قال تعالي:

بسم الله الرحمن الرحيم

((وما أوتيتم من العلم إلا قليلا))

صدق الله العظيم

الاسراء(85)

Dedication

To my Father soul

To my mother for her moral support and all the work she did to get me where I am today.

To my lovely sisters and brothers for their kind support.

To my Husband and friends who stood beside me and supported me.

To my supervisor and teachers.

Thanks for all

ACKNOLODEGMENT

I thank almighty God for giving me the strength, courage and determination in conducting this study, despite all difficulties.

I would like to thank gratefully my supervisor

Dr. Ahmed Mostafa Abukonna

Phrases may not cover what I mean to show, but a word must be penned to those who helped me and guided me through the way and to those who intended to help me accomplish this work, it's because of their patience and splendid character I reached this far.

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List of Abbreviations

Abbreviation	Full meaning
DRLs	Diagnostic reference levels.
ICRP	International Commission on Radiological Protection.
ACR	American College of Radiology.
AAPM	American Association of Physicists in Medicine.
IAEA	International Atomic Energy Agency.
EC	European Commission.
ALARA	As Low As Reasonably Achievable
ICRU	International Commission on Radiation Units
MPD	Maximum Permissible Dose
mSv	millisieverts
EqD	Equivalent dose
DAP	Dose Area Product
kVp	kilovolts peak
J	Joule
kg	kilogram
SID	Surface Integral Dose
TEDE	Total effective dose equivalent
NRC	Nuclear Regulatory Commission
CEDE	Committed effective dose equivalent
R/F	Radiography/ fluoroscopy
ESD	Entrance surface dose
NRPB	National
AP	Anterior Posterior
LAT	Lateral abdomen
PA	Posterior Anterior

Abstract

The DRL is usually set at the third quartile value of the distribution of typical doses derived from those surveys both nationally and internationally. Using the third quartile or 75th percentile is a compromise between being overly stringent and overly complacent. The result of initial proposed DRL was obtained by calculating the entrance surface dose (ESD) for Conventional Radiological examinations.

The aim of this study was to evaluate the local diagnostic reference levels (DRLs) in diagnostic radiology departments of some conventional x-ray examinations in Sudan. A total of ten governmental hospitals were assessed by estimating entrance surface dose (ESD) for six radiographic examinations including: skull (AP, LAT), chest (PA, LAT), abdomen (AP), lumbar spines (LAT) and pelvis (AP) exam. The proposed DRLs values were compared with the measured entrance surface doses in different countries and their results were compared with dose levels recommended by relevant organizations. The descriptive were reported.

The results obtained in mGy were, 6.0 for the skull (AP), 7.1 for the skull (LAT), 0.9 for chest (PA), 9.2 for abdomen (AP), 18.3 for lumbar spines (LAT) and 8.1 for pelvis (AP).

The obtained DRLs can provide a database for future dose measurements and improve the image quality and eventually reducing the dose to the patients.

خلاصة البحث

يتم وضع وتحديد مستوى التشخيص المرجعى عادةً على القيمة الربعية الثالثة الخاصة بتوزيع الجرعات النموذجية التى يتم الحصول عليها من خلال الموجات التى تجرى على المستويين الفومى والعالمى . إن استخدام القيمة الربعية الثالثة عبارة عن عملية توافق بين القصور المبالغ فيه والرضا المالف فيه أيضاً . إن الحصول على مستوى التشخيص المرجعى المبدئى تم من خلال حساب الجرعة الإشعاعية الداخله إلى الجلد بالنسبة للفحوصات الإشعاعية التقليدية .

إن الهدف من هذه الدراسة هو تقييم مستويات التشخيص المرجعى في أقسام الأشعة التشخيصية في السودان . تم إختيار عشرة مستشفيات كبرى (ثمانية مستشفيات حكومية واثنين من المستشفيات العسكرية) لهذه الدراسة حيث تم قياس الجرعات الإشعاعية الداخلة إلى الجلد لفحوصات سبعة أعضاء هي : الجمجمة (فحص أمامي خلفي وفحص جانبى) ، الصدر (فحص خلفي أمامي وجانبي) ، البطن (أمامي خلفي) الفقارات القطنية (جانبي) ، والحوض (أمامي خلفي) . تمت مقارنة النتائج المقترحة لمستويات التشخيص المرجعية مع الجرعات الداخلة السطحية في عدة أقطار ، وتمت مقارنة هذه النتائج مع مستويات الجرعة الموصى بها بواسطة المنظمات ذات الصلة . تم في هذه الدراسة تحديد قيم مستويات التشخيص المرجعى للعوامل الوصفية مثل العامل الربعي الأول والمتوسط والوسط الحسابى والعامل الربعي الثالث والحد الأدنى والحد الأقصى والإنحراف المعيارى لكل مستوى .

كانت النتائج المتحصل عليها بالملى قراي هي: 6.0 للجمجمة (فحص أمامي خلفي)، 7.1 للجمجمة (فحص جانبي) ، 0.9 للصدر (خلفي أمامي) ، 9.2 للبطن (أمامي خلفي) ، 18.3 للفقارات القطنية (فحص جانبي) ، 8.1 للحوض (أمامي خلفي).

إن هذه النتائج يمكن أن توفر قاعدة بيانات لقياسات الجرعة في المستقبل ، وأن تحسن نوعية الصور الإشعاعية وبالتالي تقليل الجرعة الإشعاعية على المرضى .

Chapter One

Introduction

1-1 Introduction

Diagnostic reference levels (DRLs) were first introduced by the International Commission on Radiological Protection (ICRP) in 1990 greater details in 1996. The use of DRL as an important dose optimization tool is confirmed by many professional and regulatory organizations, including the ICRP, American College of Radiology (ACR), American Association of Physicists in Medicine (AAPM), United Kingdom, Health Protection agency, International Atomic Energy Agency (IAEA) and European Commission (EC).

There have been a number of different quantities used for reference levels. The selected quantity is dependent on the type of clinical procedure, The quantity used is also dependent on the body setting the reference level, and relates to the desired aim, local preference and the unique irradiation conditions. Data from European countries shows a wide variation in common. DRL which may be due to differences in socioeconomic conditions, regulatory regime activeness of professional bodies and health care implementation (IAEA, 2007).

The result of assessing image quality and patient radiation dose in 12 countries in Africa, Asia, and Eastern Europe covering 45 hospitals revealed that there were high rate of unsatisfactory images. The image quality improved up to 16% in Africa, 13% in Asia, and 22% in Eastern Europe after implementation of a QC program (Al-Kinani and Mohsen, 2014). The ESD for adult patients were determined and compared with diagnostic reference levels. The majority of doses were below diagnostic reference levels. The International Commission on Radiological Protection (ICRP) has produced a useful advisory document on DRLs (Holm, 2004). The following comments are extracted from this ICRP document.

The objective of a DRL is to help avoid radiation dose to the patient that does not contribute to the clinical purpose of the image. This is accomplished by comparison between the numerical value of the DRL and the mean or other appropriate value observed for a suitable reference group of patients or a suitable reference phantom. A DRL does not apply to individual patients. DRLs should be applied with flexibility to allow higher doses when indicated by sound clinical judgment .The guiding principles for setting a DRL are the regional, national or local objective is clearly defined, including the degree of specification of clinical and technical conditions for the medical imaging task. The selected value of the DRL is based on relevant regional, national or local data (Clarke and Valentin, 2005).

The definition by Donabedian "the quality of care in medicine as" That kind of care which expected to maximize an inclusive measure of patient welfare, after one has taken account of the balance of expected gains and losses that attend the process of care in all parts". The ESD doses were compared with reference level values recommended by IAEA. It is found that the measured values were greater than recommended values for the most X-ray unit, because the QA program in diagnostic radiology was not conducted in Sudan medical hospital (Donabedian, 1988). This study concerned with the assessment of DRLS to reduce patient dose and increase radiographic image quality and to ensure that all radiological examinations are performed under the terms of less received dose for the patients.

1.2 The Problem of the Study

In Sudan the diagnostic Reference Values for most X ray investigations were unestablished and unevaluated before. Compared with expected dose and real used doses, significant difference were founded in pilot studies, so that establishment of local reference dose of a fetal need in the field of x ray diagnosis.

1.3 Objectives of the study

1.3.1 General objectives.

To establish Diagnostic Reference levels (DRLs) in Sudanese hospitals.

1.3.2 Specific Objectives.

- To perform representative survey of patient doses in most common X-ray examinations in Sudan.

1.4 Overview of the study

This thesis will of five chapters:

Chapter one: is general introduction which include: problem of study, objective of the study. Chapter two: theoretical background and literature review. Chapter three: materials and method. Chapter four: result and analysis. Chapter five: discussion, conclusion & recommendation, references and appendices.

