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Estimation of Entrance skin dose (ESD) for pediatric Chest X-ray examination

تقدير الجرعة الداخلة للجلد للأطفال عند التصوير الإشعاعي للصدر

Thesis submitted for partial fulfillment for the requirements of Master degree in Medical Physics

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الآية

قال تعالى:

"واصبر لحكم ربك فإنك بأعيننا وسبح بحمد ربك حين تقوم"

(سورة الطورالآيه 48)

Dedication

I dedicate this thesis:
To My beloved father who has supported me throughout my life

To the dearest of all, my mother for her endless support, guidance and encouragement

To my brothers who gave me all the love and support

To all the doctors who taught and directed me in my master program

To all my friends and colleagues

Acknowledgment

First of all I would like to thank Allah who's without his mercy, blessing and his kind to me I was never be able to finish this work.

Then I would like to express my sincere gratitude to my supervisor **D r: Hussein Ahmad Hassan** for his suggestion, patient, guidance, encouragement, cooperation and supervision of this work.

I am also so grateful to every person helped me in gathering different information, collecting data and guiding me from time to time in making this project.

Contents

Chapter three: Material and method

Abstract

This Study was performed to evaluate radiation Entrance skin dose ESD for pediatric patients undergoing chest X-ray examination in three selected centers in khartoum state (A, B and C center) which use Computed Radiography (CR) unit. The exposure parameters (kV, mAs and FSD) were chosen for each age category of pediatric from 0-15 years , then the ESD was calculated -by using the Microsoft excel - for each category in the three hospitals and compared with the reference dose level and some previous studies.

In A center, the ESD at the ages ((0-5), (6-10),(11-15)) years found to be(25.2,40.7,125.2) µGy, In B center the ESD at the ages((0-5),(6-10),(11-15)) years found to be(33.7,56.8,146)µGy and In C center the ESD for the ages ((6-10), (11-15)) years was (31.4, 114.5) µGy.

The final results showed that The ESD depends and changes with the exposure parameters (KV & mAs) and changes with age.

The ESD in the three centers is within the reference level and lower than the previous studies, also Variations were observed in ESD values among hospitals under study. From this study we recommended that for all x-ray equipment should be regular maintenance and quality control tests and to standardize the exposure parameters in pediatric imaging.

ملخص الدراسة

أجريت هذه الدراسه لحساب الجرعه الداخلة للجلد للمرضى الاطفال اللذين يخضعون لفحص التصوير الاشعاعي للصدرفي ثلاث مراكز داخل ولاية الخرطوم (أ ,ب و ج) وقد تم اختيار عوامل التعرض (المسافه بين السطح والجهاز , ومضروب التيار ف الزمن و الجهد لكل فئه عمريه ما بين 15-0 سنه ثم تم حساب الجرعه (kv,mAs FSD)(بالكيلو فولت الداخلة للجلد عن طريق برنامج مايكروسوفت اكسيل لكل فئه عمريه في كل مستشفى,في المركز أ وجد أن الجرعة الداخلة للجلد للأعمار((0-5),(6-10),(11-15))سنة كانت (

وفي المركز ب وجد أن الجرعة الداخلة للجلد للأعمار((0-5),(µGy,(22.2,40.7و 125.2

اما المركز ج فكانت الجرعه الداخلة,µGy (6-10),(11-15))سنة هي (33.7,56.8,146

31.4,114.5) سنه((6-10),(11-15))للجلد للأعمار) (µGy.

وجد ان الجرعه الداخلة للجلد تتناسب طرديا مع الجهد و مضروب التيار والمسافه بين السطح للجهاز وكذلك تزيد مع العمر ووجد ان الجرعه الداخلة للجلد في بعض المراكز أعلى من الاخرى كما قورنت هذه النتائج ببعض الدراسات السابقه والقيم المرجعيه ووجد ان الجرعه الداخلة للجلد في هذه الدراسه اقل من الدراسات السابقه ولا تتعدى القيم المرجعيه من خلال هذه الدراسه نوصي بالقيام بالمزيد من الدراسات حول تقليل الجرعات الاشعاعيه وتوحيد عوامل التعريض والقيام باختبارات دوريه لضبط الجوده.

Chapter One

1.1Introduction:

The children chest radiography is the most frequent exam ordered, or referred to the department of Radiology Pediatric patients are a specific group regarding radiation protection in radiology because of their elevated risk for radiation detriment. As pediatric patients have higher probability for late radiation effects, they are assumed to be 2_3 times more radiation sensitive compared to adults, since the longer expected life span is combined with higher radiation sensitivity of the developing organs. To be able to keep doses as low as reasonably achievable (ALARA), fundamental knowledge of factors concerning patient doses is needed. Pediatric X-ray examinations comprise approximately 10% of all radiological examinations, which may result in situations in which pediatric examinations are not well optimized due to a lack of knowledge in choosing the proper acquisition parameters. Many departments do not use recommended radiographic parameters for neonates and children. Furthermore, wide variations have been found in techniques, equipment performance and radiation doses among different hospitals over the world. The study first attempt to measuring ESDs for children in the area of study, the entrance skin dose ESD, in diagnostic radiology permits the radiation exposure of diagnostic procedures to be quantified and evaluated. Although it is not a rigorous physical quantity, it provides practical information for referring doctors to clarify which modality is the most appropriate choice concerning the application of the ALARA principle for any particular clinical problem, measuring the ESD also add to the pool of data available in national records for general use it

Will provide guidance on where efforts on dose reduction will need to be directed to fulfill the requirements of the optimization process and serve as a reference for future work, as well as provide information for comparison with patients of the same category in other countries.

