ESTIMATION OF PATIENT RADIATION DOSES FOR SELECTED X-RAY EXAMINATIONS AND CENTRES IN NORTH-CENTRAL, NIGERIA

BY

KEHINDE, Olaide Odunayo
MTech/SPS/2017/6784

DEPARTMENT OF PHYSICS
FEDERAL UNIVERSITY OF TECHNOLOGY
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ABSTRACT

The risk of occurrence of cancer in developed and developing nations has become a major concern in the scientific and medical circle. Cancer induction is therefore one of the risk to guard against during medical X-ray exposure. Constant assessment of radiological procedure are thereby crucial in ensuring radiation doses to patients are as low as reasonably achievable. The aim of this study is to determine the patient radiation dose during some X-ray diagnostic procedure in selected centres in North central, Nigeria. These centres include; general hospital Minna (GHM), general hospital Ilorin (GHI) and general hospital Kubwa, FCT (GHK) with a total of 552 patients. The focus to skin distance (FSD), tube potential (kVp) and tube loading (mAs) were measured from the X-ray machine and used to calculate the entrance surface dose, effective dose, absorbed organ dose and the cancer risk index using the Caldose_X 5.0 software. The entrance surface dose (ESD) was also computed using mathematical formula for comparison purpose. Data on sex, age, body mass index (BMI) were recorded for the patients.The obtained results were compared with the documents of international atomic energy agency (IAEA) and other previous studies. The highest and lowest values obtained for ESD were7.10 mGy and 1.00 mGy for GHI and GHM respectively for Caldose_X software while for mathematical estimation, 6.76 mGy and 0.56mGy for GHK and GHM respectively. The effective doses (mSv) for GHI, GHK and GHM ranged from 0.28-0.66, 0.1-0.59 and 0.06-0.37 respectively and the pelvis and breast are with the highest and lowest absorbed organ dose of 2.82 mGy and 0.004 mGy for GHI and GHM respectively. The low dose obtained at GHM is traceable to good radiological practices. The absorbed organ doses when compared with international commission on radiological protection (ICRP) were all within the risk estimates of 35 cancer cases per million cases. The effective dose and ESD shows that for the exception of a few, the patients in selected Nigerian hospitals have their dose within established diagnostic reference levels. For radiation risks and variations in patients dose to be within the recommended limit, quality assurance should be emphasized.

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CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Radiation, radioisotopes, and fissionable materials have been of immense benefit to man in medicine, industry, research and power generation. The radionuclides involved include cosmic, which is believed to have originated at the birth of the universe, about 13 to 14 billion years ago, one source is the sun, which emits mainly alpha particles and protons which has increased in subsequent years due to advanced technology (Herman and Thomas, 2009).

According to Turner (2007), the largest proportion of total radiation in the environment comes from natural background (85%) which varies greatly from place to place, followed by medical (diagnostic X-ray, 14%). Environmental radiations, which are due to fallouts from testing of nuclear weapons, and released radionuclides from nuclear accidents, contributes less than 1%.

In November 1895, Roentgen's discovery of X-ray marks the beginning of ionizing radiation in modern Physics. After this discovery, X-ray rapidly became common in medical usage although it was not immediately obvious that significant or prolonged exposure could be harmful. However, after few years, patients and operator's record of skin burn became common which gave rise to measures to protect both patients and operators (Turner, 2007). X-rays are made up of X-radiation which is a form of electromagnetic radiation with short wavelength and high frequency. Its interaction with matter results in the transfer of some of its energy to the atoms and consequently removes electrons from it in a process known as ionization (Akinlade, 2011).

In medicine, diagnosis and therapy are two major uses of ionizing radiation. For diagnostic purposes, X-ray is used to detect; tumors, bone loss, dental issues and also to diagnose infection such as pneumonia, view bones fractures as they contain calcium with high atomic number and thus absorbs this X-ray efficiently. Diagnostic radiation has been a leading cause of man-made radiation exposure to the population (Sherifat and Oyeleke, 2009). Majorly, man-made radiation serves humanity through the use of several medical diagnostic devices, particularly nuclear medicine, X-ray and computed tomography with about 14% of the total radiation burden released from hospitals and medical research institutes (Turner, 2007).

World health organization's international agency on cancer classified X-rays as carcinogenic because the ionizing radiations involved are responsible for cancerous growth in biological cells. For this reason, cancer induction is one of the risks to guard against during medical X-ray exposure. The risk of cancer induction to an individual during a diagnostic procedure is likely small since radiation doses are typically low (usually <10mGy) as mandated by radiation monitoring and regulatory agencies (Mohamadain *et al*., 2015). However, a substantial number of cancer cases are caused by the vast number of people exposed annually to these small person threat, combined with growing exposure per examination and repeated procedure. The lifetime risk of developing cancer due to diagnostic X-ray is 0.6-3.2 % (Saeed, 2015) which can surface in an exposed individual's later years.

Patients' exposure to radiographic examination and radiation therapy has led to increased background radiation dose and radiation to patients and industrial workers, causing injury and clinical symptoms. Observed radiation injuries include chromosomal transformation, cancer induction, skin burn, cataract, infertility, genetic effect and death but still the health of the population would deteriorate without the use of ionizing radiation techniques to diagnose disease and detect trauma (Ibrahim *et al.*, 2014).

1.2 Statement of the Research Problem

Cancer has been recognized as a significant cause of mortality in developed and developing countries including Nigeria. According to Luntsi *et al.* (2015) and Adebamowo *et al.* (2017), the prevalence of cancer in the northern part of Nigeria is at the rate of 12.5% out of 20.7% total incidence. According to the International Atomic Energy Agency (IAEA, 2007), a common factor responsible for high rate of cancer occurrences is exposure to medical ionizing radiation source which provide by far the greatest contribution to artificial population dose (Basmor *et al.*, 2018). About 90% of this contribution comes from diagnostic X-rays Akinlade (2011), revealed that about 70% of Nigerian population undergo X-ray examination either for admission into secondary and tertiary institution, employment or for medical purposes. This continuous exposure has increased the likelihood of cancer occurrence among the Nigerian population. For every X-ray examination a patient undergo, millions of photons (packets of energy) that pass through the body have the potential to damage molecules in the deoxyribonucleic acid (DNA) resulting in the induction of a carcinogenic process (Turner, 2007). Even though the risk to an individual patient may appear not to be significant, it is imperative to understand how much dose the radiation medical imaging delivers in order to establish a balance between the benefits and any likely potential health challenge from X-ray examination processes.

1.3 Justification of the Study

Emphasis placed on justification of diagnostic examination in radiology centers outweighs the optimization of the protection of patient during each examination. Notwithstanding the benefit of radiation in terms of diagnosis and therapy, the aim of achieving quality images have resulted into exposing patients to high radiation dose from repeated procedures. Medical personnel and patients are continually exposed to high radiation burden, therefore, estimating patient dose will provide a means of checking standards of good practice and assist in maintaining dose of exposure to patients to as low as reasonably achievable (ALARA).

This study will also generate organ and tissue doses in some Nigeria diagnostic centres which can be used as basis for future study.

1.4 Aim and Objective of the Study

The Aim of this research is to determine patients' radiation doses for selected X-ray examinations and centres in North central Nigeria.

The objectives of the study are to;

(i) collate X-ray examinations performed on patients

(ii) estimate the entrance surface dose, effective dose and absorbed organ dose for exposed patients using Caldose-X 5.0 software

(iii) compute the cancer risk index for the patients based on data .

1.6 Scope of Study

Adult (male and female) patients are the main sample population in the research. Children are not considered because of their low demand generally for X-ray examination. Quantities for the estimation of patient dose includes the entrance surface dose, effective dose and absorbed organ and tissue dose shall be considered in this study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Radiation Detriment

Since the discovery of X-ray and its uses for medical purposes, the medical imaging technology has evolved rapidly to the stage where three dimensional images of many part of the body can be obtained in full details in a few minutes. Some of these X-ray imaging equipment include fluoroscopy, computed tomography, the mammography machine, and the conventional radiography. The fluoroscopy machine is the use of higher doses to produce live images of internal structures. It is useful in assessing stomach and bowel movement and to detect obstructions in blood vessels, this is carried out by displaying the organ on monitor screen, which should only be used when radiography will not provide the required information.

The computed tomography is another X-ray machine with appropriate shape and intensity distribution and ability to rotate around the body of patient and typically used to determine tumor, bone trauma. Mammography on the other hand is an X-ray machine which uses low doses to examine human breast to detect and diagnose several breast disease especially cancer. With an early detection, it saves lives through increase treatment options but which economically developing countries still struggles with its cost and lastly the Conventional radiography which is the main focus of this research is the use of high energy radiation to visualize internal structures to reveal abnormalities in bones, lungs, heart and certain body tissues (Akinlade, 2011). In some cases, that is all that is needed to diagnose and assess presenting symptoms while more advanced imaging methods are required for precise and further evaluation in other cases.

2.1.1 Acute radiation syndrome (ARS)

This is an effect of radiation which occurs in a person that receives a large, whole body dose of radiation at a single instance, such as the survivors of Hiroshima, Nagaski atomic bombs, and the first responder in the Chernobyl and Fukushima Nuclear Power Plant. This results in simultaneous damage of vital tissues and organs which results in nauseating, loss of appetite, sweating and tiredness. Depending on the dose received, symptoms manifest within minutes and days after exposure. ARS can either be very severe or mild, as very severe symptoms could indicate a minimal survival for the individual. Specifically 0-1mGy would cause no significant effect while 1-3mGy will experience mild symptoms and 3-6mGy will result in severe effect plus fatalities and lastly impairment, incapacitation and eventual death is expected for an individual exposed to dose above 6mGy (Turner, 2011)

The radiation dose received from medical diagnostic X-ray such as the one considered in this research are too small to produce ARS

2.1.2 Stochastic effect

This is an effect of exposure to radiation with no particular threshold. The occurrence increases with increasing dose and no detectable short term radiation effect is visible as its severity in an exposed individual does not depend on the dose absorbed. This effect surface when irradiated cell is changed instead of being killed, these modified cells thereby develop into cancer which usually takes longer time to become evident. Due to human body's repair mechanism, it is quite improbable at small doses as damage to the DNA of even a single cell can lead to cancer, however there is no proof of a dose level below which cancer cannot occur (Turner, 2011).

This effect can be sub-divided into; Somatic and Genetic effect.

(i) Somatic effect is a lifetime effect in the exposed individual such as sterility and cancers and it is limited to the exposed individual.

(ii) Genetic effect is the mutation in the genes and DNA of the irradiated individual due to alteration resulting from breakage or damage in the chromosome and errors in rejoining of broken chromosomes (Turner, 2011) which consequently result in hereditary defect in offspring and descendant of the exposed individual.

2.1.3 Deterministic effect

This is a threshold dose characterized by radiation effect. The effect is not observed until the threshold dose is reached (The threshold dose is subject to biological variation). When a person exceed the threshold dose, the severity of injury increases with increased dose. At an exceeded threshold level of mostly ≥0.1Gy of an absorbed dose, symptoms ranging from eye cataract from about 2Gy, up to central nervous system death for doses above 20Gy. Upon exposure, other common occurrences includes reddening of the skin, nausea, are clinically evident in a limited time in the exposed individual which means the severity depends on the dose. Occurrences after months or even few years after exposure are possible such as the survivors of atomic bombing or radiation accident (Little, 2004)These occurrences are mainly due to cell death or delayed cell division caused by the high level of radiation exposure as the tissue being exposed is at the risk of impairment if extensive enough.

2.2 Cancer Rate in Nigeria

Cancer in developed and developing countries has been a major burden. Its increasing nature, a result of cancer-associated lifestyle which man has imbibe such as smoking, western diets, physical inactivity (Ahmedin *et al.,* 2011), others include aging, family history, alcohol consumption, low socio-economic level and exposure to ionizing radiation Akinlade, (2011) revealed in her study that about 70% will undergo X-ray examination, which is the most regular way of exposure to ionizing radiation out of a group of 100 Nigerians in their lifetime either for admission into secondary and tertiary institution, employment or medical purpose.

Lack of statistics in Nigeria, Africa and other developing countries of the world has made the information, prevalence and mortality of cancer unknown. In Nigeria, there has only been case series report, medical statistics, death records, hospital-based cancer registries such as the Ibadan Population Based Cancer Registry (IBCR) located at the University College Hospital (UCH) in the ancient city of Ibadan, Oyo state and the newly founded Abuja Population Based Cancer Registry(ABCR) located in Abuja, FCT (Ahmedin *et al.*, 2011).

The occurrence of cancer has taken a widespread as research reveals 8.8 million cancer deaths globally per annual out of which Nigeria experience 80,000 morbidity annually. Nigeria is predicted to expect 75% increase in cancer induced death come the year 2030 as it happens to be a member of the low income countries and a level IV health care sector (Ogundare *et al.,* 2004), with fewer than 30% having access to cancer diagnosis and treatment services. Available data shows that cervical cancer which basically is 100 percent avoidable kills one Nigerian woman every hour, breast cancer kills 40 Nigerian women daily whilst prostate cancer kills 26 Nigerian men every day, these three popular cancers kill 90 Nigerians every day. This calls for the Federal Government to establish various professional bodies such as The Society of Oncology, Cancer Research of Nigeria, Nigeria

Cancer Society, and Union of International Cancer Control to see to the diagnosis, the spread and treatment as duly necessary.