CHAPTER TWO

Theoretical background and Literature Review

2.1 Effective Radiation Protection

Diagnostic imaging professionals have an ongoing responsibility to ensure radiation safety during all medical radiation procedures. They fulfill this obligation by adhering to an established radiation protection program. Radiation protection may be defined simply as effective measures employed by radiation workers to safeguard patients, personnel, and the general public from unnecessary exposure to ionizing radiation. This is any radiation exposure that does not benefit a person in terms of diagnostic information obtained for the clinical management of medical Biologic Effects. The need for safeguarding against significant and continuing radiation exposure is based on evidence of harmful biologic effects (i.e., damage to living tissue of animals and humans exposed to radiation). Various methods of radiation protection may be applied to ensure safety for persons employed in radiation industries, including medicine, and for the population at large. In medicine, when radiation safety principles are correctly applied during imaging procedures, the energy deposited in living tissue by the radiation can be limited, thereby reducing the potential for adverse biologic effects (Gollnick, 1994).

2.2 Justification and Responsibility for Imaging Procedures Benefit versus Risk

Radiation exposure should always be kept at the lowest possible level for the general public. However, when illness or injury occurs or when a specific imaging procedure for health screening purposes is prudent, a patient may elect to assume the relatively small risk of exposure to ionizing radiation to obtain essential

diagnostic medical information. A prime example of such a voluntary assumption of risk occurs when women elect to undergo screening mammography to detect breast cancer in its early stages. Because mammography continues to be the most effective tool for diagnosing breast cancer early, when the disease can best be treated, its use contributes significantly to improving the quality of life for women. When ionizing radiation is used in this fashion for the welfare of the patient, the directly realized benefits of the exposure to this radiant energy far outweigh any slight risk of inducing a radiogenic malignancy or any genetic defects (NCRP., 1992).

2.3 As Low As Reasonably Achievable (ALARA) Principle Concepts of Radiologic Practice

ALARA is an acronym for as low as reasonably achievable. This term is synonymous with the term optimization for radiation protection (ORP). The intention behind these concepts of radiologic practice is to keep radiation exposure and consequent dose to the lowest possible level. The rationale for this intention comes from evidence compiled by scientists over the past century. At the time of this publication, radiation protection guidelines are rooted in the philosophy of ALARA. Therefore, this philosophy, as low as reasonably achievable, should be a main part of every health care facility's personnel radiation control program. In addition, because no dose limits have been established for the amount of radiation that patients may receive for individual imaging procedures, the ALARA philosophy should be established and maintained and must show that we have considered reasonable actions that will reduce doses to patients and personnel below required limits. Radiation-induced cancer does not have a fixed threshold, that is, a dose level below which individuals would have no chance of developing this disease. Therefore, because it appears that no safe dose levels exist for

radiation-induced malignant disease, radiation exposure should always be kept ALARA for all medical imaging procedures, and ALARA should serve as a guide to radiographers and radiologists for the selection of technical exposure factors. For many radiation regulatory agencies, the ALARA principle provides a method for comparing the amount of radiation used in various health care facilities in a particular area for specific imaging procedures (NCRP., 1992).

2.4 Ionizing and Nonionizing Radiation

For our purposes in the study of radiation protection, the electromagnetic spectrum can be divided into two parts Ionizing radiation and Nonionizing radiation of the entire span of electromagnetic radiations included in the electromagnetic spectrum, only the following radiations are classified as ionizing radiations as X-rays Gamma rays High-energy ultraviolet radiation (energy higher than 10 eV) Because they do not have sufficient kinetic energy to eject electrons from the atom, the following radiations are considered to be nonion-1zmg, Low-energy ultraviolet radiation, Visible light, Infrared rays, Microwaves and Radio waves. If electromagnetic radiation is of a high enough frequency, it can transfer sufficient energy to some orbital electrons to remove them from the atoms to which they were attached. This process, called ionization, is the foundation of the interactions of x-rays with human tissue. It makes them valuable for creating images but has the undesirable result of potentially producing some damage in the biologic material. The amount of energy transferred to electrons by ionizing radiation is the basis of the concept of radiation dose. Thus, a radiation quantity such as equivalent dose (EqD), which correlates the absorbed dose in biologic tissue with the type and energy of the radiation to which a human has been subjected, applies only to ionizing types of radiation. EqD cannot be used to specify the amount of energy imparted to a potato in a microwave oven or to a sunbather on the beach because no ionization is produced by microwaves or sunlight (NCRP., 1992).

2.5 Particulate Radiation

In addition to electromagnetic radiation, there is another category of ionizing radiation, called particulate radiation. This form of radiation includes the following: Alpha particles, Beta particles, Neutrons and Protons.

All these are subatomic particles that are ejected from atoms at very high speeds. They possess sufficient kinetic energy to be capable of causing ionization by direct atomic collision. However, no ionization occurs when the subatomic particles are at rest. Alpha particles (also known as alpha rays) are emitted from nuclei of very heavy elements such as uranium and plutonium during the process of radioactive decay. Radioactive decay is a naturally occurring process in which unstable nuclei relieve that instability by various types of nuclear spontaneous emissions, one of which is the emission of charged particles. Alpha particles each contain two protons and two neutrons. They are simply helium nuclei (i.e., helium atoms minus their electrons). Alpha particles have a large mass (approximately four times the mass of a hydrogen atom) and a positive charge twice that of an electron. This permits them to have the potential of transferring very substantial kinetic energy to orbital electrons of other atoms (Watt et al., 2005).

Particulate radiations vary in their ability to penetrate matter. Compared with beta particles, which are just fast electrons, alpha particles are less penetrating. Because they lose energy quickly as they travel a short distance in biologic matter (i.e., into the superficial layers of the skin), they are considered virtually harmless as an external source of radiation. A piece of ordinary paper can absorb them or function as a shield. However, as an internal source of radiation, the reverse is true. If emitted from a radioisotope deposited in the body, for example, in the lungs, alpha particles can be absorbed in the relatively radiosensitive epithelial tissue and are very damaging to that tissue. It is in a way analogous to what a bowling ball does to a set of pins. Beta particles, also known as beta rays, are identical to high-speed

electrons except for their origin. Electrons originate in atomic shells outside of the nucleus, whereas beta particles, like alpha particles, are emitted from within the nuclei of radioactive atoms, but radioactive atoms that relieve their instability in a different fashion. This process of beta decay, along with some therapeutic uses of beta radiation, is discussed in Beta particles are 8000 times lighter than alpha particles and have only one unit of electrical charge ($^{-}1$) as compared with the alpha's two units of electrical charge ($^{+}2$).

These attributes mean that beta particles will not interact as strongly with their surroundings as alpha particles do. Therefore, they are capable of penetrating biologic matter to a greater depth than alpha particles with far less ionization along their paths. Not all high-speed electrons are beta radiation. Alternate sources of high-speed electrons are produced in a radiation oncology treatment machine called a linear accelerator. These electrons are most often used to treat superficial skin lesions in small areas or to deliver radiation boost treatments to breast tumors at tissue depths typically not exceeding 5 to 6 cm. Such very high-energy electrons require either millimeter of lead or multi centimeter thick slabs of wood to absorb them. As previously stated, alpha rays can be absorbed by a piece of ordinary paper because they interact so readily with matter and lose their kinetic energy quite rapidly as a consequence. Beta rays, however, with a lesser probability of interaction, can penetrate matter more deeply and therefore cannot be stopped by an ordinary piece of paper. For energies of less than 2 MeV, either a 1-cm-thick piece of wood or a1-mm-thick lead shield would be sufficient for absorption. Protons are positively charged components of an atom. An isolated proton, which is simply an ionized hydrogen atom, has a relatively small mass that, however, exceeds the mass of an electron by a factor of 1800. The number of protons in the nucleus of an atom constitutes its atomic number, or "Z" number. The atomic

number identifies an element and determines its placement in the periodic table of elements (Gollnick, 1983).

2.6 Radiation Quantities and Units

2.6.1 Early Definition of Quantities and Units

The First International Congress of Radiology was held in London, England, in 1925. This international meeting allowed radiologists from all over the world to collaborate. Unfortunately, no definite decisions for measuring the effects of ionizing radiation were made based on the recommendations presented. The International Commission on Radiation Units and Measurements (ICRU) was also formed in 1925. In 1928, a Second International Congress of Radiology was held in Stockholm, Sweden. Although the "roentgen" was accepted as a unit of exposure, it was not adequately defined. The congress charged the ICRU to define this conventional unit of exposure. The congress also established the International X-Ray and Radium Protection Commission, predecessor of the International Commission on Radiological Protection (NCRP., 1992).

Since the early days of radiology, biologic effects in humans caused by exposure to ionizing radiation were only too apparent. These early deterministic somatic effects, which appeared within minutes, hours, days, or weeks of the time of radiation exposure, were believed to be preventable, if doses to radiation workers were limited and kept lower than a value at which no adverse biologic effects were demonstrated. A tolerance dose is a radiation dose to which occupationally exposed persons could be continuously subjected without any apparent harmful acute effects, such as erythema of the skin. The general belief was that no adverse effects from radiation exposure would be demonstrated at doses lower than this level. Alternatively, this tolerance exposure level could be regarded as a threshold dose, that is, a dose of radiation lower than which an individual has a negligible chance of sustaining specific biologic damage, the tolerance dose was stated in

units of what at that time was an imprecise measure of the quantity called "exposure." This unit, the roentgen, was the principal guideline for occupational radiation exposure during the 1930s. Neither tolerance dose nor threshold dose is currently used for the purposes of radiation safety (McCollough et al., 2008).

