(والله أخرجكم من بطون امهاتكم لا تعلمون شيئًا" وجعل

لكم السمع والأبصار والأفئدة لعلكم تشكرون)

صدق الله العظيم
سورة النحل الآية

Dedication

This work is dedicated to my parents, brothers and sisters,

To my teachers,

To my friends,

And colleagues

Acknowledgements

My acknowledgements and gratefulness at the beginning and at last is to God who gave us the gift of the mind.

My gratitude is extended to my supervisor **Dr. Ahmed Mostafa Abukonna** for his support and guidance, without his help this work could not have been accomplished.

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Finally, my profound thanks and gratitude to everyone who encouraged me to complete this thesis.

ABSTRACT

In intensive care unit the patient checked with x ray periodically, the radiation protection procedures will be applied perfectly. However patients and their neighboring ones will receive radiation dose. This study aims to evaluate the received dose by staff and adjacent patient during mobile procedures in intensive care unit.

Radiation dose was measured for three months with thermoluminescent dosimeters (TLD); which was given to each of the two resident nurses; they were handed over to the next team during shift changeover. In addition, and one TLD was placed in the bed of adjacent patient who was not examined. One TLD was kept in the doctors' duty room which was within the premises of the ICU. Thus, a total of four TLDs were used in the study.

The result of the study revealed that the dose received by nurses, adjacent patient and resident doctor was 0.045(mSv), 0.069(mSv) and 0.022 (mSv) respectively. It found that if standard safety precautions were followed, cumulative radiation exposure to ICU resident doctor, nurses and adjacent patient was well within permissible limits and was not the cause of concern and hence routine personal dosimetric monitoring is not needed for residents in ICU. However, in view of changing practice, there is a need to repeat such audits periodically to monitor radiation exposure.

ملخص الدراسة:

في وحدة العناية المركزة يتم فحص المريض بالأشعة السينية بشكل دوري، في هذه الحالة يجب تطبيق إجراءات الحماية من الإشعاع. ومع ذلك فان المريض المجاور له سيحصل علي جرعة من الاشعاع. تهدف هذه الدراسة إلى تقييم الجرعة التي يتلقاها العاملون والمريض المجاور خلال إجراءات فحص بالاشعة النقالة في وحدة العناية المركزة

؛ الذي كان(TLD) تم قياس جرعة الإشعاع لمدة ثلاثة أشهرباستخدام مقياس الجرعة الحراري الضوئي يوضع لكل من المرضتين ؛ بحيث يتم تسليمه للفريق القادم للمناوبة. وبالإضافة إلى ذلك، وضع كاشف واحد في سرير المريض المجاور، وكاشف واحد في غرفة الطبيب المناوب داخل مبنى وحدة العناية المركزة. وهكذا تم استخدام ما مجموعه أربعة في هذه الدراسة

وكشفت نتائج الدراسة أن الجرعة من قبل المرضات، والمريض المجاور والطبيب المقيم كانت 0.045 (ملي سيفرت)، 0.069 (ملي سيفرت) و 0.022 (ملي سيفرت) على التوالي. وجد أنه إذا تم اتباع احتياطات السلامة ، فان التعرض للإشعاع التراكمي للطبيب المقيم في وحدة العناية المركزة والمرضات والمريض المجاور في نطاق الحدود المسموح بها. فلا داعي للقلق ومراقبة قياس الجرعات الشخصية في وحدة العناية المركزة. ومع ذلك، نظرا لتغيير الواقع، هناك حاجة إلى تكرار مثل هذه المراجعات بشكل دوري لمراقبة التعرض للإشعاع.

Contents

Chapter One
INTRODUCTION

1.1 Introduction:

Diagnostic X-rays are used so extensively in medicine that they represent by far the largest man-made source of public exposure to ionizing radiation. Each year, Thousands of diagnostic x-ray procedures are performed in Sudan. Although radiation exposure connected with these procedures cannot be avoided, there are means to reduce it as much as possible. Patient radiation dose from conventional radiographic procedures ranges from 0.1 mSv to 10 mSv, resulting in a collective dose to the population that can be significant (Suliman et al., 2007). In addition the cell proliferation is adversely affected by doses within the range of some radiological examinations (Ludlow et al., 2008). Also the DNA double-strand breaks DSBs induced in cultures of non-dividing primary human fibroblasts by very low radiation doses remain unrepaired for many days, in strong contrast to efficient DSB repair that is observed at higher doses. Today, Quality and safety have become hallmarks for efficient and successful of any medical procedure. The establishment of the Quality Criteria for Diagnostic Radiology Images started in 1984 when the first Directive on.

The International Commission of Radiological Protection (ICRP) introduced the term dose reference level “DRL” for the first time in 1996. Specifying that it is advisory, set by professional bodies, apply dose to patients or intake of pharmaceutical, and call for local review if consistently exceeded (Frayre et al., 2012).

Johnston (Ireland) emphasized the importance of each country establishing its own reference dose levels that are appropriate to their own radiographic techniques and practices in order to optimize patient protection. Entrance Skin Dose ESD is the easily measurable quantity for establishing DRLs. Thermo luminescent dosimeters (TLDs) and ionization chambers are the commonly used dosimeters for estimating ESDs for patients during radiographic examinations (Onai et al., 1978).