2.3 System of Radiation Protection

Radiation protection is a tool to protect against the risks (for people and environment) generated by the use of ionizing radiation, according to International Commission for Radiological Protection (ICRP) (Herman and Thomas, 2009), some underlying principles were recommended to ensure patients are protected from radiation damage, namely justification, optimization and dose limit.

2.3.1 Justification

Justification is the process whereby the potential benefits of a procedure overweigh possible harms associated with such exposure, thus implying that the essence of the radiation exposure to the patient is identified.

2.3.2 Optimization

Optimization is such that the dose from an exposure to the patient is the lowest necessary to fulfill the clinical aim, this is known as the ALARA (as low as reasonably achievable) principle as economic and social factor is being taken into consideration. To ensure this, standard equipment, proper operational parameters for diagnostic procedures, regular periodic monitoring of the performance of radiological equipment, clinical dosimetry and adequate quality assurance should be put in place to improve performance improvement of the whole radiological process (Iyang, 2015).

2.3.3 Dose limit

This is the dose applicable to individuals as a result of practices being exposed to such as the radiation workers, miners and general public. It is a measure put in place to ensure that the radiation dose accumulated by workers during their normal working hours does not exceed the recommended effective and equivalent dose limit. The effective dose limit for occupational workers is 20 mSv per year, averaged over 5 consecutive years and equivalent dose limit is 50 mSv in any single year while for the general public 1mSv is the required dose limit. Although in special circumstances, an effective dose of up to 5mSv in a single year is possible provided that the average dose over five consecutive years does not exceed 1mSv per year (Mohammed, 2017).

Another significant factor in the protection of patients is to ensure that images of adequate sufficient quality are generated for accurate diagnosis without the need for any repetition which means there is a need for trained and experienced staff with robust operating procedures.

2.4 Quality Control and Quality Assurance

Quality Control which is known to predict the radiographs that satisfies set clinical target (Egbe *et al*., 2009) is also a necessary procedure which includes; maintenance checks, image quality, adjustment of the output parameters, electrical, mechanical and dosimetry which all should be put in place for maintenance and monitoring of equipment of an X-ray system in order to ensure optimal performance. During this process, malfunctioning of any kind is identified and appropriate measures are ensured.

Akpochafor *et al.* (2016) carried out his research on the QC of radiology facilities in southwestern, Nigeria and it was understood that irregularities in QC is the cause of failed tube voltage (kVp), resulting in the production of lower energy and thereby causing increase in patient dose and repeated examinations.

The goal of every quality control, according to Ishiekwen and Aliyu (2018), when they carried out their study in the North eastern part of Nigeria using the multi-function QC kit, RMI model 181B, with kV, mA and timer accuracy meters and compared their result with Association of American Physicist in Medicine (AAPM) besides dose reduction, reduces cost through the elimination of unproductive imaging caused by inefficiency of the devices used during radiographic procedure. The absence of QC records in any hospital probably indicates lack of institutional QC program resulting in unproductive exposures to the population of the state.

Quality Assurance is a logical step focusing on image quality and patient dose which is an important item to be considered in a radiological diagnostic examination. Variation has been discovered among different radiology facility and even different rooms in the same radiology facility, and also for different patient with the same BMI, this has only suggested one thing, optimum patient protection technique is not in use.

These variations suggested that a good imaging procedure was needed to minimize patient doses to the lowest possible levels consistent with the medical examination's clinical intent. QA has therefore helped to ensure the quick discovery in the inconsistencies and error in techniques and equipment (Saeed, 2015). A number of studies have presented its utilization and emerging modalities but unfortunately, a supposed QA in radiology has been taken over by the testing of radiographic equipment and thus neglect to the evaluation of image quality and patient dose.

2.5 Factors Affecting Patient's Dose

The diligence on the part of the Nigeria Nuclear Radiation Authority (NNRA) to ensure optimization has been on the increase as awareness to the danger of ionizing radiation in human and bringing into effect a substantial reduction in radiation dose. All radiological facilities in the country cannot be said to have undergone the necessary Quality Control and Quality Assurance as in the case of many third-world countries. Variation in patient dose can be attributed to some factors which include: patient size, exposure parameters, focus-to-skin distance (FSD), total filtration, collimator, image quality, choice and year of equipment and others. These factors are discussed below.

2.5.1 Exposure parameters

These are factors generated from the X-ray machine before diagnostic examination could take place and are responsible for determining the quality and quantity of X-radiation absorbed by the patient in the process of a radiographic procedure. They are the current-time product (mAs) and the peak kilovoltage (kVp).

The kVp which ascertain the penetrating ability of X-ray beams is an important factor of an X-ray machine that ensures accuracy and consistency in diagnostic imaging as well as controlling of the patient radiation dose. In a typical X-ray tube, X-rays produced are bremstrahlung which are usually spectrum of energies ranging from zero to the applied voltage. At the increase of electron energy, the efficiency of bremstrahlung production thus increases rapidly therefore this tube potential determines the proportion of high energy photon in the X-ray beam. The tube potential selected for each examination depends on the imaged body part, patient size, the required information, the image receptor and the display method. Research has shown (Olarinoye *et al.*, 2010) that increase in the tube voltage reduces patient dose and also in the process increases the beam intensity or exposure rate Akpochafor *et al*. (2017) conducted a kilovoltage QC on 23 X-rayunit in Jos, Nigeria whose result shows 60.87% total compliance and 39% non-compliance to set standards. This poor result was attributed to poor maintenance and also to the fact that most of these radiological centres have no qualified personnel (medical Physicist) to carry out adequate quality control on the machines and most of the units (≥ 50%) are over ten years of age and as peak kilovoltage failures are known to results over time.

The kVp chosen for a given projection is under the control of the radiographer, within the constraint of the examination type and policy of the institution. Minimum patient dose is generally obtained at high kVp with corresponding low mAs values or vice versa (Esen and Obed, 2013; Inyang *et al.*, 2015). However, the kVp chosen has to be matched to the screen and film combination, the degree of contrast preferred by the radiologist, the required projection and the fact that kVp settings varies with different institution suggests that in many cases are not optimized.

The current-time product as its name implies is the current responsible for the emission of electron from the filament over a set amount of time(s) which is the electron production duration in a process known as thermionic emission (Akinlade, 2011). An increase in current-time results in higher production of electron inside the X-ray tube.

Radiographers are therefore constantly faced with the challenges of minimizing patient dose, and still using exposures that are high enough to produce good quality images so as to provide a proper diagnosis. Therefore, accuracy achieved from any selected exposure factor can be said to be dependent on other several factors alongside the optimal functioning of an X-ray machine (Akpochafor *et al*., 2016)

BasMor *et al*. (2018) estimated adult patient doses for chest X-ray, examination and compared with diagnostic reference levels (DRLS). Using (IAEA) and Davies model, the result obtained was within DRLS except for a few centres and thus the low doses were attributed to low exposure factors, higher value layer (HVL) and FSD as radiographers concentrate more on adjusting the X-ray image brightness.

2.5.2 Size of the patient

Study has shown that the measurement of ESD can be compared with the patient's thickness as increase in the thickness of the section to be presented for examination will determine the quantity of X-ray beam required to pass through the patient. An increase in radiation energy will enable deep penetration of the X-ray beam in the required projection, giving a quality image, all at the cost of a larger dose to patients.

Other evidences such as one investigated by Pollet (1994) in Table 1 reveals the effect of patient dose and mAs with patient's BMI.

Table 2.1: Effect of patient's BMI on ESD and effective dose for selected projection

BMI	mAs	ESD (mGy)	Effective dose (mSv)
13	43	1.67	0.161
17	110	4.5	0.216
22	314	13.74	0.293

Source: (Pollet, 1994)

2.5.3 Focus to skin distance

The inverse square law which depict that the inverse square law where intensity I, decreases as the square of the distance, d increases $\left(I = {}^{1}/_{d^2}\right)$, hence there is greater radiation dose at the focal point.Increase in the distance between the focal point and the patient entrance surface reduces the intensity of the energy of the X-ray beam and since the dose to the image receptor must be constant this therefore results in the reduction of the patient dose.

2.5.4 Filtration

Filtration is the process employed to prevent unwanted and less penetrating energy from entering the patient and producing cleaner image by absorbing lower energy as such absorption by patients only increases the dose. Material such as Al or Cu between the X-ray tube anode and the patient is known as the filtration material. The total amount of filtration in a given X-ray machine is generally specified in terms of an equivalent Aluminium thickness with US guidelines stating minimum total filtration of 2.5mmAl for X-ray tubes which usually operates above 70kVp (Bell and Goe, 2018). The two types of filtration in an X-ray machine are; added and inherent.

Inherent filtration: the X-ray tube is known to have an in-built internal casing with 2.5mmAl as the smallest amount of total filtration which is a recommended value by NCRP.

Added filtration: in the X-ray beam, a thin sheet of metal is inserted which is equivalent to 0.5 - 1.0mmAl

Table 2.2. Standard recommended filtration

KVp	Filtration (mmAl)
30	0.3
50	1.2
70	1.5
90	2.5
110	3

Source: (Akinlade, 2011)

2.5.5 Image quality

X-ray film serves as archival medium and a display device Radiographic procedure. Its quality is therefore dependent on the equipment specificity, the imaging method and the selection of variables. An image quality consists of five components which are contrast, blur, noise, artifact and distortion (Akinlade, 2011).In developing countries of which Nigeria belongs, the tremendous amount of waste due to poor quality of images should be of concern with a reported number of 15-40% of poor quality from all images reported from earlier studies (Muhogora *et al.*, 2008). It is revealed that changes in radiographic techniques, tube voltage, positioning, tube current-time product and staff experience are major causes responsible for poor quality of image which usually results in film reject. For every film rejected, there is always a second or third exposure which could be detrimental to patients' health.

Not enough importance has been given to film rejects which ensue from the quality of radiographic images as related to the established patient dose levels in previous studies. Therefore studies has revealed a considerable improvement in image quality after QC and QA by ensuring that radiation protection is put as foremost consideration and image quality is not as good as possible but as good as necessary with adequate quality for exact diagnosis without the call for repetition.

2.5.6 Collimation

Collimator is the moveable part on the lower side of an X-ray tube through which the X-ray beam is emitted. In practice, this is equivalent to choosing a film size to cover the region of clinical interest and then collimating the beam to the film size The collimator size is directly proportionate to the amount of scattered radiation available during an X-ray procedure, such that increase in collimator size would increase scattered radiation and reduce image contrast thereby leading to a poor image quality as any X-ray beam that falls beyond the image receiver region is totally wasted and contribute to scatter and fog level. Essentially, to cover a specific region, the collimator should be adjusted in such a way that the field size of the patient corresponds to the area under examination. By this practice, exposure of patient to unwanted radiation and scattered radiation that could affect the image quality is greatly reduced.

A major effect related to collimation is the somatic or genetic dose index, particularly if the organ of interest is adjacent to clinically relevant areas such as the female breast, gonads or thyroid (Pollet, 1994)

Collimation should always be of concern as visualization of the collimator edges on the image indicates that no unspecified part of the patient is vulnerable (Osman *et al.*, 2010)

2.5.7 Choice of equipment

Within the guidelines set by the X-ray facility, the radiograph has a range of technical available, the equipment available have a considerable influence in the way the examination is performed and on the dose of the patient.

Use of inadequately powered generator with low rated X-ray tubes result in poor radiographic technique thereby leading to high ESD and geometric distortion as a result of such machines having short focus distance. Excessive exposure times may be required leading to possible patient movement blurring and retake, in a misguided attempt to increase the X-ray output of a low powered machine, filtration may be reduced again increasing ESDs.

2.6 Radiation Dose to Patient and its Associated Risk

Since the discovery of ionizing radiation, risk has been known to be associated with it. Risk is the quantitative function of exposure and biological effect (Akinlade, 2011).Its known process of removing an electron from the atom or molecules from the propagated medium also changes living materials causing damages to cells and leading to cancerous growth or inherited diseases. Other problematic conditions could be severe mental retardation and reduction in IQ of fetus of an exposed patient.

As earlier stated, nuclear medicine is the highest man-made source of ionizing radiation encountered in the process of radiology diagnosis and radiotheraphy. Unlike the natural source of ionizing radiation, only the exposed individual directly benefits and is also at risk of doses received.

The philosophy of radiation protection practices is centered on the idea that irrespective of the quantity of a radiation dose is, biological detriment and health effect is still likely to occur as increasingly high doses per examination resulting from repeated procedure and such alike could translate into many cases of cancer and other established effect.

2.6.1 Determination of effective dose from radiation exposure

Effective dose, a concept introduced by the ICRP for the radiological safety of staff and the public at large from cancer and hereditary effect (Ernest and Darko, 2013). It is a calculated quantity that cannot be measured and since direct method is not possible, several methods ranging from Monte Carlo, Dose Area Product Meter, Computer Model, Personnel Radiation Dose Calculation are being used in estimating patient's effective dose. Although it is used to compare relative detriment between procedures that utilize ionizing radiation, it cannot be used to determine individual risk. Hence, in diagnostic radiology, risk assessment is better based on suitable risk coefficients for the individual tissues at risk, putting into consideration the age and gender distributions of people undertaking the medical procedure. Muhogora and Nyanda (2001) envisage the effective dose as the quantity employed to estimate the stochastic effect of ionizing radiation. They described the reduction of current-time product, increase in filtration, tube voltage and speed of film screen are factors contributing to reduction in effective dose.

