ORIGINAL RESEARCH

Estimation of Radiation Dose Received in Knee Joint x-ray Examination

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Abstract

Background: Diagnostic X-ray examinations play an important role in the health care of the population. These examinations may involve significant irradiation of the patient and probably represent the largest manufactured source of radiation exposure for the population.

Purpose: This study performed to assess the effective dose (ED) received in lumbosacral radiographic examination in order to analyze effective dose distributions among radiological departments under study.

Materials and Methods: The study was performed in Khartoum teaching hospital, covering two x-ray units and a sample of 50 patients. The following parameters were recorded age, weight, height, body mass index (BMI) derived from weight (kg) and (height (m)) and exposure factors. The dose was measured for knee joint x-rays examination. For effective dose calculation, the entrance surface dose (ESD) values were estimated from the x-ray tube output parameters for knee joint AP and lateral examinations. The ED values were then calculated from the obtained ESD values using IAEA calculation methods. Effective doses were then calculated from energy imparted using ED conversion factors proposed by IAEA.

Results: The results of ED values calculated showed that patient exposure were within the normal range of exposure. The mean ED values calculated were 2.49 $\pm$0.03 and 5.60 $\pm$ 0.22 for knee joint AP and lateral examinations, respectively.

Conclusion: Further studies are recommended with more number of patients and using more two modalities for comparison.

Keywords: Dose, Knee Joint, x-ray Examination

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Introduction

Radiography started in 1895 with the discovery of X-rays (later also called Roentgen rays after the man who first described their properties in rigorous detail), a type of electromagnetic radiation. Soon these found various applications, from helping to find shoes that fit, to the more lasting medical uses[1-2]. Initially, many groups of staff conducted radiography in hospitals, including physicists, photographers, doctors, nurses, and engineers. The medical specialty of radiology grew up around the new technology, and this lasted many years. When new diagnostic tests involving X-rays were developed, it was natural for the radiographers to be trained and adopt this new technology[3-5]. This happened first with fluoroscopy, computed tomography (1960s), and mammography. Ultrasound (1970s) and magnetic resonance imaging (1980s) was added to the list of skills used by radiographers because they are also medical imaging, but these disciplines do not use ionizing radiation or X-rays. Although a no specialist dictionary might define radiography quite narrowly as "taking X-ray images", this has only been part of the work of an "X-ray department", radiographers, and radiologists for a very long time. Industrial radiographers in the field of nondestructive testing, where the newer technology of ultrasound is also used, also exploit X-rays. Diagnostic radiography involves the use of both ionizing radiation and non-ionizing radiation to create images for medical diagnoses [6-8]. The predominant test is still the X-ray (the word X-ray often used for both the test and the actual film or digital image). X-rays are the second most commonly used medical tests, after laboratory tests. This application known as diagnostic radiography. Since the body is made up of various substances with differing densities, X-rays can be used to reveal the internal structure of the body on film by highlighting these differences using attenuation, or the absorption of X-ray photons by the denser substances (like calcium-rich bones)[9]. A specially trained professional called a diagnostic radiographer in the UK, or a radiologic technologist in the USA undertakes medical diagnostic radiography. The creation of images by exposing an object to X-rays or other high-energy forms of electromagnetic radiation and capturing the resulting remnant beam (or "shadow") as a latent image known as "projection radiography." The "shadow" may be converted to light using a fluorescent screen, which is then captured on photographic film, it may be captured by a phosphor screen to be "read" later by a laser (CR), or it may directly activate a matrix of solid-state detectors (DR similar to a very large version of a CCD in a digital camera). Bone and some organs (such as lungs) especially lend themselves to projection radiography[10-12]. It is a relatively low-cost investigation with a high diagnostic yield. Projection radiography uses X-rays in different amounts and strengths depending on what body part are being imaged. Hard tissues such as bone require a relatively high-energy photon source, and typically, a tungsten anode is used with a high voltage (50-150 kVp) on a 3-

