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Radiation Doses and Cancer Risk Assessment for Patients Undergoing Computed Tomography Angiography Procedures in Palestine

Reema Abduallah Ahmad Za’roor

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Prepared By:

Reema Abduallah Ahmad Za'roor

B.Sc. Medical Imaging Science, Arab American University, Palestine.

Supervisor: **Dr. Hussein ALMasri**

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Thesis Approval

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Prepared by: **Reema Abduallh Ahmad Za'roor**

Registration No: **21811941**

Supervisor: **Dr. Hussein ALMasri**

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The names and signatures of the examining committee members are as follows:

1- Head of Committee: **Dr. Hussein ALMasri** Signature: Hussein ALMasri

2- Internal Examiner: **Dr. Mohammad Hjouj** Signature:

3- External Examiner: **Dr. Adnan Judeh** Signature:

Jerusalem – Palestine

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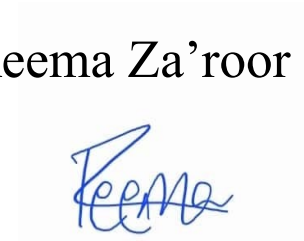
Dedication

I dedicate my effort to all whom I love …

Reema Za'roor



Declaration:

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

Reema Abduallah Ahmad Za'roor

Signed: 

Date: 21/8/2022

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Abstract

CT procedures may cause radiogenic risk because of the high radiation dose used in image acquisition, comparing to other diagnostic imaging modalities. In global studies, there was a large variation in the Effective Dose (ED) values duringcomputed tomography angiogram (CTA) procedures(2.2-24.4) mSv.The increasing use of CT scans in Palestine has spurredresearchers to do dose assessments and cancer risk studies. However, there is no previous study conducted in Palestine about estimation of radiation dose of CTA scans. Therefore, a dose assessment for CTA patients is highly recommended in Palestine.

The main objective of this study is to estimate the radiation effective dose and cancer risk to adult patients (>18years old) CTA procedures, including: lower limp angiogram (LLA), pulmonary embolism angiogram (PEA), head and neck angiogram (HNA) in the selected governmental hospitals in the Palestine. A quantitative cohort retrospective design was used to conduct this study. All adult patients (>18 years old)underwent the selected CTA examinations in the chosen three governmental hospitals. Data collection was through PACS system during two months. The average effective dose was estimated by CT-EXPO softwarefor LLA, PEA and HNA was 7.2±2.9, 5.2±2 and 4.18±2 mSv, respectively, for the total study populationof the three scans ranged between 3 mSv - 11.3 mSv, which was lower than the international studies. Based on hospitals in LLA protocol, the largest value of ED was in Beit Jala Hospital (B.J.H) with 11.3±1mSv in arterial phase and 10.6 in venous phase, Palestine medical complex Hospital (P.M.C) had done only arterial phase with 7±2 mSv then Rafedia surgical Hospital (R.S.H) with 4.79 ± 1 mSv in arterial phase and 4.68±1.1 in venous phase. In PEA protocol, the highest value of ED was also in Beit Jala Hospital (B.J.H) with 7.9±0.9 mSv, Rafedia surgical Hospital (R.S.H) with 4.54±1 mSv then Palestine medical complex Hospital (P.M.C) with 4±1.9 mSv. While in HNA protocol, the largest value of ED in arterial phase was R.S.H with 5.5±1.5 mSv, B.J.H with 4.5±3 mSv then P.M.C with 3.3 ± 0.3 mSv.The overall cancer risk per 100000 procedures for all CTA scans included in the study was 39.7±15.9 for LLA, 28±11.5 for PEA and 23±11.6 for HNA.These values are considered as a low-dose risk estimates due to results derived from Hiroshima atomic bomb data that stated, effective doses ranging between 5 to 50 mSv are associated with higher chances to increase risk of cancer mortality.

Table of Contents

List of Tables

List of Figure

List of Equations

Abbreviations and Units

As Low As Reasonably Achievable (ALARA)

Arterio-Venous (AV)

Bait-Jalla Hospital (B.J.H).

Biological Effects of Ionizing Radiations (BEIR)

ComputedTomography Angiography (CTA)

Computed Tomography Dose Index volume (CTDIvol)

Computed Tomography (CT)

DeoxyriboNucleic Acid (DNA)

Diagnostic Reference Levels (DRLs)

Dose Length Product (DLP)

Dual-Source CT (DSCT)

Effective Dose (ED)

European Commission Report(EUR)

Female (F)

Filtered Back Projection (FBP)

HeadNeck Angiogram (HNA)

International Commission on Radiation Protection (ICRP)

Killo-Voltage peak (KVp)

Linear No-Threshold (LNT)

Lifetime Attributable Risk (LAR)

Lower Limp Angiogram (LLA)

Male (M)

milliAmpiresecond (mAs)

milli-Gray (mGy)

milli-Gray. Centimeter (mGy.cm)

millimeter (mm)

milliSievert (mSv)

Ministry of Health (MoH)

National Council on Radiation Protection (NCRP)

National Lung Screening Trial (NLST)

Normalized coefficients (“K” factor)

Organ-Specific Dose Reduction (OSDR)

Palestine Medical Complex (P.M.C).

Picture Archiving and Communication System (PACS)

Pulmonary EmbolismAngiogram (PEA)

Rafedia Surgical Hospital (R.S.H)

Slice thickness (T)

United Kingdom (UK)

Untited Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)

United States of America (USA)

Ventilation–perfusion (V/Q)

without contrast (WOT).

Chapter One: Introduction

This chapter gives the background, problem statement, justification, study aim or objectiveshypothesis and research question.

1.1Historical Background

X-ray was discovered in late-1895 by Wilhelm Conrad Röntgen, which is used in computed tomography (CT) scanners with ionizing energy of 40-140 Kev which is high enough to penetrate the patient's body and produce diagnostic images without invasive and interventional procedures(Mould & Richard, 1995).

CT machine developedby Godfrey Hounsfield and Allen Cormack, who succeeded to make a cross-sectional image of the brain in 1972(Mould & Richard, 1995). In early1990s the first helical CT scanners were used with a special technique called slip-ring with single-row detector that is based on moving the patient into the scanner while the tube/detector array gantry rotate continuously to produce a single image per rotation. This drawback was overcome in 1990s with multiple rows of detectors and suitable workstation which produce many images in a single helical rotation. The improvement was in smaller scan time, improve Z-axis resolutionand scanning longerparts of the body.The fast development CT scannercomprises: 4-row detector CT scanner was invented in 2000. After that, 8-row scanners were in a state of art in 2001. By 2003, 16-row scanners were used. Nowadays, 32- and 40-row scanners are introduced,finally,64,128 and 256 row detector scanners. These fast scanners helped by replacing the complex and invasive catheter-based angiography procedure with computed tomography angiography procedure by using intravenous contrast with acceptable volumes injected into the patient(Dolmatch, 2005).However, the improvement in temporal (165–175 ms) and isotropic spatial resolution (0.3–0.4 mm) of image quality which allows three dimensional images, also the reduction of image acquisition time, that allow angiographic procedures associated with higher patient doses(Sun, Choo, & Ng, 2012). Thus, affecting relative risk from exposure to ionizing radiation.

Due to the fast improvement in scanning technique which results in high diagnostic resolution accuracy and speed,the number of CTA scans procedures are getting larger, for example,in United

States, it increased from 64,846 to 1,709,088 between 2001 and 2014. (Prabhakar, Misono, Hemingway, Hughes, & Duszak Jr, 2016). This growth gives rise to certain concerns about higher absorbed dose of organs. For Instance, it has been documented that the maximumorgan dose of a group of CT scans for a single disease ranges from about 5 to 100 mSv (Hall & Brenner, 2008); these differences in readings because of different types of scans, machine variability, also patient age and size variability (Hall & Brenner, 2008; Stern, Kaczmarek, Spelic, & Suleiman, 2001). In this dose range (5–100 mSv), there are potential risks related to CT scans as the International Commission on Radiological Protection (ICRP) commented that: ‘‘The absorbed dose to tissue from CT can often approach or exceed the levels known to increase the probability of cancer’’(ICRP, 2001).

Since the X-ray beam cause ionization to irradiated cells and any mis repaircould lead to DNA damage and mutations, this may grow to form tumors (Berrington de Gonzalez, Pasqual, & Veiga, 2021). Therefore, the resulting absorbed dose from CT examinations became a global health issue.

CT-procedures dose assessment and optimization was published such as Diagnostic Reference Levels (DRLs) and specific European Guidelines (Muhogora et al., 2009).Theregulation goals to guarantee acceptable ranges of all CT doses. Furthermore, these regulations permitthe estimation possibility of stochastic and deterministic effects of radiation exposure by using the effective Dose (ED: describe the amount of radiation received, the magnitude of ED is related to the stochastic radiation risks of cancer induction and the production of genetic effects(ICRP, 1990; ICRP, 1977).it is considered as a CT-dose descriptor, and as a report of the potential cancer risk(Ghilea & Vasilescu, 1996).

There is a huge focus worldwide from researchers about the relationship between patient’s absorbed dose and biological cancer risks. In this study, radiation doses to patients from CTA procedures such as: lower limp angiogram (LLA), pulmonary embolism angiogram (PEA), head neck angiogram (HNA)is estimated using equations. The aim is to gather detailed knowledge of radiation exposure from CT examinations, including CTA scans, so that it is essential for radiology healthcare professionals to calculate the effective dose and radiation risks of malignancyof adult patients with ages above years. Moreover, provide more awareness about CT-overdose for radiologist and radiographers and other related medical staff.

1.2Problem statement

According to health annual report of ministry of health (MoH) in Palestine, the number of diagnostic radiographs conducted in the hospitals of MoH in Palestine was 643,324 including 66,096 CT approximately 10.3% of total scanswhich is higher than ultrasound and magnetic resonance imaging by (MoH,2017).The increasing use of CT scan was also reported in United States of approximately 13% of total scans(Foley, McEntee, & Rainford, 2012). ICRP has reported that radiation exposure of CT scans is more significant according to other diagnostic imaging modalities so that there aremore concerns about the use of this modality.

Computing Tomography Angiography (CTA) is an important tool for the diagnosis of vascular disease with a sensitivity and specificity of 95% and 93%, respectively(Sun et al., 2012). However, angiographic procedures performed with large anatomic volume and of thinner slices associated with higher patient doses. As International commission of radiation protection (ICRP) reported that there is a linear non-threshold relation between low dose radiation exposure and an increased incidence of malignancy(D. J. Brenner & E. J. Hall, 2007). This gives rise to even bigger concerns about CTA procedures because of its higher doses and its related radiogenic risk to the patients.

Pulmonary angiography (PA) has high accuracy of detecting pulmonary embolism in arteries. Although, it has been reported that this procedure results in effective dose of more than 10 mSv, in which epidemiological data suggest itcould give rise to induced malignancy(Sauter et al., 2019). In addition, effective dose of HNA was reported to be 11 mSv (Manuel, Eleftheoris, Emeka, Karl, & Mechial, 2008), finally lower limp angiograph (LLA) has reported to be 12.2 mSv which is even larger than PA and HNA(Catalano et al., 2004). Available data for radiation-induced cancers suggest that 1 mSv of radiation exposure may lead to five additional cancers in 100,000 exposed patients (ICRP, 1991).

For all CTAhelical scans included in the study bolustracking technique with the regionof interest -placed in the pulmonary trunkfor PEA protocol, ascending aorta in HNA protocol and in in aortic lumen (celiac axis level) for LLA protocol- to monitor changes in region of interest (ROI) to reach the threshold of contrast enhancement level (usually a 100– 150 HU value), there is automatic triggering of the scanner to acquire images in the desired scan range.

Scanning parameters such as kVp, mAs, pitch, scan length and slice thickness plays an important role in patients radiation dose.For example, Qi et al. (2014)in LLA study, showed thata reduction of 80% of patients' dose values by lowering the tube potentialto 70 kVp and increasing pitch value to 2.2 compared to the standard value of 120 kVp and 0.85 pitch value. Another study for LLA by Fraioli et al. (2006)showed that there is a reduction of 74% of patient dose when lowering of mAs setting from 130 to 50.

The effect of the scan length on patient radiation dose is established in PEA protocol study by Harun, AbdulKarim, Abd Rahman, et al. (2020). a body leghth of 14-19cm will produce 6.13 mGy CTDIvol and a body length of 24-31cm will produce a 21.4mGy CTDIvol, for an averege length patients (19-24)cm the CTDIvol will be 8.35mGy. so that any increase in scan length will affect patient radiation dose.

Moreover, slice thickness would be increased or decreased according to the protocol used and if small details were under investigation. And it is directly proportional to radiation dose to the patient.

1.3Justification

There wereinternational studiesthathave been conducted, which focused on patient radiation during several CTA procedures. Most studies focus on coronary artery angiography (Bischoff et al., 2010; Hollingsworth et al., 2007; Rixe et al., 2009; Sabarudin & Sun, 2013; Stocker et al., 2018; Sun et al., 2012), lower limp angiography(Saltybaeva, Jafari, Hupfer, & Kalender, 2014), pulmonary embolism(Watson et al., 2013) and abdominal aorta (Nijhof et al., 2016). There was a large variation in patient radiation dose. Furthermore, it has been reported that patient effective doses during CTA procedures range between 2.2 and 24.4 mSv (Mafalanka, Etard, Rehel, Pesenti-Rossi, et al., 2015). In addition, there is limited data about other CTA scans available worldwide regarding patient effective doses and their cancer risk. hence, it is important to evaluate patient doses during CTA procedures to justify and optimize the procedure and balance the benefit against radiation risk.

To our knowledge, this it is the firststudy that assesses radiation dose from CTA scans in Palestine.

1.4Study Goal

To achieve the LLA, PEA, HNA protocols in governmental hospitals in the Palestine with reasonable radiation dose compared to globally used ones.

1.5 Study Objectives

1.5.1 General objective:

To estimate the radiation effective dose and cancer risk to adult patients above 18 years undergoing CTA procedures includes: LLA, PA, HNA

1.5.2 Specific objectives:

1) Evaluation of the effective dose from CTA scans including: with and without contrast media if available.

2) Estimation of the cancer risk of the radiosensitive organs and overall cancer risk.

3) To assess collective average effective dose from LLA, PEA, HNA CT scans per hospital.

4) To compare total effective dose between included CT scanner models.

Chapter Two: Literature Review

This chapter includes areview aboutpublished literatures and scientific research on CT-dose assessment and related risk, and shows variousmethods that were used to determine effective dose and associated cancer risk.

2.1Introduction

There are two central risks related to computed tomography angiography (CTA), contrast allergy and cancer risk associated to radiation exposure during scanning procedure (Parker et al., 2005; Singh & Daftary, 2008). The former will not be included in this study.

Ionizing radiation have the potential to kill the cell by apoptosis or it may produce reproductive failure, that couldprogressinto alteration in the genes which is responsible of cell growth regulation, then degradation of DNA, and formation of a tumor occurs(Shah, Sachs, & Wilson, 2012).Also, hereditary effect may occur after exposing to radiation in future generations.At high dose exposure at specific threshold atissue reaction effect occurs(ICRP, 2007a). ICRP determine nominal radiation detriment coefficients for cancer and hereditary effects as follows: $5.5\times 10^{-2}$and $0.2 \times 10^{-2}\mathrm{Sv}^{-1}$for the whole population (ICRP, 2007a). Moreover, effective dose (E) was developed by ICRP and NCRP recommends using it as a tool for managing radiogenic cancer risk to the entire population (ICRP,2007).

Both the NCRP and ICRP use the linear no-threshold (LNT) model based on effective dose as an appropriate tool for estimating radiation risks to populations to assign dose limits for big groups. For example, radiation workers and total population.

Generally, exposure from CT scan is greater than plane x ray radiography. The acquisition of CT image requires about 800–1400 x-ray exposures around the patient compared to that used in a single plain x ray.So that, the CT dose is greatly larger approximately 100–400 times(Mayo & Thakur, 2013).

As a result, there is a large interest of cancer risk induced by CT scan globally. For example, study conducted in Boston by Jenny et al., 2014 about malignancy risk associated with head and neck

CT scan for children, the results showed that there is one excess brain tumor happened after 4000 brain CTs (40 mSv per scan).

Moreover, there is a study focused on the benefits and harms of lung CT screening of cancer, the results predicted that 1 cancer death resultsfrom radiation per 2,500 people screened with the National Lung Screening Trial (NLST)in united states protocol(Bach et al., 2012).Another study of lung screening based on a retrospective analysis calculated a risk of 0.05% of having a cancer after 10 years of screening with CT(Rampinelli, De Marco, & Bellomi, 2017).

Although there is internationally interest in CT cancer risk, there is no sufficient knowledge and awareness about radiation dose and its risk by public people and health physicians. For example, there is a study conducted in united states about assessment of patient, Physician, and radiologist awareness of radiation dose and possible risks. The patients were given a consent formand asked if they have been told about risks and benefits of the CT scan, also they were asked to calculate CT-dose and comparedto plain chest X-ray radiation dose(Lee, Haims, Monico, Brink, & Forman, 2004).

