Addis Ababa University
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Research Paper on

Prospective Study of Variation of Entrance Surface Dose in Conventional and Digital Radiography in Pediatric Age Group

By

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List of Acronyms and Abbreviations

A.A=Addis Ababa

BSF=Back scatter factor

CXR=chest x-ray

CT=Computed Tomography

ESD=Entrance surface dose

FSD=Focus to skin distance

Gy=gray

ICRP=International commission on radiological protection

Kev=Kilo electron volt

kVp=peak kilo volt

MAS=Milliampere second

PACS=Picture Archiving and Communication System

QAP= Quality Assurance Program

SFR=Screen-film radiography

TFD=Thin film diodes

TLD=Thermo luminescent dosimeter

Executive summary

Background

Radiation exposure at the early stage of life usually results in a likelihood of two or three fold increase in lifetime risk for certain detrimental effects compared with that of adult. Radiation protection in pediatric radiology requires special attention because children are more sensitive to radiation and at higher risk than adults. The objective of this study is to assess variation of ESD in conventional and digital radiography in pediatrics age group of some hospitals in Addis Ababa, Ethiopia.

Method

Prospective cross sectional study was conducted using convenience sampling; data were collected, checked for clarity and completeness and entered into SPSS version 23 for analysis. The data were analyzed statistically, and compared with the international reference dose values.

Result

Out of 620 study participants 309 (49.8%) were exposed to conventional radiograph while 311 (50.2) were exposed to digital radiograph. Calculation of ESD shows that mean ESD of conventional radiograph to be 1.13, while that of digital radiograph is 1.84. The third quartile of Conventional is 1.72 and that of digital radiography is 0.92. In age group 5-15 digital radiography ESD's are greater than conventional ESD's, while in those less than 5 years conventional radiography ESD's are higher than that of digital ESD's. In abdomen, extremities, pelvis and spine digital radiograph ESD's are higher than conventional ones but in CXR and skull those of conventional ones are higher than digital radiograph ESDs.

Conclusion

According to this study, radiation dose (mean ESD) is relatively higher in conventional radiography in chest x ray and skull when compared to Digital Radiography whereas in abdomen, extrimities, pelvis and spine digital radiography mean ESDs are higher than conventional radiography mean ESDs

Key Words: Radiation, Pediatrics, Ethiopia

Introduction

Background

Since its discovery in 1985 by Roentgen, x-rays have played an important role in medicine. Evolution of modern medicine would have never been possible without the use of x-rays. Today, equipments that utilize x-rays are used in all aspects of diagnostic as well therapeutic radiology. Applications include: general radiography, fluoroscopy, computed tomography and mammography. Despite the discovery of alternative imaging techniques such as ultrasound and magnetic resonance imaging (MRI), that utilize non-ionizing radiation, and hence deliver no risk to patients, x-ray radiation remains the most favorable technique for reasons related to its low cost and easy operation [1]. However, the use of x-ray radiation, even at low doses typically encountered in diagnostic radiology, is associated with the risk of cancer induction and other stochastic effects. In interventional radiology procedures radiation doses often exceed the threshold for deterministic effects. Numerous cases were reported in the literature for skin injuries during such procedures(2).

Evidences suggests that radiation exposure of fetus in utero during pregnancy may lead to wide range of malformations, fetal death(stillbirth).Early childhood(up to 10yr) exposure carries an enhanced radiation risk and estimated that the probability of induction of cancer specially leukemia is about two to three times as high as in adults. This may be explained by their small size, rapid cellular growth and longer life expectancy. For these reasons, it is mandatory to minimize radiation dose or exposure in children and fetus during pregnancy as much as possible (3,4) to reduce or estimate radiation risks to the patient, radiation doses should be measured in diagnostic medical radiology.

Literature review

Biological effects of ionizing radiation

There are two main biological effects of ionizing radiation: deterministic effects and stochastic effects.

(a)Deterministic effects: These include the types of injuries resulting from whole-body or local exposures to radiation that cause sufficient cell damage or cell killing to substantial numbers or proportions of cells to impair functions in the irradiated tissues or organs (5). A certain threshold has to be exceeded before the effect is seen, and above the threshold, the severity of the effect is dose-related i.e. it will increase with increasing dose rate. The doses that result in the clinical appearance of the deterministic effects are generally of the order of a few Gray (Gy) to tens of Gray. The time at which the effect becomes noticeable may extend from a few hours to some years after exposure, depending on the type of the effect and the type of the irradiated tissue.

(b) Stochastic radiation effects: Instead of being killed, the irradiated cell may be modified and continue to reproduce, potentially causing malignancy. Unlike the deterministic effects, there is no threshold for stochastic effects to occur. The probability of an effect occurring is a function of dose, but the severity of the effect is dose-independent(5) Stochastic effects can be categorized as somatic (carcinogenic) effects or hereditary (genetic) effects, which may occur from injury to one or a small number of cells. Since a single cell may be enough to initiate the effect, there is a finite probability that the effect will occur however small the dose. Living things have evolved in an environment that has significant levels of ionizing radiation. Many of us owe our lives and health to radiation that is artificially produced. X-ray is the type of radiation that is widely used in medical diagnoses but with problems. Radiation is used to diagnose ailments and to treat patients thus people benefit from a multitude of products and services made possible by the careful use of radiation (6).

Ionizing radiation damages living tissue; the extent of damage may vary. If this damage is limited to a small number of insignificant cells, the effect on the body may be insignificant. However, if a large amount of cells or if only one cell vital to the functioning of the body is damaged, this may be harmful to the patients' health and wellbeing. The ICRP recommended that medical activities involving ionizing radiation should fulfill the two basic principles of justification and optimization. One of the requirements of the optimization process is regular periodic monitoring of the performance of radiological equipment and assessment of techniques employed in their use Diagnostic Radiology is an accepted imaging modality for the diagnosis of pathological conditions in both children and adults. However, x-rays have inherent hazards that are of special concern when applied to young children. Studies have shown that children less than ten years of age are more sensitive to ionizing radiation than middle-aged adults (5). This is because ionizing radiation can cause genetic mutations and congenital malformations in the fetus. Furthermore, the risk of inducing malignancy is greater in growing organs and tissues. In general, children have a longer life expectancy than adults have and are therefore, at a greater risk to the long-term side effects of radiation.

The risk of movement procedure during x-ray procedure is greater with children and this can lead to repeating of the x-ray procedure. This in turn, leads to an increase of the absorbed dose of radiation to the patient. For these reasons, it is mandatory to minimize radiation dose or exposure in children as such as possible (7). Patient dose reduction in diagnostic radiology is important in radiation protection program, and is nowadays a public concern and a legal issue, especially in developed world. Since there is increasing awareness and greater realization of the effect of ionization radiations, users are demanding of dose information and dose reduction(8).Quality radiographs and safety to patients undergoing x-ray examinations have become hallmarks of efficient and successful diagnostic radiology unit. So quality control measures have been developed in different countries. The ionizing radiation received by patients and health workers due to radiological imaging may increase the risks of radiation effects, such as cancer and cataracts (9).

