DETERMINATION OF DIAGNOSTIC REFERENCE LEVELS (DRLs) FOR DIGITAL RADIOGRAPHY (ABDOMEN & PELVIC EXAMINATIONS) IN HOSPITAL UNIVERSITI SAINS MALAYSIA (HUSM)

BY

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(Medical Radiation)

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CERTIFICATE

This is to certify that the dissertation entitled "Determination of Diagnostic Reference Levels (DRLs) in Digital Radiography (Abdomen & Pelvic Examinations) in Hospital Universiti Sains Malaysia (HUSM)" is the bona field record of research work done by

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Shafirah Binti Mohd Zain,
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LIST OF ABBREVIATIONS

DRLs - Diagnostic Reference Levels

ESD – Entrance Surface Dose

ICRP – International Commission Radiological Protection

ICRU – International Commission Radiation Protection

IAEA – International Atomic Energy Agency

ACR – American College of Radiology

AAPM – American Association of Physicists in Medicine

EC – Europe Commission

UNSCEAR – United Nations Scientific Committee on the Effects of Atomic Radiation

CEC – Correction Element Coefficient

HUSM – Hospital Universiti Sains Malaysia

MOH – Ministry of Health

AP – Anterior Posterior

TLD – Thermoluminescencent Dosimetry

SPSS – Statistical Package for Social Science

SI – Standard International system of unit

Kerma – Kinetic Energy Released in Matter

J/ Kg – Joule per Kilogram

Gy – Gray

Ksi – Individual sensitivity factor

ESAK – Entrance Surface Air Kerma

ABSTRACT

The aim of this study is measurement the diagnostic reference levels (DRLs) for digital radiography (abdomen & pelvic examinations) in Hospital USM. This study is the estimation of the entrance surface dose (ESD) delivered to patients. ESD can be measured directly by using Thermoluminescence Dosimeter (TLD) which is LiF: Mg,Cu,P (TLD 100H). The examination involved 30 patients for each procedures of abdomen (AP) and pelvic (AP). The participants involved in range 18 years old and above, weight between 35 to 100 kg, and both male and female are included. The ESD were measured directly with TLD 100H that mounted on tape and placed at the centre x-ray beam on patient skin.

The DRLs value found in Hospital USM were compared to DRLs stated by national and international. Hospital USM third quartile of ESDs value estimated for abdomen is 3.75 mGy and pelvic is 2.75 mGy. This result indicate that the ESD received by patients were to be lowered than or in acceptance range with the guidance level set by the national, IAEA and other international country.

One possible reason is that the patient size is relatively smaller than a European patient. It is also possible that x-ray machine at Hospital USM was well maintained and have pass all the annual Quality Assurance evaluations before being operate. Consequently, the radiation risk to patients is minimized and will help in optimization radiation protection of patient. Overall it was found this result will be useful for the formulation of reference in HUSM as recommended by the IAEA.

ABSTRAK

Tujuan utama kajian ini dijalankan adalah untuk mengukur tahap rujukan diagnostik (DRLs) untuk radiografi digital (pemeriksaan perut & pinggang) di Hospital USM. Kajian ini adalah untuk mengira permukaan dos (ESD) yang diterima oleh pesakit. ESD boleh diukur secara langsung dengan menggunakan thermoluminescence Dosimeter (TLD) yang merupakan LIF: Mg, Cu, P (TLD 100H). Pemeriksaan ini melibatkan 30 pesakit bagi setiap prosedur perut (AP) dan pinggang (AP). Para peserta yang terlibat ialah dalam lingukangan umur 18 tahun ke atas, berat antara 35 kg hingga 100 kg, dan kedua-dua lelaki dan perempuan juga dibenarkan. ESD diukur secara langsung menggunakan TLD 100H yang telah dilekatkan pada pita dan diletakkan di tengah-tengah cahaya x-ray di atas permukaan kulit pesakit.

Nilai DRLs yang telah diukur di Hospital USM akan dibandingkan dengan nilai DRLs yang telah ditetapkan oleh dalam negara dan negara antarabangsa. Ia mendapati kuartil ketiga nilai ESD di Hospital USM untuk perut adalah 3.75 mGy dan pinggang adalah 2.75 mGy. Keputusan ini menunjukkan bahawa ESD diterima oleh pesakit adalah kurang daripada atau dalam julat penerimaan dengan tahap petunjuk yang ditetapkan oleh dalam negara, IAEA dan negara antarabangsa yang lain.