The results were as follow, the knowledge of CT-dose raised cancer-lifetime riskwas only 3% of patients and 9% of physician. unexpectedly, the correct answer was given by radiologists with only 47%.Moreover, in estimation of CT dose compared to plain chest X-ray, the results were 64% of patients, 44% of physician, and 56% of radiologists who chose 2-10times answer from five options. By contrast, in fact, CT-dose is nearly 100-250 times more than a chest X-ra-y dose. The correct answers were chosen by only 22% of the physicians and 13% of radiologists. Furthermore, 78% of the physicians had notinterpreted CT scan risks and benefits to patients and approximately 93% of patients answered that CT scans' risks and benefits had not been informed to them previously (Lee et al., 2004). The lack of knowledge was also noted in several other studies in different countriesincluding:Turky(Günalp et al., 2014; Yurt, Çavuşoğlu, & Günay, 2014), Romania(Mihai, Milu, Voicu, & Enachescu, 2005), Canada (Thomas et al., 2006), Nigeria (Eze, Abonyi, Njoku, Irurhe, & Olowu, 2013).

2.2 Previous studies

2.2.1 Local and regional studies:

There is no previous study conducted in Palestine talked about estimation of radiation dose of CTA scans. There are two studies generally investigate the knowledge and awareness of radiological examinations potential hazards in Palestine, the first one wasamong Palestinian physicians. Interestingly, the results of the questionnairewereonly 6.1% of participants could identify the ALARA principle and a huge percentage of (98.2%) of participants have no previous knowledge that there is no safe dose limit according to international recommendations(A Hamarsheh & Ahmead, 2012). The second study further investigated the knowledge of 94.4% of Palestinian radiation technologists were asked about ALARA principle and hormesis hypothesis, the associated risks of radiological examinations and radiation hazards. The results indicated that there is a serious lack of knowledge of 26.4% who answered correctly(A Hamarsheh & Amro, 2017).

From these results it is highly recommended to further investigate the radiation dose from CTA procedures to increase the awareness health workers and general public of health risks associated of CTA scans.

There are some local studies that investigated effective dose from chest, abdomen, abdomen pelvis CT scans. In chest CT scan author's study radiation dose of female breast and associated cancer risk. The results indicate different radiation effective doses from different hospitals to the same exam (3-14.7mSv, mean 7 mSv), based on protocol parameters that were used and the type of scanner. Lifetime attributable risk (LAR) of breast cancer was calculated for younger females (15–29 years) and it was 0.05%. Moreover, for older female patients (60–79 years), the LAR value was 0.001%. these values were generally low and harmonious with other studies reported worldwide. (Lahham, ALMasri, & Kameel, 2017).

Another study conducted byLahham and ALMasri (2018),which estimated radiation doses from abdominal CT scan. The organs under investigation were liver, stomach and colon. The calculated average organ doses by Virtual dose software were 13.1, 1.7, 13.2 mGy respectively. Moreover, the calculated effective dose ranged between 2-10 mSv (mean: 5.5 mSv). These results are considered low and matched with other international studies.

Furthermore, in abdomen pelvis CT scan study conducted by ALMasri and Inayyem (2021), a web-based Monte Carlo CT dose calculator- WAZA-ARI dosimetry system was used to calculate organ and effective doses. The organ in this search was colon (average 5.4-26.1 mGy, mean: 14 mGy. In addition, thecalculated effective dose from abdominopelvic CT scan per examination on average was 4.8 mSv (ranged 2.04 to 8.4 mSv). The authors emphasis that is important to improve radiographers' knowledge of radiation dose in CT protocols.

ALMasri et al. (2010) reported in a study entitled "Assessment of Effective Dose from Brain CT" that effective dose statistical difference of Philips and GE CT scan was not significant (1.43 and 2.12) mSv, respectively.

These studies focus only on routine scans without expatiate to CTA angiography dose assessment. So that, it is important to expand to other branches of CT procedures. including computing tomography angiography, such as pulmonary angiography (PA), head and neck angiography (HNA), and lower limp angiography (LLA).

2.2.2 International studies:

Accurate diagnosis has been improved in cardiovascular system disorders by using CTA procedures compared to other imaging modalities(D. Brenner & E. Hall, 2007; Willinsky et al., 2003),which leads to improved health care provided to patients. However, according to ICRP (2007) report,CT procedures may cause radiogenic risk because of the high radiation dose used in image acquisition, that depends on age, gender, and health status. Moreover, some studies have reported thehigher possibilities of cancer after exposure to diagnostic radiological procedures(Myles et al., 2008). Furthermore, Brenner (2004)calculations states that if 600000 children were scannedwith abdomen and head (CT) annually in the United States, then 500 patients may eventually die from cancer caused by radiation. Also,Arslanoglu et al. (2007) stated that in the United Kingdom (UK), approximately 250 people pass away annually as a result of cancer associated to medical radiation exposure.

A studyin France, focusing on patient radiation dose during cardiac CTA procedure using 64-320 detectors.reportedthe need for dose optimization and the need of diagnostic reference levels (DRL) due to the large variability between(26-44) mGy for CTDIvol, and (370-970) mGy cm for DLP, respectively(Mafalanka, Etard, Rehel, Pesenti, et al., 2015). Furthermore, Pernas et al. (2014) focused on dose calculation of lower limp angiogram (LLA) for 60Spain patients using 64 slice Siemens Medical CT scan with two different protocols (100 kv and 80 kv).The results show a significant difference in radiation dose with DLP (570.1 mGy cm ± 131.5 vs 278.6 mGy cm ± 64.9), and in the effective radiation dose (ERD) (9.6 mSv ± 2.2 vs 4.7 mSv ± 1.1). There was no effect of low dose on image quality.

Qi et al. (2014) used different protocols of LLA to 44 Chinese patients: 22 patients of protocol A with a first-generation dual-source CT (120 kVp, pitch of 0.85 and 120 ml of contrast agent) and 22 patients of protocol B with second-generation dual-source CT (70 kVp, pitch of 2.2 and 80 ml of contrast). The results show that protocol B causes 81.3% radiation dose reduction (ED,DLP, CTDIvol of group A 1.6±0.7 mSv, 434.5±164.1 mGy.cm, 4.0±1.4 mGy respectively VS group B 0.3±0.1 mSv, 83.7±7.4 mGy.cm, 0.7±0.1 mGy respectively). This reduction of patient dose results in image noise which is overcomed by using special algorithm called SAFIRE algorithm. However, in a Saudi study conducted by Alkhorayef et al. (2017)with 64 slice Toshiba CT scan

had a higher results of ED, DLP, CTDIvol (3.9 ± 1.4(3.2–8.0) mSv, 437.8 ± 166 (357.0–884.0) mGy.cm, 3.9 ± 1.4(3.2–8.0) mGy respectively.

However, when using a standard dose settings as reported by Rubin, Schmidt, Logan, and Sofilos (2001) in four channel detector row CT scanofLLA studywith a 120 kV and a 300 mAs, the scan results in a radiation exposure of 12.97 mGy and an effective dose of 9.3 mSv. In modern CT scans an option calledautomated tube current modulation that helps in significant dose savings. Fraioli et al. (2006) conducted a peripheral MDCTA study with different mAs setting(50, 100 and 130) in three groups of patients and the results were compared with gold standard digital subtraction angiography(DSA). It indicated that there were similar sensitivity and specificity in diagnoses with MDCTA performed at the three mAs settings. The 50 mAs allowed 74% reduction of the effective dose with optimal image quality and diagnostic accuracy. Moreover, Willmann et al. (2005) compared effective dose of DSA with LLA with a 16-detector Siemens CT scanner and determined a lower values of mean effective radiation dose 3.0 mSv in men and 2.3 mSv in women for MDCTA compared to 11 mSv (range, 6.4–16.0 mSv) for both sexes for DSA.

The last study conducted about LLA were in Sudan by Rasha Jaafar a et al. (2021) about estimation of patient's doses and cancer risk in vascular lower limb computed tomography (CT). The study included three hospitals with three CT scanners: 160,128,64 slices. CT dose estimation software CT-Expowas used to calculate the effective dose. The average and range of DLP (mGy.cm) values were 3711.5 (279.1–8374.4) and 3283.9 (1200.3–3839) and 3203.44 (2848.1–5292) for hospitals A, B and C, respectively. Volume CT dose index (CTDIvol (mGy) were 7.3 (2.9–16.8), 8.81 (2.3–22.9) and 8.01 (5.1–17.2),respectively. The average effective doses (mSv) per vascular CT procedure were 16.3, 12.5 and 19.2 for hospitals A, B and C, respectively.The overall average and range CTDIvol (mGy) and DLP (mGy.cm) 7.3 (2.3–22.9), and 3000 (279.1–8374.4) respectively. In addition, the overall effective dose was 18 mSv per procedure,which is higher than DRL values that is 9 mGy (CTDIvol) and 2500 mGy cm (DLP) per vascular lower limb CT procedure. Finally, the study calculated risk of cancer from LLA procedures which ranges from 1 in 1000 to 1 in 3000 procedures.

PEA procedure is a very important technique to roll out pulmonary embolism (PE) which is associated with high mortality rate. PEA can detect around 90% of PE conditions (Sauter et al., 2019). However, according to(Astani, Davis, Harkness, Supanich, & Dalal, 2014; Sauter et al.,

2019; Takahashi & Yoon, 2013)a single PEAscancouldproduce 10.7 mSv of effective dose thatcontribute to a high possibility of the risk of radiation-induced cancer to populations.

As reported byDiederich and Lenzen (2000), PEA and chest CT scan have the same dose rate 2.0–4.0 rad (20–40 mGy). Generally, in chest CT scan, the average-sized woman receivesa radiation dose of 2.0–5.0 rad (20–50 mGy) to breasts tissue. This dose could beapproximated to 10–25 twoview mammograms and equivalent to 100–400 chest radiographs (McCollough & Zink, 1999)

There were some attempts to reduce radiation exposure caused by PEA CT scan. For example, Stein et al. (2010) put an imaging protocol to emergency department patients with suspected PE between 2006-2007. The protocol stated thatif the chest radiograph was normal, ventilation–perfusion (V/Q) scan is recommended, otherwise PEA CT scan is recommended. This attempt reduced ED approximately 20%,from 8.0 mSv in 2006 to 6.4 mSv in 2007.

A study conducted in Malysia by (Harun, Abdul Karim, Abbas, et al., 2020)entitled" Association of Radiation Doses and Cancer Risks from CT Pulmonary Angiography Examinations in Relation to Body Diameter',organ dose for breast (women only), lung, and liver was calculated by CT-EXPO software. The results were 17.05 ± 10.40, 17.55 ± 10.86, and 15.04 ± 9.75 mSv, respectively. In addition, CTDIvol, DLP, and effective dose mean values were 11.06 ± 7.1 mGy, 400.38 ± 259.10 mGy.cm, and 8.68 ± 5.47 mSv respectively. The author indicated that using automated tube current modulation will producea higher tube current for patients with large body diameter and this led to significant differences in organ doses and their cancer risk. Moreover,breast absorbed organ dose in total was the highest, causing 94 future cancer risks per million procedures.A study bySun and Lei (2017)reported that included 450 patients included CTDIvol, DLP, and effective dose mean values were lower than Harun et al as follow 8.5±9.4 mGy, 327.5±402.2 mGy.cm, 4.5±5.6mSv respectively. Another study conducted by Mark et al. (2005) also showed a high absorbed dose to average size female breast tissue (2.0 rad (20 mGy) this greatly surpasses the American College of Radiology recommendation of ≤ 0.300 rad (3 mGy) or less for standard two-view mammography. The author encourages scanning with lower radiation and another alternative non ionizing diagnosis methods.

Interestingly, Lukas et al. (2019) compares the effective dose associated with PEA scan between second and third generation dual-source CT (DSCT) Siemens systems acquired in single- and dual-energy mode. The results showed that there is no significant difference. Although, the third-

generation system had a lower effective dose each in single and dual energy mode (1.5 mSv ± 0.8 mSv) and (1.4 mSv ± 0.7 mSv) respectively compared to second-generation system (single: 2.5 mSv ± 0.9 mSv) and (dual: 2.3 mSv ± 0.6 mSv).

On the other hand,Jan, Jacob, Niels, Wouter, and Peter (2003)compared ED between PEA Siemens CT scan in 27 patients and DSA scan using a Philips Integris V-3000 system for 12 patients. The authors used standard protocol and the result was 4.2 mSv (range 2.2–6.0 mSv) for PEA CT scan and of 7.1 mSv (range 3.3–17.3 mSv) for DSA.

Andreas et al. (2016) compared ED of three algorithm for scannin 16 patientshow were scanned with low dose data sets and the data was reconstructed by new iterative reconstruction algorithm, the first-generation iterative reconstruction algorithm iDose and the standard reconstruction algorithm “filtered back projection” (FBP) using 256-slice multidetector CT Brilliance iCT.

FBP registered the highest ED between them (3.57 mSv) then 0.89mSv for iDose and the lower effective dose was 0.45 mSv for iterative reconstruction algorithm. These results were performed by simulated minimum dose level from the original data that provided acceptable diagnostic performance. Andreas et al. (2016) indicated that IMR could achieve a dose reduction up to 75% with an excellent diagnostic confidence and a mean effective dose of 0.9 mSv.

While Guang et al. (2014) used iterative reconstruction with 80 kVp, high pitch (2.2) and 20 ml of contrast media and compared the results with the old method (100 kVp, 1.2 pitch, 60 ml of contrast). The results showed no significant difference of diagnostic accuracy. But there is around 50.3% of dose reduction from the old method and a less than 1 mSv of effective dose. However, this new protocol as the author indicated is only feasible at 80 kVp using only 20 ml of contrast agent also in normal-weight individuals.

By 2020, a study conducted by (Dino, Marcus, & Anetta) to investigate radiation dose for pregnant patients’ and their fetus who undergo PEA CT scan with shielding and reducing scanning time.The results indicated that the shield increase both the effective dose to pregnant patient approximately 47% (2.8 with shield vs 1.9 mSv without shield) also fetus absorbed dose was increased 0.12 mGy with shield from without shield 0.1 mGy. This increase was based on automatic exposure control. However, reducing scan time with shielding only affect absorbed dose to fetus and reduce it from 0.03 to 0.02 mGy.

In case of head and neck angiogram dose assessment, the effective doses, absorbed dose, and organ dose for CTA scan were previously reported(Wei-lan et all., 2013). There were a range of variability due to the insufficiency of dependable conversion factors for angiographic examinations. Moreover, the effective dose of CTA is robustly reliable on the CT scanner type and the protocol parameters used in the scan. For example, mAs, kvp, the scan length. This issue complicates the rapprochement between the several imaging methods.

In (2012),Manninen et al. conducted a study in whichthe effective dose was compared between diagnostic CTA 64-row multidetector scanner and DSA using anthropomorphic phantom for both cerebral and cervicocerebral vessels starting from e aortic arch to the vertex. The results showed that effective dose of CTA of head and neck is around one-third higher than DSA (4.85 mSv for CTA and 3.60 mSv for DSA). However, the absorbed dose for skin, brain, salivary glands, and eyes was lower in CTA as the following 19, 16.9, 20.4, and 14.8 mGy, respectively. A lower value of effective dosewas reported by Cohnen et al. (2006) that ranged from 1.7 to 2.8 mSv due to a shorter scan length and a smaller mAs setting. anthropomorphic phantoms were used to measure brain, eyelenses and thyroid organ doses which were (22.2, 5.4,1.1) mGyrespectively.Mnyusiwalla, Aviv, and Symons (2009) used the same scan length as Manninen et al. although the Kvp was higher and the calculation was based on predetermined conversion factors. So that, effective dose was different with a mean effective dose of 5.4±2.2 mSv and a mean DLP of 1,565.4±647.5 mGy·cm. Klingebiel et al. (2008)also reported an effective dose of in closer values2.2– 4.3 mSv for head and neck angiogramscanwith 4- to 64-slice CT scanners.

There was an effort to reduce radiation dose to patients undergoing head and neck angiogram,such as Chen et al. (2017) attempts in a study were he compared the results with the standard protocol. It showed that the new protocol could give a good image with an acceptable quality and a 56% dose reduction from(0.92 ± 0.08) mSv to0.40 ± 0.03 mSv.

A similar attempt had been published by GuanGminG et al. (2018) with additional use of dual-energy spectral CT using rapid kV-switching technique and he compared it with the traditional technique. The results indicated that there is no significant difference in image quality but there is a great reduction in effective dose about 57% lower than traditional protocol (2.64 mSv VS 6.18 mSv).In addition, Schimmöller et al. (2013) used a special algorithm that reduce exposure up to 56% to radiosensitive organs in head and neck angiogram procedures and it called organ-specific

dose reduction (OSDR). The results of the study showed no significant differences of image quality and diagnosis findings between traditional protocol and images reconstructed by OSHDR algorithm. But there was a difference in CTDIvol and DLP (26.9±1.5 mGy and 1,000.7± 107.7 mGy.cm (without OSDR) VS 27.7± 2.0 mGy and 1,022.4±98.7 mGy.cm (with OSDR). As the author described the algorithm principle, it decreases the mAs setting 20% for the first 120° tube anterior projections then it increases mAs setting for the posterior 240° of projections. This help to reduce exposure to the anterior radiosensitive organs. Wei-lan et al. (2013) used iterative reconstruction algorithm techniques with some modification on Kvp (from 120 to 80 kvp) setting and iodine concentration (320 to f 270 mgI/ml). Image quality and vascular visualization had no significant difference. However, there were a dose reduction around 50%. Mean overall CTDI (3.9 mGy vs 7.8 mGy) and the DLP (189.5 mGycm vs 379 mGycm).

Interestingly, Deipolyi et al. investigated diagnostic benefit of scanning a patient with suspected stroke from arch-to-vertex CTA scan. Surprisingly, the diagnostic finding was only 1% in the chest region which means it did not contribute meaningfully to patients with stroke. The author stated that by shortening the scan length from above shoulder to the vertex this could reduce effective doe by 50%.

