DOSIMETRIC VERIFICATION USING OPTICALLY STIMULATED LUMINESCENCE (OSLD) NANODOTS FOR POSTERO-ANTERIOR (PA) CHEST EXAMINATIONS IN PERAK HEALTH CLINICS

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by

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LIST OF ABBREVIATIONS

AAPM	American Association of Physicists in Medicine
AL Eq	Aluminum Equivalent
ALARA	As Low As Reasonably Achievable
AP	Anterior Posterior
BSRP	Basic Safety Radiation Protection
CFL	Commercial Solid Fluorescent Light Bulb
cm	Centimeter
CT	Computed Tomography
cGy	Centi Gray
CRCPD	Conference of Radiation Control Program Director
DD	Depth Dose
DRL	Diagnostic Reference Level
ESD	Entrance Surface Dose
ED	Exit Dose
EUR	European Commission
FSD	Focus Skin Distance
Gy	Gray
HC	Health Clinic
HVL	Half Value Layer
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiation Units and Measurements.
IPSM	Institute of Physical Sciences in Medicine
KAP	Kerma Air Product
KeV	Kilo electron Volt
kV	Kilovolt
kVp	Peak Kilovolt
LiF	Lithium Fluoride
mAs	Milli-Ampere-Second
mGy	Milligray
min	Minute

mm	Millimeter
MOH	Ministry of Health
mSv	Mili Sievert
NRPB	National Radiological Protection Board
OSLD	Optically Stimulated Luminescence Dosimeter
PA	Posterior Anterior
PDD	Percentage Depth Dose
PMMA	Polymethylmethacrylate
PMT	Photomultiplier Tube
ROI	Region of Interest
SSD	Source to Skin Distance
TLD	Thermoluminescense Dosimeter
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
UV	Ultra Violet
Z	Atomic Number
uGy	Micro Gray

LIST OF APPENDICES

PENGESAHAN DOSIMETRI MENGGUNAKAN NANODOT PENDARKILAU RANGSANGAN OPTIK (OSLD) BAGI PEMERIKSAAN POSTERO-ANTERIOR (PA) DADA DI KLINIK KESIHATAN NEGERI PERAK

ABSTRAK

Kajian ini dijalankan untuk menentukan dosimetri pesakit yang diterima dalam menjalankan Prosedur Pemeriksaan X-ray di Klinik Kesihatan Perak. Sebagai hasil kajian ini, pengukuran kemAsukan dos permukaan (ESD) akan direkodkan. Terdapat beberapa prosedur diagnostik yang dilaksanakan di Klinik Kesihatan di mana kebanyakan kes adalah untuk prosedur pengimejan Postero-anterior (PA) dada. Oleh itu, pengukuran dosimetri untuk prosedur pengimejan Postero-anterior (PA) dada akan direkodkan di mana faktor pendedahan yang digunakan biasanya digunakan oleh juruxray di Klinik Kesihatan. Pengukuran dosimetri ESD akan menggunakan Nanodot OSLD (Al_2 O_3: C) yang diletakkan pada fantom Perspex dengan ketebalan 10 cm dan direkodkan dalam unit mGy. Pengukuran ESD dosimetri menggunakan Nanodot OSLD untuk prosedur pengimejan Postero-anterior (PA) dada untuk Klinik Kesihatan Perak direkod serta dianalisa dalam mimimun, median, *1st Quatile* dan *3 Quartile*. Pada dasarnya ukuran ESD yang direkodkan didapati lebih rendah daripada paras garis panduan yang ditetapkan untuk ujian X-ray Postero-anterior (PA) dada di Malaysia. Sebagai panduan untuk Tahap Rujukan Dos (DRL) yang disyorkan oleh Kementerian Kesihatan Malaysia adalah 0.9 mGy manakala bagi Agensi Atom Antarabangsa (IAEA) adalah 0.4 mGy. Hasil kajian penyelidikan yang diharapkan dari semua klinik adalah merangkumi semua mesin di Klinik Kesihatan Negeri Perak berdasarkan model seperti Shimadzu, Philip, Toshiba, Siemens GE dan

Bennett Hologic serta akan dikenalpasti berdasarkan pengukuran ESD menggunakan Nanodots OSLD. Pengukuran menggunakan Nanodots OSLD akan menyediakan bacaan maksima dan minimum ESD untuk setiap klinik yang terlibat. Data pengukuran ESD boleh digunakan sebagai tahap rujukan untuk semua klinik kesihatan serta Bahagian Kesihatan Awam khususnya bagi meningkatkan kualiti perkhidmatan diagnostik Klinik Kesihatan. Di samping aspek perlindungan radiasi untuk pesakit, teknik yang betul serta kemampuan peralatan sinar -x yang berfungsi membantu juruxray dalam perkhidmatan diagnostik serta proses dalam aspek dos yang diterima pesakit berdasarkan konsep ALARA. Pada mAsa ini terdapat satu piawaian yang telah dibangunkan melalui Garis Panduan tahap Rujukan Diagnostik Malaysia dalam Pengimejan Perubatan (Radiologi) yang diterbitkan pada tahun 2013 oleh Kementerian Kesihatan Malaysia dan Tahap Antarabangsa melalui Agensi Tenaga Atom Antarabangsa (IAEA). Bagi pemeriksaan dada X-ray PA di Malaysia merujuk kepada Tahap Rujukan Dos (DRL) yang disyorkan oleh Kementerian Kesihatan Malaysia adalah 0.9 mGy dan juga oleh Agensi Atom Antarabangsa (IAEA) ialah 0.4 mGy. Hasil kajian menunjukkan bahawa dosimeter Nanodot OSLD yang diukur adalah 0.271 mGy - 0.368 mGy atau 30.11% - 47.89% lebih rendah daripada tahap panduan yang disyorkan di Malaysia.