Chest examinations in pediatric patients using computed radiography (CR) provide high image quality with lower ESD comparing with other radiological equipment. (M.hardy et al,2003)

1.2 Problem of the study:

Pediatric examinations are not well optimized due to a lack of knowledge in choosing the proper acquisition parameters.

1.3 Objectives:

1.3.1General objectives:

To estimate entrance skin dose (ESD) for the pediatric patients who is exposed to radiation during chest X-ray examination**.**

1.3.2 Specific objectives:

- Evaluate entrance surface dose (ESD).

-Optimization of radiation dose to the pediatric population.

-Evaluate the results with the literature.

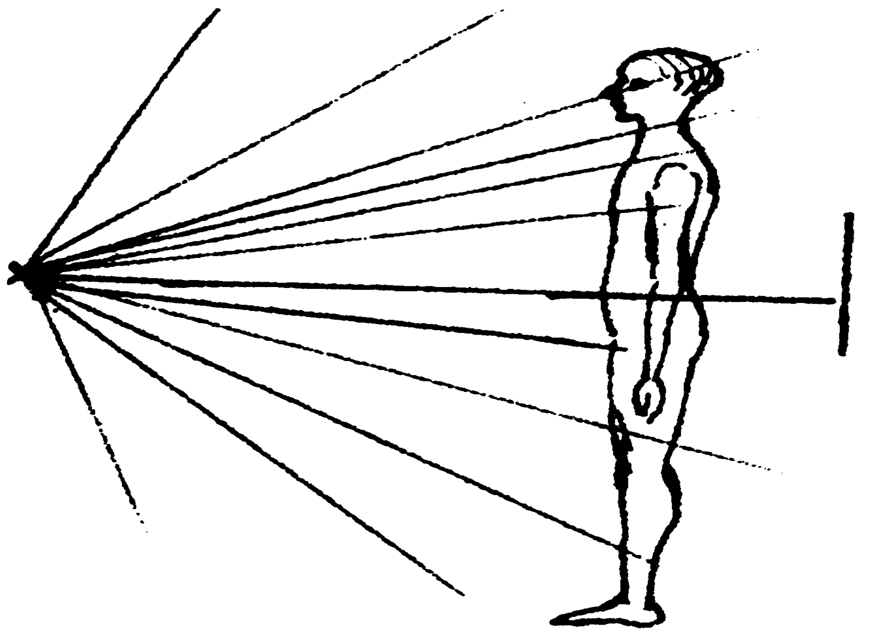
1.4. Thesis outlines:

This study falls into five chapters, Chapter one, which is an introduction, consists of general objectives of the study ,specific objectives, the problem and thesis outlines, chapter two consists of theoretical study and previous studies, Chapter three consists of material and method of data collection, Chapter four consists of the collected results . Chapter five consists of discussion of results, conclusion, recommendations and references.

Chapter Two
Background &literature review

Introduction and overview: 2.1

In X-ray diagnostics, radiation that is partly transmitted through and partly absorbed in the irradiated object is utilized. An X-ray image shows the variations in transmission caused by structures in the object of varying thickness, density or atomic composition. (carl et.al 1996)



Figure(2.1) , the necessary attributes for X-ray imaging are shown: X-ray source, object (patient) and a radiation detector (image receptor).

2.1.1. The nature of x-rays:

X-rays are like radio waves and visible light electromagnetic radiation. X-rays, however, have higher frequency, *n*, and shorter wavelength, *l*, than light and radio waves. The radiation can be considered as emitted in quanta, photons, each quantum having a well-defined energy, h*n* , where h is a physical constant, Planck's constant, and *n* is the frequency. The energy of X-ray photons are considerably higher than those of light.

A number of the phenomena, which are observed with X-rays are most conveniently described by the wave properties of the radiation while other phenomena can be more easily understood if the X-rays are considered as being composed of particles (photons) with well-defined energies and momentum. The rest mass of a photon is zero. This means that photons can never be found at rest. All photons move at the same velocity, c, in a vacuum, given by c = 2.998 108 m/s. (Carl et.al 1996).

2.1.2. x-rays tube:

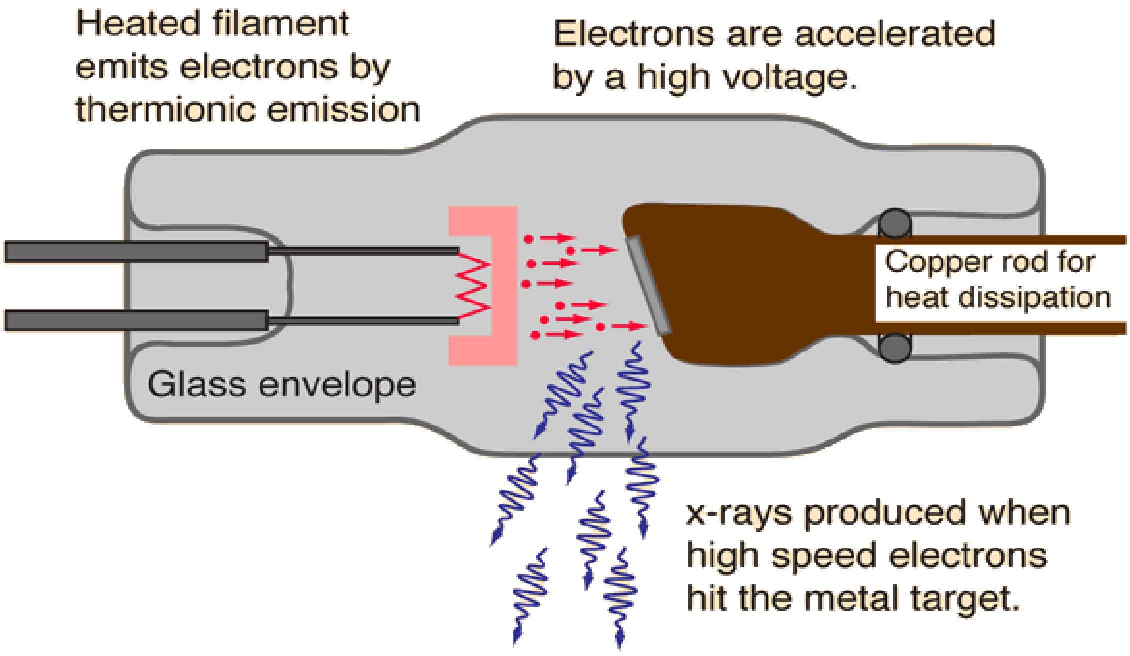


Figure (2.2) the x-ray tube components

X-rays for medical diagnostic procedures or for research purposes are produced in a standard way: by accelerating electrons with a high voltage and allowing them to collide with a metal target. X-rays are produced when the electrons are suddenly decelerated upon collision with the metal target; these x-rays are commonly called brehmsstrahlung or "braking radiation". If the bombarding electrons have sufficient energy, they can knock an electron out of an inner shell of the target metal atoms .Then electrons from higher states drop down to fill the vacancy, emitting x-ray photons with precise energies determined by the electron energy levels. These x-rays are called characteristic x-rays. (hyperphysics.com)

2.1.3. Characteristic X-Rays:

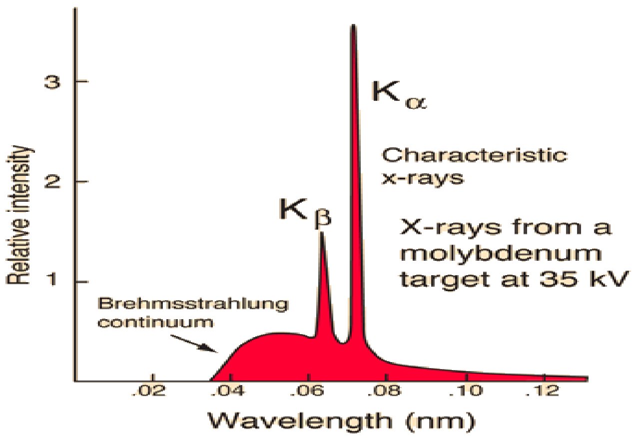


Figure (2.3) characteristic x-rays

Characteristic x-rays are emitted from heavy elements when their electrons make transitions between the lower atomic energy levels. The characteristic x-ray emission which is shown as two sharp peaks in the illustration at left occur when vacancies are produced in the n=1 or K-shell of the atom and electrons drop down from above to fill the gap. The x-rays produced by transitions from the n=2 to n=1 levels are called K-alpha x-rays, and those for the n=3→1 transition are called K-beta x-rays.

Transitions to the n=2 or L-shell are designated as L x-rays (n=3→2 is L-alpha, n=4→2 is L-beta, etc.). The continuous distribution of x-rays which forms the base for the two sharp peaks at left is called "bremsstrahlung" radiation.

X-ray production typically involves bombarding a metal target in an x-ray tube with high speed electrons which have been accelerated by tens to hundreds of kilovolts of potential. The bombarding electrons can eject electrons from the inner shells of the atoms of the metal target. Those vacancies will be quickly filled by electrons dropping down from higher levels, emitting x-rays with sharply defined frequencies associated with the difference between the atomic energy levels of the target atoms. The frequencies of the characteristic x-rays can be predicted from the Bohr model. Moseley measured the frequencies of the characteristic x-rays from a large fraction of the elements of the periodic table and produced a plot of them which is now called a "Moseley plot". Characteristic x-rays are used for the investigation of crystal structure by x-ray diffraction. Crystal lattice dimensions may be determined with the use of Bragg's law in a Bragg spectrometer. (hyperphysics.com)