Chapter Three: Methodology

This chapter provides conceptual and experimental frameworks of the study, from data collection, to the calculations of effective dose and assessment of cancer risk, data analysis and comparison.

3.1 Introduction

This study aims to assess the value of the effective dose and the cancer risk incidence per 100000 procedures from CTA procedures including: (LLA), (PEA) and (HNA). Required data was taken from CT scan registries in radiological departments included in the study from the chosen governmental hospitals in Palestine. These scans were carried out within twoyears period from 2019-2020 and the data were collected from PACS system within two months.

3.2Conceptual framework

3.2.1 Independent Variables:

Independent Variables of this study include:

a. Patient's examination data:

Include Kilo-Voltage peak (kVp), milliAmpere-seconds (mAs), slice thickness (T), Dose Length Product (DLP), CT dose index volume (CTDIvol)and pitch value.

b. Socio-demographic factors:

- Gender (Male / Female).
- Age above 18 years old.

3.2.2 Dependent Variables:

a. Average ED for all hospitals included in the study.
b. cancer risk incidence per 100000 procedures.

3.3CT dose

The value of effective dose estimated in CT scans basically depends on radiation exposure factors that include kVp, mAs, CTDIvol, DLP, and Pitch values.

3.3.1 Kilo-Voltage peak (kVp):

It is the X-ray photons energy. kVp value directly proportion with radiation absorbed dose during CT examination, which means increasing in effective dose value.

3.3.2 milliAmpere-seconds (mAs):

Is the x-ray tube current milliAmpere (mA) multiplied by the scan time (s), which represents the amount of X-ray radiation that pass through the tube during the scan time, the relationship between mAs and patient absorbed dose is directly proportional in which a 50% reduction of mAs value will be associated with 50% reduction of the radiation dose.

$$\text{milliAmpereseconds (mAs)} = \text{tube current(mA) X exposure time (s)} \quad \text{.....(1)}$$

3.3.3 Pitch Ratio (P):

Estimated by the table movement (increment distance) per on full rotation of the X-ray tube divided by the width of the X-ray beam. There is a reverse relationship between the Pitch value and the patient dose, so increasing pitch leads to a decrease in patient dose, and vice versa.

3.3.4 Computed Tomography Dose Index volume (CTDIvol):

CTDIvol measured in milliGray (mGy), is an estimation of the mount of radiation dose during the CT scan volume in a standardized phantom (16cm or 32cm) by using 100-mm-long pencil-shaped ionization chamber. Total amount of delivered radiation to a standardized phantom is equal Dose Length Product (DLP) value, which is represented by CTDIvol and scan length.

3.3.5 Dose Length Product (DLP):

It represents the amount of radiation used in the scan and it is directly proportional to the patient's ED. It is also used in the effective dose estimation by multiplying the DLP yields to k factor. In some of CT scanners, the DLP and CTDIvol values appear for each CT examinations. DLP represents the whole energy amount that is delivered by a given CT examination:

$$\text{DLP (mGy. cm)} = \text{CTDIv (mGy) X Scan Length (cm)} \quad \text{.....} \quad (2)$$

DLP depends on the converge imaged area length of the patient body during CT scan, so that any increase in DLP directly means increase in the effective dose value.

3.4Settings

The study was conducted at chosen governmental hospitals that have modern CT-unit that are capable to perform angiogram procedures in Palestine. Governmental hospitals include Rafedia surgical hospital-Nablus, beit Jalla hospital- Bethlehem, and Palestinian medical complex hospital-Ramallah. They have the largest load on CT-examinations, and has become the main source of angiographic CT examinations. Results is compared between the three hospitals and an investigation about the reasons for the differences in ED. Finally, cancer risk is calculated.

3.5Research design

Quantitative retrospective cohort study was chosen to fulfill the aim of the study. Data was obtained from PACS system of the chosen governmental and hospitals in Palestine within 2019-2020 years and the data were collected within two months.

3.6Study Population

Study population includes all adult patients with ages above>18 because the included scanning protocols was found in this age range, who undergone computed tomography angiography procedures including: lower limp angiogram (LLA), Pulmonary angiography (PEA) and head and neck angiogram (HNA) examinations.

3.7Study Sample

Multistage sampling methodology was adopted. Palestinehave multiple governmental hospitals in each region such as Tubas, Qalqylia, Jenin, Nablus, Salfit Jerusalem, Ramallah, Jericho, Hebron and Bethlehem. One major Hospital was selected in each region (one governmental hospital) which represents the second stage. Then, all adult patient files that are in the inclusion criteria and undergone computed tomography angiography procedures including: (LLA), (PEA) and (HNA) examinations, between 2019-2020 in the selected Hospital, were included in the study. The chosen Hospital were:Rafedia surgical Hospital was chosen because it receives the greatest number of patients transfers to scan in Rafedia Hospital such as Tubas Hospital, Al-watani hospital. Moreover, JeninHospital does not provide the angiogram service. The second Hospital was Palestine Medical Complex (Governmental hospital). Finally Bait-Jalla Hospital.

3.7.1 Inclusion criteria:

All adult patients ranging above 18 years who underwent computed tomography angiography procedures including: (LLA), (PEA) and (HNA) examinations in the chosen governmental hospitals in Palestine, during two years between 2019-2020, were included.

3.7.2 Exclusion criteria:

Children andpatients with gross abnormalities and those who needed procedures involving special details or additional body parts in CT imaging were excluded.

3.8Study tool

Study tool used to assess effective dose and cancer risk contained two parts:

3.8.1 Patient's data:

Data about Patient's age and sex, slice thickness, and DLP, CTDIv and pitch, were extracted from patients file from the PACS system for each participant in the study.

3.8.2 Global equations:

Global equations were used for radiation dose and cancer risk assessment. Equations were used as a dosimetry tool for quantifying CT doses, and improving patient protection (reduce any attributed risk of overdose). It permits radiation professionals to take very accurate CT images with much more patient safety from any associated risks of overdose.

3.8.3 ICRP report

The International Commission on Radiological Protection was first founded in 1928, the major aim of the Commission's Recommendations is to provide protection of human health from radiation either if it is high dose that overcome threshold value and cause deterministic effects or low dose. In both cases it could results in stochastic effect such as heritable effects and cancer. The basis of the commission's recommendation was made from epidemiological studies, animal experiments at molecular and cellular levels, human experience at Hiroshima and Nagasaki atomic bomb by continuing follow-up of survivors at 1945 (the Life Span Study-LSS). Moreover, it based on three fundamental principles of protection: Justification, optimization of protection and application of dose limits. They also adapted the linear-non-threshold (LNT) as a better practical way to handle the risk from radiation exposure, which is based on is based on the supposition that at doses below about 100 mSv, a given increase in dose will produce a directly proportionate

increase in the probability of incurring cancer or heritable effects attributable to radiation. The Commission sees that the LNT model still the closest approach for radiological protection at low doses and low dose rates (ICRP, 2005d).

The Commission's estimated risks called nominal due to nominal population (female and male) that exposed to radiation, and computed based on averaging age groups and both sexes. the nominal risk coefficients are derived from a combination of epidemiological, animal, and cellular data. The commission used cancer risk reduction of 2 for all cancers (table 3.1). They also developed Nominal cancer risks and tissue weights for 12 organs (skin, ovary, breast, lung, bone, colon, thyroid, bladder, stomach, esophagus, liver and red bone marrow. There is a remainder category for the rest of organs.

Table 3.1: Detriment-adjusted nominal risk coefficients (10^- 2 Sv- 1) for stochastic effect after exposure to low dose rate (ICRP 103, 2007).

Exposed population	Cancer		Heritable effects		Total	
	Present[1]	*Publ. 60*	Present[1]	*Publ. 60*	Present[1]	*Publ. 60*
Whole	5.5	6.0	0.2	1.3	5.7	7.3
Adult	4.1	4.8	0.1	0.8	4.2	5.6

3.9. Data collection

Data were collected from the PACS system of each included Hospital in the study and all adult patients who underwentLLA, PEA, HNA scans in the included hospitals during study period. The data were reinterred to excel spread sheet for more calculation and data analysis to insure the consistency of the data. This stage was performed in three main steps:

3.9.1 Patient's data collection:

Patient's data and factors used for ED and cancer assessment include Patient's sex, age, kVp, mAs, slice thickness, scanning length, and CTDIvol. Data was filled in specified self-designed worksheets in excel software, for more accuracy and consistency.

3.9.2 Comparison between total effective dose between departments:

Three sites were included in the study with the sameCT-scanners modelwere included toestimate EDs and cancer risk during this study. These scanners are installed in three governmental hospitals radiological departments in the in Palestine to know if there is a significant difference of radiation dose between different departments of the same manufacture (Philips) (Table3.2).

Table 3.2:CT scanners included in the study.

hospital	sector	Manufacturer/ Installation year	Scanner model
Rafedia surgical hospital-Nablus	Governmental	Philips medical system, 2019	128 slice
Palestinian medical complex hospital-Ramallah	Governmental	Philips medical system, 2010	64 slice
beit Jalla hospital-Bethlehem	Governmental	Philips medical system, 2010	16 slice

3.9.3 Distribution of CTA scans:

3.9.3.1 Number of selected CTA scans in governmental hospital:

Total study population was distributed in one sector (governmental).It consisted of three hospitals, and the total data that were collected for each scan protocol was for LLA,HNA and PEA 414,77 and 253 respectively, since there were some data have additional non CTA scans thus,they were not included in the study. So that the total number included in the study were 273 (48%), 77 (14%) and 223 (38 %) adult patients respectively (Figure 3.1).

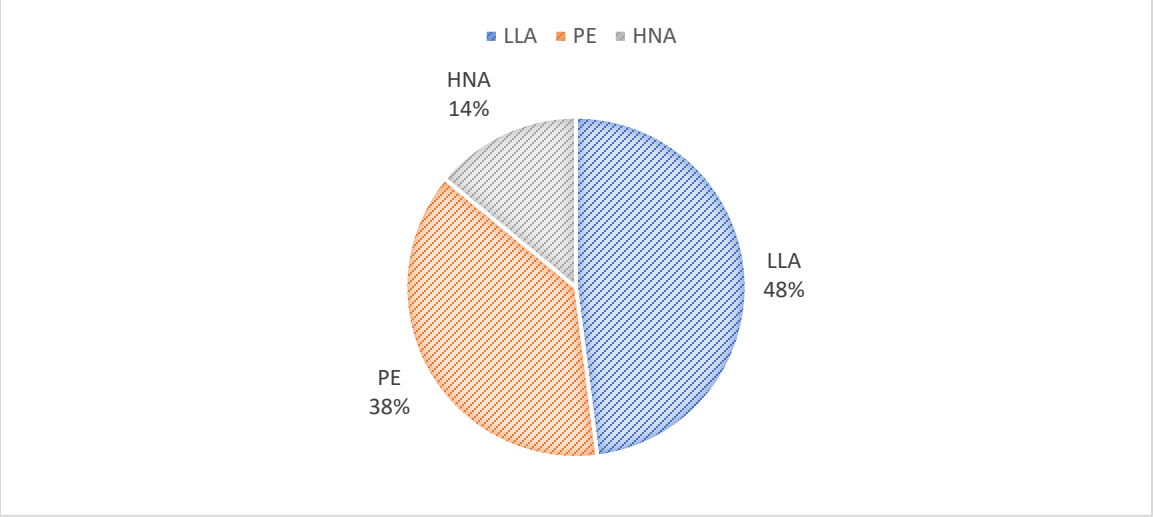

Figure 3.1:Number of selected CTA scans in governmental Hospital

3.9.3.2 Distribution of the CTA scans per hospital:

The distribution of CTA examinations, which were performed at included hospitals for the period of study, is shown in Figure 3.2,3.3,3.4. A total number of 273 adult LLA scan were recorded from the three hospitals CTunit. The highest number of LLA scan was in P.M.CHospital of 199 patients (44%%) of total LLA scans, with 89 male (75%) and 30 female (25%). Then comes 94 patients from Rafedia Hospital (34%), Out of them, 70 male (74%) and 24 female (26%). The lowest number of LLA scan was in B.J.HHospital 60 patient (22%), 45 male patient (75%) and 15 female patient (25%) (Figure3.2).

For PEA scan, the total number of PEA scan was 223 from the three included governmental Hospital. the highest number of scans were in Rafedia Hospital with 100 PEA scan (44.8%) of total PE scans, 45 male patient (45%) and 55 female patient (55%). Then P.M.CHospital with 67 patient (30%), out of them, 25 male (37%) and 42 female (63%). The lowest number of PE scan was in B.J.H 56 patient (25%), 19 male (34%) and 37 female (66%) (Figure3.3).

Finally, for HNA scans, the total number of HNA scan was 78 from the three included governmental hospitals. the highest number of scans were in P.M.CHospital with 33 scan (43%) of total HNA scans, 22 male patient (67%) and 11 female patient (33%). Then B.J.HHospital with 24 patient (30%), out of them, 20 male (83%) and 4 female (17%). The lowest number of HNA scan was in Rafedia Hospital 21 patient (27%), 17 male (81%) and 4 female (19%) (Figure 3.4).

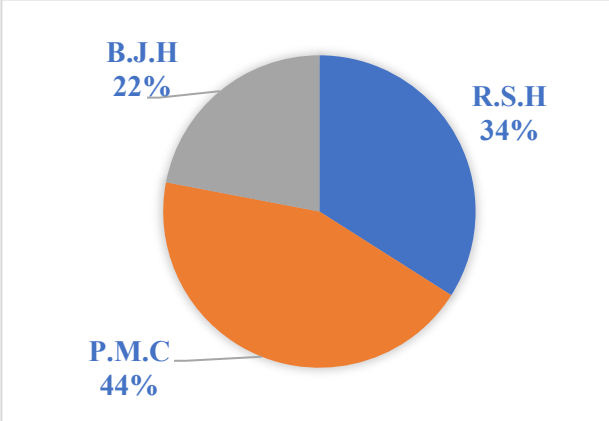

Figure 3.2:Distribution of LLA scans in the selected governmental hospitals.

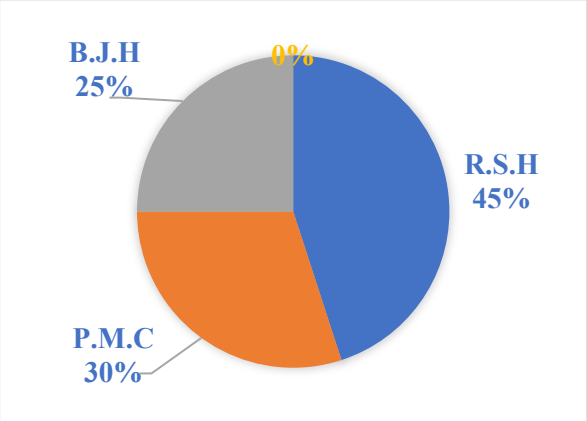

Figure 3.3: Distribution of PEA scans in the selected governmental hospitals

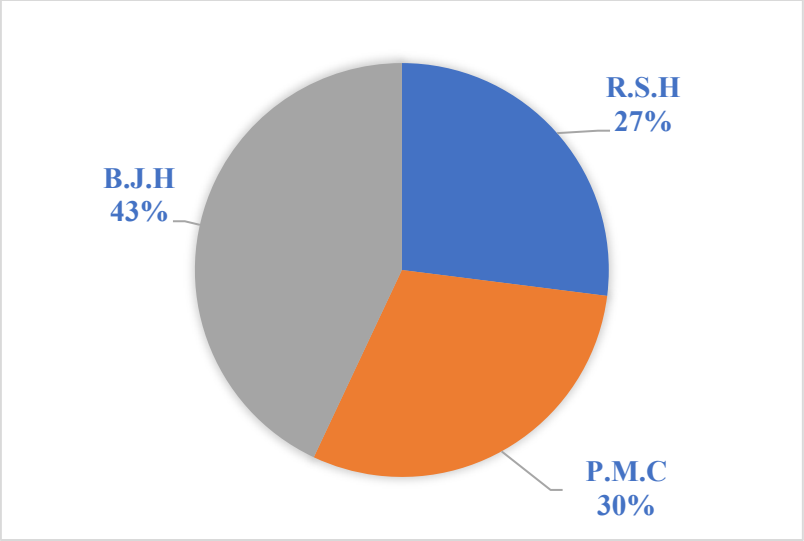

Figure 3.4: Distribution of HNA scans in the selected governmental hospitals

3.9.3.3 number of arteriovenous scans:

There was a large variation in the actual protocol followed by the included hospitals in the study. all patients were scanned in arterial phase. However, a limited number of patients who were scanned with (arteriovenous) and without contrast. First of all, in LLA scan neither of the three hospitals did without contrast scan protocol and the arteriovenous scan was onlydone on 14 patients in P.M.CHospital and 66 patients inR.S.H. Furthermore, in PEA scan, arteriovenous scan done only in one patient in B.J.H and the only Hospital which applicated without contrast scan was R.S.H to only 3 patients. Finally, HNA scan had the largest number of with and without scans in R.S.H7 arteriovenous and 21 without contrast. Then, B.J.H with 10 arteriovenous scans and 13 without contrast. Finally, P.M.C with 7 arteriovenous scans and 11 without contrast scans.In without contrast protocol will be excluded from the study because of the lack of data.

3.9.4 EDs and cancer assessment:

3.9.4.1 Effective dose assessment:

ED was calculated by DLP extracted from CT units for each patient after the scan and appropriate "K" factor (normalized coefficients, the k factor used for PEA and HNA in the study based on ICRP 102 in table A.2. however, for LLA k factor is not available in ICRP and European Commission (EUR) Report, so that, k value was taken from international studies for male and female respectively, that equal LLA (0.006, 0.0073), PEA (0.014), HNA (0.0041, 0.0048) (ICRP 103) mSv/mGy.cm.