Table 2-1: Effects of Ionizing Radiation

Early Deterministic Somatic Effects
Nausea
Fatigue
Diffuse redness of the skin
Loss of hair
Intestinal disorders
Fever
Blood disorders
Shedding of the outer layer of skin
Late Deterministic Somatic Effects
Cataract formation
Fibrosis
Organ atrophy
Loss of parenchymal cells
Reduced fertility
Sterility
Late Stochastic Effects
Cancer
Genetic (hereditary) effects

2.7 The Modern Era of Radiation Protection

By the early 1950s, Maximum Permissible Dose (MPD) replaced the tolerance dose for radiation protection purposes. MPD basically indicated the largest dose of ionizing radiation that an occupationally exposed person was permitted and that was not anticipated to result in major adverse biologic effects as a consequence of radiation exposure. This meant that absorbed doses of ionizing radiation lower than the established MPD would not result in any appreciable bodily Injury or in injury to the reproductive cells. However, some small risk of damage could exist with radiation doses at the MPD level. MPD was expressed in rem (an acronym for "radiation equivalent man," historically known as "Roentgen equivalent man"), the traditional British unit used for radiation protection purposes at that time.

Eventually the concept of "tolerance dose" was no longer accepted as a means for protecting radiation workers from the acute effects of ionizing radiation (McCollough et al., 2008).

The dose decreased, but it was not expected to become zero at any dose. This raised a dilemma: If no amount of radiation was safe, and if it was impossible to design a work environment where the dose was zero (and still be able to perform procedures such as interventional angiography), then what would determine the maximum allowed occupational exposure? The solution was to compare rates of death and accident among various occupations. Insurance companies had been using this method of comparison for many years to determine insurance rates. Some occupations are very hazardous. Examples of such occupations are:

Deep sea diving Professional mountaineering some nonhazardous occupations are:

Trade Government desk work However, even in nonhazardous occupations,

There is still a small risk of fatality or serious injury (approximately 1chance in 10,000 each year1). With this in mind, the decision was made to base recommendations for dose limits on the concept that the probability of harm

associated with typical dosimeter readings should be no more than the amount of harm in industries that are generally considered reasonably safe (McCollough et al., 2008).

There was also growing recognition that the consequences for the health of the human as a whole organism depended on which organs and organ systems had been irradiated. For example, irradiation of the bone marrow was seen as more significant to the health of an organism than irradiation of the skin. Equal doses of radiation to bone marrow and skin had different consequences.

In the late 1970s, dose limits were calculated and established to ensure that the risk from radiation exposure acquired on the job did not exceed risks encountered in "safe" occupations, such as clerical work, in which the risk is approximately 10-4 (one chance in 10,000) per year (Gerber et al., 2009).

In 1991, the ICRP revised tissue weighting factors. The revision was based on data from more recent epidemiologic studies of the atomic bomb survivors. The ICRP adopted the term effective dose. EID is based on the energy deposited in biologic tissue by ionizing radiation. It takes into account the following: The type of radiation (e.g., x-radiation, gamma, and neutron) and the variable sensitivity of the tissues exposed to radiation. This quantity, EID, is actually a measure of the overall risk arising from the irradiation of biologic tissue and organs. It takes into consideration the exposure to the entire body. EID is expressed in Sieverts (Sv), which are SI units, or in millisieverts (mSv), subunits of the Sievert (Long et al., 2016).

2.8 Quantities and Units in Use Today

In 1980, the ICRU adopted SI units, a unified system of metric units, for use with ionizing radiation and urged full implementation of the units as soon as possible. Many developed countries, particularly in Europe, have already made the transition to SI units. In the United States, SI units, the gray, and the centigray are now used

routinely in therapeutic radiology to specify absorbed dose. Even though the NCRP. Adopted the internationally accepted SI units for use in 1985, traditional units, older special units associated with radiation protection and dosimetry, such as the roentgen (with minor exceptions) are becoming obsolete. As previously noted, the roentgen (R) was at one time the internationally accepted unit for the measurement of exposure to x-radiation and gamma radiation. The traditional unit, the rem was previously used for the radiation quantity equivalent dose, a currently used metric quantity especially in radiation dosimetry reports for occupationally exposed personnel. In the SI system of units, the sievert (Sv) replaced the rem for radiation protection purposes. This unit provides a common scale whereby varying degrees of biologic damage caused by equal absorbed doses of different types of ionizing radiation can be compared with the degree of biologic damage caused by the same amount of x-radiation or gamma radiation. One Sievert is equal to 100 rem.

Fluoroscopic entrance dose rates can now be measured in milligray per minute (mGy.afmin), but in many facilities they are measured as exposure rates in roentgens per minute (R/min), and essentially all radiation survey instruments continue to provide readings in traditional units. In addition, many regulatory criteria are specified in terms of traditional units. Even though the SI units and their subunits are now predominant, the traditional units and their subunits should be recognized because they are still being used in more than a few situations. For this reason, the current generation of radiation workers must understand both the metric unit systems and the traditional system for the safety of patients and personnel until a complete transition to metric units is made. Although this edition of the textbook focuses on the metric units, the traditional units are presented where appropriate. Traditional units are identified in parentheses after the SI units occasionally.

The SI unit of absorbed dose, the gray (Csillag and Lengyel), was named after the English radiobiologist Louis Harold Gray (1901-1965), who was instrumental in developing what is arguably the most important theory in all of radiation dosimetry. The Bragg-Gray theory (1936) relates the ionization produced in a small cavity within an irradiated medium or object to the energy absorbed in that medium as a result of its radiation exposure. With the use of appropriate correction factors, the theory essentially links the determination of the absorbed radiation dose in a medium to a relatively simple measurement of ionization charge. the Swedish physicist for whom the SI unit of equivalent dose was named, is best known for his method (the Sievert integral) for determining the exposure rates at various points near linear radium sources (NCRP.)

2.9 Radiation Quantities and Their Units of Measurement

Diagnostic imaging professionals need to understand the following: Exposure (X), air kerma, absorbed dose (D) and equivalent dose (EqD).

2.10 Effective dose owing basic radiation quantities:

In a simplified sense, exposure may be described as the amount of ionizing radiation that may strike an object such as the human body when in the vicinity of a radiation source. Absorbed dose is the deposition of energy per unit mass in the patient's body tissue from exposure to ionizing radiation. EqD is a radiation quantity used for radiation purposes when a person receives exposure from various types of ionizing radiation. Besides serving as a measure of absorbed energy resulting from ionization, this quantity also attempts to take into account the potential variation in biologic harm that is produced by different kinds of radiation. Both the type and the energy of the radiation are considered. EID is another radiation quantity that is important when discussing radiation protection issues. It begins with EqD, and then by incorporating modifying or weighting factors, which correspond to the relative degrees of radiosensitivity of various organs and tissues,

attempts to take into account the different levels of radiation effects on the parts of the body that are being irradiated to arrive at an index of overall harm to a human. EID, then, is the quantity that summarizes the potential for biologic damage to a human from exposure to ionizing radiation. Each radiation quantity has its own special unit of measure (Mary Alice et al , 2013).

2.11 Exposure

When a volume of air is irradiated with x-rays or with gamma rays, the interaction that occurs between the radiation and neutral atoms in the air causes some electrons to be liberated from those air atoms as they are ionized. Consequently, the ionized air can function as a conductor and carry electricity because of the negatively charged free electrons and positively charged ions that have been created. As the intensity of x-ray exposure of the air volume increases, the number of electron-ion pairs produced also increases. Thus the amount of radiation responsible for the ionization of a well-defined volume of air may be determined by measuring the number of electron ion pairs or charged particles in that volume of air. This radiation ionization in the air is termed exposure. Exposure (X) is defined as the total electrical charge of one sign, either all pluses or all minuses, per unit mass that x-ray and gamma ray photons with energies up to 3 million electron volts (MeV) generate in dry (i.e., nonhumid) air at standard temperature and pressure (760 mm Hg or 1 atmosphere at sea level and 22°C). It is a radiation quantity "that expresses the concentration of radiation delivered to a specific area, such as the surface of the human body. Like other forms of radiation measurement, exposure is based on a response produced when radiation interacts with a medium. It can be quickly evaluated. For precise measurement of radiation exposure in radiography, however, the total amount of ionization (charge) an x-ray beam produces in a known mass of air must be obtained. This type of direct measurement is accomplished in an accredited calibration laboratory by using a

standard, or free-air, ionization chamber (Fig. 4-6). The chamber contains a known quantity of air with precisely measured temperature, pressure, and humidity.

If in that specified volume of dry air the total charge of all the ions of one sign (either all pluses or all minuses) produced is collected and measured, the total amount of radiation exposure may be accurately determined. The free-air chamber response is modified to correspond to standard temperature and pressure of dry air. Such an instrument, however, is not a practical device at locations other than a standardization laboratory. As a result, much smaller and less complicated instruments have been developed for use away from the laboratory. Although very convenient, these instruments must be periodically recalibrated in a standardization laboratory against a free-air chamber (Mary Alice et al , 2013).

