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Estimation of the Patients Doses in Conventional Radiography in Red Sea State

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Abstract

The purpose of this study is to provide new data on patient doses for estimation purposes in conventional X-ray examinations in Red Sea State and to enhance and compare different dosimetric protocols to promote the establishment of Diagnostic Reference Levels (DRLs). Patients doses from conventional X-ray were calculated using CALDose. The study revealed that there is wide variations in patients' doses within and between hospitals for conventional X-ray were observed. Even for the same type of X-ray equipment, the patient dose at different hospitals can vary widely. The causes for these wide variations in patient doses observed in this study required investigation to reduce the variability and ensure that all patient doses are as low as reasonably achievable. Furthermore, Local diagnostic reference levels (LDRLs) are suggested as a further step for patient dose optimization.
Keywords: List Conventional X-ray, Patients, Red Sea State, Dose

Introduction

All People are constantly exposed to low levels of ionizing radiation that are naturally present in the environment [1]. Other sources of exposure include some medical treatments and other activities that involve the use of radioactive materials. Research has shown that exposure to ionizing radiation above certain levels can cause adverse health effects, including cancer and hereditary effects (effects that can be passed on to offspring). Therefore, exposure to ionizing radiation is monitored and controlled.

Ionizing radiation is energy in the form of waves or particles that has enough force to remove electrons from atoms. One source of radiation is the nuclei of unstable atoms. As these radioactive atoms (also referred to as radionuclides or radioisotopes) seek to become more stable, their nuclei eject or emit particles and high-energy waves. This process is known as radioactive decay. Some radionuclides, such as radium,

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uranium, and thorium, have existed since the formation of the earth. The radioactive gas radon is one type of radioactive material produced as these naturally-occurring radioisotopes decay. Human activities, such as the splitting of atoms in a nuclear reactor, can also create radionuclides. Regardless of how they are created, all radionuclides release radiation.

The major types of radiation emitted during radioactive decay are alpha particles, beta particles, and gamma rays. Radiation can come from natural sources or man-made radionuclides. Man-made x-rays, another type of radiation, are produced outside of the nucleus. Most x-ray exposure that people receive is technologically produced.

X-rays are high-energy photons produced by the interaction of charged particles with matter. X-rays and gamma rays have essentially the same properties but differ in origin. X-rays are either produced from a change in the electron structure of the atom or are machine produced. They are emitted from processes outside the nucleus, while gamma rays originate inside the nucleus. They also are generally lower in energy and therefore less penetrating than gamma rays. A few millimeters of lead can stop x-rays.

Literally thousands of x-ray machines are used daily in medicine and industry for examinations, inspections, and process controls. Because of their many uses, x-rays are the single largest source of man-made radiation exposure.

X-ray tubes are the most common source of x-rays [2]. A diagram of an x-ray tube (Figure 1) illustrates the minimum components. A large voltage is applied between two electrodes (the cathode and the anode) in an evacuated envelope. The cathode is negatively charged and is the source of electrons; the anode is positively charged and is the target of the electrons. As electrons travel from the cathode to the anode, they are accelerated by the electrical potential difference between these electrodes and attain kinetic energy. The kinetic energy gained by an electron is proportional to the potential difference between the cathode and the anode.

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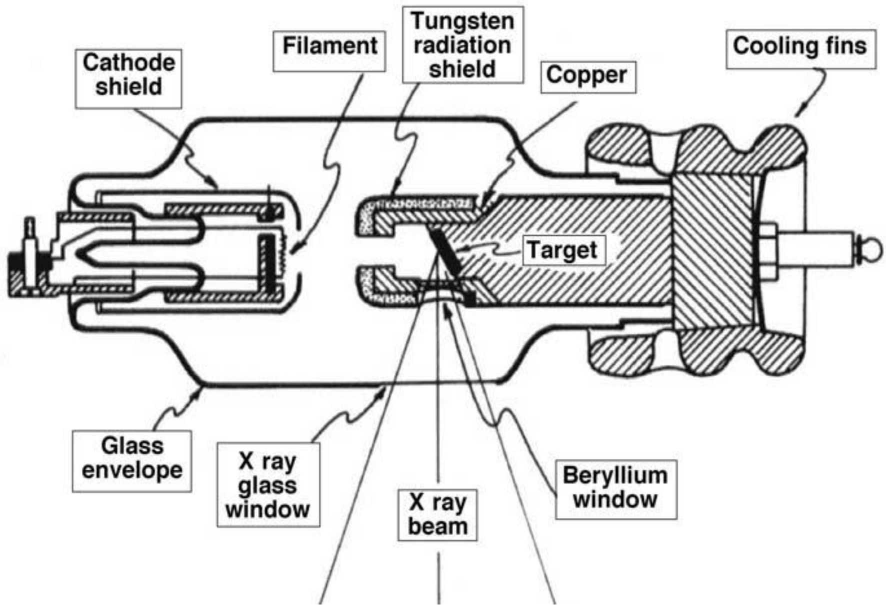

