DETERMINATION OF DOSES AND CANCER RISK TO PATIENTS UNDERGOING DIGITAL X-RAY EXAMINATIONS AT THE TAMALE TEACHING HOSPITAL

A THESIS SUBMITTED TO THE DEPARTMENT OF NUCLEAR SAFETY AND SECURITY OF THE SCHOOL OF NUCLEAR AND ALLIED SCIENCES

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DECLARATION

I hereby declare that this submission is my own work towards the MPhil and that, to the best of my knowledge, it contains no material previously published by another person, nor material which has been accepted for the award of any other degree of the Institute, except where due acknowledgement has been made in the text.

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ABSTRACT

Entrance surface and effective doses as well as cancer risk to patients for three common radiological examinations were estimated at the radiology department of the Tamale Teaching Hospital. The quality control assessment indicated that the digital x-ray equipment used, performed self-consistently in line with acceptable performance criteria. The study included eighty-two (82) adult patients undergoing three x-ray imaging modalities; Chest, Abdomen and Pelvis Examinations. From the study the mean entrance dose to abdomen and pelvis were found to be 0.6 ± 0.2 mGy whiles that of chest was found to be 0.2 ± 0.1 mGy. These were found to be lower than results of studies carried out elsewhere. The effective dose to patient was computed using PCXMC 2.0 software. The results shows an average effective dose of 0.036 mSv, 0.084 mSv and 0.067 mSv for chest, abdomen and pelvis examinations respectively. The risk of radiation induced cancer as a result to entrance surface dose was found to be 5.68×10^{-5} %, 1.58×10^{-4} % and 1.49×10^{-4} % for Chest, Abdomen and Pelvis examinations respectively. The third quartile values of the entrance surface dose were found to be lower than recommended diagnostic reference levels published by NRPB, UK and the IAEA for the examinations under study.

CHAPTER ONE

INTRODUCTION

1.0 BACKGROUND

The discovery of x-rays by Professor Wilhelm Conrad Roentgen, of the University of Wurzburg, Germany, in November 1895 paved way for Radiography. Radiography is recording of information about an object using x-ray transmission. It has evolved over the years from using screen-film technology to digital imaging, which is sometimes referred to as filmless radiography (Nyathi et al, 2010). Digital Radiography heralds a new era for x-ray imaging. Nowadays, digital x-ray units are in most radiology departments (Marshall NW, 2009). Digital radiography is a form of x-ray imaging, where digital x-ray sensors are used instead of traditional photographic film. There are several methods of capturing digital radiography images. These methods include computed radiography (CR), digital fluoroscopy (DF) and flat panel radiography systems such as direct radiography and indirect radiography. Computed Radiography is currently the most commonly used method of capturing Digital Radiographic images (Verma & Indrajit, 2008). Computed Radiography systems use storage-phosphor image plates with a separate image readout process; digital radiography is a way of converting x-rays into electrical charges by means of a direct readout process. The physical principles of digital radiography do not differ much from those of screen-film radiography. However, in contrast to screen-film radiography, in which the film serves as both detector and storage medium, digital detectors are used only to generate the digital image, which is then stored on a digital medium. Digital imaging comprises of four separate steps: Generation, Processing,

Archiving, and Presentation of the image. The digital detector is exposed to x-rays generated by a standard x-ray tube. Ultimately, the energy absorbed by the detector must be transformed into electrical charges, which are then recorded, digitized, and quantified into a gray scale that represents the amount of x-ray energy deposited at each digitization locus in the resultant digital image. After sampling, post processing software is needed for organizing the raw data into a clinically meaningful image.

1.1 STATEMENT OF THE PROBLEM

Tamale Teaching Hospital is the referral hospital in the northern region of Ghana. Over the years, the radiology department of the hospital has been using conventional film technology for medical diagnostic procedures. Recently, the hospital in a bid to keep abreast with technology has switched to digital x-ray system.

The hospital have been using the digital system for four (4) years now. However, there is no known assessment on dose distribution and associated risk to patients undergoing routine x-ray examination at the radiology department. Other hospitals have followed suite to acquire digital x-ray systems. However, without any known data on patient dose situations, some clinicians are of the view that the radiology department could be over exposing patients with the new system since Digital x-ray equipment has the potential of over exposing patients because of its wide dynamic range coupled with the lack of specific training for radiographers on dose management using digital systems.

This work therefore seek to research into the situational knowledge regarding patient doses and associated risk to patients undergoing selected imaging procedures at the radiology department of the Tamale Teaching Hospital

1.2 OBJECTIVES OF THE STUDY

The objective of this study is to determine doses to patients undergoing medical exposure at the Tamale Teaching Hospital using the newly installed Philip 0PTIMUS 980620611102 digital x-ray system. The specific objectives of this study are to;

- Establish a baseline Quality Assurance and Quality Control status of the newly installed Philip 0PTIMUS 980620611102 digital x-ray system for periodic audit of the performance during clinical use.
- Estimate the Entrance Surface Dose to patients undergoing routine medical examination.
- Estimate the effective dose received by patients undergoing medical diagnosis using the new digital radiography system
- Estimate cancer risk to patients
- Make appropriate recommendations to the regulatory body and the Tamale Teaching Hospital
- Disseminate findings to radiographers and radiologists in the country

1.3 RELEVANCE AND JUSTIFICATION

Radiation protection of patients forms a relevant part for the regulation of practices in Ghana. According to the BSS (IAEA) BSS, 2011), every practice must be justified and patient dose optimized weighing the medical benefits against the dose received. Digital x-rays systems are relatively new in Ghana.

An assessment of the dose received by patients undergoing routine medical examination need to be carried out. This study will enable the department update their Quality Assurance systems and Procedures relevant to the introduction of a Philip 0PTIMUS 980620611102 digital x-ray machine at the department.

1.4 SCOPE OF STUDY

This work is limited to the radiology department of the Tamale Teaching Hospital for the digital x-ray imaging procedure - Chest, Abdomen and Pelvis examination for some selected adult patients visiting the hospital for routine examination. Patients were selected at random. However, only abled patients were considered for the study.

CHAPTER TWO

LITERATURE REVIEW

2.0 INTRODUCTION

This chapter presents a review on digital radiography, patient protection, Quality Control and Quality Assurance, Performance Indicators and Exposure parameters, Patient Dose Assessment and Patient Protection in the medical application of digital radiography.

2.1 GENERAL CONSIDERATION

The subject of radiography has been widely studied and discussed in many peer review journals since the discovery of the x-ray. Particularly the medical application of radiography has gained wider study since diagnostic radiology plays a very important role in modern medicine for fast diagnosis and treatment. Globally digital radiography has proven to be safer and feasible for performing quicker process with better result in the presence of wide range of body parts vision (Fowler & Ilyas, 2011). Yet various factors such as cost of the technology, acceptability etc. may overshadow its fast growing introduction in developing countries with limited resources. The benefits and limitations of digital radiography has been a subject for discussion since this technology was introduced. Whilst the technology promises better images at low doses, it is also true that digital radiography could be a source of high dose to patients especially through patient and radiographer factors which lead to retakes etc. This has widely been studied and reported in peer review journals by various researchers (Andersen, et al 2011; Waseem et al 2011; Prieto et al 2009; Vano & Fernandez, 2007). It is now clear that the future of radiography will be digital and it behooves on radiologists to be familiar with

the technical principles, image quality criteria, and radiation exposure issues associated with the various digital radiography systems available to them.

Digital Radiography has been in clinical use since the late 1980s. Clinical experience with digital radiography systems has been widely reported (Smathers & Brody, 1985; Vizy, 1983; Partain et al, 1981). The use of digital radiography is now extending into non-clinical areas of non-destructive testing (Deprin & Gervaet, 2004). The transition from film based general radiography system to Digital based general radiography systems has had an impact on many areas of radiographers' practice and roles. These include training, new skill attainment and changes to work patterns (Dzingle, May & Garland, 2001). Computed radiography and other digital radiography systems are now widely accepted as image recording media in general radiography.

2.2 X-RAY PRODUCTION

x-rays are radiations within the electromagnetic spectrum with wavelength ranging between 0.01 to 10nm. The general principle for the production of x-rays for both medical and industrial use is the same. x-rays was created whenever high- energy electrons suddenly gave up energy. Machines produce x-rays by accelerating electrons to extremely high speeds and then crashing them into a piece of solid material called a target. There the electrons rapidly slowed down because they collide with atoms in the target, and part of the energy is changed into x-rays. These x-rays are often filtered and collimated (or focused) as they leave the x-ray tube.

For diagnostic purposes, the rays are passed through the body part of interest in a straight line and are then recorded onto film or captured by an image

intensifier and TV system to make the final image. Fig. 1 shows an x-ray tube with the basic parts and how x-rays are generated from it.

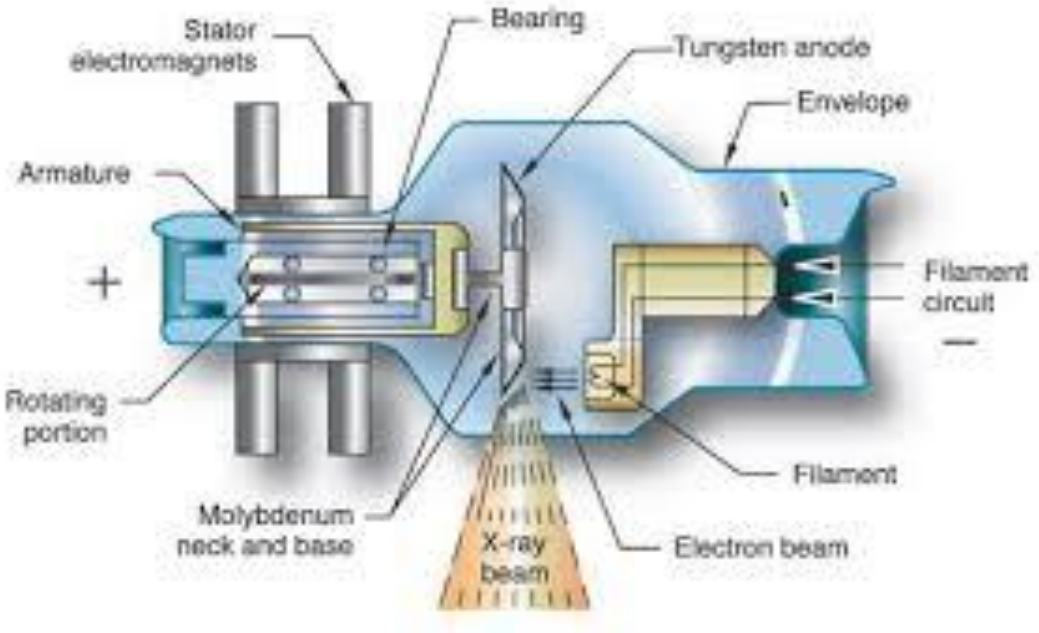

Figure 2. 1: Diagram to show the production of x-rays

2.2.1 COMPUTED RADIOGRAPHY SYSTEMS

In photo stimulable storage phosphor computed radiography systems, x-ray photons are absorbed in the storage phosphor, also known as the imaging plate (IP). Unlike conventional screens, the deposition of x-ray energy in storage phosphors results in the storage of a portion of the energy in highly localized, metastable areas called f-centers (centre where there is high attraction of electrons by positively charged ions) which serve as energy wells. During an x-ray exposure, the image is built up in the phosphor through the accumulation of f-centers. After the exposure, plate readers scan a (red) laser beam over the surface of the Imaging Plate. In one implementation, the laser beam sweeps across the Imaging Plate (scan direction) and in combination with Imaging Plate translation (subscan direction) the beam extracts the latent image from the Imaging Plate. The plate reading time depends on the size of the detector

and the scan speed of the reader. Some newer readers use a line-scan approach (the laser illumination on the plate is a line) rather than a point-scan approach to increase readout speed, but the principle is the same in both approaches. At each location, the energy of the incident laser photons triggers a de-excitation of the f-centers, resulting in the prompt emission of (indigo) light photons. A portion of these photons is detected by a photosensitive device (usually a photomultiplier tube for point-scan readers or a linear solid-state photodiode array for linescan readers), whose output is then digitized and stored. Although the amount of photostimulated light detected is proportional to the number of f-centers and thus to the number of absorbed x-rays at that location (i.e., the relationship between the photomultiplier tube signal and the number of absorbed x- rays is linear), nonlinear amplification of the photomultiplier tube signal before digitization is often used. The resulting raw pixel values are subsequently processed for display using a combination of segmentation, rescaling, and filtering algorithms.