Air Kerma

Air kerma is another SI quantity that can be used to express radiation concentration transferred to a point, which may be at the surface of a patient's or radiographer's body. It is replacing the traditional quantity, exposure. Air kerma actually denotes a calculation of radiation intensity in air. "X-ray tube output and inputs to image receptors are sometimes described in air kerma. "3 A standard or free air ionization chamber is the instrument that can be calibrated to read air kerma.2 "A conversion factor can also be used to convert between air kerma and exposure values. "2 "Kinetic energy released in matter, "kinetic energy released in material," and "kinetic energy released per unit mass" all use the word "kerma"as an acronym. In simple terms, air kerma is kinetic energy released in a unit mass (kilogram) of air and is expressed in metric units of joule per kilogram (J/kg).2 In a similar way one can define tissue kerma as the kinetic energy released in a unit mass of tissue. Tissue kerma is also given in units of joules per kilogram. This is in fact the same radiation unit, the gray, which was previously defined as the SI unit used to measure the radiation quantity absorbed dose. When the Gy is used to indicate

kinetic radiation energy deposited or absorbed in a mass of air, it is written as Gy a, where the subscript "a" indicates "air." Conversely, when the Gy is used to indicate the absorbed dose of kinetic radiation energy in tissue, it is written as Gro where the subscript "r" indicates "tissue." If air kerma is determined at a specific point within soft tissue of the body, the absorbed dose of radiation in that mass of tissue will be approximately equal to this "tissue" kerma value. With respect to radiographic and fluoroscopic units, however, "air" kerma is the primary concept because in these situations we are concerned with exposure and the patient's entrance dose. Modern radiographic and fluoroscopic units have incorporated an ability to determine the entire amount of energy delivered to the patient by the x-ray beam. This quantity is often referred to as the dose area product (DAP). It is essentially the sum total of air kerma over the exposed area of the patient's surface or, in other words, a measure of the amount of radiant energy that has been thrust into a portion of the patient's body surface. DAP is usually specified in units of mGy-cm^2. As an illustration of this concept, consider a patient whose irradiated surface receives an air kerma dose of 0.02 Gy. If the area of the irradiated surface is 100 cm^2, then the DAP will be 20 mGy × 100 cm^2 = 2000 mGy-cm^2 (Mary Alice et al , 2013).

2.11.1 Absorbed Dose

As ionizing radiation passes through an object such as a human body, some of the energy of that radiation is transferred to that biologic material. It is actually absorbed by the body and stays within it. The quantity absorbed dose (D) is defined as the amount of energy per unit mass absorbed by an irradiated object. This absorbed energy is responsible for any biologic damage resulting from exposure of the tissues to radiation (Martin and Sutton, 2015).

For this reason the absorbed dose may be used to indicate the amount of ionizing radiation a patient receives during a diagnostic imaging procedure. Anatomic structures in the body possess different absorption properties; some structures can Absorb more radiant energy than others. The amount of energy absorbed by a structure depends on the atomic number (Z) of the tissues comprising the structure, the mass density of the tissue (measured in kg/m3), and the energy of the incident photon. Absorption increases as atomic number and mass density increase and also as photon energy decreases. Therefore, low-energy photons are more easily absorbed in a material such as biologic tissue than are high-energy photons.

The effective atomic number (Zeff) of a given biologic tissue is a "composite," or weighted average, of the atomic numbers of the many chemical elements comprising the tissue. Bone has a higher effective atomic number (Zeff =13.8) than does soft tissue (Zeff = 7.4) because bone contains calcium (Z = 20) and phosphorus (Z = 15), whereas soft tissue is composed mostly of fat (Zeff = 5.9) and structures with atomic numbers close to that of water (Zeff = 7.4). Bone absorbs more ionizing radiation than soft tissue in the diagnostic energy range of 23 to 150 kilovolts peak (kVp), (which includes mammography), because the photoelectric process for bone is the dominant mode of energy absorption within this range. The probability of photoelectric interaction strongly depends on the atomic number of the irradiated material. The higher the atomic number of the material, the greater is the amount of energy absorbed by that material (Martin and Sutton, 2015).

As stated earlier, the SI unit of absorbed dose is the gray (Csillag and Lengyel), previously defined as an energy absorption of 1 joule (J) per kilogram (kg) of matter in the irradiated object. One gray is therefore determined by the following simple equation:

1Gy=1 J/kg.

A joule may be defined as the work done or energy expended when a force of 1 Newton (N) acts on an object along a distance of 1 meter (m). A single joule does not correspond to a large amount of energy. A typical microwave oven, for example, imparts 750 J/sec to the food it is; heating traditionally, the rad was used as the unit of absorbed dose. One rad is expressed mathematically. As follows: 1rad=100 erg /g or 1 rad= 1/100J/kg=1/100 Gy

Even though the traditional system of units for radiation quantities is gradually being eliminated in favor of the SI units now used to be consistent with scientific groups, the U.S. government, and many other countries and also current textbooks and scientific journals, some individuals may want to understand how to convert from one system to the other in case they need to do so.

As shown earlier, gray and rad units are easily convertible. Appendix A illustrates conversions among the systems of units. Because many x-ray examinations require Relatively small radiation doses, subunits may frequently be used to indicate absorbed dose values (Martin and Sutton, 2015).

Table 2-2. Typical Values for Radiation Doses Associated with an Anteroposterior Lumbar Spine Examination.

Absorbed dose to skin at entrance surface	6.4 mGy
Absorbed dose to bone marrow	0.6 mGy
Absorbed dose to a fetus	3.5 mGy
Equivalent dose to a fetus	3.5 mSv
Effective dose	3.3 mSv

2.11.2 Surface Integral Dose

The surface integral dose (SID) is the total amount of radiant energy transferred by ionizing radiation to the body during a radiation exposure. Historically, it has been also known as exposure area product. This quantity is determined by the product of the exposure value (Parry et al.) and the size of the area (cm2) that receives the total amount of radiation delivered. Thus R-cm^2 is the traditional unit for SID. The equivalent SI unit for SID is the Gy-m2 (Mary Alice et al , 2013).

2.11.3 Equivalent Dose

Equivalent dose (EqD) is the product of the average absorbed dose in a tissue or organ in the human body and its associated radiation weighting factor (Wrixon) chosen for the type and energy of the radiation in question. X-radiation and gamma radiation have a WR of 1, whereby 1 Gy equals 1 Sv. Other types of radiation have different radiation weighting factors.

Stochastic effects are non-threshold, randomly occurring biologic effects of ionizing radiation such as cancer and genetic (hereditary) abnormalities.

These effects can result from relatively low radiation exposure, and it can take a long time before they are demonstrated. The probability of occurrence depends on the radiation dose and the type and energy of the radiation.

What this means is that some radiations are more biologically efficient for causing damage than others for a given dose .The radiation weighting factor (Wrixon) takes this into account. The radiation weighting factors are selected by national and international scientific advisory bodies (NCRP, ICRP 2002) and are based on quality factors and LET. The NCRP, in Report No. 1 16, described the radiation weighting factor as “a dimensionless factor" (a multiplier) that was chosen for radiation protection purposes to account for differences in biologic impact among various types of ionizing radiations. This factor places risks associated with

biologic effects ona common scale. Each type and energy of radiation has a specific radiation weighting factor, the numeric value of which may be found in Table 4-2. The radiation weighting factor actually has the same numeric value as the quality factor that was previously used for determining dose equivalence. EqD is used for radiation protection purposes when a person receives exposure from various types of ionizing radiation. EqD for measuring biologic effects may be determined and expressed in Sieverts or in a subunit of the Sievert (Sprawls P et al 2013).

The Sievert replaces the rem for accounting for differences in biologic effectiveness of various types of ionizing radiations. Equivalent dose is obtained by multiplying the absorbed dose (D) by the radiation weighting factor (Wrixon) as follows:

$$EqD = Ox\ WR$$

Which in terms of units corresponds to?

$$Sv=GyxWR$$

An example of determining and expressing EqD using grays and Sieverts is provided in because radiation doses for radiation workers employed in diagnostic radiology are relatively small, they may be specified in terms of millisieverts. To change Sieverts to millisieverts (McCollough et al., 2008).

2.11.4 Effective Dose

EID provides a measure of the overall risk of exposure to humans from ionizing radiation. The NCRP, in Report No. 116, defines it as "the sum of the weighted equivalent doses for all irradiated tissues or organs."1 EID incorporates both the effect of the type of radiation used (e.g. x-radiation, gamma, neutron) and the variability in radiosensitivity of the specific organ or body part irradiated through the use of appropriate weighting factors. These factors determine the overall harm

to those biologic components and the risk of developing a radiation-induced cancer. The weighting factor that takes into account the relative detriment to each specific organ and tissue is called the tissue weighting factor (Wrixon). The tissue weighting factor is a conceptual (McCollough et al., 2008) .

Measure for the relative risk associated with irradiation of different body tissues.