Entrance skin dose (ESD) is an important parameter in assessing the dose received by a patient in a single radiographic exposure. The European Union has identified this physical quantity as one to be monitored as a diagnostic reference level in the hopes of optimizing patient dose (Onai et al., 1978).

The performance of radiography in the Intensive Care Unit (ICU) may be associated with a certain level of radiation exposure for staff and patients in the unit. Little evidence on exposure levels is available in the literature. However, healthcare professionals in the ICUs at our centre tend to leave the room during radiographic examinations, potentially compromising patient care.

In intensive care unit the patient checked with x ray periodically, the radiation protection procedures will be applied perfectly. However patients and their neighboring ones will receive radiation dose. This study aims to evaluate the received dose by staff and adjacent patient during mobile procedures in intensive care unit.

1.2 Problem of the study

While filming the patient by X-ray device sometimes problems occur such as the adjacent patients expose to high radiation doses not comply with the standard of radiation protection that may lead to future problems.

1.3 Objectives

1.3.1 General objective:

The objective of this research was to estimate the effective dose during chest examination in the intensive care unit.

1.3.2 Specific objectives:

1. To optimize the exposure factors those give good image quality and do not exceed the limited radiation dose.
2. To estimate the received dose by nurse, adjacent patient on different radiologic techniques used in mobile examination in the intensive care unit.
3. To compare the estimated dose with published works and internationally established diagnostic reference levels.

1.4 Thesis layout:

This study contains five chapters, chapter one contains introduction and objectives of the study. Chapter two contains literature review, chapter three contains material and method, chapter four contains results and in chapter five includes discussion, conclusion and recommendations.

Chapter Two

2. Literature review

2.1 Properties of x ray:

X-ray photons carry enough energy to ionize atoms and disrupt molecular bonds. This makes it a type of ionizing radiation, and therefore harmful to living tissue. A very high radiation dose over a short amount of time causes radiation sickness, while lower doses can give an increased risk of cancer. In medical imaging this increased cancer risk is generally greatly outweighed by the benefits of the examination. The ionizing capability of X-rays can be utilized in cancer treatment to kill malignant cells using radiation therapy (Streffer et al., 2003).

Hard X-rays can traverse relatively thick objects without being much absorbed or scattered. For this reason, X-rays are widely used to image the inside of visually opaque objects.The penetration depth varies with several orders of magnitude over the X-ray spectrum. This allows the photon energy to be adjusted for the application so as to give sufficient transmission through the object and at the same time good contrast in the image (Streffer et al., 2003) .

2.2 Interaction with matter:

X-rays interact with matter in three main ways, through photo absorption, Compton scattering, and Rayleigh scattering. The strength of these interactions depends on the energy of the X-rays and the elemental composition of the material. Photoelectric absorption is the dominant interaction mechanism in the soft X-ray regime and for the lower hard X-ray energies. At higher energies, Compton scattering dominates (Christner et al., 2010).

2.3 Photoelectric absorption:

A photo absorbed photon transfers all its energy to the electron with which it interacts, thus ionizing the atom to which the electron was bound and producing a photoelectron that is likely to ionize more atoms in its path. An outer electron will fill the vacant electron position and produce either a characteristic photon or an Auger electron. The probability of a photoelectric absorption per unit mass is approximately proportional to Z^3/E^3, where Z is the atomic number and E is the energy of the incident photon (Geijer, 2002)

2.4 Computed radiograph:

The CR is a marketing term for photostimulable phosphor detector (PSP) systems. The phosphors used in CR imaging plates are usually europium doped barium fluorohalides, for example, BaFBr and BaFI. During x-ray exposure to the imaging plate, electrons are excited from the valence band to the conduction band, and some of these are trapped in the F-centers. After x-ray exposure, the latent image exists as a spatially dependent distribution of electrons trapped in high-energy states. During readout, laser light is used to stimulate the trapped electrons back up to the conduction band, where they are free to transition to the valence band so blue-green light is emitted; the light intensity emitted by the imaging plate is proportional to the absorbed x-ray energy.