Salah satu sebab yang mungkin adalah bahawa saiz pesakit adalah agak lebih kecil daripada pesakit Eropah. Ia juga adalah mungkin bahawa mesin x-ray di Hospital USM telah diselenggara dengan baik dan telah lulus semua penilaian tahunan Jaminan Kualiti sebelum beroperasi. Oleh itu, risiko radiasi kepada pesakit dapat dikurangkan dan dapat membantu dalam perlindungan sinaran pengoptimuman pesakit. Secara keseluruhan didapati keputusan ini akan berguna untuk penggubalan rujukan di HUSM seperti yang disyorkan oleh IAEA,

CHAPTER 1

INTRODUCTION

This chapter will provide a brief explanation regarding important terms and main objectives of the research. It starts with background of the study, introduction of Diagnostic Reference Levels (DRLs) and an overview about abdomen and pelvic radiography examination. This chapter also present an overview of digital imaging. This study will bring the understanding of the problems encountered which leads to the objectives of this study. Next, the significance of this study are revealed and ended with the scope and limitations that I had while conducting this study.

1.0 Background of Study

1.0.1 Digital Radiography.

The basic definition of digital radiography is any imaging acquisition process that produce an electronic image that can be viewed and manipulated on a computer. Most modern medical imaging modalities produce digital image that can be sent through a computer network to various location. The concept of moving images digitally was introduced by Albert Jutras in Canada during his experimentation with teleradiology (Christi & Beth, 2014).

The sensors of digital radiography are used instead of conventional photographic film to produce the image radiography. The digital radiography has been advantages in time efficiency, ability transfer and enhances digitally images, and also less radiation used to produce image of similar contrast to conventional radiography. Furthermore, the digital

radiography uses a digital image capture device, thus will be gives advantages of immediate image preview and availability and also elimination of costly film processing steps. This digital radiography has ability to apply special image processing techniques that enhance overall display quality of the image. Therefore, the images can immediately acquire, modified, deleted and sent to a network of computers.

Besides that, digital processing involves the systematic application of highly complex mathematical formulas called algorithms. Numerous mathematical manipulations are performed on image data to enhance image appearance and to optimize quality. Digital imaging systems are capable of producing a radiographic image across a large range of exposure and are described as having a wide dynamic range. According to Bontrager, 2104 because of this wide dynamic range, it is essential that to define the exposure latitude as the acceptable level of exposure that produces the desired image quality for a digital imaging system. The photodetector will ensure that the exposure is appropriate for the available dynamic range. IAEA (2013) stated, the benefits from digital radiology are enormous. The physician can view the requested image on desktop computer or often report in just a few minutes after the examination was performed. The images no longer held in single location but can be seen by physicians who are kilometres apart from hospital.

1.0.2 Abdomen and Pelvis Radiography Examination.

An x-ray radiation is a non-invasive medical test for diagnose the disease. X-ray radiation involves the exposed radiation to body with the small dose ionizing radiation to produce the image of the structural inside the body. X-rays are the oldest and most frequently used form of medical imaging. In this study the abdomen and pelvis radiography examination were selected to measure Entrance Surface Dose (ESD). The ESD can be measured by placing the TLD 100H on the surface skin with the central of the x-ray beams.

Abdomen is the region between the thorax and pelvic. Abdomen contains all the digestive organs such as stomach, small intestines, large intestines, pancreas, liver and gallbladder. The abdomen also contains the kidney and spleen. These organs are held together loosely by connecting tissues which allow them to expand and slide against each other. Hence, for the diagnosis abdominal with the x-ray radiation will produces pictures of the kidneys, ureters and bladder which called as KUB x-ray. Whereas pelvic is a bony ring, interposed between the movable vertebrae of the vertebral column. Pelvic is stronger and more massively constructed than the wall of the cranial or thoracic cavities. It is composed of four bones which are the two hip bones laterally and in front and the sacrum and coccyx behind. Hence, for the pelvis x-ray examination these four bones will produces in radiographic image. The diagnosis pelvic commonly is used to detect arthritis, fractures or other injuries (RadiologyInfo, 2015).