DOSIMETRIC VERIFICATION USING OPTICALLY STIMULATED LUMINESCENCE (OSLD) NANODOTS FOR POSTERO – ANTERIOR (PA) CHEST EXAMINATIONS IN PERAK HEALTH CLINICS

ABSTRACT

The study was conducted to determine the patients dosimetry received in carrying out an X-ray Examination Procedure at the Perak Health Clinic. As a result of this study the Entrance Surface Dose (ESD) measurement of the procedure will be recorded. There are a number of diagnostic procedures implemented at the Health Clinic where most of the cases are for Postero – Anterior (PA) Chest imaging procedures. Therefore, dosimetry measurements for PA Chest imaging procedures will be recorded for the exposure factors used by the radiographer at the Health Clinic. The measurement of the dosimetry ESD will use the Nanodots OSLD (Al_2 O_3: C) placed on the Perspex phantom with a thickness of 10 cm and recorded in the unit of mGy. Dosimetry ESD units measured using Nanodots OSLD for the PA Chest imaging procedure for the Perak Health Clinic were recorded and reported as mean, median, first and third quartile values. Basically the recorded ESD measurements are found to be lower than the guideline level set for PA Chest X-ray examination in Malaysia as a guide for the Dose Reference Level (DRL) recommended by the Ministry of Health Malaysia is 0.9 mGy and also by the International Atomic Agency (IAEA) is 0.4 mGy. In addtion, research study results is able to determine the ESD value from all clinics will include machines at Health Clinics in Perak based on models such as Shimadzu, Philip, Toshiba, Siemens GE and Bennett Hologic. Measurements using Nanodots OSLD will provide the maximum reading and minimum ESD for each involved clinics. ESD measurement data can be used as reference level for all health clinic as well as to Public Health Division in particular for improving the quality of Health Clinic diagnostic services. In addition to the aspect of radiation protection for patient, the correct technique as well as the ability of x-ray equipment to function efficiently can assist radiographer in the work process of diagnostic services to the patient dose received aspect based on ALARA concepts.There is currently a standard that has been developed through the Malaysian Diagnostic Reference Levels in Medical Imaging (Radiology) published in 2013 and International level through the International Atomic Energy Agency. The results show that the Nanodot OSLD dosimeter measured in the 3rd quartile ESD was 0.271 mGy – 0.368 mGy or 30.11% - 47.89% which less than the recommended Malaysia national guidance level .

CHAPTER 1

INTRODUCTION

1.1 Introduction and background study

Referring to diagnostic environment, useful diagnostic radiology information includes generally to the interpretation images for identifying and monitoring treatment. The diagnostic radiology modalities are general radiography, mammography, fluoroscopy, angiography, bone mineral densitometry, dental radiology and computed tomography. Although the radiography examination doses are generally low, but the exact dose to patient needs to be monitored and known. There are probability criteria for high absorbed doses that can come from choice of exposure factors, film screen speed, technique, focus to film distance (FFD), collimation and the output of the x-ray machine used.

In accordance with the International Agency, clause Regulation 5, 42(1) 48 and 54 in Basic Safety Radiation Protection Regulations 2010 (BSRP), explains that the licensee shall ensure that guidance levels for medical exposure is determined in accordance with this regulation either worker or member of public and requires medical institutions to comply with the requirement of medical exposure.

The use of man-made radiation sources is largely used in medicine, in the UNSCEAR 2000 diagnostic imaging procedure estimates that annual effective dose per capita worldwide from medical diagnostic examination is 0.4 mSv. Compared to the value of the atmospheric nuclear test is 0.005 mSv, Chernobyl accident is 0.002 mSv and nuclear energy production is 0.0002 mSv(United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2000)**.** In medical application, the use of x ray in diagnostic was practiced in the 19th century. Recent advances and improvements that have been made after its first use in medical has made X-ray a very important method for diagnostics and therapy. The importance of providing safe and safety culture especially in terms of radiation protection and safety to radiation workers and patients should be considered without compromising the importance and benefits of medical radiation. As recommended by the International Commission on Radiology Protection (ICRP) the use of radiation in diagnostic radiology should be justified, optimisation and dose limitation. For medical exposures of patients as part of their investigation or treatment, dose limit has not been specified by ICRP. The Diagnostic reference levels (DRL) is recommended for use as a guide for medical exposure and to avoid unnecessary high doses to the patient(Vañó et al., 2017).