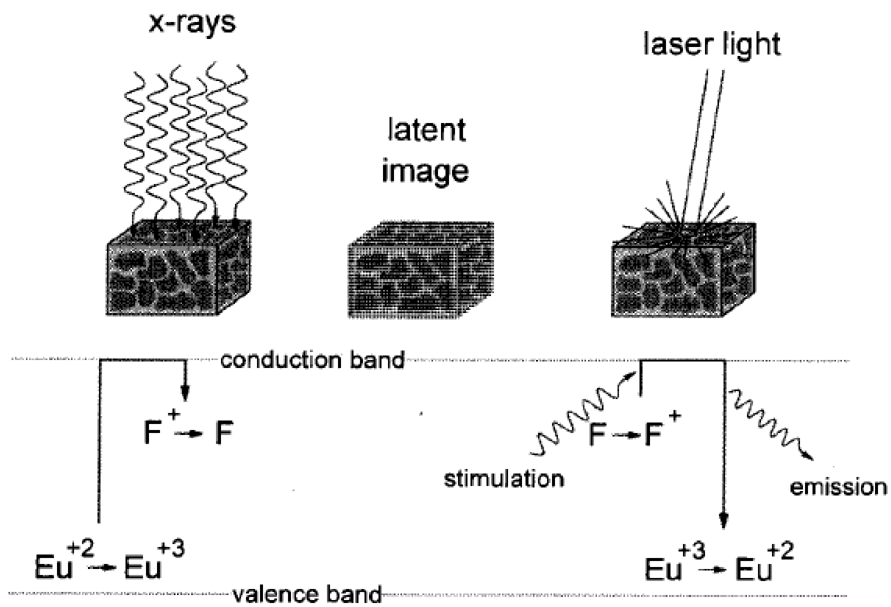

Figure (2.1): this figure illustrates the sequence of events during the x-ray exposure and readout of a photostimulable phosphor.

The blue-green photostimulated luminescence signal is collected by a light guide, which eventually feeds the signal to a photomultiplier tube (PMT). The PMT signal is then digitized to form the image on a point-by-point basis. The digital image that is generated by the CR reader is stored temporarily on a local hard disk. Many CR systems are joined directly to laser printers that make film hard copies of the digital images.

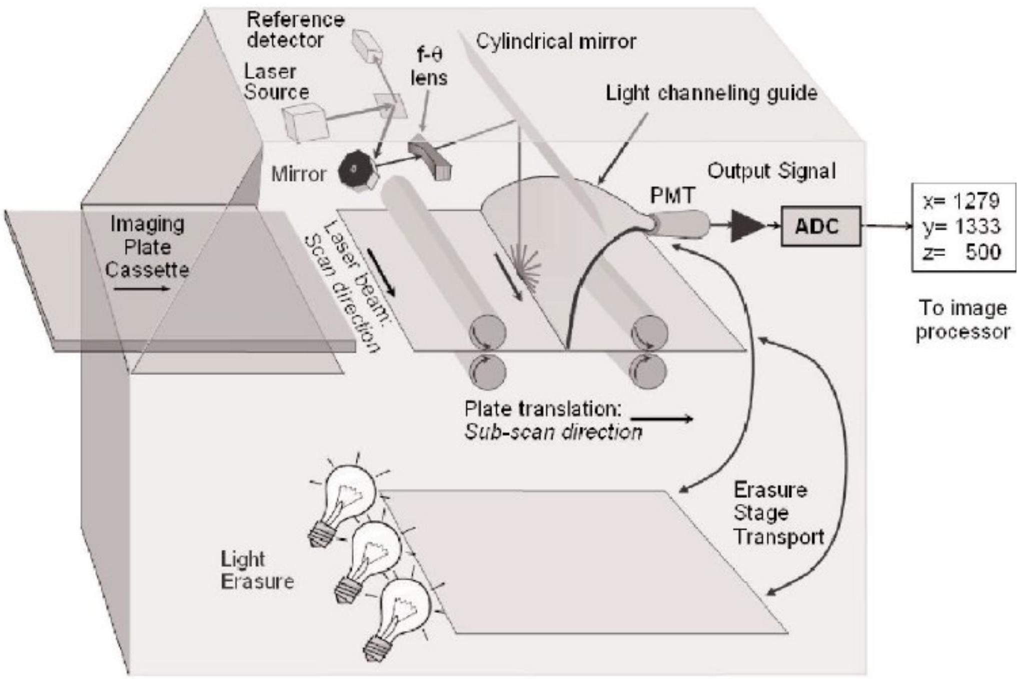

Figure (2.2): a representation of the CR imaging plate reading process workflow

2.5 Direct Digital Radiography:

Direct digital radiography does away with the read out process by providing for instantaneous display of images. In digital radiography, the digitization of the X-ray projection image occurs within the image receptor. Detectors in digital radiography can be in the form of charged coupled devices (CCD) or flat panel imagers (FPI). Furthermore FPIs are generally of two types namely, direct detection or indirect detection flat panel imager (Watt et al., 2005).

2.6 The biological effects of ionizing radiation:

The biological effects of ionizing radiation can be grouped into two kinds: deterministic effects (tissue reaction) and stochastic effects (cancer and heredity effects).

2.6.1 Deterministic effects (tissue reaction):

Deterministic effects are largely caused by the death or radiation-induced reproductive sterilization of large numbers of cells. This is not expressed clinically until these cells unsuccessfully attempt division or differentiation. The severity of the effect varies with radiation dose. A dose threshold usually exists. The threshold dose is subject to biologic variation (Thomas et al., 2002).

2.6.2 Stochastic effects (cancer and heredity effects):

Stochastic injuries (e.g., cancer induction) arise from misrepair of damage to the DNA. The result is a genetic transformation. The likelihood of stochastic effects increases with the total radiation energy absorbed by the different organs and tissues of an individual, but their severity is independent of total dose (Thomas et al., 2002).