Paydar *et al.* (2012) estimated the effective dose of digital chest radiography of an adult male phantom, using the monte-carlo programe (MNCP) simulation. Comparing their result with the Iranian national dose reference level (NDRL) reveals increase in effective dose with increased tube voltage.

Other factors include Patient size, examination technique, technical skills are contributory factors affecting effective dose estimations (Ernest and Darko, 2013). In order to quantify the stochastic risk, a most complete and preferable approach for risk estimation is accurate expertise of all relevant dose of organs and the suitable risk ratio for an individual patient submitted for a radiological procedure, it is necessary to determine the age, gender, tissue and organ specificity and multiply this with the mean corresponding organ or tissue. While there are established calculative processes for effective dose, they are heavily dependent on dose assessment capability for radiosensitive organs from radiological procedures where the weighting factor is the radiation drawback for a given organ as a proportion of the overall adverse radiation.

Turner (2011) described that although the body tissue react to radiation in diverse ways , the likelihood for stochastic effects resulting from a given equivalent dose depends on the tissue or organ irradiated. In order to take these variations into account, ICRP and NCRP have assigned dimensionless tissue weighting factors $W_T$which add to unity when summed over all tissues T as described in equation (2.1).

$$E = \sum_T W_T H_T \qquad (2.1)$$

where,

W_T is the tissue weighing factor

H_T is the equivalent dose

The equivalent dose H_T in a given tissue, weighted by W_T, gives a quantity intended to equate with an individual's overall detriment, irrespective of T. The drawback involves the multiple risk of cancer mortality and morbidity, serious genetic consequence and the resulting period of life lost.

Meanwhile, McCollough and Schueler (2000) described the effective dose as a means of measuring radiation detrimental to partial body irradiation as a result of body-wide irradiation results. Preferred and most rigorous risk assessment method is accurate knowledge of all specific organ doses and the correct risk coefficient for the specific age, sex and organs were seen as a complete approach for risk. Following the practices of International Commission of Radiation Protection (ICRP) and United Nation for Scientific Energy and Atomic Radiation (UNSCEAR), effective dose can be used in patient populations for the purposes of

1. Evaluating the relative drawbacks of non-uniform, selective-body irradiations,
2. Modifying radiological techniques involving different body organs or tissues.

For practical estimation of effective dose, methods based on human body mathematical models with different amendment to take into account variation among gender, adults and children have been established.

Ernest and Darko (2013) therefore indicated that dose-area product (DAP) or entrance surface dose (ESD) which are observable quantities can be used for organ dose estimation. Due to factors earlier mentioned, it is commonly observed that calculated effective dose varies even for similar radiological procedures and thus it is tough to compare the dose. However, as effective dose takes into account estimates of relative biological risk which has developed over time, and is not a measurable metric that can be calculated or checked directly, there is no true value for the effective dose from an analysis

According to Mettler *et al.* (2008), the effective dose which is used to allow a comparison of the harm between procedures that use ionizing radiation should not be used to determine individual risk as this is best assessed by determining the average doses to all the individual’s radiosensitive tissues and combining them with age and sex. A clinically based anthropomorphic phantom with internal dosimeters or Monte Carlo computer programs can be used to estimate organ-specific ingested doses. These phantoms and programs represent a standard patient and are valuable means of gathering data over time.

2.6.2 Estimation of entrance surface dose

The evaluation of entrance surface dose is necessary to determine patient's risk and establish dose constraints since the exposure is highest on the surface where radiation reaches the patient's body. Several works has been done in assessing the patient dose in radiographic examination both home and abroad (Shrimpton *et al.*, 1988., Stamm and Saure., 1998; Sharifat and Olarinoye, 2009; Osman *et al.*, 2010; Saeed, 2015; Alatta *et al.*, 2017).

Suliman *et al.* (2006) carried out a survey in Sudan in anticipation of optimizing the protection of patients from radiation with the use of established formular. His estimated result was compared with related works in Nigeria and international established diagnostic reference level, the ESDs measured are 24% lower than the values that should have been measured according to the normal patient size used in related works.

Akinlade (2011) carried out a research on the effect of radiation associated with diagnostic X-ray examinations alongside its detriment to health at four centres in Nigeria. ESD and ED was estimated using PCXMC program and obtained results were compared with similar examinations in published studies. From estimated ED in some of the selected facilities, the risk of fatal cancer was higher than the ICRP recommended limit. This could serve as an update to existing data on patients' radiation dose from diagnostic X-ray procedures in Nigeria and measures in assessing the detrimental effect to health (such as fatal cancer) of radiation associated with diagnostic X-ray examination of different regions of the body.

Ogunseyinde *et al*. (2015) compare the entrance surface dose and backscatter factors of some selected X-ray examination in southwestern, Nigeria with CEC reference doses. A well annealed TLD-100 LiF were used and their results indicated that there are radiographic examination that have ESD to be greater than the CEC reference doses.

Alghoul *et al*. (2017) with the use of mathematical evaluation, investigated the entrance surface dose of patient during a diagnostic X-rays procedure for five different projections in Sebbha city of Libya. The mean ESD values which were 41.73±5.84 mGy, 7.43±2.58 mGy, 103.7±125.53 mGy, 7.25±4.32 mGy and 11.24±16.18 mGy respectively for Pelvis (AP), Chest (AP), Lumbar Spine (AP), Cervical Spine (AP) and Skull (AP) were observed to be higher than the average ESD standard values suggesting the need to reduce the patient dosage to the appropriate level recommended by ICRP.

Entrance surface dose as defined earlier is the absorbed dose to air on the X-ray beam axis at the point of entrance of the X-ray beam to the patient or phantom alongside the backscatter factor. Literature has revealed significant disparity in entrance surface dose for the same diagnostic examination between one radiological facility to another which has brought about the existence of QC and QA to ensure adequate optimization. There are several methods by which entrance surface dose can be estimated, from the use of TLDs, Monte Carlo simulations, Dosecal, CALDose_X software programe and the use of a semi-empirical formulae..

Muhogora and Nyanda (2001) investigated the measurement of entrance surface dose with the use of LiF thermoluminescence, a well-calibrated dosemeter. Their study have also buttress the fact that the reduction of current–time product and increase the speed of the film–screen combination result to a reduction of effective dose by the same factor and also does a small increment of filtration and/or optimally increased tube voltage. Therefore, the reduced ESD achieved in their study imply a reduction of effective dose to patients undergoing diagnostic X-ray procedures. Dose reductions between 4% and 73% were achieved and contrasted well with the recorded dose reductions between 10% and 60%. It was concluded that there is a substantial potential for dose reduction in Tanzanian Hospitals and as a result, the risk of radiation to patients can also be practically reduced as the radiology departments pursues to achieve a dose reduction.

Ogundare *et al.* (2004) investigated the ESDs of patient undergoing pelvis, abdomen and lumbar spine diagnostic X-ray examination in Nigeria using a thermoluminescent dosimeters (TLDs) The findings showed that, in most cases, the individual ESD values were found to be comparable and higher than, those of Ghana and Tanzania, respectively for each of the test. The mean ESD values are also found to be within the range of mean ESD values previously reported from non-Africa countries. Compared to the European Community (EC) reference values, mean ESDs were found to be below the reference values in only two hospitals. The ranges found in their research were high and thus suggest that more attention needs to be paid to X-ray facilities in the region. This also suggests that the review of radiographic procedure is pivotal for radiographic department in order to get their doses to optimal level.

Muhogora *et al.* (2008) in a multinational prospective study, patient radiation exposures have been studied in 12 countries in Africa, Asia, and Eastern Europe, covering 45 hospitals. The unsatisfactory number of images and the grade of image quality were noted and reasons for poor image quality were investigated. The entrance surface doses for adult patients were calculated from the entrance surface air kerma on the basis of X-ray tube output measurements and X-ray exposure parameters. Patient doses ranged by a factor of up to 88, but the majority of doses were below diagnosis reference point. Comparison with other studies indicates that patient dosage rates in these countries are not higher than those in developed countries. For a particular radiographic examination, the X-ray tube output and mAs used in the radiographic examination determines the incident air kerma for each patient and then multiplying this to the appropriate backscatter factor (BSF) results in the entrance surface air kerma. Hence, the study counterfeited the common assumption that developing countries have higher patients' radiation dosages than developed countries.

It was understood that the correct functioning of members of the radiology team contribute immensely to the principles of good imaging and not restricted to machine inspection and QC tests as usually seen. Nevertheless, the magnitudes of patient doses in developing countries were not higher than doses in developed countries and in some cases were actually low

2.6.3 Absorbed radiation dose to organs and tissues

When different tissues interact with ionizing radiation, the observable biological responses differ. When any part of the body is exposed to radiation and these tissues interacting with ionizing radiation, the stochastic effect experienced by the tissues involved is a function of the density of the tissue and equivalent dose received. (Akinlade, 2011). Calculation of effective dose entails the summation of radiation dosage to several organs in the body as it is impractical to execute in-vivo analysis of radiation doses to about 25 organs and tissues present in the body of man.

Ogundare *et al*. (2009) conducted the research on a total of eight organ dose of chest, skull and abdomen radiographs in two Nigerian X-ray facilities. This was analysed using the product of air kerma and conversion coefficient factors from published literature. Organ doses varies between <0.01 to 2.18 mGy in abdomen examination, <0.01 to 0.20 mGy and

<0.01 to 3.90 mGy for skull and chest examination respectively. Except for the fact that the organ dose is higher in one facility than the other, no major variation exist between the male and female organ dose.

Similarly in Nigeria, Esen and Obed (2013) investigated the seven organ doses of a thorax examination for 102 patients with the use of a Caldose_X5.0 software. The highest organ dose of 270 μGy was found in the adrenals for thorax PA and Liver (263 μGy) for thorax RLAT, as a result of these values, quality assurance program (QAP) was recommended for diagnostic X-ray facilities in Nigeria hospitals.

Inyang *et al.* (2015) evaluated one thousand five hundred and forty-one (1541) patient's organ dose using the Caldose_X software from nine random hospitals in Nigeria. Five specific organs were estimated and the result ranged from 0.01-0.38. The age range of patients in this study is 18-75 with a greater percentage in their fertile stage and thereby making them susceptible to radiation-induced hereditary effect. Therefore adequate radiation protection was recommended during the process of an X-ray examination. Some other methods used in calculating are discussed below;

2.7 The Use of Caldose_x Software Program

The software (CALculation of DOSE for X-ray diagnosis) package developed by J.C. Leron is used to analyse the entrance surface kerma and incident air kerma, the two significant parameters used in diagnostic X-ray procedure. The software created with the use of FAX06 and MAX06 phantoms for female and male respectively which consist of organs and soft tissue whose masses is according to the reference data of ICRP89. It uses the conversion coefficient to evaluate the dose absorbed to patient's organ and tissue as well as the effective dose and patient's cancer risk during a radiographic procedure

(Kramer *et al*., 2008). It's been widely accepted by researchers (Esen and Obed, 2013; Inyang *et al.*, 2015) and hospitals due to its ability to assess ESD and as such considered extremely reliable. It can determine absorbed dose within the range of 50-80mGy with efficiency within 20% as compared with the use of thermoluminescence dosimeters (TLDs). The input data needed to run the program are; the peak kilovoltage (kVp), current-time potential (mAs), FDD, filters, backscattered factor (BSF) is calculated automatically after all data has been inputted manually in the programme. It has been useful in education designed for training technicians, radiographers and radiologist to comprehend the minimum exposure to patients during X-ray procedure as the radiation risk depends on appropriate selection of exposure parameters.

As compared to MIRD5-phantoms used in DOSECAL software for diagnostic radiology, two improvement has occurred with the use of CALDose_X software:

Firstly, is the use of the two adult phantoms which has allowed the calculation of the absorbed dose to organ and tissue represented with true human anatomy and also the right calculation of the sex-specific effective dose according to ICRP103.

Secondly, the evaluation of cancer risk provides an alternative to the effective dose, which cannot be used for an individual patient. The ICRP is currently preparing the publication of the adult reference computational phantoms

2.8 System of Calculation

The semi-empirical formular is an indirect method of measuring patient dose through the evaluation of entrance surface dose (ESD) which is recommended by the International Atomic Energy Agency protocol and code of practice (Esen and Obed, 2013)

$$ESD = Y(d) \times \left(\frac{kV}{80}\right)^2 \times \left(\frac{100}{FSD}\right)^2 \times mAs \times BSF \qquad (2.2)$$

where;

Y(d) is the radiation output $\frac{mGy}{mAs}$ for different types of xray machine, as radiation output Y(d) for single phase, three phase and high frequency generators X – ray machines are given as;

$3.27\times 10^{-4} mR$, $5.22\times10^{-4} mR$ and $6.53\times10^{-4} mR$ respectively

These values are multiplied by 0.00877/mAs to convert from milliroentgento air kerma in mGy/mAs.

Where Output is the output in mGy/mAs, of the X-rays tube at 80kV at a distance of 1m normalised to 10 mAs

kV - tube potential

FSD - focus to skin distance (cm)

mAs - tube current product (mA) and the exposure time (seconds)

BSF - the backscattering factor.