Dosimetric radiation methods are utilised to estimate dose absorbed by the radiation in detector material, either by the technique of thermoluminescence (TL) or by the techniques of optically stimulated luminescence (OSLD). These dosimetric methods are needed for estimating the doses absorbed in various radiation applications such as human and environmental dosimetry, retrospective/accident dosimetry, radiation medical applications and high Linear Energy Transfer (LET). The application of TL as a tool for ionising radiation dosimetry is developed over the years and has found many useful applications in several areas such as personal monitoring, environmental monitoring, medical dosimetry and spatial dosimetry (Kortov, 2007). In the field of radiation dosimetry, TL is an important player, particularly in the field of personal dosimetry (Cassata et al., 2002), and there are several commercial TLD systems used for the different dosimetric application. Modern luminescence development is more oriented towards optically stimulated luminescence (OSLD) induced (Lars et al., 2003). OSLD is an occurrence in which an irradiated substance emits a light signal proportional to the absorbed radiation dose when induced by the required wavelength of light (Akselrod & Gorelova, 1993) and later investigations into its suitability in personnel dosimetry using pulsing OSLD (POSLD) stimulation technology, reportedly did not make responsive OSLD phosphors available until the production of Al_2O_3: C (Akselrod & McKeever, 1999). These lead to the development of Landauer personnel dosimetry Al_2O_3: C OSLD phosphorus-based dosimetry system. So OSLD was only used in the late 1990s as a personal dosimetry technique. OSLD dosimeters have since been increasingly used in the fields of workers, environmental control and medical physics (Polf et al., 2004). In its efforts to date, however, the OSLD has, since the implementation of the process in this field, been a common technique for assessing environmental amounts obtained by archaeological and geological materials (Godfrey-Smith, Huntley, & Chen, 1988). OSLD technology provides key advantages (Lars et al., 2003):

i. There is no need for sample heating which also removes thermal quenching problems;
ii. Optical aspect of the read-out process also enables the use of low-melting-point dosimeter materials, namely impregnated luminescence phosphorus.
iii. In some phosphors, such as Al2O3: C, the high sensitivity of OSLD may also result in benefits associated with multiple reads (using POSLD re-readers mode) because it is often not necessary to stimulate the whole load to read the luminescence signal and

iv. Reading can be done very quickly (< 1s) by adjusting the luminous stimulating speed, which gives rise to the value of rapid dosimeter analysis.

1.2 Problem Statement

The first national dose survey in Malaysia in collaboration with the Ministry Of Health Malaysia (MOH) and University of Malaya initiated and conducted from 1993 – 1995 for 3 years period of time was published under UNSCEAR 2000 report to set baseline for seven routine types of examinations patient dose data. The second national dose survey by MOH itself in radiation exposure study as the follow up to the first study was conducted from 2005 – 2009. This time the scope covers dental radiology, diagnostic, interventional radiology, radiotherapy and nuclear medicine.

Nowadays, every person including public, patients and medical practitioner interest in dose measurement and besides that, International Atomic Energy Agency Safety Standard: Radiation Protection and Safety of Radiation Sources: International Basic Safety Standard (IAEA, 2011) states that the government shall ensure that a set of Diagnostic Radiation Levels (DRLs) is established for medical exposures incurred in medical imaging. And with the growing technology, doctor's and operator X-ray knowledge in the aspects of radiation or radiation safety aspects are often underestimated and it can increasingly to frequent level.

Medical radiation exposure studies have shown that it is necessary to calculate the radiation dose provided to patients during their diagnostic tests(MOH, 2013). Although patients are exposed to ionising radiation to help diagnose a disease, they through receive more radiation than is required. The dosage levels for patients undergoing diagnostic X-ray exams are largely dictated by the quality of the images needed and the scope of the investigation necessary to satisfy the relevant clinical objectives. Normally, the routine for tracking the dose to be obtained by the patient during projection imaging is based on explicitly observable dose levels, such as the intake surface dose (ESD)(Shahbazi-Gahrouei, 2006). In its Technical Reports Series No. 457, ESD is classified as the absorbed dose in air, including the contribution from the backscatter, assessed at the point on the entrance surface of the specified object(IAEA, 2014).

Dosimetry measurement study performed will provide useful data and inputs to ensuring that the dose received by the patient during the PA Chest examination at health clinic in Perak is under the guidance level according Ministry Of Health Malaysia and international agencies such as the IAEA. Although the doses from diagnostic radiology examination are generally low, the magnitude of the practice makes for a significant radiation impact in stochastic and deterministic effects but this is outweighed by the direct benefits in health improvement

1.3 Objectives of Study

Aim and objectives of this research are to develop a measurement set for Perak Health Clinic for Entrance Surface Dose (ESD) obtained from diagnostic procedure which is PA Chest examinations using Nanodots OSLD (Al_2O_3:C) and as per state below:

1. To evaluate the Entrance Surface Dose (ESD) using Nanodots OSLD (Al_2O_3:C) for Chest X-Ray PA examination among HCs in Perak.