2.7 Patient dosimetry in radiological imaging:

The objective of dosimetry in radiological imaging is the quantification of radiation exposure within an approach to optimize the image quality to absorbed dose ration.

2.8 Compton scattering

Compton scattering is the predominant interaction of X-ray and gamma photons in the diagnostic energy range with soft tissue. In fact, Compton scattering not only predominates in the diagnostic energy range above 26keV in soft tissue, but continues to predominate well beyond diagnostic energies to approximately 30Mev.This interaction is most likely to occur between photons and outer shell electrons. The electron is ejected from the atom, and the photon is scattered with some reduction in energy. As with all types of interactions, both energy and momentum must be conserved. Thus the energy of the incident photon (E_0) is equal to the sum of the energy of the scattered photon (E_{SC}) and the kinetic energy of the ejected electron (E_e), the binding energy of the electron that was ejected is comparatively small and can be ignored.

$$E_0 = E_{Sc} + E_e \quad (2-3)$$

Compton scattering results in the ionization of the atom and a division of the incident photon energy between the scattered photon and ejected electron; the ejected electron will lose its kinetic energy via excitation and ionization of atoms in the surrounding material. The Compton scattered photon may traverse the medium without interaction or may undergo subsequent interactions such as Compton scattering, photoelectric absorption, or Rayleigh scattering. The energy of the scattered photon can be calculated from the energy of the incident photon and the angle of the scattered photon.

$$E_{sc}=\frac{E_0}{1+\frac{E_0}{511\text{KeV}}\left(1-\cos\theta\right)} \quad (2-4)$$

Where:

$E_{sc} \equiv$ *the energy of the scattered photon.*

$E_0 \equiv$ *the incident photon energy.*

$\theta \equiv$ *the angle of the scattered photon* .

As the incident photon energy increases, both scattered photons and electrons are scattered more toward the forward direction. In X-ray transmission imaging, these photons are much more likely to be detected by the image receptor, thus reducing image contrast. In addition for given scattering angle, the fraction of energy transferred to the scattered photon decreases with increasing incident photon energy. Thus, for higher energy incident photons, the majority of the energy is transferred to the scattered electron. When Compton scattering does occur at the lower X-ray energies used in diagnostic imaging (18 to 150kev)

,the majority of the incident photon energy is transferred to the scattered photon which, if detected by the image receptor, contributes to image degradation by reducing the primary photon attenuation differences of the tissues. For example, following the Compton interaction of an 80 keV photon, the minimum energy of the scattered photon is 61 keV. Thus, even with maximal energy loss, the scattered photons have relatively high energies and tissue penetrability. The laws of conservation of energy and momentum place limits on both scattering angle and energy transfer. For example the maximal energy transfer to the Compton electron occurs with a 180-degree photon backscatter. In fact, the maximal energy of the scattered photon is limited to 511 keV at 90 degrees scattering and to 255 keV for 180-degree scattering (backscatter) event. These limits on scattered photon energy hold even for extremely high-energy photons (e.g., therapeutic energy range).The scattering angle of the ejected electron cannot exceed 90 degrees, whereas that of the scattered photon can be any value including a 180-degree backscatter. In contrast to the scattered photon, the energy of the ejected electron is usually absorbed near the scattering site. The incident photon energy must be substantially greater than the electron's binding energy before a Compton interaction is likely to take place. Thus, the probability of a Compton interaction increases, compared to Rayleigh scattering or photoelectric absorption, as the incident photon energy increases. The probability of Compton interaction also depends on the electron density. The probability of Compton scattering per unit volume is approximately proportional to the density of the material. Compared to other elements, the absence of neutrons in the hydrogen atom results in an approximate doubling of electron density. Thus, hydrogenous materials have a higher probability of Compton scattering than a non-hydrogenous material of equal mass (Streffer et al., 2003).

2.9 Entrance surface air kerma (ESAK)

The entrance surface air kerma (ESAK) is defined as the kerma in air at the point where the central radiation beam axis enters the hypothetical object, i.e. patient or phantom, in the absence of the specified object.

The entrance surface dose, or alternatively the entrance skin dose (ESD) is defined as the absorbed dose to air on the x-ray beam axis at the point where x-ray beam enters the patient or a phantom, including the contribution of the backscatter. The ESD is to be expressed in mGy. Some confusion exists in the literature with regard to the definition of the ESD. That is, whether the definition should refer to the absorbed dose to the air as defined above or absorbed dose to tissue (Streffer et al., 2003)

2.10 Equivalent dose HT:

Accounts for biological effect per unit dose

$H_T = W_R x D$

Table2-1 Radiation weighting factors (Wrixon):

Radiation type and energy range	weighting factors (W_R):
Photons (X-rays and gamma-rays) all Energies	1
Electron all Energies Neutrons	1
<10 keV	5
10-100 keV	10
>100 kev to 2 MeV	20
2-20 MeV	10
>20 MeV	5
Protons >20MeV	5
Alpha particles , Fission fragments	20

2.11 Effective dose

Risk related parameter, taking relative *radiosensitivity* of each organ and tissue into account:

$E (Sv)= \Sigma_T W_T \times H_T$

W_T : tissue weighting factor for organ T

H_T: eequivalent dose received by organ or tissue

Table 2-2 Tissue and organ weighting factors:

weighting factors for different organs

Tissue	Tissue weighting factors		
	ICRP 30(136) 1979	ICRP 60(13) 1991	ICRP 103(16) 2008
Gonads	0.25	0.20	0.08
Red bone marrow	0.12	0.12	0.12
Colon	-	0.12	0.12
Lung	0.12	0.12	0.12
Breast	0.15	0.05	0.12
Esophagus	-	0.05	0.04
Thyroid	0.03	0.05	0.04
Skin	-	0.01	0.01
Bone surfaces	0.03	0.01	0.01
Salivary glands	-	-	0.01
Brain	-	-	0.01
Remainder	0.30	0.05	0.12

2.12 Radiation Units:

2.12.1 Roentgen:

The roentgen is a unit used to measure a quantity called exposure. It can only be used to describe an amount of gamma and X-rays, and only in air. One roentgen is equal to depositing in dry air enough energy to cause 2.58 x 10-4 coulombs per kg. It is a measure of the ionizations of the molecules in a mass of air. The main advantage of this unit is that it is easy to measure directly, but it is limited because it is only for deposition in air, and only for gamma and x-ray (Streffer et al., 2003).

2.12.2 **Radiation absorbed dose:**

The rad is a unit used to measure a quantity called absorbed dose. This relates to the amount of energy actually absorbed in some material, and is used for any type of radiation and any material. One rad is defined as the absorption of 100 ergs per gram of material. The unit rad can be used for any type of radiation, but it does not describe the biological effects of the different radiations.

2.12.3 **Rem:**

The rem is a unit used to derive a quantity called equivalent dose. This relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Equivalent dose is often expressed in terms of thousandths of a rem, or mrem. To determine equivalent dose (rem), you multiply absorbed dose (rad) by a quality factor (Q) that is unique to the type of incident radiation (Stadnyk et al., 2015).

2.12.4 **Gray (Gy):**

The gray is a unit used to measure a quantity called absorbed dose. This relates to the amount of energy actually absorbed in some material, and is used for any type of radiation and any material. One gray is equal to one joule of energy deposited in one kg of a material. The unit gray can be used for any type of radiation, but it does not describe the biological effects of the different radiations. Absorbed dose is often expressed in terms of hundredths of a gray, or centi-grays. One gray is equivalent to 100 rads (Stadnyk et al., 2015).

2.12.5 **Sievert (Sv):**

The sievert is a unit used to derive a quantity called equivalent dose. This relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Equivalent dose is often expressed in terms of millionths of a sievert, or micro-sievert. To determine equivalent dose (Sv), you multiply absorbed dose (Gy) by a quality factor (Q) that is unique to the type of incident radiation. One sievert is equivalent to 100 rem (Stadnyk et al., 2015).

2.13 Radiation measurements:

With respect to measurement, three separate features of an X-ray beam must be identified .The first consideration is the flux of photons travelling through air from the anode towards the patient .The ionization produced by this flux is a measure of the Radiation exposure. If expressed per unit area per second it is the intensity of more fundamental importance as far as the biological risk is concerned is the absorbed dose of radiation. This is a measure of the amount of energy deposited as a result of ionization processes (Sowby, 2001).

2.13.1 **Dose measurement:**

There are several ways of measuring doses from ionizing radiation. Workers who come in contact with radioactive substances or may be exposed to radiation routinely carry personal dosimeters. In the United States, these dosimeters usually contain materials that can be used in thermo luminescent dosimeter (TLD) or optically stimulated luminescence (OSL). Outside the United States, the most widely used type of personal dosimeter is the film badge dosimeter, which uses photographic emulsions that are sensitive to ionizing radiation. The equipment used in radiotherapy (linear particle accelerator in external beam therapy) is routinely calibrated using ionization chambers or the new and more accurate diode technology (Sowby, 2001).