Medical X-ray exposures are the largest man-made source of population exposure to ionizing radiation in many countries(10). Early childhood exposure carries an enhanced radiation risk and estimated that the probability of induction of cancer especially leukemia is about two to three times as high as in adults(11).A research done In India, entrance surface dose and induced DNA damage in blood lymphocytes of patients exposed to low-dose and low-dose-rate X-irradiation during diagnostic and therapeutic interventional radiology procedures showed that interventional imaging procedures deliver significant radiation doses and induce measurable DNA damage in lymphocytes of subjects, highlighting the need for rigorous patient safety protocols(9).

1. conventional radiography

Conventional radiography (also known as SFR) is still used more widely than digital radiography but this dominance is fast dwindling. The reasons behind the declining popularity of SFR are—fixed dose latitude, fixed non-linear grey scale response, and limited potential for reducing dose to the patient. All these parameters limit the information that can be captured on film. The images cannot be changed in contrast once they have been processed. Apart from this, film is expensive, uses hazardous materials for processing, is labour intensive, and long term storage and retrieval of film is difficult. Patient radiation dose from conventional radio-graphic procedures ranges from 0.1 to 10 mSv, resulting in a collective dose to the population that can be significant**.** For diagnostic x-rays, it is by indirect action where free radicals are produced by interacting with other atoms and molecules, which is water, an abundant molecule in our body (12). SFR is not compatible with the picture archiving and communication systems (PACS). X-Rays are produced by bombarding a metal target by high energy electrons.

In conventional radiography, x rays passed through the human body are absorbed, which causes attenuation of the incident beam. The uniform x ray beam emitted from the source is modulated as it passes through the human body and these changes are recorded on the film. The contrast in an x ray image depends on differential attenuation of x rays as they pass through different body tissues. The x ray equipment must be calibrated to accurately produce the desired voltage, current, and exposure time. This has to be frequently checked to ensure correct radiation dose. The film is composed of supercoat—protective layer of hardened gelatin; emulsion—radiosensitive silver halide grains suspended in gelatin; adhesive layer and film base. The amount of silver bromide is directly proportional to the sensitivity of the film. In SFR, the film acts as the medium for acquisition, display, and storage of images. On the other hand, the production of image in CR can be considered over four discrete broad heading—image acquisition, processing, storage, and display. All these four processes are separate and the performance of each can be optimized individually for maximum efficiency. silver halide plates used in conventional radiography in contrast to Phosphor plates containing a thin layer of fine grain crystals of Barium fluoro halide doped divalent Europium (Eu+) are used in CR . Incident x ray photons are absorbed by the phosphor crystals producing high energy photo electrons. The electrons are trapped at Halide vacancies (color centers) to form F centers.

A helium neon 633 nm laser beam is used to scan the plate. The color centers absorb energy and electrons drop to low energy level with release of energy in the form of light photons. These photons are converted to electric current by high sensitivity photo multiplier tube. The analogue electrical signal is then digitized to provide the image and this can either be printed from a laser printer or viewed on grey scale high resolution monitors.

The key stones on which the SFR survives in current radiological practice are resolution and familiarity of the medical profession. The high resolution makes it useful to diagnose undisplaced fractures and in other situations like subperiosteal erosions in hyperparathyroidism. Conventional film is subject to loss through storage and the images may deteriorate with time, and this problem does not exist for digital images. Limitations of the SFR system are related to storage, cost, and film distribution. Also, the dose to the patient cannot be reduced and screen film has fixed non-linear grey scale response and fixed dose latitude. The popularity of CR has generated an expansion of PACS services as the conventional SFR was incompatible with this system. (13).

There is no doubt that the most efficient application of ionizing radiation is for medical purposes and using this radiation has caused people to know that artificial sources of radiation exposure among these resources can be of highest exposure rate (14). Compared to other imaging modalities such as MRI, CT scan and Digital Radiography, conventional radiography is still prevailing as an important and essential diagnostic tool in many developed countries.

Screen-film combinations and film processing conditions:

In conventional radiography, most current radiographic intensifying screens are composed of rare earth elements. Previously calcium tungstate was the most common used material. The speed, or the overall efficiency, of calcium tungstate screens is often referred as to as par speed and is assigned an arbitrary speed of 100. The speed numbers are relative; that is, 400-speed requires only half the dose used with 200-speed system. Use of faster screen-film combination can substantially reduce dose, and modern rare earth screens up to 600 speed may typically be used (15). Faster systems result in some loss of detail, but if the examination in question permits less detail, the faster system should be used. The film processor should be functioning according to film manufactures' recommendations. If temperature, transport rate, or replenishment rates differ substantially from recommended values, the effect on image quality can be significant. Poor image quality can lead to modification of radiographic techniques, which in turn directly affect patient dose.

2. Digital radiography

Digital radiography and fluoroscopy utilized a matrix of discrete numerical 60 values to represent an image. A matrix is square or rectangular area divided into rows and columns. The smallest element of a matrix is called a pixel (from picture element). The location of a pixel in a matrix is encoded by its row and column number (x,y). Each pixel of a matrix is used to store binary number with range of 8-16 bit (binary digit). The functional value f(x,y) of a pixel (x,y) is called the grey level value, a non-negative integer. Eight bits allow the storage of integer values (grey level values) between 0 and 255; 16 bits allow values between 0 and 65535(16) When it was introduced in late 1970s and early 1980s, there were two approaches in digital radiology: To utilize the existing equipment in the radiographic procedure room and change only the image receptor component or to redesign the conventional radiographic procedure equipment, including the geometry of the x-ray beams and image receptor. The first approach was dominated by two technologies known as imaging plates and digital fluorography whereas the later approach was rather expensive and was applied in digital fluoroscopy systems.

1: Imaging plate radiography

Computed radiography or imaging plate consists of two components, photo-stimulated phosphor plate (also known as storage phosphor) and scanning mechanism. The phosphors are mainly in barium fluoro-halide family, typically $BaFBr:Eu^{2+}$. When exposed to x-rays, the storage phosphor stores part of absorbed x-ray energy as a latent image on the imaging plate. Stimulation of the plate by a laser beam leads to emission of luminescence radiation corresponding to the incident x-ray energy. The luminescence radiation stimulated by the laser scanning is collected through focusing lens and light guide in to photomultiplier tube, which converts it into electrical signal(17)

2: Digital fluorography

In digital fluorography a digital chain is added to an existing fluorographic unit. Fluorography is a procedure of displaying fluoroscopic image on a video monitor using an image intensifier coupling with a video camera, and the technique is used to visualize the motion of body compartment. To redesign the conventional radiographic procedure equipment, including the geometry of the x-ray beams and image receptor.