2. To assess Entrance Surface Dose (ESD) of x-ray machines for each model.

1.4 Scope of Study

In this research, Nanodots OSLD were used as a dosimetry measurement tool to obtain ESD readings for each clinic involved. The study focused and involved floor mounted x-ray machines available at the Perak health clinics such as Toshiba, Quantum, Bennett, Philips, Shimadzu and Siemens. Dosimetry measurements using Nanodots OSLD include exposure factors that are commonly used by radiographer in health clinics from ranging from 50 kV up to 90 kV and exposure factors used are at 5 mAs, 16 mAs and 25 mAs. This selection of exposure factors includes techniques used by radiographer either low kV technique or high kV technique for chest X-ray examination. PMMA and also known as perspex phantom thickness of 10 cm in total was used by putting the Nanodots OSLD on it for measuring dosimetry for PA Chest examination. These measurements were performed at clinics included in the Kuala Kurau Health Clinic, Simpang Health Clinic, Buntong Health Clinic, Gunung Rapat Health Clinic, Taiping Health Clinic, Teluk Intan Health Clinic and Pengkalan Hulu Health Clinic.

1.5 Outline Of Research

In this research, Chapter 1 covers a brief background of radiology, act and dose verification in chest x-ray, problem statement, objectives of research study and scope of research study are also stated in this Chapter 1. Chapter 2 is mainly on the reviews past research that have been conducted before and theory relevant to this thesis concerning to the Entrance Surface Dose. Next, Chapter 3 consists of methodology, material and apparatus that were used in this research to fulfill the research objectives. Chapter 4 is on results and discussion that include in sampling and overall discussion obtained from all health clinic. Chapter 5 is the conclusion and future recommendation including limitation of studies and future studies that can be done.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Nowadays, worldwide interest in patient dose measurement and besides that, referring to standard International Atomic Energy Agency (IAEA) that was published and enforced in 2011 for Radiation Protection and Safety of Radiation Sources states that the government shall ensure that a set of Diagnostic Reference Levels (DRLs) is established for medical exposures incurred in medical imaging. Such DRLs shall be based on wide scale surveys or on published values that are appreciate for the local circumstance.

Quality assurance program that implement and continuous to ensure that each device meets the standards and assists in optimising patient protection are the best practices for organisations involved in providing accurate information on each patient's ESD. There are currently ongoing studies in ESD measurements that show acceptable ESD doses can be optimised. The study aimed at ensuring lower patient doses without reducing and improving image quality will attract more studies in ESD.

In diagnostic imaging, the assessment of the dose delivered to the patient while performing diagnostic imaging procedure can be obtained using ESD parameter. However, all radiation exposures in the medical field require justification for every procedure needed and optimisation in terms of benefits and risks for that procedure (ICRP, 1991).

2.2 Dosimetry Quantities

The International Commission on Radiation Units and Measurements (ICRU) introduced operational quantities for practical use in radiological protection where exposure to external sources is concerned. Various dose quantities have been designed by ICRP and ICRU to meet the needs to protect human beings (protection quantities) and operational dose quantities which are designed for use in radiation measurements of external irradiation (ICRU, 2011). Radiological or radiation protection is intended as a control measure in the field of ionising radiation to ensure that acute damage is prevented, and the risk of long-term effects can be minimised. The specific protection quantities that ICRP has developed for radiological protection allow quantification of the extent of exposure to ionising radiation from both whole and partial body external irradiation and from intakes of radionuclides. They are based upon assessment of the energy imparted to organs and tissues of the body. The estimated doses can then be compared with recommended dose limits for people who are occupationally exposed and for members of the public.

2.2.1 Absorbed dose

According to Atomic Energy Licensing (Basic Safety Radiation Protection) regulation 2010), the "absorbed dose" (D) means is the quotient of de by dm, where de is the mean energy imparted by ionising radiation to matter in a volume element and dm is the mAss of matter in that volume element, represented by the equation (2.1) follows (BSRP, 2010):

$$D = de/dm \tag{2.1}$$

The special name for the unit of absorbed dose is Gray (Gy) equivalent to 1 J/kg. Absorbed dose is derived from the mean value of the stochastic quantity of energy imparted and therefore does not reflect the random fluctuations of the interaction events in tissue. It is defined at any point in matter and, in principle, is a measurable quantity. Primary standards exist to determine the absorbed dose experimentally or by computation. The definition of absorbed dose has the scientific rigour required for a basic physical quantity. It implicitly takes account of the radiation field as well as of all of its interactions with matter inside and outside the specified volume(Dietze et al., 2005). It does not, however, take account of the atomic structure of matter and the stochastic nature of the interactions.

2.2.2 Equivalent dose

ICRP first introduced a single protection quantity, effective dose equivalent and was developed principally for use in occupational exposure although it has been used more broadly for members of the public. According to ICRU publication No. 39 (1985) introduced these operational quantities for practical use in radiological protection where exposure to external sources is concerned. It was intended to be used for exposure limitation and risk management at low doses. According to Atomic Energy Licensing (Basic Safety Radiation Protection) regulation, BSRP (2010), the “equivalent dose” (H) “” means the product of the absorbed dose delivered by each types of radiations averaged over a tissue or organ and the radiation weighting factor for the same type of radiation;

The dose equivalent H is defined as equation (2.2)

$$H = DQN \qquad (2.2)$$

where D is the absorbed dose, Q is the quality factor and N is the product of all other modifying factors. The operational dosimetry quantity recommended in the IAEA Basic Safety Standard (BSS) for individual monitoring is the personal dose equivalent Hp(d). This is the dose equivalent in soft tissue below a specified point on the body, at an appropriate depth d. One possible approach to measuring Hp(d) would be to use a detector worn at the surface of the body and covered with an appropriate thickness of tissue substitute(Benmakhlouf et al., 2011). According to (Dietze et al., 2005) mention these operational quantities have been defined in such a way that the measuring value in general gives a conservative estimate of the effective dose or local skin dose with adequate accuracy.