phase or high frequency machine to generate braking radiation. Bony tissue and metals are denser than the surrounding tissue, and thus by absorbing more of the X-ray photons they prevent the film from being exposed as much. Wherever dense tissue absorbs or stops the X-rays, the resulting X-ray film is unexposed, and appears translucent blue, whereas the black parts of the film represent lower-density tissues such as fat, skin, and internal organs, which could not stop the X-rays. This is usually used to see bony fractures, foreign objects (such as ingested coins), and used for finding bony pathology such as osteoarthritis, infection (osteomyelitis), cancer (osteosarcoma), as well as growth studies (leg length, achondroplasia, scoliosis, etc.) [13-14]. Soft tissues demonstrate with the same machine as for hard tissues, but a "softer" or less-penetrating X-ray beam is used. Tissues commonly imaged include the lungs and heart shadow in a chest X-ray, the air pattern of the bowel in abdominal X-rays, the soft tissues of the neck, the orbits by a skull X-ray before an MRI to check for radiopaque foreign bodies (especially metal), and of course the soft tissue shadows in X-rays of bony injuries are looked at by the radiologist for signs of hidden trauma (for example, the famous "fat pad" sign on a fractured elbow)[15-16]. Dental radiography uses a small radiation dose with high penetration to view teeth, which are relatively dense. A dentist may examine a painful tooth and gum using X-ray equipment. The machines used are typically single-phase pulsating DC, the oldest and simplest sort. Dental technicians or the dentist may run these machines radiologic technologists are not required by law to be present. Mammography is an X-ray examination of breasts and other soft tissues[17-18]. This has been used mostly on women to screen for breast cancer, but is also used to view male breasts, and used in conjunction with a radiologist or a surgeon to localize suspicious tissues before a biopsy or a lumpectomy. Breast implants designed to enlarge the breasts reduce the viewing ability of mammography, and require more time for imaging as more views need to be taken. This is because the material used in the implant is very dense compared to breast tissue, and looks white (clear) on the film. The radiation used for mammography tends to be softer (has a lower photon energy) than that used for the harder tissues. Often a tube with a molybdenum anode is used with about 30 000 volts (30 kV), giving a range of X-ray energies of about 15-30 keV. Many of these photons are "characteristic radiation" of a specific energy determined by the atomic structure of the target material (Mo-K radiation) [19].

Materials and Methods

Subjects

This study involved patients undergoing knee joint radiographic examinations in the emergency department at Khartoum Teaching Hospital. The The radiographic equipment used was Toshiba imaging system. It has a Polydoros LX 50 Lite high frequency generator with a general radiographic X-ray tube Opti 150/30/50HC. The target angle for the X-ray tube was 12°, and the measured ripple for tube potential was in the region of 1%. Total filtration for the X-ray system was measure as 2.7 mm of aluminum equivalent. A single exposure control system was available for use in the under-table or vertical position. Preliminary work will establish that lateral lumbar spine examinations will carry out in two different ways depending on the clinical condition of the patient. Patients with good mobility was lying on their side on the X-ray table with the X-ray beam vertically above them. Immobile patients was lying supine on a trolley in front of a vertical bucky with the X-ray beam horizontal. Both techniques used exposure control and a tube potential range of between 85 kV and 100 kV depending on the patient size. Average tube potential for both techniques will be in the region of 93 kV. With dose audit, there were difficulties in complying with the requirement to collect dose data for patients of a particular weight range (50–90 kg) within the busy environment of an emergency department. In this case, the decision took to increase the sample size to approximately 50 patients and to exclude those of very large or small build but not require the collection of patient weight information. Separate sets of DAP dose data were collected for each of the two radiographic techniques.

Dose measurement:

ESD defined as the absorbed dose to air at the center of the beam including backscattered radiation, measured for all patients using mathematical equation in addition to output factor and patient exposure factors. The exposure to the skin of the patient during standard radiographic examination or fluoroscopy can be measured directly or estimated by a calculation to exposure factors used and the equipment specifications from formula below:

$$ESD = OPx\left(\frac{kV}{80}\right)^2 xmAsx\left(\frac{100}{FSD}\right)^2 BSF$$

(OP) is the output in mGy/ (mA) of the X-ray tube at 80 kV at a focus distance of 1 m normalized to 10 mA s, (kV) the tube potential,(mA) the product of the tube current (mA) and the exposure time(s), (FSD) the focus-to-skin distance (in cm). (BSF) the backscatter factor, the normalization at 80 kV and 10 mAs used as the potentials across the X-ray tube and the tube current are highly stabilized at this point. BSF calculated automatically by the Dose Cal software after all input data entered manually in the software. The tube s, FSD and filtration) initially inserted in the software. The kinds of examination and projection selected afterwards output, the patient anthropometrical data and the radiographic parameters (kVp, mA.