$ED = DLP * K\ factor$ …………………………………………………………………………………3

3.9.4.2 overall cancer risk per 100000:

According to the ICRP 103 proposes nominal risk coefficients for lethality-adjusted cancer risk as $5.5 * 10^{-2} \mathrm{Sv}^{-1}$ for the whole population. For heritable effects, the lethality-adjusted nominal risk in the whole population is estimated as $0.2 * 10^{-2} \mathrm{Sv}^{-1}$. These estimates are shown in Table A.4.4 of the ICRP 103 report. The overall cancer risk per 100000 is calculated according to equation 4.

$\text{cancer risk} = \text{nominal risk coefficients} * \text{effective dose}$……………………..………………..4

Moreover, cancer risk for sensitive organs (thyroid,breast,lung,salivary gland,eye lenses, brain, heart, stomach, colon, skin, bone was calculated according to equation (5).

$\text{cancer for specific organ} = \text{equivalent dose} * \text{nominal risk coefficient}$ …………………………5

Were the equivalent dose is calculated according to equation (6).

$\text{equivalent dose} = \text{radiation weighting factor} * \text{absorbed dose}$ …………………………………6

Nominal Risk Coefficient (cases per 100,000 persons per Sv) can be found in table A.4.1 in ICRP 103 (2007) report.

The absorbed dose is calculated by CT-EXPO software version 2.3 which isa Microsoft Excel application used in a visual Basic form to estimate CT dose for patient. The software estimation is based on data that were collected from a German surveyin 1999 and 2002 (Nagel, 2002).CT-Expo V 2.3 provides calculation of the several dose quantities such as: CTDw, CTDIv, DLP, organ dose, and effective dose based on ICRP 60 and 103. This program provides the user some of unique features, such as: all scanner models included in dose calculations for all age groups, and for each gender. It also provides over beaming effects corrections. It also has four calculation mode including: Calculation: used for age- and sex-specific patient dose estimations with selectionof the scan range,standard: provides dose calculations for adult patients only for pre-definedstandard CT examinations; scan range is selected automatically for both genders. Benchmarking: allows calculations for adult only and provide s comparison with the results of the German CT survey. Finally, light: offers calculations of ED and organ dose for adults only as a pre-defined standard CT examination. In this study the scanning protocol is not fully provided so that the light option is used for dose calculation. The drawback for the program that it provides calculations only to

standard body size only (70-80) kg.There were no data about patients' weight in the study so that we suppose they all have standard weight.

The effective dose calculations were used for the following comparisons:

1) Total population dose vs. global average comparison.

To compare total results of ED and overall cancer for total population in this study with previous studies results.

2) Scan Protocol comparisons

To compare EDs and calculated overall cancer risk in LLA, PEA, HNA scanning protocols.

3.10 Statistical analysis

The collected data was used as input to Microsoft Excel version 2007. Anova test was used to compare ED results between the three hospitals (α= 0.05) with POST-HOC-TEST (Bonferroni Correction p value =0.016) and F test (α=0.05) is used to compare the effective dose based on patients'gender.

Chapter Four: Results and Discussion

4.1Results

4.1.1 Parameters for LLA scans for total population:

There are some parameters that influence the values of ED, organ dose and overall cancer risk assessment for total study population (Table 4.1).

Table 4.1: Dosimetry parameters of LLA, PEA, HNA protocols for total population.

Protocol	No. of patients	mAs	kVp	Scan length (cm)	Slice thickness (mm)	CTDIvol (mGy)	DLP (mGy.cm)
LLA	273	120±34	128±20	136±13	3±1	8.54±3.75	1145±460
PEA	223	153±52	120	30±5.6	1± 0.25	12.7±13	375±148
HNA	78	300±44	120±6	38±6	3±1	28±17	1014±514

4.1.2 ED, overall cancer risk per 100000 and Organ dose for total population:

4.1.2.1 Lower limp angiogram LLA:

For the total population, mean effective dose of lower limp CT scan in arterial phase was 7.2±2.9 mSv ranging between 2.8 to11.3 mSv, which is internationally accepted range of LLA for adults. In addition, in venous phase, the mean effective dose of lower limp CT scan was 6 ±2.3 mSv ranging between 2.6to12.2 mSv.

The calculated mean cancer risk per 100000 procedures of LLAscan of arterial phase for total population was 39.7±15.9 ranged between 16.9 to 73.5 cancer risk per 100000 procedure. For venous phase, calculated mean cancer risk per 100000 procedure was 30.9±12.9 ranged between 16.5 to 67.3 cancer risk per 100000 procedure. The organs dose from EXPO-CT software and their cancer risk of small intestine, colon, ovaries, uterus, prostate, testes, bladder, bone, skin was calculated for total population of LLA procedure only in arterial phase(Table 4.2).

Table 4.2: Equivalent dose and cancer risk per 100000 procedures of the selected organs in LLA.

Organ	Equivalent dose mSv mean± standard deviation	Cancer risk per 100000 procedures. mean± SD
Small intestine	4.3±1.2	73.0±47.7
Colon	8. 65±3.8	44.9±20
ovaries	12.1±4.9	8.43±3.23
uterus	17±15	161.6±140
prostate	13.7±6.7	124.5±59.2
testes	15.9±7.8	19.6±9.4
bladder	14±6	60.5±26.4
bone	13.7±8.1	7.06±4.21
skin	8.7±4.1	599.4±269.1

4.1.2.2 Pulmonary Embolism angiogram (PEA):

For the total population, mean effective dose of PE in arterial phase was 5.2±2 mSv ranging between 1.15to 11.9 mSv, which is internationally accepted range of PEA for adults.

The calculated mean cancer risk per 100000 procedure of PEAscan of arterial phase for total population was 28.8±11.5 ranged between 7.8to49 cancer risk per 100000 procedure.

The organs dose from EXPO-CT software and their cancer risk of brain, eye lenses, salivary gland, thyroid, lung, breast, heart, stomach, stomach, skin was calculated for total population of PEA procedure (Table 4.3).

Table 4.3: Equivalent dose and cancer risk per 100000 procedures of the selected organs in PEA.

Organ	Equivalent dose mSv mean± standard deviation	Cancer risk per 100000 procedures. mean± SD
brain	0.112±0.05	1.12±0.4
eye lenses	0.13±.06	1.24±0.52
salivary gland	0.76±0.34	7.6±0.3
thyroid	2.3±1	2.08±0.9
lung	13.2±5.7	168.15±72.56
breast	14.2±6.4	69.83±31.5
heart	11.5±6	102.04±53.1
stomach	0.8±0.3	5.14±2.2
Bone	8.5±3.6	4.2±1.8
skin	2.7±1.1	184±79.6

4.1.2.3 Head and Neck angiogram (HNA)

For the total population, mean effective dose of HNACT scan in arterial phase was 4.18±2 mSv ranging between 1.3to8.5 mSv, which is internationally accepted range of HNA for adults. In addition, in venous phase, the mean effective dose of HNA CT scan was 4.15 ±2 mSv ranging between 1.2to6.8 mSv.

The calculated mean cancer risk per 100000 procedures of HNAscan of arterial phase for total population was 23±11.6 ranged between 15.5to50 cancer risk per 100000 procedure. For venous phase, calculated mean cancer risk per 100000 procedure was 21.5±11.6 ranged between 6.7to34 cancer risk per 100000 procedure.

The organs absorbed dose from EXPO-CT software were extracted thus the equivalent dosewas calculatedand their cancer risk of small intestine, colon, ovaries, uterus, prostate, testes, bladder, bone, skin was calculated for total population of HNA procedure only in arterial phase (Table 4.4).

Table 4.4: Equivalent dose and cancer risk per 100000 procedures of the selected organs of HNA CT scan.

Organ	Equivalent dose mSv mean± standard deviation	Cancer risk per 100000 procedures. mean± SD
brain	21±13	192.48±120.7
eye lenses	27.7±16.8	241.85±150.65
salivary gland	27.9±16.8	243.2±151.2
thyroid	30.8±19.3	28.4±17.5
lung	6±3.8	77.35±48.3
stomach	0.16±0.12	1.18±0.715
Bone	15.6±9.4	11.2±6.9
skin	5.3±3.2	359.66±222.2

4.1.3 Parameters for CTA scans per hospital:

CTA scans included in the study was LLA, PEA and HNA.

4.1.3.1 Parameters for LLA CT scans per Hospital:

A. Palestine medical complex Hospital (P.M.C):

Palestine medical complex Hospital was the most frequent LLA CT examination source during the study period with 119 (44%) adult patients, with 30 females and 89 males. Scan parameters are shown in table 4.5.

Table 4.5: scan parameters of LLA CT examination in P.M.C.

Hospital	No. of patients	Percentage (%)/total study population	mAs	kVp	pitch	Scan length (cm)	Slice thickness (mm)	CTDIvol (mGy)	DLP (mGy.cm)
P.M.C	119	44	136.5± 38.5	120	0.981	139±11	3±1.5	7.9±2.1	1114.7±321

The average effective dose for Palestine medical complex Hospital-that represent 44% of total population- was 7 ± 2 mSv, ranging between 3.3to 11.3 mSv. Moreover, the overall cancer risk

per 100000 procedure was 38.7±11.5.The organs' absorbed dose was estimated by EXPO-CT software and their cancer risk of small intestine, colon, ovaries, uterus, prostate, testes, bladder, bone, skin was calculated for total population of LLA procedure (Table 4.6).

Table 4.6: Equivalent dose and cancer risk per 100000 procedures of the selected organs of LLA in the P.M.C Hospital

Organ	Equivalent dose mSv mean± standard deviation	Cancer risk per 100000 procedures. mean± SD
Small intestine	8±6.6	70.8±58.2
Colon	8.4±2.3	42.2±11.8
ovaries	12.2±2.7	85.5±19.1
uterus	18.4±15.2	162.2±122.0
prostate	13.3±3.7	56.1±15.63
testes	12.4±4.4	109.8±38.75
bladder	14.4±4.9	17.36±6.1
bone	13.5±9.5	6.79±4.77
skin	8.2±2.2	552.55±150.91

B. Rafedia surgical Hospital (R.S.H):

Rafedia surgical Hospital is the second Hospital by its load which represent 34% of total population including 24 females and 70 males. Scan protocols are shown in Table4.7.

Table 4.7: Average parameters of LLA CT examination in R.S.H.

Hospital	No. of patients	Percentage (%)/total study population	mAs	kVp	pitch	Scan length (cm)	Slice thickness (mm)	CTDIvol (mGy)	DLP (mGy.cm)
R.S.H	94	34	100.4± 2.9	138.6± 30.6	1.25	140±12.6	3	5.4±1.2	756.6±179 .9

The average effective dose for R.S.H -that represent 34% of total population- was 4.79 ± 1 mSv in arterial phase and 4.68±1.1 in venous phase, ranging between 2.9to6.9 mSv, 2.4 to 6.8

respectively. Moreover, the overall cancer risk per 100000 procedures of arterial and venous phase of LLA was 26.3±5.8 ranging between 13.3-37.7 and13.3-36.1 respectively.The organs' absorbed dose was estimatedby EXPO-CT software and their cancer risk of small intestine, colon, ovaries, uterus, prostate, testes, bladder, bone, skin was calculated for total population of LLA procedure (Table 4.8).

Table 4.8: Equivalent dose and cancer risk per 100000 procedures of the selected organs of LLA in the R.S.H

Organ	Equivalent dose mSv mean± standard deviation	Cancer risk per 100000 procedures. mean± SD
Small intestine	5.1±1.4	45.1±58.2
Colon	5.8±1.7	28.9±11.8
ovaries	8.2±1.4	55±12
uterus	9.3±1.4	81.7±13.5
prostate	9.1±1.7	38.7±7.5
testes	8.9±2	79.7±16.4
bladder	10.3±2.3	12.61±2.5
bone	8.7±1.6	44±8.5
skin	5.6±.17	379.6±72.6

C. Beit Jala hospital- Bethlehem (B.J.H):

Beit Jala Hospital represented 22% of total study population including 15 females and 45 males. There were no documented data on PACS system about the Kvp and mAs used in the scan.The mean scan length was calculated123±10 cm. Slice thicknesses was 3±1.5 mm (Table 4.9).

Table 4.9: Average parameters of LLA CT examination in B.J.H.

Hospital	No. of patients	Percentage (%)/total study population	mAs	kVp	pitch	Scan length (cm)	Slice thickness (mm)	CTDIvol (mGy)	DLP (mGy.cm)
B.J.H	60	22	100	120	0.6	123±10	2	14.6±0.64	1808.7±175.7

The average effective dose for B.J.H -that represent 22% of total population- was 11.3 ± 1 mSv in arterial phase and 10±1.66 in venous phase, ranging between 7.3to13.3 mSv, 7.2to12.2 respectively. Moreover, the overall cancer risk per 100000 procedures of arterial and venous phase of LLA was 62±5.9 ranged between 40-73.6 and39-67.3 respectively. The organs' absorbed dose was estimatedby EXPO-CT software and cancer risk of small intestine, colon, ovaries, uterus, prostate, testes, bladder, bone, skin was calculated for total population of LLA procedure (Table 4.10).

Table 4.10: Equivalent dose and cancer risk per 100000 procedures of the selected organs of LLA in the B.J.H

Organ	Equivalent dose mSv mean± standard deviation	Cancer risk per 100000 procedures. mean± SD
Small intestine	13.5±0.9	120.0±7.4
Colon	15.5±0.8	74.7±16.7
ovaries	20.7±1.6	14.5±1.0
uterus	23.8±1	210.32±8.59
prostate	24.4±1.4	103.0±49
testes	23.8±3.3	210.4±31.09
bladder	27.9±4	33.6±5.0
bone	23.4±2	11.8±0.75
skin	15.4±1.6	1034.4±87.47

4.1.3.2 Parameters for PEA CT scans per hospital:

A. Rafedia surgical Hospital (R.S.H):

Rafedia surgical Hospital was the most frequent PEA CT examination source during the study period with (45%) adult patients, with 55 females and 45 males.The PEA dosimetry parameters are shown in Table 4.11.

Table 4.11: Average parameters of PEA CT examination in R.S.H

Hospital	No. of patients	Percentage (%)/total study population	mAs	kVp	pitch	Scan length (cm)	Slice thickness (mm)	CTDIvol (mGy)	DLP (mGy.cm)
R.S.H	100	45	143±31	120	1.2	35±5	1	11±4	327.4±65.5

The average effective dose forRafedia surgical Hospital -that represent 45% of total population- was 4.5± 1 mSv, ranged between 2.5to6.2 mSv. Moreover, the overall cancer risk per 100000 procedure was 24.9±5.5. the lower value was 15.5 and the largest value was 34.3.The organs' absorbed dose was estimated by EXPO-CT software and their cancer risk of brain, eye lenses, salivary glands, thyroid, lung, breast, heart, stomach, bone and skin was calculated for total population of LLA procedure (Table 4.12).

Table 4.12: Equivalent dose and cancer risk per 100000 procedures of the selected organs of PEA in the R.S.H.

Organ	Equivalent dose mSv mean± standard deviation	Cancer risk per 100000 procedures. mean± SD
brain	0.098±0.01	0.86±0.123
eye lense	0.111±0.03	0.97±0.2
salivary gland	0.6±0.14	5.3±1.2
thyroid	1.8±0.4	1.6±0.3
lung	10±2.3	132.1±29.3
breast	10.7±3	53.5±13
heart	9.5±6	83.6±53.4
stomach	0.6±0.15	3.99±0.9
Bone	6.6±1.4	3.3±0.7
skin	2±0.4	144.1±32

B. Palestine medical complex Hospital (P.M.C):

Palestine medical complex Hospital is the second most frequent PEA CT examination source during the study period with (30%) adult patients, with 42 females and 25 males. The PEA of P.M.C are shown in table parameters are shown in Table 4.13

Table 4.13: Average parameters of PEA CT examination in P.M.C.

Hospital	No. of patients	Percentage (%)/total study population	mAs	kVp	pitch	Scan length (cm)	Slice thickness (mm)	CTDIvol (mGy)	DLP (mGy.cm)
P.M.C	67	30	168±70.5	120	1.375	28±5	1	9.5±4	286±141.5

The average effective dose for Palestine medical complex Hospital -that represent 30% of total population- was 4± 1.9 mSv, ranging between 1.15to9.7 mSv. Moreover, the overall cancer risk per 100000 procedure was 22.1±10.9. the lowest value was 6.3 and the largest value was 53.7 The organs' absorbed dose was estimated by EXPO-CT software and their cancer risk of brain, eye lenses, salivary glands, thyroid, lung, breast, heart, stomach, bonewas calculated for total population of PEA procedure (Table 4.14).

Table 4.14: Equivalent dose and cancer risk per 100000 procedures of the selected organs of PEA in the P.M.C.

Organ	Equivalent dose mSv mean± standard deviation	Cancer risk per 100000 procedures. mean± SD
brain	0.122±0.05	1.1±0.42
eye lense	0.13±0.06	1.24±0.52
salivary gland	0.8±0.34	6.8±3.0
thyroid	2.3±1	2.0±0.9
lung	13.2±5.7	168.15±72.56
breast	14.2±6.4	69.83±31.5
heart	11.5±6	102.04±53.1
stomach	1±0.37	5.14±2.2
Bone	8.5±3.6	4.85±1.22
skin	2.7±1.1	184.04±79.64

C. Beit Jala hospital- Bethlehem (B.J.H):

Beit Jala Hospital represented 25% of total study population including 37 females and 19 males.The mean scan length was calculated29.5±2.5cm. Slice thicknesses was 3±1.5 mm (Table 4.15).