2.2.3 Effective dose

The "effective dose" means the sum of each of the tissue equivalent doses multiplied by the appropriate tissue weighting factor (BSRP, 2010). The concept of "effective dose" (E) was developed by ICRP as a risk-adjusted dosimetric quantity for the management of protection against stochastic effects, principally cancer, enabling comparison of planned or received doses with dose limits, dose constraints, and reference levels expressed in the same quantity. The unit effective dose is Joule per kilogram (1 J/kg), which is termed the Sievert (Sv), represented by the equation (2.3) and tissue weighting factor (WT) for various tissues reference is shown in Table 2.1

$$E = \sum WT.\ HT \qquad (2.3)$$

Table 2.1 The weighting factor, WT for calculation effective dose, E

Tissue Or Organ	Weighting factor, WT
Gonads	0.20
Bone marrow	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Oesophagus	0.05
Thyroid	0.05
Skin	0.01
Bone surface	0.01
Remainder (e.g. kidney, pancreas and uterus)	0.05

Effective dose and the tissue weighting factors used in its calculation relate to detriment from radiation-induced cancer and hereditary effects (Harrison & Lopez, 2015). For the purposes of radiation protection of occupationally exposed workers and public, dose limits have been prescribed for the effective dose and the local skin dose. Both dosimetry quantities are defined as mean values of doses of organs or tissue in the human body.

2.3 Optically Stimulated Luminescence Dosimeter (OSLD)

Optically Stimulated Luminescence (OSLD) ia a radiation dosimeter device, instrument or system that measures, either directly or indirectly the radiation quantities exposure, air kerma, absorbed dose, equivalent dose and related ionising radiation quantities. The OSLD dosimetry system includes OSLD and their reader. Measurement of a dosimetry quantity is the process of finding the value of the quantity experimentally using dosimetry systems. The result of a measurement is the value of a dosimetry quantity expressed as the product of a numerical value and an appropriate unit (Podgorsak, 2006).

In recent times and in the last 2 decades, the use of Optically stimulated luminescence dosimetry (OSLD) has been very widespread in the field of dosimetry on patients as well as radiation workers involved in ionising radiation. The tendency of using OSLD for radiation workers to record exposure during ionising radiation from industrial and health activities can be seen from the shift of film application to thermoluminescence Dosimeter (TLD) and now to Optically stimulated luminescence Dosimeter (OSLD). In the patient's dosimetry the use of OSLD especially during the implementation of the treatment for exposure to the dose received by the patient and in the research carried out mainly in the field of diagnostic imaging, radiotherapy services and nuclear medicine.

Luminescence (OSLD) doses using Aluminum doped Carbon Oxide (Al_2O_3: C) as an Optically Stimulated Dosimetry material have become a widely accepted personal dosimetry method and commonly used in the current research. The OSLD reading measurement is conceptually recorded by producing signal light proportional to the ionising radiation of the exposed material.

In theory, material in the OSLD is exposed to ionising radiation, it creates a trapped state of the electron in the OSLD material. When OSLD material is exposed to light with wavelengths of between 400 nm and 700 nm, the excited electronic states of the material are warmed, providing energy in the form of light(Jursinic, 2007). The stimulated optical luminescence results in the emission of light, which is proportional to the dose of ionising radiation absorbed by the OSLD material. OSLD readers have two functions, namely, stimulate OSLD material with light while simultaneously measuring the light emitted by a photomultiplier (PMT) tube and translating it into a single number, which the reader provides as an accusation.

In medical applications, reading the OSLD is basically faster and easier than TLDs where the output light reading process is similar to the process used for reading Thermo-luminescence dosimeters (TLDs), which are luminescence signals measured using PMT (Lars Botter-Jen et al., 2003). However, TLD based on the heating compared to the OSLD where the stimulus is by light. Currently the use of OSLD dosimetry is more focused than TLD use as OSLD can be read repeatedly after a single exposure to radiation without losing any of the original signal of induction radiation. When OSLD is stimulated by light, only a small fraction of the trapped electrons are released. This is unlike TLD where, the dosimeter material is heated, the heat stimulation causes almost all states to be inspired by the radiation to de-excited by releasing trapped electrons. This essentially sets the dosimeter reading to zero (i.e. background reading) (Jursinic, 2007).

However, there is a strong dependence of OSLD that responds to photon energy when used with low x-rays in the 50 keV-120 keV range. OSLD are more likely to respond and deliver higher doses than what they receive. To overcome this OSLD dosimetry tendency, measurements were made using a vendor's OSLD calibration set for OSLD Readers, where the measurement set was exposed to a reference x-ray beam with a maximum tube voltage setting at 80 kVp (Landauer, 2012).