Results

For the group of patients where age distribution was measured, 19 % of patients were within the 15-25 years age range, 21 % of patients were within the 26-35 years age range, 18 % of patients were within the 36-45 years age range, 22 % of patients were within the 46-55 years age range, 20 % of patients were within the 56-65 years age range. For the group of patients where Body Mass Index (BMI) was measured, 19 % of patients were within the 2.1 ± .51 (male), 2.35 ± 0.93

Table 1. Shows the mean and standard deviation of exposure factors used for knee joint examination in the study sample

Age Group (years)	*X-ray Exposure Factors (Mean ± Standard deviation)*	
	kVp	***mAs***
15-25	51.0 ± 3.1	28.6 ± 5.3
26-35	53.1 ± 6.2	29.6 ± 6.4
36-45	58.1 ± 7.7	28.5 ± 5.8
46-55	56.4 ± 6.07	29.8 ± 5.8
56-65	57.31 ± 7.3	27.7 ± 6.1

(female) BMI ratio range, 21 % of patients were within the 2.80 ± 0.79 (male) , 2.97 ± 0.92 (female) BMI ratio range, 18 % of patients were within the 2.91 ± 0.53 (male), 2.94 ± 0.88 (female) BMI ratio range, 22 % of patients were within the 3.1 ± 0.43 (male) and 2.9 ± 0.61 (female) BMI ratio range, 20 % of patients were within the 3.5 ± 0.37 (male) and 3.74 ± 1.04 (female) BMI ratio range. The key parameters for this group are shown in figure 1.

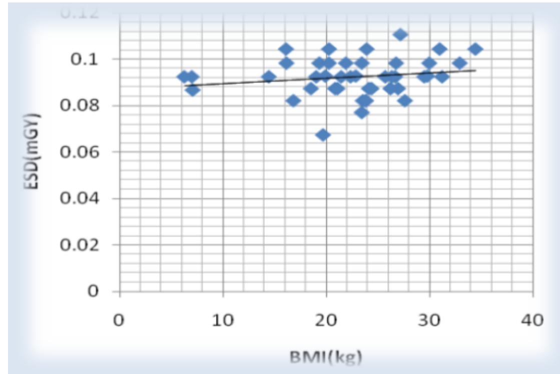

Figure 1. Correlation between Entrance Skin Dose (ESD) and Body Mass Index (BMI) of patients undergoing Knee joint X-ray

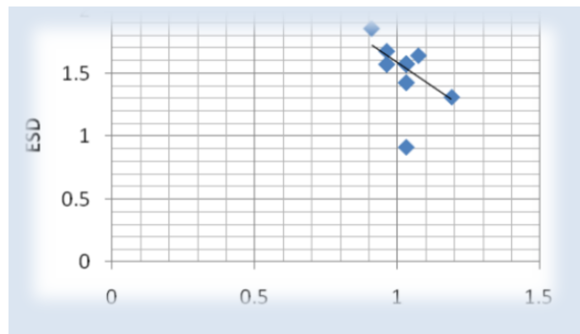

Figure 2: Correlation between Entrance Skin Dose (ESD) and weight (mass) of the body (Kg) of patients undergoing knee joint X-ray.

For the group of patients where x-rays exposure factors (kVp and mAs) was measured, 19 % of patients were within the 51.0 ± 3.1 (kVp), 28.6 + 5.3 (mAs) exposure factors ratio range, 21 % of patients were within the 53.1 ± 6.2 (kVp) and 29.6 ± 6.4 (mAs) exposure factors ratio range, 18 % of patients were within the 58.1 ± 7.7 (kVp) and 28.5 ± 5.8 (mAs) exposure factors ratio range, 22 % of patients were within the 56.4 ± 6.07 (kVp) and 29.8 ± 5.8 (mAs) exposure factors ratio range, 20 % of patients were within the 57.31 ± 7.3 (kVp) and 27.7 ± 6.1 (mAs) exposure factors ratio range (Table 1) exposure factors ratio range, 21 % of patients were within the 53.1 ± 6.2 (kVp) and 29.6 ± 6.4 (mAs) exposure factors ratio range, 18 % of patients were within the 58.1 ± 7.7 (kVp) and 28.5 ± 5.8 (mAs) exposure factors ratio range, 22 % of patients were within the 56.4 ± 6.07 (kVp) and 29.8 ± 5.8 (mAs) exposure factors ratio range, 20 % of patients were within the 57.31 ± 7.3 (kVp) and 27.7 ± 6.1 (mAs) exposure factors ratio range (Table 1).

