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كلية الدراسات العليا

Evaluation of patients Effective Radiation Dose during Orthopedic Surgery

تقويم الجرعة الإشعاعية الفعالة للمرضى أثناء جراحة العظام

A Thesis Submitted in Partial Fulfillment of the Requirements for the M.Sc. Degree in Medical Physics

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2019

الاية

قال تعالى:

سورة طة ، الاية (144)

Dedication

To the spirit my dearest father ,who taught me to promote life stairs wisely and patiently.

To the spring that never stops giving ,to my mother . to whose love my brothers and sisters .

To my lovely family from the bottom of my heart ,for their support.

To my friends and my colleagues.

Acknowledgments

All praise be to Allah .I would like to express my most sincere gratitude to my supervisor Dr : Suhaib Mohamedsalih for his support and priceless guidelines during this research.

I would like to Dr: Ali Hyder to help me in gathering collecting data.

I am also like to thank all my colleagues , my teachers and my friends .

Abstract

This study aimed to evaluation of patients radiation dose in orthopedic surgery in Khartoum state . A total of 91 patient from orthopedic surgery conducted using mobile c-arm fluoroscopic from three hospitals ,of period from July to November of 2018. To obtained formation of patients during orthopedic surgery used mobile C-arm fluoroscopy ,to recorded the demographic data (gender, age ,weight, hight) .

The results presented as mean ± SD were the mean of ESAK was (mean ±0.31 SD) and mean of ED found (mean ±0.29 SD), and the mean ESAK(0.32), mean ED (0.30 mSv) of male higher than female mean ESAK (0.30) mean ED(0.27 mSv) .

Compared the dose between all hospitals found that the dose in hospital B (0.32 mSv) was higher than the dose in hospital C (0.29 mSv) and hospital A (0.26 mSv). The mean effective dose in present study (0.29 mSv) was lower than mean effective dose from national and international studies (0.46 mSv) and (2.90 mSv), and international organizations ICRP (1.3 mSv) and IAEA (1-3 mSv). So the study recommended that the patients should be positioned in suitable distance from the x-ray tube to minimize patient doses .

الملخص

الهدف من الدراسة تقويم الجرعة الإشعاعية الفعالة للمرضى الذين خضعوا لجراحة العظام في ولاية الخرطوم .كان مجموع المرضى في هذه الدراسة 91 مريض خضعوا لجراحة العظام بواسطة جهاز الأشعة المرئية في ثلاثة مستشفيات مختلفة في ولاية الخرطوم في الفترة من يوليو إلى نوفمبر 2018 .تم تسجيل بيانات المرضى و كانت عبارة عن (النوع- العمر- الوزن- الطول).

تم مقارنة النتائج وجدت أن متوسط الجرعة الفعالة في مستشفى B(0.32 mSv)كان أعلي في القيمة الإشعاعية للمرضي من مستشفى C mSv(0.29) ومستشفىA (0.26 mSv).

وجد في هذه الدراسة أن متوسط الجرعة الإشعاعية الفعالة (0.29 mSv) تمت مقارنة النتائج مع الدراسات السابقة (mSv 0.46) و(2.90 mSv) .ووجدت انها أقل جرعة إشعاعية وكذلك تمت مقارنتها مع المنظمة الدولية للوقاية من الإشعاع (1-3 mSv) والوكالة الدولية للطاقة الذرية (1.3 mSv) .

هذه الدراسة توصي أن تكون المسافة بين أنبوب الأشعة السينية والمريض مناسبة لتقليل الجرعة للمريض.

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List of abbreviation

CCD : Charge Coupled Device.

FPD : Flat Panel Detector.

XRII : X-Ray Image Intensifier.

kVp : Kilo Volt Peak.

mA : tube current.

SNR : Signal to noise Ratio.

C/Kg : Coulomb per Kilogram.

Gy : Gray.

Sv : Sievert.

Kerma : Kinetic energy released per unit mass.

ESAK : Entrance Surface Air Kerma.

Rem : Radiation equivalent mass.

Rad : Radiation absorbed dose.

DAP : Dose Area Product.

D : Absorbed Dose.

H : Equivalent Dose.

ED : Effective Dose.

DHS :Dynamic Hip Screw.

FFD : Focal Film Distance.

STD : Standard Deviation.

Min : Minimum.

Max : Maximum.

ICRP : International Commission on Radiological Protection.

IAEA : International Atomic Energy Agency.

Chapter One

Introduction

1.1 Introduction:

Fluoroscopy is an imaging technique commonly used by physicians to obtain real-time moving images of the internal structures of a patient through the use of a fluoroscope. In its simplest form, a fluoroscope consists of an x-ray source and fluorescent screen . However, modern fluoroscopes couple the screen to an x-ray image intensifier and CCD video camera allowing the images to be recorded and played on a monitor. The use of x-rays, a form of ionizing radiation, requires the potential risks from a procedure to be carefully balanced with the benefits of the procedure to the patient. While physicians always try to use low dose rates during fluoroscopic procedures, the length of a typical procedure often results in a relatively high absorbed dose to the patient. Recent advances include the digitization of the images captured and flat-panel detector systems which reduce the radiation dose to the patient still further. The beginning of fluoroscopy can be traced back to 8 November 1895 when Wilhelm Rontgen noticed a barium Platniocyanide screen fluorescing as a result of being exposed . Within months of this discovery, the first fluoroscopes were created. Early fluoroscopes were simply cardboard funnels, open at narrow end for the eyes of the observer, while the wide end was closed with a thin cardboard piece that had been coated on the inside with a layer of fluorescent metal salt (Simon et al 2002).

The fluoroscopic image obtained in this way is rather faint. Thomas Edison quickly discovered that calcium tungstate screens produced brighter images and is credited with designing and producing the first commercially available fluoroscope. In its infancy, many incorrectly predicted that the moving images from fluoroscopy would completely replace the still x-ray radiographs, but the superior diagnostic quality of the earlier radiographs prevented this from occurring. Early radiologists were required to sit in a darkened room, in which the procedure was to be performed, accustoming their eyes to the dark and thereby increasing their sensitivity to the light. The placement of the radiologist behind the screen resulted in significant radiation doses to the radiologist. The development of the X-ray image intensifier and the television camera in the 1950s revolutionized fluoroscopy. The red adaptation goggles became obsolete as image intensifiers allowed the light produced by the fluorescent screen to be amplified, allowing it to be seen even in a lighted room. The addition of the camera enabled viewing of the image on a monitor, allowing a radiologist to view the images in a separate room away from the risk of radiation exposure. Fluoroscopy 2 More modern improvements in screen phosphors, image intensifiers and even flat panel detectors have allowed for increased image quality while minimizing the radiation dose to the patient. Modern fluoroscopes produce noise-limited images, ensuring that the minimal radiation dose results while still obtaining images of acceptable quality (Richarad et al 1998).

1.1.1 Mobile C-arm Fluoroscopic X-Ray Systems:

Are used for a variety of diagnostic imaging and minimally invasive surgical procedures. In the operating room , they help in visualizing kidney drainage, abdominal and thoracic aortic aneurysm repair, percutaneous valve replacements, cardiac surgery, vascular surgery, gastroenterology, neuro stimulation, orthopedics, pain management and neurology procedures (Yang et al 2015).