OSLD dosimetry concept of has been existed for many years with the first use of what is known today as OSLD by Antonov-Romanovsky. Working with a variety of sulfide materials, it has been observed that when these materials are exposed to infrared light, luminescence can be observed. It will take decades until a suitable material is found that can be used as an OSLD. The search is slow because many of the materials tested produce only shallow traps when exposed to radiation, and with shallow traps the dosimeter will fade. Fading is where the dosimeter easily loses the dose signal from either normal ambient light or is exposed to room temperature (EG Yukihara, 2011). Finally, a breakthrough came when scientists at the Urals Polytechnic Institute in Russia designed new materials for use in thermoluminescence. They form anion oxide-deficient aluminum oxides. This new material provides sensitive dosimetry reactions, but it is also noted that the dosimeter signal fades or loses its dose when exposed to direct sunlight or room light. Further work is being done at Oklahoma State University which has produced several U.S. patents. and finally, the development of a commercialised OSLD (EG Yukihara, 2011).

The OSLD phenomenon can be visually understood in terms of the solid band theory which describes the state of the electron energy moving in the solid (Knoll, 2010). While in an atom, an electron can have a discrete energy state, in the solid state it forms an energy band. The highest energy bands in the solid are referred to as the valence bands. The first blank band above the valence line is called the conduction path. Between these two groups there is an energy gap. The classification of materials as electrical conductors, insulators and semiconductors can be easily understood by band theory; the conductor easily allows the flow of electricity, the insulation retains the flow of electricity and the semiconductor properties between the conductor and the insulator(Knoll & Kraner, 2010)

When OSLD is exposed to radiation, radiation interacts with electrons in the valence groups of materials that cause them to move to the conduction path. When this happens, the next "hole" is created in the valence band. These electrons and holes can then move freely within their band until either a recombinant electron with a hole or they are trapped in one of the intermediate energies in the band gap known as the trapped state (EG Yukihara, 2011). Electric charges (either holes or electrons) can stay trapped in these states for a long time unless materials are exposed to light or thermal stimulation. In the case of OSLD dosimetry, when the material is stimulated by light, these trapped charges are released, producing visible light due to the damage to the trapped state. As the number of trapped states increases, so does the intensity of light emitted. The intensity of this light is proportional to the radiation dose absorbed by the OSLD (Jursinic, 2009).

2.4 Polymethylmethacrylate (PMMA) Phantom

In ionising radiation and medicine, where the basic principle of radiation protection other than justification is optimisation, also known as ALARA (as low as reasonably achievable) states while maintaining good diagnostic quality that it is necessary to ensure minimal exposure to patients and staff. In order to achieve these goals and the concept of optimisation achieved, it is necessary to monitor and make sure patient radiation dose received on a regular basis.

The use of phantom for dose and image evaluation is very helpful and useful in simulating radiation ionization interactions with the body. Scans of these objects become anthropomorphic as they represent anatomically body structure, or geometry when geo-shaped metric. For its function, it can be utilised in dosimetry calibration and image analysis (ICRU, 1992).

According to (Henriques et al., 2014), studies on the characterisation for dose measurement of an anthromorpic chest phantom in radiology beam, where the phantom contains equivalent tissue. For comparison purposes, geometric chest pallet PMMA with dimension size of 30 × 30 × 15 cm^3. Dose measurement for incident water kerma and entrance surface dose(ESD) were calculated using ionising radiation. From the result, the backscatter factor of the two phantoms was identified and ESD showed a good similarity between the two phantoms. In terms of conformity also shows that both phantoms are good to each other.

Referring to (Sandborg & Carlo, 1990) in QA and QC to medical equipment especially in PMMA diagnostic imaging such as Lucite are often used in comparison to water to imitate the patient body. PMMA has higher density and lower average atomic number than water, energy absorption and different scattering properties of photons. Phantom thicknesses of 10 cm and 20 cm were used to simulate patients. As a result, there is a slight difference between the water and the soft tissue phantom. The use of Lucite PMMA as a phantom gives greater diversity. Therefore, thinner phantom with nearly same to density to water of 1.19 g / cm^3 (water density 0.9982 g/cm^3) should be considered.

2.5 Diagnostic Radiation Level (DRL)

Definition for the term of Diagnostic Reference Level (DRL) by International Commission on Radiological Protection (ICRP) as state below

“a form of investigation level of patient dose or administered activity (amount of radioactive material) for a specified procedure used in medical imaging, to indicate whether, in routine conditions, the patient dose or administered activity is unusually high or low for that procedure”

DRL objective is to optimise also avoid excessive radiation exposure and make a corrective action taken as necessary according to radiation protection principles if exposures do not provide useful diagnostic information dan medical benefit to patients. According to (MOH, 2013) DRL can be asessed using Entrance Surface Dose measured with a TLD fixed on the patient body or the kerma Area Product (KAP). Comparison of DRL data (derived from relevant regional, national or local data) and practices from appropriate patient reference groups will meet the objective of DRL. In the DRL measurement, aspect there are different quantities used and depending on the quantity selected such as the type of clinical procedure, whether it is an individual radiographic projection, procedure and examination consisting of multiple projections. The quantity used also depends on the authority setting the level of reference for the DRL. The DRL concept enables the flexibility in selecting quantities, numerical values and technical or clinical specifications, to allow authorised bodies to meet the objectives relevant to their circumstances. Therefore, a protocol has been developed and used for countries involved in dose measurements to set guidance level to allow and compare their x-ray department own performance to ensure that implementation and practices have been placed to ensure that action is taken and needed to reduce dose. Table 2.2 shows guidance levels (in mGy) as prescribed by various agencies for diagnostic radiological examinations.