The tissue weighting factor (Table 4-3), more precisely, is a value that denotes the percentage of the summed stochastic (cancer plus genetic) risk stemming from irradiation of tissue (T) to the all-inclusive risk, when the entire body is irradiated in a uniform fashion. EID accounts for the risk to the entire organism brought on by irradiation of individual tissues and organs. The ICRP originally introduced the tissue weighting factor concept because uniform, whole-body irradiation seldom occurs, and some organs and body tissues vary considerably in the absorbed.

Dose received and their sensitivity to random radiation-induced responses. To determine EID, an absorbed dose (D) is multiplied by a radiation weighting factor (Wrixon) to obtain EqD and that product is multiplied by a tissue weighting factor to give:

$$EfD=D \times WR \times Wr$$

EID is expressed in Sieverts or Millisieverts. An example of determining and expressing EID in Sieverts is provided in Box 4-9. Appendix A provides an example of expressing EID in rem. EID can be used to compare the average amount of radiation received by the entire body from a specific radiologic examination with that from natural background radiation .By using the background equivalent radiation time (BERT) method as Table 4-4 gives some typical values for radiation doses that are associated with a radiographic examination of the lumbar spine, and it illustrates some of the principles of the different ways to specify radiation dose. The dose to the patient is highest at the "entrance skin

surface," the surface of the patient that is toward the x-ray tube. This surface will be exposed to the unattenuated primary beam of x-ray s. Absorbed doses to various organs may be calculated from standard tables. Two organ absorbed doses are given in Table 4-4, namely, bone marrow and fetus. The EqD to the fetus is also given and is the same as the absorbed dose to the fetus because the radiation weighting factor is 1. Finally, the EID is given. It was calculated from the various tissue weighting factors and organ absorbed doses for organs in the field of view of this examination (Mary Alice et al , 2013).

2.11.5 Collective Effective Dose

In addition to EqD and EID, another dosimetric quantity has been derived and implemented for use in radiation protection to describe internal and external dose measurements. The quantity, collective effective dose (Col EID), is used to describe radiation exposure of a population or group from low doses of different sources of ionizing radiation. It is determined as the product of the average EID for an individual belonging to the exposed population or group and the number of persons exposed. The radiation unit for this quantity is person-sievert (previously referred to as man-rem) (Nickoloff et al., 2008).

2.11.6 Total Effective Dose Equivalent

Total effective dose equivalent (TEDE) is a radiation dosimetry quantity that was defined by the Nuclear Regulatory Commission (NRC) to monitor and control human exposure to ionizing radiation. Essentially, as described by NRC regulations, it is the sum of effective dose equivalent from external radiation exposures and a quantity called committed effective dose equivalent (CEDE)" from internal radiation exposures. Thus TEDE is designed to take into account all possible sources of radiation exposure. It is a particularly useful dose monitor for

occupationally exposed personnel such as nuclear medicine technologists and interventional radiologists, who are likely to receive possibly significant radiation exposure during the course of a year (Van Dyk, 2013).

Traditionally, for occupationally exposed personnel, the whole-body TEDE regulatory limit is 0.05 Sv and 0.001 Sv for the general public. Radiation monitoring services such as Landauer, Inc. and Global Dosimetry Solutions can provide annual TEDE values for individuals (Nickoloff et al., 2008).

Table 2.3: SI and Traditional Unit Equivalents

1 SI exposure unit equals	1. $C/kg = \frac{1}{(2.58\times10^{-4})}R$
1 coulomb equals	1. 1 ampere-second
1 coulomb per kilogram of air equals	1. 1 SI unit of exposure 2. $\frac{1}{(2.58\times10^{-4})}R$
1 gray equals	1. 1 J/kg 2. 100 rad 3. 100 cGy 4. 1000 mGy
1 sievert equals	1. 1 J/kg (for x-radiation, Q = 1) 2. 100 rem 3. 100 centisievert (cSv) 4. 1000 mSv
1 erg equals	1. 10^{-7} J
1 joule equals	1. 10^{7} erg 2. 1 newton-meter 3. 6.24×10^{18} eV

2.12 Diagnostic Reference Levels (DRLs) in Medical Imaging

The optimization of patient protection in diagnostic radiology, diagnostic nuclear medicine or image guided interventional procedures requires the application of examination-specific protocols tailored to patient age or size, region of imaging and clinical indication in order to ensure that patient doses are as low as reasonably achievable for the clinical purpose of the examination. Diagnostic reference levels (DRLs) are a practical tool to promote optimization. DRLs were first successfully implemented in relation to conventional radiography in the 1980s and subsequently developed for other modalities in the 1990s. The current International BSS defines DRL as a level used in medical imaging to indicate whether, in routine conditions, the dose to the patient or the amount of radiopharmaceuticals administered in a specified radiological procedure for medical imaging is unusually high or unusually low for that procedure. It is important to recognize that DRLs are a useful tool but only the one step in the overall process of optimization (Van Dyk, 2013).

2.11.1 Dose Reference Levels in Medical Imaging

Surveys of dose estimates from different imaging modalities highlight the substantial variations in dose between some healthcare facilities for same examination or procedure and similar patient group (adults or children of defined sizes). Such observations indicate the need for standardization of dose and reduction in variation in dose without compromising the clinical purpose of each examination or procedure. Examination-specific or procedure-specific DRLs for various patient groups can provide the stimulus for monitoring practice to promote improvements in patient protection (Nickoloff et al., 2008).

2.11.2 The purpose of DRLs.

DRLs should be set for representative examinations or procedures performed in the local area, country or region where they are applied. National DRLs (NDRLs) should be set on the basis of wide scale surveys of the median doses representing typical practice for a patient group (e.g. adults or children of different sizes) at a range of representative healthcare facilities for a specific type of examination or procedure. NDRLs are commonly set at the third quartile values (the values that splits off the highest 25% of data from the remaining 75%) of these national distributions [IPEM, 2004]. As such, NDRLs are not optimum doses, but nevertheless they are helpful in identifying potentially unusual practice (healthcare facilities where median doses are among the highest 25% of the national dose distribution). DRLs can be also established for a region within the country or, in some cases, regions of several countries. They can also be used to set updated values for new technologies that may allow lower dose levels to be achieved. Where no national or regional DRLs are available, DRLs can be set based on local dosimetry or practice data, or can be based on published values that are appropriate for the local circumstances (Liang et al., 2017).

2.11.3 The Setting of DRLs

DRLs should be set for representative examinations or procedures performed in the local area, country or region where they are applied. National DRLs (NDRLs) should be set on the basis of wide scale surveys of the median doses representing typical practice for a patient group (e.g. adults or children of different sizes) at a range of representative healthcare facilities for a specific type of examination or procedure. NDRLs are commonly set at the third quartile values (the values that splits off the highest 25% of data from the remaining 75%) of these national distributions [IPEM, 2004]. As such, NDRLs are not optimum doses, but nevertheless they are helpful in identifying potentially unusual practice (healthcare

facilities where median doses are among the highest 25% of the national dose distribution). DRLs can be also established for a region within the country or, in some cases, regions of several countries. They can also be used to set updated values for new technologies that may allow lower dose levels to be achieved. Where no national or regional DRLs are available, DRLs can be set based on local dosimetry or practice data, or can be based on published values that are appropriate for the local circumstances (Thomas et al., 2015).

2.11.4 Responsible for setting and updating DRLs

The government has a responsibility to ensure that DRLs are established for the country [Requirement 34, GSR Part 3, 2014]. The processes and steps towards establishing DRLs are likely to involve many players, including the imaging facilities, the health authority, the professional bodies, and the regulatory body. In particular there should be collective 'ownership' of the DRLs in deciding on what procedures and what size groups will be used, how the data will be collected, who will manage the data, and when the DRLs should be reviewed and updated. In some countries, a national governmental body administers the national patient dose database that underpins the establishing of DRLs. In other countries, this role may be taken by the regulatory body or a professional body. There is no preferred custodian: what is important is that a patient dose database (for DRLs) is established and maintained, DRL values are set, these are promulgated through the regulatory processes, and a process for periodic review is established. It may be more appropriate to take a regional rather than a national approach to DRLs (Thomas et al., 2015).

2.11.5 Dose quantities are used for setting DRLs.

DRLs should be set in terms of the practical dose quantities used to monitor practice. These dose metrics should be easily measurable. The following are

commonly used terms (Martin, 2001). For radiography, air kerma-area product (PKA) and entrance surface air kerma (Ka,e) are recommended DRL quantities.

For fluoroscopy and interventional radiology procedures, air kerma-area product (PKA) is the recommended primary DRL quantity. Air kerma at patient entrance reference point (Ka,r), fluoroscopy time and number of images are recommended as useful additional DRL quantities (a multiple DRL).

For CT, volume computed tomography dose index (CTDIvol) and dose length product (DLP) are recommended quantities.

For mammography and breast tomosynthesis, the recommended DRL quantity is one or more of incident air kerma (Ka,i), entrance surface air kerma (Ka,e), or mean glandular dose (Vanderpump and Tunbridge), with the choice of quantity depending on local practices.

