.5
4	28	11	0.000319 % 1 in 3135
5	30	15	0.00034 % 1 in 2632
6	66	11	0.000022 % 1 in 45,454
7	22	15	0.000585 % 1 in 1709
8	44	11	0.00012 % 1 in 8333
9	24	15	0.000525 % 1 in 1905
10	52	11	0.00007 % 1 in 14,705
11	60	15	0.0000465 % 1 in 21,505

12	45	11	0.000116 % 1 in 8621
13	30	15	0.00038 % 1 in 2632
14	44	11	0.00012 % 1 in 8130
15	32	15	0.000345 % 1 in 2899

H3

Table 3: Shows Lifetime attributable breast cancer risk of age Patients in hospital three in Palestine.

Patients number	Age (Y)	Breast organ equivalent dose (mSv)	lifetime attributable risk (LAR) %
1	75	15	0.000012 % 1 in 83.333
2	65	15	0.000032 % 1 in 52,631
3	45	13	0.00014 % 1 in 7299
4	30	12.5	0.000316 % 1 in 3165
5	34	15.5	0.00031 % 1 in 3226
6	54	15	0.00008 %

			1 in 12,500
7	33	13	0.00028 % 1 in 3571
8	62	12.5	0.000034 % 1 in 29,412
9	22	15.5	0.0006 % 1 in 1667
10	50	15	0.0001 % 1 in 9524
11	30	13	0.00033 % 1 in 3030
12	33	12.5	0.00027 % 1 in 3703
13	52	15.5	0.0001 % 1 in 10,526
14	46	15	0.00016 % 1 in 6250
15	32	13	0.0003 % 1 in 3333

H4

Table 4: Shows Lifetime attributable breast cancer risk of age Patients in hospital four in Palestine.

Patients number	Age (Y)	Breast organ equivalent dose (mSv)	lifetime attributable risk (LAR) %
1	68	20	0.000034 % 1 in 29,411
2	65	22	0.00005 % 1 in 21,277
3	40	20	0.0003 % 1 in 4762
4	45	25	0.00026 % 1 in 3846
5	24	20	0.0007 % 1 in 1429
6	35	25	0.0004 % 1 in 2041
7	37	20	0.00033 % 1 in 3067
8	62	25	0.00007 % 1 in 14,286
9	27	20	0.0006 % 1 in 1667
10	44	25	0.0003 % 1 in 3571
11	35	20	0.0004 % 1 in 2564

12	34	25	0.0005 % 1 in 2000
13	32	20	0.00046 % 1 in 2174
14	54	20	0.00011 % 1 in 9091
15	26	20	0.00062 % 1 in 1613
16	24	22	0.00077 % 1 in 1300
17	52	25	0.00016 % 1 in 6452
18	60	20	0.00006 % 1 in 16,667
19	45	25	0.00026 % 1 in 3846
20	30	20	0.0005 % 1 in 1976
21	44	25	0.0003 % 1 in 3571
22	32	20	0.00046 % 1 in 2174
23	60	25	0.00008 % 1 in 12,500
24	65	20	0.00004 % 1 in 25.000
25	32	20	0.00046 %

			1 in 2174
26	60	20	0.00006 % 1 in 16,667
27	40	25	0.00035 % 1 in 2857
28	50	20	0.00014 % 1 in 7143
29	45	20	0.0002 % 1 in 4762
30	34	20	0.0004 % 1 in 2500

H5

Table 5: Shows Lifetime attributable breast cancer risk of cancer incidence age Patients in hospital five in Palestine.

Patients number	Age (Y)	Breast organ equivalent dose (mSv)	lifetime attributable risk (LAR) %
1	72	10	0.000011 % 1 in 90,909
2	60	11	0.000034 % 1 in 29.411
3	60	8	0.000025 % 1 in 40,000
4	55	11	0.000056 % 1 in 18,189
5	45	6	0.00006 %

			1 in 16,667
6	54	9	0.00005 % 1 in 20.000
7	36	9	0.00017 % 1 in 5882
8	22	8	0.0003 % 1 in 3226
9	50	9	0.00006 % 1 in 16,667
10	30	8	0.0002 % 1 in 5000
11	33	7	0.00015 % 1 in 6494
12	52	8	0.00005 % 1 in 20,000
13	46	8	0.00009 % 1 in 11,111
14	32	9	0.0002 % 1 in 4762
15	27	8	0.00023 % 1 in 4167
16	38	9	0.00015 % 1 in 6667
17	24	8	0.00028 % 1 in 3571
18	60	11	0.000034 % 1 in 29,411

19	42	8	0.0001 % 1 in 10,000
20	66	8	0.000015 % 1 in 66,667
21	55	9	0.000045 % 1 in 22,222
22	40	8	0.00011 % 1 in 9091
23	35	9	0.00017 % 1 in 5650
24	34	8	0.00016 % 1 in 6250
25	32	11	0.00025 % 1 in 4000
26	54	8	0.000044 % 1 in 22727
27	26	8	0.00025 % 1 in 4000
28	24	9	0.0003 % 1 in 3175
29	52	8	0.00005 % 1 in 20.000
30	60	9	0.000028 % 1 in 33,333

H6

Table 6: Shows Lifetime attributable breast cancer risk of age Patients in hospital six in Palestine.