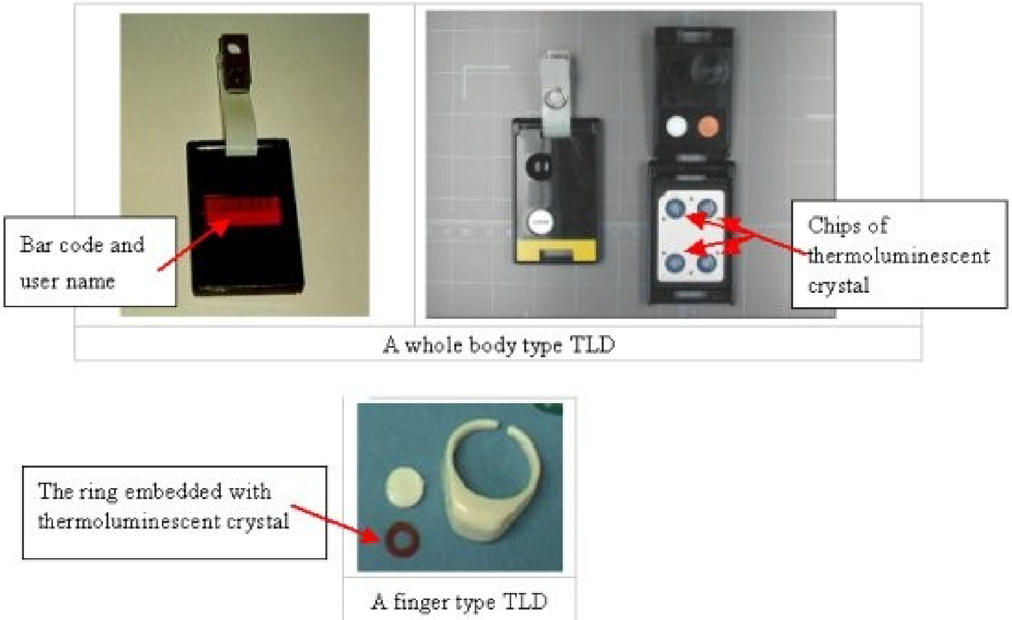

Figure 2.3 a whole body type TLD

2.13.2 **Ionization chamber:**

In medical x-ray imaging the Free-in-air air kerma measurements are best made with suitably designed ionization chambers of typically between 0.6 and 180 cm3 volume. The chambers should have ‘air equivalent’ walls so that their energy response in terms of air kerma is substantially uniform for all relevant x-ray spectra. The leakage current should be very small compared with the ionization current produced by the minimum dose rate to be measured and the response should not be affected appreciably by ion recombination at high dose rates. Dosimeters should be calibrated in a manner traceable to a national primary standard of air kerma as described; there are special requirements for ionization chambers used for air-kerma measurements in mammography: these are a thin entrance wall to reduce attenuation at low photon energies, and ideally a structure that does not appreciably disturb the primary radiation field. Thin entrance window chambers with small volumes generally have a rather massive construction on the exit side, which implies that the charge produced in the cavity contains a significant contribution from scattered radiation (Sowby, 2001).

2.14 Mobile radiographic units

These units are used for radiographic imaging of patients who cannot be moved to the radiology department and who are in areas—such as intensive and critical care units or operating and emergency rooms—that lack standard, field radiographic equipment. Medical applications can include general radiography and orthopedic, pediatric, skeletal, and abdominal imaging (Frayre et al., 2012).

2.14.1 Principles of operation

Mobile CR units capture images using a photostimulable-phosphor plate. Mobile DR units are equipped with built-in or tethered flat panel detectors, which use a scintillator material to convert x-rays to visible light. An array of photodiodes on the aSi layer absorbs the light and translates it into a signal for digital display. On some units, the x-ray exposure is powered directly from the line voltage. While on others, the input line voltage charges the battery that powers the x-ray exposure (Frayre et al., 2012) .

2.14.2 Reported problems

Critical care units are typically not equipped to shield patients and medical staff from radiation exposure. Personnel and nearby patients can be somewhat protected by protective lead aprons and movable radiation shielding. Mobile units may be large, heavy, and hard to maneuver; some units are unevenly balanced and may tip over. Because of the weight of the unit's chassis, tube locks and support mechanisms may fail or require frequent alignment. Most units have safety features to prevent collisions during transport (Frayre et al., 2012).

Figure 2.4 mobile x-ray unit.

2.15 Intensive care unit:

Intensive care may be broadly defined as a service for patients who have potentially recoverable conditions, who can benefit from more detailed observation and invasive treatment than can be provided safely in an ordinary ward or high dependency area. It is usually reserved for patients with threatened or established organ failure, often arising as a result or complication of an acute illness or trauma, or as a predictable phase in a planned treatment programme. Intensive care represents the highest level of continuing patient care and treatment. It is distinguished from the care and treatment pertaining to a special procedure of limited duration such as a surgical operation, plasma exchange or haemodialysis, although it may embrace such procedures. Intensive care has, as its primary objective, the recovery of the patient to leaving hospital. The return of a patient to an intermediate care ward, such as a high dependency unit (HDU) is only the first step in this progression. Intensive care involves continuing supervision, care and treatment by doctors, nurses, physiotherapists, technicians, dieticians and others (Reynolds and Bander, 2015).