3. Flat panel digital radiography systems

3.1: Indirect flat-panel digital radiography systems: Systems using indirect conversion detectors employ a two steps process for x-ray detection. Scintillation materials (e.g. cesium iodide) or phosphors (e.g. gadolinium sulfur oxide) capture x-ray energy and convert it to light for indirect devices. An array of thin-film diodes (TFD) converts the light energy to electronic signals. Ultimately, the spatial resolution of the x-ray image depends on the captured signal profile and pixel size. X-ray capture systems that use light compromise image sharpness because the light scatter blurs the image.

3.2: Direct flat-panel digital radiography systems: Direct x-ray capture systems produce a precise signal profile with no intermediate steps to degrade image quality. In both cases direct and indirect systems, the electric charge pattern, temporarily stored during x-ray exposure, is sensed by an electronic readout mechanism, and an analog-to-digital conversion process produces the digital image (direct readout). The resulting digital image covers a dynamic range wider than necessary for most clinical examinations. Therefore while film systems risk under- or overexposure, fully automatic digital image processing eliminates the need for retakes and produces quality images for display and diagnosis.

4: Amorphous selenium detectors

This type of receptor uses a thin photoconductive layer of amorphous selenium as the primary detector. Absorbed X-ray photon energy is converted directly into electrons and holes. The number of released charge carriers is directly proportional to the absorbed X-ray fluence. A large electric field across the thin selenium layer ensures that the charge carriers are separated and flow directly to a surface bias electrode (electrons) or to an array of signal electrodes associated with charge storage capacitors and a thin-film transistor array (holes). This array allows the addressing of all the charge storage capacitors and passes the stored charge in each to charge sensitive read-out amplifiers and hence to external amplifiers and digitizers, prior to processing and image display.

The amorphous selenium detector is again characterized by a wide dynamic range (linear over three decades). Its long-term efficiency is not yet determined. Although the primary photon detector is an element, and therefore not prone to chemical changes, the thin-film transistor array is thought to be prone to eventual radiation damage after prolonged use. Damage to this array would require the replacement of the whole detector at considerable expense.

This class of detector is based on large arrays of electronically addressable photosensitive electronic devices in contact with a phosphor screen, typically of cesium iodide. Real time readout is a possibility to give a function like fluoroscopy but with a flat panel detector. This type of design relies on the established performance of cesium iodide as the primary photon detector, but requires that the image information be transferred by secondary carriers (light photons) to a large-area amorphous silicon array of light sensitive electronic devices. Some resolution and efficiency losses would be anticipated due to the requirement for secondary carriers, but large-scale commercial development of this technology is taking place.

The performance of this detector long-term is not yet determined, but both the fluorescent screen and amorphous silicon array would be susceptible to eventual radiation damage and quality assurance measurements capable of detecting slow reductions in efficiency for this type of detector would be advisable.

5: Optically-coupled fluorescent detectors

Several designs of small-field digital radiography receptor are on the market for mammography applications. These utilize charge-coupled device (CCD) light sensitive arrays of relatively small dimensions, linked via mirror/lens systems or tapered/parallel optical fibers to the input fluorescent screen. Generally, compared to film-screen systems, computed and digital radiography machines yield quality images at lower radiation doses(18).

1.2 Factors affecting patient dose in diagnostic radiology

Factors affecting patient doses in all x-ray modalities include beam energy, filtration, collimation, patient size, and image processing.

1.2.1 Beam energy and filtration

Beam energy primary depends on peak kilo-voltage (kVp) selected and the amount of filtration in the beam. If all other variables held constant, ESD will change as the square of the change in peak kilo-voltage. The selection of higher kilo-voltages increases the averages energy of the x-ray and there for the beam penetrability. As the beam comes more penetrating, more x-ray will reach the image receptor during the same period time. In practice, this may allow the uses of lower tube current or shorter exposure, thus reducing the dose to the patient.

In developed countries, diagnostic radiography units are required by regulations to contain a total filtration of at least 2.5 mm aluminum equivalent if they are operated at tube potentials above 70 kVp (19). This filtration preferentially absorbs the low energy x-ray in the beam. Absorption primarily takes place with x-ray of less than 40 keV of energy, and virtually all x-rays below 10 keV are absorbed (19). Without filtration, this low energy radiation would most likely to be completely absorbed in the patient. Because image formation requires transmission of x-ray through the patient to expose the image receptor, low energy x-ray contributes to the patient dose without contributing to the image formation. In effect, the added filtration serves to further increase the average energy of the beam. In the range of energies of x-rays used in diagnostic radiology, however, increasing the average energy of the x-ray beam will decrease the contrast of the resulting image. Therefore, to reduce patient dose, the goal should be to use the highest peak kilo-voltage possible that results in acceptable image contrast. A research done in South Africa to evaluate the effect of reduced entrance surface dose on neonatal chest imaging using subjective image quality evaluation showed that a 64% dose reduction was achievable by altering the beam parameters (20).

1.2.2 Collimation

During any radiographic procedures, the area of the patient exposed to the x-ray beam should be limited to the area of clinical interest. Tissues inside the primary beam receive doses that are orders of magnitude higher than doses received by tissues outside the primary beam. By using collimation to expose only the areas of clinical interest, one can substantially reduce unnecessary patient exposure. The use of collimation has another important effect: By reducing the area of the x-ray beam, the amount of scattered radiation that reaches the image receptor is also decreased. The resulting images have better contrast.

1.2.3 Digital radiographic receptors

One of the special characteristics of digital radiographic receptors is that they, unlike film/screen receptors, can produce images with good contrast over a wide range of receptor exposure. They do not have a "fixed" speed or receptor sensitivity value like film receptors. The significance of this is that exposure used in digital radiography should be monitored and adjusted by the operator, or the correctly calibrated and set automatic exposure control, to produce the necessary image quality with the lowest possible exposure(18).

1.2.4 Grids

Grids were introduced into radiography to reduce the amount of scattered radiation that reaches the images receptor. Modern grids do an exceptional job, resulting in an image with much more improved contrast. Unfortunately, this improved contrast comes at the cost of increased patient dose. A grid also absorbs a portion of the primary – that is, those that would have contributed to exposing the image receptor – and the only way to achieve the degree of the exposure required to produce the image is to increase the amount of radiation incident on the grid and therefore the patient. A grid removes a much larger fraction of scattered x-rays than unscattered, or primary, x-rays, and the doses are typically increased from two to fives times those encountered without the use of a grid. This proportion is commonly referred as the Bucky factor and represents the ratio of the dose with a grid to the dose without grid (16). The higher quality images with a grid, however, may result in fewer retakes and accurate diagnoses.