Table 4.15: Average parameters of PEA CT examination in B.J.H.

Hospital	No. of patients	Percentage (%)/total study population	mAs	kVp	pitch	Scan length (cm)	Slice thickness (mm)	CTDIvol (mGy)	DLP (mGy.cm)
B.J.H	56	25	160	120	0.9	29.5±2.5	1	19.3±1.7	568.3±71.1

The average effective dose for B.J.H was7.9 ± 1 mSv of CTA scan, ranging between 6.6 to11.9 mSv. Moreover, the overall cancer risk per 100000 procedures of CTA was 43.7±5.4 ranging between 36.7 to 65.6respectively.The organs' absorbed dose was estimated by EXPO-CT software and their cancer risk of brain, eye lenses, salivary glands, thyroid, lung, breast, heart, stomach, bone was calculated for total population of PEA procedure (Table 4.16).

Table 4.16: Equivalent dose and cancer risk per 100000 procedures of the selected organs of PEA in the B.J.H.

Organ	Equivalent dose mSv mean± standard deviation	Cancer risk per 100000 procedures. mean± SD
brain	0.19±0.02	1.76±0.16
eye lense	0.2±0.04	1.88±0.38
salivary gland	1.15±08	11.0±1.64
thyroid	3.7±0.38	3.38±0.34
lung	21.4±1.9	272.0±24.68
breast	14.5±11.3	109.98±21.99
heart	18±1.7	159.8±15.6
stomach	1.3±0.11	8.38±0.7
Bone	13.8±1.2	6.96±0.62
skin	4.4±0.4	299.6±27.29

4.1.3.3. Parameters for HNA CT scans per hospital:

A. Palestine medical complex Hospital (P.M.C):

Palestine medical complex Hospital was the most frequent HNA CT examination source during the study period with (43%) adult patients, with 11 females and 22 males.The average tube voltage was 120 kVp, average tube current-time product was 295.9±15.7 mAs, and mean scan length was 41±4.6cm. Slice thicknesses was 3±1 mm (Table 4.17).

Table 4.17: Average parameters of HNA CT for total scan, arterial (A), and venous (V) examination in P.M.C.

Hospital	No. of patients	mAs	kVp	pitch	Scan length (cm)	Slice thickness (mm)	CTDIvol (mGy)	DLP (mGy.cm)
P.M.C	33	295.9±15.7	120	0.297	41±4.6	3±1	22.5±7.5	777±96
A	33	295.9±15.7	120	0.297	41	3±1	19	758.5±44.8
V	7	250	120	0.297	33	3±1	22	713±174

The average effective dose for Palestine medical complex Hospital forHNA CT scan in arterial phase was 3.3±0.43mSv ranging between 2.8to3.8 mSv, which is internationally accepted range of HNA for adults. In addition, in venous phase, the mean effective dose of HNACT scan was 3 ±0.61mSv ranging between 2.23to3.61 mSv.

The calculated mean cancer risk per 100000 procedures of HNAof arterial phase was 18±1.7ranged between 15.58to21.3 cancer risk per 100000 procedure. For venous phase, calculated mean cancer risk per 100000 procedure was 17.4 ranged between 12.28to19.89 cancer risk per 100000 procedures.

The organs absorbed dose from EXPO-CT software was extracted thus the Equivalent dosewas calculatedand their cancer risk ofbrain, eye lenses, salivary glands, thyroid, lung, stomach, bone was calculated for total population of PEA procedure (Table 4.18).

Table 4.18: Equivalent dose and cancer risk per 100000 procedures of the selected organs of HNA CT scan.

Organ	Equivalent dose mSv mean± standard deviation	Cancer risk per 100000 procedures. mean± SD
brain	18±6	133.1±35.1
eye lenses	23±7.7	169.5±44.4
salivary gland	23.6±7.9	172.1.6±45.89
thyroid	25.3±9.8	20.33±6.03
lung	5.1±1.6	54.0±13.0
stomach	0.14±0.064	0.7±0.284

Bone	13.3±4.3	7.94±1.94
skin	4.5±1.4	259.26±67.6

B. Beit Jala hospital- Bethlehem (B.J.H):

Beit Jala Hospital represented30% of HNA CT examination source during the study period with 33 adult patients, including4 females and 20 males. The parameters are shown in Table 4.19.

Table 4.19: Average parameters of HNA CT for total scan, arterial (A), and venous (V) examinations in B.J.H.

Hospital	No. of patients	mAs	kVp	Pitch	Scan length (cm)	Slice thickness (mm)	CTDIvol (mGy)	DLP (mGy.cm)
B.J.H	24	295.9±15.7	120	1.23	41±4.6	3±1	38±29	2087±784
A	24	295.9±15.7	120	1.23	35±6	3±1	31±24	1104±769
V	10	200	120	1.23	34±10	3±1	8.4	302±71

The average effective dose for Beit Jala Hospital in arterial phase was 4.5±3mSv ranging between 1.23to9.7 mSv, which is internationally accepted range of HNA for adults. In addition, in venous phase, the mean effective dose of HNA CT scan was 1.24 ±0.32mSv ranging between 0.7to1.23 mSv.

The calculated mean cancer risk per 100000 procedures of HNA of arterial phase was 25.6±18ranged between 6.8to53.4. cancer risk per 100000 procedures. For venous phase, calculated mean cancer risk per 100000 procedure was 6.9±1.8 ranged between 3.8to6.8 cancer risk per 100000 procedure. The organs absorbed dose from EXPO-CT software was extracted thus the Equivalent dose was calculated and their cancer risk of brain, eye lenses, salivary glands, thyroid, lung, stomach, bone was calculated for total population of PEA procedure (Table 4.20).

Table 4.20: Equivalent dose and cancer risk per 100000 procedures of the selected organs of HNA CT scan.

Organ	Equivalent dose mSv mean± standard deviation	Cancer risk per 100000 procedures. mean± SD
brain	19±6	194.3±35.1
eye lenses	24.5±7.7	161.1±44.4
salivary gland	24.5±7.9	176.11±45.89
thyroid	27.4±9.8	30.92±6.03
lung	5.3±1.6	83.0±13
stomach	0.32±0.14	1.9±0.88
Bone	14±4.3	12.1±1.94
skin	4.75±1.4	386.1±67.6

C. Rafedia surgical Hospital (R.S.H):

Rafedia surgical Hospital represented 27% of HNA CT examination source during the study period with 21 adult patients, with 4 females and 17 males. The parameters used are shown in Table 4.21.

Table 4.21: Average parameters of HNA CT for total scan, arterial (A), and venous (V) examinations in R.S.H.

Hospital	No. of patients	mAs	kVp	Pitch	Scan length (cm)	Slice thickness (mm)	TCTDIvol (mGy)	TDLP (mGy.cm)
R.S.H	21	307±66	120	0.2	31±8	3±1	46±15	1373±399
A	21	307±66	120	0.2	35±6	3±1	31±24	1312±348
V	11	393±82	120	0.2	34±10	3±1	8.4	1217±227

The average effective dose for Rafedia surgical Hospital in arterial phase was 5.2±1.5mSv ranging between 2.5to6.8 mSv, which is internationally accepted range of HNA for adults. In addition, in venous phase, the mean effective dose of HNA CT scan was 5.1 ±1.1mSv ranging between 2.7to6.45 mSv.The calculated mean cancer risk per 100000 procedures of HNA of arterial phase was 30.6±8.3ranged between13.45to37.4 cancer risk per 100000 procedure. For venous phase, calculated mean cancer risk per 100000 procedure was 29.4±6.4 ranged between 15.2to35.5. The organs absorbed dose from EXPO-CT software was extracted thus the Equivalent dose was calculated and their cancer risk of brain, eye lenses, salivary glands, thyroid, lung, stomach, bone was calculated for total population of PEA procedure (Table 4.22).

Table 4.22: Equivalent dose and cancer risk per 100000 procedures of the selected organs of HNA CT scan.

Organ	Equivalent dose mSv mean± standard deviation	Cancer risk per 100000 procedures. mean± SD
brain	30±11	266.5±84.6
eye lenses	39±14	332.4±100.5
salivary gland	39.4±14.3	336.3±104.94
thyroid	43±16	28.3±12.6
lung	8.6±3	105.2±34.3
stomach	0.32±0.09	1.4±0.5
Bone	21±8	15.2±4.8
skin	7.5±2.6	485.9±154.5

4.2Discussion

4.2.1 Summary of Parameters for CTA scans

4.2.1.1 summary of Parameters for LLA scan

Between the three governmental hospitals, the largest value of ED was found in Beit Jala Hospital (B.J.H) with 11.3±1mSv, Palestine medical complex Hospital (P.M.C) with 7±2 mSv then Rafedia surgical Hospital (R.S.H) with 4.79 ± 1 mSv in arterial phase and 4.68±1.1 in venous phase. The results of Anova test indicated that there was a significant difference between ED values due to different scanner models with different scan protocols($P<0.05$).

The highest value of ED in B.J.H with 11.3±1mSv maybe due to a 123±10.7 mm high scan length value, highest CTDIv with 14.6mGy, highest DLP with 1808.7±175.7 mGy.cm, and lowest pitch value of 0.6. In contrast, the lowest value of ED 4.68±1.1 mSv was in R.S.H due to a lowest mean value of mAs with 100± 3, lowest mean CTDIv of 5.4 mGy, the lowest mean DLP value with 756.6± 179.9 mGy.cm, and a highest pitch value of 1.25. (Table 4.23)

In addition, the overall cancer risk per 100000 procedures was also the highest in B.J.H with 62.6± 6 in arterial phase and 55±9 in venous phase. Then P.M.C with 38±11, and the lowest value was R.S.H with 26.3±5.8 for arterial phase and 25.7±6.2 for venous phase. This difference in cancer risk is related to the higher values of ED that produce a higher values of overall cancer risk.

Table 4.23: Parameters of EDs and cancer risk for adult patients in three hospitals in LLA.

Hospital	No. of patients	(%)/ total study pop	mAs	kVp	Pitch	Scan Length (cm)	Slice thickness (mm)	CTDIvol (mGy)	DLP (mGy.cm)	ED (mSv)	Overall cancer risk
P.M.C	120	44	136.5±38.5	120	0.981	139±11	3±1.5	7.9±2.1	1114.7±321	7±2	38.7±11.5
R.S.H	94	34	100.4±2.9	138.6	1.25	140±12.6	1.5	5.4±1.2	756.6±179.9	A:4.79 ± 1 V:4.68±1.1	A: 26.3±5.8 V: 25.7±6.2
B.J.H	60	22	250	120	0.6	123±10	3±1.5	14.6±0.64	1808.7±175.7	A:11.3±1 V:10.6±1.6	A:62.6± 6 V: 55±9

There is a prominent variation between CTDIv, DLP, and ED values for the three included hospitals, since the value of CTDIv ranging from 5.4 to 14.6 mGy, and DLP values ranging between 756.6 to 1808.7 mGy.cm, so that ED values ranging between 4to11.3 mSv, oneHospital had ED value greater than the recommended global value of 10 mSv.

4.2.1.2 summary of Parameters for PEA scan

Among the three governmental hospitals, the largest value of ED was Beit Jala Hospital (B.J.H) with 7.9±0.9 mSv, Rafedia surgical Hospital (R.S.H) with 4.54±1 mSv, thenPalestine medical complex Hospital (P.M.C) with 4±1.9mSv. The POST-HOC-TEST showed that there is no significant difference between R.S.H ED and P.M.C (P-value 0.027>0.016). while there is a significant difference between the other hospitals in the study.

The highest value of ED in B.J.H with 7.9±0.9 mSv maybe due to a 29.5± 2.9 cm high scan length compared toP.M.C28.5±5.6 cmscan length value, highest CTDIv with 19.3± 1.7 mGy, highest DLP with 568±71 mGy.cm and lowest pitch value of 0.9. In contrast, the lowest value of ED with 4±1.9 was in P.M.C due to lowest mean CTDIv with 9.5±4 mGy, the lowest mean DLP value with 286± 141.6 mGy.cm, and highest pitch value 1.375. (Table 4.24)

In addition, the overall cancer risk per 100000 procedures was also the highest in B.J.H with 43.7±5.4. Then R.S.H with 24.9±5.5, and the lowest value was P.M.C with 22±10.9. This difference of cancer risk is related to the higher values of ED that produce higher values of overall cancer risk.

Table 4.24: Parameters of EDs and cancer risk for adult patients in three hospitals in PEA.

Hospital	No. of patients	(%)/ total study pop	mAs	kVp	pitch	Scan Length (cm)	Slice thickness (mm)	CTDIv (mGy)	DLP (mGy.cm)	ED (mSv)	Overall cancer risk
P.M.C	100	45	168± 70	120	1.375	28.5±5.6	1	9.5±4	286± 141.6	4±1.9	22±10.9
R.S.H	67	30	143± 31	120	1.2	35±5	1	11.2± 1.8	327±65	4.54±1	24.9±5.5
B.J.H	56	25	250± 63	120	0.9	29.5± 2.9	1	19.3± 1.7	568±71	7.9±0.9	43.7±5.4

From Table 4.24 there is a wide variation between CTDIvol, DLP, and ED values for the three included hospitals, since the value of CTDIvol ranging from 9.5 to 19.3 mGy, and DLP values ranging between 286to568 mGy.cm, so that ED values ranging between 4 to 7.9 mSv. all hospitalsincluded in the study had ED value lower than the recommended global value that equal nearly 10 mSv.

4.2.1.3 summary of Parameters for HNA scan

Among three governmental hospitals, the largest value of ED in arterial phase wasR.S.H with 5.5±1.5 mSv, B.J.H with 4.5±3 mSv then P.M.C with 3.3 ± 0.3 mSv. Furthermore, in venous phase,the largest value of ED was also R.S.H with 5.1 ±1.1mSv, P.M.C with 3±0.6 mSv, then B.J.H with 1.24±0.3 mSv. According to POST-HOC-test there were no significant difference between R.S.H and B.J.H (P-value 0.16>0.016) and the P.M.C with B.J.H (P-value 0.052>0.016) respectively. While there is a significant difference between R.S.H and P.M.C ED values due to

different scanning protocols as shown in Table 4.25. The highest value of EDin R.S.H for arterial and venous phase with (5.5±1.5,5.1 ±1.1)mSv respectively,which is due to highest mAs setting (307±66, 393±83), highest CTDIv with (37.7±11.8, 48±15) mGy, and highest DLP with (1312.4±348.6, 1217±227.9) mGy.cm also, they used a lowest pitch value 0.2 (inversely proportional with dose). In contrast, the lowest value of ED in arterial phase wasP.M.C with 3.3 ± 0.3 mSv because of a lower mean value of mAs with 295±15, lowest mean CTDIv with 18.7±4 mGy, the lowest mean DLP value with 758.5±44 mGy.cm and, higher pitch value (0.297)(Table 4.25). In venous phase the lower value was B.J.H with 1.24±0.3mSv due to a lowest value of CTDIvol and DLP, 8.4 mGy, 302±71 respectively. While the lowest ED value was P.M.C with 3±0.6mSv due to a lowest value of CTDIvol, DLP and mAs setting with a value of 33.9 mGy, 870.87 ±87 mGy.cm and 300 respectively (Table 4.25).According to POST-HOC-test there were significant difference only in B.J.H. (A Vs V). This indicated that utilized parameters played a crucial role in ED values.

In addition, the overall cancer risk per 100000 procedures was also the highest in R.S.H with 34.5±7.7 in arterial phase, and 26.9±6.8 in venous phase. Then B.J.H with a moderate value 25.6±18 in arterial phase and lowest value in venous phase 6.9±1.8, and the lowest value was in P.M.C with 23±11 for arterial phase, and 21±12 for venous phase. This difference of cancer risk is related to the higher values of ED that produce a higher values of overall cancer risk(Table 4.25).

Table 4.25: Parameters of EDs and cancer risk for adult patients in three hospitals in HNA.

Hospital	No. of patients	(%)/ total study pop	mAs	kVp	Pitch	Scan Length (cm)	Slice thickness (mm)	CTDIvol (mGy)	DLP (mGy.cm)	ED (mSv)	Overall cancer risk per 100000 procedures
P.M.C	33	43	A:296±16 V:300	120	0.297	A:41±5 V:33±9	1.5	A:18.7±4 V:22±7	A: 758.5±44 V:713±174	A: 3.3 ± 0.3 V: 3±0.6	A: 18±1.7 V:17±4
R.S.H	21	27	A:307±66 V:393±82	120	0.2	A:36±6 V:26±6	3	A: 37.7±11.8 V: 48±15	A:1312.4±348.6 V: 1217±227.9	A: 5.5±1.5 V:5.1 ±1.1	A:30±8 V:29±6
B.J.H	24	30	400	120	1.23	A:35±6 V:34±10	3±1.5	A:32.7±23 V: 8.4±1.7	A:1104±769 V: 302±71	A:4.5±3 V: 1.24	A:25.6±18 V:7±1.8

From table 4.24 there is a scale of values variation between CTDIvol, DLP, and ED values for the three included hospitals in Palestine, since the value of CTDIvol ranging from 18 to 37.3 mGy in arterial phase,and 8.4 to 48 in venous phase. Also,the DLP values ranged between 758 to1312.4 mGy.cm in arterial phase, and 302 to 1217 in venous phase.ED values ranged between 3.3to5.5 mSvin arterial phase, and 1.24 to 5.1 in venous phase. All hospitals included in the study had ED value lower than the recommended global value of 10 mSv.