1.0.3 Diagnostic Reference Levels (DRLs)

DRL is defined by (ICRP) as: " a form of investigation level of patient dose or administered activity (amount of radioactive material) for a specific procedure used in medical imaging, to indicate whether in routine condition the patient dose or administered activity is unusually high or low for that procedure." DRL is recommended as guide for medical exposure from various examinations and use to avoid unnecessarily high dose to the patient (Ministry of Health, 2013).

ICRP Publication 73 also defined and explained the term DRLs are in the broader ICRP concept of reference levels. The main points of DRLs are to investigate the level of identify unusually high levels, which is for local review if consistently exceeded. DRLs are not for regulatory or commercial purposes, not dose limits, and have no relationship with numerical dose limits or dose constraints. ICRP indicated the DRLs are easily measured dose quantity, such as absorbed dose in air, or entrance surface dose for a tissue equivalent phantom or representative patient. DRLs are an investigation level, which if it's exceeded, should lead to a review of procedures and equipment in order to evaluate whether the approaches to optimisation are adequate, and to indicate when consideration of dose reducing measures should be made. DRLs also intended for use as a simple test for identifying situations where the levels of patient dose are unusually high (Kate & Patrick, 2009).

The objective of DRLs is to optimize the use of radiation in medicine and help avoid excessive radiation exposure. The DRL are a practical tool in diagnostic radiology and nuclear medicine. Achieving acceptable image quality or adequate diagnostic information, consistent with the medical imaging task, is the overriding clinical objective. DRLs are then used to help manage the radiation dose to patients so that the dose is commensurate with the clinical purpose.

1.0.4 Dose Quantities

In radiation protection, the specific radiation quantities firstly were introduced by International Commission on Radiation Units & Measurements (ICRU, 1980) and (ICRP, 1991) to relate the risk of the ionizing radiation to human. For patient and personal safety, it is imperative for therapists to have a practical knowledge of radiation safety and measurement of radiation.

General term used in radiation protection is a dose. The dose was defined by International Atomic Energy Agency (IAEA, 2007) is stated "a measurement of energy deposited by radiation in target". In the context of interaction of radiation with human body, the amount of energy deposited in the target will picturing how damage the tissues from the interactions. High dose more harmful to human compared to low dose.

1.0.4.1 Kerma (K)

Kerma, K is acronym for kinetic energy released in the matter at a point of interest. When photons interact with matter, atoms in the matter are ionized. The electrons are knocked out of their atoms and set into motion with various kinetic energies. The amount of kinetic energy transferred to electrons is called Kerma. ICRU (1998) defined kerma as:

$$K = dE_{tr} / dm \quad (1)$$

Where dE_{tr} is sum of initial kinetic energy of all charged ionising particles liberated by uncharged ionizing particles in material. The dm is the mass. The International System of Units (SI) of kerma is joule per kilogram (J/Kg) which is given the special name gray (Gy).

Kerma is a physical quantity used in radiation protection measurement purposes especially for photon radiation (Wernli, 2004). Kerma requires specific material in which the

deposition of energy can takes place. Kerma is easy to measure with ionisation chamber, which gives an advantage in doing radiation measurement (Sprawls, 2002).

1.0.4.2 Absorbed Dose (D)

Absorbed dose, D is a physical quantity and it is similar in concept to kerma. Absorbed dose can be used to quantify the deposition of energy by ionizing radiation. The dose is defined as:

$$D = dE / dm \tag{2}$$

Where dE is mean energy imparted by ionising radiation to matter in a volume element. The dm is the mass of matter in the volume element. It also has SI unit which is J/Kg and special term is Gray, Gy (ICRU, 1998).

According to Robert and Donna (1996), the SI unit of absorbed dose, Gray is quite different from the unit of exposure, R. The gray not limited to x-rays and gamma rays and is used in the dosimetry of photon, charged (electron and proton) and uncharged (neutron) particle beams. The gray also used to measure kerma. Besides that, there are some advantages of using absorbed dose instead of exposure which is it applicable to all ionising radiations, applicable even in areas where electronic equilibrium does not exist. The absorbed dose also advantage in directly related to radiation effects because it is the deposition of energy by ionising radiation, not the mere ionization of air molecules.

Buono (2011), mentions the absorbed dose is equal to kerma when electronic equilibrium occur in the material of mass, dm. It accepted with assumption no attenuation of the photon beam occur along the path before the electronic equilibrium point. This assumption gives advantage for doing measurement in monitoring programme for radiation protection.