1.2.5 Patient size

As the thickness of the area being imaged increases, the amount of the radiation incident on the patient increases because adequate x-ray penetration is needed to create an acceptable images. Although the examiner has little or no control over patient size, it is beneficial to know the type of exposure expected for examinations of different anatomical areas of patients of different sizes. Technique charts that display suggested radiographic technique factors for various examinations and patient thicknesses placed near the operator’s console maybe helpful.

2. Dose measurements methodology

2.1 Determination of ESD from TLD measurements

TLD’s are considered as the gold standard for determination of the entrance surface dose in practice. Measurements are made with thermo-luminescent dosimeters, TLDs, attached to the patient or phantom at points where the x-ray beam enters the patient. TLDs are read in a standard manner and the value read is used as an estimate of the ESD received by the patient. If correctly calibrated to measure air kerma free in air, the TLD should give a direct reading of the entrance surface dose, and no correction is needed for back scattered radiation or distance from the tube focus.

2.4.2 Calculation of ESD from tube output data

ESD may be calculated in practice by means of knowledge of the tube output.The relationship between x-ray unit current time product (mAs) and the air kerma free in air is established at a reference point in the x-ray field at 80 kVp tube potential. Subsequent estimates of the ESD can be done by recording the relevant parameters (tube potential, filtration, mAs and FSD) and correcting for distances and back scattered radiation according to the following equation.

$$ESD=OP\times(KV/80)^2\times MAS\times(100/FSD)^2\times BSF \quad (21)$$

where OP is the output per mAs measured at a distance of 100 cm from the tube focus along the beam axis at 80 kVp, kV is peak tube voltage (kVp) recorded for any given examination (in many cases the output is measured at 80 kVp, and therefore this appears in the equation as a quotient to convert the output into an estimate of that which would be expected at the operational kVp. The value of 80 kVp should be substituted with whatever kVp the actual output is recorded at in any given instance).

Where; ESD -is entrance surface dose for each exposure, in mGY, Output -is the x-ray tube output in mGY/mAS normalized at 80 KV, mAS of 20, FSD of 1 meter, KVp- is tube potential in KiloVolt(KV) mAS- is the product of the tube current in milliampere(mA) and the exposure time in second(S).

FSD- is the Focus to Skin Distance in centimeter (cm) and BSF -is the back scatter factor, the average value of 1.3 was taken for all patients in this study. It ranges 1.2 - 1.5 in diagnostic radiology (22). Research done in our country about entrance surface dose measurement in pediatric patients undergoing common diagnostic x-ray examinations in black lion and Yekatit 12 Hospital Addis Ababa, Ethiopia showed wider dose variation suggests that there is a pressing need to seek dose optimization to children in order to reduce the detriment caused by the unnecessary high doses imparted to them(11).

Another study done in kyoto school of medicine in Japan A feasibility study on reduction of the entrance-surface dose to neonates by use of a new digital mobile X-ray system showed that the potential of reducing the ESD to the patient and operator. The ESD was 51-52 microGy with an 8-cm-thick phantom and 33-34 microGy with a 4.5-cm phantom, for one exposure (23).

A study of entrance surface dose with CR and film/screen systems, and analysis of the X-ray conditions for chest radiography in Suzuka University of Medical Science In the case of chest radiography(adult patients) by CR, the entrance surface dose was 150% of the median value for the overall examination and 160% of the median value for orthochromatic screen systems(24).

A research done in seven hospitals in Iran to assess the entrance surface dose and health risk from common conventional radiology ,the ESD measurements as well as the calculated effective dose values between different X-ray examinations showed values significantly greater than those recorded in some other countries especially for the high tube potential technique (such as the skull) by factors of 2.5-5.0.(25)

Significance of the study

There is substantial evidence to suggest that children are more susceptible to the effects of ionizing radiation than adults. As a consequence of the longer life expectation this places an added burden on staff to attain the best possible results every time. Likewise, the probability that there may be late radiation effects is also higher. Exposures to ionizing radiation are dependent on the age at which exposure occurs. Exposure during childhood results in a likely two or three fold increase in lifetime risk for certain detrimental effects, including solid cancers, compared with that in an adult. Wide variations in patient doses up to a factor of 100 for radiation exposure of the same projection have been reported in the literature. Diagnostic Reference dose levels (DRL) provide a framework to reduce this variability. Variations of dose within a hospital emphasize the importance of Quality Assurance Program (QAP) so that inconsistencies and errors in technique and equipment can be discovered early and hence reduce the variation in dose to patient (26).

In addition to that studying the variability of radiation exposure between conventional and digital radiography helps to identify the type of machine exposing children to radiation at most so that recommendations to decrease radiation exposure also put into account type of machine.

Objective

General objectives:

- To determine ESD in conventional and digital radiography in pediatric age group

Specific objectives

- To determine ESD in conventional radiography
- To determine ESD in digital radiography
- To compare ESD in conventional and digital radiography

Methods and materials

Prospective hospital based cross sectional study was conducted to asses the variation of ESD in conventional and digital radiography in both private and public hospital in A.A.

The study area:

Private and public hospital located in A.A , the capital of Ethiopia

Study period:

October 1,2017 up to August 1,2018 G.C

Study design:

Prospective hospital based cross-sectional study

Source population:

All padiatric patient visisting the above hospitals

Study population:

All patients undergoing plain film that fulfill the inclusion and exclusion criteria

Sampling technique and sample size

The sample size was determined based on the ICRP recommendations to conduct such study.According to the ICRP,patient dose surveys should include atleast 10 standard size patient.Since the study is new in this country and to increase the precision a minimum of 40 patients included from each hospital/clinics.

Data Collection procedure

Data on kVp, mAs, and FSD was collected from both private and public hospitals for both conventional and digital radiography for ESD calculation.

Methods of data analysis

The collected data was checked for clarity and completeness and then organized and recorded. The entrance dose in air per examination was measured in eleven hospitals for a sample of 620 radiographs. The entrance dose in air was measured using dositime RaySafe Xi dosimeter. The data were analyzed statistically, and the minimum, mean, and maximum values of ESDs are reported. Finally, the proposed ESDs are compared with the values reported by the International radiation agencies. Data obtained from recorded parameters during examination periods were used to calculate ESD and analysis was made by using computer (excel and SPSS method).

Inclusion and exclusion criteria

Inclusion criteria

All patients undergone PA,AP and Lateral CXR,PA,APand lateral skull x-ray,PA,AP and Lateral spine,AP,AP and lateral extremities,AP,PA and lateral pelvis for any indication for ages ≤15yrs

Exclusion criteria

Those parents refused to give a written consent.

Ethical Consideration

In order to respect patient's bill of right, regulation of the hospital where the study was conducted, ethical considerations was taken in to account. Any piece of information was kept confidential by not recording names of patient.