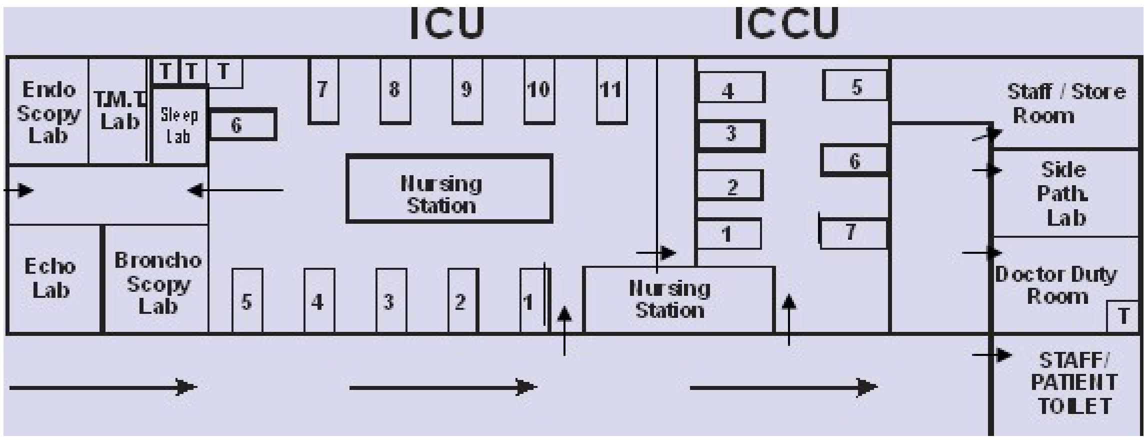

Figure 2.5 design of intensive care unit

2.16 Ideally an ICU requires these equipments:

- Oxygen and compressed air and means of administration.
- Mechanical Ventilation air and assistance equipment including airways, manual breathing bag and ventilation/ respirators.
- Cardiac defibrillator.
- Respiratory and cardiac maintaining equipment.

- Thoracocentasis and Thoracostomy sets.
- Tourniquets.
- Vascular wet down sets- infection pump.
- Laryngoscope and gastric suction equipment
- Portable X-ray machine
- An emergency cart within unit should be ready with drugs and equipments and drugs as determined by the medical staff.

2.17 The previous studies:

They are many studies have been carried out in this field local and broad to optimization of patient dose and image quality in diagnostic radiology, in view of evaluate the entrance surface doses (ESDs)

Suleiman et al in (2007), evaluated the entrance surface doses ESD to patients undergoing selected diagnostic x-ray examinations in major Sudanese hospitals. Their study Conducted in four hospitals and included a sample of 346 radiographs. They estimated the ESD from the x-ray tube output parameters and their study results founded to be range from 0.17 to 0.27 mGy for chest AP, 1.04-2.26 mGy for Skull AP/PA, 0.83-1.32 mGy for Skull

LAT, 1.31-1.89 mGy for Pelvis AP, 1.46-3.33 mGy for Lumbar Spine AP and 2.9-9.9 mGy for Lumbar Spine LAT (Suliman et al., 2007).

Borretzen et al (2004) , assessed the patient doses for most frequent x-ray examinations in Norway, their study included a total 491 procedures for 11 different examination categories. They calculated the ESD mathematically from the x-ray tube output data and the patient parameters as the effective dose for each patient. Their study results showed that the ESDs are 1.3 mGy for cervical spine AP, 1.03 mGy for cervical spine LAT, 2.07 mGy for Pelvis AP, 1.5 mGy for Thoracic spine AP, 2.8 mGy for Lumbar spine AP, 4.4 mGy for Lumbar spine LAT, 0.4 mGy for Chest PA, 0.3 mGy for Chest LAT, 1.15 mGy for Skull PA and 0.95 mGy for Skull LAT (Borretzen et al., 2007).

The performance of radiography in the Intensive Care Unit (ICU) may be associated with a certain level of radiation exposure for staff and patients in the unit. This issue has been discussed by Begum on his study to compromise patient care. The objectives of his study were to quantify dose levels within the ICU and to evaluate the performance of ICU x-ray studies according to patient dose measurements. This study was conducted in the 18-bed ICU of a third-level hospital. The scattering radiation due to mobile x-ray examinations was measured by using four personal thermoluminiscent dosimeters (TLDs)

The dose area product (DAP) was measured at each examination using a transmission chamber installed on the diaphragm of the x-ray equipment. Based on the TLD readings and taking account of the error margin, the annual dose to patients and staff was less than 0.6 mSv. The value given by the DAP meter for chest x-rays was 94 ± 17 mGy cm(2); this value is well below the lower limit recommended by different agencies and committees. Exposure levels were found to be extremely low and pose no apparent risk to staff or to those in beds adjacent to the patients undergoing x-ray examinations, which were correctly performed in the unit (Begum, 2001).

Chapter 3

Materials and Method

3.1 Materials

3.1.1. Subjects:

This is a prospective, observational study in the ICU conducted in Fedail Hospital, from September 2014 to February 2015. The study was approved by the hospital's ethics committee. All resident nurses who gave voluntary written consent to participate in the study were included. Since the study did not involve patient contact, the requirement for obtaining consent from patients was waived by the ethics committee. The study was carried out in accordance with the principles of good clinical research practice.

The resident nurses provide 24 h cover, working in 12 h shifts, with two nurses in each shift in ICU which has a total of 14 beds.

3.1.2. Machine used:

Siemens MOBILETT XP Hybrid with Maximum tube current of up to 450 mA and short exposure times down to 1 ms.

3.1.3. Dose measurement device:

To detect levels of radiation, thermoluminescent dosimeters (TLDs) were used. The TLD measures cumulative dose of ionizing radiation exposure by measuring the amount of visible light emitted from a crystal in the detector when the crystal is heated. The amount of light emitted is dependent upon the amount of radiation exposure. TLDs can measure a wide dosimetric range (from 10 µGray to 10 Grays) of radiation exposure and are routinely used as personal dosimeters because they are small in size, convenient to use and not expensive.