2.2.2 DIGITAL RADIOGRAPHY SYSTEMS

Digital Radiography (DR) systems encompass a number of different technologies that are rapidly evolving. At this time, the majority of DR systems use thin-film transistor (TFT) arrays, commonly known as flat-panel arrays. The thin-film transistor arrays are composed of a matrix of discrete dels, each of which contains a transistor. The transistors operate as gates, permitting an electric charge to flow through them only when they are turned on. During an x-ray exposure, the gates are turned off, and the image is built up in the dels in the form of an electric charge, with the amount of charge in

each del proportional to the number of x-rays absorbed in that region of the detector (again, a linear relationship). The means by which x-ray energy is converted to a stored electrical charge varies somewhat between manufacturers but can be broadly classified according to whether it involves an intermediate conversion of x- ray energy to visible photons (indirect flat-panel devices) or not (direct flat-panel devices). In an indirect device, an x-ray-to-light converter, similar to that used in screen-film (SF) imaging, is placed in contact with the TFT array. Each del of the TFT array contains a light sensor (a photodiode) to convert the fluorescent light to a stored electric charge. In a direct device, a layer of material is deposited directly onto the TFT array. When an x-ray photon is absorbed in this photoconductor material, an electric charge is generated and collected in the dels of the TFT array. For both indirect and direct flat panel detectors, after the x-ray exposure, the TFT array gates are turned on one row at a time, and the amount of charge stored in each del of that row is transferred through drain lines to a row of charge amplifiers at the edge of the array for digitization and storage. The entire detector is read out by successively turning on all of the rows in a sequential fashion and storing the digital data in corresponding locations in the output digital image matrix.

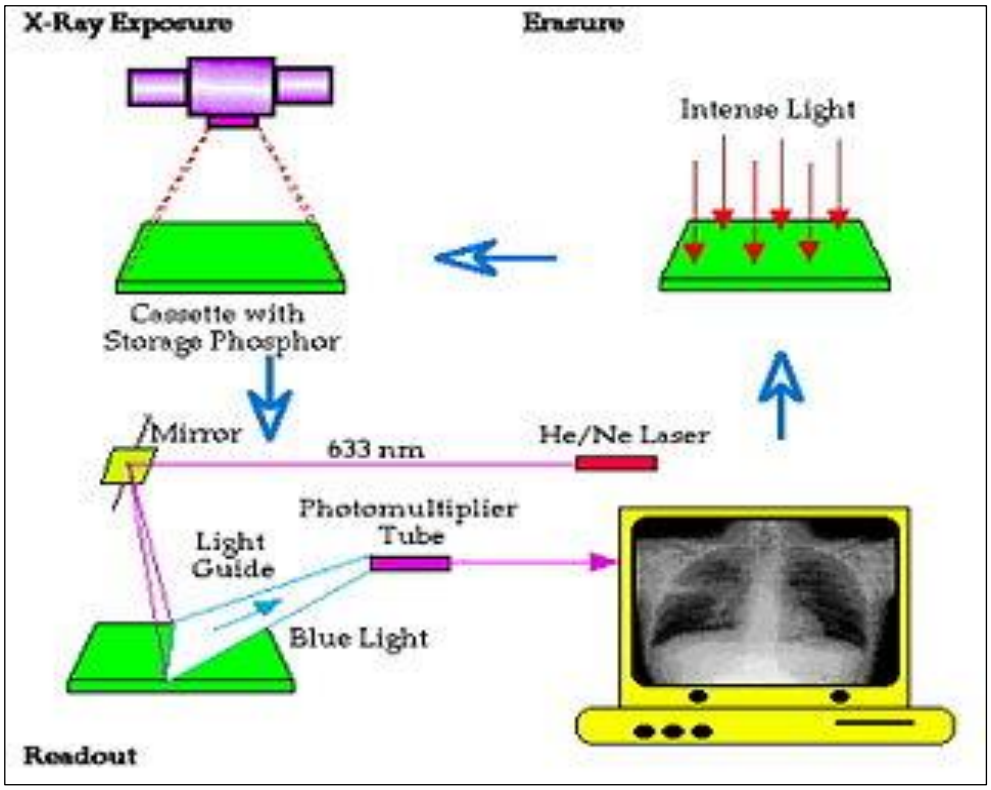

Figure 2. 2: Direct and indirect method of image acquisition in Digital radiography

2.2.3 PERFORMANCE INDICATORS AND EXPOSURE PARAMETERS IN DIGITAL RADIOGRAPHY

The performance requirement for a digital radiography system can be specified in terms of parameters such as Detective Quantum Efficiency (DQE), Modulation Transfer Function (MTF), patient dose, dynamic range and exposure level. For evaluation purposes, these parameters for digital systems are often compared against those for analogue systems. However, some of the parameters can be difficult to measure and an alternative is to compare images of test phantoms and the detectability of details contained within the phantoms. Whilst this can be of great utility, it does not replace the

need for clinical evaluation. Such evaluation should be based on the clinical objective of the examination.

2.2.4 DETECTIVE QUANTUM EFFICIENCY

Detective quantum efficiency (DQE) is one of the fundamental physical variables related to image quality in radiography and refers to the efficiency of a detector in converting incident x-ray energy into an image signal. DQE is calculated by comparing the signal-to-noise ratio at the detector output with that at the detector input as a function of spatial frequency. DQE is dependent on radiation exposure, spatial frequency, MTF, and detector material. The quality of the radiation applied is also an important influence on DQE. High DQE values indicate that less radiation is needed to achieve identical image quality; increasing the DQE and leaving radiation exposure constant will improve image quality.

2.2.5 MODULATION TRANSFER FUNCTION

Modulation transfer function (MTF) is the capacity of the detector to transfer the modulation of the input signal at a given spatial frequency to its output. In digital radiography, objects having different sizes and opacity are displayed with different gray-scale values in an image. MTF has to do with the display of contrast and object size. More specifically, MTF is responsible for converting contrast values of different-sized objects (object contrast) into contrast intensity levels in the image (image contrast). MTF is a useful measure of true or effective resolution, since it accounts for the amount of blur and contrast over a range of spatial frequencies. The Optimization of the radiation protection according to the ALARA principle requires feedback on

the actual dose levels and the quality of the acquired images in clinical routine, both for each individual examination and as averages. The latter are especially important for comparison with the diagnostic reference levels propagated in ICRP Publication 73 (ICRP 73, 1996) and translated into legal requirements. While the image quality can be judged directly from the resulting image, determination of the dose needs special attention in digital radiography as the conventional indications of dose level in the form of film speed and film density are not available. Several dose quantities are in use to describe the radiation level used for an examination. The quantity that best describes the radiation risk to the patient is the effective dose, but this quantity cannot be measured in clinical routine. The surrogate quantities usually adopted for radiation protection purposes are the entrance skin exposure (ESE) or the kerma-area product (KAP). The KAP has the advantage that it also includes the effect of collimation on patient dose. For a given situation (patient size, examination type, Projection) the effective dose can be estimated from the KAP value using conversion factors or Monte-Carlo simulation programs. The kerma-area product is the product of the dose (kerma) value of the incident radiation and the irradiated field size. Due to the inverse square-law dependence of the dose value, it can be determined or measured at any distance from the focal spot, provided that the full beam is covered. Translucent ionization chambers directly attached to the tube collimator are often used to measure the KAP during clinical exposures. Given proper calibration of the tube output, the KAP value can also be derived from the generator settings (kV, mAs), taking into account a prefilter, if fitted. The advantage of this method is that it needs no additional device in the beam, and that the KAP data can be displayed and stored with the digital image.

2.2.6 MEDICAL USE OF X-RAYS

x-rays have been widely used as the most important and reliable scientific tool for effective and proper diagnosis of diseases as well as assessing the results of a given treatment to patients (Toossi et al, 2012). Close to fifty percent of all crucial medical decisions are dependent on x-ray diagnosis and early diagnosis of some diseases depend completely upon x-ray examination. Modern diagnostic radiology assures faster, more precise diagnosis and enables monitoring of a large proportion of diseases. According to ICRP, 2013 about one half of cases, radiological procedures (plain film radiography, fluoroscopy, computed tomography) have a substantial impact on the speed of diagnosis and in a large fraction of cases they are of decisive importance. Furthermore, several screening procedures (such as mammography) have been developed which are beneficial for specific populations at relatively high risk of some diseases. In addition, a number of interventional radiological procedures (e.g. angioplasty), introduced in the last 10-20 years, contribute significantly to the effectiveness of treatment of very serious and life threatening diseases of the cardiovascular, central nervous system and other organ systems.

2.2.7 EFFECTS OF X-RAYS ON PATIENTS

The undisputed health benefits of x-rays in diagnostics may be accompanied by a generally small risk (probability) of deleterious effects (including the onset of cancer, some thyroid conditions, diabetes, high BP, coronary heart disease, strokes and cataracts). This fact therefore has to be taken into account while using ionizing radiation sources in diagnosis. Today, the fact that ionizing radiation in medical field contributes significantly to the source of

exposure of the population cannot be ignored (UNSCEAR, 2008, Clement & Sasaki, 2013). The aim of managing radiation exposure is to minimize the putative risk without sacrificing, or unduly limiting, the obvious benefits in the prevention, diagnosis and also in effective cure of diseases. According to the International Basic Safety Standard BSS (IAEA, 2014) all exposures to diagnostic x-rays must be justified and optimized, taking into consideration the benefits and risks to the patients from the radiation protection point of view. The number and types of x-ray examination, the physical parameters and radiation dose delivered to a patient must be justified as a requirement of radiation protection.

Advances in diagnostic imaging are contributing substantially to improved healthcare worldwide (Tan & Ong, 2002). One of these advances is digital radiography. This is a technology that is advancing rapidly and will soon affect hundreds of millions of patients. According to the ICRP 93 (ICRP, 2004) implementation of digital radiography techniques can entail an increase in patient radiation doses if a strict Quality Control program is not launched in parallel. Care must therefore be given to the radiation protection issues of digital radiology, during medical exposure of patients so as not to increase significantly doses without concurrent benefit. One of the main causes of this increase is the wide dynamic range of digital imaging systems, allowing overexposure with no adverse effect on image quality. In addition, the lack of specific training in the new digital techniques for some radiographers and the lack of well-established methods to audit patient doses in digital systems can worsen the problem of patient exposure. According to the ICRP, appropriate training, particularly in aspects of patient dose management, revision of DRLs

and frequent patient dose audits could help avert over exposing Patients undergoing medical radiography using digital systems.

In Ghana today, most hospitals; private and state owned are replacing the conventional film x-ray technology with digital x-ray systems and this comes with benefits and detriments.

2.3 RADIATION PROTECTION IN DIGITAL RADIOGRAPHY

The protection of patients undergoing medical exposure is very important and thus need every attention it deserves. According to the GRS-Part 3 (BSS, 2011), every medical exposure must be justified, optimized and doses limited using the ALARA principle. Radiation protection is of importance especially in pediatric radiology because of the higher sensitivity of tissue in childhood and adolescence, and the relatively longer life expectancy of young patients that may increase the chances of the development of stochastic effects (Neitzel, 2004). Measures are therefore needed to control and reduce the radiation dose from x-ray examinations, while retaining adequate diagnostic image quality. Patients undoubtedly benefit from these examinations, although the ionizing nature of x-rays means that their use is not entirely devoid of risk. For this reason, all exposures to diagnostic x-rays need to be justified and optimized in terms of benefit and risks. Compared with screen-film imaging, digital radiography offers higher detective quantum efficiency (DQE), which may translate into a corresponding dose reduction potential, while retaining the same level of image quality. Moreover, in digital radiography the x-ray generation and image detection are usually integrated into a single computer controlled system, making it possible to achieve much better control and monitoring of all parameters influencing patient dose. According to (Olivera

et al, 2004) Regular patient dosimetry is recommended to evaluate the potential for optimization of radiation protection of patients. They also recommend that, the extent of dose survey must be limited and measurements have to be confined to most frequent x-ray examinations which give a large collective dose to the population. In Ghana, various studies have been carried out to investigate doses to patients and safety assessment of radiology systems (Ofori et al, 2013, Inkoom et al, 2011, Mintah et al, 2011) mostly due to conventional screen-film x-ray systems. According to Ofori et al, 2013, given the potential harmful effects associated with exposure to ionizing radiation, it is important not just to provide gonad shielding, but also to measure patient doses, and reduce them where possible. They also assert that QA programmes and quality control (QC) protocols form an essential part of the patient dose optimization process in diagnostic imaging and therefore recommend such programmes covering physical and technical parameters associated with the types of x-ray examination being carried out need to be instigated in every medical x-ray facility. Regular patient dose measurements, film reject analysis (FRA), and image quality assessment need to become part and parcel of the ethics and norms of every diagnostic imaging department.