1.2 Problem of the study:

Mobile C-arms fluoroscopy used in the surgical, The patients exposed to high radiation dose do not need it as additional dose with different projection and can be positioned the x-ray tube close for patient which increases the patients dose drastically.

1.3 Objectives:

1.3.1 General objective:

The main objective of this study was to evaluate of patients dose from orthopedic surgery in Khartoum state hospitals.

1.3.2 Specific objectives:

- To Measurements patients dose during orthopedic surgery.
- To Calculate Entrance of Surface Air Kerma (ESAK).
- To Calculate effective dose for all patients.
- TO Compare the patients dose between different hospitals.
- To Compare the present study with national and international studies and with international organizations (IAEA , ICRP,…)

1.4 Thesis layouts:

Thesis is concerned with the measurement of effective dose for patient during surgical room. It divided into the five chapters.

Chapter one, which is an introduction, it presents the problem of study, objective of study; it also provides an outlines of the thesis.

Chapter two includes background and literature review.

Chapter three deals with material and method used the measure the effective dose and explain in details the method.

Chapter four presents of the result of the thesis.

Chapter five discusses the result of the thesis and conclusion, recommendation for thesis.

Chapter Two

Theoretical Background

2.1 Fundamentals of Fluoroscopy:

Radiation is the transfer of energy in the form of particles or waves. X-rays generated by fluoroscopy and radiography is a form of electromagnetic radiation; other examples of EM radiation include visible light and radio waves. However, unlike visible light and radio waves, x rays generate enough energy to be ionizing, which allows for the removal of an electron from the outer shell of an atom. X-rays are produced when a heated filament (cathode) within an x-ray tube generates electrons that are accelerated to a tungsten target (anode) by application of high voltage (50-150) kVp to the tube. The electron creates an electric field that interacts with the nucleus of the anode, thereby releasing energy in the form of x-rays. The flow of electrons from the filament to the target is called the tube current and is described in units of (mA). Fluoroscopy is normally performed using (2-6) mA and an accelerating voltage of (75 to 125) kVp. The rate of x-ray production is directly proportional to the tube current, but is more sensitive to increasing kVp than mA (Johns et al 2014).

Fluoroscopy units are usually operated in an automatic brightness control model, in which a sensory in the image intensifier monitors the image brightness. When there is inadequate brightness, the increases the kVp first, which increases the x-ray penetration through the patient, and then adjusts the mA to increase the brightness . When x-rays traverse tissue, they can result in 1) complete penetration, 2) total absorption, or 3) partial absorption with scatter. Complete penetration means that the x-rays completely passed through the tissue, resulting in an image. Total absorption means that the x-ray energy was completely absorbed by the tissue, resulting in no image. Partial absorption with scatter involves partial transfer of energy to tissue, with the scattered x-ray possessing less energy and following a different trajectory. The scattered radiation is responsible for causing radiation exposure to the operator and staff **(**Johns et al 2014).

2.2 Components of Fluoroscopy:

Fluoroscopic imaging systems use much of the same technology as radiographic systems, with some modifications and additions. Depending on the intended use, a fluoroscopic system may require a high power generator and a high heat capacity X ray tube. The major difference between radiographic and fluoroscopic equipment is the image receptor. Early fluoroscopic systems used an intensifying screen, similar to that used in radiographic screen film imaging that was viewed directly by the radiologist. However, direct view systems produced dim images that required the radiologist's eyes to be dark adapted, and frequently resulted in high doses to both patient and radiologist(Gingold et al 2014).

The development of the X ray image intensifier (XRII) was essential to the success of modern fluoroscopic imaging. Fluoroscopic imaging systems commonly include an anti-scatter grid as the first element in the imaging chain. The focused anti-scatter grid serves the same purpose in fluoroscopic imaging as it dose in radiographic imaging; namely, removing contrast degrading scattered radiation from the X-ray beam. A schematic of an image-intensified fluoroscopy system is shown in Figure 1. The key components include an X-ray tube, spectral shaping filters, a field restriction device (collimator), an anti-scatter grid, an image receptor, an image processing computer and a display device. Ancillary but necessary components include a high-voltage generator, a patient-support device (table or couch) and hardware to allow positioning of the X-ray source assembly and the image receptor assembly relative to the patient (Gingold et al 2014).

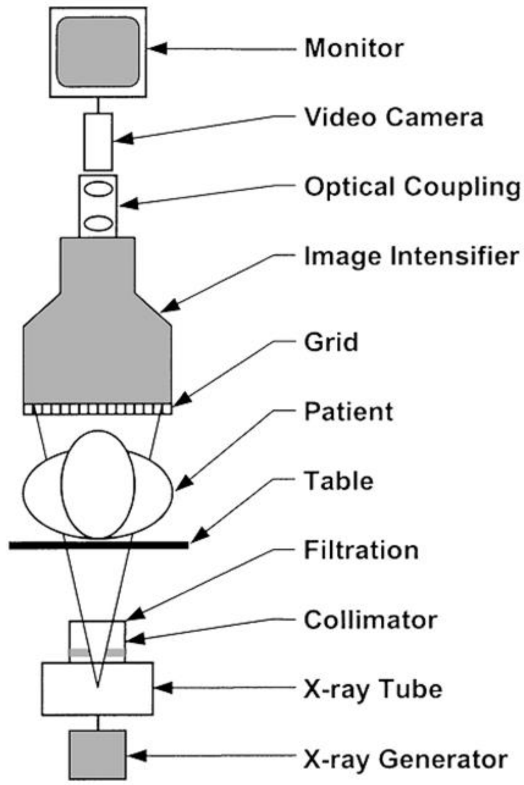


Figure (2.1): Schematic Diagram of a fluoroscopic system using an X-ray image intensifier (XRII) and video camera

The components pertinent to orthopedic surgery are the x-ray generator, x-ray tube, collimator, patient table and pad, and image intensifier. X-ray generator - Produces electrical energy and allows selection of kilovolt peak (kVp) and tube current (mA) that is delivered to x-ray tube. X ray tube - Converts electrical energy of x-ray generator to x-ray beam. Source of radiation; want to increase distance from x-ray tube. Collimator - contains multiple sets of shutter blades that define the shape of the x-ray beam. There is a rectangular and a round set of blades. By further collimating the beam to the area of interest, the exposed volume of tissue is reduced, which results in less scatter production and better image contrast. It also reduces the overall patient and surgeon radiation dose by minimizing scatter and direct exposure. Patient table and pad . This can be accomplished with carbon fiber composite. A system containing an image intensifier may be used either as a fixed piece of equipment in a dedicated screening room or as mobile materials . Image intensifier - Converts x-rays and amplifies image brightness. Major components include an input layer to convert x-rays to electrons, electron lenses to focus the electrons, an anode to accelerate them, and an output layer to convert them into a visible image (Johns et al 2014).