Patients number	Age (Y)	Breast organ equivalent dose (mSv)	lifetime attributable risk (LAR) %
1	72	14	0.000014 % 1 in 66,667
2	60	9	0.00003 % 1 in 33,333
3	60	14	0.000043 % 1 in 23,256
4	55	14	0.00007 % 1 in 14,286
5	45	9	0.000095 % 1 in 10,526
6	54	14	0.000077 % 1 in 12,987
7	36	9	0.00017 % 1 in 5882
8	22	14	0.00055 % 1 in 1818
9	50	14	0.00007 % 1 in 10,204
10	30	9	0.00023 % 1 in 4348
11	33	14	0.00031 %

			1 in 3226
12	52	14	0.000087 % 1 in 11,494
13	46	14	0.00015 % 1 in 6667
14	32	12	0.00028 % 1 in 3636
15	27	14	0.0004 % 1 in 2326
16	38	14	0.00023 % 1 in 4349
17	24	9	0.0003 % 1 in 3175
18	60	14	0.00004 % 1 in 25,000
19	42	14	0.00018 % 1 in 1778
20	66	9	0.000017 % 1 in 58824

H7

Table 7: Shows Lifetime attributable breast cancer risk of age Patients in hospital seven in Palestine.

Patients number	Age (Y)	Breast organ equivalent dose (mSv)	lifetime attributable risk (LAR) %
1	38	16	0.00026 % 1 in 3774
2	60	15	0.00005 % 1 in 20,000
3	55	15	0.000076 % 1 in 13,158
4	26	16	0.0005 % 1 in 2000
5	60	15	0.000046 % 1 in 21739
6	25	16	0.00055 % 1 in 1818
7	62	15	0.00004 % 1 in 25,000
8	26	15	0.00047 % 1 in 2151
9	24	16	0.00056 % 1 in 1786
10	50	15	0.0001 % 1 in 9524
11	60	15	0.000047 %

			1 in 21,739
12	38	16	0.00026 % 1 in 3788
13	28	15	0.00044 % 1 in 2300
14	45	16	0.00017 % 1 in 5882
15	51	15	0.0001 % 1 in 10,000
16	27	16	0.0005 % 1 in 2083
17	38	15	0.00025 % 1 in 4000
18	24	16	0.00056 % 1 in 1786
19	60	15	0.00005 % 1 in 21,739
20	42	16	0.0002 % 1 in 5000

H8

Table 8: Shows Lifetime attributable breast cancer risk of age Patients in hospital eight in Palestine.

Patients number	Age (Y)	Breast organ equivalent dose (mSv)	lifetime attributable risk (LAR) %
1	36	28	0.0005 % 1 in 1887
2	60	28	0.00009 % 1 in 11,111
3	35	28	0.00055 % 1 in 1818
4	40	28	0.0004 % 1 in 2564
5	65	28	0.00006 % 1 in 16,667
6	27	28	0.0008 % 1 in 1205
7	55	28	0.00014 % 1 in 7143
8	35	28	0.00055 % 1 in 1818
9	26	28	0.0009 % 1 in 1149
10	48	28	0.0002 % 1 in 4255
11	43	28	0.00034 % 1 in 2941

12	17	28	0.0014 % 1 in 725
13	53	28	0.00016 % 1 in 6250
14	32	28	0.0006 % 1 in 1563
15	18	28	0.00136 % 1 in 735
16	36	28	0.0005 % 1 in 752
17	55	28	0.00014 % 1 in 7142
18	35	28	0.00055 % 1 in 1818
19	26	28	0.0009 % 1 in 1111
20	48	28	0.00023 % 1 in 4255

H9

Table 9: Shows Lifetime attributable breast cancer risk of age Patients in hospital nine in Palestine.

Patients number	Age (Y)	Breast organ equivalent dose (mSv)	lifetime attributable risk (LAR) %
1	75	6.5	0.000008 % 1 in 200,000
2	28	6.5	0.00019 % 1 in 5263
3	52	6.5	0.00004 % 1 in 25,000
4	19	6.5	0.0003 % 1 in 3571
5	55	6.5	0.00003 % 1 in 33,333
6	32	6.5	0.00015 % 1 in 6667
7	63	6.5	0.000017 % 1 in 50,000
8	44	6.5	0.00007 % 1 in 14,286
9	60	6.5	0.00002 % 1 in 50,000
10	36	6.5	0.0001 % 1 in 8333
11	65	6.5	0.000014 % 1 in 71,429

12	23	6.5	0.00023 % 1 in 4267
13	37	6.5	0.00011 % 1 in 9090
14	33	6.5	0.00014 % 1 in 7143
15	52	6.5	0.00004 % 1 in 25,000
16	46	6.5	0.00007 % 1 in 14,286
17	32	6.5	0.00015 % 1 in 6667
18	27	6.5	0.0002 % 1 in 5263
19	38	6.5	0.0001 % 1 in 9346
20	24	6.5	0.00022 % 1 in 4444

H10

Table 10: Shows Lifetime attributable breast cancer risk of age Patients in hospital ten in Palestine.