2.1.4. Bremsstrahlung X-Rays:

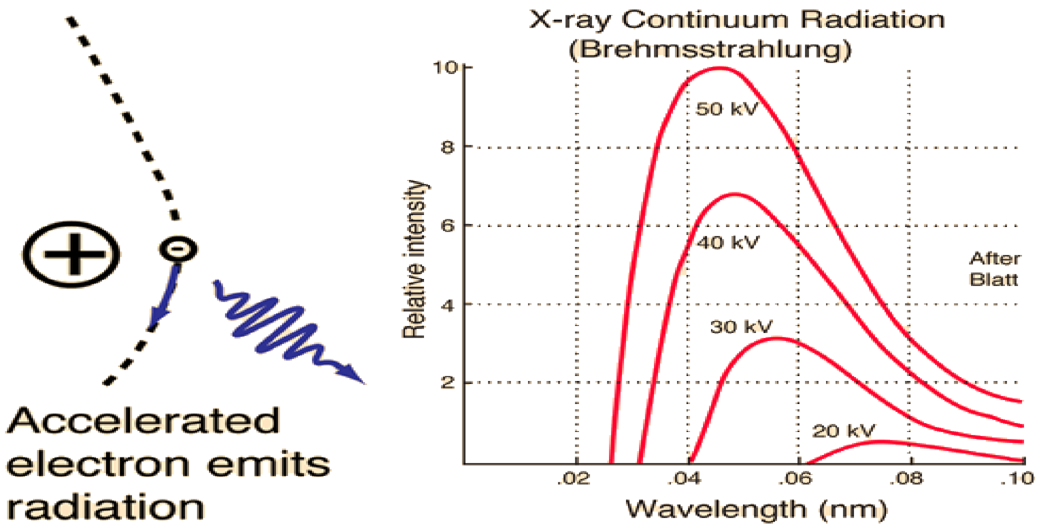


Figure (2.4) **Bremsstrahlung x-rays**

"Bremsstrahlung" means "braking radiation" and is retained from the original German to describe the radiation which is emitted when electrons are decelerated or "braked" when they are fired at a metal target. Accelerated charges give off electromagnetic radiation, and when the energy of the bombarding electrons is high enough, that radiation is in the x-ray region of the electromagnetic spectrum. It is characterized by a continuous distribution of radiation which becomes more intense and shifts toward higher frequencies when the energy of the bombarding electrons is increased. The curves above are from the 1918 data of Ulrey, who bombarded tungsten targets with electrons of four different energies. The bombarding electrons can also eject electrons from the inner shells of the atoms of the metal target, and the quick filling of those vacancies by electrons dropping down from higher levels gives rise to sharply defined characteristic x-rays. (hyperphysics.com)

2.2. Interaction of x-rays with matter:

X-rays possess intrinsic energy that may be imparted to the matter they interact with. That interaction takes place as either absorption (transfer of energy from the X-ray photon to the absorbing material) or scattering (in which the X-ray photon is “redirected” by interaction with the scattering material). The process of scattering is the primary process responsible for diffraction, but both processes (that are, in many ways, interdependent) result in the production of potentially damaging secondary radiation. That radiation is capable of producing significant short- and long-term health effects in the event of exposure to human tissue.

The X-rays produced for diffraction analysis by an X-ray source consist of the characteristic radiation (dependent on the anode target) plus the continuous spectrum.

The energy of X-rays and their wavelength are inversely proportional (higher energy = lower wavelength), and the continuous spectrum minimum wavelength decreases as the accelerating voltage (kV) of the X-ray source increases. It is important to understand that an increase in filament current (ma) and kV (beyond the minimum value required to produce characteristic radiation for the target) will result in an increase in the intensity of the generated X-rays, but will not change their energy (JAMES 2012).

2.2.1. Energy Transfer:

There are two basic types of energy transfer that may occur when X-rays interact with matter:

- Ionization, in which the incoming radiation causes the removal of an electron from an atom or molecule leaving the material with a net positive charge.
- Excitation, in which some of the X-ray's energy is transferred to the target material leaving it in an excited (or more energetic) state.

Theoretically there are twelve processes that can occur when X-rays interact with matter, but only three of these processes are important. These processes are:

- The photoelectric effect

- The Compton Effect and
- Pair Production (JAMES 2012).

2.2.2. The Photoelectric Effect:

Simply stated, the photoelectric effect occurs when photons interact with matter with resulting ejection of electrons from the matter. Photoelectric (PE) absorption of x-rays occurs when the x-ray photon is absorbed resulting in the ejection of electrons from the atom. This leaves the atom in an ionized (i.e., charged) state. The ionized atom then returns to the neutral state with the emission of an x-ray characteristic of the atom. PE absorption is the dominant process for x-ray absorption up to energies of about 500 KeV. PE absorption is also dominant for atoms of high atomic numbers.

The photoelectric effect is responsible for the production of characteristic x-rays in the x-ray tube, but the process is also important as a secondary process that occurs when x-rays interact with matter. An x-ray photon transfers its energy to an orbital electron, which is then dislodged and exits the atom at high speed with a kinetic energy equal to:

$$KE = Ex - P$$

Where KE is the kinetic energy of the photoelectron Ex is the energy of the incident X-ray photon P is the energy required to remove the electron. This is equivalent to its binding energy in the atom.

The energy equivalent of the rest mass of an electron is moc2, and is equal to about 0.51 MeV (mo is the rest mass of an electron and c is the speed of light). When Ex is much lower than this value, the electron will exit at a high angle to the incident beam; when Ex is closer to this value, the electron will exit at close to parallel with the beam.

When the photoelectron is ejected, it has the capability, depending on its energy, to interact with subsequent electrons in other molecules or atoms in a chain reaction until all its energy is lost. If that interaction results in the ejection of an outer orbital electron, this is known as the Auger (au-jay) effect, and the electron called an Auger electron. The probability of producing a secondary photoelectron vs. an Auger electron is directly proportional to the KE of the photoelectron. (JAMES 2012).