Results

620 study participants were included in this study. Out of these 340 (54.8%) were males and 280 (45.2%) were females (See figure 1 below)

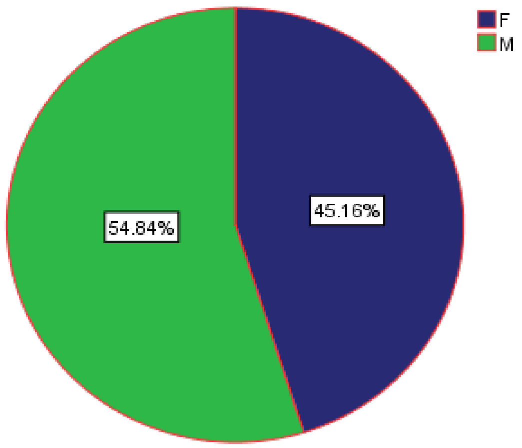

Figure 1: Percentage of participants by gender

Pediatrics age group ranging from 1 day old to 15 yrs was included in this study. The mean age of participants is 4.2 years. The age group distribution shows that 363 (58.5%) are under one year, 48 (7.7%) are 1-5 years old, 72 (11.6%) are 5-10 years, 137 (22.1%) are 10-15 years (See table 1 below).

Table 1: Frequencies of participants by age group

		Frequency	Percent
Age group	<1	363	58.5
	1-5	48	7.7
	5-10	72	11.6
	10-15	137	22.1
	Total	620	100.0

Out of 620 study participants 309 (49.8%) were exposed to conventional radiograph while 311 (50.2) were exposed to digital radiograph (see figure 2 below).

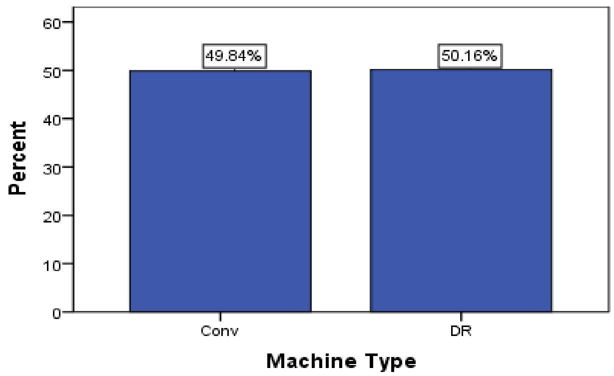

Figure 2: Type of X-ray machine employed by percent

Out of total 620 radiographs 347 (56%) were chest radiographs, 161 (26%) were extremities, 46 (7.4%) were Skull, 31(5%) were abdomen, 18 (2.9%) were Pelvis and 17 (2.7%) were Spine radiographs as shown in figure 3 below.

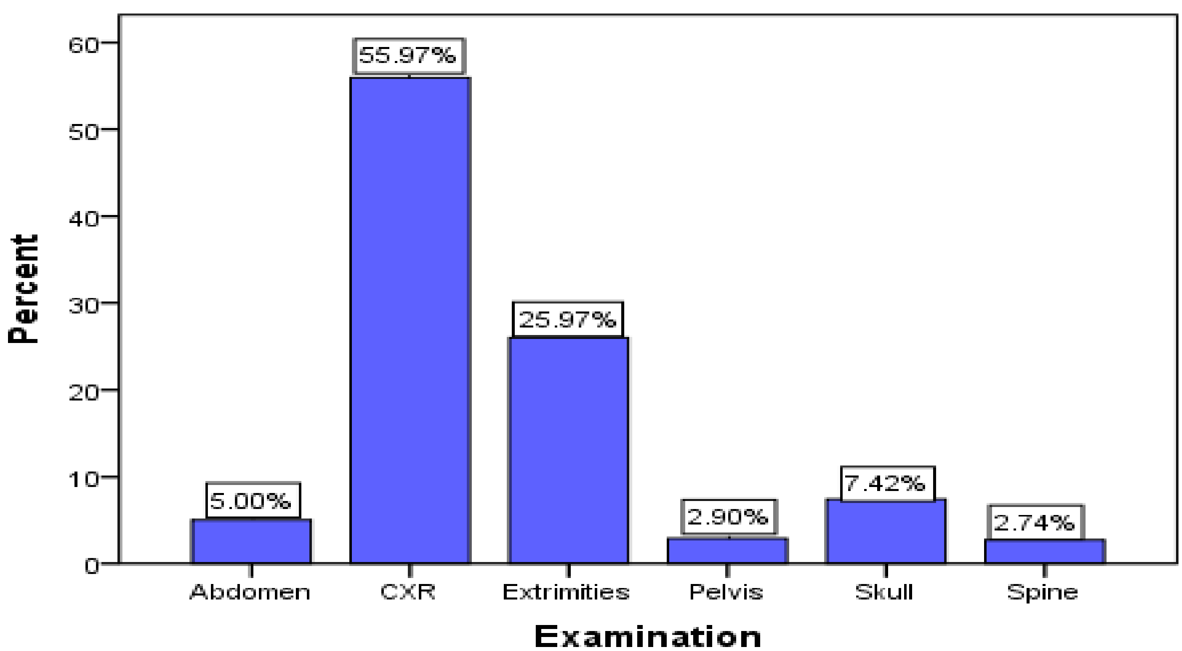

Figure 3: Types of examination performed during the study period

Calculation of ESD shows that mean ESD of conventional radiograph to be 1.13, while that of digital radiograph is 1.84. (See table 2 below)

Table 2: Entrance surface dose by type of machine

		ESD				
		Mean	Minimum	Maximum	Range	Third quartile
Machine Type	Conv	1.13	0.052	13.20	13.15	1.72
	DR	1.84	0.007	34.33	34.32	0.92

Maximum digital ESD (34.33) was with PA skull taken on 1.5yr male and lateral neck on 1.5 yr male patient.

Additionally in this table the third quartile of Conventional is 1.72 meaning that if all observation are put in their order of magnitude 75% of them are less than 1.72mGY. Similarly 75% of ordered digital radiography ESD is less than 0.92.

We can also compare radiographic data (kVp, mAs, FSD, ESD) of both conventional and digital radiograph by age group as shown in table 3 below:

Table 3: Radiographic data by types of machine used

Machine Type	Age Group	Radiographic Data (mean, minimum, maximum)			
		kVp	mAs	FSD	ESD
Conventional=309	<1 (n=132)	90(40-150)	24.47(2-448)	110(40-160)	1.496(0.052-13.201)
	1-5 (n=22)	59(42-150)	14.64(2-40)	100(56-150)	0.744(0.071-7.455)
	5-10 (n=52)	66(40-150)	14.07(2-40)	102(50-150)	0.930(0.057-5.281)
	10-15 (n=103)	71(42-150)	18 (1.6-112)	107(50-160)	0.853(0.061-4.944)
Digital=311	<1 (n=231)	65(40-90)	74.68(0.56-583)	94(38-160)	1.887(0.007-34.328)
	1-5 (n=26)	55(43-77)	30.52(1.6-213)	98(74-128)	0.358(0.044-

					2.327)
	5-10 (n=20)	60(40-84)	69.45(1-400)	88(38-150)	3.854(0.022-27.901)
	10-15 (n=34)	61(45-80)	52.35(1.6-333)	93(39-140)	1.481(0.058-7.632)

As seen on the above table higher mean conventional ESD in those less than one year could be due to higher mAs and higher kVp. Similarly higher digital mean ESD in those less than one year could be due to higher mAs and kVp. Higher mean digital ESD's in both 5-10 yrs and 10-15 yrs could also be explained similarly.