CTDIv values for adult patients in the included three hospitals are presented in Figure 4.1. The values were higher in head and neck angiogram procedure from the three procedures in R.S.H in arterial and venous phase, then comes B.J.H with higher values in PEA and LLA duringarterial phase.

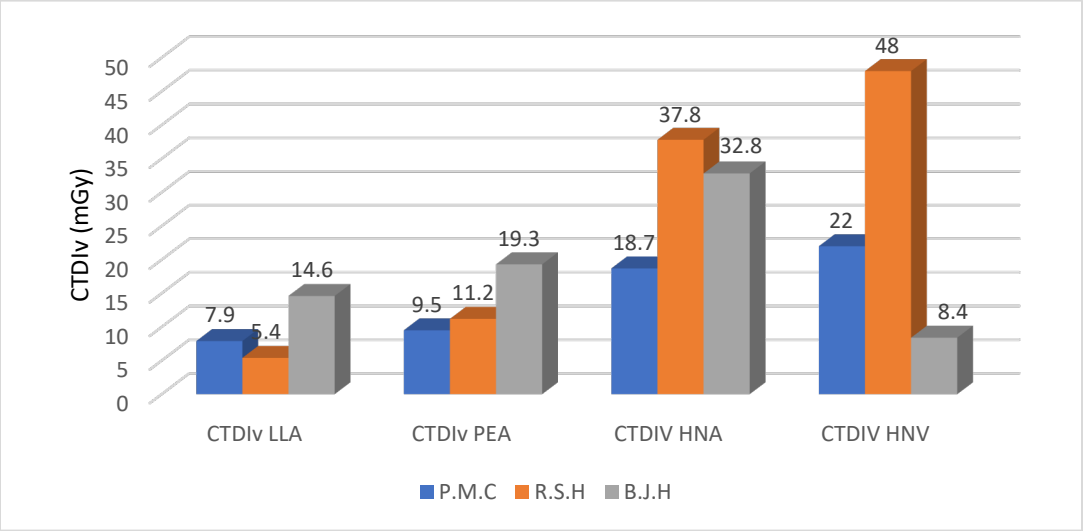

Figure 4.1: CTDIv of the three hospitals, PMC, R.S.H and B.J.H of the three scanning protocol of LLA, PEA and HNA in arterial and venous phase

DLP values for adult patients in the included three hospitals are presented in Figure 4.2. R.S.H had a higher value of DLP in head and neck angiogram procedure (arterial +venous).

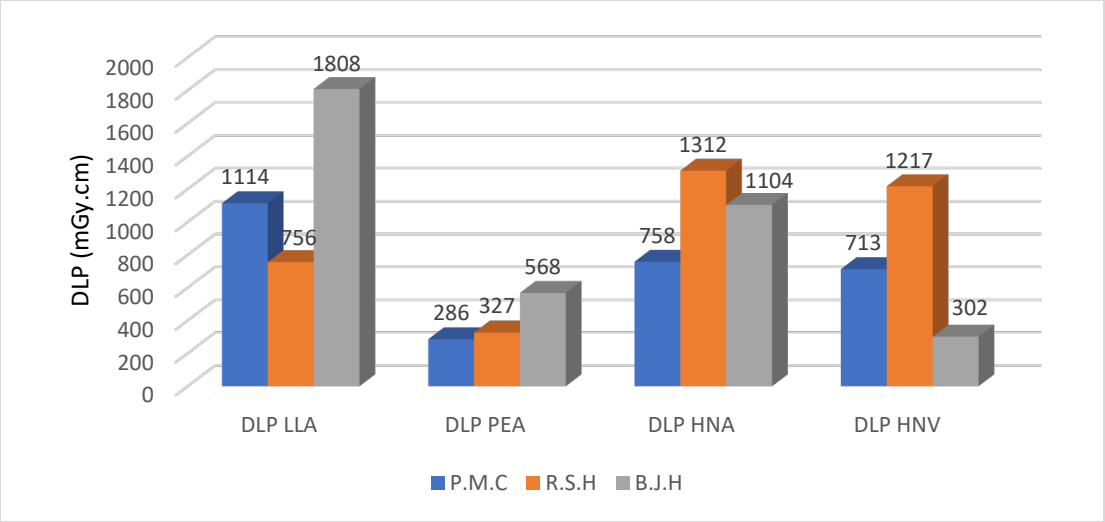

Figure 4.2: DLP of the three hospitals, PMC, R.S.H and B.J.H of the three-scanning protocol of LLA, PEA and HNA in arterial and venous phase.

Average ED values for adult patients in the included hospitals are presented in Figure 4.3.The values were higher in B.J.H in LLA, PEA. Also, R.S.H had a higher value of ED in head and neck angiogram procedure (arterial +venous).

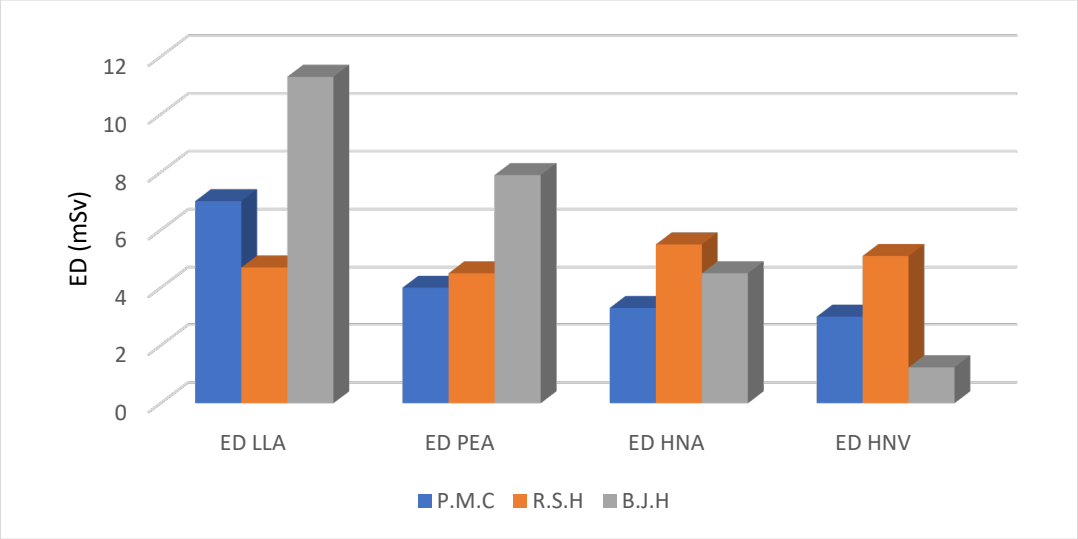

Figure 4.3: Distribution of average ED values for adult patients in the included hospitals.

The variation between DLP values for all CTA scans included in the study maybe causedby differences in mAs setting, and pitch values (inverselyproportional to dose).

There was also a strong relationship between scan length of each study and ED for total study population in LLA, PEA and HNA in which, any Increase in scan length will be associated with increase in average ED value (Figure 4.4).

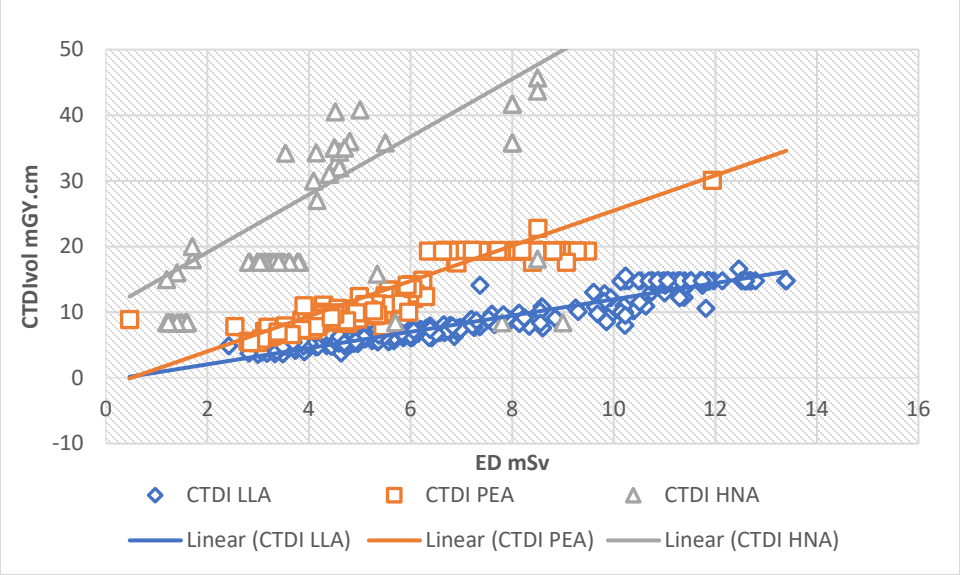

Figure 4.4: Correlation between CTDIv and ED for total study population of LLA, PEA and HNA.

4.2.2 CT radiation doses comparison between the study's results in Palestine and other international dose level references

4.2.2.1 CTDIv, DLP and effective dose for adult patient's LLA CT in Palestine and other countries:

our study results compared to dose reference levels (DRLs), Palestine is in acceptable level regarding CTDIv, DLP and ED values for all included scans. First of all, LLA scans,Figure 4.5 shows CTDIv in various references, values ranging between 3.9 to 37 mGy; while in Palestine it was 8.5±3.7 mGy. In addition, the DLP values of different DRL of various countries ranges between 434-3000 mGy.cm, while in Palestine, the value is 1145 mGy.cm (Figure 4.6). For ED value of LLA, in the Palestine it is 7 mSv which is within the range of DRL (1.6-18) mSv

(Figure4.7).

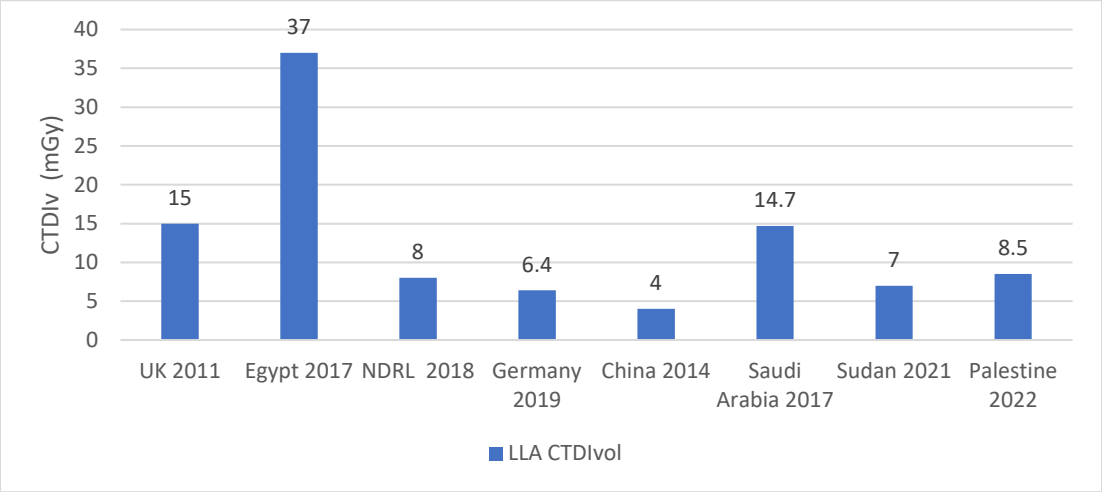

Figure 4.5: LLA CTDIvol parameters of our study and various dose references worldwide.

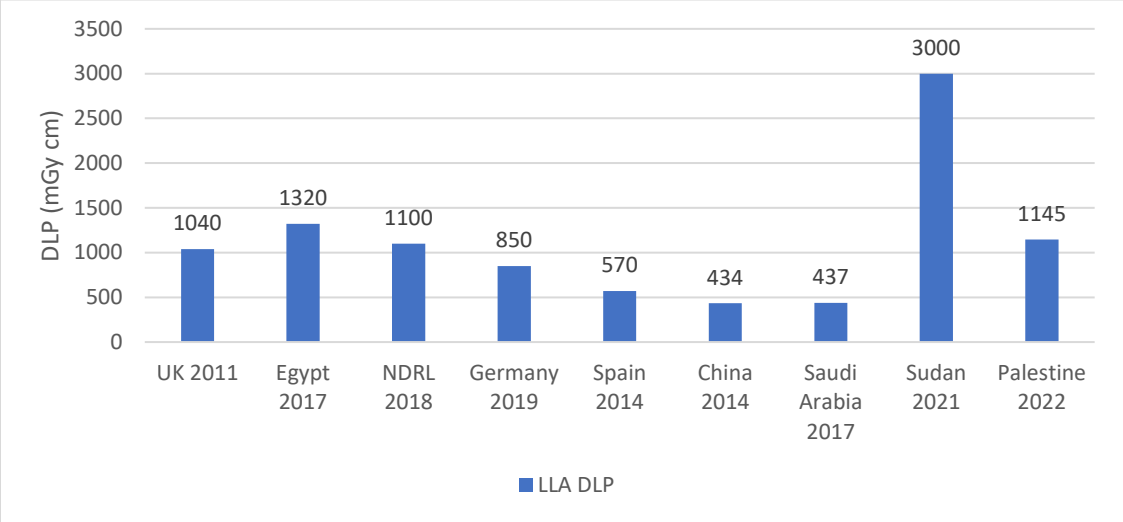

Figure 4.6: LLA DLP parameters of our study and various dose references worldwide.

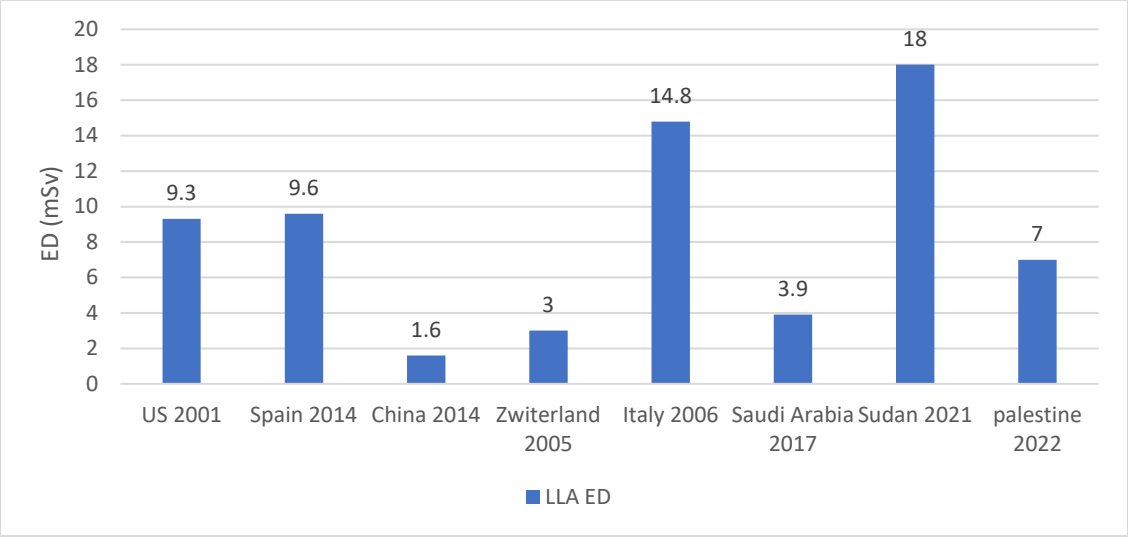

Figure 4.7: the mean of LLA ED parameters of our study and various dose references worldwide.

4.2.2.2 CTDIv, DLP and effective dose for adult patient's PEA CT in Palestine and other countries:

In comparison between our study results with various dose reference levels (DRL), Palestine is in acceptable level in CTDIvol, DLP and effective dose values for PEA scans, Figure 4.8 shows CTDIvol in various references, values ranging between 10 to 20.9 mGy; while Palestine was 12.7± mGy. In addition, the DLP values of different DRL of various countries ranges between 350-631 mGy.cm, while in Palestinethe value was 375 mGy.cm (Figure 4.9). For ED value of PEA, in Palestinewas5 mSv which is within the range of DRL (2.8-10.7) mSv(Figure 4.10).According toHarun**,** AbdulKarim**,** Abd Rahman, et al. (2020)CTDIvol may range from 6.13 to 21.4 depending on the body legnth. For example, a body leghth of 14-19cm will produce 6.13 mGy CTDIvol and a body length of 24-31cm will produce a 21.4mGy CTDIvol, for an averege length patients (19-24)cm the CTDIvol will be 8.35mGy. Also , Klosterkemper et al. (2018)indicated that a body length of 37–41 cm will produce a CTDIvol of 20.9 ± 2.6.