3.2 Method

3.2.1 Radiation dose measurement:

TLD was given to each of the two resident nurses; they were handed over to the next team during shift changeover. In addition, and one TLD was placed in the bed of adjacent patient who was not examined. One TLD was kept in the doctors' duty room which was within the premises of the ICU. Thus, a total of four TLDs were used in the study. Each of the TLDs was numbered for easy identification and for analysis.

The participants were instructed to wear the TLDs at all times during their duty hours. Standard radiation protection precautions were practiced throughout the study period. Chest and abdominal X-rays were commonly performed in the ICU.

The TLDs were handed over to Department of Nuclear Medicine for analysis. During the period of the study, a database of procedures performed in the ICU along with the bed number and the patient's hospital registration numbers were maintained.

Chapter 4

Results

4.1 Results:

Table 4.1 descriptive statistic far age and exposure factors

	N	Minimum	Maximum	Mean	Std. Deviation
KVp	50	100	115	107.60	2.755
mAs	50	0.50	0.75	0.7066	0.03474
Age	50	28	83	55.02	14.402

Table 4.2 cases during the period of study

Exam	No	Percentage

Chest	**35**	**70%**
Abdomen	**15**	**30%**

Table 4.3 radiation doses for different residents

TLD No	Radiation dose (mSv)
TLD1 (Nurse 1)	0.042
TLD 2 (Nurse 2)	0.049
TLD 3 (Adjacent patient)	0.069
TLD 4 (doctors’ duty room)	0.022

Figure 4.1 reading from various TLDs

Table 4.4 comparison of radiation dose per year with standard reference level

TLD No	Radiation dose (mSv) /year	Reference Level
TLD1 (Nurse 1)	0.168	20
TLD 2 (Nurse 2)	0.196	20
TLD 3 (Adjacent patient)	0.276	20
TLD 4 (doctors’ duty room)	0.088	20

Chapter five
Discussion, conclusion and recommendations

5.1 Discussion:

Revolutionary progress in the field of medical imaging has given a big leap to advances in medical diagnostics and therapeutics. This development has also infiltrated the field of critical care medicine, and radio-diagnosis and interventional radiological procedures now play a key role in the management of critically ill patients. While this advancement offers the advantages of rapid bedside diagnosis, and cost-effective and minimally invasive treatment options to critically ill patients, it carries the danger of exposure of patient and physician to radiation.

The detrimental effects of exposure to even low-level ionizing radiation have always been known; however, there is renewed concern because of its wide-spread use in medical radio-diagnosis and therapeutics in critically ill patients. It is, therefore, natural that there may be concerns about the long-term effects of radiation exposure to staff working for long periods of time in the

ICU.

There is considerable literature on occupational hazards of radiation exposure among doctors working in the ICU (Siddiqui et al., 2014); however, studies did not take into account the radiation dose to the adjacent patient. Few previous studies have looked at radiation exposure among ICU personnel. A study performed in a trauma ICU (TICU) has concluded that radiation exposure is not a significant occupational hazard for the TICU personnel(Mostafa et al., 2002). Similarly, another study looked into the radiation exposure to ICU nurses and found that the exposure was well below the permissible level (Cupitt et al., 2001). The findings of this study have reiterated the results of these previous studies.

The strength of this study is that the radiation dose to adjacent patient was considered; because his neighbor is regularly checked, so he will be at risk to radiation dose.

This study has some limitations. The number and types of bedside and radiological procedures can vary on a day-to-day basis according to the case-mix of the ICU population, and this may affect the overall radiation exposure; however, this study was carried out over a period of 3 months, and the data obtained would have been adequately representative. The other limitation relates to the generalization of the study; differences in the types of cases, design of the ICU, quality and maintenance of radiological equipment between hospitals may restrict the applicability of these results to other hospitals.

Though, with advances in technology, the number and types of radiological procedures performed on patients are likely to increase. Furthermore, there is a growing trend toward using radionuclide-based positron emission tomography scans for diagnostic procedures in critically ill patients especially when they are admitted to ICU during their diagnostic work-up. Some of these patients may continue to emit radiation long after their procedures are completed. Though none of these patients featured in this study, it will add radiation exposure to adjacent patients and staff.

5.2 Conclusion:

This study has been carried out to estimate the radiation dose n the intensive care unit. It found that if standard safety precautions were followed, cumulative radiation exposure to ICU resident doctor, nurses and adjacent patient was well within permissible limits and was not the cause of concern and hence routine personal dosimetric monitoring is not needed for residents in ICU. However, in view of changing practice, there is a need to repeat such audits periodically to monitor radiation exposure

The results of this study do not in any way underrate the need to follow safety precautions, while carrying out radiological procedures in critically ill patients. The levels of exposure found in this study should be interpreted bearing in mind that standard protection norms were used by all personnel involved in the study.

5.3 **Recommendations:**

- Radiological procedure should be considered in the design of ICU
- Radiation protection to the staff and adjacent patient should be applied
- Radiation dose measurement tools should be available in Sudanese hospital
- Regular check for x-ray machine should be applied

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