2.3 Optimizing C-arm position:

Most often, there will be a radiology technician operating the C-arm. However, it is important to understand how the C-arm moves so that you can direct the technician. The C-arm unit can be maneuvered in various ways, depending on whether one moves the entire unit or just the C-arm. The position of the image intensifier is also important. This enables one to move the C-arm in the plane of the C-arm and is most commonly used for obtaining AP, lateral, and oblique views Positioning the image intensifier (base) - Structures closer to the image intensifier will appear smaller compared to those further away. To increase the field of view, bring the base as close as possible to the structure of interest; this is particularly important for assessing alignment and also results in the least amount of radiation exposure for the patient and physician. In general, one should center the base of the C-arm over the area of interest. Positioning the C-arm - The final consideration is positioning the C-arm during pre-operative planning. It is difficult to work on the same side as the C-arm because of risk of contaminating the machine, in addition to the limited amount of space. It is easier to have the C-arm coming in from the opposite side of the area you will be operating. Studies Show decreased exposure dose when standing on the same side of the patient as the image intensifier. This is most useful when imaging a large body part that filles the entire radiation beam; a smaller body part will allow some beams to pass through. It is also preferable to position the C-arm x-ray tube underneath the patient and the operating table, if possible. Positioning of body part in relation to radiation source Cadaveric study shows that positioning the image intensifier as close to the body part as possible (c) within the arc of the C-arm reduces patient exposure tenfold and surgeon exposure by half compared to positioning adjacent to the radiation source (a) This is due to automatic increase in the mA to provide brightness, which increases the radiation dose. Positioning the image intensifier closer to the body part also results in a sharper(Johns et al 2014).

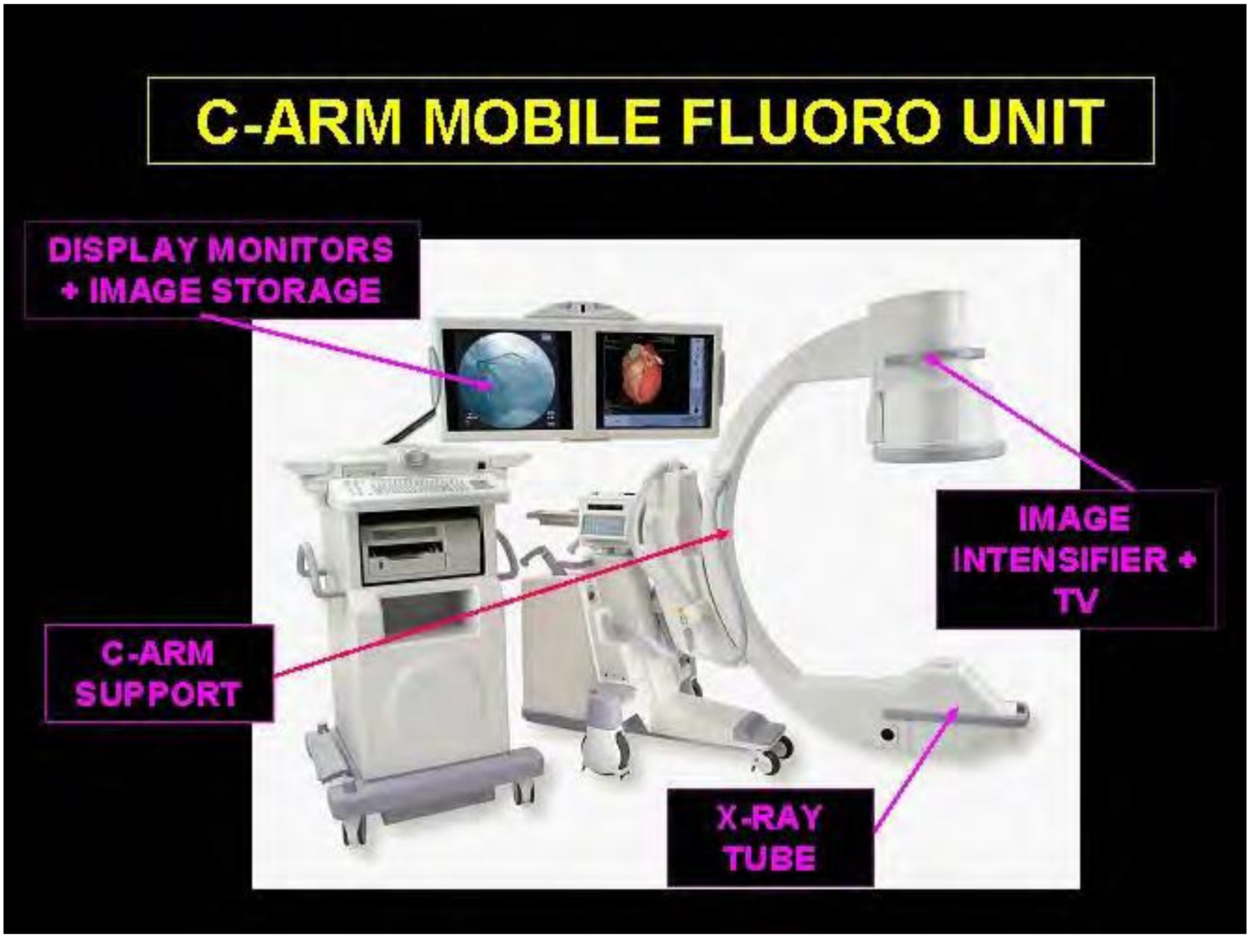
2.3.1 Mobile C-arm:

A mobile C-arm is a medical imaging device that is based on X-ray technology and can be used flexibly in various ORs within a clinic. The name is derived from the C-shaped arm used to connect the X-ray source and X-ray detector to one another. Since the introduction of the first C-arm in 1955 the technology has advanced rapidly. Today, mobile imaging systems are an essential part of everyday hospital life. Specialists in fields such as surgery, orthopedics, traumatology, vascular surgery and cardiology use C-arms for intraoperative imaging. The devices provide high-resolution X-ray images in real time, thus allowing the physician to monitor progress at any point during the operation and immediately make any corrections that may be required. Consequently, the treatment results are better and patients recover more quickly. Hospitals benefit from cost savings through fewer follow-up operations and from minimized installation efforts (Desilva et al 2017).

2.3.2 Mobile C-arm work:

A C-arm comprises a generator (X-ray source) and an image intensifier or flat-panel detector. The C-shaped connecting element allows movement horizontally, vertically and around the swivel axes, so that X-ray images of the patient can be produced from almost any angle. The generator emits X-rays that penetrate the patient's body. The image intensifier or detector converts the X-rays into a visible image that is displayed on the C-arm monitor (Desilva et al 2017).

The doctor can identify and check anatomical details on the image such as blood vessels, bones, kidney stones and the position of implants and instruments at any time. In the case of analog image intensifiers the X-ray strikes a fluorescent surface after being attenuated to different degrees through the patient's body. Depending on the strength of the radiation it causes the surface to glow more or less brightly. Behind the surface is a vacuum tube, at the end of which an analog camera captures the glow and displays it on the monitor. Due to the curved surface of the tube the accuracy of the image diminishes toward the edges, leading to distortions. Modern flat-panel technology is the digital development of image intensifier technology. The intensity of the incoming X-rays is converted directly into a digital value. Dispensing with electron optics allows distortion-free images to be produced, hence improving the image quality. The world's first c-arm with flat-panel detector was presented by Ziehm Imaging in 2006 (Desilva et al 2017).