Additionally, Changing the way a radiographic examination is performed impacts on the patient dose as well as the corresponding image quality. Optimization of diagnostic imaging is an important part of the overall radiation protection process in a radiology department. It involves finding the technique that offers the lowest patient dose while image quality (i.e. diagnostic performance) is kept constant.

2.5 QUALITY CONTROL AND QUALITY ASSURANCE IN DIGITAL RADIOGRAPHY

An acceptable QC programme in digital radiography should have three major components; Acceptance Testing, Routine performance monitoring and testing after repair. Maintenance of the x-ray machine systems are the largest capital expenditure a Radiology department may experience. It therefore makes economic sense to make sure that the equipment meets the performance standards. Acceptance testing ensures that the machine was installed and calibrated properly. According to Inkoom, S et al 2011, the determination of what constitutes high quality in any QA programme will be made by the diagnostic radiology facility producing the images and must cover the entire x-ray system from machine, to processor, to view box. According to them a good Quality Assurance programme must include both quality control (QC) techniques and quality administration programme. Quality administration procedures are those management actions intended to guarantee that monitoring techniques are properly performed and evaluated and that necessary corrective measures are taken in response to monitoring results. These procedures provide the organizational framework for the quality assurance programme.

The performance of x-ray systems may drift or deteriorate over time. Consequently, periodic testing is required to monitor the performance. After a major repair, the machine should be retested to ensure that it was repaired properly. If the testing results show that the machine is not performing properly, service or preventive maintenance is required.

Generally, for quality control (QC) purposes in digital radiography, the systems usually provide exposure indicators (EI), derived from the (mean) image signal and therefore, related to the detector exposure. They can be seen as the equivalence of the combination of film speed and film density that serves as an exposure indicator in conventional radiography. Exposure indicators in conventional and Digital Radiography systems differ in scale and definition, making it difficult to compare EI values from different vendors or installations. However, the main purpose of the exposure indicator is to allow longitudinal (time) comparisons of system operation in one installation. Also, since the EI is derived from the actual patient image, variations may occur due to the varying image content, even when a fixed or precisely comparable exposure setting is used. The definition of the EI follows the speed definition of conventional screen-film systems. The EI values are directly related to the (mean) detector entrance exposure, which in turn is derived from an appropriately defined mean pixel value. As the pixel values in a clinical image may vary greatly due to differences in the anatomical structure under examination, the procedure used to determine the mean pixel value has a great influence on the resulting EI. Most systems use some type of histogram analysis for this purpose. In the Digital Radiography additional system information is available and used for the EI determination. For photo timed exposures, only the area of the activated measuring fields is used as the input for the calculation whiles for manually exposed images, the central part of the collimated area is evaluated, excluding areas of direct radiation by means of a segmentation algorithm. This principle leads to highly consistent EI values with good correlation to the exposure level. Quality control can be performed by phantom exposures that assess the whole imaging chain. Qualitative

evaluation can be obtained at the level of digitally stored images, monitors or film documentation. This can be achieved by subjective assessment of image quality displayed on dedicated monitors or films (for example, spatial resolution or contrast detectability) or by direct evaluation of the digital images using computer QA programs. The safety of patients in terms of justification and the as low as reasonably achievable (ALARA) principle is inadequate without quality assurance measures. The magnitude of patient dose due to rejects, poor equipment performance, poor radiographic techniques and equipment age can be significant. These results in unnecessary cost that can be avoided if effective quality assurance measures are in place. Quality improvement processes within radiological facilities could be enhanced through accreditation of diagnostic facilities, audits and surveillance programmes. In most digital Diagnostic system a direct feedback on the exposure factors and dose values after each image exposure is provided and displayed on the operating console. All relevant exposure parameters (kV, mAs, ms, filter, grid used) and dose values (KAP and EI) are stored together with the acquired image, and are documented on the film hardcopy and included in the DICOM header for display at the radiologist's reading station. Internally, the system collects all data for each x-ray exposure in a log file that can be accessed by service and system specialists for further analysis. For instance, this feature can be used to compare the dose values applied in clinical routine use with the diagnostic reference levels. Radiological protection of patients should be an integral part of a radiology facility's QA Programme. x-ray equipment should therefore be installed with KAP meters to facilitate routine patient dose measurements. In Ghana, results from previous quality assurance studies (Schandorf & Tetteh, 1998, Ofori et al 2011) showed

a lack of compliance leading to high patient doses in some hospitals. Other studies also revealed that most radiology departments did not have an implemented QA programme, QA committee or QC test protocols. Therefore for a developing country like Ghana, with a minimal number of radiology qualified experts, quality assurance can be achieved through collaboration between the competent authority, regional hospital and a national referral hospital where the qualified experts are based. The imaging professionals can then perform the necessary QC tests, assess the level of quality improvement, and do acceptance tests on imaging equipment.

2.6 DOSIMETRY IN DIGITAL RADIOGRAPHY

Radiation Dosimetry is an integral part of the overall quality assurance and quality control process. It is defined as the measurement, usually, of the absorbed dose, or other relevant quantities like KERMA, exposure or equivalent dose, which is produced due to the interaction of the ionizing radiation with tissue. That measurement can be achieved using a dosimeter. External dosimetry is a measure of absorbed doses, produced from radiation sources, which are outside of the body of the exposed worker. The imparted energy is responsible for the effects that radiation causes in matter, for instance, a rise in temperature, or chemical or physical changes in the material properties. Some dosimetric parameters have been discussed below.

2.6.1 ENERGY IMPARTED (ε)

The energy imparted to a patient undergoing any x-ray examination can be estimated by modeling the patient as a slab of water using the expression.

$$\boldsymbol{\varepsilon = w \times DAP} \qquad 2.1$$

Where w is the energy imparted per unit exposure area product and depends on the water phantom thickness, x-ray tube potential, and x-ray beam HVL, DAP is the dose area product where the dose is air kerma measured at the entrance area (free in air).

2.6.2 ENTRANCE SURFACE AIR KERMA.

This is the Air kerma on the x-ray beam axis at the entrance surface of the patient. For a single exposure it is equal to the product of the backscattering factor and the incident beam air kerma.

$$\mathbf{K_e(Gy) = K_i\ (Gy) \times B} \qquad 2.2$$

Where K_e is the Entrance Surface Dose, K_i is the incident Air Kerma and B is the backscatter factor.

2.6.3 ABSORBED DOSE ($D_{T,R}$)

Absorbed dose is the quantity that better indicates the effects of radiation on materials or on human beings, and, accordingly, all the protection related quantities are based on it. The use of dosimetric quantities is important in many aspects of the application of radiation. in diagnostic radiology, radiation protection of staff and patients is the most important application of the dosimetric quantities. Examinations in diagnostic radiology usually result in a limited irradiation of the body. As the doses delivered are relatively low and the uncertainty in the absolute risk for a stochastic effect is high, a required accuracy of 20% in dosimetry measurements for estimating the absolute risk during radiology examination of adults is sufficient. In diagnostic radiology, KERMA and $D_{T,R}$ are equal.

2.6.4 EQUIVALENT DOSE: $H_{T,R}$

This is the absorbed dose in an organ or tissue multiplied by the relevant radiation weighting factor. Mathematically equivalent dose is given by

$$H_{T,R} = \sum_{T} w_R \cdot D_{T,R} \qquad 2.3$$

Where $D_{T,R}$ is the average absorbed dose in the organ or tissue T, and w_R is the radiation weighting factor for radiation R.

2.6.5 EFFECTIVE DOSE

The Effective Dose is a radiation dose parameter which takes in to account the absorbed Dose received by each irradiated organ and the organs relative sensitivity according to ICRP. It is a protection level dosimetry quantity which could be used as an approximate measure of stochastic effect. According to wall et al, it can be used to quantify the amount of radiation received by a patient undergoing diagnostic examination. For non-uniform exposures which is normally the case in diagnostic examinations (wall et al, 1988,). The relative sensitivity of an irradiated region needs to be taken into account when the effective dose is being calculated. According to ICRP tissue weighting factors are chosen to represent the fraction of health risk, or biological effect, which is attributable to the specific tissue named. Thus for patient undergoing any radiological procedure, the effective dose is expressed as

$$E = \sum_T W_T \sum_R W_R . D_{T,R} \qquad 2.4$$

Where E is the effective Dose imparted to an organ, $D_{T,R}$ is the Absorbed Dose and W_T is the Tissue Weighting factor and W_R is the radiation weighting factor

2.7. PATIENT PROTECTION IN DIGITAL RADIOGRAPHY

The need for patient protection in radiology cannot be over emphasized due to the effects radiation has on human health. Specifically, Medical ionizing radiation sources provide by far the largest contribution to the population dose from artificial sources and most of this contribution comes from diagnostic x-rays (above 90%). When following the ALARA principle, radiographers should minimize patient exposure from digital radiography procedures. The use of digital image receptors can result in lower radiation dose than the use of film-screen image receptors, without loss of image quality. This however, requires strict adherence to institutional protocols in order not to over expose patients without a change in image quality, because of a much higher dynamic range of digital receptors. According to Zhang & Chu, 2011, this makes optimization (OT) of radiation protection undergoing digital radiography (DR) more complex, while a chance to reduced patient dose also exists. For image quality and patient safety, international and national bodies, such as International Atomic Energy Agency (IAEA); IAEA, 2004, European Commission (EC); EC,1999, National Radiological Protection Board (NRPB); NRPB, 2002, have addressed corresponding documents and recommended diagnostic reference levels (DRLs) or guidance levels of dose for the common types of diagnostic examinations. However all these guidance values are based on conventional film technology systems. The best practice is to select the appropriate exposure technique factors for the patient's size and condition, based on a planned exposure system designed in collaboration with radiologists, to determine adequate image quality for diagnosis (Herrmann et al, 2012).

2.8 ADVANTAGES AND LIMITATIONS OF DIGITAL RADIOGRAPHY

The main limitations of digital radiographic systems are higher initial cost, a lack of familiarity on the part of both radiologists and technologists with electronic image display and with online soft copy reading (compared with alternator-based batch mode reading), and the lack of consistent feedback to technologists concerning the use of optimal acquisition techniques. The latter problem, along with the much larger dynamic range of digital systems, has led to a gradual increase in patient radiation dose, an issue discussed in more detail below (Vano & Fenendez, 2007; Williams et al, 2007). The advantages of digital radiography include the separation of acquisition, display, and archiving, allowing tremendous flexibility using image-processing functions such as those that adjust the level and window width of the image gray-scale presentation. However, display contrast is limited by the inherent image signal-to-noise ratio (SNR), because as the signal contrast is increased, so is the visibility of noise. Other advantages include: anatomy-specific presentation and disease-specific algorithms; in most cases better x-ray detection efficiency and higher detective quantum efficiency (DQE), permitting lower doses to patients; the ability to use a second computer reader to assist the radiologist; a reduction in the number of image retakes due to underexposure or overexposure; and the elimination of labor-intensive handling and distribution of images during the acquisition process.

CHAPTER THREE

MATERIALS AND METHOD

3.0 This chapter presents information on materials and methods used in this work. It also describes methodology for the measurement of various parameter

3.1 MATERIALS

The materials used in this study include the following: Philip 0PTIMUS 980620611102 digital x-ray machine with serial number – 233030 manufactured in 2011, TLD-100 which is made-up of Lithium Fluoride crystal chip doped with Titanium and Magnesium, Harshaw 6600 TLD reader; serial No: 9805167 manufacture in 1997, RMI Multifunction Meter; Model No: 240Am serial No:240A-1607, Fuji IP type cc speed 400

Plate 3. 1: Tube and Couch of the digital x-ray machine

Source: (Field work 2015)

Plate 3. 2 : Multifunction meter placed on couch for Quality control test.