For dental intra-oral radiography, the recommended quantity is incident air kerma (Ka,i), and PKA for dental panoramic radiography.

For nuclear medicine, DRLs are set in activity administered to patient, and/or in administered activity per kg of body mass (Taylor, 2002).

These quantities are not patient doses that can allow estimation of risk to individuals, but are dose indicators characterizing radiation exposure for the purposes of comparison of practice. There is no merit in setting DRLs in terms of other dose quantities, such as effective dose, that are derived from the well-defined monitoring quantities by coefficients that could vary depending on the particular dose model adopted (Taylor, 2002).

2.11.6 Examinations should have DRLs.

DRLs are intended to promote improvements in patient protection by allowing comparison of current practice. National and local DRLs should (ideally) be set for each examination or procedure, for each clinical indication and each patient group

(adults and children of defined sizes). The examinations or procedures included should represent at least the most frequent examinations performed in the region for which dose assessment is practicable, with priority given to those that result in the highest patient radiation dose. In order to allow meaningful comparison of truly similar examinations or procedures conducted for similar purpose and requiring similar technique, it is crucial to specify detailed descriptions of the examination or procedure, including a clinical indication (such as CT abdomen in relation to liver metastases), rather than simply broad categories of examination or procedure (such as CT abdomen). This usefully allows the comparison of 'apples with apples' rather than a mixed bag of fruit. For interventional practices the complexity of the procedures should be taken into account (Nickoloff et al., 2008).

2.11.7 The effectiveness of DRLs in improving patient radiation protection:

DRLs have already proved useful as a tool in support of dose audit and practice review for promoting improvements in patient protection. Their application since 1989 in the UK within a coherent framework for managing patient dose has been instrumental in promoting increased awareness of dose and helping to reduce unnecessary x-ray exposure. UK national DRLs for conventional X-ray examinations on adult patients, for example, have typically fallen by a factor of two over the last 20 years owing to improvements in imaging practice (Nickoloff et al., 2008).

Table 2.4: Notational Diagnostic Reference Levels (NDRLs)

X-ray Projection	Notational Diagnostic Reference Levels (NDRLs)					
	NRPB2000		IAEA1996		EU 1996	
	AP	LAT	AP	LAT	AP	LAT
SKULL	4	2	5	3	5	3
CHEST	0.2	0.7	0.4	1.5	0.3	1.4
ABDOMEN	7		10		10	
LUMBER	7	20	10	30	10	30
PELVIS	5		10		10	

2.11.8 Ray Safe Detector Principles

2.11.8.1 R/F Measurement

For best accuracy, center the selected sensor field (R/F low or R/F high) and position the long axis of the sensor field perpendicular to the anode-cathode axis of the tube.

2.11.8.2 *Sensor Menu*

- R/F low sensor for conventional low dose rate measurements lower than 1 mGy/s (7 r/min), normally after a phantom.
- R/F high sensor for conventional high dose rate measurements higher than 1 mGy/s (7 r/min), normally before a phantom.

2.11.8.3 Measure Mode

The displayed values are updated after each exposure, or continuously after 4 seconds of fluoroscopy.

kVp (for the R/F high sensor at adequate signal levels) or kV Dose Gy (air kerma, free in air) or *r* (exposure) Dose rate Gy or *r* per second, *m* or *h* Time ms, HVL mm Aluminum Total Filtration (TF mm).

Fig.2.1: Ray safe Xi R/F sensor

2.11.8.4 Setup Menu

Press SELECTS to enter the SETUP MENU (from MEASURE MODE) and STEP to step between setup parameters. All values are stored in a non-volatile memory and are valid until manually changed. At start up (after the battery status information), valid trig delay, kVp delay and Calc. delay are displayed in sequence.

Trig delay a delay in ms after the normal trig of the Ray Safe Xi Detector, utilize when an unwanted part of an exposure, such as a pre-pulse, should be excluded from the measurement.

No measurements are performed during the trig delay. (0, 5, 10, 50, 100, 200, 500, 1000, 2000 ms) Trig level use trig level to measure correct exposure time on waveforms with slowly increasing output, such as with single phase dental. The default setting is a low value that depends on the selected sensor; see specifications. Can be set to (25, 50 or 75 %) of the peak value of the previous exposure. kVp delay defined as the delay in ms, after the trig delay, but before the kVp measurement (and waveform) window begins. Use a kVp delay on machines with slow rising output, such as single phase intra oral machines and fluoroscopy

systems. (0, 2, 5, 10, 50, 150, 300, 1000, 1200, 1500, 1700, 2000 ms) Calc. delay defined as the dead time after end trig, before data is calculated. Default is 0.5 s but it is recommended to use a longer delay when measuring on pulsed fluoroscopy where the time between pulses may exceed 0.5 s. (0.5, 2, 4, 6, 7 s)

2.11.8.5 Keys on the Ray Safe Xi Detector Base unit

ON/OFF: turns on the Ray Safe Xi Detector and off when in

SENSOR MENU.

EXIT: exit to the previous menu.

STEP: a short press steps through available options.

SELECT: a long press selects an option.

Figure 2.2: Keys on the ray safe Xi Base unit

2.10.8. 5 R/F Measurement Technique Procedures

The ray safe Xi base unit automatically identifies the connected detector and displays the settings and parameters available for that detector. The built-in active compensation automatically applies corrections for different beam qualities, filtrations and temperatures. During fluoroscopy, survey or light measurements the displayed values are continuously updated.

- Connect a Ray Safe Xi detector of your choice to the ray safe Xi base unit with one of the two (2 and 10 m) ray safe Xi cables. (Figur3.6)

- Center the selected sensor field (R/F low or R/F high) and position the long axis of the sensor field perpendicular to the anode-cathode axis of the tube. (Figure 3.7)
- Position as required for the selected sensor.
- Turn on the Ray Safe Xi Detector (ON/OFF key, see below), and the instrument specific setup information is displayed. In the SENSOR MENU a detector or sensor field for your application can be selected.
- The Ray Safe Xi Detector is now in MEASURE MODE and ready to measure. Press STEP to scroll through measured parameters (also possible during fluoroscopy). The last three displayed parameters will automatically show up after the next exposure. To change setup values (SETUP MENU) such as various delays, displayed units and other choices, press SELECT.

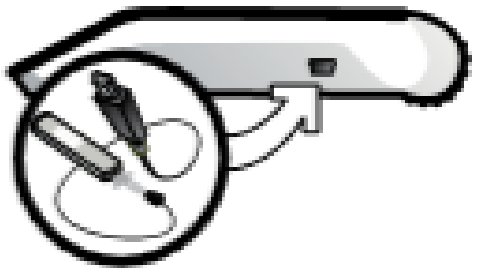

Figure 2.3: Connecting a Ray Safe Xi detector to the ray safe Xi base unit

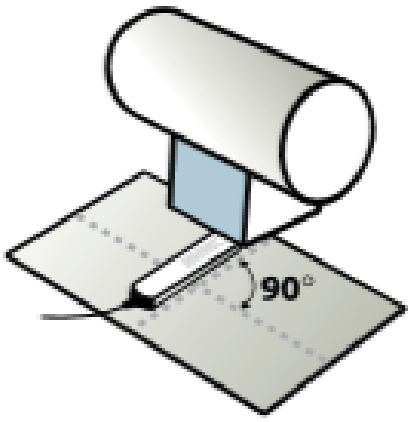

Figure 2.4: Center the selected sensor field (R/F low or R/F high) and position the long axis of the sensor field perpendicular to the anode-cathode axis of the tube.

Chapter Three

Materials and Method

3.1 Materials

3.1.1 Subjects

This is a survey study conducted in radiological departments ten Governmental & militarily Hospitals in Sudan including Khartoum Teaching hospital, Bahari Teaching Hospital, Omdurman Teaching Hospital, Omdurman Military Hospital, Alnaw Hospital, Ibrahim Malik Teaching Hospital, Al-Maknimir Teaching Hospital, Shandi General Hospital, Wad Madani Teaching Hospital and Wad Madani Military Hospital. ESD per examination was estimated from X-ray tube output parameters in ten hospitals comprising ten rooms and a sample of five most common X-ray examinations with 6 basic views and a total of 60 projections.

The study was carried out over duration of two years from September 2015 to June 2017, all protocols done in hospital after oral agreement from Head departments of radiology.

3.1.2 Dosimeter

Ray Safe XI R/F detector was used, it consists of a base unit and several different external detectors measuring: radiography/ fluoroscopy (R/F), mammography, Computed tomography, ambient and emitted light (Light) and scattered or low level radiation (Survey). Communication between detector and base unit is purely digital, thereby minimizing sensitivity to mechanical or electrical stress. The base unit may also be equipped with an optional integrated tube current meter (mA/mAs).

Figure 3-1: Ray Safe Xi detector Base unit

3.2 Method

3.2.1 Dosimeter method

Ray Safe XI R/F detector is used as dosimeter tool positioned in the central beam axis of X-ray tube with the focal spot-detector distance of 100 cm and its long axis was positioned perpendicular to the anode-cathode axis of the tube.