Figure(2.2): Mobile C-arm fluoroscopy

2.4 Image Display:

Fluoroscopy requires high-quality video displays that allow users to appreciate fine details and subtle contrast differences in the anatomy of interest. Modern systems feature high resolution flat-panel with high maximum luminance and high-contrast ratios.

2.4.1 Image Receptor -X-Ray Image Intensifier (XRII):

The X-ray image intensifier is an electronic device that converts the X-ray beam into a visible image suitable for capture by a video camera and displayed on a video display monitor. The key components of an XRII are an input phosphor layer, a photocathode, electron optics and an output phosphor. The cesium iodide input phosphor coverts the X-ray image into a visible light image. The photocathode is placed in close proximity to the input phosphor, and it releases electrons in direct proportion to the visible light from the input phosphor that is incident on its surface. The electrons are steered, accelerated and multiplied in number by the electron optic components, and finally impinge upon a surface coated with a phosphor material that glows visibly when struck by high-energy electrons. The video signal is then displayed directly (or digitized), post processed in a computer and rendered for display. The XRII achieves orders of magnitude more light per X-ray photon than a simple fluorescent screen (Gingold et al 2014).

2.4.2 Image Receptor- Flat Panel Detector (FPD):

In recent years we have seen the introduction of fluoroscopic systems in which the XRII and video camera components are replaced by a "flat panel detector" (FPD) assembly. When flat panel X-ray detectors first appeared in radiography, they offered the advantages of a "digital camera" compared with existing technologies. characteristics low enough to achieve good signal-to-noise ratio (SNR) under low exposure conditions. Flat panel detectors are more physically compact than XRII/video systems, allowing more flexibility in movement and patient positioning These phenomena simply do not occur in FPDs. FPDs often have wider dynamic range than some XRII/video systems. Another advantage of FPDs is that the image receptor's spatial resolution (Gingold et al 2014).

2.5 Radiation Exposure:

Is a measure of the ionization of air due to ionizing radiation from photons; that is, gamma rays and X-rays. It is defined as the electric charge freed by such radiation in a specified volume of air divided by the mass of that air. The SI unit of exposure is the coulomb per kilogram (C/kg), which has largely replaced the roentgen (R) (Carron et al 2007).

2.6 Radiation Units :

In the course of the 100 years of dealing with ionizing radiation, several different dose units have been used. Some of these units are still used in different countries. It is useful, therefore, to consider some of these units and to see the relations between the old units and the gray unit (Gy) (Carron et al 2007).

2.6.1 Coulomb Per Kilogram (C/Kg):

Is the SI unit of ionizing radiation exposure and it the amount of radiation required to create one coulomb of charge of each polarity in one kilogram of matter (Cember et al 1996).

2.6.2 Roentgen:

Is the measurement of energy produced by Gamma or X-Ray radiation in a cubic centimeter of air, It is abbreviated with the capital "R" (Forward et al 1990).

2.6.3 RAD:

Radiation Absorbed Dose. Original measuring unit for expressing the absorption of all types of ionizing radiation into any medium. One rad is equivalent to the absorption of 100 ergs of energy per gram of absorbing tissue.

1rad=100ergs/g.

1Gy=100rad. (F0rward et al 1990).

2.6.4 Gray (Gy):

Terms of Use Measuring Radiation. There are four different but interrelated units for measuring radioactivity, exposure, absorbed dose, and dose equivalent. The (Gy) is defined as one grey is an absorbed radiation dose of 1 joule per kilogram.

1Gy=1J/Kg (Huang et al 2009).

2.6.5 REM:

Is the traditional unit of equivalent dose . For x-rays it is equal to the rad or millijoules of energy deposited per kilogram (Cember et al 1996).

2.6.6 Sievert (Sv):

The unit for measuring ionizing radiation effective dose, which accounts for relative sensitivities of different tissues and organs exposed to radiation. The radiation quantity measured by the Sievert is called effective dose (Knoll et al 2010).

2.7 Dosimetric Quantities:

2.7.1 Kerma:

The physical, non-stochastic quantity kerma (K) is related to the energy transferred from uncharged particles to matter. Kerma is the acronym for kinetic energy released per unit mass and it is defined as:

$$K = d\varepsilon tr/dm$$

where the quantity dεtr is the expectation value of the energy transferred from indirectly ionizing radiation to charged particles in the elemental volume dV of mass dm. Unit: J/kg. The special name for the unit of kerma is gray (Gy) (Attix et al 2008).

2.7.2 Entrance surface air kerma

The entrance surface air kerma, is defined as the kerma to air measured on the central beam axis at the position of the patient or phantom surface . The contribution of backscattered radiation

The symbol for the entrance surface air kerma is Ka,e.

Unit: J/kg. The name for the unit of entrance surface air kerma is gray (Gy).

The entrance-surface air kerma is related to the incident air kerma by the backscatter factor, B. Thus:

$$Ka,e = Ka,iB$$

where B is the backscatter factor, which depends on the field size, radiation quality and backscatter material (Anastasia 2017).

2.7.3 Dose Area Product:

Dose area product (DAP) is a quantity used in assessing the radiation risk from diagnostic X-ray examinations and interventional procedures. It is defined as the absorbed dose multiplied by the area irradiated, expressed in gray-centimeters squared (Gy·cm2 – sometimes the prefixed units mGy·cm2 or cGy·cm2 are also used). Manufacturers of DAP meters usually calibrate them in terms of absorbed dose to air. DAP reflects not only the dose within the radiation field but also the area of tissue irradiated .DAP is measured An ionization chamber is placed beyond the X-ray collimators and must intercept the entire X-ray field for an accurate reading (Kim et al 2009).

2.7.4 Absorbed Dose:

Absorbed dose (D), a physical non-stochastic quantity, can be used to quantity the deposition of energy by ionizing radiation and it is defined in ICRU 60 (1998) as the ratio:

$$D=d\bar{\varepsilon}/dm$$

where $d\bar{\varepsilon}$ is the mean energy imparted to the matter of mass, dm. Unit: J/kg or special name gray (Gy).

2.7.5 Equivalent Dose:

This quantity has the same physical dimensions as absorbed dose. It is used to take into account the fact that different particle types have biological effects . It is usually denoted by the symbol H. The customary unit is the rem while the SI unit is the Sievert (Sv). One Sievert is equal to 100 rem.

The equivalent dose H_T is defined as:

$$HT = wR\ DT,R,$$

where

$D_{T,R}$ is the absorbed dose delivered by radiation type R averaged over a tissue or organ T and w_R is the radiation-weighting factor for radiation type R (Podgoraak et al 2003) .

2.7.6 Effective Dose:

The effective dose E is defined as the summation of tissue equivalent doses, each multiplied by the appropriate tissue-weighting factor wT.

$$E = \Sigma w_T H_T$$

• Tissue-weighting factors wT. The SI unit is the Sievert (Sv) (Podgorsak et al 2003).