Source: (Field work 2015)

Plate 3. 3: Harshaw 6600 TLD reader

Source: (www.thermoscientific.com)

3.2 METHOD

3.2.1 Quality Assurance of Thermoluminiscence Dosimeters (TLD) Chips

Twenty (20) TLD were used in the dose measurements. All the TLDs were calibrated. Sensitivity, reproducibility and linearity tests were done at the Secondary Standard Dosimetry Laboratory of the Radiation Protection Institute. TLDs with sensitivity within 5% standard deviation were selected and used for the study. Consent form was given to each patient for their approval to partake in the study.

3.2.2 Performance Testing of Digital X-Ray System

To ensure the accuracy of results. A performance test was carried out on the Digital x-ray System at the Tamale Teaching Hospital. During the process, Leakage Test, kV Accuracy, Tube Output Consistency, Half Value layer were measured.

3.2.2.1 Measurement of kVp Accuracy

A multifunction x-ray QC meter was used for the measurement of the kVp and kVp Accuracy. A set of known kVp values were selected. The multifunction meter was placed in the path of the beam and exposures taken. Three exposures were taken for each kVp value. The mean value was calculated and the percentage deviation of the mean for each kVp value was computed.

3.2.2.2 Measurement of Half Value Layer

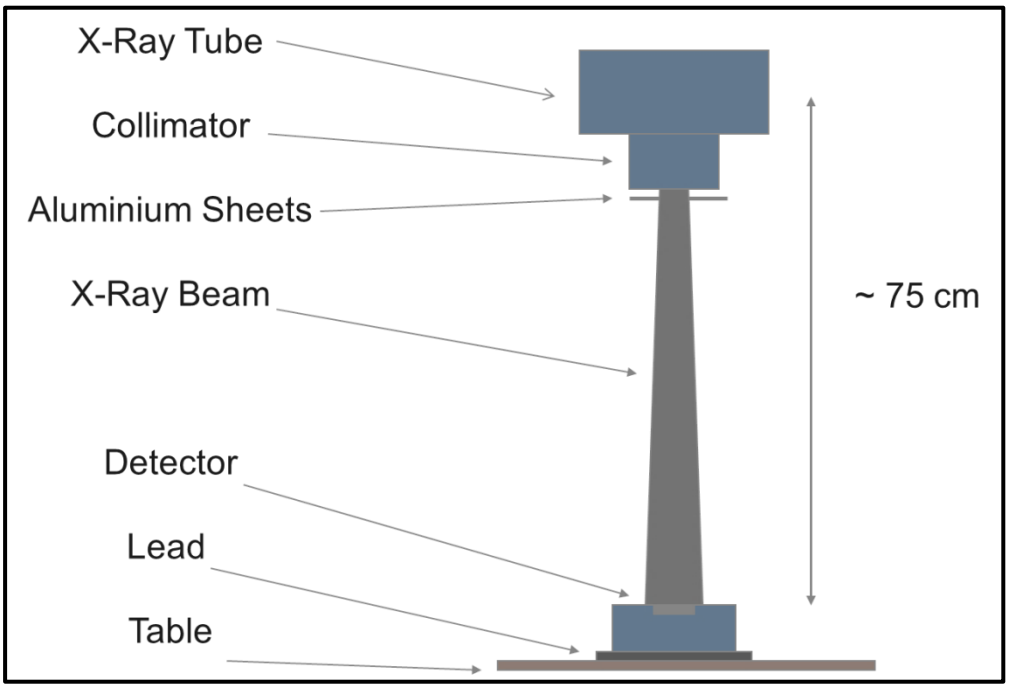

Figure 3. 1 Experimental Setup for Half Value Layer

The focus to Surface distance of the digital x-ray system was set at a fixed distance of 75cm, a fixed kV value of 81 and mAs of 25 was used for this QC Assessment. A multifunction x-ray QC meter was placed in the collimated beam and three exposures taken. The mean exposure reading on the meter was recorded and taken as the exposure value for 100% beam transmission. Different thickness of Aluminium absorbers (i.e. 2.0 mm, 2.5 mm, 3.0 mm, 3.5 mm, 4.0 mm and 4.5 mm) were then placed under the meter and three exposures taken for each Aluminium absorber. The mean exposure output for each absorber thickness was calculated as a percentage of the exposure for 100% transmission. A graph of percentage transmission against Aluminium thickness was plotted and the value of Aluminium thickness that gives 50% transmission percentage is taken as the Half Value Layer.

3.2.2.3 Measurement of Tube Output Consistency

The exposure value for a set of known kVp values (60, 70, 90) were calculated for known but varied mAs values (16, 20, 25). For each kVp and mAs value set on the x-ray system, three exposures were taken and the mean output (mR) calculated. For consistency calculation; the formula below was used.

$$\frac{\textbf{Mean Output (mR)}}{\textbf{mAs}} \sim \textbf{constant} \qquad 3.1$$

3.2.2.4 Leakage Test

The x-ray tube collimator is closed and exposure taken with a known kVp and mAs values. A survey meter is used to measure to the level of radiation 1m around the x-ray system during the exposure.

3.2.3 TLD Calibration

The variance in the sensitivity of a typical batch of TL dosimeters is unavoidable but can be reduced from 10-15% to 1-2% when dosimeters are calibrated. It was therefore important to calibrate the TLD's for this work

3.2.3.1 Sensitivity Test

TLD chips come in already exposed to a certain amount of radiation dose by the manufacturer. This standard dose is often indicated with the batch of TLDs purchased. At the Personnel Dosimetry Laboratory. A fresh batch of TLDs will be read using the Harshaw 6600 system. The chips are annealed and exposed to a known dose of Radiation at reference conditions at the SSDL and read with again. This process is repeated three times under the same reference conditions. Chips with a dose deviation of ±5% from the manufacturers value are considered fit for use.

3.2.3.2 Reproducibility Test

After the determination of sensitive chips, the next quality control test that is determined is the reproducibility of the chips. The batch of TLD chips are exposed to radiation under reference conditions at the Secondary Standard Dosimetry Laboratory (SSDL), the chips are counted or read and the dose determined. The chips are then annealed and the experiment repeated for the same known dose three times. The deviation in the values of dose determined for the three experiments is determined. Chips with good reproducibility are chips whose deviation were within ±5%.

3.2.4 Measurement of Entrance Surface Dose (ESD)

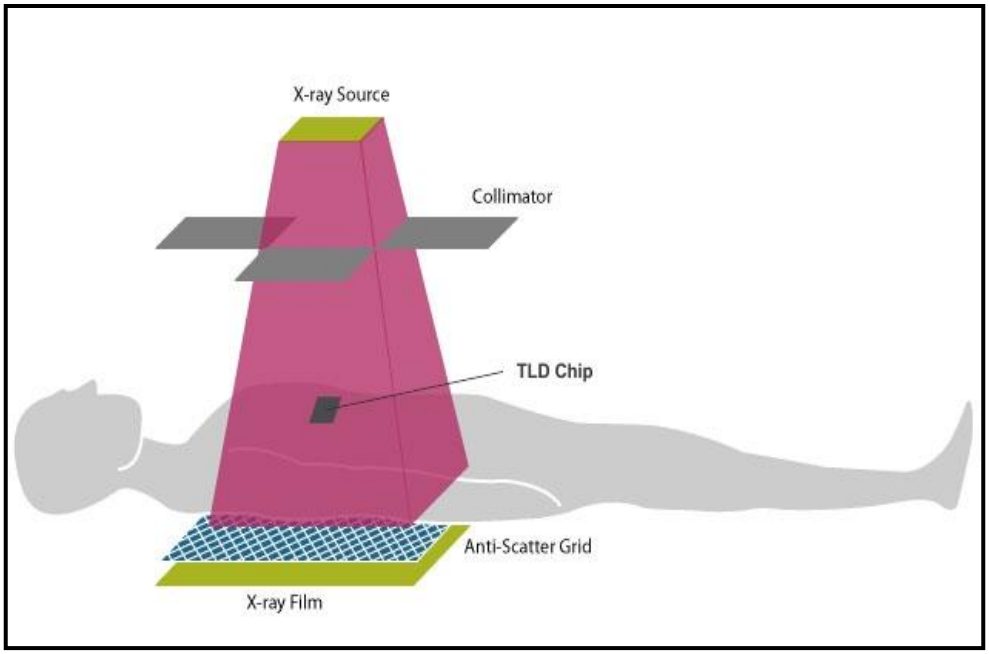

Figure 3. 2 Experimental Setup for determining Entrance Surface Dose

The common modalities that are undertaken by patient visiting the hospital are (Chest, Abdomen and Pelvis). The entrance surface dose to patients were assessed for 82 patients selected at random undergoing medical exposure in

Chest, Abdomen and Pelvis examinations at the Radiology Department of the Tamale Teaching Hospital.

Entrance surface dose is the absorbed dose to the entrance skin of the patient at the central point of the irradiated area. The entrance surface doses were assessed for routine radiographic examinations such as chest, Abdomen and Pelvic radiographs using TLD chips. The Thermo luminescence dosimeters were placed at the center of x-ray beam on the patient's skin. Therefore, the backscatter radiation is included. The exposure data such as kVp, mAs, speed of cassette and the focus to skin distance for each examination were also recorded. One TLD chip was placed on the skin of each patient for the assessment of the of ESD.

3.2.5 PCXMC Software

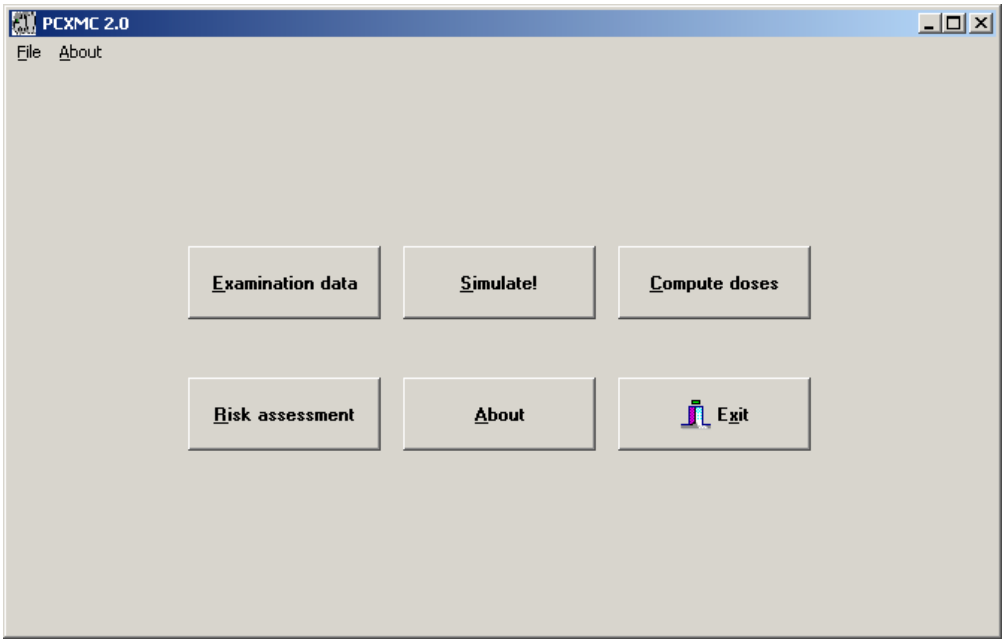

Figure 3. 3: Screen capture of PCXMC Software

The PCXMC software is a Monte Carlo based program (24) developed by the Radiation and Nuclear Safety Authority in Finland (STUK), it is used to calculate patients' organ doses and the effective dose in medical x-ray examinations. It allows a free adjustment of the x-ray projection and other examination conditions of projection radiography and fluoroscopy. The anatomical data are based on the mathematical hermaphrodite phantom models of Cristy and Eckerman (1987), with some modifications and user-adjustable phantom sizes. The program calculates the effective dose with both the new tissue weighting factors of ICRP Publication 103 (2007) and the old tissue weighting factors of ICRP Publication 60 (1991). The program incorporates adjustable-size pediatric and adult patient models, and allows a free choice of the x-ray examination technique. The program also calculates an estimate of the patient's risk of death due to radiation-induced cancer according to the sex- and age-dependent risk model of the BEIR VII committee (BEIR, 2006).