2.9 Current status of radiological practices in Nigeria

Ahidjo *et al*. (2012) assessed doctor's knowledge of the radiation which they referred their patients to undertake and it was realized that only 23.1% of them could ascertain the deterministic and non–deterministic effect of the radiation these patients are exposed to and most of the doctors have poor knowledge and therefore submit their patients to a radiation dose that is 16 times larger than necessary. Recruited radiographers also agreed to the fact that regulation of maintenance on the energy output of their X-ray machine has not been timely, and recurring breakdown as a result of power loss with no maintenance checks exceeding repair is reported. X-ray machine age contributes to image's poor quality as most developing nations still use very old, almost outdated or refurbished X-ray machines and devices.

Akpochafor *et al.* (2016) reported that over 4000 diagnostic X-ray devices in Nigeria with $< 5\%$ of them are under any sort of regulatory authority and also Eze *et al*. (2011) described how many public and private hospitals in Nigeria, with the aim of conserving funds and improve profits lead to different types of practices that are detrimental to health. Some junior staffs are employed with little formal education and they function with the little in-house training and experience acquired at the workplace. The use of protection accessories by the radiographers during an examination is not taken into full consideration despite the availability of these accessories as most workers thinks this ionizing radiation detriment are being overrated.

2.9.1 Compliance status

With the establishment of X-ray radiodiagnosis devices in the University College Hospital Ibadan, which comes with the need to control the use of both the ionizing and non-ionizing radiation during the process of radiodiagnosis coupled with the monitoring of radioactive fallout, the Federal Radiation Protection Services was established by Act of parliament in 1964.

The FRPS responsibilities increases with time and the need to meet the established requirement by IAEA in 1996 resulted in the institution evolving to Interim Regulatory

Competent Authority before the establishment of the Nigeria Nuclear Regulatory Authority (Babalola, 2004).

Following the subsequent creation of National Institute for Radiation Protection and Research (NIRPR) in 2005 by Act 19 of 1995 alongside the department of physics, university of Ibadan sees to the research, regulation and training of Radiation Protection Personnel (RPP) in Nigeria (Olowookere *et al.*, 2012).

The significant bodies put in place to ensure the public and personnel are safe from the use of ionizing radiation including the environment from the harmful effect of ionizing radiation are NNRA and NIRPR. This corresponds to the important roles of other international bodies such as the National Radiological Protection Board and Royal College of Radiologist (UK) and American Association of Physicist in Medicine and American College of Radiologist (US) (Inyang *et al.,* 2010).

Their other roles include:

X-ray facilities are expected to fully comply with the pre designed rules and regulations of the authority before the establishment and even during consecutive procedures carried out in the X-ray facility.

Detailed information is required of the X-ray facility so as to establish the location of the facility and adequate record of the type of X-ray machine in use. All X-ray facilities are expected to state the maximum kVp, mAs and timer applicable. Safety systems which include the filtration, collimators are to be put in place.

Radiation safety officer are assigned to the particular X-ray facility to ensure assigning of monitoring badges to workers, reviewing their individual dose and ensure appropriate actions are taken when these values are exceeded. NNRA is duly responsible for ensuring correct operational procedure and how workers actions may affect safety. They ensure all rules, procedures, protections measures and safety procedures are observed.

Patient exposure parameter, instrument test, records of leak test of sources, records of incidence, accident and investigation and records of staff training (Egbe *et al.*, 2009).

2.9.2 Regulation and policy in radiation protection

The absence of regulatory authority in radiology practice in the past paved way for unhealthy radiation practices among diagnostic centres such as the usage of obsolete X-ray machines, absence of beam quality control, measurement record and lack of record on dose to patient per X-ray examinations. All these had made it difficult to audit radiology practices in Nigeria (Akinlade, 2011).

Other existing international organizations includes International Atomic Energy Agency (IAEA), the American Association of Physicist in Medicine (AAPM), National Radiological Protection Board, American College of Radiologist, International Commission on Radiation Units and Measurements (ICRU), these all stand as an assurance to the public of the security of life, properties and the world at large from the unhealthy effects of ionizing radiation as they categorize and license all practices involving nuclearand ionizing radiation sources (Dlama, 2018).Although different countries have authorities controlling the use of ionizing radiation, the dose levels recommended by the ICRP, together with its general philosophy and recommendations, are common factors (Adejumo *et al*., 2012).

2.10 Production of X-ray

When a vacancy is opened within an inner shell as a result of an ionization or excitation process, an outer shell electron will make a transition to fill the vacancy, usually within a nanosecond for solid materials. The energy liberated in this transition is released in the form of a characteristic X-ray. It is a type of electromagnetic radiation with short wavelength and high frequency. When X-rays interact with matter, it transfers some of its energy to the atoms and consequently removes electrons from it in a process known as ionization. When an electron passes a nucleus, it is slowed and its path is deflected, energy lost is known as bremsstrahlung X-ray also referred to as braking radiation.The energy spectrum of bremsstrahlung is non-discrete and ranges between zero and the kinetic energy of the initial charged particle. X-rays which are produced with high voltage and are being used to capture the human skeleton also travel in a straight line and do not carry an electric charge with them (Graham, 2016).When interacting with matter, they are energetic enough to cause neutral atoms to eject electrons through which the energy of the X-rays is deposited in the matter.

2.11 Working Principles of X-Ray Machine

An X-ray generator is a device used to generate X-ray which consists of an X-ray source or generator (X-ray tube) and an image detection system. The X-ray tube (high vacuum diode) operates by emitting electrons from a heated cathode tungsten filament toward a rotating high voltage anode disc. The point where the electrons (beam) strike the target is called the focal spot. At the focal spot, X-ray photons are directed at all directions which are hence focused by a collimator. X-ray machines work by applying controlled voltage and current to the X-ray tube. The resulting pattern of radiation is detected in a photographic film and when the X-ray hits the film, they expose it just as light would. Since bone, fat and muscle all absorbs X-ray at different level, the image on the film lets you see different structures inside the body because of the different level of exposure on the film (Hrishikesan, 2018).

In an X-ray tube, the rotating anode is used to overcome the overheat problem. Also the anode is made of tungsten alloy which helps in avoiding over heat.The basic schematic of an X-ray tube is shown in Figure 2.1.

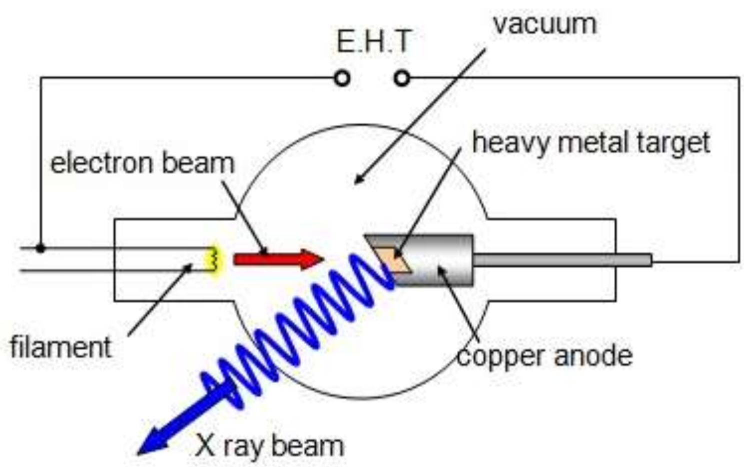


Figure 2.1 Schematic of an X-ray tube (Hrishikesan, 2018).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The Northern part of Nigeria can be segregated into 3 region which include the North Central, North East and North West, in which the North central consist of 6 states, these include; Niger, Benue, Kwara, Kogi, Nassarawa, Plateau and F.C.T.

Northern Nigeria in general is regarded as one of the poorly served in terms of education, coupled with ignorance, cultural disposition and low socio-economic level compared to other regions of Nigeria. Luntsi *et al*., (2015) put the prevalence of cancer in the northern part of Nigeria at the rate of 12.5% out of 20.7% total incidence. The North-West according to Adebanmwo *et al*. (2017) had the highest cancer prevalence with 42.0%. For instance, a progressive increase in number of cases is realized in Kano state of Nigeria in the pattern of cancer recorded in its cancer registry for a period of ten years, followed by North-Central with a prevalence of 21.0%, and then North-East with 17.0%. The least were from South-West with 8.0%, South-East with 6.0% and South-South with 6.0%. It is therefore imperative to evaluate the level of adherence of X-ray radiology facilities especially in North Central Nigeria (Figure 3.1) to established regulations alongside their philosophy and recommendation.

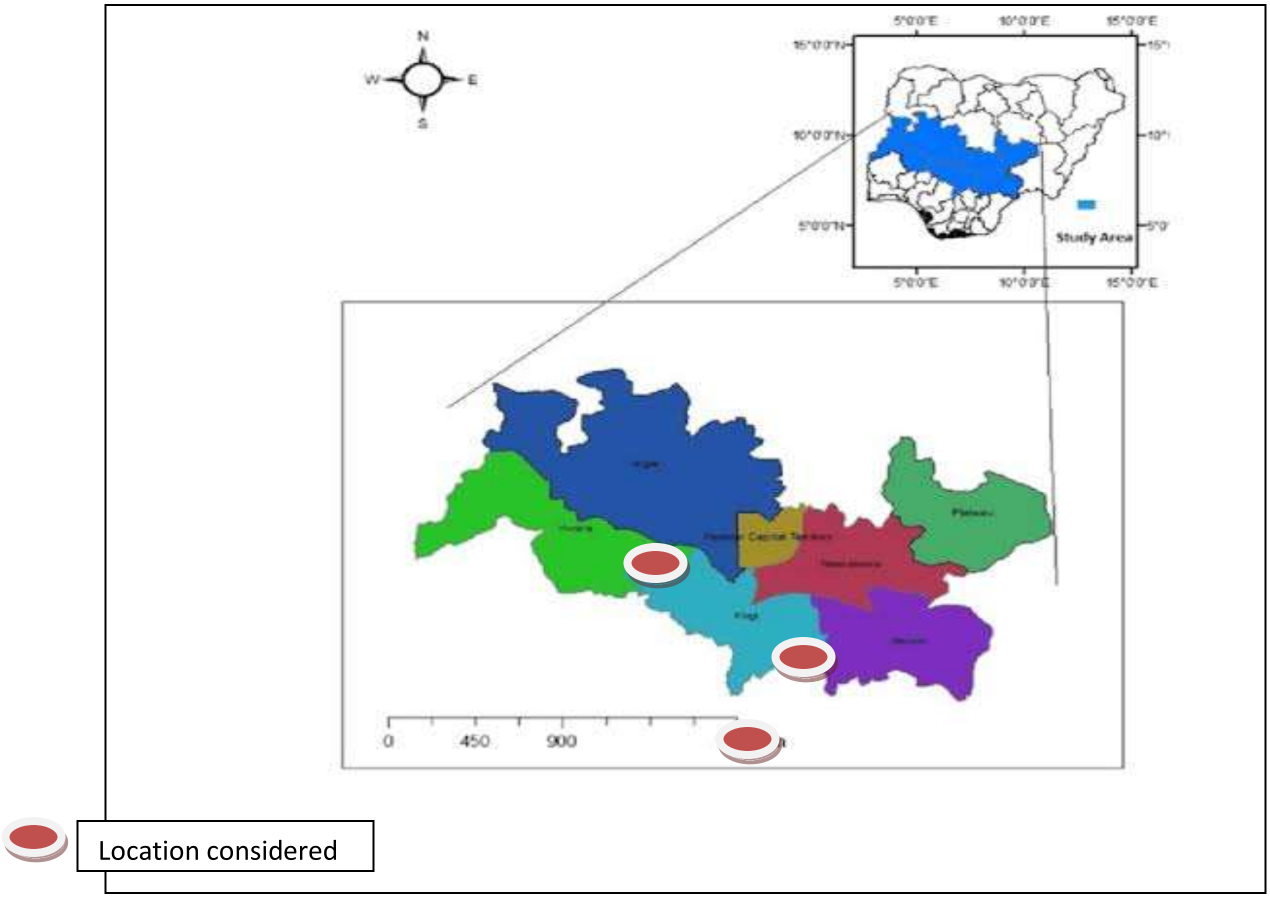


Figure 3.1: Map of study area (www.aboutnigeria.com)

3.2 Sample Collection Centres

Three foremost diagnostic facilities from three selected state general hospitals were considered in this study. They are: General Hospital Ilorin, (GHI) Kwara state, General Hospital Kubwa, FCT (GHK) and the General Hospital Minna, Niger state (GHM). Data used for this research were collected between January and August, 2019. In accordance to research involving human subject, ethical clearance was sought from all necessary ethical clearance committees of the hospitals involved in the study (APPENDIX A). Informed consent form prepared for the patients or relations of patients where appropriate are also attached in APPENDIX B.

3.2.1 X-ray unit, general hospital Ilorin

The General Hospital Ilorin is a grand standing hospital which has been adopted and used as the Kwara State University Teaching Hospital. The radiology department has two X-ray unit of which only one was functioning as at the time of this research. The only functioning X-ray machine is Chinese made whose name, year of manufacture or any other information regarding the machine could not be found either on the body of the machine nor from the head of radiology unit throughout the period of this study. At the period of this research, the X-ray machine was not performing optimally due to the malfunctioning of some components.