2.8 Radiation Hazards:

Ionizing radiation can damage living tissue in the human body. Its trips away electrons from atoms breaks some chemical bonds. Radiation may be ionizing and nonionizing. Alpha and beta, gamma and X-rays particles are the most common forms of ionizing radiations. The amount of energy the radiations can deposit in a given space varies with each type. Radiations also differ in the power to penetrate. Inside the body the alpha particle will deposit all its energy in a very small volume of tissue while gamma radiation will spread energy over a much larger volume. Medical X-rays generally deliver less than 10 mrem. All kinds of ionizing radiations produce health effects. The damages incurred by different kinds of tissue vary with the type of radiation to which the person is exposed and the means of exposure. Direct exposure to radiation and radiation emitters can affect the whole body while inhalation or ingestion affects tissues inside the body. Radiations can damage the process of normal cell division leading to cancers (Stevan et al 2017).

2.9 Radiation Effects:

Exposure to radiation cause detrimental health effects that fall into one of two categories: deterministic and stochastic.

2.9.1 Deterministic Effects:

At large doses, radiation effects such as nausea, reddening of the skin or, in severe cases, more acute syndromes are clinically expressed in exposed individuals within a relatively short period of time after the exposure; such effects are called deterministic because they are certain to occur, if the dose exceeds a threshold level. Deterministic effects are the result of various processes, mainly cell death or delayed cell division, caused by exposure to high levels of radiation. The severity of a particular deterministic effect in an exposed individual increases with dose above the threshold for the occurrence of the effect (Podgorsak et al 2003).

2.9.2 Stochastic Effects:

Radiation exposure can also induce delayed effects such as malignancies, which are expressed after a latency period and may be epidemiologically detectable in a population; this induction is assumed to take place over the entire range of doses without a threshold level. Hereditary effects due to radiation exposure have been statistically detected . are termed stochastic effects because of their random nature. Stochastic effects may ensue, if an irradiated cell is modified rather than killed. Modified cells may, after a prolonged delay, develop into a cancer. The body's repair mechanisms make this a very improbable outcome at small doses. The probability of occurrence of cancer is higher for higher doses, but the severity of any cancer that may result from irradiation is independent of dose. If the cell damaged by radiation exposure is a germ cell whose function is to transmit genetic information to progeny, it is conceivable that hereditary effects of various types may develop in the descendants of the exposed individual. The likelihood of stochastic effects is presumed to be proportional to the dose received, and this without a dose threshold (Podgorsak et al 2003).

2.10 Radiation Safety for Operator Protection:

Occupational radiation protection considerations are often variations on the three cardinal rules of radiation protection: time, distance and shielding. Operators and other personnel remaining in the procedure room during fluoroscopically guided procedures are exposed to scattered radiation and are at risk of developing both stochastic effects and deterministic effects . The three most productive means of reducing radiation dose is:

2.10.1 Time: Minimize time spent in the radiation field. Use of “last-image-hold” and pulse fluoroscopy features is technical advantages in reducing the total time x-rays are produced.

2.10.2 Distance: Radiation dose rates increase or decrease according to the inverse square law.

2.10.3 Shielding: Use of lead garments, lead gloves, thyroid shields, leaded eyeglasses, lead drapes and clear leaded glass barriers between the patient and operator (Martin et al 2006).

2.11 Radiation protection devise:

It essential that radiation workers be protected when they need to work outside the protective cubicle. There are several essential protective devices , including protective clothing , which should be readily available for use in every X- ray room. These devices are use protected staff from receiving unnecessary radiation dose (Horner et al 2009).

2.11.1 Lead rubber aprons:

Radiation workers such as radiographers ,radiological technologists and radiologist remain in the protected area during exposure. When this is not possible , they should be provided with lead rubber aprons of at least 0.25 mm lead equivalence . If the stand within one meter of the X- ray tube or patient when the unit is operated at tube voltage above 100Kv ,they should wear protective lead rubber aprons of at least 0.35 mm lead equivalence Lead rubber aprons are available as single-sided or double – sided (Horner et al 2009).

2.11.2 Lead rubber gloves:

According to the ICRP publication 57, lead rubber gloves should be at least 0.35 mm lead equivalence. Gloves should be used to protect workers hands when placed in close proximity or under the primary beam (Horner et al 2009).

2.11.3 Thyroid shields:

The thyroid gland is relatively sensitive to ionizing radiation .Therefore , it is recommended to use a radiation protection device whenever possible . The are several type of shields (Horner et al 2009).

2.11.4 Personnel monitoring:

Even when radiation protection techniques and engineering controls are in place to reduce personnel exposure, individual dose monitoring is required.

Badges are assigned to an individual and must not be shared.

A badge designed to measure the whole body (including head) should be worn at the collar outside the lead apron (Writng et al 2005)

Figure(2.3):protective devices.

2.11.5 Protective drapes:

protective drapes suspended from the table and from the ceiling. Table-suspended drapes hang from the side of the patient table, between the under-table X-ray tube and the operator. They should always be employed, as they have been shown to substantially reduce operator dose . Unfortunately, they sometimes cannot be used if the X-ray gantry (C-arm) is in a steep oblique or lateral position. Ceiling-suspended shields, generally constructed of a transparent leaded plastic (Horner et al 2009).

Figure (2.4):protective drapes.

2.12 Previous study :

Yang et al (2015),was reported of Analysis of radiation risk to patients from intra-operative use of the mobile X-ray system (C-arm) .In this study a total of 374 surgical operations, conducted using a portable fluoroscopic X-ray system from January to March of 2013, were analyzed. Dose summaries produced by the General Electric C-arm and data elements in digital imaging and communications in the medicine header of Ziehm C-arm, fluoroscopy time were used to obtain dose-area product (DAP) and effective dose. Corresponding mean and maximum values were calculated, and the resulting data on the frequency of application, fluoroscopy time, DAP, and effective dose were compared and analyzed in terms of surgical specialty and operation types. Was results Orthopedic surgery was the most frequent with 165 cases (44.1%). The highest DAP value and effective dose were found in liver transplant among surgical specialty fields, with mean values of 2.90 ± 3.76 mGy·m2 and 58 ± 75.2 mSv, respectively (P = 0.0001). The highest DAP value and effective dose were observed in intra-operative mesenteric portography among types of surgery, showing mean values of 2.90 ± 3.81 mGy·m2 and 58.03 ± 76.24 mSv, respectively (P = 0.0001).Conclusion because DAP varies significantly across surgical specialties and types of operation, aggressive efforts to understand the effects of radiation dose is critical for radiation protection from intra-operative use of mobile C-arms.

Sulieman et al (2014)Reported of Evaluation of occupational and patient radiation dose in orthopedic surgery. A total of 76 patients in Medical Corps Hospital, Sudan were investigated (56 patients, 73.7% for DHS and 20 patients, 26.3% for and DCS procedures). Ethics and research committee approved the study and informed consent was obtained from all patients prior to the procedure . The collection of patient exposure parameters data was done using standard data collection sheet prepared for collection of patient exposure-related parameters Three orthopedists performed all procedures at the five departments. Groups of 3 TLDs were packed in transparent plastic envelopes and were attached with surgical tape to five sites on the operator body: The forehead, the neck, the chest : over the lead apron, the hand and the leg. Surgeons' wore a rubber lead apron of 0.5 mm lead equivalent as protection. from scattered radiation. A total of 76 procedures were investigated measured patients' doses in terms of mean ED (0.46mGy) values for both patients groups along with the exposure factors per procedures. for both groups are the same number (84 Kvp) tube voltage , (4.2 mAs). Orthopedic surgeons and staff are exposed to ionizing radiation during a variety of procedures. The radiation dose to orthopedic surgeons was shown to be well below the limits for prevention of tissue reactions Accurate use of radiation protection measures will reduce the dose and hence the probability of cancer risk for staff and patients .