Table 2.2 Guidance levels (in mGy) as prescribed by various agencies for diagnostic radiological examinations (Ng et al., 1998)

Radiograph	Projection	IAEA[17]	CEC[9]	UK [6]	CDRH[5] (mean value)	Ng *et al.*[16]
Chest	PA	0.4	0.3	0.15	0.17	0.28
	LAT	1.5	1.5	0.6	-	1.40
Abdomen	AP	10	-	4	5.6	10.00
Pelvis/hip	AP	10	10	4	-	8.41
Skull	AP/PA	5	5	2	-	4.78
	LAT	3	3	1.3	1.6	3.34
Cervical spine	AP	-	-	-	1.5	1.02
Lumber spine	AP	10	10	5	6.4	10.56
	LAT	30	30	11	-	18.60

In 2013 under Technical Working Group Diagnostic Reference Levels (DRLs), Radiation Health and Safety Section Ministry Of Health Malaysia (MOH) carried out radiation exposure study between 2007 and 2009 and had published the results involving both public and private medical institutions. For the (PA) chest x-ray examination show that the ESD reading was 0.9 mGy. Table 2.3 shows the comparison of ESD (mGy) for general X-ray (PA Chest Examination) collected from various agencies for the diagnostic radiological examination:

Table 2.3 Comparison of ESD with other international bodies (MOH, 2013)

Exam. Type	Projection	Entrance Surface Dose (mGy)						
		MALAYSIA MOH (2009)	UK [1]NRPB (1999)	US [2]AAPM (1999)	EC [3]EUR96 (1996)	IAEA [4]BSS (1996)	UK [5]IPSM (1992)	USA [6]CRCPD (1988)
Chest	PA	0.9	0.30	0.25	0.30	0.40	0.30	0.10

Based on the Report Medical Radiation Exposure Study in Malaysia (2007 – 2009) : Ministry of Health Malaysia published in 2013 as a Guidelines Malaysian Diagnostic Reference Levels In Medical Imaging (Radiology) , number of cases from the report for PA Chest examination contributed 42% of the total cases taken by 2743 cases from 6533 cases in total.

Referring to (MOH, 2013), DRL certainly a practical tool for continuously optimising the medical procedures and radiation protection of the patients which need to be considered in justification principle must be respected first and optimisation their practice. DRL national survey has led to an increased awareness amongst professional in diagnostic radiology in Malaysia on the need for reduction in patient dose(Ng et al., 1998).

2.6 Entrance Surface Dose (ESD)

ESD study was conducted by (Shahbazi-Gahrouei, 2006) for PA chest examination, chest lateral, AP or PA skull and LAT skull at in hospitals in Iran. In the study, six hospitals were recorded and x-ray machines namely GE, Shimadzu, Philips, Siemens and Varian. The dosimetry measurements and dosimetry readings received are an average of three TLDs per radiograph for all patients calculated. TLD measurement method are placed in the middle of the x-ray field on the patient's skin. ESD readings for PA chest and LAT chest are available in the range of 0.22-1.45mGy and 0.34-4.90 mGy. While for AP or PA skulls in range of 2.55-8.45 mGy and LAT skulls are in range of 2.85-9.12 mGy. The results show that other than image quality that needs to be emphasised and also for dose reduction in patients and quality control programs that need to be improved and streamlined to achieve the ALARA concept as part of the optimisation process.

Abdullah *et. al*. (2010) conducted a study at two hospitals in Penang for Entrance Surface Dose (ESD) measurements and to assess the dose received by patients. This study involved the imaging procedures commonly used in the department. 59 total samples conducted and 71 recorded data as shown in Table 2.4 involving imaging procedures AP/PA chest (anterior/posterior), lateral chest, AP/PA abdomen, AP lumber spine, lateral lumber spine, AP cervical spine, AP pelvis, lateral skull and AP skull using thermoluminescence dosimeters (TLDs).

Table 2.4 Distribution of entrance surface dose (ESDs) for nine common types of x-ray examinations from two hospitals in Penang (M.H.R.O. Abdullah, S. Kandaiya, T.H. Lim, 2010)

Type of Examination	Projection	Number of Data	Mean ESD (mGy)					
			Min.	1st quartile	Median	Mean	3rd quartile	Max.
Chest	AP/PA	25	0.07	0.12	0.15	0.18	0.19	0.68
	LAT	1	-	-	-	0.69	-	-
Abdomen	AP/PA	16	2.26	2.87	4.93	4.89	6.28	9.23
Cervical spine	AP	2	-	-	-	0.21	-	-
Lumber spine	AP	10	2.35	3.78	4.90	5.74	6.81	13.15
	LAT	12	4.83	7.80	10.21	11.36	13.72	19.48
Pelvis	AP	2	-	-	-	4.83	-	-
Skull	LAT	1	-	-	-	1.69	-	-
	AP	2	-	-	-	1.72	-	-

The results show that the ESD received by patients who took the chest x-ray at two hospitals in this study adhered with the guidance levels set by the IAEA and other international bodies. This shows that the x-ray staffs at the two hospitals were very competent and x-ray equipments were well-maintained and had passed the annual quality control assessment before they were allowed to be used on the patients. ALARA concept has been used for protection to radiation workers and patients.