A radiographic exposure was made and the dosimeter reading recorded, this step was repeated three times at the same settings and the average dosimeter reading determined. The Ray safe Xi R/F detector is capable of measuring kVp, dose, dose rate, pulse, pulse rate, dose/frame, time, HVL, total filtration and waveforms simultaneously.

For the following seven radiographic examinations; skull (AP, LAT), chest (PA), abdomen (AP), lumbar spines (Kidwell et al.) and pelvis (AP), the DRLs were measured.

3.2.2 Data Analysis

Data were analyzed using SPSS version 16, significant tests like T test, frequencies, regression and correlation were applied.

Chapter Four

Results

Table 4.1: Descriptive of distributed the exposure parameters (kVp) from ten hospitals

ROUTINE EXAM	**SKUL**		**CHEST**	**ABDOMEN**	**LUMBAR**	**PELVIS**
PROJECTION	AP	LAT	PA	AP	LAT	AP
Mean	73.39	66.97	76.70	75.29	88.65	76.26
Std. Deviation	4.30	5.08	11.90	6.12	7.66	4.65
Range	12.25	15.00	28.60	21.08	28.15	15.45
Minimum	68.00	62.00	67.60	69.15	68.10	68.25
Maximum	80.25	77.00	96.20	90.23	96.25	83.70
3rd Quartile	77.30	71.00	76.70	78.54	95.02	79.23

Table 4.2: Descriptive of distributed X-ray tube exposure parameters (mAs) from ten hospitals

ROUTINE EXAM	**SKUL**		**CHEST**	**ABDOMEN**	**LUMBAR**	**PELVIS**
PROJECTION	AP	LAT	PA	AP	LAT	AP
Mean	25.7	21.1	29.2	33.6	49.3	37.0
Std. Deviation	11.5	7.6	19.2	15.3	10.3	11.6
Variance	131.1	57.5	368.9	232.9	105.7	134.5
Range	37.1	24.1	32.0	42.8	34.1	33.9
Minimum	8.0	16.0	16.1	12.4	32.0	15.2
Maximum	45.1	40.1	48.1	55.1	66.1	49.1
3rd Quartile	38.1	20.2	44.4	48.1	56.1	46.1

Table 4.3: The distribution of ESD for five routine X-ray examinations (six projections) from ten hospitals

ROUTINE EXAM	SKUL		CHEST	ABDOMEN	LUMBAR	PELVIS
PROJECTION	AP	LAT	PA	AP	LAT	AP
Mean	5.4	5.6	2.7	8.5	16.7	6.9
Median	5.1	5.2	3.2	8.2	16.3	6.7
Std. Deviation	1.0	1.1	2.0	0.7	1.4	1.0
Variance	1.0	1.1	4.1	0.4	1.9	1.1
Range	3.0	3.0	2.1	2.1	4.1	3.1
Minimum	4.2	4.2	3.1	7.2	15.2	5.2
Maximum	7.2	7.2	3.2	9.3	19.3	8.3
3rd Quartile	6.0	7.1	0.9	9.2	18.3	8.1

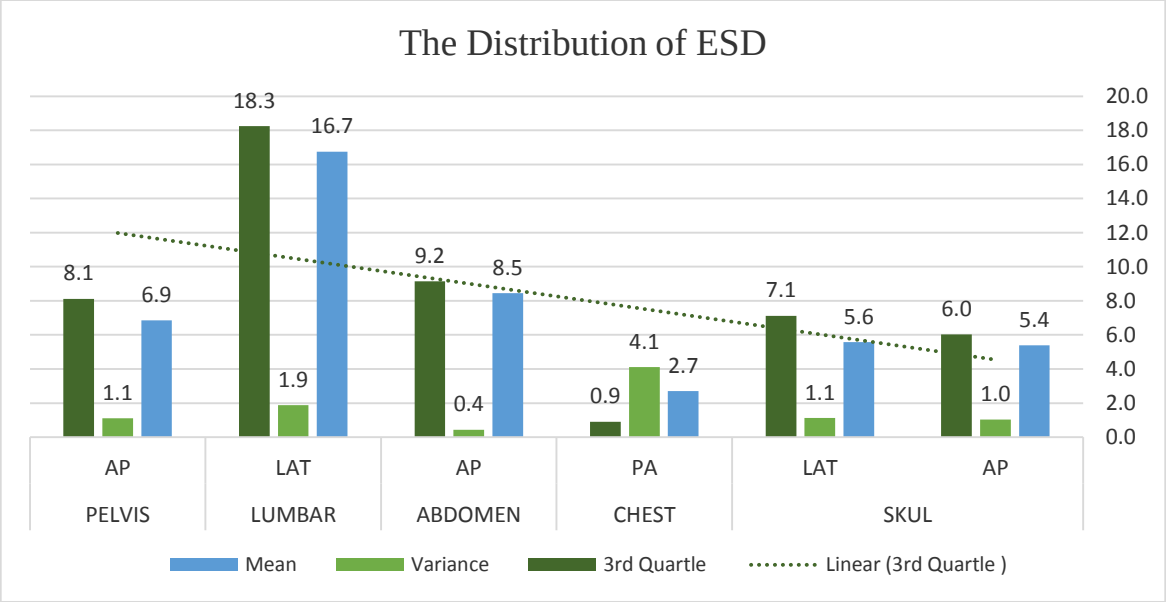

Figure 4.1: The distribution of ESD for five routine X- ray examinations (six projections) from ten hospitals

Table 4.4: The distribution of ESD for five routine X- ray examinations (six projections) Proposed DRL expressed in third quartile of the mean ESD in Sudan.

Proposed DRR	**SKUL**		**CHEST**	**ABDOMEN**	**LUMBAR**	**PELVIS**
PROJECTION	AP	LAT	PA	AP	LAT	AP
NRPB2000	4	2	0.2	7	20	5
Mean	5.4	5.6	2.7	8.5	16.7	6.9
3rd Quartile	6	7.1	0.9	9.2	18.3	8.1

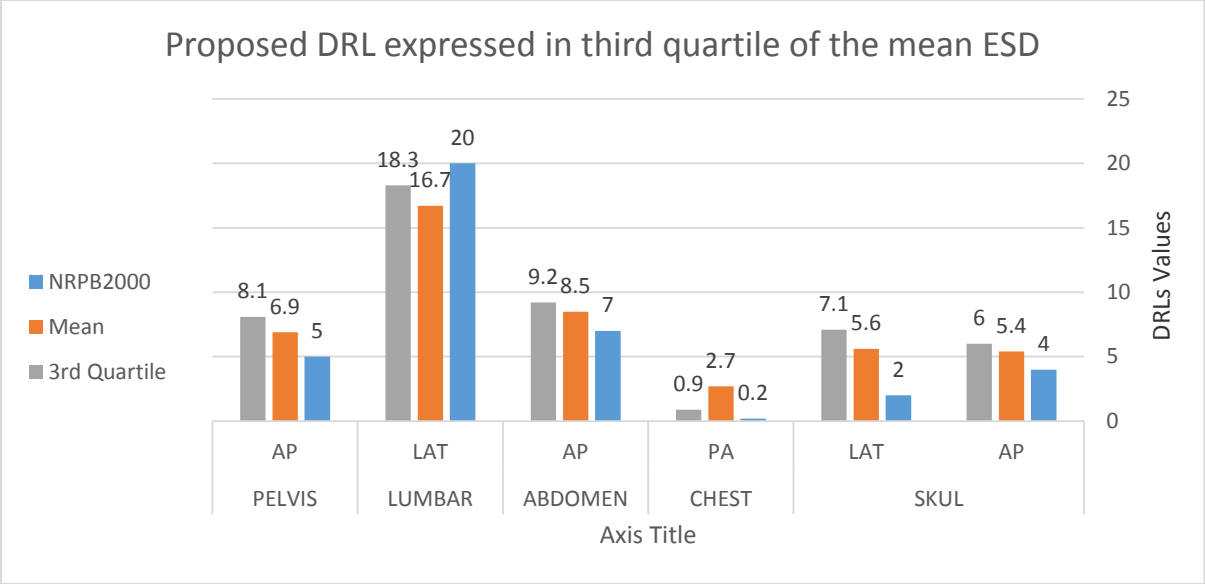

Figure 4.2: The distribution of ESD for five routine X- ray examinations (six projections) Proposed DRL expressed in third quartile of the mean ESD in Sudan:

Table 4.5: The distributing of variation between national DRLs (NRPB) & proposed DRLs expressed in the third quartile of the mean entrance surface dose ESD (mGy):

Proposed DRR	SKUL		CHEST	ABDOMEN	LUMBAR	PELVIS
PROJECTION	AP	LAT	PA	AP	LAT	AP
NRPB2000	4	2	0.2	7	20	5
Mean	5.4	5.6	2.7	8.5	16.7	6.9
Proposed DRL.3rd Quartile	6	7.1	0.9	9.2	18.3	8.1
Variance	2	5.1	0.7	2.2	-1.7	3.1
Percent	50%	255%	350%	31%	-9%	62%