Figure 1. Production of x-rays in an x-ray tube. High-speed electrons impinges on a metal disk releasing x-rays

On impact with the target, the kinetic energy of the electrons is converted to other forms of energy. The vast majority of interactions produce unwanted heat by small collisional energy exchanges with electrons in the target. Occasionally an electron comes within the proximity of a positively charged nucleus in the target electrode. The electron interacts with the Coulomb field of the nucleus of an anode atom and experiences a deceleration. As it slows down, it loses energy. The electron emits this energy in the form of radiation. The more the electron is slowed down, the more energy it gives off. The radiation created by this process is called Bremsstrahlung. Bremsstrahlung yields a continuous x-ray spectrum with a maximum energy that equals the energy with which the electrons hit the anode material. The numbers of photons emitted per unit time is controlled by the cathode current (mAs), whereas, the maximum energy of the emitted photons (keV) is controlled by the tube voltage (kVp).

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There are various studies were carried out in patient doses measurement from general x-ray radiography. Most of these studies were done in the Sudanese capital, Khartoum. Besides their role in optimisation, dose surveys provide patient exposure data required for the formulation of national diagnostic reference levels. As a continuation of this effort, the present dose survey was performed in Red Sea State . The objective of this study was to measure radiation dose to patients from X-ray examinations of the chest, pelvis and lumbar spine, and to compare them with established international diagnostic reference levels (DRLs).

Materials and Methods

In total, three hospitals and 180 patients were included in this study. Patient information (age and weight) and exposure parameters such as tube potential KVP, current-time product (mAs) and focus-to-film distance (FFD) were recorded for conventional x-ray examinations Patient doses were measured in terms of the entrance surface air kerma (ESAK), defined as the air kerma measured on the x-ray beam axis at the point where the x-ray beam enters the patient or a phantom, including the contribution of the backscatter radiation [3,4]. Information on x-ray units are presented in Table 1.

Table 1. Information on x-ray units

Hospital	X-ray unit manufacturer/model	Year of installation	Total filtration (mm Al eq)
A	X-ray TOSHIBA/DRX	2003	2.8
B	X-ray SHIMADZU/ ½ P13DK	2008	2.6
C	X-ray SHIMADZU/M15DK	2010	2.5

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In order to increase the speed and efficiency of the patient dosimetry process, windows-based computer program, CALDose_X 5.0, which is developed by Kramer et al (2008)., was used in the present study.

CALDose_X 5.0 is a software tool that enables the calculation of the Incident Air Kerma (INAK) based on the output curve of an x-ray tube and of the Entrance surface air kerma (ESAK) by multiplying the INAK with a backscatter factor, as well as organ and tissue absorbed doses and effective doses for posture-specific female and a male adult phantoms, using conversion coefficients (CCs) normalized to the INAK, the ESAK or the Air Kerma Area Product (AKAP) for examinations frequently performed in X-ray diagnosis. Additionally, CALDose_X determines the risks of cancer incidence and cancer mortality for the examination selected by the user.

The selection of the x-ray examinations and of the exposure parameters was based on textbooks for X-ray practitioners and on studies performed in x-ray departments. In version 5.0, CALDose_X covers 24 examinations with 2.5 mm Al standard filtration for standing and/or supine posture. Instead of using the focus-to-skin distance of previous versions, CALDose_X 5.0 examinations are based on focus-to-detector distance (FDD) which can be selected by the user within a given interval.

ESAK was calculated in this study using CALDose_X 5.0 software according to the following equation:

$$K_i = Y(d, kV)P_{It}\left(\frac{d}{FSD}\right)^2 xBSF$$

Y(d,KV) represents the tube output (µGy.mAs-1) at 1 m from the focus and for a given kV obtained from the equipment output, PIt is tube-current exposure time product (mAs), FSD is the focus-to-surface distance, BSF is a backscatter factor for a particular examination at the required potential, taken from UK Health Protection Agency HPA [5] numerical simulations.