PCXMC uses three different quantities to assess risk:

- Risk of exposure-induced death (REID)/radiation induced fatal cancer
- Loss of life expectancy (LLE)
- Loss of life expectancy per radiation induced fatal cancer (LLE/REID)

The definitions of these quantities are (Thomas et al. 1992)

$$\mathrm{REID}_c(e,D) = \int_{\tau}^{\infty} [\mu_c(t \mid e,D) - \mu_c(t)] S(t \mid e,D) dt \qquad 3.2$$

and

$$\mathrm{LLE}(e, D) = \int_{\tau}^{\infty} S(t \mid e)dt - \int_{\tau}^{\infty} S(t \mid e, D)dt. \qquad 3.3$$

where, $\mu_c(t \mid e, D)$ is the mortality rate at age t due to death cause c, given that the subject was alive at the age of exposure e and the corresponding dose at that age was D.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 This section deals with the results and discussion of major findings from the study.

4.1 QUALITY ASSURANCE OF X-RAY SYSTEM

The performance indicators of an x-ray system have been found to have a bearing on the dose a patient receives. Performance testing is therefore very important in the overall quality Assurance and Quality Control Process.

4.1.1 Output Consistency Variation With kVp and mAs

The results of output consistency variation with kV and mAs are shown in Table 4.4 . For consistency, the variation of the mean output /mAs should be constant for a given kV value. This is evident from the Table 4.1 (see Appendix).

4.1.2 Results of Timer Accuracy Check

For a accuracy, the deviation between the indicated and measure timer value should not be more than 5%. From the results in Table 4.2 (see Appendix) it is clear that with the exception of test 3, the percentage deviation for all the tests are lower than 5%. This presents an average percentage value of 3.68%.

4.1.3 kVp Accuracy And Consistency

The effect on kVp on patient dose has been proven and published in various literature (Khan et al., 2013; Lee et al , 2010). It is therefore very important that x- ray systems are accurate and consistent as far as kVp is concerned. For

an indicated kVp value the measured kVp should not deviate more or less than 5%. From table 4.3 (see Appendix), it is observed that the percentage deviation for all measured kVp values are less than 5%. This indicates that the kVp output from the x-ray system is accurate and consistent.

4.1.4 Result of Beam Quality: Half Value Layer

The half Value layer is the thickness of absorber material (mostly Aluminium that attenuate the beam to 50% of the initial value. A graph of percentage transmission and absorber thickness (mmAl) is shown in Figure 4.1 the results indicates that an Aluminium thickness of 3.8 mmAl is required to attenuate the initial output by 50% for a fixed kV value of 81.

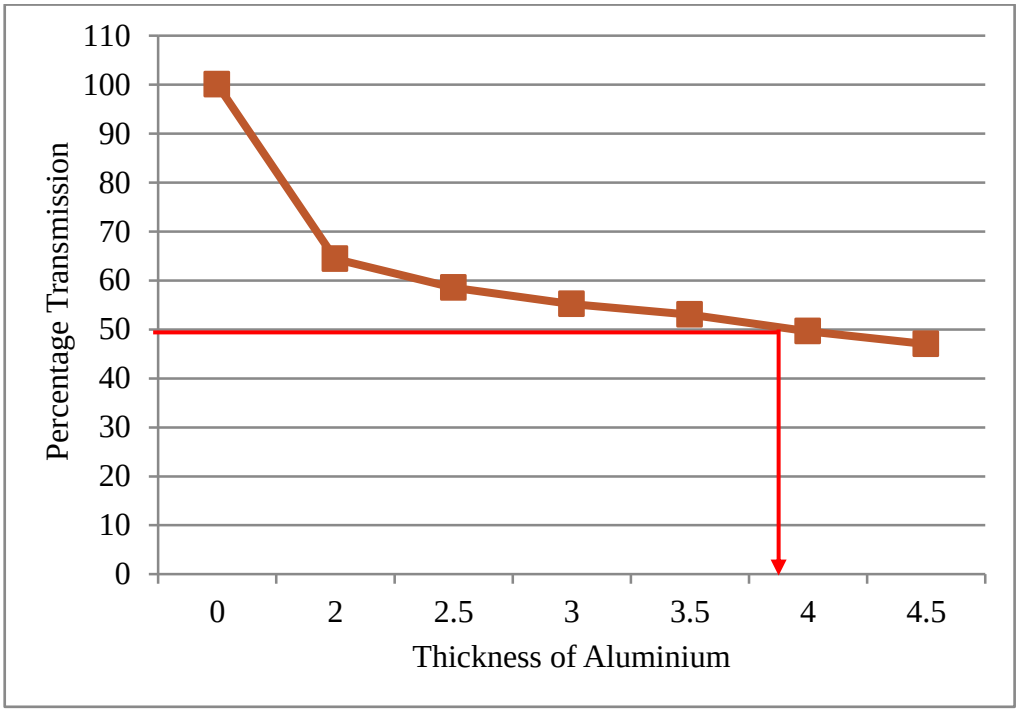

Figure 4. 1: A graph of Percentage transmission and thickness of Aluminium

Table 4. 1; Result of Beam Quality: Half Value Layer

Test	Absorber thickness (mmAl)	Output measurement (mSv)			Mean Output (mSv)	% Transmission
		1	2	3		
1	0	0.00276	0.00265	0.00269	0.0027	100.0
2	2	0.00174	0.00174	0.00174	0.00174	60.4
3	2.5	0.00155	0.0016	0.00157	0.00158	58.5
4	3.0	0.00147	0.0015	0.00148	0.00149	55.2
5	3.5	0.00143	0.00143	0.00143	0.00143	53.0
6	4.0	0.00136	0.00133	0.00134	0.00134	49.6
7	4.5	0.00129	0.00125	0.00126	0.00127	47.0

4.2 ENTRANCE SURFACE DOSE FOR RADIOGRAPHIC PROCEDURES

The entrance surface dose (mGy), examination procedure, patient height (cm), kVp and mAs for the three radiographic procedures chest, Abdomen and Pelvis studied are presented in Table 4.5, Table 4.6 and Table 4.7 respectively

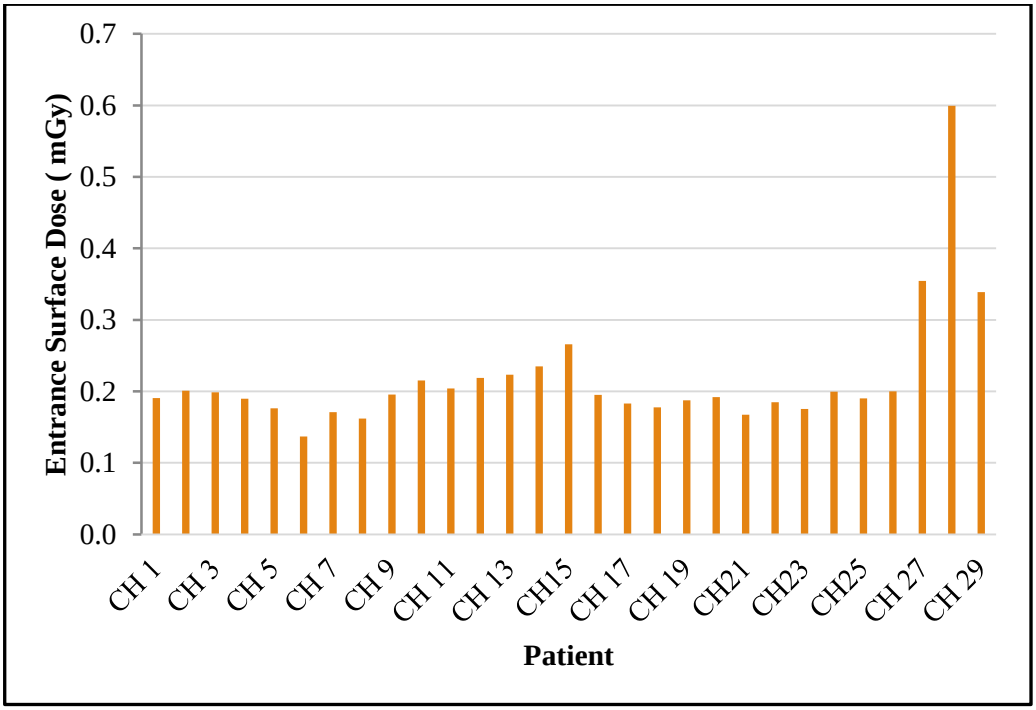

Figure 4. 2: A graph of Entrance Surface Dose to Patient for Chest Examinations

Table 4. 2: Entrance Surface Dose Associated with Chest Radiography at the Tamale Teaching Hospital

PATIENT ID	Radiological Parameters					ESD/mGy
	Gender	Patient Height/cm	kVp	mAs	FSD/ cm	
CH 1	Female	165	125	1.4	180	0.2
CH 2	Female	160	125	0.92	180	0.2
CH 3	Female	165	125	1.21	180	0.2
CH 4	Female	155	117	0.91	180	0.2
CH 5	Female	154	125	0.98	180	0.2
CH 6	Female	180	117	0.55	180	0.1
CH 7	Female	170	125	1.32	180	0.2
CH 8	Female	180	117	0.74	180	0.2
CH 9	Female	157	125	0.92	180	0.2
CH10	Male	180	117	0.91	180	0.2
CH 11	Female	168	117	1.3	180	0.2
CH 12	Female	168	117	1.3	180	0.2
CH 13	Female	65	117	0.58	180	0.2
CH 14	Female	174	133	1.15	180	0.2
CH15	Male	170	117	0.77	180	0.3
CH 16	Female	151	117	0.67	180	0.2
CH 17	Female	156	117	0.66	180	0.2
CH18	Male	173	117	0.63	180	0.2
CH 19	Female	163	117	0.63	180	0.2
CH 20	Female	152	125	0.94	180	0.2
CH21	Male	173	125	0.64	180	0.2
CH 22	Female	157	125	0.69	180	0.2
CH23	Male	179	125	0.52	180	0.2
CH 24	Female	165	125	0.74	180	0.2
CH25	Male	164	125	1.2	180	0.2
CH 26	Female	160	120	0.97	180	0.2
CH 27	Male	178	125	1.2	180	0.4
CH28	Male	170	124	10	180	0.6
CH 29	Female	165	141	3.2	180	0.3
Mean		166.1	122.3	1.3	180	0.2
Max		180	141	10	180	0.6
Min		151	117	0.5	180	0.1
Std Dev		20.7	5.6	1.7	0.0	0.1

Table 4. 3: Entrance Surface Dose Associated with Abdominal Radiography at the Tamale Teaching Hospital

PATIENT ID	Radiological Parameters					ESD/mGy
	Gender	Patient Height/ cm	KVp	mAs	FSD/cm	
ABD 1	Female	170	81	28.1	100	0.6
ABD 2	Male	162	81	6.42	100	0.5
ABD 3	Male	180	77	3.77	100	0.5
ABD 4	Female	156	81	14.5	100	0.7
ABD 5	Female	174	81	17.6	100	0.6
ABD 6	Female	167	81	17.6	100	0.5
ABD 7	Female	162	77	12.5	100	0.6
ABD 8	Female	170	81	2.9	100	0.4
ABD 9	Male	180	77	8.57	100	0.4
ABD 10	Male	168	81	4.07	100	0.4
ABD 11	Male	150	81	5.83	100	0.7
ABD 12	Male	160	77	1.68	100	0.6
ABD 13	Female	150	85	5.66	100	0.5
ABD 14	Female	163	81	4.26	100	0.4
ABD 15	Female	165	81	6.34	100	0.5
ABD 16	Female	147	81	26.9	100	0.5
ABD 17	Female	158	81	12.6	100	0.7
ABD 18	Male	158	77	3.37	100	0.5
ABD 19	Female	157	77	13.9	100	0.6
ABD 20	Male	157	77	10	100	0.5
ABD 21	Male	159	81	5.2	100	0.3
ABD 22	Female	168	81	6.72	100	0.9
ABD 23	Female	158	77	10.5	100	1.1
ABD 24	Female	172	81	10	100	0.9
ABD 25	Female	160	81	10	100	1.2
Mean		162.8	79.9	10	100	0.6
Max		180	85	28.1	100	1.2
Min		147	77	1.7	100	0.3
Std Dev		8.4	2.1	6.8	0.0	0.2

Table 4. 4: Entrance Surface Dose Associated with Pelvis Examination at the Tamale Teaching Hospital