1.0.4.3 Effective dose (E)

The effective dose, E is a protection quantity. Effective dose is defines as the sum of tissue equivalent dose. W_T is tissue weighting factor to indicate the combination of different doses to several different tissues in a way that correlates well with all stochastic effects combined. ICRP also defined the effective dose as a whole body dose equivalent to supersede effective dose equivalent, H_T.

$$E = \Sigma_T W_T \times H_T \quad (3)$$

Where H_T is the equivalent dose in tissue T and W_T is the tissue weighting factor for tissue, T. Total W_T for the whole body is 1. The W_T are tabulated in ICRP Publication 60 and in IAEA safety standards. The values W_T are different according to tissues sensitivity by ionizing radiation. The SI unit of effective dose are the same as those of equivalent dose, J/kg, with Sievert (Sv) as the special term.

1.1 Problem Statement

DRL in Malaysia was newly introduced in 2013 after report of Medical Radiation Exposure Study published in year 2006. This study was funded by Ministry of Health (MOH) Malaysia through its research grant, No. MRG-2006-34. This study, was conducted following the guidelines established by UNSCEAR, in 437 public and private hospitals, medical centres or general practitioner's clinics throughout Malaysia. The study also conducted in 329 public and private dental clinics in Malaysia. These hospitals / medical centres /clinics were selected randomly nationwide to represent 30 percentage of the total number of sites in the country.

However, most hospital in Malaysia were still not performing the guidelines of DRL that preferred by Ministry of Health (MOH) Malaysia. This national guideline for radiation protection has designed and developed for the measurement of patient dose. Thus, the measurement will provide information for optimization of radiation dose by obtaining radiological images with lowest amount of radiation.

Therefore, the objective of this study was to conform that whether Hospital USM follows the national and international guidelines range of exposure. This study will measure the entrance surface dose (ESD) to patients who undergoing abdomen and pelvic radiographic examination especially in Digital Radiography at Radiology Department, Hospital USM. Hence, it is to establish a set of DRLs for abdominal and pelvic radiography examinations that performed in Hospital USM. The values of ESD were measured by using TLD because TLD is easy to handle, can be reused and also can directly to estimate dose received by patients.

1.2 Objectives of Study

1.2.1 General Objective

The general objective in conducting this study was to measure entrance surface dose (ESD) for abdomen and pelvic radiography examination for diagnostic radiology in Hospital USM.

1.2.2 Specific Objectives

i. To measure the ESD value using TLD and establish a sets of DRLs in Hospital USM.

ii. To compare DRLs value in Hospital USM with DRLs value stated by national and international for clinical radiation exposure management.

iii. To provide optimum range for exposure parameter in avoid excessive and reduce radiation exposure during radiography examination.

1.3 Significant of Study

Significance of this study was to evaluate and to assess method of estimation the ESD values for abdomen and pelvic radiographic examinations. In this study, the measurement of ESD were done using TLD 100H for direct measurement. Then, the value ESD for abdomen and pelvic radiography examination in Hospital USM will compare to value ESD from Ministry of Health for observed the local distribution results for general medical imaging task. The values ESD from Hospital USM also were compared with other international country hence to promote attainment of an optimum range of values for a specified medical imaging protocol.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews some of the literatures related to this study. The first subsection reviews some of the studies related to Entrance Surface Dose (ESD), then review of properties of TLD 100H as dosimeter device. This chapter continue with some review about dose quantities, and lastly will be end with subsection about radiological protection.

2.0 Diagnostic Reference Levels (DRLs) Studies

International Commission on Radiological Protection (ICRP, 2007) stated that the primary purpose of a DRL is to minimize radiation dose to the patient that does not contribute to the clinical purpose of medical imaging task. As a consequence, DRLs can be used to promote a narrower range of dose value that represents good practice for a particular examination.

IAEA (2011), states that the government shall ensure that a set of DRLs is established for medical exposures incurred in medical imaging, interventional procedures and diagnostic nuclear medicine. Such DRLs shall be based on wide scale surveys or on published values that are appropriate for the local circumstances. The DRLs is used in examination such diagnostic radiology and nuclear medicine. The quantities should be easily measured, such as absorbed dose in air or tissue-equivalent material at the surface of phantom or representative patient for diagnostic radiology and nuclear medicine (Ministry of Health, 2013).