3.2.2 Radiology unit, Kubwa general hospital

The General Hospital Kubwa, which was chosen out of the numerous general hospital in the Federal Capital Territory (FCT) has just one state of the art X-ray machine, a Philip rotating anode X-ray tube, manufactured in august 2010 and installed in 2012. It consists of a total filtration of 2.5mmAl/75kv with the presence of a collimator and makes use of an Agfa film and an analog chemical processor for its photographic film processing. A 3 phase generator is used at the facility as the power source for the X-ray machine.

The walls of the X-ray machine room are lined with lead for the protection of staff and patients outside the X-ray room from scattered doses. Two lead aprons are available for protection purposes which are mostly used only during special procedure or in the case of pediatric exposures

3.2.3 X-ray unit, general hospital Minna

The general hospital Minna is one of the oldest health centres in the capital city of Niger state, providing health care to more than half of the resident of Minna and environs. Although the hospital has been modernized and move to its permanent site, the radiology department still maintain its old building. The unit which makes use of a 3 phase generator has just one state of the art X-ray machine, a Nortek rotating anode X-ray tube, manufactured and installed in 2014 with the presence of a collimator. It consist of an inherent filtration of 1.00mmAl/75kv and makes use of an Agfa digital processor for its photographic film processing.

The X-ray room was well lined with lead and an appropriate demarcation of lead wall between the X-ray machine and the control panel. 2 lead aprons are available in the facility.

3.3 Examined patients

Total number of patients that participated in this research in the three diagnostics centres are presented in Table 3.1

Table 3.1 **Examined patients in the three diagnostic centers**

Diagnostics center	Male patients	Female patients	Total patients
GHI	59	66	125
GHK	85	116	201
GHM	105	121	226

Patients parameters which were obtained for all the patients in all the investigated diagnostics centers are the age, sex, height and weight of all the patients. additionally the body mass index (BMI) for all the patients examined was computed using the equation:

$$BMI = \frac{patientsweight}{(patientsheight)^2} \tag{3.1}$$

Patients body parts that were examined for the purpose of this research include the chest (posteriorantero), chest (lateral), lumber sacral (posteriorantero), lumber sacral (anteroposterior) and pelvis (anteroposterior). However, in General Hospital Ilorin, the X-ray machine was not fully operational which therefore placed some restrictions on the projections. The equipment (machine) parameters which were recorded from the respective machine control panels include voltage measured in kVp and current inmAs. .

3.4 Estimation of entrance surface dose using caldose_x

The caldose_x software is a program useful in the calculation of radiation dosage to various organs of the patient during medical diagnostic X-ray procedure,

At a click on the enter button, the page which consist of name of institution and the room in the case of two or more X-ray unit in a facility comes up as shown in Figure 3.1. Other major parameters to be completed before the calculation of the dose on the same page are discussed below;

Adult patient: The adult age, sex and the position of procedure is selected Examination and projection: from a drop down window, one of the twenty-four (24) examinations is selected and one of the 8 projections considered in the software.

X-ray tube: This is the tube potential (kV) usually between 50 and 120 and the charge (mAs) is filled. The focus-to-detector distance is also inputted as the software automatically calculates the focus-to-skin distance.

Field position: This represent the standard field location which demonstrate the effect of absorbed doses to organs in a certain direction. CALDose_X offer an alternative field location for some other examinations with a 4 cm shift in a certain direction also in a bid to demonstrate the effect on organ absorbed doses.

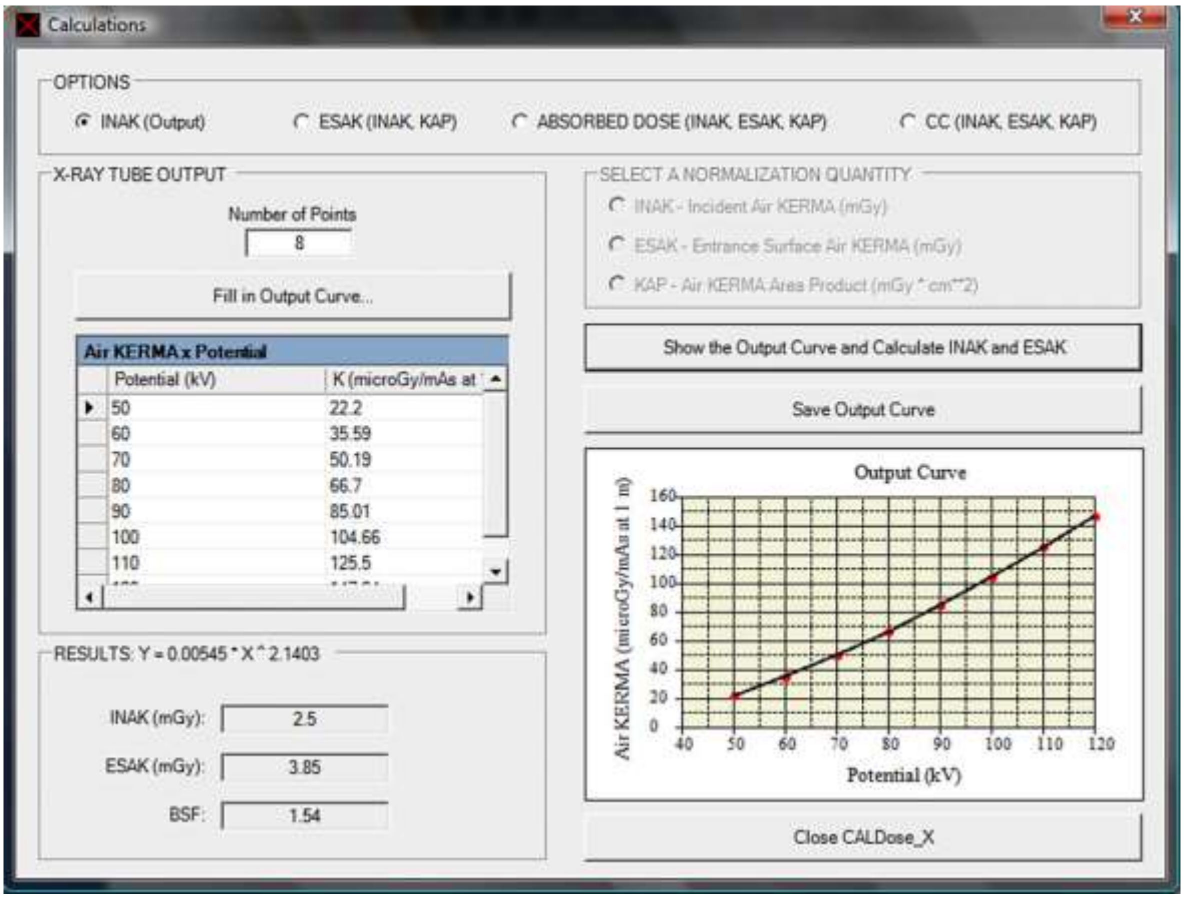


Figure 3.2: Interphase of caldose_X

After the field position has been selected, a ‘select an output curve’ window pops up, the ‘show the selected curve’ is selected. At the click of calculate INAK, ESAK and BSF (output), these quantities are displayed alongside the output curve. If the user wishes to see the image and click on ‘show image’, two images such as the one shown in Figure 3.2(a) and (b) pops up. The frontal and lateral view of the position of the FAX06 phantom, size of the X-ray field and the X-ray beam position respectively, such as the pelvic radiograph on display. Field height and width are specified in centimeters for the detector plane (film).

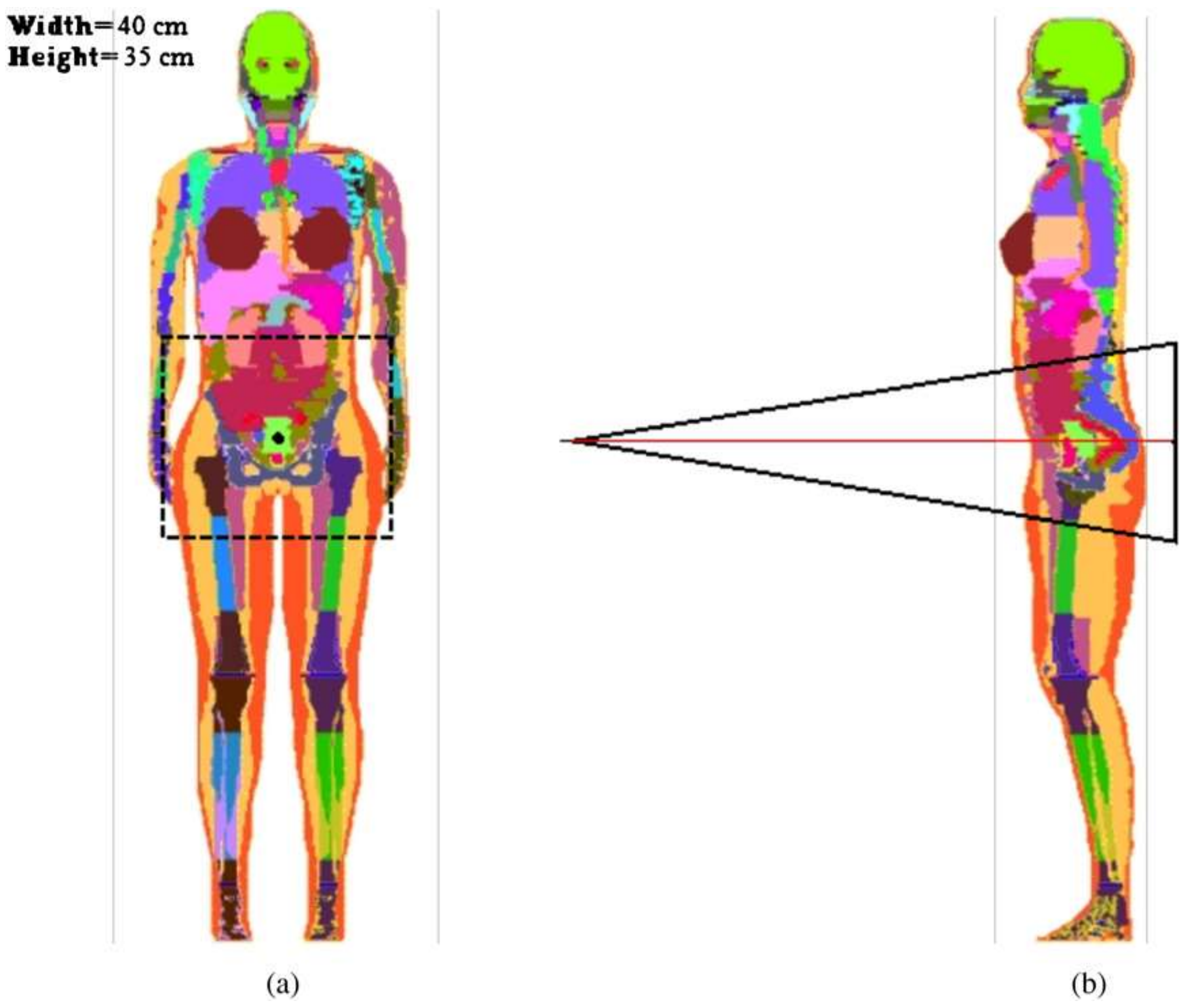


Figure 3.3:(a)Anterorposteror view of a phantom (b) Lateral pelvic view of a phantom

After clicking the 'Calculations' button, the following options are presented:

(i) Incident air kerma (INAK): This is the primary radiation absorbed by the patient or phantom without the contribution of the backscattered radiation. It is referred to as the air kerma at the focal-spot-to-surface distance (skin-entrance plane) from the incident beam on the central X-ray beam axis.

(ii) Entrance surface air kerma (ESAK); this is the contribution of backscattered radiation to the air kerma on the central X-ray beam axis at the point where the xray beams reaches the phantom or patients.

(iii) Air kerma-area product (KAP); It is the integral of the air kerma free-in-air over the area of the X-ray beam to the beam axis in a perpendicular plane.

(iv) Backscattered factor (BSF): It is the conversion coefficient that relates the incident air kerma, to the entrance surface air kerma,.

Figure 3.3 which consist of the name of facility, gender, age and name is produced after clicking on the button which indicates 'Calculate Organ and Tissue Absorbed Doses'. Included are the examination parameters and the absorbed organ and tissue dosage represented in mGy alongside the statistical error. CALDose_X also supplies the mean spectral energy and an absorbed fraction that is the body's proportion of the energy released. Also included in the table is the weighted Female/Male whole body dose and finally are the two entries that displays the probability of cancer incidence and cancer mortality for the patient based on the probability coefficients reported in BEIRVII article. The Tables whose results can either be printed or saved.