It is also possible to compare conventional and digital radiographs by examination type as shown in table 4 below

Table 4: Radiographic data by types of examination performed

Examination	Machine type	Radiographic data (mean, minimum, maximum)			
		kVp	mAs	FSD	ESD
Abdomen=31	Conv=7	70(50-100)	22.03(3.2-50)	99(90-100)	1.274(0.066-5.112)
	Digital=24	65(40-90)	105.69(2.5-400)	92(85-108)	1.787(0.093-14.485)
CXR=347	Conv=167	88(40-150)	22.51(1.6-448)	117(40-160)	1.355(0.052-13.201)
	Digital=180	66(40-90)	49.59(0.56-583)	97(53-160)	0.760(0.007-8.789)
Extremities=161	Conv=86	59(40-100)	13.61(2.5-50)	93(50-100)	0.615(0.062-3.683)
	Digital=75	56(40-85)	73.24(2.5-400)	90(38-150)	2.508(0.043-32.754)
Pelvis=18	Conv=10	75(42-150)	22.93(2.0-75)	98(80-140)	1.414(0.071-7.455)
	Digital=8	71(40-84)	146.56(4.0-500)	89(58-116)	7.782(0.141-34.328)
Skull=46	Conv=30	88(76-100)	25(10-40)	100(100-100)	1.000(0.252-1.747)
	Digital=16	80(79-80)	183(116-250)	85(85-85)	0.817(0.509-1.125)
Spine=17	Conv=9	80 (58-150)	36.72(25-75)	98(80-100)	2.32(0.45-7.45)
	Digital=8	71(60-80)	147.08(10-400)	91(60-116)	5.53(0.26-34.32

- The above table indicates the highest mean ESD is in pelvis digital examinations with the value of 7.782mGy,followed by digital spine examination (5.53mGy) and extrimities digital mean ESD (2.508mGy) which could all be because of higher mean mAs. The highest mean ESD in conventional examination is 2.32mGy for spine and the lowest mean is o.615mGy for extremities

One can also compare conventional and digital radiographs with respect examination segregated by age group as shown in table 5 below

Table 5: Radiographic data by types of examination and machine employed

Examination	Machine type	Age group	KVp	mAs	FSD	ESD
Abdomen=31	Conv=7	<1 1-5 5-10 10-15	70(50-100) 70(70-70) - -	25.17(6-50) 3.20(3.20-3.20) - -	98(90-100) 100(100-100) - -	1.45(0.66-5.11) .25(.25-.25) - -
	Digital=24	<1 1-5 5-10 10-15	67(40-90) 65(55-79) - 55(55-55)	117.5(2.5-400) 96.17(12.5-160) - 51.2(51.2-51.2)	92(85-108) 90(85-101) - 90(90-90)	1.89(0.09-14.485) 0.42(0.36-0.50) - 1.88(1.88-1.88)
CXR=347	Conv=167	<1 1-5 5-10 10-15	87(46-150) 96(40-150) 77(42-150) 86(53-150)	26.42(5-448)) 19.01(2-40)) 14.05(2-25) 20.36(1.6-112)	105(40-160) 127(56-150) 121(100-150) 140(90-160)	1.61(0.05-13.20) 1.19(0.05-5.46) 0.9(0.57-3.58) 1.02(0.06-4.94)
	Digital=180	<1 1-5 5-10 10-15	67(40-90) 62(43-80) 62(56-66) 67(65-71)	40.61(0.56-583) 88.24(1.6-333) 35.22(1-157.5) 52.57(1.6-	97(58-160) 93(56-128) 96(53-150) 99(90-107)	0.51(0.007-8.79) 1.38(0.04-7.53) 0.96(0.02-3.86) 2.72(0.06-7.63)

				125)		
Extremities=161	Conv=86	<1 1-5 5-10 10-15	52(455-60) 51(45-60) 54(40-100) 61(42-100)	22.10(6.30-50) 12.15(3.20-25.2) 9.02(2.5-36) 14.96(2.5-50)	79(56-90) 93(56-100) 93(56-100) 95(50-100)	0.82(0.18-1.19) 0.42(0.62-0.88) 0.33(0.07-3.18) 0.57(0.07-2.98)
	Digital=75	<1 1-5 5-10 10-15	56(40-85) 57(45-80) 49(40-60) 55(45-74)	88.80(2.5-400) 87.74(5-333) 35.78(3.6-100) 38.72(5-201.60) 25(10-40))	95(63-150) 79(38-104) 86(38-100) 92(39-140)	1.58(0.04-32.75) 3.19(0.09-29.93) 1.97(0.08-12.66) 1.3(0.06-6.28)
Pelvis=18	Conv=10	<1 1-5 5-10 10-15	88(76-100) - 75(70-80) 83(58-100)	25(10-40) - 27.50(25-30) 15.87(3.20-25)	100(100-100) - 85(70-100) 92(54-100)	1(.25-1.74) - 2.48(2.11-2.86) 1.69(0.175-3.68)
	Digital=8	<1 1-5 5-10 10-15	57(40-69) 76(76-76) 76(76-76) -	46.38(6.30-186) 320(320-320) 320(320-320) -	103(85-118) 56(56-56) 58(58-58) -	0.53(0.12-.88) 29.9(29.9-29.9) 27.9(27.9-27.9) -
skull=46	Conv=30	<1 1-5 5-10 10-15	- 58(42-75) 85(68-100) 73(50-150)	- 21.13(2-40) 25.14(10-40) 15.95(2.5-50)	95(90-100) 97(80-140) 99 (90-100)	- .54(0.07-1.07) 2.5(0.1-7.4) 0.76(0.13-4.37)
	Digital=16	<1 1-5 5-10 10-15	69(40-82) 78(78-78) 74(70-84) 70(68-80)	210.67(4-500) 400(400-400) 114.16(20-400) 26.50(20-36)	84(60-100) 60(60-60) 91(58-100) 98(90-100)	12.93(0.14-32.59) 34.32(34.32-34.32) 5.32(0.55-15.88)