IAEA also stated that DRLs are important for optimisation of image quality and the radiation dose delivered to patients in diagnostic fields. DRLs are supplements to

professional judgment and do not provide a dividing line between good and bad medicine. The use of DRLs is important for dose optimization tool by many professional and organization such as: ICRP, American College of Radiology (ACR), American Association of Physicists in Medicine (AAPM), International Atomic Energy Agency (IAEA) and European Commission (EC).

The European ALARA network reports in 2006 that national DRLs for some radiographic examinations are established in France, Germany, Italy, Sweden, Switzerland, United Kingdom, and in Greece. The common X-ray examinations which the EC originally published were: chest, lumbar spine, pelvic, skull, and abdomen (Kate & Patrick, 2009).

Table 2.0: Recent Publication concerning DRLs by European Comission.

Country	**Values of DRLs (mGy)**						
	Chest (PA)	**Lumbar spine (AP)**	**Lumbar spine (Lateral)**	**Pelvic (AP)**	**Skull (AP)**	**Skull (Lateral)**	**Abdomen (AP)**
France	0.9	20	12	7	5	3	-
Germany	0.6	12	35	8	4	3	8
Italy	0.3	3.8	10.8	3.7	2	1.3	3.7
Sweden	0.6	10	-	4	-	-	-
Switzerland	0.2	8.7	26	7.8	5.4	3.5	7
United Kingdom	0.15	5	11	4	2	1.3	4
Greece	0.7	9	20	5	-	-	-

2.1 Entrance Surface Dose (ESD) Studies

In recent years, health physicists have devoted much effort to the minimization doses to patient in diagnostic radiology. Through these efforts, substantial reductions in radiation doses to patients resulting from radiographic procedures have been achieved in many countries. IAEA has recommended guidance levels of dose for diagnostic radiography for a typical adult patient. Since guidance levels should be derived from wide scale surveys of exposure factors performed in individual hospitals.

IAEA recommends the use of ESD for the dose guidance level in diagnostic radiography. The ESD generally used in the period checking of patient doses and it is simplicity and indication of the maximum skin dose. However, the ESD has little biological significance regarding the health risks. ESD was measure of the absorbed dose by the skin at the entrance point of the x-ray beam (Tung *et al.*, 2001).

ESD in diagnostic radiography is proportional to factors such as the tube current, exposure time, the square of tube voltage, filtration, collimation and patient size (Parry et al., 2002). The ESD is based on the use of the ratio of mass-energy absorption coefficients and backscatter factors. The ESD constitutes an important quantity that can be determined experimentally in diagnostic radiology. In diagnostic radiology, the ESD is generally calculated as tissue (med) absorbed dose according to the formula:

$$ESD^{(med)} = K_{air}\, B\, (\bar{\mu}\, en/\rho)^{med} \qquad (4)$$

Where K_{air} is the air kerma reading given by a detector free-in-air at the calibration distance. B is the backscatter factor and $(\bar{\mu}\, en/\rho)^{med}$ is the ratio of the absorbed dose in tissue media to that in air.

Milad & Daryoush (2012) stated, the patient effective dose is proportional to the ESD and depends on x-ray penetrating power. In diagnostic radiology examinations, effective dose is used to estimate health risk and hereditary effects. Moreover, assessments of the patients' effective dose should be done to provide effective protection to the patients.The effective dose is a radiation dose parameter, which takes into account the absorbed dose received by each irradiated organ and the organ's relative sensitivity. For determine the patient dose, the body region that being examined is important factor. ESD is the absorbed dose to the entrance skin of the patient at the central point of the irradiated area. Since the ESD consider as an approximate measurement of stochastic radiation risk, thus it may be used to quantify the amount of radiation received by patients undergoing diagnostic examinations.

ICRP defined the effective dose as the sum of risk-weighted organ equivalent doses to the exposed individual, is applied to measure the total detriment due to stochastic effects. These health-related doses may be calculated from the ESD using phantom by the Monte Carlo method. These phantoms usually represent an average adult with simplified organ shape and position within the body. The individual patients with vary body thickness which affects the organ and effective doses under the same ESD. This thickness may be estimated from either the body weight and height or the transmission of x-ray beam through the patients. In order to determine patient dose, the body size of patients should be taken into consideration (Lee *et al.*, 2006).