INSTITUTION: GHM
ROOM: NIL
X-RAY TUBE (Filter: 2.5 mm Al): RendimentoTeórico/Theoretical Output
ADULT PATIENT: Female Standing Age: 55 years
Name: NIL
ID: NIL
Calculation date: 15/06/2019 CALDose_X_5.0
EXPOSURE CONDITIONS
FASH3STA: THORAX, POSTERIOR-ANTERIOR (PA)
IMAGE IN FRONT OF THE BODY
64 kVcp 2.5 mm Al 17 Deg Tungsten IPEM/SR78
MEAN SPECTRAL ENERGY: 37.0 keV ABSORBED FRACTION: 0.56
SOURCE-TO-DETECTOR (FILM): 130 cm
SOURCE-TO-SKIN: 107.0 cm
FIELD SIZE IN DETECTOR PLANE: 35 cm x 40 cm
FIELD POSITION: STANDARD POSTURE: STANDING
FEMALE ADULT (ICRP89)
BODY MASS: 60.0 KG, STANDING HEIGHT: 163.0 CM
CHARGE: 12.5 mAs

ORGAN/TISSUE ABSORBED DOSES

ORGAN/TISSUE	mGy	%
ESAK	0.980	0.00
ADRENALS	0.225	2.39
ORAL MUCOSA	0.012	4.03
COLON WALL	0.007	2.22
BREASTS,glandular	0.033	1.84
KIDNEYS	0.181	1.41
LIVER	0.087	1.36
LUNGS	0.231	1.35
OESOPHAGUS	0.096	2.28
PANCREAS	0.039	1.95
SMALL INTESTINE WALL	0.003	2.89
SKIN ENTRANCE DOSE 7.2cm X 7.2cm	0.986	1.72
SPLEEN	0.158	1.52
STOMACH WALL	0.066	1.73
SALIVARY GLANDS	0.011	3.96
THYMUS	0.054	3.47
THYROID	0.073	3.28
EXTRATHORARCIC AIRWAYS	0.009	3.79
HEART WALL	0.117	1.47
LYMPHATIC NODES	0.047	1.59
GALL BLADDER WALL	0.019	7.75
SKELETON AVERAGE	0.196	1.33
MAXIMUM RBM ABSORBED DOSE	0.246	2.00
MAXIMUM BSC ABSORBED DOSE	0.308	2.84
WEIGHTED FASH DOSE	0.070	1.83
RISK OF CANCER INCIDENCE	0.698	CASES PER 100000
RISK OF CANCER MORTALITY	0.609	CASES PER 100000

Figure 3.4: Dose calculation window of Caldose_X

For the use of Caldose _X 5.0 in the calculation of ESD, it is necessary to furnish the output in mGy/mAs, of all X-rays machines used in the evaluation of doses (Esen and Obed, 2013 and Ofori *et al.*, 2014). Once the tube potential, the tube current, the exposure time, the FDD, and focus-to-skin distance (FSD) are known, Entrance Skin Dose can be recorded.

3.4.1 Estimation of effective dose with caldose_x software

Kramer *et al.*, (2008) estimated effective dose as an arithmetic mean of two sex specific effective doses as seen in Equation 3.2. The female and male patient effective dose is denoted by F and M respectively.

$$
\begin{aligned}
E &= \textstyle\sum_{W_T}\left[H_{T(female)} + H_{T(male)}\right]/2 \\
&= {}^1\!/_2 \left[\textstyle\sum_{W_T H_T(female)} + \textstyle\sum_{W_T H_T}(male)\right] \\
&= {}^1\!/_2 \left[F + M\right] \qquad (3.2)
\end{aligned}
$$

The effective dose estimated by Caldose_X 5.0 and specified by the ICRP103 (1996) is therefore the average of the sex-specific weighted doses. The calculated weighted female dose (F) or weighted male dose (M) is given and recorded.

3.4.2 Estimation of cancer risk

This is the probability that an individual would develop cancer from a radiological diagnostic procedure. Caldose_X 5.0 calculates this as the sum over risk-weighted organs and tissues equivalent doses. This shows the whole body effective dose as it can be used to assess overall detriment associated with radiation exposure using Equation 3.3

$$R = \sum r_T H_T \qquad (3.3)$$

Where r_T is the lifetime attributable tissue specific cancer risks per unit organ equivalent dose estimated as $5 \times 10^{-2} sv^{-1}$ (ICRP, 1990; Akinlade, 2011) and H_T is the average organ and tissue equivalent doses in tissues T.

3.5 Estimation of entrance surface dose (ESD) using mathematical formular

An indirect means of patient dose assessment is by using Equation 2.2. The radiation output $Y(d)$ for the different phases of X-ray machines used in this study at a source to target distance of 100 cm is analytically obtained using Equation 3.4 (Inyang *et al.*, 2015)

For single phase output; $Y(d) = 0.5 \times 6.53 \times 10^{-4} mR$

For three phase output; $Y(d) = 0.8 \times 6.53 \times 10^{-4} mR$ (3.4)

For high phase generator; $Y(d) = 1.0 \times 6.53 \times 10^{-4} mR$

CHAPTER FOUR

RESULTS AND DISCUSSION

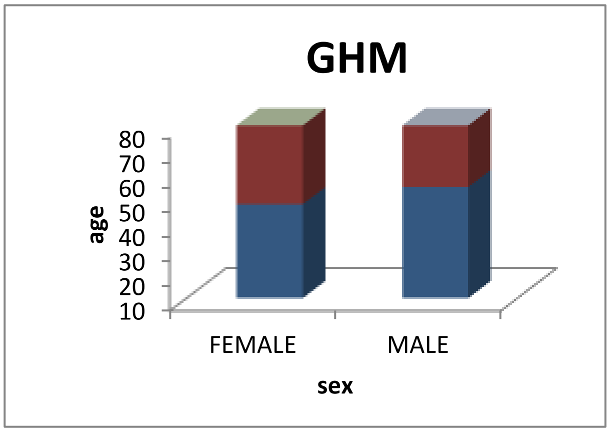
4.1 Patient demographic data

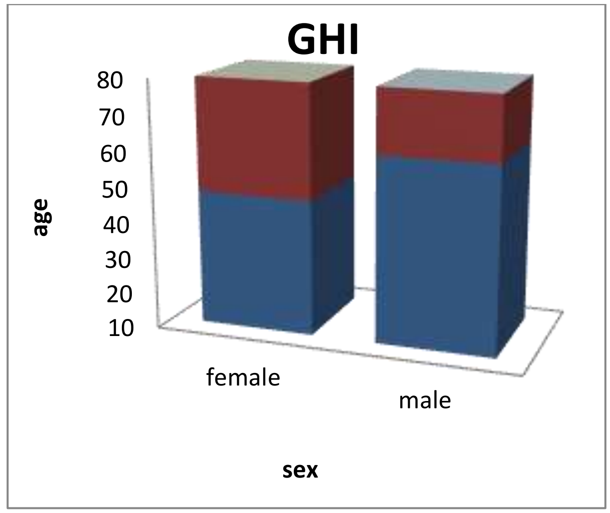
The demographic data obtained for 552 patients in the three different X-ray facilities considered in this study are indicated in Table 4.1.

Table 4.1: Patient demographic data

X-ray Centers	No of patients (%)	Age (yr)	Weight (kg)	Height (m)	BMI (kg/m^2)
GHI	125	21-75	45-95	1.5-1.85	15-42
Female	66(52.8%)	49.4	63.4	1.56	26.2
Male	59(47.2%)	43.2	72	1.68	25.2
GHK	201	20-75	42-115	1.48-1.92	19-44
Female	116(57.7%)	41	71.7	1.61	27.7
Male	85(42.2%)	51	74.3	1.69	25.6
GHM	226	18-73	40-110	1.4-1.9	19-50
Female	121(53.5%)	40.3	70.5	1.59	28.1
Male	105(46.4%)	40.6	64.7	1.62	24.7
Total	552				

Of the 552 patients involved in this study, 303 (54.9%) are females and 249 (45.1%) are males. All patients age ranges from 18 to 75 years with female patients averaging between 40.3 and 49.4 years which according to WHO (2020) are still in their reproductive years.





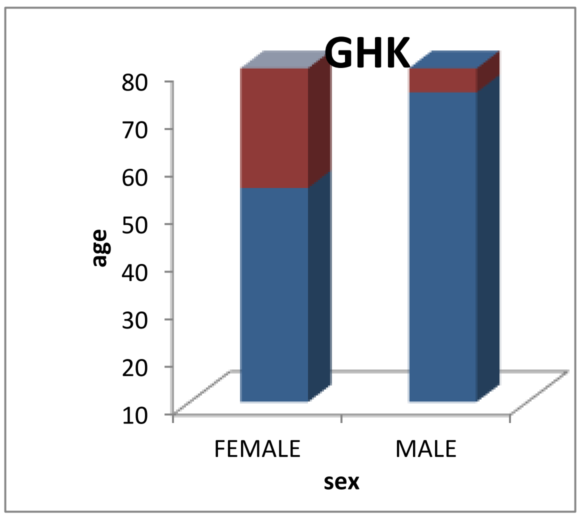


Figure 4.1: Distribution of patients according to age and sex

The range of patients' weight (40 to 115 kg) was considered in this study. Within this weight bracket however, the increase in patient's dose may go unnoticed as some facilities tends to increase their exposure factors according to the patient's weight thereby increasing patient's dosage.

The BMI range (15-50 kg/m^2), derived from weight/$height^2$ is therefore an appropriate measure that determines the patient's size and shape.

4.2 Radiographic examination considered

Presented on Table 4.2 is the number and percentage of patients involved in the different examination and projections of the X-ray tube.

Table 4.2: Radiographic examination of patients body

X-ray Centers	Chest (AP)	Chest (PA)	Chest (LAT)	L/S (AP)	L/S (LAT)	Pelvis (AP)
GHI	85(68%)	NA	NA	16(13%)	11(9%)	13(10%)
GHK	NA	78(39%)	NA	51(25%)	51(25%)	21(10%)
GHM	NA	71(31%)	43(19%)	35(15%)	39(17%)	38(19%)

L/S-Lumbersacral; Number in ( ) indicates the percentage of each radiographic examination over total examination performed in respective centers.

The three major examinations considered in the study for both gender are the chest, lumbersacral and pelvis. The radiographic projection of X-ray tube with respect to the position of patients during diagnostic examination considered for each facility includes the Anteror-Posteror (AP), Posteror-Anteror (PA) and Lateral (LAT).The three centres, GHI, GHK and GHM considered undertook the lumbersacral (AP and LAT) while only one centre carried out the chest examination (AP and LAT), the chest (PA) examination was carried out in two centres. The chest (thoracic) is seen to have the highest number of request for the X-ray procedure with a total of 50.1%, lumbersacral having 36.8% and 13% for pelvis. This could be as a result of patient request either for admission or employment purposes in addition to the medical request.

The not applicable (NA) indicated in the Table simply shows that some facilities are not privileged to undertake some particular radiographic projection. This can be said to be due to technical fault and/or insufficient number of patients during this study. IAEA (1996) stipulated that at least ten patients (male and female) should be evaluated for any procedure.

4.3 X-ray radiographic exposure parameters

Table 4.3 shows the range of exposure factors which were selected by the operator for respective sex in the radiographic examination of different body regions at the three examination centers.

Table 4.3: X-ray radiographic exposure parameters

Centres	Projections	KVp	Mas	FSD
GHI	CHEST(AP)	60-75	10-15	50-86
	L/S (AP)	85-95	15-25	53-80
	L/S (LAT)	89-109	15-35	53-80
	PELVIS(AP)	90-105	25-35	57-67
GHK	CHEST (PA)	66-96	4-25	123-132
	L/S (AP)	90-109	16-40	48-56
	L/S (LAT)	81-109	12.5-40	54-58
GHM	CHEST(PA)	58-72	8-25	103-107
	CHEST(LAT)	60-78	10-25	106-123
	L/S (AP)	70-78	20-25	69
	L/S(LAT)	60-78	12.5-32	65
	PELVIS(AP)	58-78	12.5-25	60-68

Figure 4.2 shows the mean values of the exposure factors. Exposure factors presented on Table 4.3 are the basic factors that determine the quantity and quality of X-radiation a patient is exposed to. The highest mean peak kilovoltage of 100.5 kVp and highest time-current product (33.6 mAs) is from GHK. This could be as a result of GHK having the highest added filtration. Nevertheless, the added filtration and highest FSD used for chest (PA) could not see to a low radiation dose to patients.

Meanwhile, the low mean kVp and mAs used gave rise to the low range of ESD obtained for GHM, and also the FSD made quite a significant contribution to the lowering of the dose. Considering the kVp and mAs used for pelvis in GHI and GHM, the high kVp and mAs used in GHI can be seen to be the reason for the increase dose obtained as even the higher FSD (68 cm) used could not accomplish a lower dose as compared to GHM.