PATIENT ID	Radiological Parameters					ESD/mGy
	Gender	Patient Height/cm	KVp	mAs	FSD/ cm	
PEL 1	Male	163	77	3.45	100	0.5
PEL 2	Female	164	77	3.45	100	0.4
PEL 3	Female	160	77	7.4	100	0.6
PEL 4	Female	150	77	19	100	0.6
PEL 5	Female	162	77	30.5	100	0.5
PEL 6	Female	163	77	10.2	100	0.5
PEL 7	Male	170	77	9.3	100	0.4
PEL 8	Female	165	77	6	100	0.6
PEL 9	Female	157	77	42.5	100	1.3
PEL 10	Male	160	77	10	100	0.6
PEL 11	Female	155	77	10.1	100	0.6
PEL 12	Male	188	77	5.77	100	0.4
PEL 13	Male	174	77	4.54	100	0.5
PEL 14	Male	177	77	5.44	100	0.5
PEL 15	Male	176	77	5.88	100	0.6
PEL 16	Female	155	77	6.34	100	0.5
PEL 17	Male	173	77	10	100	0.4
PEL 18	Female	164	77	13.4	100	0.4
PEL 19	Male	162	77	6.97	100	0.4
PEL 20	Male	163	77	7.13	100	0.7
PEL 21	Female	171	73	6.54	100	0.8
PEL 22	Male	169	70	5.69	100	0.6
PEL 23	Female	165	70	5.67	100	0.5
PEL 24	Male	175	73	11.2	100	0.7
PEL 25	Female	164	70	9.27	100	0.7
PEL 26	Female	166	73	11.9	100	0.5
PEL 27	Male	170	77	10	100	0.7
PEL 28	Male	161	81	6.6	100	0.5
Mean		165.8	76	10.2	100	0.6
Max		150	81	3.2	100	1.3
Min		188	70	42.5	100	0.4
Std Dev		7.8	2.5	8.2	0.0	0.2

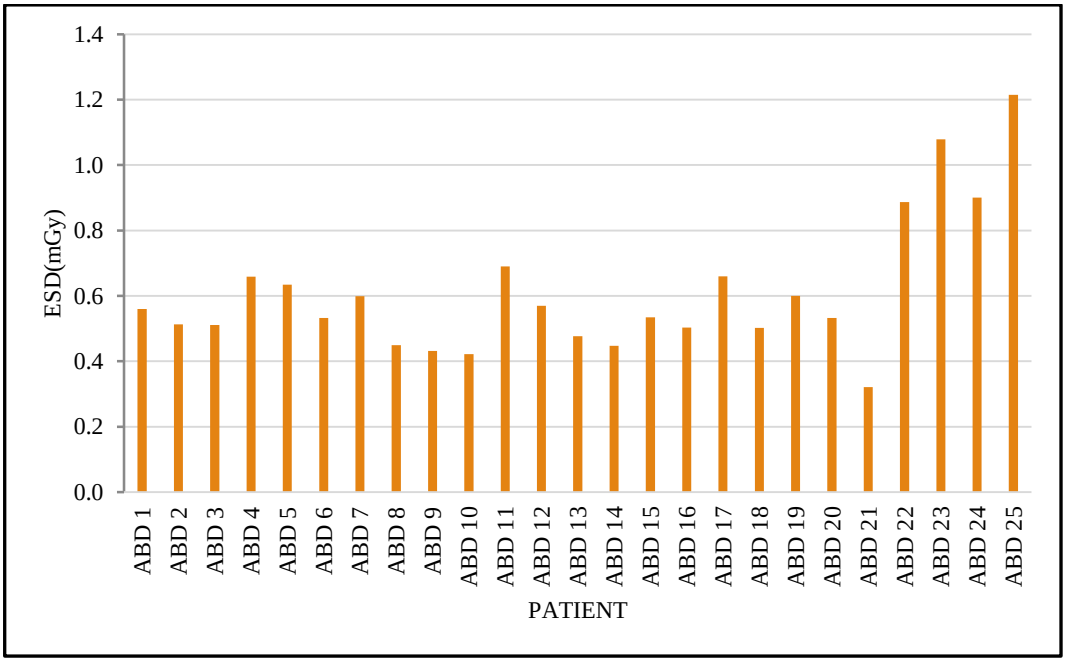

Figure 4. 3: A graph of Entrance Surface Dose to Patient for Abdominal Examinations

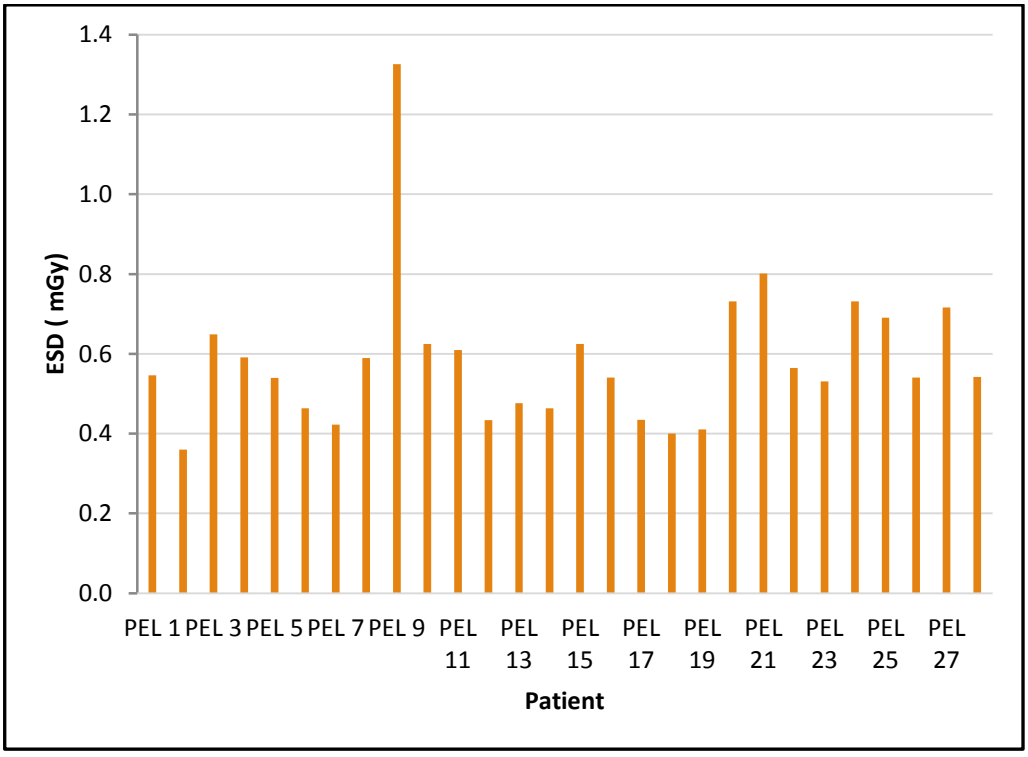

Figure 4. 4: A graph of Entrance Surface Dose to Patient for Pelvis Examinations

From Figure 4.2, the entrance surface dose associated with chest were found to vary with each patient. Specifically, it ranged from 0.1 mGy to 0.6 mGy with an average of 0.2 mGy and a standard deviation of 0.1 mGy. From Figure 4.3, the entrance surface dose for abdominal examination is found to range from 0.3 mGy – 1.2 mGy with an average of 0.6 mGy and a standard deviation of 0.2 mGy. From Figure 4.4 it can be seen that the entrance surface dose for pelvis examination range from 0.4 mGy – 1.3mGy with an average of 0.6 mGy and a standard deviation of 0.2 mGy.

Generally, the results of doses to patient were found to vary within examinations and for different examination. This trend is evidently shown in Figure 4.2, Figure 4.3 and Fiureg 4.4. It reveals that patient received varying levels of doses. These could be due to differences in exposure factors such as mAs and kVp used in the examinations. The mean entrance dose to abdomen and pelvis where found to be 0.6±0.2 mGy whiles that of chest was found to be 0.2±0.1 mGy this could be attributed to the low mAs selected for chest examinations.

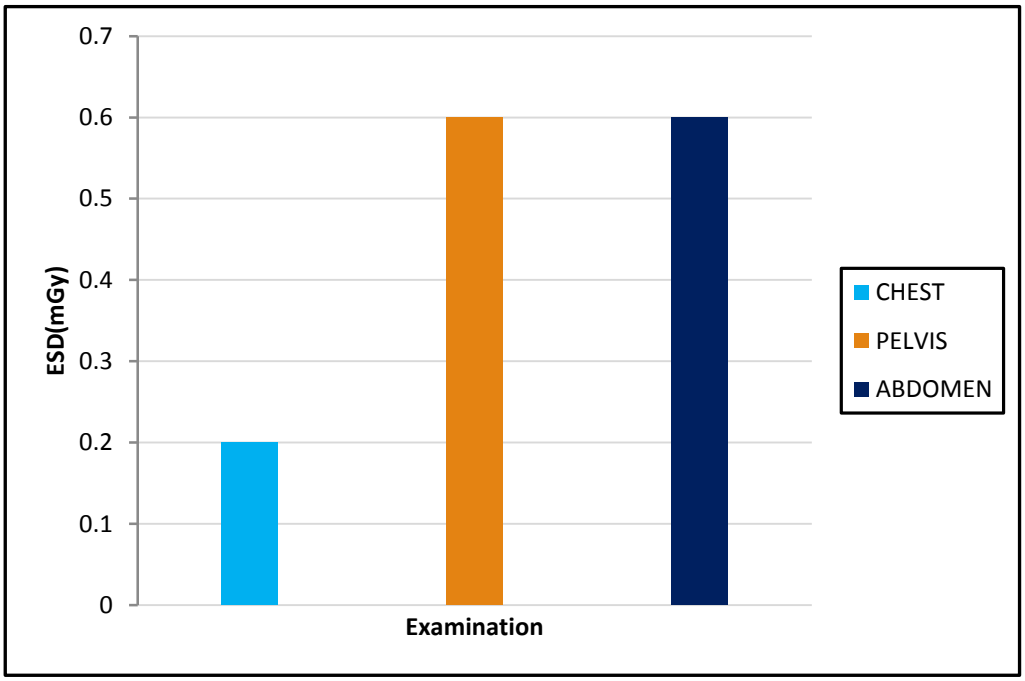

Figure 4. 5: A graph of Average Entrance Surface Dose for Three imaging Modalities at the Tamale Teaching Hospital.

The mean entrance surface dose for this study 0.2 mGy, 0.6 mGy and 0.6 mGy for chest, abdomen and pelvis respectively was compared to other works. Table 4.8 show the results from this study are lower than those from other countries. This could be attributed to the use of different exposure factors like kV and mAs used in the study. Other reason could be that, the studies presented were carried out using conventional x-ray machines.

Table 4. 5: Entrance Surface Dose from this study compared to other works

PROCEDURE	THIS WORK	SERBIA AND MONTENEGRO	UK	ITALY
CHEST	0.2	0.4	0.16	0.57
PELVIS	0.6	2.36	4.4	7.7
ABDOMEN	0.6	1.86		

Given that operator training and knowledge could also influence the criteria for the selection for exposure factors as well as the performance of the x-ray system on the output of selected factors, the result presented could have differed due to any of these factors. However, since the goal of patient protection is to reduce doses to patient while retaining the required image quality for diagnostic purposes, unless a film reject analysis indicate that the low dose from the Tamale Teaching Hospital are resulting in film rejection and retake thereby increasing patient doses. It is conclusive to say that from the radiation protection standpoint, this present low doses to patients thereby reducing the risk of stochastic detriments to them.

4.3 EFFECTIVE DOSE DUE TO RADIOGRAPHIC PROCEDURES

The use of effective dose presents a single parameter for comparing radiation detriment from different modalities and is an ideal parameter for use in the optimization effort. Table 4.9, shows the effective dose due to the three x-ray examination procedures Abdomen, Chest and Pelvis respectively.