Results & Discussion.

The Surveys on the status of image quality and radiation doses to patients in radiographic examinations form an important component of Quality Assurance

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program. Knowledge of the patient dose level and the reasons behind higher doses provides a basis for setting corrective actions to optimize the protection of the patient in an effective manner. Patients (and their relatives) expect to be informed about clinical risks, including radiation [6,7] - another aspect of the usefulness of patient dose data.

Table 2, 3 and 4 shows the patients Entrance Surface Air Kerma, ESAK for the major radiographic examinations (chest, pelvis and lumbar spine) in hospitals A, B and C respectively. Statistical analysis, age, weight, MAs and KVp are also shown in the tables.

Current ESAK are comparable to those previously reported in Sudan [9]. Furthermore, ESAK values in all hospitals in this study are below reference dose levels.

The Radiology Departments in this study are covered under the National Quality Assurance Program (NQAP) provided by the Sudan Atomic Energy Commission (SAEC).

NQAP includes acceptance/ commissioning and annual routine testing. The QA tests performed prior to the current study showed that the kV and HVL were within the acceptable tolerance limit. The equipment passed the kVp and mAs reproducibility and mAs linearity tests.

Table 2 patients Entrance Surface Air Kerma, ESAK (mGy) for the major radiographic examinations (chest, pelvis and lumbar spine) in hospital A

SAMPLE		AGE	WEIGHT	MAS	ESAK	KV
chest	N	20	20	20	20	20
	Mean	55.7500	64.6500	10.4120	.9005	66.2000
	Median	54.5000	66.0000	9.3500	.7450	65.0000
	Std. Deviation	13.66084	17.31527	3.62870	.45327	5.55925
	Minimum	22.00	20.00	6.93	.47	60.00
	Maximum	80.00	96.00	20.00	2.27	80.00
Pelvis	N	20	20	20	20	20
	Mean	59.0000	65.2000	3.7420	.1745	68.5000
	Median	61.0000	65.0000	3.8750	.1800	67.0000
	Std. Deviation	11.64384	11.85704	1.34285	.07244	6.93200
	Minimum	38.00	46.00	1.50	.06	60.00
	Maximum	80.00	90.00	5.93	.28	80.00
Lumbar spine	N	20	20	20	20	20
	Mean	57.3500	65.9000	8.6480	.4810	65.0500
	Median	58.0000	66.5000	8.6000	.4500	65.0000
	Std. Deviation	16.17430	11.64790	.68820	.12904	4.54770
	Minimum	23.00	49.00	7.52	.32	60.00
	Maximum	80.00	93.00	9.90	.78	75.00

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Table 3 patients Entrance Surface Air Kerma, ESAK (mGy) for the major radiographic examinations (chest, pelvis and lumbar spine) in hospital B

SAMPLE		AGE	WEIGHT	MAS	ESAK	KV
chest	N	20	20	20	20	20
	Mean	54.1500	70.0000	39.9600	6.6240	93.5000
	Median	65.0000	65.5000	39.5500	4.1250	89.0000
	Std. Deviation	21.35730	18.60956	20.48030	6.91392	27.76689
	Minimum	23.00	46.00	10.00	.45	60.00
	Maximum	80.00	118.00	75.00	23.82	150.00
Pelvis	N	20	20	20	20	20
	Mean	54.5500	67.9500	37.2600	4.3420	78.4000
	Median	56.0000	67.0000	35.1000	3.5850	78.5000
	Std. Deviation	19.11317	17.10794	15.08060	2.95780	12.02804
	Minimum	23.00	47.00	16.20	.90	60.00
	Maximum	80.00	105.00	65.00	10.46	98.00
Lumbar spine	N	20	20	20	20	20
	Mean	49.4000	72.8000	34.2500	4.7835	73.7000
	Median	45.0000	67.5000	36.0000	4.3750	73.0000
	Std. Deviation	17.56911	20.47746	15.64028	3.16366	8.70027
	Minimum	25.00	49.00	10.00	.78	60.00
	Maximum	80.00	125.00	60.00	11.55	90.00

Table 4 patients Entrance Surface Air Kerma, ESAK (mGy) for the major radiographic examinations (chest, pelvis and lumbar spine) in hospital C

From the above tables it can be observed that, for the chest exam the mean KVp, mAs and ESAK ranged (66.2 –103), (10.4 –39.9) and (0.9 –6.6) respectively. For the pelvis exam the mean KVp, mAs and ESAK ranged from (68.5 – 78.4), (3.7 – 37.2) and (0.17 – 4.3) respectively. For the lumbar spine exam, the mean KVp, mAs and ESAK ranged from (65 – 74.4), (8.6 – 34.2) and (0.48 – 4.7) respectively.