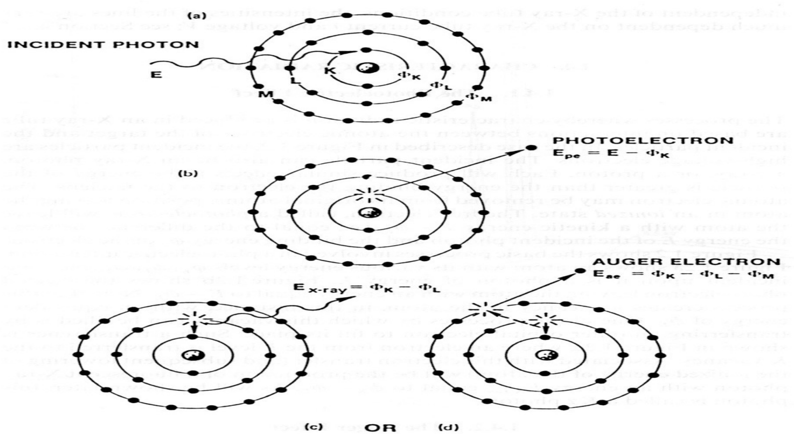


Figure (2.5) the production of photoelectric , In the diagram (a) shows the incident X-ray photon, (b) shows the production of a high-energy primary photoelectron. In (c) a lower energy electron moves into the vacated K-shell resulting in the production of an X-ray photon that leaves the atom, and in (d) the X-ray photon is absorbed by an outer shell electron resulting in the emission of an Auger electron.

2.2.3. The Compton Effect:

The Compton Effect or Compton scattering (C), also known a incoherent scattering, occurs when the incident x-ray photon ejects a electron from an atom and an x-ray photon of lower energy is scattered from the atom. Relativistic energy and momentum are conserved in this process1 and the scattered x-ray photon has less energy and therefore greater wavelength than the incident photon. Compton Scattering is important for low atomic number specimens. At energies of 100 keV -- 10 MeV the absorption of radiation is mainly due to the Compton Effect.

The Compton Effect will occur with very low atomic weight targets even at relatively low X-ray energies. The effect may be thought of as a scattering of the photons by atomic electrons. In the process, also called Compton scattering, the incident X-ray changes direction and loses energy, imparting that energy to the electron (now called a Compton electron). The Compton electron will typically interact with other atoms producing secondary ionizations. Since they possess relatively low energy, the x-rays produced will generally be low energy also.

The maximum possible energy, *E*, of a Compton electron (the “Compton edge”) is equal to:

$$E = \frac{E_X}{1 + 4\,E_X}$$

Where *Ex* is the energy of the incident photon . Qualitatively, it is easy to see that the Compton electrons will be significantly less energetic than photoelectrons for an equal value of *Ex*.

In x-ray diffraction, Compton scatter will contribute to the overall background in the x-ray data produced, but because of the relatively low energies of the incident x-rays and the higher mass of the specimens and specimen holders, the contribution will usually be very small (JAMES 2012).

2.2.4. Pair Production:

Pair Production (PP) can occur when the x-ray photon energy is greater than 1.02 MeV, when an electron and positron are created with the annihilation of the x-ray photon. Positrons are very short lived and disappear (positron annihilation) with the formation of two photons of 0.51 MeV energy. Pair production is of particular importance when high-energy photons pass through materials of a high atomic number.

Pair production is a rare process and only occurs at high X-ray photon energies with high atomic weight targets. It is virtually nonexistent at the low-energies involved in X-ray diffraction work. Pair production is impossible unless the incident X-rays exceed 1.02 MeV and does not become important until this exceeds about 2 MeV.

Pair production is not a significant process at the X-ray energies involved in X-ray diffraction (JAMES 2012).

Effects of ionizing radiation: 2.3

The deleterious effect ionizing radiation has on human tissue can be divided into two types: non-stochastic deterministic or stochastic effects.

2.3.1. Deterministic (Non-Stochastic) Effects:

Deterministic effects only occur once a threshold of exposure has been exceeded. The severity of deterministic effects increases as the dose of exposure increases. Because of an identifiable threshold level, appropriate radiation protection mechanisms and occupational exposure dose limits can be put in place to reduce the likelihood of these effects occurring.

Deterministic effects are caused by significant cell damage or death. The physical effects will occur when the cell death burden is large enough to cause obvious functional impairment of a tissue or organ.

Examples for deterministic effects:

- Skin Erythema/Necrosis/Epilation occurs 1 to 24 hours after 2 Sv have been received. Breakdown of the skin surface occurs approximately four weeks after 15 Sv have been received. Epilation is reversible after 3 Sv but irreversible after 7 Sv and occurs three weeks following exposure.

- Cataract occurs due to accumulation of damaged or dead cells within the lens, the removal of which cannot take place naturally. Cataract occurs after 2 to 10 Gy have been received, but may take years to develop.
- Sterility: Radiation can impair oocyte function, leading to impaired or non-fertility. The radiation dose required to have this effect decreases with age due to falling total oocyte numbers. Similarly, radiation exposure to the testes can result in temporary or permanent azoospermia. Permanent sterility occurs after 2.5 to 3.5 Gy have been received by the gonads.
- Radiation Sickness (correctly termed acute radiation syndrome) involves nausea, vomiting, and diarrhea developing within hours or minutes of a radiation exposure. This is due to deterministic effects on the bone marrow, GI tract, and CNS (imagewisely.com).