Ionising radiation is a powerful tool both as an aid to diagnosis and a means of therapy. Diagnostic x-ray is the most familiar application and is used in wide variety of examinations. In Publication 60 of the International Commission on Radiological Protection (ICRP) an annual effective dose limit of 1 mSv for individual members of the public was

recommended. To prevent deterministic effects, ICRP also recommends a dose limit of 15 mSv.y1 for the lens of the eye and 50 mSv.y1 for the skin (Ajayi & Akinwumiju, 2000).

ESD from tube output may be calculated in practice by means of knowledge of tube output. The relationship between x-ray unit current time product (mAs) and the air kerma free in air is establish at reference point in the x-ray field at 80 kVp tube potential. For manual calculating the ESD, can be done by recording the relevant parameters (peak tube potential, filtration, mAs and FSD) and correcting for distance and backscatter radiation according to the following equation:

$$ESD = O/P \times (kV/80)^2 \times mAs \times (100/FSD)^2 \times BSF \quad (5)$$

Where O/P is tube output per mAs measured with 100cm distance from tube focus along the beam axis at 80 kVp. kVp is peak tube voltage. mAs is tube current-time product. FSD is focus-to-patient entrance surface dose and BSF is backscatter factor (Halato et al., 2008).

Mohammedzein (2009) has stated the entrance-surface air kerma (ESAK) is the air kerma on the central x-ray beam axis at the point where the x-ray beam enters the patient or phantom. The contribution of backscattered radiation is included. ESAK is called it as Ke. The Standard Unit (SI) is J/kg with the special name is gray (Gy). The ESAK is related to the incident air kerma by the backscatter factor B. The backscatter factor depends on the x-ray spectrum, the x-ray field size, and the thickness and composition of the patient or phantom. Thus the equation is:

$$K_e = K_i \times B \quad (6)$$

$$K_i = Y(d) \times P_i \times \left(\frac{d}{d\ FTD - tp}\right)^2 \quad (7)$$

Where B is backscatter factor. K_i is general correction factor used in the formalism to correct for the effect of the difference in the value of an influence quantity between the calibration of a dosimeter under reference conditions in the standards laboratory and the use of the dosimeter in the user facility under different condition. Y(d) is the tube output per mAs measured at a distance of 100 cm from the tube focus along the beam axis at different kVps for a constant value of mAs of 10. P_i is tube current exposure time product (mAs). kV is peak tube voltage recorded for any given examination, mAs is the tube current–time product, FSD is the focus-to- patient entrance surface distance and BSF is the backscatter factor.

2.2 Radiation Dosimeter Devices (TLD)

Radiation detectors are important for dose measurement. It is used to generate a signal for the purpose of measuring exposure or dose are called dosimeters. A generalized definition of a dosimeter is a volume of medium sensitive to radiation, possibly surrounded by a wall of another medium. The sensitive volume is identified as a ``cavity''. The medium within the cavity can be gas, liquid or solid. Cavity theory defines the method of calculating the dose delivered using a detector of this description (Larry & Louis, 2000).

Common detector used in this study is thermoluminescent dosimeter (TLD). TLD is simple in clinical use, speed and being unobtrusive. The TLD is the recommended method for entrance dose measurements (Burke and Sutton 1997). TLD is widely used for dose measurements in diagnostic radiology and considered as the gold standard for determination of ESD in practice. The availability of TL dosimeters in a variety of physical makes them particularly suitable for measurements of the quantity ESD. TLD is properly encapsulated, small-size and can be attached directly to the patient's skin with very little interference patient mobility and comfort.

Measurement is made with TLDs attached to the patient or phantom at pointes where the x-ray beam enters the patient. TLDs are read in a standard manner and the value read is used as an estimate of the ESD received by the patient. If correctly calibrated to measure air kerma free in air, the TLD should give a direct reading of the ESD, and no correction is needed for back scatter radiation or distance from the tube focus.

2.2.1 TLD 100H

In research by Ming Yeh, Hwei Wang & Kwang Pan (2015) was showed thorough survey of the quality characteristics of TLD 100T and TLD-100H is performed using diagnostic x-rays under 80 kVp setting of the maximum operating voltage and with four mAs setting (56, 100, 200 and 315) were used. The linearity, reproducibility, sensitivity and the minimum detectable dose limit for TLD 100H were obtained from dose calibration lines. Both TLDs performed similarly when exposed to x-ray beam.