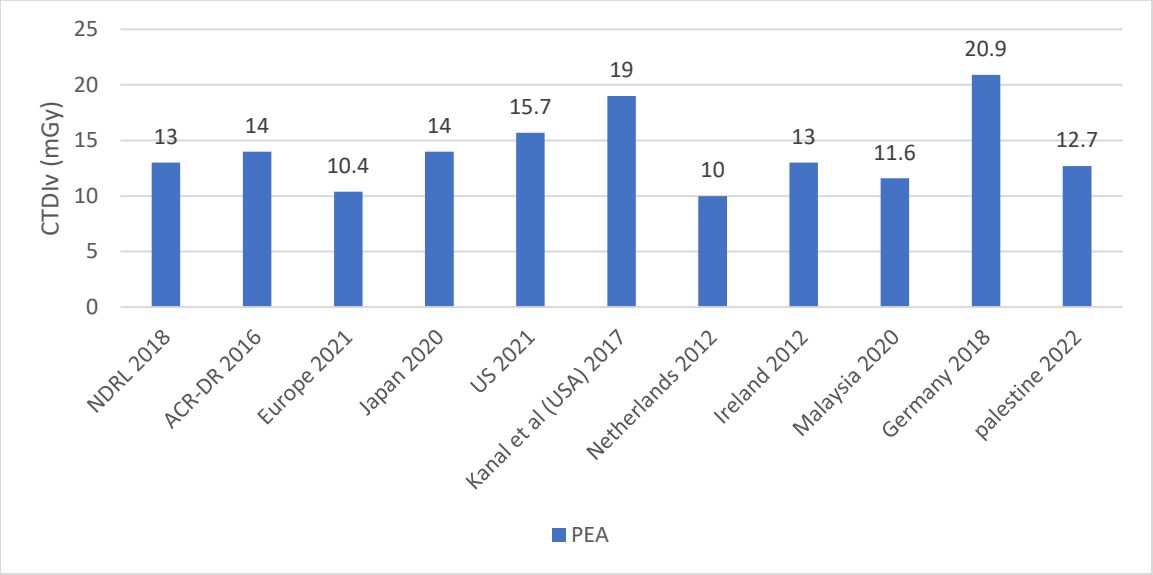

Figure 4.8: PEA CTDIvol parameters ofour study and various dose references worldwide.

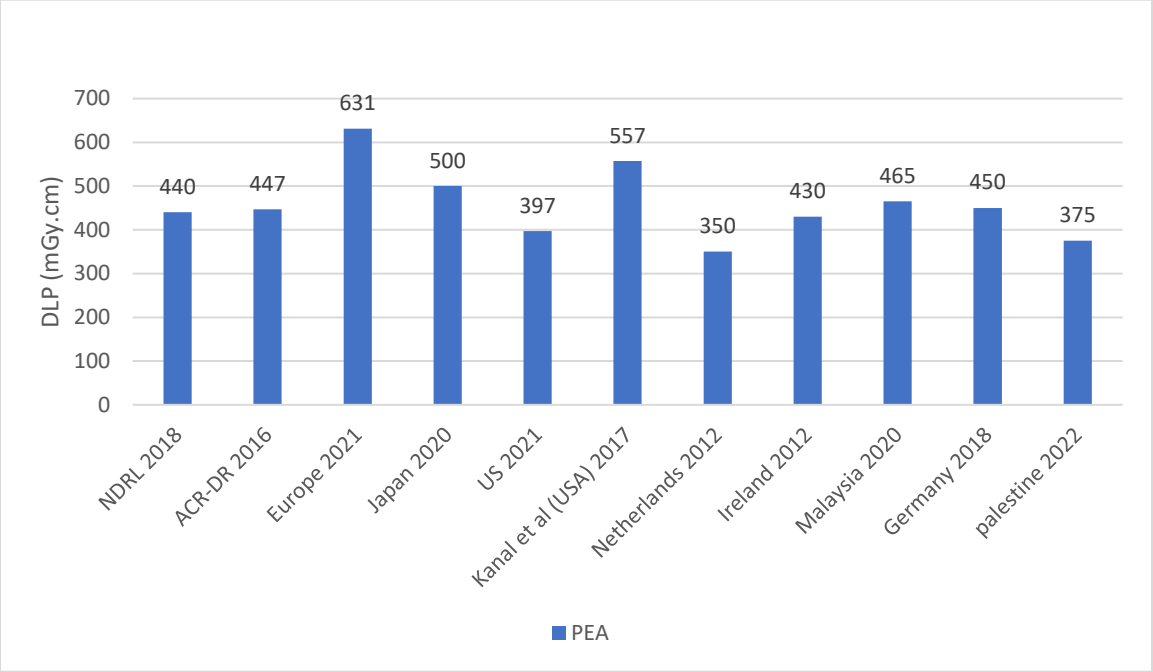

Figure 4.9: PEA DLP parameters of our study and various dose references worldwide.

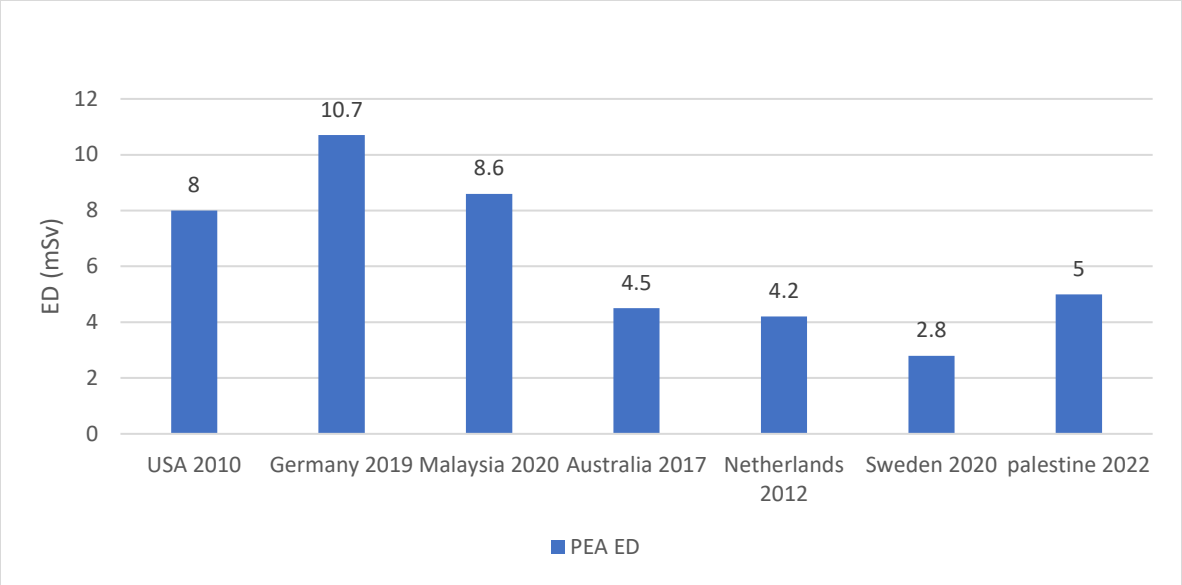

Figure 4.10: the mean of PEA ED parameters ofour study and various dose referencesworldwide.

4.2.2.3 CTDIv, DLP and effective dose for adult patient's HNA CT in Palestine and other countries:

In comparison between our study results with various dose reference levels (DRL), Palestine is in acceptable level in CTDIv, DLP and effective dose values for HNA scans, Figure 4.11 shows CTDIv in various references, values ranging between 20 to 65 mGy; while Palestine was 29±17 mGy. In addition, the DLP values of different DRL of various countries ranges between 663-1612 mGy.cm, while in Palestinethe value is 1014 mGy.cm (Figure 4.12). For ED value of LLA, in Palestineit is 4 mSv which is within the range of DRL (4-9.6) mSv (Figure 4.13).

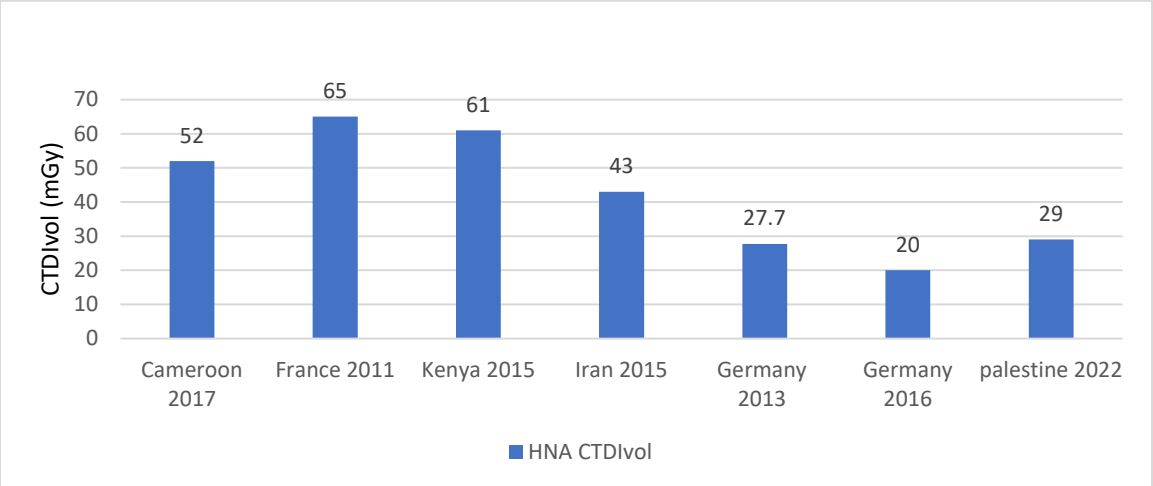

Figure 4.11: Comparison between HNA CTDIvol parameters of our study and in various dose references worldwide.

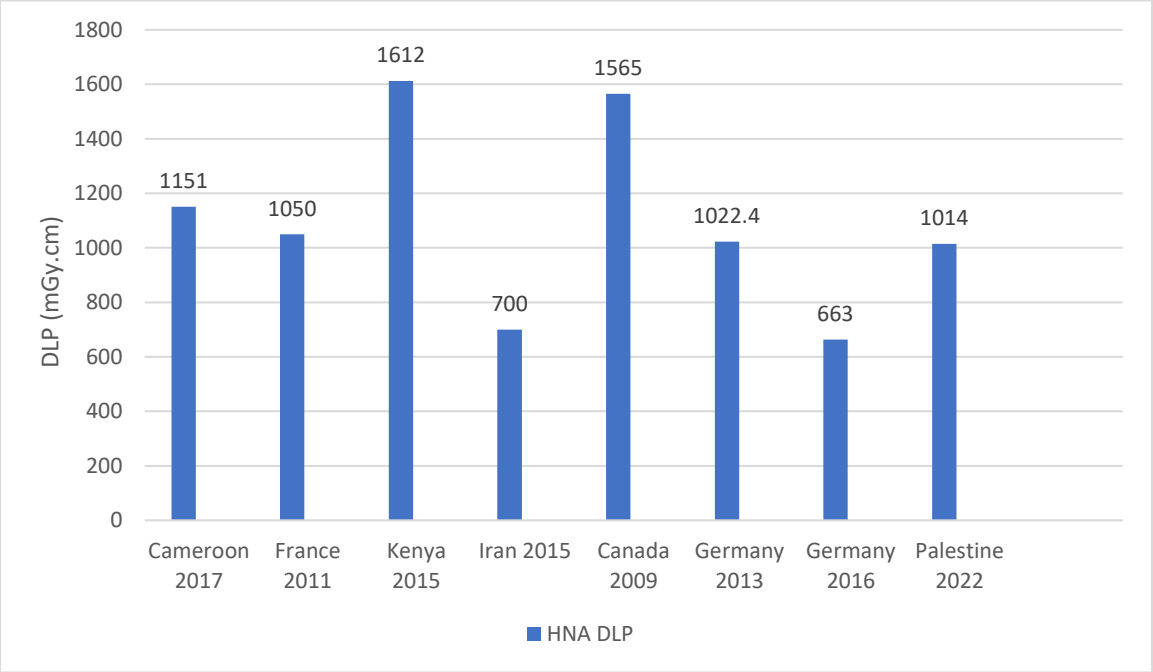

Figure 4.12: Comparison between HNA DLP parameters of our study and various dose references worldwide.

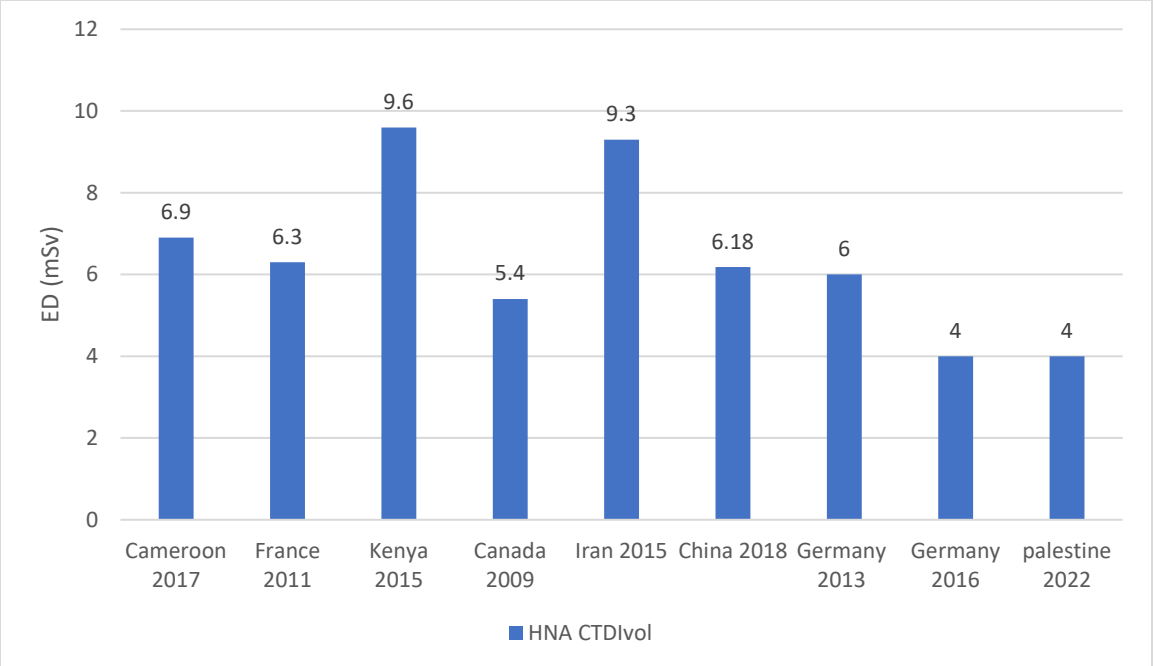

Figure 4.13: Comparison between the mean of HNA ED parameters of our study and various dose references worldwide.

4.2.3 Age and cancer risk:

4.2.3.1.1 Age dependent and cancer risk for R.S.H, P.M.C and P.J.H population of LLA scan:

There was a large variability between the three included hospitals of age dependency of ED and cancer risk. For example, in R.S.H, there was a positive relationship between cancer risk and age with correlation of 0.24. while in P.M.C hospital, the correlation coefficient was strong positive0.84 Finally, in B.J.H it was 0.57 (Figure 4.14)

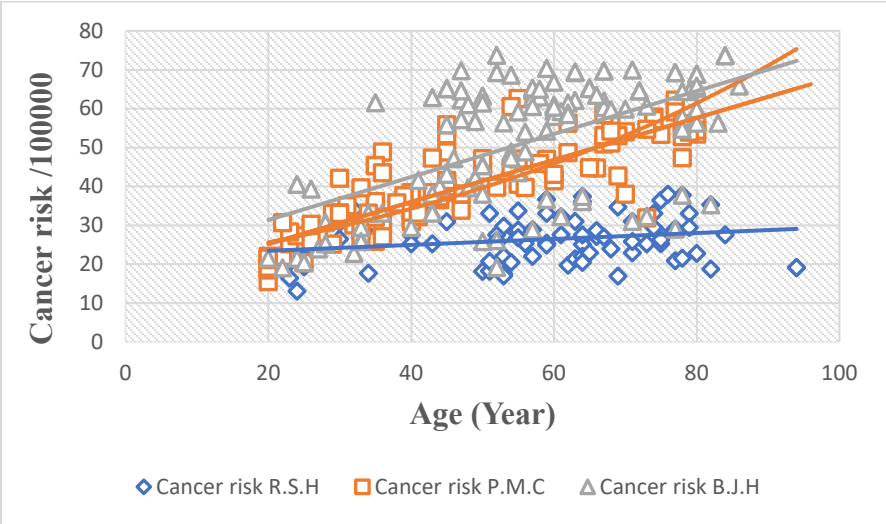

Figure 4.14: A positive relationship between cancer risk and the age for study population of LLA scan.

4.2.3.1.2 Age and cancer risk for study's population of PEA scan:

R.S.H and P.M.C represented similar patterns of a positive relationship between Age and cancer risk with a correlation of 0.52 and 0.41, respectively, for both hospitals (Figure 4.15). While P.J.H represented a correlation of 0.369.

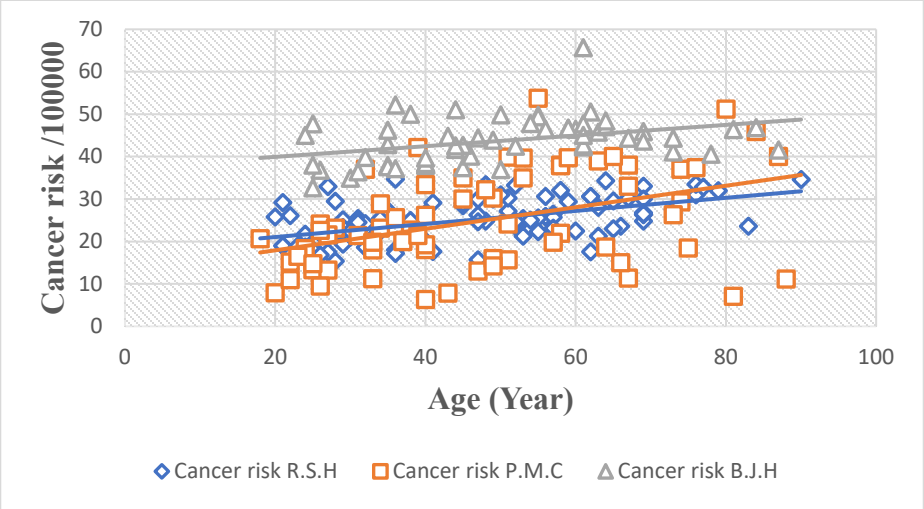

Figure 4.15: A positive relationship between cancer risk and the age for R.S.H, P.M.C and P.J.H population of PEA scan.