Table 4. 6: Effective Dose due to the three x-ray examination procedures Abdomen, Chest and Pelvis

Radiograph	Average Effective Dose /mSv
Chest PA	0.036
Abdomen AP	0.084
Pelvis AP	0.067

Figure 4.6 below show a graph of Average Entrance Effective Doses (mSv) for Three imaging Modalities at the Tamale Teaching Hospital, it shows that abdominal examination results in more effective dose (0.084mSv) than pelvis and chest examination. This could be attributed to the entrance surface dose to that region and also underlying tissues within that region. Generally there are more adipose tissues within the abdominal region

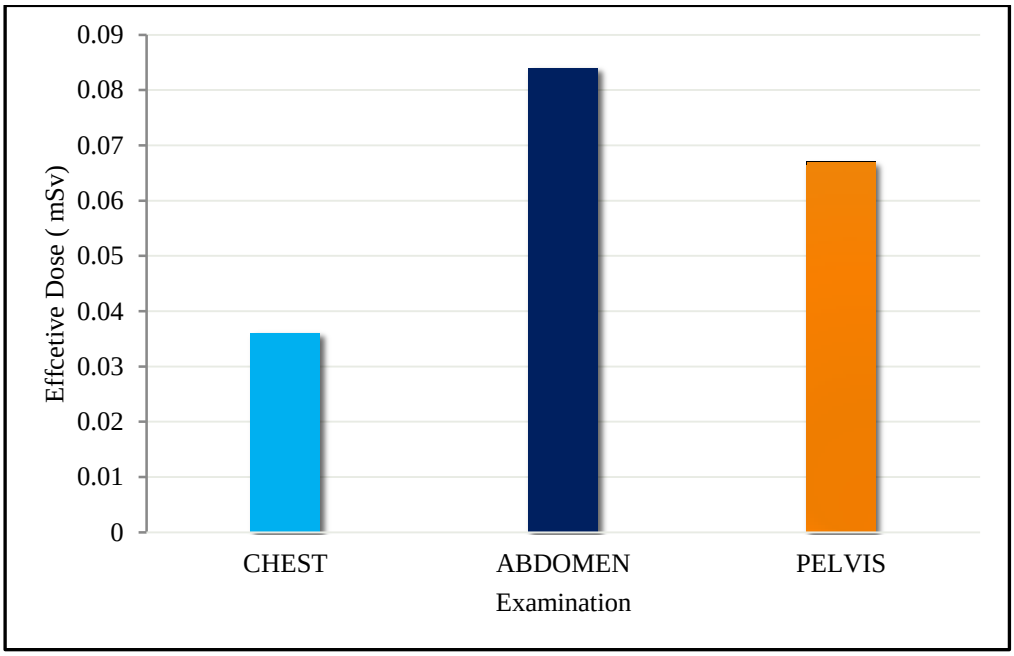

Figure 4. 6: A graph of Average Effective Doses (mSv) for the three most frequent radiological examinations at the Tamale Teaching Hospital.

4.4 DIAGNOSTIC REFERENCE LEVELS

Diagnostic Reference Levels (DRL) are suggested action levels above which a facility should review its methods and determine if acceptable image quality can be achieved at lower doses. It is an essential part of the facility optimization process. The objective of establishing diagnostic reference levels (DRL) in diagnostic imaging is to provide radiology and other departments that use x-ray imaging with a convenient DRL dose comparison to ensure that

radiation doses to patients are kept within reasonable limits. In practice the Diagnostic Reference Level should be expressed as a readily measurable patient-related quantity for the specified procedure. Usually, the Entrance Surface Dose or the Dose Area Product are quantities that are used. Table 4. 10, shows recommended Diagnostic Reference levels for various examinations.

Table 4. 7: Recommended diagnostic reference doses for individual radiographs on adult patients and Average Entrance Surface Dose per radiograph from this study.

Radiograph	NRPB, 2000	IAEA,1999	EC, 1999	This work
Chest	0.2	0.4	0.3	0.20
Abdomen	6	10	-	0.66
Pelvis	4	10	10	0.62

From the table it is observed that, the third quartile values of entrance surface dose for Chest, Pelvis and Abdominal Examination for this study are within the recommended Diagnostic Reference Level set by the United Kingdom.

4.4 CANCER RISK TO PATIENT DUE TO X-RAY PROCEDURES

Stochastic Radiation Risk due to entrance surface Doses for each patient was also computed using PCXMC 2.0. The results are shown in the Table 4.11, table 4.12 and Table 4.13 (see Appendix).

From the tables 4.11, 4.12, 4.13 above, it is seen that the average REID was found to be 5.68×10^{-5} %, 1.58×10^{-4} % and 6.9×10^{-2} % for Chest, abdomen and Pelvis examinations respectively.

The values for Pelvic and Abdomen examinations were slightly higher than chest examination. This is observed in the Figure 4.7. This could be due to low entrance doses to the chest region as shown in Figure 4.2. It could also be due to the fact that there are more radiosensitive organs within pelvis and abdominal regions than the chest region.

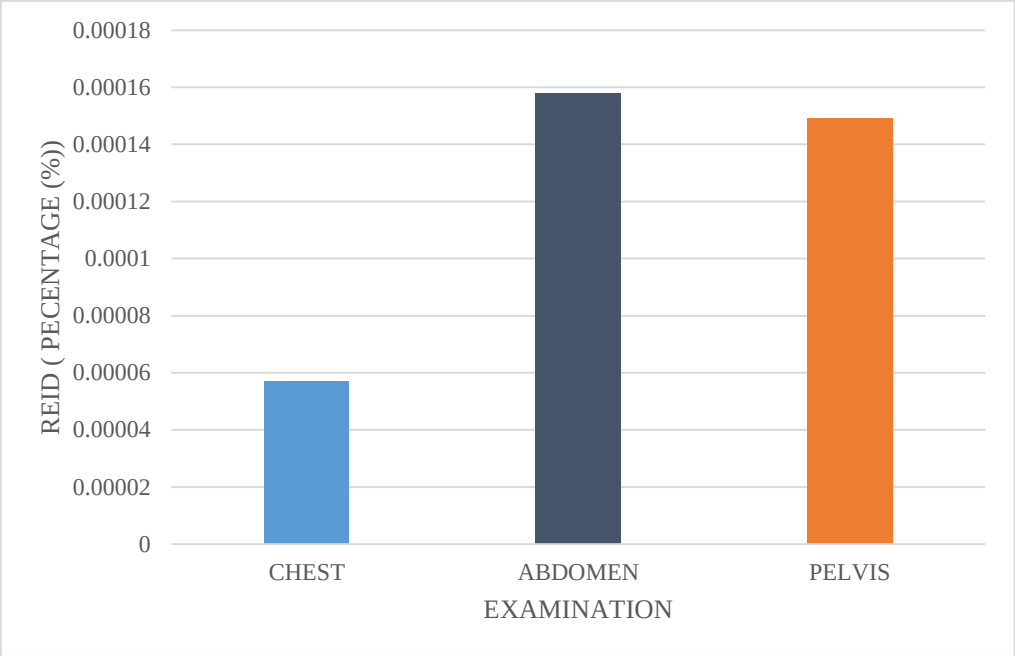

Figure 4. 7: A graph of Risk of Exposure Induced Cancer Death for the three most frequent radiological examinations at the Tamale Teaching Hospital.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.0 This section deals with the conclusions and recommendations from the study.

5.1 CONCLUSIONS

The baseline Quality Assurance and Quality Control status of the newly installed Philip 0PTIMUS 980620611102 digital x-ray system at the Tamale Teaching Hospital has been determined through a series of quality control tests. The results of the study shows the equipment is performing within required recommendation of the Radiation Protection Board of Ghana.

This study have also determined patient doses due to three common x-ray examinations; Chest, Abdomen and Pelvis using the newly acquired digital x-ray machine at the Tamale Teaching Hospital. The results from the study shows that the doses to patient are within recommended diagnostic reference level levels published by the NRPA,UK, 2000, IAEA, 1999 and the European Commission, 1999. The average risk of cancer induced death was found to be 5.68×10^{-5} %, 1.58×10^{-4} % and 6.9×10^{-2} % for Chest, abdomen and Pelvis examinations respectively.

Dose distribution among patient were found to vary even for the same examination. Dose to the chest were found to be lower than abdomen and pelvis. They were however found to be lower than doses found for similar works (Ciraj et al, 2005, Padovani et al., 1987). The risk of exposure induced death due to the three examinations are generally low. However, the REID for

abdomen and pelvis were higher than that for chest for reasons already discussed.

5.2 RECOMMENDATIONS TO TAMALE TEACHING HOSPITAL.

- The Radiology department of the Tamale Teaching Hospital should continually implement and update quality Assurance and Control system within the department to ensure that patient protection is paramount and doses kept As Low as Reasonably Achievable.
- The department should undertake periodic patient dose assessments to ensure that doses to patients are within recommended levels.
- Training and refresher training programmes should be established to ensure that appropriate level of competence is maintained

5.3 RECOMMENDATIONS TO THE RADIATION PROTECTION BOARD

- The Radiation Protection Board should undertake a nationwide dose audit at other radiology departments and in collaboration with relevant professional organizations establish National Diagnostic Reference Levels to form the basis for optimization of patient protection in Ghana

REFERENCES

Akhtar, W., Hussain, M., Aslam, M., Ali, A., & Faisal, A. (2011). Predictors of positioning error in digital radiography, 21(3): 102 -106.

Andersen, E., Jorde, J., Taoussi, N., Yaqoob, S., Konst, B., & Seierstad, T. (2012). Reject analysis in direct digital radiography. Acta Radiologica, 53(2): 174-178. doi:10.1258/ar.2011.110350

BEIR,. (2006). Health Risks from Exposure to Low Levels of Ionizing Radiation. http://dx.doi.org/10.17226/11340

Ciraj, O., Kosutic, D., Kovacevic, M., & Markovic, S. (2005). A survey of patient doses from conventional diagnostic radiology examinations: first results from Serbia and Montenegro. Physica Medica, 21(4): 159-163. doi:10.1016/s1120-1797(05)80005-5

Clement, C., & Sasaki, M. (2013). *Radiological protection in paediatric diagnostic and interventional radiology*. Exeter, UK: Polestar Wheatons Ltd.

Cristy, M., & Eckerman, K. (1987). *Specific absorbed fractions of energy at various ages from internal photon sources: 1, methods*. Atomic Energy Research Establishment.

Dzingle, D., May, G., & Garland, H. (2001). Digital radiography and film scanners: Automating the transition to filmless radiology. Journal Of Digital Imaging, 14(S1): 128-130. doi:10.1007/bf03190315

European, C. (1999). Guidance on diagnostic reference levels for medical exposures. Radiation protection 109. Luxembourg: Office for Official Publications of the European Communities.

Gray, J., Archer, B., Butler, P., Hobbs, B., Mettler, F., & Pizzutiello, R. et al. (2005). Reference Values for Diagnostic Radiology: Application and Impact1. Radiology, 235(2), 354-358. doi:10.1148/radiol.2352020016

Herrmann, T., Fauber, T., Gill, J., Hoffman, C., Orth, D., & Peterson, P. et al. (2012). Best Practices In Digital Radiography. Central Ave. SE, Albuquerque: the American Society of Radiologic Technologists.

IAEA (1996). International basic safety standards for protection against ionizing radiation of and for the safety of radiation sources. Journal of Hazardous Materials, 45(2-3), 282. doi:10.1016/s0304-3894(96)90055-2

IAEA,. (1999). Radiological Protection of Patients in Diagnostic And Interventional Radiology, Nuclear Medicine and Radiotherapy. Vienna, Austria: International Atomic Energy Agency,.

ICRP (2004). *Managing patient dose in digital radiology*. Oxford: Published for the International Commission on Radiological Protection by Elsevier.

ICRP (2007). *The 2007 recommendations of the International Commission on Radiological Protection*. Oxford, England: Published for the International Commission on Radiological Protection by Elsevier.

ICRP,. (1991). *1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60*. Ann. ICRP 21.

Inkoom, S., Schandorf, C., Emi-Reynolds, G., & Fletcher, J. (2011). Quality Assurance and Quality Control of Equipment in Diagnostic Radiology Practice-The Ghanaian Experience. Wide Spectra Of Quality Control, Dr. Isin Akyar (Ed.). doi:10.5772/22591

International Atomic Energy Agency (2004). Optimization of the radiological protection of patients undergoing radiography, fluoroscopy and computed tomography. Vienna: IAEA.