						0.99(.55-2.01)
spine=17	Conv=9	<1 1-5 5-10 10- 15	- 150(150- 150) 66(60-72) 73(58-80)	- 37.50(37.5- 37.5) 25(25-25) 40.5(25-75)	- 100(100- 100) 90(80-100) 100(100- 100)	- 7.45(7.45-7.45) 1.52 (1.34-1.71) 1.72(0.45-2.53)
	Digital=8	<1 1-5 5-10 10- 15	63(60-65) 77(76-78) - 73(70-80)	14(10-16) 300.8(201.6- 400) - 177.67(100- 333)	105(100- 116) 79(60-98) - 85(85-85)	0.52(.26-0.66) 20.24(6.15- 34.32) - 0.72(.34-1.49)

- The above table indicates highest mean ESD is in digital skull radiography in age group of 1-5 yrs (34.32mGy) followed by pelvis digital radiography in the age group 1-5 yrs (29.9mGy) and pelvis digital radiography in the age group 5-10 yrs (27.9 mGy) and spine digital radiography in the age group of 1-5 yrs (20.24mGy). All this could be because of higher mAs values as in seen in the table above. above,the minimum is 0.42mGy for abdomen for the age group 1-5yrs
- The highest mean ESD in conventional radiography is 7.45mGy for spine,age 1-5yrs and the lowest is 0.25mGy for abdomen age 1-5yrs because mAs variation.

It is also possible to compare conventional and digital radiographic data with respect to projection type as shown in table 6 below:

Table 6: Radiographic data with respect to projection type (AP, PA, Lateral, Oblique, ,,,,)

Examination	Projection	Machine type	Radiographic data (mean, minimum, maximum)			
			kVp	mAs	FSD	ESD
Abdomen =31	AP=29	Conv=6 DR=23	65(50-88) 65(40-90)	23.2(3.2-50) 102.23(2.5-400)	98(90-100) 92(85-108)	1.383(0.07-5.11) 1.8(0.09-14.49)
	PA=2	Conv=1 DR=1	100(100-100) 79(79-79)	15(15-15) 333(333-333)	100(100-100) 85(85-	0.63(0.63-0.63) 1.46(1.46-

					85)	1.46)
CXR=347	AP=278	Conv=133 DR=145	94(43-150) 66(40-90)	23.8(3.2-448) 31.2(0.56-583)	115(40-160) 95(56-150)	1.47(0.06-13.2) 0.72(0.01-8.79)
	Lateral=2	Conv=2 DR=0	150(150-150) -	31.3(27.5-35) -	100(100-100) -	6.2(5.47-6.96) -
	PA=67	Conv=32 DR=35	61(40-72) 65(40-90)	16.8(1.6-112) 125.9(1-400)	127(80-160) 103(53-160)	0.6(0.05-4.9) 0.9(0.02-7.63)
Extrimities=161	AP=55	Conv=26 DR=29	58(43-100) 55(40-85)	15.62 (2.5-40) 39.7(2.5-266)	93(50-100) 99(60-150)	0.5(.071-3.683) 0.3(0.043-2.7)
	AP and Lateral=6	Conv=3 DR=3	65(45-100) 43(40-45)	9.7(2.5-20) 45.5(28.8-63)	93(80-100) 93(90-100)	0.48(0.08-0.8) 0.94(0.71-1.22)
	AP and Oblique=4	Conv=0 DR=4	- 44(40-46)	- 37(22.4-52)	- 93(90-100)	- 0.8(0.6-1.03)
	Lateral=36	Conv=17 DR=19	59(42-100) 59(50-70)	10.25(2.5-40) 94.2(8.4-333)	88(50-100) 73(38-100)	0.49(0.07-2.86) 2.34(0.12-6.62)
	PA=57	Conv=37 DR=20	56(40-100) 56(45-80)	13.63(2.5-50) 102.8(4-400)	97(80-100) 88(38-140)	0.57(0.06-3) 4.56(0.06-32.75)
	PA and Lateral=3	Conv=3 DR=0	53(45-60) -	6.5(3.2-10) -	97(90-100) -	0.26(0.11-0.48) -
	PA and Oblique=1	Conv=0 DR=1	- 60(60-60)	- 12.5(12.5-12.5)	- 100(100-100)	- 0.44(0.44-0.44)
Skulls=46	AP=7	Conv=4 DR=3	53(42-65) 60(40-70)	4.6(2-10.5) 28.6(25-36)	95(90-100) 100(100-100)	0.13(0.07-0.19) 0.65(0.56-0.7)
	Lateral=18	Conv=15 DR=3	70(50-86) 72(70-76)	27.5(2.5-75) 48.6(20-100.8)	95(80-100) 86(58-100)	1.5(0.14-5.28) 3.34(0.55-8.78)
	PA=18	Conv=9 DR=9	91(61-150) 75(60-84)	14.4(5-36) 230.3(4-500)	103(90-140) 84(60-100)	1.2(0.17-4.3) 14.3(0.14-34.33)
	PA and Lateral=3	Conv=2 DR=1	64(60-68) 68(68-68)	3.6(3.2-4) 36(36-36)	100(100-100) 90(90-90)	0.24(0.19-0.3) 2.02(2.02-2.02)
Pelvis=18	AP=9	Conv=3 DR=6	84(75-100)	23.3(10-40 46.4(6.3-	85(54-100)	1.89(0.25-3.68)

			57(40-69)	186)	103(85-118)	0.53(0.12-0.88)
	Lateral=1	Conv=1 DR=0	70(70-70)	30(30-30)	70(70-70)	2.86(2.86-2.86)
	PA=8	Conv=6 DR=2	84(58-100) 76(76-76)	16.7(3.2-25) 320(320-320)	100(100-100) 57(56-58)	1.44(0.17-2.27) 28.9(27.9-30)
Spine=17	AP=2	Conv=0 DR=2	- 68(65-70)	- 58(16-100)	- 93(85-100)	- 0.5(0.34-0.7)
	Ap and Lateral=1	Conv=0 DR=1	65(65-65)	16(16-16)	100(100-100)	0.66(0.66-0.66)
	Lateral=12	Conv=8 DR=4	71(58-80) 71(60-78)	36.7(25-75) 177.9(10-400)	98(80-100) 90(60-116)	1.67(0.45-2.5) 10.3(0.26-34.33)
	PA=2	Conv =1 DR=1	150(150-150) 80(80-80)	37.5(37.5-37.5) 333(333-333)	100(100-100) 85(85,85)	7.45(7.45-7.45) 1.5(1.5-1.5)

The highest mean ESD for conventional radiography is 7.45mGy for spine PA projection de to high KVP and mAs and the lowest mean ESD is 0.13 for skull AP projection due to low mAs and Kvp

The highest mean for digital radiography is 28.9mGy for pelvic PA projection due to high mAs and low FSD,and the lowest mean ESD is 0.3mGy for extremity AP projection due to low mAs and Kvp