2.3.2. Stochastic Effects:

Current thinking is that stochastic effect occurrence follows a linear no-threshold hypothesis. This means that although there is no threshold level for these effects, the risk of an effect occurring increases linearly as the dose increases.

Stochastic effects occur due to the ionizing radiation effect of symmetrical translocations taking place during cell division.

Examples for stochastic effects:

- Cancer Over time, anecdotal evidence suggested that ionizing radiation could cause cancer. However, reliable evidence has only relatively recently become available. Data from the Radiation Effects Research Foundation on individuals exposed to radiation from the atomic bombs in Hiroshima and Nagasaki have shown an increased relative risk of developing malignancy (leukemia, oral cavity, esophagus, stomach, colon, lung, breast, ovary, urinary bladder, thyroid, liver, non-melanoma skin, and nervous system) as a result of radiation exposure. As such, multiple bodies, including the U.S. Department of Health and Human Services, have classified ionizing radiation as a human carcinogen (imagewisely.com).

- Hereditary Defects (e.g., Down syndrome) although the incidence of hereditary defects in patients exposed to radiation in Japan and Chernobyl have shown no increased evidence for hereditary defects, animal experiments would suggest that this risk does exist. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and ICRP propose a hereditary defect risk of between 0.3 to 0.8% per Sv. (imagewisely.com)

2.4. Radiation quantities & units:

For the purpose of radiation protection, dose quantities are expressed in three ways: absorbed, equivalent, and effective.

2.4.1. Absorbed dose:

When ionizing radiation penetrates the human body or an object, it deposits energy. The energy absorbed from exposure to radiation is called an absorbed dose.

The absorbed dose is measured in a unit called the gray (Gy). A dose of one gray is equivalent to a unit of energy (joule) deposited in a kilogram of a substance (CNSC 2012)

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2.4.2. Equivalent dose:

When radiation is absorbed in living matter, a biological effect may be observed. However, equal absorbed doses will not necessarily produce equal biological effects. The effect depends on the type of radiation (e.g., alpha, beta or gamma). For example, 1 Gy of alpha radiation is more harmful to a given tissue than 1 Gy of beta radiation. To obtain the equivalent dose, the absorbed dose is multiplied by a specified radiation weighting factor (wR). A radiation weighting factor (wR) is used to equate different types of radiation with different biological effectiveness. The equivalent dose is expressed in a measure called the sievert (Sv). This means that 1 Sv of alpha radiation will have the same biological effect as 1 Sv of beta radiation. In other words, the equivalent dose provides a single unit that accounts for the degree of harm that different types of radiation would cause to the same tissue. (CNSC 2012)

2.4.3. Effective dose:

Different tissues and organs have different radiation sensitivities For example; bone marrow is much more radiosensitive than muscle or nerve tissue. To obtain an indication of how exposure can affect overall health, the equivalent dose is multiplied by a tissue weighting factor (w_t) related to the risk for a particular tissue or organ. This multiplication provides the effective dose absorbed by the body.

The unit used for effective dose is also the sievert. (CNSC 2012)

2.5. Specific dosimetric quantities:

2.5.1. Entrance skin dose:

The entrance surface dose, ESD , is the Dose to air measured on the central beam axis at the position of the patient or phantom surface .

$$ESD = op_x (kv/80)^2 \times mAs \times (100/fsd)^2 \times BSF$$

Where (OP) is the output in mGy/ (mA s) of the X-ray tube ,(kV) is the the tube potential,(mA s) is the product of the tube current (in mA) and the exposure time(in s), (FSD) the focus-to-skin distance (in cm) and (BSF) the backscatter factor

Unit is gray (Gy) (IAEA, 2007).

2.5.2. Incident air kerma:

is the kerma to air from an incident X ray beam measured on the central beam axis at the position of the patient or phantom surface
Unit: J/kg. The name for the unit of kerma is gray (Gy) (IAEA, 2007).

2.5.3. Entrance surface air kerma:

The entrance surface air kerma, Ke, is the kerma to air measured on the central beam axis at the position of the patient or phantom surface.

The radiation incident on the patient or phantom and the backscattered radiation are included (IAEA, 2007).

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

2.6. Exposure factors:

- Tube voltage (kVp) determines the maximum energy in the bremsstrahlung spectrum and affects the quality of the output spectrum. In addition, the efficiency of x-ray production is directly related to tube voltage. Exposure is approximately proportional to the square of the kVp in the diagnostic energy range:

Exposure α Kv p^2

An increase in kVp increases the efficiency of x-ray production and the quantity and quality of the x-ray beam.

- The tube current (mA) is equal to the number of electrons flowing from the cathode to the anode per unit time. The exposure of the beam for a given kVp and filtration is proportional to the tube current.
- The exposure time is the duration of x-ray production. The quantity of x-rays is directly proportional to the product of tube current and exposure time (mAs). (Jerrold et.al 2001)

2.8. Computed Radiography (CR):

Computed Radiography refers to the use of storage phosphor imaging plates instead of the film screen combination used in traditional radiography. Imaging plates and processing systems have been developed and marketed by the same manufacturers who sell film, screens and chemical processing units. As a result the cassettes used in CR are often similar to the cassettes used in film screen systems, which means you can generally recognize which manufacturer has supplied the system by the cassettes used)qualityimage.com).