TLD-100H undergoes rapid annealing and it has a high sensitivity (10 to 65 times higher than that of TLD-100T) to an exposed dose (Shoushan et al., 2001). The short annealing time of TLD-100H benefits the acceptance of TLD-100H in personal and environmental surveys as well as the evaluation of diagnostic doses of either x-rays or CTs. Furthermore, there are many desired characteristics (i.e. rapid annealing time, high sensitivity and immediate readability), of the TLD-100H that makes it more feasible for the use in medical, personal or environmental fields. However, the effective atomic number (Zeff) of TLD-100H is generally higher than that of TLD-100T, because the higher-Z dopants have a greater effect on the electron interaction cross-sections over a wide range of energies (Taylor, 2011).

TLD-100H, disk of 3.6mm diameter and 0.38mm thickness, had a sensitivity of 1 μGy and 2% energy dependence at 30 keV (Luo & Rotunda, 2006). Before each

measurement, the TLDs were annealed at 240 ^{0}C for 10 min in a TLD oven. At reading, the heating rates were programmed to 10 ^{0}C from 135 to 240 ◦C in a Harshaw model 3500 TLD reader. The TLDs were calibrated for exposure at the accredited calibration laboratory. Calibration of individual TLDs was performed with the sensitivity correction applied to each TLD. Following the UK protocol (IPSM, 1992), TLDs were positioned on patient skin with adhesive tape near the central axis of the x-ray beam.

2.3 Radiological Protection

The international commission on radiological protection (ICRP) has formulated the system of radiological protection of the human from harmful effect of ionizing radiation. This system is based on three principles: Justification, optimization and dose limit. Justification of action, optimization of protection and dose limits for individual are the main principles of general radiation protection system (Ishiguchi, 2001).

Justification simply means that in medical exposures, the benefits should exceed any possible harmful effect. Optimization means that medical exposures should be kept as low as can be rationally achieved. Therefore, standardization and optimization have been introduced both to reduce the patient exposure and to increase image quality (Almen *et al.* 2000).

Optimisation also involves patient dosimeter measurements. Optimisation studies involve the assessment of the detriment associated with the radiation exposure, but also an estimation of the benefit the patient derives from the procedure. The optimisation task is to maximise the benefit/risk ratio for the diagnostic radiology procedure. The benefit risk ratio may be maximised by improving the benefit (such as an improved diagnosis) and by reducing the radiation risk by lowering the patient doses (Faulker, 2000).

The current philosophy of the International Commission on Radiological Protection (ICRP) in medical practice is that any use of radiation should be justified. After justification, it is important to optimize the procedure. In radiography this means using as low a dose as reasonable to obtain an optimum image of diagnostic quality (Abdullah, 2010).

The process reaching a balance between radiation dose and image quality is called optimization. X-ray machine unit are adjusted so that the exposure factor (tube voltage and tube current) and film density are optimized. Optimization can achieved by changing x-ray beam quality or sensitivity of screen-film combination (Geijer, 2001).

The dose limit is exposure of individual resulting from combination of all the relevant practices should be subject. These are aimed at ensuring that no individual exposed to radiation risks from such practices. Not all sources of radiation are susceptible to control by action at the facility, and it necessary to specify the sources to be included as relevant before selecting a dose limit. For medical purpose, dose limits are not applied. If a practice is justified and protection optimized, the dose to patient will be as low as compatible with the medical procedure. Any further constraint of doses might lead to the patient's detriment.

CHAPTER 3

MATERIAL AND METHODOLOGY

This chapter will explain the description of research design and study location. This chapter also will describe the several important materials and equipment was used for data collection in this study. The materials used such as digital x-ray machine, TLD 100H, Unfors Xi solid state detector, TLD Oven and TLD reader with WinREMS software. Then this chapter ended with the methodology that explained by sequence in this study.

3.0 Research Design

This research was a quantitative design which is refers to a process of enquiring and explaining about the existence and persistence of phenomena understudy by the researchers based on the philosophy of logical empiricism as a basis of maintaining the true meaning of validity and reliability in their research.

This research was done by random sampling of 30 patients for those who had registered for abdomen and pelvic examination in Hospital USM. Random 30 patients for each produces were select as the magic number issues in sample size estimation. At least 30 patients were needed for the reasonably expect an analysis based upon the normal distribution (i.e. z test) to be valid. That is it represents a threshold above which the sample size is no longer considered "small'. Besides that, by using 30 patients as sample size, to be "sure" that the exact enough mean and deviation estimates. This number comes from considering the central limit theorem to approximate experimental results distribution with a gaussian, so that confidence intervals are easier to calculate.