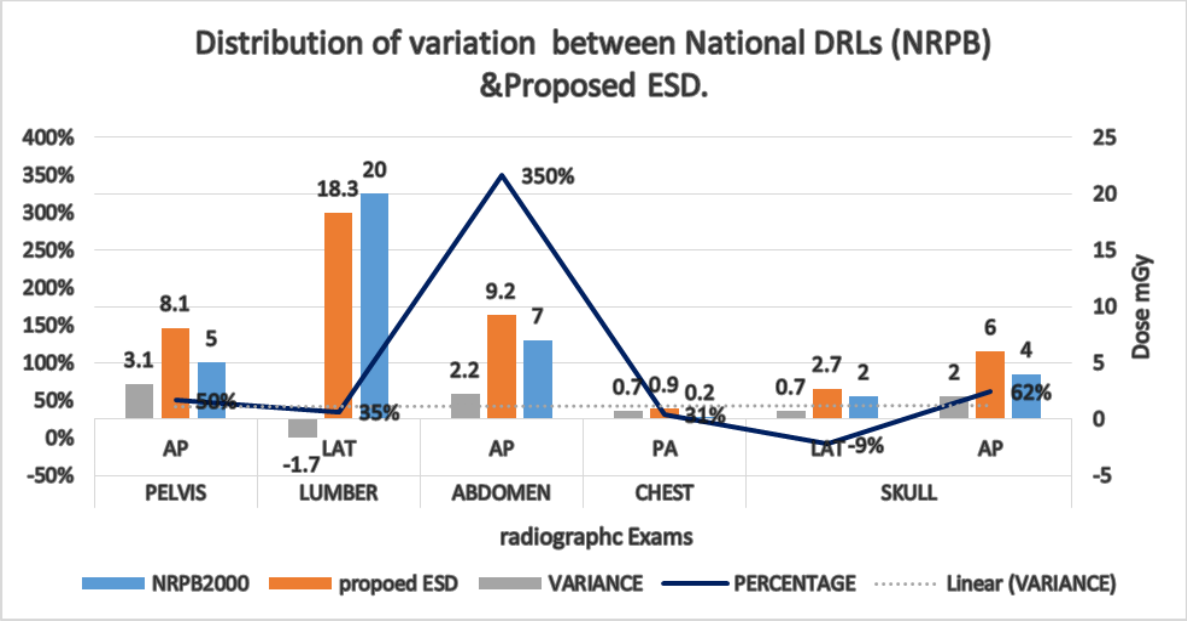

Figure 4.3: The distributing of variation between national DRLs (NRPB) & Proposed DRLs expressed in the third quartile of the mean entrance surface dose ESD (mGy)

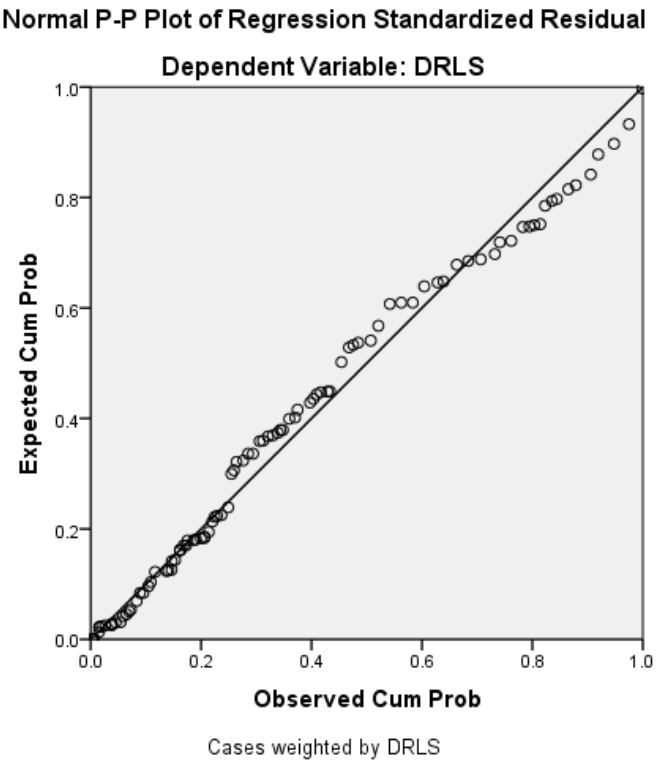

Figure 4.4: The distributing Normal P.P Plot of Regression Standardized Residual.

CHAPTER FIVE

Discussion, Conclusion & Recommendation

5.1 Discussion

The development of the DRL practice of diagnostic radiology in Sudan is still at an early stage as no national surveys have been carried out for any radiological examinations for the express purpose of establishing national DRL except a few studies done by (KhiarA et al., 2016). At a local level, various organizations, regulatory authorities and individual practices have carried out limited at general radiography, fluoroscopy and CT surveys.

The results of this study provide valuable information about the patient dose in Sudan. The wide variations in the patient dose levels, even in the same examination carried out by different radiographers are mainly due to the choice of different exposure setting, focus to film distance and finally output of the X-ray units (Brenda Rinehart, 2011).

There are data from a sufficient Number of hospitals (or X-ray rooms) to set reference doses that are more representative of national practice for a much larger selection of examinations than was possible previously.

The ESD doses were compared with reference level values recommended by the IAEA, It is found that the measured values were greater than recommended values for the most X-ray unit, because the QA program in diagnostic radiology were not conducted in Sudanese hospital periodically by (r^2=.875.P= 0.005).

There is a clear need to manage (optimize) the radiation doses from diagnostic radiology in order to minimize the risks of radiation induced cancers. The establishment and use of DRL is recommended by international radiation protection organizations as an important component of the management of these

doses and many countries have incorporated them into their radiation Protection regulations (Clement, 2014).

From the given result of this study it was noticed that the descriptive statistics of X-ray tube exposure parameters (table: 4:1&4:2) from ten hospitals in Sudan which represents the mean value, minimum, maximum, mean, standard deviation and third quartile for each examination done in this survey, there was significant gap between the applied input exposure parameters and measured output exposure parameters.

(P value =0.005). This reflects the wide variations in each projection. It is also apparent that, variation between the minimum and the maximum too big compared with standard values.

The third quartile in each hospital can be used to assess the local DRL. As it was seen from the given results, a total ten major hospital radiological department were assessed by estimating entrance surface dose (ESD) for six radiographic examinations projections including: skull (AP, LAT), chest (PA, LAT), abdomen (AP), lumbar spines and pelvis (AP) exam. The assessed DRLs values were compared with (DRLs) in the world especially (NRPB) The descriptive parameters such as, 1st quartile, mean, median, 3rd quartile, minimum, maximum and standard deviation of each DRL values are reported and compared to (NRPB et al 2000) guide levels. The results obtained considering the value of third quartile in mGy were, 6.0 for the skull (AP), 7.1 for the skull (Kidwell et al.2015), 0.9 for chest (PA), 9.2 for abdomen (AP), 18.3 for lumbar spines and 8.1 for pelvis (AP). With exception of LAT lumbar spine in all hospitals, all values were greater than those reported by guideline levels (NRPB et al 2000) .

The result of the study also showed that the distributing of variation between national DRLs (NRPB) &Proposed DRLs expressed in percentage were greater than national guideline levels DRLs (NRPB et al 2000), skull AP is (≥50%), skull

LAT is (≥35%), chest PA is (≥350%), abdomen AP is (≥31%), pelvis (AP) except lumbar spines LAT is lesser than national guideline levels DRLs (NRPB et al 2000) is (≤-9%).

In this study The large variations in ESD values indicate that there is significant correlation between increasing exposure factors (kVp, mAs), this lead of greater gap and variation in proposed DRLs, other reasons caused the greater variation in ESD like The technique adopted in each hospital has led to identification of great variations in ESD for the same procedure, rarely equipment calibration, inadequate processing environment, did not use the anti-scatter grid, which made the dose several times lower and Tube specifications were also included, i.e. filtrations. Equipment calibration and automatic Exposure Control was not used (KhiarA et al., 2016) and agree with the study the variation of significant difference of diagnostic Reference Levels in Sudan comparison with NDRLs,

5.2 Conclusion

- Local baseline data of doses for some conventional radiological examination were established.
- Calibration and quality control test should be periodically handled and of total should periodically handle and of total need in radiology departments.
- Radiation Protection culture is very for X ray users.

5.3 Recommendation

- This study has recommended that X-ray images must meet a certain level of quality, to minimize errors of interpretation and allowing an accurate diagnosis with low radiation dose
- Periodic quality control testing and monitoring the technical performance of radiographers might effectively improve the image quality and reducing the dose to patients
- Radiation protection centers in the Sudan should be equipped with recent RraySafe XI R/F detector. In that case some of the data could be collected using this method.
- It is recommended that local dose surveys be performed annually while national surveys every five years DRL would therefore serve as an important means of minimizing radiation doses as well as dose variations at minimal cost to radiology departments.
- They also increase staff awareness and imaging technologists will be better equipped to deal with patient enquiries.
- The data collected during the investigations could be important as a useful baseline for future patient dose measurements in the field of the medical diagnostic radiology.

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