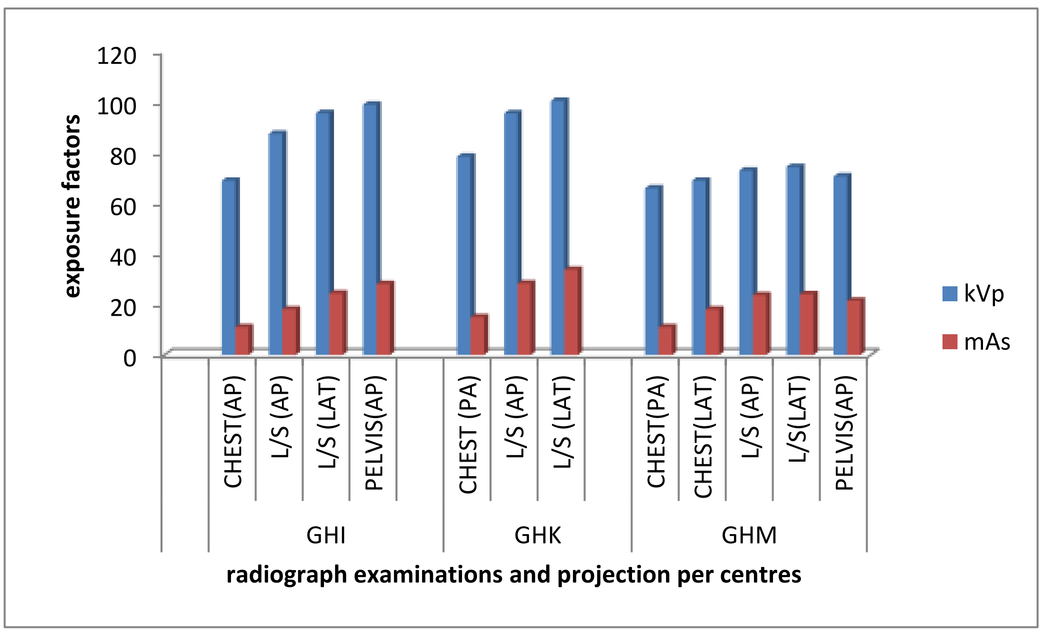


Figure 4.2: radiograph examination and mean exposure factors

4.4 Estimation of ESD

Table 4.4 and 4.5 presents the mean estimated entrance surface dose using the Caldose_X software and the mathematical equation respectively. Estimating patients dose using mathematical equation can be easily accessible as only microsoft excel is needed, however, to avoid error with large data base, Caldose_X is reliable. Patient dose requires the summation of radiation dose to several organ as shown in equation 3.1 and 3.2 and conducting in-vivo measurement of radiation doses to about 15 organs is impractical (Akinlade, 2011). To facilitate accuracy, modern resource in dosimetry such as Caldose_X software is used. Other patient doses to be evaluated are the absorbed organ and tissue doses, effective dose and the cancer risk

Table 4.4: Estimated entrance surface dose using software (ESD, mGy)

		ESD		
EXAMINATION	PROJECTION	GHI	GHK	GHM
CHEST	AP	1.8-3.4 (2.37)	NA	NA
CHEST	PA	NA	0.8-3.1(1.32)	0.8-2.8(1.00)
CHEST	LAT	NA	NA	0.8-3.3(1.75)
L/S	AP	4.5-6.1(5.26)	4.9-6.9(6.11)	3.8-5.9(5.09)
L/S	LAT	0.6-3.8(2.15)	0.69-3.43(2.21)	0.3-3.6(2.03)
PELVIS	AP	4.9-9.3 (7.10)	NA	3.0-7.6(4.53)

NA-Not Applicable

Table 4.5: Mean values of estimated entrance surface dose using mathematical computation (ESD, mGy)

Examination	Projection	ESD(mGy)		
		GHI	GHK	GHM
CHEST	AP	1.769	NA	NA
CHEST	PA	NA	0.563	0.595
CHEST	LAT	NA	NA	1.041
L/S	AP	2.806	6.345	2.627
L/S	LAT	3.602	6.757	2.129
PELVIS	AP	3.615	NA	3.419

NA- Not Applicable

From X-ray examination of chest region, the highest value (2.37 and 1.77) mGy for Caldose_X and the mathematical formular respectively of ESD was obtained at GHI while the lowest value (1.00 and 0.55) mGy was obtained at GHM. The higher ESD obtained at GHI is traceable to low mean FSD (65.2 cm) selected at the centre for the AP projection as compared with those selected at other centres, with GHK and GHM having a FSD of 127 cm and 105.5 cm for PA and LAT projections respectively. The use of optimum FSD is paramount as increase in the distance between the focal point and the patient entrance surface reduces the intensity of the energy of the X-ray beam.

The obtained ESD in the study were all within the diagnostic reference level except in the case of chest (PA and LAT) examination which were higher than the national diagnostic reference level of 0.4 and 1.5 respectively (IAEA, 1996). Although Caldose_X software uses weight of 70 kg and height of 176.0 cm for reference male (MAX 06) and height of 174.0 cm for reference female phantom (FAX 06) whereas the mathematical equation only takes into account the real physical attributes of the patients. However, the sex specific conversion factor for the organ in the phantom is a major factor responsible for variation in the two methods used.

Majority of the results obtained from the X-ray examinations considered are seen to follow a particular pattern in the two methods used. Generally, the ESD goes in the increasing order of GHK > GHI > GHM. This trend is definitely obvious in the two methods used which could be traced to the high kVp used in the respective facilities.

4.5 Computed organ doses

Table 4.6 shows the typical organ doses calculated by Caldose_X 5.0 software for all the radiographic examinations and recorded from the output page. The appropriate dose estimate for the risk of a particular type of cancer is the dose absorbed dose into the suitable organ of the body known as the organ-specific radiation dose. The highest organ dose in the study (2.82) mGy is that of testes in pelvis from GHI and the lowest is 0.004 mGy of breast at the lumbersacral region for GHM.

The organ absorbed doses in GHI are slightly higher than those of GHK and GHM, this is obvious for dose such as the testes and ovaries with 2.8 mGy and 2.4 mGy respectively for the pelvis examination and also 1.58 mGy and 1.3 mGy from breast and red bone marrow of the chest AP projection. This increase doses is traceable to the obtained entrance skin dose as GHI has higher dose in these projections such as pelvis and chest AP. This follows suites in the case of GHM which has the least organ dose of 0.004 mGy in breast of lumbersacral examination and also possess a minimal dose within previous study (Akinlade, 2011) and on no account is there an organ dose from GHI or GHK lower than it and this also could be as a result of the entrance skin dose which are achieved with the use of significantly high FSD.

A comparison of the absorbed organ dose with those of United Nations Scientific Committee on the Effects of Atomic Radiation (UNSEAR, 1982) and IAEA shows that the in this analysis, doses are typically greater than the recommended values except for GHM. Several other factors such as patients' anatomy, differences in X-ray machines are also to be considered for the variations of values.

Table 4.6: Organ dose (mGy) for respective radiograph

CENTRES	PROJECTIONS	THYROID		OVARIES		BREAST		TESTES		LUNGS		RED BONE MARROW	
		ORGANS											
		Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
GHI	CHEST(AP)	1.08	0.81	NA	NA	1.0±0.251	1.58±0.332	NA	NA	0.45±0.108	0.56±0.117	1.07±0.209	1.13±0.241
	L/S(PA)	NA	NA	NA	NA	0.005	NA	NA	0.008	0.01	0.02	0.24	0.17
	L/S(LAT)	NA	NA	NA	NA	*	*	NA	NA	0.05	0.02	0.25	0.17
	PELVIS(AP)	NA	NA	2.04	NA	0.006±0.002	NA	NA	2.8±0.768	0.006±0.001	NA	1.17±0.279	0.9±0.306
GHK	CHEST(AP)	0.143	0.134			NA	NA	NA	NA	0.378±0.21	0.252±	0.401±	0.286±0.18
				NA	NA								
	CHEST (PA)	NA	NA			0.067±0.04	0.036	NA	NA	NA	NA	NA	NA
				NA	NA								
	L/S(AP)			1.274	NA	0.007	NA	NA	NA	0.014	0.044	0.342	0.292
	L/S(LAT)			0.128	NA	0.068	NA	NA	NA	0.086	0.029	0.417	0.197
GHM	CHEST (PA)	0.08	0.06	NA	NA	0.03±0.007	0.016	NA	NA	0.25±0.12	0.13±0.08	0.26±0.123	0.16±0.084
	CHEST(LAT)	0.29	0.05	NA	NA	0.07±0.019	0.07	NA	NA	0.24±0.066	0.17±0.069	0.46±0.129	0.37±
	L/S(AP)	NA	NA	0.85	NA	0.004	NA	NA	0.03±0.007	0.007±0.007	NA	0.21±0.037	0.16±
	L/S (LAT)	NA	NA	NA	NA					0.052	0.021	0.252	0.145
						0.040	NA	NA	NA				
	PELVIS	NA	NA	0.90	NA	NA	NA	NA	2.18±1.26	NA	NA	0.46	0.3

4.6 Estimated Effective Dose

The Caldose_X 5.0 software was used to calculate the effective dose and the result presented in Figure 4.3. The effective dose is a way of determining the whole body biological damage as a result of exposure to ionizing radiation. The highest value of effective dose of 0.66 mSv was obtained at GHI for pelvis examination and the lowest dose from chest (PA) at GHM. For pelvis examination, GHI is seen to have the highest ESD of 9.3 mGy and cancer risk index, which can be traceable to the higher voltage and higher current followed by lower FSD used, coupled with patients' sizes and radiographers experience. The range of effective dose obtained in this study (0.052-0.692) mSv was less than those reported (0.01-4.74) mSv in the previous study of Akinlade, 2011. The effective dose can be seen to be generally low in GHM compared to other centres which may be due to low mean kVp for GHM.

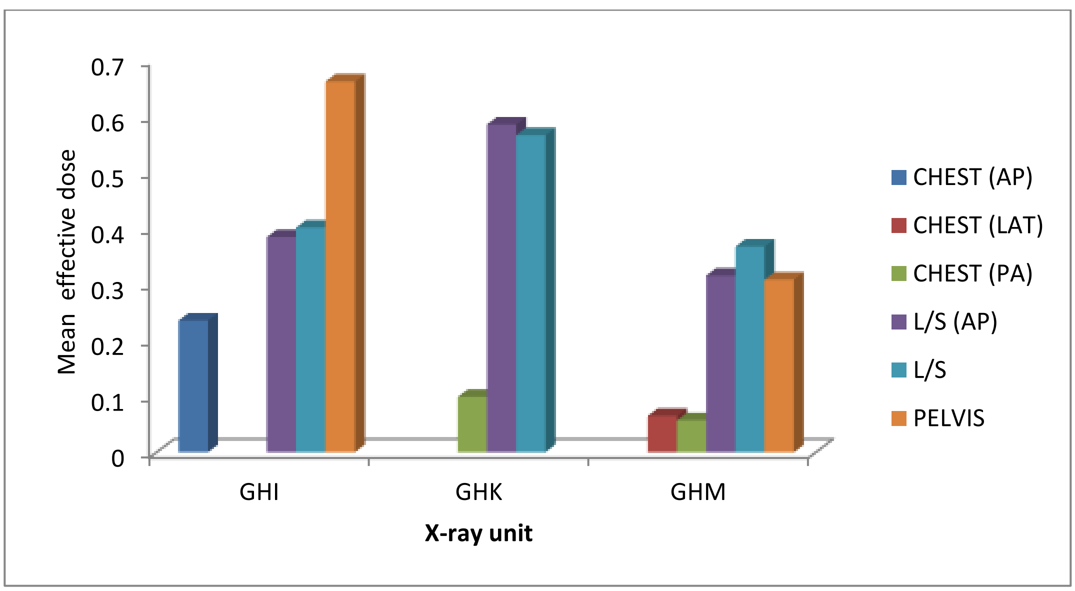


Figure 4.3: Patients' mean effective dose

4.7 Estimated risk of cancer

Summation of detriment in different organs of exposed patient gave the total harm associated with X-ray examination of that body region. The result of the estimated risk of cancer associated with different radiographic examination for all the centers considered in this study are presented in Tables 4.7(a) and (b). The risk of fatal cancer estimated from X-ray examination at GHI is 2.97×10^{-6} for chest (AP) in females and 1.46×10^{-6} for males. Chest (LAT) and (PA) is however not noticeable in GHI. In GHK, chest (PA) recorded values of 1.41×10^{-6} and 0.48×10^{-6} for female and male patients respectively, while chest (AP) and chest (LAT) are not applicable. Similarly for GHM, chest (PA) have values of 0.84×10^{-6} for female patients and 0.28×10^{-6} for male patients while chest(AP) is non applicable. For pelvis (AP) examination, 3.78×10^{-6} and 4.20×10^{-6} were the values recorded for female and male patients respectively in GHI while no values were applicable for GHK. Results as seen in Table 4.7 shows that significantly higher whole body effective cancer risk is recorded for female patients than their male counterparts not only for the sex-specific organs such as the breast, uterus, ovaries but also for the lungs, which reveals greater risk coefficient for female patients (Kramer *et al*, 2008 and Akinlade, 2011). Aging however reduces the risk coefficient for both sexes.

Following recommendation by the International Commission on Radiation Protection, Akinlade (2011), reported that if one million patients receive a whole body irradiation of 1 Sv, the number of patients likely to develop cancer in their lifetime should not exceed 35. The risk of fatal cancer estimated from X-ray examination recorded the highest value of 4.20×10^{-6} for pelvis examination in GHI and lowest value of 0.28×10^{-6} for chest PA in

GHM. Therefore,number of patients who are likely to develop cancer from this procedure in the studied examination centers are within the ICRP recommended limit of safety.