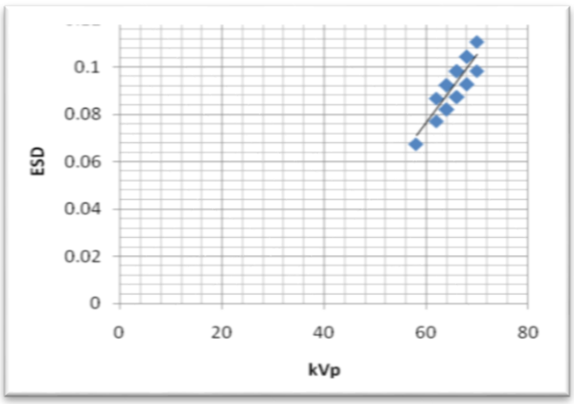

Figure 3: correlation between entrance skin dose (ESD) and tube potential kVp to patients undergoing lateral knee joint X-ray

Table 2: Exposure factors, number of films and dose values for Lumbosacral exam

Projection	KVp	mAs	Time (sec.)	Dose (mGy) (Mean +/- SD)
Antero-posterior (AP)	57.40	28.4	0.21	2.49 +/- 0.03
Lateral	65.7	28.7	0.21	5.60 +/- 0.22

For the group of patients where Body Mass Index (BMI) was measured, 19 % of patients were within the 2.1 ± .51 (male), 2.35 ± 0.93 (female) BMI ratio range, 21 % of patients were within the 2.80 ± 0.79 (male) , 2.97 ± 0.92 (female) BMI ratio range, 18 % of patients were within the 2.91 ± 0.53 (male), 2.94 ± 0.88 (female) BMI ratio range, 22 % of patients were within the 3.1 ± 0.43 (male) and 2.9 ± 0.61 (female) BMI ratio range, 20 % of patients were within the 3.5 ± 0.37 (male) and 3.74 ± 1.04 (female) BMI ratio range. The key parameters for this group are shown in Table 3-2. For the group of patients where x-rays exposure factors (kVp and mAs) was measured, 19 % of patients were within the 51.0 ± 3.1 (kVp), 28.6 ± 5.3 (mAs) exposure factors ratio range, 21 % of patients were within the 53.1 ± 6.2 (kVp) and 29.6 ± 6.4 (mAs) exposure factors ratio range, 18 % of patients were within the 58.1 ± 7.7 (kVp) and 28.5 ± 5.8 (mAs) exposure factors ratio range, 22 % of patients were within the 56.4 ± 6.07 (kVp) and 29.8 ± 5.8 (mAs) exposure factors ratio range, 20 % of patients were within the 57.31 ± 7.3 (kVp) and 27.7 ± 6.1 (mAs) exposure factors ratio range. The key parameters for this group are shown in Table 2.

Discussion:

Diagnostic X-ray examinations play an important role in the health care of the population. These examinations may involve significant irradiation of the patient and probably represent the largest man-made source of radiation exposure for the population. Radiation has been long known to be harmful to humans. The radiation exposure received in X-ray examinations is known to increase the risk of malignancy as well as, above a certain dose, the probability of skin damage and cataract. Strategies for reduction of patient doses without loss of diagnostic accuracy are therefore of great interest to society and have been focused in general terms by the ICRP through the introduction of the concept of diagnostic reference levels. The main objective of this study was to assess the dose received by organ in lumbosacral radiographic examination. A total of 50 patients were examined in two radiology department which equipped with different imaging modalities in the Khartoum teaching hospital Tables 2-1 showed the details of x-rays equipment specifications. For the group of patients where age distribution was measured, 19 % of patients were within the 15-25 years age range, 21 % of patients were within the 26-35 years age range, 18 % of patients were within the 36-45 years age range, 22 % of patients were within the 46-55 years age range, 20 % of patients were within the 56-65 years age range. The key parameters for this group are shown in Table 3-1. Dose measurement during knee joint examination have been reported by Ogundare et al (2010) and Berman et al (2007) the results of this study confirm the findings of the two reported studies, i.e. that conventional radiology generally results in high ESDs in lateral projection rather than AP projection in both conventional and computed radiology.. The dose values for all examinations were below the previous reported studies except the study of Oluwafisoye et al, (2009). This variation could be attributed to exposure factors and patient morphologic characteristics and the sensitivity of the detectors. The limited experience with digital technology and the technologist may attempt to avoid noisy images by using milliamp ere-second settings higher than necessary for good image quality. The effect of the kilovolt peak setting on the patient entrance dose at conventional radiology has been described by Al-Zaharni and Bakheit, (2005) who suggested the use of higher kilovolt peak settings with additional filtration and alternative projection to study knee joint pathologies with low dose and high contrast-detail detect ability. In this study, it was found that doses for knee joint for the entire examination were lower than IAEA guidelines. The image quality met the criteria of the departments for all investigation. The findings of this study are therefore neither completely optimization during CR imaging must be considered.

Conclusion

The findings of this study are therefore neither completely unexpected nor in contradiction with those of other trials. Therefore the importance of dose optimization during conventional radiology imaging must be considered.

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