Fred et al(2008) Reported of Effective Doses in Radiology and Diagnostic Nuclear Medicine. Medical uses of radiation have grown very rapidly over the past decade, and, as of 2007, medical uses represent the largest source of exposure to the U.S. population. Most physicians have difficulty assessing the magnitude of exposure or potential risk. Effective dose provides an approximate indicator of potential detriment from ionizing radiation and should be used as one parameter in evaluating the appropriateness of examinations involving ionizing radiation. The purpose of this review is to provide a compilation of effective doses for radiologic and nuclear medicine procedures. Standard radiographic examinations have average effective doses that vary by over a factor of 1000 (0.01–10 mSv).

Computed tomographic examinations tend to be in a more narrow range but have relatively high average effective doses (approximately 2–20 mSv), and average effective doses for interventional procedures usually range from 5–70 mSv. Average effective dose for most nuclear medicine procedures varies between 0.3 and 20 mSv. These doses can be compared with the average annual effective dose from background radiation of about 3 mSv.

Schmid et al (2006) reported of Effective dose of CT- and fluoroscopy-guided perineural/epidural injections of the lumbar spine a comparative study. The objective of this study was to compare the effective radiation dose of perineural and epidural injections of the lumbar spine under fluoroscopic guidance with respect to dose-reduced protocols. We assessed the radiation dose with an Alderson Rando phantom at the lumbar segment L4/5 using 29 thermo luminescence dosimeters. Based on our clinical experience, 4-10 CT scans and 1-min fluoroscopy are appropriate. Effective doses were calculated for CT for a routine lumbar spine protocol and for maximum dose reduction; as well as for fluoroscopy in a continuous and a pulsed mode (3-15 pulses/s). Effective doses under CT guidance were 1.51 mSv for 4 scans and 3.53 mSv for 10 scans using a standard protocol and 0.22 mSv and 0.43 mSv for the low-dose protocol. In continuous mode, the effective doses ranged from 0.43 to 1.25 mSv for 1-3 min of fluoroscopy. Using 1 min of pulsed fluoroscopy, the effective dose was less than 0.1 mSv for 3 pulses/s. A consequent low-dose CT protocol reduces the effective dose compared to a standard lumbar spine protocol by more than 85%. The latter dose might be expected when applying about 1 min of continuous fluoroscopy for guidance. A pulsed mode further reduces the effective dose of fluoroscopy by 80-90%.

Chapter Three

Materials and Method

3.1 Materials:

In the study used mobile c-arm fluoroscopy .

Table (3-1) shows the specification devices.

Hospitals	Manufactured date	Model	SR.NO	Power supply
A	Allengers2014	COR05-9	H-1403078	230VAC
B	Allengers2008	HFRev.0	2K807230-C	230VAC
C	Bengq 2015	HF49R	2K15080177-DC	230VAC

3.2 Subject of study:

In the study a total of 91patients from different orthopedic surgery used mobile c-arm fluoroscopy form patients different (gender , age ,weight and hight).

3.3 place of study and duration :

From three hospitals in Khartoum state. Of period five month from July to November of 2018.

3.4 Data collection:

The data were collected from different hospitals in Khartoum state. From different orthopedic surgery used mobile c-arm fluoroscopic ,number of type bone surgical (external fixation ,disc removal ,plate hip, plate knee, nail , DHS…..) .The collected data sheet based (age, gender , weight, hight , kvp, mAs and FFD).

3.5 Methods of dose calculation:

In the study for the these calculation effective dose and entrance surface air kerma from patients used mobile c-arm fluoroscopy in surgical room from different orthopedic surgery. First to obtained formation for the patients data some variables (age , gender, weight and hight). The different data patients and orthopedic surgery to lead different position angle mobile c-arm and position x-ray generator. Second moved mobile c-arm to located near for the patient position .Third choose suitable positioned to the generator and image intensifier because to obtained good image inside bone. Forth selected suitable angle and adjusted suitable kilo voltage value (kvp) and adjusted tube current (mA) automatic. During surgical to obtained for the patient was pulsed mode and recorded time (s) automatic in the panel equipment to obtained distance between patient and x-ray tube (FFD).

Dose calculation:

$$ESAK = OP(KV/80)^2 \ mAs \ (100/FSD) \ BSF.$$

$$ED = ESAK*0.92.$$

3.6 Data analysis:

The data were analyzed by statistic analysis , which all the obtained were used to camper between three hospitals in Khartoum state .

Chapter Four

Results

4.1 Results

Table (4-1) shows the statistics analysis a total of 91patients form orthopedic surgery.

Variables	Mean	Median	STD	Min	Max	3dQuartile
Age yrs	47.55	45.00	23.964	2	90	70.00
BMI	32.746	30.382	12.3838	10.4	72.00	38.462
Kv	59.22	55.00	12.113	43	90	86.00
mAs	9.00	6.00	5.528	3	25	14.00
FFD	82.25	80.00	11.673	40	100	90.00
ESAK	.3164	.1800	.29769	.03	1.27	.5013
ED	.2911	.1656	.27387	.03	1.16	.4612

Table (4-2) shows the statistics analysis of male patients.

Variables	Mean	Median	STD	Min	Max	3dQuartile
Age yrs	43.64	45.00	23.357	2	90	60.00
BMI	30.884	28.889	12.7021	13.9	72.0	33.333
Kv	59.84	58.00	12.583	43	90	68.00
mAs	9.44	7.00	5.659	3	25	15.00
FFD	84.36	80.00	10.931	40	100	90.00
ESAK	.3269	.1875	.30283	.03	1.27	.5039
ED	.3008	.1725	.27860	.03	1.16	.4636

Table (4-3) show the statistics analysis of female patients .

Variables	Mean	Median	STD	Min	Max	3dQuartile
Age yrs	53.53	57.50	23.961	7	90	71.50
BMI	35.590	37.619	11.4742	43	90	68.75
Kv	58.28	55.00	11.468	43	90	68.75
mAs	8.33	5.00	5.329	3	25	12.75
FFD	79.03	80.00	12.178	50	100	90.00
ESAK	.3003	.1778	.29317	.04	1.11	.4840
ED	.2763	.1636	.26927	.03	1.02	.4453

Hospital A:

Table (4-4) show the statistics analysis a total of patients form orthopedic surgery.