Patients number	Age (Y)	Breast organ equivalent dose (mSv)	lifetime attributable risk (LAR) %
1	45	16	0.00017 % 1 in 5882
2	30	19	0.0005 % 1 in 2083
3	22	16	0.0006 % 1 in 1613
4	60	19	0.00006 % 1 in 16,667
5	40	16	0.00022 % 1 in 4444
6	18	19	0.0009 % 1 in 1087
7	28	16	0.00046 % 1 in 2174
8	43	19	0.00023 % 1 in 4348
9	55	16	0.00008 % 1 in 20,000
10	31	19	0.00044 % 1 in 2222
11	20	16	0.0007 % 1 in 1449

12	28	19	0.00055 % 1 in 1818
13	42	16	0.0002 % 1 in 5000
14	50	19	0.00013 % 1 in 7692
15	24	16	0.00056 % 1 in 1786
16	55	19	0.0001 % 1 in 10,000
17	32	16	0.0004 % 1 in 2703
18	63	19	0.00005 % 1 in 20,000
19	44	16	0.00017 % 1 in 5714
20	60	19	0.00006 % 1 in 16,667

الجرعة الاشعاعية للثدي ومخاطر الإصابة بالسرطان لدى الإناث نتيجة التصوير الطبقي المقطعي في فلسطين

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الملخص:

استخدام التصوير المقطعي في التشخيص الطبي يعطي جرعات إشعاعية للمرضى أعلى من جرعات التصوير الطبي التقليدي. ويمكن أن يشكل سوء استخدام البروتوكولات الى زيادة جرعة الإشعاع للمرضى. الأشعة المقطعية تمثل حوالي 20 ٪ من إجمالي الإجراءات الطبية الأشعة السينية التي أجريت في جميع أنحاء العالم. الصورة المقطعية للصدر هي واحدة من الإجراءات الأكثر شيوعا.

في فلسطين ، يوجد حاليا حوالي 28 جهاز طبقي مقطعي ، 24 منها في الضفة الغربية و 4 في قطاع غزة. في حالة مرضى الإناث ، تقدم الصورة المقطعية للصدر جرعة عالية للثدي إلى حد كبير لحساسية للاشعة. ويهدف هذا العمل إلى تقييم جرعة الثدي ومدة الحياة المرتبطة بخطر التعرض الذي أجري على 200 مريضة في 10 مستشفيات في فلسطين ، الضفة الغربية وقطاع غزة.

تم إجراء تقدير الجرعة نظريا باستخدام البرمجيات المتاحة تجاريا على أساس محاكاة مونتي كارلو لجسم الإنسان مع الأنسجة التى تحاكي جسم الأنسان لجميع الأعمار والأحجام. وتم استخدم نموذج بير سبعة من المرحلة 2 لتقييم دقيق لمخاطر السرطان لجرعة العضو النسيجي الداخلي المرتبطة بالعمر.

تم جمع جميع البيانات المدخلة ذات الصلة في قاعدة البيانات بما في ذلك بيانات المريض مثل العمر والوزن ومؤشر كتلة الجسم ، وبيانات عن اجهزة التصوير المقطعي مثل مؤشر التصوير المقطعي المحوسب ، طول الجرعة المنتجة ، التيار الكهربائي للتيوب ، وفرق الجهد. ووجد أن الجرعة الإشعاعية الناتجة عن نفس الاختبار تختلف اختلافا كبيرا بين المستشفيات اعتمادا على المعايير المستخدمة ونوع الجهاز المقطعي.

بالنسبة لجميع المرضى، الجرعة الفعالة للصدر لكل اختبار تختلف من 3 إلى 14.7 ملي سيفرت ومع متوسط هو 7 ملي سيفرت لكل إجراء ، في حين أن جرعة الثدي تختلف من 6.5 إلى 17.5 ملي جراي لكل إجراء، مع متوسط هو 15 ملي جراي. وكان معدل التعرض للإصابة بسرطان الثدي المرتبط بالعمر لدى الإناث في فلسطين ، في الإناث الاصغر سنا هو 0.00042٪ أو 1 في 2645 من عمر 15– 39 سنة وعند الإناث الاكبر سنا هو 0.00014٪ أو 1 في 10.473 من عمر 40–60 سنة، وأوصت اللجنة الدولية للوقاية من الأشعاع أن لا تتجاوز الجرعة الأشعاعية للثدي من التصوير المقطعي للصدرهو 45 ملي جراي ، وأن لا يتجاوز معدل التعرض للإصابة بسرطان الثدي المرتبط بالعمر لدى الإناث الاصغر سنا والإناث الاكبر سنا هو 0.00865% ، 0,00160% ، على التوالي.

تشير النتائج إلى أن الجرعة الإشعاعية للأنسجة الثدي الغدية تنخفض عموما مع استخدام المعايير المناسبة للتعرض الأشعاعي.