However by choosing 30 sample size in this study, there is no formal proof that any of these numbers are useful because they all rely on assumptions that can fail to hold true in one or more ways, and thus the adequate sample size can't be derived using the methods typically taught and used in the medical, social, cognitive, & behavioral sciences.

Then, the data was analysis by using the Statistical Package for the Social Sciences (SPSS) version 16. SPSS is established statistical analysis software used for descriptive statistics, bivariate statistics, prediction for numerical outcomes and prediction for identifying groups.

Generally, the data analysis in this study has two main categories, which are descriptive statistics and dosimetric analysis. Descriptive statistics include the analysis of number of personnel, number of equipment and frequency of cases performed; whereas the dosimetric analysis include the numerical calculation for the radiation exposure such as mean, minimum, maximum, standard deviation, median, 1st quartile and 3rd quartile. The analysis outputs are displayed in pie charts and tables for descriptive statistics and box plots for the dosimetric analysis..

3.1 Population Setting

Population of male and female patients at Department Radiology in Hospital USM according to statistics data in year 2014 for abdomen and pelvis are 3,636 and 3,421 respectively.

3.2 Sampling Method

The representative sample of adult patients are more than 18 years old and within a range between 35 to 90 kg. Both male and female patients are included. Table 3.2 had shown the inclusion and exclusion criteria of sample size.

Table 3.2: Inclusion and exclusion criteria of sample size.

Inclusion criteria	Exclusion criteria
1. The participant must be adult (18 to 60 years old)	1. Children (1 to 17 years old)
2. The participant must be patient that is registered for an X-ray examination in HUSM.	2. Unable to comprehend normal English/Malay language
3. Voluntary participation	3. Have medical Illness that may be affected during the study (Undergoes Surgery and etc.)
4. Able to comprehend normal English/Malay language	
5. No medical Illness that may be affected during the study (Undergoes Surgery and etc.)	

3.2.1 Sample Size Calculation

Raosoft Software was used to calculate the sample size calculation. The sample size of male and female patients from General Radiography in 2014 for abdomen procedures is 384 while for pelvic procedure is 332. Ministry of Health Malaysia, (2013) stated the 30 percent sampling size served as the minimum number of sites for this study. The sample size

in Hospital USM after measured as 30% sampling size which stated by MOH for abdomen is 99 while for pelvic is 115.

However, this number sample size for both examinations is too large since I did this study for requirement for the degree of Bachelor in Health Science. I also have no enough time to collect the large number patient. Then, I had to choose only 30 patients as sample size of each procedure in this study. The random sampling 30 patients were chosen as the magic number issues in sample size estimation.

3.2.2 Participant Selection

a) Gender

Participant involved in this research are male and female patients from General Radiography which are undergoing abdomen and pelvic radiography procedures in Hospital USM. The participant selected will be among these years.

b) Ethnicity

The ethnicity does not matter in this study as the selection of the participants is random. There are ethnicity combination among the patients such as Malay and Chinese.

3.3 Study Location

In this study, there are three locations I had used to finish my study. First is at dosimetry room TLD in Medical Radiation laboratory at School of Health Science, Universiti Sains Malaysia (USM). The TLD reader and TLD oven are placed in this room. I had used this room for physical and radiological screening procedures of TLD 100H. All the TLD 100H were been through heat treatment with TLD oven and was read using TLD reader. The reading of readout TLD was analysed using dedicated analysis software.

The second location I had used was at room 3 general radiography at Department Radiology, Hospital USM. This room I had used for the process of calibration and selected the sensitivity of TLD100H. Next, the last location I had used is at room 1 digital radiography at Satelit, Hospital USM. This room was selected to measure the ESD from every patients that undergoing abdomen and pelvic radiography examination. I choose room 1 because there is only one the digital radiography had in Hospital USM.

3.4 Materials

3.4.1 Digital X-ray Machine

Figure 3.4.1: Philips Optimus 80 Digital X-ray Machine

X-ray machine used in this study is Philips Optimus 80 with 3 phase x-ray generator with power supply maximum 50 Kw. For ensure best x-ray output, this static unit of x-ray machine was done quality control test before the experiment. This machine was used for process determine the reproducibility sensitivity of TLD 100H. Besides that, it is also used for the process calibration of TLD 100H and as a radiation source for measured the entrance surface dose studies.