4.2.3.1.3 Age and cancer risk for study's population of HNA scan:

There was a positive correlation in the three included hospitals between the age and cancer risk. For example, in R.S.H it was 0.54, in P.M.C (0.16) and B.J.H 0.14 (Figure 4.16).

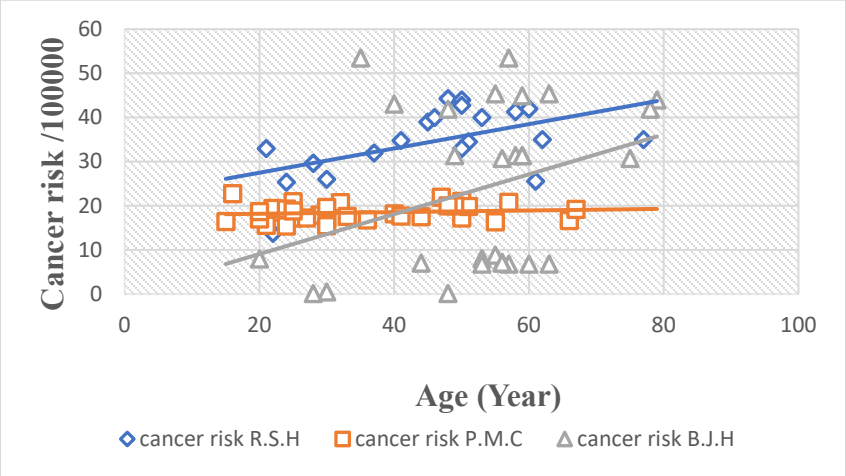

Figure 4.16: A positive relationship between cancer risk and the age for R.S.H, P.M.C and P.J.H population of HNA scan.

4.2.4 Gender dependent EDs and cancer risk:

4.2.4.1 Measurements of EDs and cancer risk based on patient's gender for total study population:

There was some variability between the included three scans. For instance, in PEA scan the average ED for male (40% of total study population) and female (60% of total study population) were approximately equal 5.3 and 5.2 mSv respectively. For LLA scan, the average ED for male

(75% of total study population) and female 25% of total study population were approximately 6.9 and 7.8 mSvrespectively(Table 4.26). Moreover, for HNA scan the average ED for male (74.5% of total study population) and female (25.5% of total study population) were approximately equal 4.23 and 4.39 mSv respectively.

Table 4.26: Average ED and cancer risk for PEA, LLA and HNA scans in total study population based on sex.

Protocol	Gender	ED (mSv)	Cancer risk/100000
PEA	M	5.3±2.1	28.9±11.2
	F	5.2±2	28.7±11.7
LLA	M	7.8±2.9	43±16
	F	6.9±2.9	38.4±15
HNA	M	4.23±2.16	25 ±12
	F	4.39±2.17	23.5±11

4.2.4.2 Measurements of EDs and cancer risk based on patient's gender for the three scans in R.S.H, P.M.C and B.J.H:

In R.S.H, according to the F test (α=0.05), there were no significant difference between female and male patients of the ED and cancer risk per 100000 procedures in all the scanning protocols PEA, LLA and HNA scansPvalue>0.05(Table 4.27).

Table 4.27: Average ED and cancer risk for PEA, LLA and HNA scans in total study population based on gender in R.S.H.

R.S.H Protocols	Gender	Mean age (Yr)	ED mSv	Cancer risk/100000	P value
PEA	M	50±18	4.6±1	25.5±5.6	ED:0.63
	F	52±17	4.5±1	24.5±5	Cancer risk:0.41
LLA	M	57±15	4.5±1	25±5.5	ED:0.51
	F	72±11	5±1.5	29±6	Cancer risk:0.63
HNA	M	52±15	5±1.5	35 ±8	ED:0.5
	F	64±11	4±2	22.5±11	Cancerrisk:0.5

In P.M.C Hospital there were no significant difference between female and male patients of the ED and cancer risk per 100000 procedures in all the scanning protocols PEA, LLA and HNA scans the P values > 0.05 (Table4.28).

Table 4.28: Average ED and cancer risk for PEA, LLA and HNA scans in total study population based on gender in P.M.C.

P.M.C Protocols	Gender	Mean age (Yr)	ED mSv	Cancer risk/100000	P value
PEA	M	54±17	4.2±2	23±11.6	ED:0.56
	F	53±18	3.8±1.9	21±10.5	Cancer risk:0.56
LLA	M	57±12	6.8±2	38±12	ED:0.55
	F	59±17	7.6±2	42±11	Cancer risk:0.57
HNA	M	48±15	3.1±0.26	17.5 ±1.4	ED:0.59
	F	46±19	3.6±0.22	19.7±1.1	Cancer risk:0.53

In B.J.H there were no significant difference between female and male patients of the ED and cancer risk per 100000 procedures in all the scanning protocols PEA, LLA and HNA scans, except in LLA in cancer risk P value< 0.05. This could be because of higher scanning protocol parameters used of 150 mAs, 120 Kvp, B.J.H also, have the highest CTDIv and DLP which were 14.6 and 1808.7 respectively(Table 4.29).

Table 4.29: Average ED and cancer risk for PEA, LLA and HNA scans in total study population based on gender in B.J.H.

B.J.H Protocols	Gender	Mean age (Yr)	ED mSv	Cancer risk/100000	P value
PEA	M	53±15	5±2	28±11.5	ED:0.63
	F	51±17	5.1±2.1	28.3±11.8	Cancer risk:0.41
LLA	M	63±14	9±2.3	50±16	ED:0.41
	F	66±14	12±1	67±4	Cancer risk:0.0003
HNA	M	48±15	3.18±0.26	17.5 ±1.4	ED:0.48
	F	46±19	3.6±	19±1.7	Cancer risk:0.46

However, in the three hospitals there was some differences between the scanning protocols. For example, in LLA the highest value of ED was in B.J.H, P.M.C then R.S.H, this could be interpreted by the fact of different number of slices of the CT machines in the study, 16, 64 and 128 respectively and the resulted changes of scanning parameters that affect ED thus manipulate cancer risk values.

4.2.5 organ dose and cancer risk

The CTA procedures should be justified by comparing radiation risk and the benefits. So that, radiation risk estimation is essential, especially when the radiosensitive organs are directly irradiated during different CTA scan procedures, such as thyroid, eye lens, breast, gonads, skin, and salivary glands etc. As noted from the results, the organs that lie near the radiation field will absorb amount of radiation dose and when the absorbed organ dose is higher the radiation risk will increase (direct proportional) and this note is in line with the BEIR VII report, which stated that the organ location to the primary beam and its sensitivity plays an important role in dose exposure and cancer risk. For example, the eye lens which is a radiosensitive organ is exposed to higher doses when it lies in the field during HNA scan it receives 27.7±16 mSv for total population of HNA scan, which is lower thanAlkhorayef et al. (2017) results that was (41.2) mSv. According to ICRP (2012) report, the threshold that produce radiation effect (cataract) to the eye lens is decreased from 5.0 to 0.5 Gy. Yet cataract effect is not cancerous compared to cancer effect caused by radiation. So that, the justification is needed for CTA procedures.

In PEA scan the higher absorbed dose was for breast tissue with equivalent dose of 14.2±6.4 mSv which is slightly higher than Alkhorayef et al. (2017)results of 13.3 mSv but it is also lower than chest CT scan compared with 15 mSv of Lahham et al. (2017),and compared to 17 mSv of Harun, Abdul Karim, Abbas, et al. (2020)studies results . Also, cancer probability was higher than eye lens and salivary glands due to higher absorbed dose. Therefore, a special concern should be taken into account for PEA procedures to young females to reducethe unnecessarily high radiation dose and probability of cancer.

In LLA scan the highest absorbed dose for total study population was for uterus and testes 17, 15.9 mSv respectively. Both organs are highly radiosensitive for female and male patients. Radiation risk was estimated using sex- averaged nominal risks and detriment for working age (18-80) population provided by ICRP (2007). According to Huda and He (2012), age in years plays an important role in calculation of cancer risk. For instance, there is a reduction in cancer risk by a factor of 5 when increasing patient age from 20 to 80 years.

The overall cancer risk per CTA procedure ranged between 23 and 40 cancer risk per 10^5 procedures of total study population which is within the range of Alkhorayef et al. (2017) results. The highest cancer risk was LLA (39.7×10^{-5}), PEA (28.8×10^{-5}) then HNA (23×10^{-5}).

This result could be interpreted to the fact that exposing the radiosensitive organs such as uterus, ovaries and testis to the primary beam will cause a higher effective dose compared to PEA and HNA.Also, the longer scan length could play a role in this result.

From the results of this study, it isclear that CTA procedures in standard protocols dose not associate with tissue reaction effect. For example, erythema and epilation that occur at 2 Gy threshold (ICRP, 2007).However, according to linear non-threshold model, cancer effect could occur at any tiny or large dose and results in cancer or genetic mutations. Thus, dose optimization and justification must be done of radiation protection during CTA procedure.

4.3Study Limitations

In data collection stage, there were some difficulties reaching the data cite due to Corona virus restrictions by putting a check point to enter the cities. So that, this cost a large effort and a long period for data collection. Moreover, because this study was a retrospective study, there were a missing scanning parameter that's restricted the data analysis to the available data. In addition,

the study sample resemble only adult patients in governmental sector hospitals, there is a need for further investigation for adult and pediatric age patients in both governmental and private hospitals. In addition, an obstacle of finding a software that is compatible with the study data and available parameters. However, the patient-specific organ dose was calculated using CT-EXPO software based on a mathematical method that were used to analysis the Germansurveydata of CT scan instead of the actual patient's body size.Thus, the uncertainties resulted from the different body habitus and the composition of each patient should be taken into consideration.

4.4Conclusion

In conclusion, results of ED values in Palestine for adult patients who underwent CTA examinations was withinUNSCEAR (2008) recommendation that stated "the average dose of CT procedures is around 10 mSv", since it was in LLA, PEA and HNA, 7.2±2.9, 5.2±2 and 4.18±2 mSv respectively for the total study population and ranging between 3 mSv and 13.3 mSv.

Based on hospitalsduring LLA protocol, the largest value of ED was Beit Jala Hospital (B.J.H) with 11.3±1mSv, Palestine medical complex Hospital (P.M.C) with 7±2 mSv then Rafedia surgical Hospital (R.S.H) with 4.79 ± 1 mSv in arterial phase and 4.68±1.1 in venous phase. In PEA protocol, the largest value of ED was also in Beit Jala Hospital (B.J.H) with 7.9±0.9 mSv, Rafedia

surgical Hospital (R.S.H) with 4.54±1 mSv then Palestine medical complex Hospital (P.M.C) with 4±1.9 mSv. While in HNA protocol, the largest value of ED in arterial phase was R.S.H with 5.5±1.5 mSv, B.J.H with 4.5±3 mSv then P.M.C with 3.3 ± 0.3 mSv.

The overall cancer risk per 100000 procedures for all CTA scans included in the study was 39.7±15.9 for LLA, 28±11.5 for PEA and 23±11.6 for HNA. These values are considered low-dose risk estimates due to results derived from Hiroshima atomic bomb data that reported, effective doses ranging between 5 to 50 mSv are associated with higher chances to increase risk of cancer mortality(Pierce & Preston, 2000).

Generally, radiation risks are related to the quality and quantity of radiation dose and patient age at exposure. So that, UNCEAR recommended radiation assessment for dose levels and to estimate radiation short and long effect (UNSCEAR, 2008).

4.5Recommendations

1) CTA scans should be requested by highly qualifieddoctors who have deep knowledge about ALARA principle, and about ED, cancer risks, or other stochastic and deterministic effects caused by high radiation exposure to maintain patient safety.

2) physicians, radiologists, and radiographers should have a continuous training about dose optimization for the patient and when to choose another nonionizing modality such as magnetic resonance angiography (MRA).

3) Radiation Safety Officer(RSO) is recommended

4) diagnostic reference level should be established in Palestine by conducting anational survey to unites average effective dose between hospitals for different scanners.

4.6Future study

A prospective study should be done to include all the parameters that were not included, either for without contrast or with contrast scan for all types of CTA scans. A study that focuses on physicianand radio0logist's knowledge of CTA scans doses in Palestine is recommended to justifythe increasing rate of requesting CT-scans in the last two years.

Ethical considerations

-To perform the study, the proposal was presented to Al-Quds University - Faculty of Health professions review board to gain agreement and permission.

- The Ministry of Health gave a permission to conduct the study in the governmental hospitals.

- The privacy of the collected data was maintained. By not mentioning names, patients ID number, or codes that could be referred to obtain detailed about personal information to a definite patient.
- The study should not present any conflict of interest.

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الجرعات الإشعاعية وتقييم مخاطر السرطان للمرضى الذين يخضعون لإجراءات التصوير المقطعي المحوسب للأوعية الدموية في فلسطين

إعداد: ريما عبدالله أحمد زعرور

المشرف: د .حسين المصري

الملخص

قد تتسبب إجراءات التصوير المقطعي المحوسب في مخاطر إشعاعية بسبب جرعة الإشعاع العالية المستخدمة في الحصول على الصور مقارنة بطرق التصوير التشخيصية الأخرى. حيث أنه في الدراساتالعالمية، كان هناك تباين كبير في قيم الجرعة المكافئة والتي تتراوح بين 2.2 الى 24.4 ملي سيفرت.

الاستخدام المتزايد للتصوير المقطعي المحوسب في فلسطيندفع الباحثين إلى إجراء تقييمات للجرعات ودراسات لمخاطر الإصابة بالسرطان. ومع ذلك، لا توجد دراسة سابقة أجريت في فلسطين تحدثت عن تقدير الجرعة الإشعاعية لفحوصات التصوير الطبقي للأوعية الدموية. لذلك يوصى بشدة تقييم جرعة المرضى لهذه الفحوصات في فلسطين.

الهدف الرئيسي من هذه الدراسة هو تقدير الجرعة الفعالة للإشعاع وخطر الإصابة بالسرطان للمرضى البالغين (18<سنة) الذين خضعوا لفحوصات طبقية للأوعية الدموية مثل فحص تصوير الرأس والرقبة للأوعية الدموية، فحص الجلطة الرئويةللأوعية الدموية وفحص تصوير الاطراف السفلية للأوعية الدموية في المستشفيات الحكومية المختارة. تم استخدام التصميم الكمي بأثر رجعي لإجراء هذه الدراسة. أجرى جميع المرضى البالغين (18< سنة) فحوصاتالتصوير الطبقي للأوعية الدموية المختارة في المستشفيات الحكومية الثلاثة. تم جمع البيانات من خلال نظامالأرشفة للصور والتواصلفي أقسام التصوير المقطعي خلال شهرين في المستشفيات المختارة.

كان متوسط الجرعة الفعالة المحسوبة عن طريق برنامج CT-EXPO في تصوير الأوعية الدموية للأطراف السفلية، الأوعية الدمويةللجلطة الرئوية وفحص الأوعية الدموية للرأس والرقبة كالتالي: 7.2±2.9, 5.2±2و 4.18±2 ملي سيفرت على الترتيب. ولمجموع مجتمع الدراسة للفحوصات الثلاثة كانت القيم تتراوح بين 3.3 ملي سيفرت و11.3 ملي سيفرت. كان هذا النطاق أقل من الدراسات الدولية.

بناءً على المستشفيات في بروتوكول تصوير الأطراف السفلية للأوعية الدموية، كانت أكبر قيمة للجرعة المكافئة لمستشفى بيت جالا بقيمة 11.2±1 ملي سيفرت في الطور الشرياني و 10.6 ملي سيفرت في الطور الوريدي، مجمع فلسطين الطبي تم عمله فقط في الطور الشرياني بقيمة 7±2 ثم مستشفى رفيديا الجراحي 4.79±1 ملي سيفرت في الطور الشرياني و 1.1±4.68 في الطور الوريدي. في بروتوكول تصوير الجلطة الرئوية، كانت أكبر قيمة للجرعة المكافئة أيضاً في مستشفى بيت جالا 7.9 ±0.9 ملي سيفرت، مستشفى رفيديا الجراحي 4.54±1 ملي سيفرت ثم مجمع فلسطين الطبي 4±1.9 ملي سيفرت. بينما في فحص

بروتوكول تصوير الرأس والرقبة للأوعية الدموية كانت أكبر قيمة لمستشفى رفيديا الجراحي بقيمة 5.5±1.5،مستشفى بيت جالا 4.5±3 ملي سيفرت ثم مجمع فلسطين الطبي 3.3±0.3 ملي سيفرت.

كان إجمالي مخاطر الإصابة بالسرطان لكل 100000 إجراء لجميع عمليات المسح المقطعي المضمنة في الدراسة 39.7±15.7 لتصوير الأطراف السفلية للأوعية الدموية، 28±11.5 لتصوير الجلطة الرئوية للأوعية الدموية ثم 23±11.6 لتصوير الرأس والرقبة للأوعية الدموية.

تعتبر هذه القيم التقديريةلمخاطر الجرعات منخفضة بسبب النتائج المستمدة من بيانات قنبلة هيروشيما الذرية التي ذكرت أن الجرعات الفعالة التي تتراوح بين 5 إلى 50 ملي سيفرت مرتبطة بفرص أعلى لزيادة خطر الوفاة بالسرطان.