Table 7: The comparison of mean exposure parameters of ESD in(mGy)DRL (third quartile value) for both Conv, DR and with other studies and International publications

Examination	Projection	Age Group in year	DRL or 3rd quartile of ESD (This study)		Other studies and International publications						
					Ethiopia (2011) Previous Study		Sudan-2010		UNSCEAR -2000	ICRP -2012	IAEA -2004
			Conv	DR	BLH	YEK12H	KH	OM			
CXR	AP=278	0-1	2.147	0.221	0.104	0.2	0.09	0.08	0.02	0.08	0.05
		1-5	1.856	2.172	0.109	0.253	0.1	0.07	0.03	0.1	0.07
		5-10	2.094	3.86	0.119	0.281	0.15	0.019	0.04	0.1	0.12
		10-15	1.723	0.409	0.108	--	--	--	0.05	--	--
CXR	PA=67	0-1	0.761	1.147	--	--	--	--	0.02	0.1	0.05
		1-5	0.761	1.08	--	--	--	--	0.03	0.1	0.07
		5-10	0.141	0.409	0.411	0.332	--	--	0.04	0.2	0.12
		10-15	0.761	7.632	0.804	0.39	--	--	0.05	--	--
Pelvis	AP=9	0-1	1.747	0.883	--	0.265	0.18	0.2	0.07	0.2	0.5
		1-5	--	--	0.253	0.377	0.22	0.23	0.08	0.2	0.6
		5-10	--	--	0.435	1.117	0.26	0.35	0.04	0.9	0.7
		10-15	3.683	--	1.438	1.785	0.32	0.5	1.13	0.9	2
Skull	AP=7	0-1	--	0.565	0.389	0.513	--	--	0.15	1.5	0.8
		1-5	0.102	--	1.125	0.834	--	--	0.48	1.5	1.1
		5-10	--	0.697	1.159	1.428	--	--	0.73	1.5	1.1
		10-15	0.185	0.697	1.52	3.189	--	--	0.94	1.5	1.1
Skull	Lateral=18	0-1	--	--	--	--	--	--	--	1.5	0.8
		1-5	1.074	--	--	--	--	--	--	1.5	1.1
		5-10	4.621	8.789	--	--	--	--	--	1.5	1.1
		10-15	0.936	0.697	--	--	--	--	--	1.5	1.1

From the table we can see that most of the 3rd quartiles in our study are higher than the international publications

Discussion

Entrance skin dose (ESD) is used in this study as one of the common type of radiation quantification method used to set the optimized dose range and cut of points of radiation amounts for different imaging examination modalities. It is done on 620 patients who are children under the age of fifteen admitted to different hospitals in Addis Ababa during the study period.

Generally, these study shows that there are different factors that cause difference in ESD. Age, examination type, machine type and examination type versus body parts causes variation in ESD for both conventional and digital x rays. The study is done to compare ESD on different body parts like skull, abdomen, chest, spine and extremities. The most common x ray type result in this study is chest x ray. These could be due to high incidence of respiratory manifestation in this particular group which could lead to more chest x-ray order than other body parts x-ray examination. This study is similar by having high proportion of chest x-ray examination with that done on pediatrics patients in Nigeria [21]. According to the United Nations Scientific committee on effect of atomic radiation (UNSCEAR) children's of less than five years of age are two to three times more sensitive to the effects of radiation than adults [27]. Pediatrics patients of different age category are studied to determine the ESD dose difference for each age group and body parts for both conventional and digital types of radiography. The study helps in selecting preferred type of test for each region of the body and age categories. This in turn minimizes the radiation dosage exposure to skin and help to prevent radiation side effects that could occur in later life of any pediatrics patients.

The mean ESD in digital radiography is greater than the mean ESD of conventional radiography (1.841 vs 1.133 mGy respectively). This dissimilarity may be due to various physical conditions of exposure (kvp, mAs and FFD) which vary from one to another. These result are higher than mean dose of ESD done on similar study participants in Jima (1.82 mGy), Brazil (0.062mGy), Nigeria (0.642 mGy) and NRPB(0.050mGy). Mean dose of ESD is highest at age range of 5- 10 years but least at age range of 1-5 years of age for conventional radiography. However, in age group of 5-10 years the digital radiography exposes to higher ESD dose than conventional radiography because of higher mAs. There is big variation (difference) in digital radiography than conventional radiography between the maximum and minimum value of recorded ESD.

Similar study done in Khartoum Sudan showed that ESD of CXR is higher in conventional radiography (mean 0.11) than digital radiography (mean0.06) similarly in our study ESD of Conventional radiography for CXR is higher than ESD of digital radiography for CXR(mean ESD CR for CXR was 1.355 and mean ESD of DR for CXR was 0.76) (28). A study done in 2006 in Canada showed the chest PA patient dose from film–screen was not significantly different from DR . For abdomen AP, showed significant difference in the average patient doses for film–screen, CR, and DR. This was due to the much lower doses observed with DR compared

to film–screen. No statistically significant difference was observed in the means of the three imaging technologies for pelvis AP (29).
The highest ESD in conventional radiography is recorded in spine, which is (2.32mGy) followed by pelvis which is (1.4mGy) while the least is in extremities (0.62 mGy). Similarly, highest dose in digital radiography is recorded in pelvis with value of (7.78 mGy) followed by spine (5.53 mGy) but the least record is in CXR (0.76 mGy). Conventional radiography also shows low ESD dose in extremities, skull projections indicating that conventional modality is preferred type for these body parts. Comparison between DR and SFR doses shows that, in general, DR results in lower ESDs than those in SFR; the AP Skull projection is the only one where the ESD for DDR is higher than that for SFR(30).

Conclusion

According to this study, radiation dose (mean ESD) is relatively higher in conventional radiography in chest x ray and skull when compared to Digital Radiography whereas in abdomen, extrimities, pelvis and spine digital radiography mean ESDs are higher than conventional radiography mean ESDs. Overall mean ESD of digital radiography is higher than mean ESD of conventional ESDs which may be due to kvp, mAs ,FSD or incombinations.

Recommendations

- The x ray equipment must be calibrated to accurately produce the desired voltage, current, and exposure time , the examiners and radiographers should be aware of burdens of unnecessary exposure to the patient undergoing particularly digital radiography so that they can reduce the dose, frequent patient dose audits can improve practice
- Simple program of education, regular provision of dose information and an approach involving collaboration between medical physicists, radiographers and radiologists, a significant impact can be made on doses received by patients in medical x-ray
- QAP should be undertaken in each and every unit on regular interval and when necessary with implementation when fault is detected on time including replacement or maintenance of malfunctioning and older equipments to improve equipment performance

Limitations

The physical parameters like weight, height and body mass index were not analyzed to further characterize the effect on ESD in both the conventional and digital radiography since a number of data were incomplete. The generation and age of the machines are not included in this study.

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