Variables	Mean	Median	STD	Min	Max	3dQuartile
Age yrs	49.73	45.00	21.544	18	90	70.75
Kv	58.93	55.00	13.062	43	90	70.00
mAs	8.93	5.00	5.317	3	20	15.00
FFD	85.67	90.00	7.739	70	100	90.00
ESAK	.2863	.1427	.27297	.03	1.01	.4699
ED	.2634	.1313	.25113	.03	.93	.4323

Table (4-5) shows the statistics analysis of male patients

Variables	Mean	Median	STD	Min	Max	3dQuartile
Age yrs	52.50	45.00	21.429	25	90	73.75
Kv	62.63	65.00	14.292	45	90	70.00
mAs	11.00	12.50	5.692	3	20	15.00
FFD	85.63	90.00	7.274	70	100	90.00
ESAK	.3830	.3525	.30700	.03	1.01	.6265
ED	.3524	.3243	.28244	.03	.93	.5764

Table (4-6) shows the statistics analysis of female patients .

Variables	Mean	Median	STD	Min	Max	3dQuartile
Age yrs	46.57	49.50	22.030	18	82	63.25
Kv	54.71	52.50	10.440	43	75	62.50
mAs	6.57	5.00	3.797	3	15	8.50
FFD	85.71	90.00	8.516	70	100	90.00
ESAK	.1759	.1071	.18116	.04	.62	.2319
ED	.1618	.0985	.16667	.03	.057	.2133

Hospital B:

Table (4-7) shows the statistics analysis a total of patients form orthopedic surgery.

Variables	Mean	Median	STD	Min	Max	3dQuartile
Age yrs	49.89	50.00	26.783	13	90	72.00
Kv	59.30	57.00	12.284	43	90	68.00
mAs	9.85	7.00	6.286	3	25	15.00
FFD	83.89	80.00	11.036	60	80	90.00
ESAK	.3513	.1799	.33230	.03	1.15	.5513
ED	.3232	.1655	.30572	.03	1.06	.5072

Table (4-8) shows the statistics analysis of the male patients .

Variables	Mean	Median	STD	Min	Max	3dQuartile
Age yrs	39.44	34.00	23.185	13	80	58.75
Kv	57.72	56.00	12.865	43	90	67.25
mAs	9.06	6.00	5.965	3	18	15.25
FFD	87.78	90.00	9.271	70	100	96.25
ESAK	.2997	.1304	.32238	.03	1.15	.5493
ED	.2758	.1200	.29659	.03	1.06	.5054

Table (4-9) shows the statistics analysis of female patients .

Variables	Mean	Median	STD	Min	Max	3dQuartile
Age yrs	70.78	72.00	21.277	20	90	87.50
Kv	62.44	60.00	11.069	45	80	72.50
mAs	11.44	10.00	6.966	5	25	16.50
FFD	76.11	80.00	10.541	60	90	85.00
ESAK	.4543	.5039	.34656	.06	1.11	.6929
ED	.4180	.4636	.31884	.06	1.01	.6374

Hospital C:

Table (4-10) shows the statistics analysis a total of patients form orthopedic surgery.

Variables	Mean	Median	STD	Min	Max	3dQuartile
Age yrs	47.15	45.00	18.465	15	77	61.25
Kv	59.41	55.00	11.455	43	90	66.25
mAs	8.38	6.50	5.135	3	25	12.00
FFD	77.94	80.00	13.823	40	100	90.00
ESAK	.3152	.2001	.29562	.03	1.27	.4651
ED	.2900	.1814	.27197	.03	1.16	.4279

Table (4-11) shows the statistics analysis of male patients.

Variables	Mean	Median	STD	Min	Max	3dQuartile
Age yrs	44.62	45.00	17.870	15	75	60.00
Kv	59.52	55.00	11.111	43	90	67.50
mAs	8.57	7.00	5.390	3	25	12.00
FFD	80.48	80.00	13.500	40	100	90.00
ESAK	.3074	.1875	.29155	.03	1.27	.4651
ED	.2828	.1725	.26822	.03	1.16	.4279

Table (4-12) show statistics analysis of female patients.

Variables	Mean	Median	STD	Min	Max	3dQuartile
Age yrs	51.23	45.00	19.400	18	77	70.00
Kv	59.23	55.00	12.451	47	90	67.50
mAs	8.08	5.00	4.890	4	18	13.00
FFD	73.85	70.00	13.868	50	90	90.00
ESAK	.3277	.2127	.31368	.06	1.03	.4452
ED	.3015	.1957	.28857	.05	.95	.4096

Table (4-13) show statistics analysis effective dose (ED) a total of patients in orthopedic surgery from three hospitals

Hospital	**Mean**	**Median**	**STD**	**Min**	**Max**	**3dQuartile**
A	.2634	.1313	.25113	.03	.93	.4323
B	.3232	.1655	.30572	.03	1.06	.5072
C	.2900	.1841	.27197	.03	1.16	.4279

Table (4-14) show statistics analysis mean effective dose a total of patients ,and mean ED national and international studies and international organizations

Present study 2018	**Sulieman2014**	**Yang 2015**	**ICRP 2013**	**IAEA 2011**
0.292 mSv	0.46 mSv	2.90 mSv	1.3 mSv	1-3 mSv

Chapter Five

Discussion , Conclusion and Recommendation

5.1 Discussion:

This study has been done three hospitals in Khartoum state. The main objective was to calculate entrance surface air kerma and effective dose for all patients from orthopedic surgery used mobile c-arm fluoroscopy and compared between three hospitals.

For each patient all the following parameters were recorded mobile c-arm data (kv, mAs and FFD) , and patient data (age , gender ,weight and hight). Table (4-1) showed a total of 91 patients form orthopedic surgery .mean patients age was found to be (47.55 yrs) was wide rang (2 to 90) yrs . these variation can be attributed to patient BMI and duration of procedure , was found mean BMI (32.74) was wide range (10.0 to72) , mean kv (59.22) was wide range (43 to 90), mean mAs (9) was different between min (3) and max (25) ,mean FFD was (82.25 cm) was variation range (40-100) ,The mean all patients ESAK was found (0.316) was wide range (0.03 to 1.27) and mean ED (0.291mSv), median ED (.165mSv), was different between min (0.03) and max (1.16) and 3dQuartile ED was found (0.461 mSv).

Compared results table (4-2)and table (4-3)showed between male and female all the patients , the mean age was found of male (43.64 yrs) and female (53.53 yrs), the wide variation can be attributed to different BMI between male and female ,was found mean BMI of male (30.88) blow the mean female (35.28) . The mean value Kv and mAs of the male and female respectively kv(59.84) , mAs (9.44) kv

(58.28) , mAs(8.33) to close value. 3dQauartile male and female the same value (90) and mean ESAK of male (0.326), mean ED (0.300mSv) higher than female mean ESAK (0.300) ,mean ED (0.276mSv).

Hospital A to compared between male and female . Table (4-5) and table (4-6) showed, the values age min to max of male (25 to 90) yrs and female (18 to 82) yrs thesis lead different mean , median and STD. The mean value kv and mAs male and female respectively kv(62.63) and mAs (11), kv (54.71)), mAs (6.57) was wide variance value ,and same mean value FFD (85cm) , was found value the male mean ESAK (0.383) ,mean ED(0.352mSv) higher than value of female mean ESAK (0.175), mean ED (0.161mSv).