The results of the study as well as the recorded dose measurement at 3rd quartile found that the ESD obtained for chest x-ray examination was below the guidance level set by international agencies and the IAEA. The use of the ALARA concept as for ensuring radiation protection for patients and radiation workers also helps personnel who manage to perform their tasks effectively as well as the equipment used is at a good level in terms of maintenance and annual quality that need to be implemented.

Yusof *et al.* (2017) said the use of TLD as a dose monitor received by radiation workers has been replaced by Al_2O_3 or better known Optically Stimulated Luminescence dosimeter (OSLD) in several countries including Malaysia. In a study conducted for dose measurement using OSLD for low power energy using X-ray machine as well as high power energy using Linear Accelerator. Measurement for low power energy using mAs setting was performed at 12.5 mAs for kV setting of 40kV, 81kV and 125kV. Meanwhile, the IAEA TRS 398: 2000 protocol with measurements at SSD 100cm, field size 10cm x 10cm, setting of 6MV energy range at 1.5cm depth and 10 MV at 2.5cm depth for High Power Energy. The use of bolus is mounted on OSLD and TLD during measurement. In conclusion results for low power energy and high-power energy showed good dose linearity. In comparison with the readings and dose measurements for ionising chambers between OSLD recorded a higher percent deviation when compared to dose measurements using TLD100 for low energy x-rays and confirmed by the ȡ2 value in comparison to ionization chamber. For High Energy power it shows a more consistent reading than OSLD and confirmed by relatively low value of ȡ2 to ionization chamber.

Faulkner et al (1999) studied to develop a good strategy for dose measurement including detailed considerations of the best methods for patient dosimetry measurement methods. The study was divided into 3 methods which are direct measurement, indirect measurement and calculations.

For direct measurement it is recommended to use TLD for ESD measurement. The use of TLDs for measurement during examination does not influence with the clinical diagnosis. The use of TLD closely related to energy response curve and needs to be calibrated, individual sensitivity of TLD and correction factor. For Indirect measurement methods also need to be emphasised in certain cases such as a procedure that uses fluoroscopy where the patient lying within the primary beam changes during the examination where the measurement is performed on the dose area product (DAP) or air-kerma area product (KAP). Based on the concepts and principle of the inverse square law which is further away from the radiation source, the radiation dose will decrease. These two effects cancel out and as a result the quantities dose-area product (DAP) and air-kerma area product (KAP) are independent of distance from the x-ray tube. The third, calculation method depends on output from x-ray tube. Calculation method requires calibration of output tube by performing measurements using ionisation chamber at same setting and technique factor. The calibration of the output tube can be used on other tubes but depends on the same x-ray machine model and generator.

Basically, the dosimetry measurement strategy using the direct measurement, indirect measurement and calculation method can be used by conducting a dose survey by looking at the number of samples, resources and requirements available in the department or research place. Measurements using TLDs for patient doses require more attention on the aspects of TLD reading, annealing of TLDs and the handling of the TLD. Therefore, the use of TLDs for large-scale studies is less appropriate and the preparation and reading of TLDs require considerable time.

Dosimetry measurement by(Hart et al., 2009) on national reference dose for the period of 2001 to 2005 in the UK for common radiographic, fluoroscopy and dental x-ray where patient dose data have been collected. Data collected from patients such as age sex and weight, x-ray machine equipment and examination procedure. For patient dosimetry measurements, direct measurements using TLD are used to measure ESD. For different patient size the dosimetry readings measured using TLD will increase according to patient size. The dose distribution and National Refence Dose were reported on the 3rd Quartile value for 30 procedure of diagnostic examination, 8 procedure of interventional procedure on adults and 4 procedure of x-ray examination on children. The reference doses are approximately 16% lower than the equivalent values in the previous analysis of (2000) and are usually less than half of the initial UK national reference doses derived from the mid-1980s survey.

CHAPTER 3

MATERIALS AND METHDOLOGY

3.1 Introduction

Statistical analysis for this study is divided into 2 descriptive studies where the analysis of this study describes the main features of data collection in quantitative terms. The first statistical analysis is to univariate (one variable) and bivariate (two variables). The use of descriptive terms used in this study is as follows:

(a) Univariate statistics:

• Frequency or counts (expressed in numbers or percentages)

(b)Bivariate statistics:

• Mean and standard deviation

• Median • Mode

• Minimum (min) and maximum (max)

• 25th percentile (1st quartile) and 75th percentile (3rd quartile)

Mean or arithmetic mean can be defined as a list of numbers is the sum of all list divided by the number of items in the list. For this research is a statistical sample as a set of data measured using OSLD at range kV from 50kV though 90 kV, 5 mAs until 25 mAs for exposure factor selected for this research, the resulting statistics is called a sample mean. Mean is sometimes called the average which carries the same meaning. The mean is often quoted along with the standard deviation: the mean