Khan, A., Khosa, F., Shuaib, W., Nasir, K., Blankstein, R., & Clouse, M. (2013). Effect of Tube Voltage (100 vs. 120 kVp) on Radiation Dose and Image Quality using Prospective Gating 320 Row Multi-detector Computed Tomography Angiography. *Journal Of Clinical Imaging Science*, *3*(4), 1-6. doi:10.4103/2156-7514.124092

Kohn, M. (1996). European guidelines on quality criteria for diagnostic radiographic images in paediatrics. Luxembourg: Office for Official Publications of the European Communities.

Lee, S., Kim, H., Kim, D., & Lee, C. (2010). Evaluat ion of Dose Re duction and Image Q uality in Pediat ric Mult i-detector CT. *Journal Of The Korean Phys Ical So Ciety*, *57*(1), 83 â˜¼ 191.

Marshall, N. (2009). An examination of automatic exposure control regimes for two digital radiography systems. Physics In Medicine And Biology, 54(15): 4645-4670. doi:10.1088/0031-9155/54/15/002

Mintah, R., Schandorf, C., & Amuasi, J. (2011). Assessment of the Operation of the Magnetic Resonance Imaging (MRI) System at 37 Military Hospital using the Specific Absorption Rate (SAR) Levels, Maxwell Scientific Organization,. Asian Journal Of Medical Sciences, 3(3), 91-105.

National Radiological Protection Board (2000). Doses to patients from medical X-ray examinations in the UK - 2000 , National Radiological Protection Board.

Nyathi, T., Chirwa, T., & van der Merwe, D. (2010). A survey of digital radiography practice in four South African teaching hospitals: an illuminative study. Biomed.

Imaging Interv. J., 6(1): doi:10.2349/biij.6.1.e5

Ofori, E., Antwi, W., & Scutt, D. (2013). Current status of quality assurance in diagnostic imaging departments in Ghana. The South African Radiographer, 51(2).

Ofori, K. E. (2013). Patient Radiation Dose Assessment in Pelvic X-ray Examination in Ghana. OMICS J Radiology 2013, 2(8):doi:10.4172/2167-7964.1000151

Olivera, C., Kosutic, D., Kovacevic, M., & Markovic, S. (2005). A survey of patient doses from conventional diagnostic radiology examinations: first results from Serbia and Montenegro. *Physica Medica*, *21*(4), 159-163. http://dx.doi.org/10.1016/s1120-1797(05)80005-5

Padovani, R., Contento, G., Fabretto, M., Malisan, M., Barbina, V., & Gozzi, G. (1987). Patient doses and risks from diagnostic radiology in North-east Italy. BJR, 60(710), 155-165. doi:10.1259/0007-1285-60-710-155

Partain, C., Price, R., Patton, J., Erickson, J., Pickens, D., & James, A. (1981). The Potential Impact of Digital Radiography (DR) on the Specialty of Nuclear Medicine. Clinical Nuclear Medicine, 6(Supplement), P2-P5.

Prieto, C., Vano, E., Ten, J., Fernandez, J., IÃ±iguez, A., & Arevalo, N. et al. (2008). Image Retake Analysis in Digital Radiography Using DICOM Header Information. J Digit Imaging, 22(4): 393-399. doi:10.1007/s10278-008-9135-y

Radiological protection and safety in medicine. (1996). Annals Of The ICRP, 26(2): 1-31. doi:10.1016/s0146-6453(00)89195-2

Schandorf, C., & Tetteh, G. (1998). Analysis of the status of X-ray diagnosis in Ghana. BJR, 71(850): 1040-1048. doi:10.1259/bjr.71.850.10211064

Shrimpton, P., Wall, B., Jones, D., Fisher, E., Hillier, M., Kendall, G., & Harrison, R. (1986). Doses to patients from routine diagnostic X-ray examinations in England*. BJR, 59(704): 749-758. doi:10.1259/0007-1285-59-704-749

Smathers, R., & Brody, W. (1985). Digital Radiography: Current and Future Trends. BJR, 58(688), 285-307. doi:10.1259/0007-1285-58-688-285

Tan, T., & Ong, K. (2002). The impact of medical technology on healthcare today. *Hong Kong Journal Of Emergency Medicine*, *9*(4), 233.

Thomas, D., Darby, S., Fagnani, F., Hubert, P., Vaeth, M., & Weiss, K. (1992). Definition and Estimation of Lifetime Detriment From Radiation Exposures. *Health Physics*, *63*(3), 259-272. http://dx.doi.org/10.1097/00004032-199209000-00001

United Nations Scientific Committee on the Effects of Atomic Radiation.,. (2008). *Sources and effects of ionizing radiation*. New York, NY: United Nations.

Vano, E., & Fernandez Soto, J. (2007). Patient dose management in digital radiography. Biomed. Imaging Interv. J., 3(2): doi:10.2349/biij.3.2.e26

Vizy, K. (1983). An overview of digital radiography systems. Cardiovascular And Interventional Radiology, 6(4-6): 295-299. doi:10.1007/bf02552451

Williams, M., Krupinski, E., Strauss, K., Breeden, W., Rzeszotarski, M., & Applegate, K. et al. (2007). Digital Radiography Image Quality: Image Acquisition. Journal Of The American College Of Radiology, 4(6), 371-388. doi:10.1016/j.jacr.2007.02.002

Zhang, M., & Chu, C. (2011). Optimization of the Radiological Protection of Patients Undergoing Digital Radiography. *Journal Of Digital Imaging*, *25*(1), 196-200. http://dx.doi.org/10.1007/s10278-011-9395-9

APPENDIX

TABLE OF RESULTS

Table 4. 8: Output Consistency Variation With kV And mAs

Test	kV	mAs	Output (mSv) measurement			Mean Output (mSv)	Mean Output (mSv) /mAs
			1	2	3		
1	60	16.0	0.00093	0.0009	5.67E-05	0.000907	5.67E-05
2	60	20.0	0.0011	0.00109	5.47E-05	0.001093	5.47E-05
3	60	25.0	0.00135	0.00135	5.41E-05	0.001353	5.41E-05
4	70	16.0	0.0012	0.0012	7.48E-05	0.001197	7.48E-05
5	70	20.0	0.00149	0.00148	7.43E-05	0.001487	7.43E-05
6	70	25.0	0.00187	0.00187	7.48E-05	0.00187	7.48E-05
7	90	10.0	0.00131	0.00127	1.28E-04	0.001277	1.28E-04
8	90	12.5	0.00161	0.00156	1.26E-04	0.001577	1.26E-04
9	90	16.0	0.00201	0.00201	1.27E-04	0.00203	1.27E-04

Table 4. 9: Results of Timer Accuracy Check

Test	Indicated value(ms)	Measured value(ms)	% Deviation
1	32.2	30.8	1.28
2	28.0	26.8	4.28
3	32.4	30.0	6.48
4	36.0	34.5	4.16
5	40.8	39.9	2.20

Table 4. 10: Results of kVp accuracy and consistency

Indicated kV	Output measurement (kV)			Mean Output (kV)	% Deviation
	1	2	3		
60	59.5	59.5	59.7	59.6	0.6
70	70.1	69.9	70.0	70.0	0.0
81	81.1	81.1	81.0	81.1	0.1
90	90.3	90.0	90.2	90.2	0.2
102	102.0	102.4	102.2	102.2	0.2

Table 4. 11: Entrance Surface Dose, Effective Dose and Risk of Cancer Induced Death due to Pelvic Examination

PATIENT ID	Entrance Surface Dose	Effective Dose	Risk of Cancer Induced Death
	ESD/mGy	E/mSv	REID/%
PEL 1	0.5	0.013342	7.75E-05
PEL 2	0.4	0.015055	5.13E-05
PEL 3	0.6	0.035404	0.000106
PEL 4	0.6	0.098491	0.000278
PEL 5	0.5	0.115475	0.000311
PEL 6	0.5	0.042399	0.000119
PEL 7	0.4	0.039843	0.000196
PEL 8	0.6	0.022489	4.42E-05
PEL 9	1.3	0.177131	0.000518
PEL 10	0.6	0.04015	0.000199
PEL 11	0.6	0.043238	0.000116
PEL 12	0.4	0.023828	0.000102
PEL 13	0.5	0.016295	9.24E-05
PEL 14	0.5	0.022601	7.62E-05
PEL 15	0.6	0.552222	0.000209
PEL 16	0.5	0.029666	9.22E-05
PEL 17	0.4	0.036835	0.000137
PEL 18	0.4	0.048468	0.000126
PEL 19	0.4	0.029452	0.000101
PEL 20	0.7	0.028892	0.000124
PEL 21	0.8	0.028236	7.93E-05
PEL 22	0.6	0.028967	0.000169
PEL 23	0.5	0.23352	7.68E-05
PEL 24	0.7	0.047779	0.000196
PEL 25	0.7	0.039895	0.000118
PEL 26	0.5	0.054915	0.000193
PEL 27	0.7	0.036668	0.000149
PEL 28	0.5	0.026035	0.000126
Mean	0.6	0.0688	0.000149
Max	0.4	0.55	0.000518
Min	1.3	0.01	0.000044
Std Dev	0.2	0.10	0.000095

Table 4. 12: Entrance Surface Dose, Effective Dose and Risk of Cancer Induced Death due to Chest Examination

PATIENT ID	Entrance Surface Dose	Effective Dose	Risk of Cancer Induced Death
	ESD/mGy	E/mSv	REID/%
CH 1	0.2	0.02	0.00016
CH 2	0.2	0.01	3.3E-05
CH 3	0.2	0.13	7.6E-05
CH 4	0.2	0.01	4.5E-05
CH 5	0.2	0.01	4.7E-05
CH 6	0.1	0.01	4.9E-05
CH 7	0.2	0.14	8.5E-05
CH 8	0.2	0.01	3.9E-05
CH 9	0.2	0.01	6.9E-05
CH10	0.2	0.01	2.8E-05
CH 11	0.2	0.12	0.00012
CH 12	0.2	0.14	0.00013
CH 13	0.2	0.01	4.5E-05
CH 14	0.2	0.01	8.1E-05
CH15	0.3	0.01	4.7E-05
CH 16	0.2	0.01	2.8E-05
CH 17	0.2	0.01	3.6E-05
CH18	0.2	0.01	1.6E-05
CH 19	0.2	0.01	2E-05
CH 20	0.2	0.01	5.6E-05
CH21	0.2	0.01	1.8E-05
CH 22	0.2	0.01	4.7E-05
CH23	0.2	0.01	1.5E-05
CH 24	0.2	0.01	4.3E-05
CH25	0.2	0.14	3.8E-05
CH 26	0.2	0.01	2.5E-05
CH 27	0.4	0.01	3.8E-05
CH28	0.6	0.12	5E-05
CH 29	0.3	0.06	0.00017
Mean	0.22	0.04	5.7E-05
Max	0.60	0.14	0.00017
Min	0.10	0.01	1.5E-05
Std Dev	0.09	0.05	3.9E-05

Table 4. 13: Entrance Surface Dose, Effective Dose and Risk of Cancer Induced Death due to Abdominal Examination

PATIENT ID	Entrance Surface Dose	Effective Dose	Risk of Cancer Induced Death
	ESD/mGy	E/mSv	REID/%
ABD 1	0.5	0.02	0.000542
ABD 2	0.4	0.01	0.000119
ABD 3	0.6	0.13	0.0000808
ABD 4	0.6	0.01	0.000235
ABD 5	0.5	0.01	0.0000261
ABD 6	0.5	0.01	0.000259
ABD 7	0.4	0.14	0.000145
ABD 8	0.6	0.01	0.000244
ABD 9	1.3	0.01	0.000052
ABD 10	0.6	0.01	0.000134
ABD 11	0.6	0.12	0.000215
ABD 12	0.4	0.14	0.0000344
ABD 13	0.5	0.01	0.000127
ABD 14	0.5	0.01	0.000078
ABD 15	0.6	0.01	0.0001
ABD 16	0.5	0.01	0.000419
ABD 17	0.4	0.01	0.000192
ABD 18	0.4	0.01	0.0000501
ABD 19	0.4	0.01	0.000149
ABD 20	0.7	0.01	0.000159
ABD 21	0.8	0.01	0.000048
ABD 22	0.6	0.01	0.0000905
ABD 23	0.5	0.01	0.000139
ABD 24	0.7	0.01	0.00015
ABD 25	0.7	0.14	0.000154
Mean	0.57	0.04	0.0001577
Max	1.30	0.14	0.0005420
Min	0.40	0.01	0.0000261
Std Dev	0.18	0.05	0.000116