2.8.1. Advantages of computed radiography:

- Image quality comparable with to conventional screen-film systems.
- Wide dynamic range- ability to mage structures of different attenuation values (thorax and abd)
- Reduction of repeat exposures CR is compatible with most conventional x-ray systems.
-Increased savings: no film chemicals dark room and storage room required.
-Computer processing o f raw image: brightness , contrast , sharpness enhancement , zooming , measurements)qualityimage.com).

2.9. Previous studies:

Various researches have carried wide variations in pediatric x-ray examination in period.

K E M Mohamadain, L A R da Rosa, A C P Azevedo,MR N Guebel3,

M C B Boechat, and F Habani 2004,The aim of their work was to estimate the entrance skin dose (ESD), the body organ dose (BOD) and the effective dose (*E*) for chest x-ray exposure of paediatric patients in five large units, three in Sudan and two in Brazil, and to compare the results obtained in both countries with each other and with other values obtained by some European countries the entrance skin dose Results of mean ESD for the age interval 1–5 years and AP projection are: 66 μGy (Instituto de Pediatria e Puericultura Martag˜ao Gesteira—IPPMG Hospital), 41, 86 and 68 μGy (Instituto Fernandes Figueira —IFF Hospital), 161 μGy (Omdurman Hospital), 395 μGy (Khartoum Hospital) and 23 μGy (Ahmed Gasim Hospital). In the case of the IFF Hospital, the results refer, respectively, to rooms 1, 2 and for the six mobile equipments. The reference dose values given by the European Guidelines were exceeded in the Khartoum Hospital whilst in all the other hospitals results obtained were below CEC reference values and comparable with the results found in Sweden, Germany.

H. Osman, A. Elzaki , A. Abd Elgyoum, E.Abd Elrahim 2014, The objectives of this study were to evaluate Entrance skin dose (ESD) in pediatric CXR posterior-anterior (PA) and lateral (Lat) projection and also to estimate organs radiation doses.100 patients underwent chest x-ray, in Taif pediatric hospital in Taif, KSA, their age range from 0-15 years, The results of radiation dose for pediatric chest in this study matched and compatible with literature.

The EU1996 guide lines recommend 100μGy ESD for the pediatric chest

NRPB (22) guide lines recommend 50 μGy for pediatric at the ages 1year and 70 μGy at the ages 10years and 120 μGy at ages 15years.

Chapter Three
Material and method
. Materials: 3.1
3.1.1 Study population:

The study population consisted of all children between 1 month and 15 years .The planned number of patients was 50 For a chest examination

3.1.2 X-RAY MACHINE:

In the present study, three different models X-ray machines, from three centers were used as described in (Table 3.1)

Table 3 .1. Shows X-rays equipment's specifications:-

Center	Manufacturer	Type	Focal Spot (mm)	Filtration (mmAl)	Max KVp	Max mAs	Max time	Installation year

A	Toshiba	Fixed	0.5	1.0	150	500	2.2	2010
B	Toshiba	Fixed	1.2-0.6	1.11	150	640	1.6	2007
C	Shimadzu	Fixed	0.5	1.5	150	500	2.2	2005

3.1.3 CR units:

All the centers are using Fujifilm computed Radiography.

3.2. Method:

This study was carried out THREE centers in Khartoum state; included several CR machines. Information was collected for Each center with respect to the computed radiography unit, the ESD was calculated for the typical exposure parameters used for patients aged between 1 month and 15 years. The parameters were: peak tube voltage (kVp), exposure current-time product (mAs), focus-to-film distance (FSD).

3.2.1 Study duration:

The duration of study was 3 months according to the patient rate in the radiology centers from December 2015 up to February 2016.

3.2.2 Study place:

This study was carried out three hospitals in Khartoum state.

3.2.3 Dose calculation:

The following parameters were recorded age, weight, thickness and exposure parameters kV and mAs was changed according to the patient size, patient ESD was determined by using Microsoft Excel which calculate and report entrance surface dose. By determining the tube output data and exposure factors encountered. Using the equation below (Suliman 2008)

$$ESD = op_x (kv/80)^2 \times mAs \times (100/fsd)^2 \times BSF$$

Where (OP) is the output in mGy/ (mA s) of the X-ray tube, (kV) the tube potential,(mA s) the product of the tube current (in mA) and the exposure time(in s), (FSD) the focus-to-skin distance (in cm) and (BSF) the backscatter factor. The tube output, the patient anthropometrical data and the radiographic parameters (kVp, mA s, FSD and filtration) are initially inserted in the Microsoft excel.

Chapter Four
Results

Table (4.1) shows Radiographic parameters used in chest X-ray examinations of pediatrics patients in center A:-

ESD (μGy)	FSD cm	mAs	Kv	Exam	Number of patients	Age years

25.2	180	1±5	2±43	AP	24	5-0
40.7	180	2±5	2±45	PA	9	10-6
125.2	180	2±7	50	PA	1	15-11

Figure (4.1) shows the correlation between mAs and ESD for chest in center A.

Figure (4.2) shows the correlation between kV and ESD for chest in center A.

Table (4.2) Radiographic parameters used in chest X-ray examinations of pediatrics patients at center B:-

ESD (µGy)	FSD (cm)	mAs	Kv	exam	Number of patients	Age (years)
33.7	180	1±5	2±45	AP	8	5-0
56.8	180	2±5	2±50	PA	6	01-6
164	180	15	60	PA	1	11-15

Figure (4.3) shows the correlation between kV and ESD for chest in center B.