Hospital B to compared between male and female .Table (4-8)and table (4-9) showed ,The male mean kv(57.72) ,mAs (9.06) and FFD(87.78cm) was big variance value the female mean kv(62.44), mAs (11.44) and FFD(76.11cm) and 3dQuartile was different values of male was found (90) and female (96.25), was found value the mean male ESAK (0.299), mean ED (0.275mSv) lower than female mean ESAK(0.454), mean ED(0.418mSv)was big variance.

Hospital C to compared between male and female .Table (4-11)and table (4-12) showed , the values age min and max to close of male was (15 to 7)yrs and female (18 to 77) yrs , was found mean age of male (44.62 yrs) was less different of female was mean age (51.32 yrs),The mean kv(59) and mAs(8) the same value two gender , was found min and max FFD of male was (40 to 100) cm and female (50 to 90) cm to result to close, value the mean of male ESAK (0.307) ,ED (0.282mSv) lower than female mean ESAK (0.327) ,ED (0.301mSv) was wide variance.

Compared were result between three hospitals (A , B and C) were different patients male and female .Table (4-4), table(4-7) sand table (4-10) showed, the mean age respectively hospitals was founded (49.73 yrs) ,(49.89 yrs)and (47.15 yrs) the values to very close . Mean value kv respectively hospitals was found (58.93),(59.30) and (59.41) the same number ,also mean mAs (8.93),(9.85) and (8.83) was very close number . mean FFD hospital A was found (85.67cm) higher than hospital B (83.89 cm) and hospital C (77.94 cm) .The mean value hospital A ESAK(0.286) , lower than hospital B mean ESAK (0.351) ,and hospital C mean ESAK(0.315) .

Table (4-13) showed effective dose(ED) was found in three hospitals and was compared between them , the mean was found for hospital A (.263mSv) lower than hospital B (.323mSv) also hospital C (.290 mSv), the median was found hospital A (.131mSv)lower than hospital B (.165mSv) and hospital C (.184mSv) and STD hospital A was found (.251) lower than hospital B (.305) and hospital C (.271mSv). the min values was the same for three hospitals (.03mSv) and max values to very close was found hospital A (.93mSv) , hospital B (1.06mSv) also hospital C (1.16mSv). result 3dQuartile the hospital B was found (.507) higher than hospital A and hospital C to value was the same (.43).

Table (4-14) showed mean ED was found in three hospital (0.299mSv), compered were result (0.29mSv) lower than mean ED national (Sulieman 0.46mSv) and the values mean ED international(Yang 2.90mSv) and lower than mean ED ICRP(1.3mSv) also lower than IAEA(1to3mSv).

5.2 Conclusion:

This study aimed to evaluation of patients radiation dose in orthopedic surgery in Khartoum state . A total of 91 patient from orthopedic surgery conducted using mobile c-arm fluoroscopic from three hospitals ,of period from July to November of 2018. To obtained formation of patients during orthopedic surgery used mobile C-arm fluoroscopy ,to recorded the demographic data (gender, age ,weight, hight).

The results presented as mean ± SD were the mean of ESAK was (mean ±0.31 SD) and mean of ED found (mean ±0.29 SD), and the mean ESAK(0.32), mean ED (0.30 mSv) of male higher than female mean ESAK (0.30) mean ED(0.27 mSv) .

Compared the dose between all hospitals found that the dose in hospital B (0.32 mSv) was higher than the dose in hospital C (0.29 mSv) and hospital A (0.26 mSv). The mean effective dose in present study (0.29 mSv) was lower than mean effective dose from national and international studies (0.46 mSv) and (2.90mSv), and international organizations ICRP (1.3 mSv) and IAEA (1-3 mSv). So the study recommended that the patients should be positioned in suitable distance from the x-ray tube to minimize patient doses .

5.3 Recommendation:

- Increase number of hospitals due to get more accurate result.
- Increase number of patients to give more significant to your result.
- The image intensifier input should be positioned as close to the patient as practicable. This result in lower patient dose and sharper image.
- Effective dose depends on x-ray fields sizes .Keeping the x-ray field as small as possible by using collimators will decreases dose to both patient and staff.
- For c-arm mobile fluoroscopy units the patient should be positioned as suitable from the x-ray tube to minimize patient entrance dose .

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Appendix:

Appendix A:

Data collection sheet

Number	Gender	Age yrs	Weight kg	High cm	Kv	mAs	FFD
1							
2							
3							
4							

Appendix B:

C-arm machines image of fluoroscopy

Figure show moblie C-arm fluoroscopy

Figure show moblie C-arm fluoroscopy

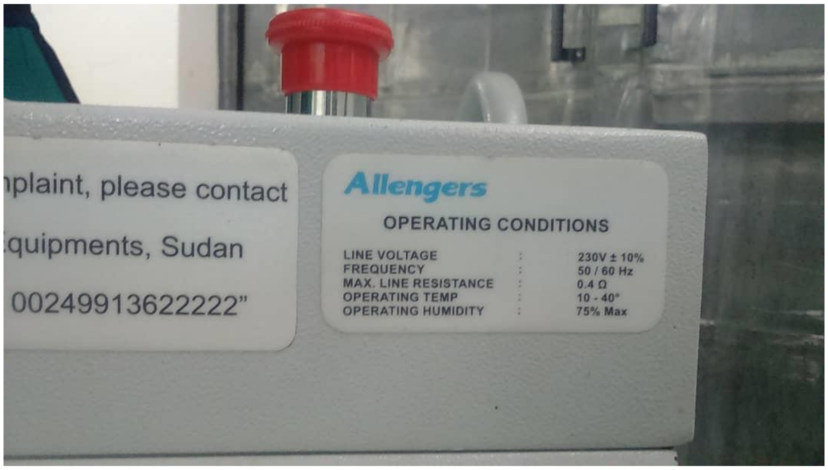

Figure show specifiction devies moblie C-arm fluoroscopy

Figure show control panel

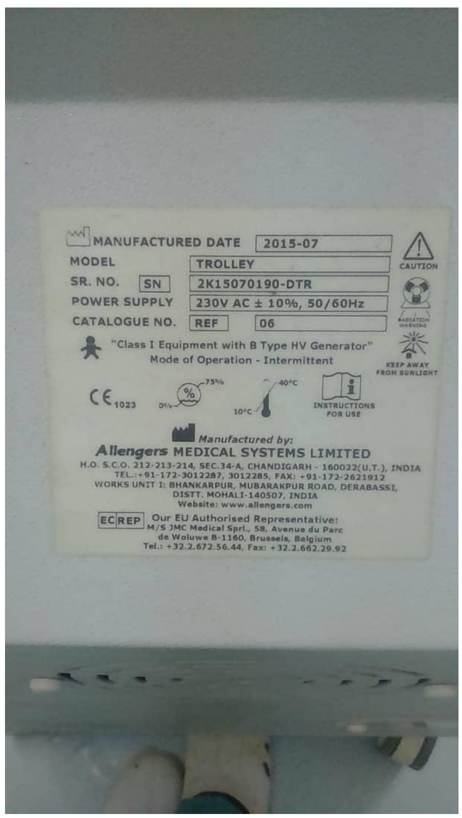

Figure show specification genertor