Table 4.7(a): Estimated cancer risk (per 1,000,000 patients)

		Projection		
Centres	Sex	Chest (AP)	Chest(PA)%	Chest(LAT)%
	F	2.97±1.55	NA	NA
GHI	M	1.46±0.35	NA	NA
GHK	F	NA	1.41±0.64	NA
	M	NA	0.48±0.31	NA
GHM	F	NA	0.84±0.37	0.93±0.35
	M	NA	0.28±0.16	0.54±0.22

Table 4.7(b): Estimated cancer risk (per 100,000 patients)

		Projection		
Centers	Sex	L/S (AP)	L/S(LAT)	PELVIS(AP)
	F	2.08	1.82	3.78±1.11
GHI	M	1.76	0.36	4.20±1.43
GHK	F	3.40	3.69	NA
	M	2.75	2.59	NA
GHM	F	2.40±0.42	2.12±0.53	2.48±0.71
	M	2.09±0.35	1.99±0.54	2.01±0.88

The results of ESD estimated for the two methods considered in this research were further compared with those of similar studies andinternationally established diagnostic reference levels documented in IAEA (1999) report. The comparative analysis presented in Table 4.8 (a) and (b)

Table 4.8(a): Mathematically estimated ESD

	This Study				Other Study			
Projection	GHI	GHK	GHM	IAEA,1996	(NIGERIA) Akinlade, 2011	(GHANA) Ofori*et al*,2014	(SUDAN) Kouther*et al*,2015	(INDIA) Alatta*et al*,2017
Chest AP	1.769	NA	NA	*	1.55	NA	NA	0.11
Chest PA	NA	0.595	0.563	0.4	1.55	0.27	0.15	0.11
Chest LAT	NA	NA	1.041	1.5	NA	0.43	0.38	0.11
L/S AP	2.806	6.345	2.627	10	NA	3.25	2.04	0.96
L/S LAT	3.602	6.757	2.129	30	NA	NA	NA	0.96
Pelvis	3.615	NA	3.419	10	10	1.31	NA	0.74

Table 4.8(b): Software estimated ESD

	This Study				Other Study			
Projection	GHI	GHK	GHM	IAEA,1999	(NIGERIA) Akinlade, 2011	(GHANA) Ofori*et al*,2014	(SUDAN) Kouther*et* *l*,2015	(INDIA) Alatta*et al*,2017
Chest AP	2.37	NA	NA	*	1.55	NA	NA	0.11
Chest PA	NA	1.32	1	0.4	1.55	0.27	0.15	0.11
Chest LAT	NA	NA	1.75	1.5	NA	0.43	0.38	0.11
L/S AP	5.26	6.11	5.09	10	NA	3.25	2.04	0.96
L/S LAT	2.15	2.21	2.03	30	NA	NA	NA	0.96
Pelvis	7.1	NA	4.53	10	10	1.31	NA	0.74

Although slight variations are observed in ESD among the different centres investigated which could be traced to differences in patient size, exposure factors and other equipment-related factors, the results falls within the IAEA internationally established diagnostic reference levels.

For the two methods, the lowest ESD was obtained from GHM with 1.00 mGy and 0.56 for software and mathematical estimation respectively which however was higher than the recommended limit of 0.4 mGy for chest (PA). The X-ray examination of lumbersacral and pelvis were within the range of recommended limits and previous studies.

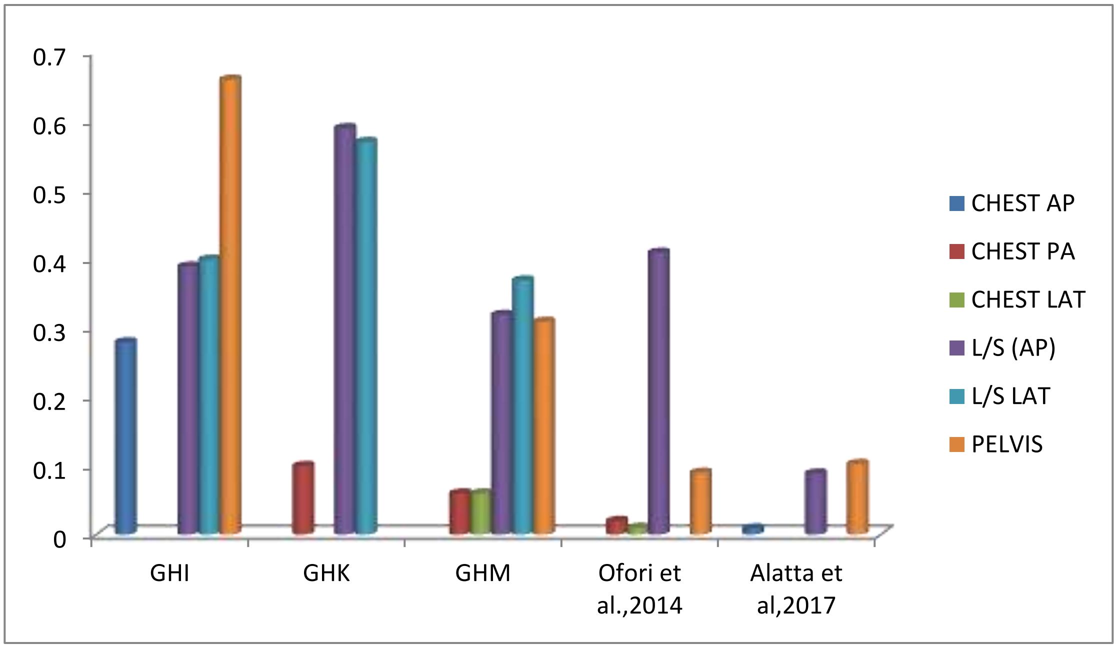


Figure 4.4: Effective dose (comparison of present study with literature)

Figure 4.4 reveals the effective dose of patient from the present study and two other previous studies. GHK has the highest ED for all examination except for GHI which reveals an obviously high value of 0.66 mSv in pelvis examination. GHM has the least value of ED in all X-ray examinations. The results obtained in this study do not in any way exclude the fact that low doses to patients are achievable in these centres.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The patient radiation doses which constitute the entrance surface dose, effective dose, absorbed organ dose and the cancer risk index for a total number of 552 exposed patients have been estimated. These radiation doses were estimated for three X-raycentres in North Central, Nigeria. The centres considered are, General Hospital, Minna (GHM); General Hospital, Kubwa (GHK); and General Hospital, Ilorin (GHI). For the estimation of ESD, two methods were used: the mathematical formular and the Caldose_X 5.0 software and for the effective dose, absorbed organ dose and cancer risk index, only the Caldose_X software was used.

The number of patients considered in this work were 552, this include 226 patients for GHM, 125 patients for GHI and 201 patients for GHK, with mean weight (kg) of the study at 75kg. The total percentage of projections for all the patients considered for each X-ray diagnostics examinations in the study are chest PA (27%), lumbersacral AP (18.5%), lumbersacral LAT (18.3%), chest AP (15.4%), pelvis (13%) and chest LAT (7%). The mean exposure factors (kVp and mAs) are 87.8 and 20.3 for GHI, 91.5 and 25.6 for GHK and 70.6 and 19.6 for GHI.

The range for the entrance skin dose (ESD) obtained using the mathematical computation are between 3.62 and 1.77 mGy for GHI, 0.56 and 6.76 mGy for GHK, 0.55 and 3.42 mGyfor GHM. Similarly, those obtained for ESD using the Caldose_X software ranged from 2.15 to 7.10 mGy for GHI, 1.32 to 6.11 mGy for GHK, 1.00 to 5.09 mGy for GHM.

The effective dose (ED) for the three centres varies between 0.29 and 0.89 mSv for GHI, 0.09 and 0.85 mSv for GHK, 0.03 and 0.569 mSv for GHM. These values were found to be within the same range reported in literature for similar investigation.

Absorbed tissue and organ dose was computed for six major organs which are thyroid, ovaries, breast, testes, lungs and red bone marrow. The highest absorbed organ dose of 2.8mGy in testes for pelvic examination was obtained at GHI while the lowest dose of 0.004mGy in breast was obtained at GHM for lumbersacral examination. The organ doses were found to be within similar ranges reported in literature.

The estimated cancer risk (per million patients) for all the X-ray examinations performed at the centres considered ranged from 0.36-4.20 for GHI, 0.48-3.69 for GHK and 0.28-2.48 for GHM. These values were within recommended limit. Dose variability observed in this study can be due to the use of different technological parameters, disparity in X-ray machine, the use of old X-ray machines, equipment performance levels and patients' anatomy.

There is high level agreement noticed between the result obtained using the mathematical computation and Caldose software which shows the reliability of this research. Radiographers in these facilities have ensured good radiological procedure that present minimal risk to the patients. Nevertheless, adequate implementation of quality control programmes in these facilities should be ensured. Furthermore, the risk for average patient with radiation is low and so is the risk to the personnel in the hospital.

5.2 Recommendations

The following are recommended to ensure low patient radiation dose

- Quality assurance should be implemented in some of these centres.
- Replacement of old X-ray machine may also be essential to ensure reduction of dose to as small as fairly possible for patient.
- Adequate focus to skin distance should commensurate with the exposure factor
- The use of lead aprons should be emphasized as more women in their reproductive stage are exposed to X-ray examinations.

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APPENDIX A: **Ethical Clearance**

FEDERAL CAPITAL TERRITORY

Health Research Ethics Committee

Research Unit, Room 10, Block A Annex, HHSS, FCTA Secretariat,
No. 1 Kapital Street 11, Garki, Abuja-Abuja.

Notice of Research Approval
Approval Number: FHREC/2019/01/15/27-02-19

Study Title: Estimation of Entrance Surface Dose and Sex Specific Effective Doses During Routine X-Ray Examination in Diagnostic Radiology Facilities.

Principal Investigator: **Kehinde, Olaide Odunayo**

Address of Principal Investigator: Department of Applied Nuclear Physics, Federal University of Technology Minna, Niger State, Nigeria.

Date of receipt of valid application: 05/02/2019

This is to confirm that the FCT Health Research Ethics Committee (FCT HREC) has approved the research described in the above stated protocol.

This approval is valid from **27/02/2019** to **26/02/2020**.

Note that no activity related to this research may be conducted outside of these dates. Only the FCT HREC approved informed consent forms may be used when written informed consent is required. They must carry FCT HREC assigned protocol approval number and duration of approval of the study. The FCT HREC reserves the right to conduct compliance visit to your research site without prior notification.

The National Code of Health Research Ethics requires the investigator to comply with all institutional guidelines, rules and regulations regarding health research, and with the tenets of the code.

Modifications: Subsequent changes are not permitted in this research without prior approval by the FCT HREC.

Problems: All adverse events or unexpected side effects arising from this project must be reported promptly to FCT HREC.

Renewal: This approval is valid until the expiration date. If this project is to proceed beyond the expiration date, an annual report should be submitted to FCT HREC early in order to request for a renewal of this approval.

Closure of Study: At the end of the project, a copy of the final report of the research should be forwarded to FCT HREC for record purposes, and to enable us close the project.

For queries and further information contact FCT HREC office. I wish you best of luck with your research.

Desmond Emereonyeokwe
Secretary, FCT HREC
February 27, 2019.

ABUJA

KWARA STATE GENERAL HOSPITAL, ILORIN

(THE PROPOSED KWARA STATE UNIVERSITY TEACHING HOSPITAL)

Providing World Class Healthcare Services

Chief Medical Director
Prof. Abdulfatai Olokoba
MBBS, DTMH, Cert.BPR, MBA, MPH, FMACP

Phone No: 07034504567, 08180021128, 09051122430, 08038050480
Email: iloringeneralhospital@gmail.com

GHI/ADM/134/VOL.I/67

5th April, 2019

Estimation of Entrance Surface Dose and Effective Dose during Routine X-Ray Examination in Diagnostic Radiology Facilities.

- General Hospital, Ilorin, Institutional Review Committee.
- Name of Applicant: Kehinde, Olaide Odunayo
- Address of Applicant:- Department of Physics, Federal University of Ilorin Technology, Minna, Niger State.
- Date of Application:- 26th March, 2019.
- Date of Full Committee Decision: - 3rd April, 2019.

NOTICE OF FULL COMMITTEE APPROVAL

I am pleased to inform you that the research described in the submitted proposal has been reviewed by General Hospital, Ilorin Institutional Review Committee and has given full committee approval.

This approval period is 5th April, 2019 to 5th April, 2020.

You are therefore requested to inform the committee at the commencement of the research to ensure compliance with the approved procedure. If there is delay in starting the research, please inform the committee so that the period of approval can be adjusted accordingly.

The stipulated period above is binding and no research can be conducted outside this given period.

Also, no changes are allowed in the research without prior approval by the Institutional Review Committee. Please note that the GHIIRC reserves the right to conduct monitoring / oversight visit to your research site without prior notification.

Thank you.

Dr Alaofin W.A.
Chairman
GHI Institutional Review Committee

Abdulrazaq Alaoh Road, Ilorin, Kwara State, Nigeria
Website: www.ghilorin.com

APPENDIX B: **Patient consent form**

Federal University of Technology, Minna.
Department of Applied Nuclear Physics.

Informed consent form

TOPIC: Estimation of entrance surface dose and effective dose in radiology facility.

Researcher: Kehinde, Olaide.O

You are hereby invited to participate in a research study conducted by a masters degree student of the Department of physics, FUTMINNA. You must be 18 years or older and your participation is voluntary.

We are asking you to take part in this research so as to determine the entrance surface dose and the sex specific effective dose for every radiographic examination as this will enable us to know the level of risk a patient is exposed to in the process of such radiographic examination.

You will be asked of your age and your thickness will be taken by measuring your height and weight using a weighing balance.

There are no anticipated risk to your participation but if you feel any discomfort in giving any of the information above, you are free to be exempted.

It should also be noted that there are no direct benefit or any form of payment for participation.

You should be rest assured that information received from you in the process of this research will not be released to a third party and will be used for the purpose of this research only.

If you have any question about this research, please contact: Kehinde, O.O (08133388954)

Kindly Indicate below your interest or not.

Yes ☐

No ☐

Signature ___________________