Figure (4.4) shows the correlation between mAs and ESD for chest in center B.

Table (4.3) Radiographic parameters used in chest X-ray examinations of pediatrics patients at center C:-

ESD (m Gy)	FSD (cm)	mAs (ma/sec)	Kv	Exam	Number of patients	age
31.4	180	2±5	2±45	PA	7	10-5
114.5	2±7	50	PA	PA	2	11-15

Figure (4.5) shows the correlation between Kv and ESD for chest in center C.

Figure (4.6) shows the correlation between mAs and ESD for chest in center C.

Figure (4.7) ESD Comparison between the three centers at different age categories

Chapter Five
Discussion, Conclusion and Recommendation

5.1. Discussion:

The ESD which calculated at certain Exposure parameters (kV, mAs, FSD) collected at each age in the specified centers, started with A, the patient ESD at the ages ((0-5),(6-10),(11-15)) years found to be(25.2,40.7,125.2) µGy as showed in table (4.1) .In B center the ESD at the ages((0-5),(6-10),(11-15)) years found to be(33.7,56.8,146)µGy as showed in table (4.2). In C center, the ESD for the ages ((6-10), (11-15)) years found to be (31.4, 114.5) µGy as showed in table (4.3). The above figures from (4-1) to (4-6) showed that the ESD increase with the age & the exposure parameters (Kv,mAs). The comparison between the three centers showed that the ESD in B center was greater than the other two centers as showed in figure (4-7) that may be due to old installation date and the absence of quality control. the ESD for the three centers was compared with previous studies (K .E.M.Mohamadain et al (2004)) and (H.Osman et al (2014)), the result showed that the ESD were higher than the resent study for all ages, this is probably due to the fact that the three centers in this study are modern hospitals with new equipment .and also could be due to the few data population in this study or due to the difference in dose calculation method and differences in exposure parameters used. .when the ESD compared with the reference level (NRPB (22), EU 1996 (23) the results found to be within the level.

5.2. Conclusion:

The ESD was higher in center B compared with the other two centers .The most of the estimated ESD values were within the range of reference level and lower than some previous studies .The ESD depends and changes with the exposure parameters (KV & mAs) and changes with age.

5.3. Recommendations:

-The pediatric radiography is a major medical issues, strategies must be done to reduce the Entrance skin dose for pediatric by following national guidelines for the dose level for protection issues.

- More local studies must be done about how to standardize the exposure parameters in pediatric imaging for ESD reduction and achieving the ALARA principle.

-training and equipment quality control is so important in pediatric radiology.

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Appendix

FSD	mAs	kv	Exam	weight	age	No
180	5	46	PA	12	6.5	1
180	5	43	AP	8.5	1.5	2
180	5	43	AP	7	2.4	3
180	5	45	PA	20	10	4
180	5	44	AP	9.5	1.7	5

180	5	42	AP	5	0.5	6
180	5	45	AP	8.5	1.5	7
180	5	45	AP	7	2.4	8
180	5	45	PA	20	10	9
180	5	45	AP	7.5	1.7	10
180	5	45	AP	9	1.9	11
180	5	45	AP	12	2.5	12
180	5	45	AP	12	2.5	13
180	5	45	AP	7	1	14
180	5	45	AP	12	3	15
180	5	45	AP	10	1.6	16
180	5	45	AP	4	0.8	17
180	5	45	AP	15.5	4	18
180	5	45	AP	8	0.7	19
180	5	45	AP	10.5	3	20
180	5	45	AP	17	5	21
180	5	43	AP	7	1.2	22
180	5	40	AP	7	0.5	23
180	5	45	AP	10.5	2.7	24
180	5	45	AP	14	5.4	25
180	7	45	AP	12	5	26
180	15	57	AP	36	14	27
180	10	50	PA	24.5	10	28
180	5	41	AP	11	2.5	29
180	7	43	AP	15.5	5	30
180	10	50	PA	19	8	31
180	7	46	PA	12	6.5	32

The data collected from center A

FSD	mAs	Kv	Exam	weight	Age	No
180		42	AP			
180		42	AP		1.6	
180	10	52	PA	26	10	
180		43	AP		1.7	
180		46	AP	12		
180		43	AP			
180	10	55	PA	36	14	
180	15	60	PA	47	15	
180		41	AP		2.5	
180		43	AP	15.5		10
180		43	AP	14		
180		45	PA	19		12

180	45	PA	17	13
180	45	PA	16	14

The data collected from center C

FSD	mAs	Kv	Exam	weight	Age	No
180	5	45	AP	12	3	1
180	5	45	AP	10	1.6	2
180	6	0	AP	15.5	4	3
180	5	45	AP	10.5	3	4
180	7	45	AP	7.5	2.5	5
180	5	43	AP	12	2	6
180	5	42	AP	8	0.8	7
180	5	45	AP	14	5.4	8
180	10	53	PA	26	10	9
180	15	60	PA	47	15	10
180	10	53	PA	27	10	11
180	7	45	AP	15.5	5	12
180	10	48	PA	17		13
180	7	53	PA	27	10	14
180	7	50	PA	21.5	10	15

The data collected from center B