In radiography, radiation dose is proportional to the tube current, exposure time, and the square of the peak voltage and inversely proportional to the square of focus to skin distance (FSD). The use of higher peak kilo-voltages increases beam penetration and this may allow the use of a lower tube current, thus reducing patient dose.

Table 5 compares mean ESAK obtained in this work with EU and UK reference dose levels and doses reported in Sudan, , Brazil , Iran and Italy [26,27,28,29,30,31,32] .From the table it can be observed that, most ESAK values are below reference dose levels and are comparable to the results reported in the literature. However, hospital A, B and C exhibited a higher dose level for chest exam when compared to the DRLs.

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Examination	This study			Doses from similar studies					DRLS	
	H(A)	H(B)	H(C)	Sudan[28]	Sudan[29]	Iran[31]	Italy[32]	Brazil[30]	EU[26]	UK[27]
Chest PA	0.9	2.1	6.6	0.3	0.2	0.4	0.3	0.2	0.3	0.15
Pelvis AP	0.2	1.6	4.3	2.0	0.9	2.8	3.7	-	10	4.0
LS AP	0.5	1.9	4.7	2.6	1.6	3.4	3.8	2.4	10	5.0

H: hospital

Table 5 Comparison between the mean ESAK (mGy) among hospitals obtained in this work with EU and UK reference doses, and results of previous studies performed in Sudan, Serbia, Italy and Brazil

Figures 2, 3 and 4 shows ESAK variations among hospitals for chest, pelvis and lumbar spine respectively. From the tables it can be seen that, there is wide variations in patient's doses within and between hospitals. The reasons for the dose variations may be attributed to multifactors such as: patient weight, exposure factors, radiographic technique, FFD, equipment type and processing performance [8]. Variations in dose within a hospital room indicate the importance of QA assurance programme, so that inconsistencies and errors in technique and equipment can be discovered early and thus reduce the variation in dose to the patients

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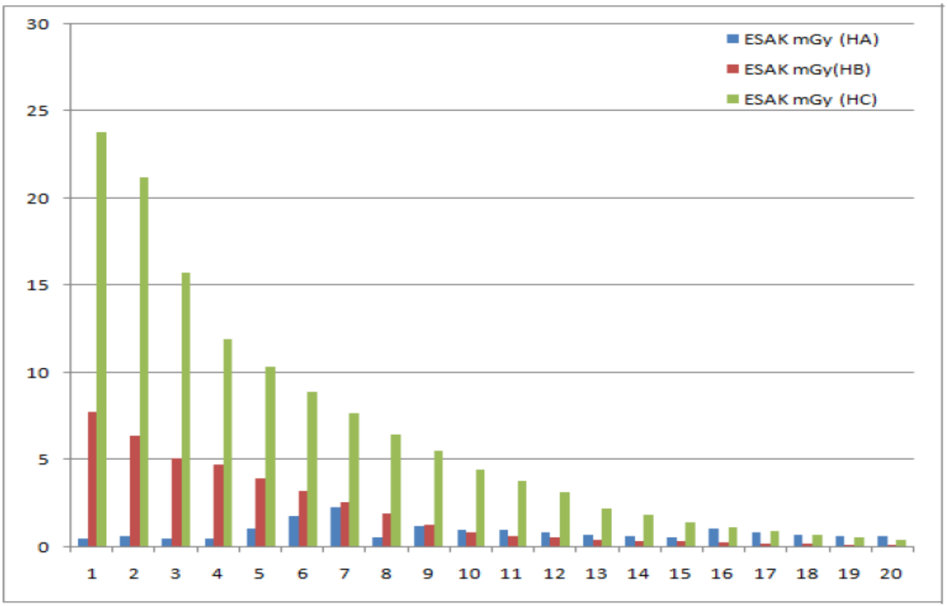

Figure 2. ESAK variations for chest exam among hospitals

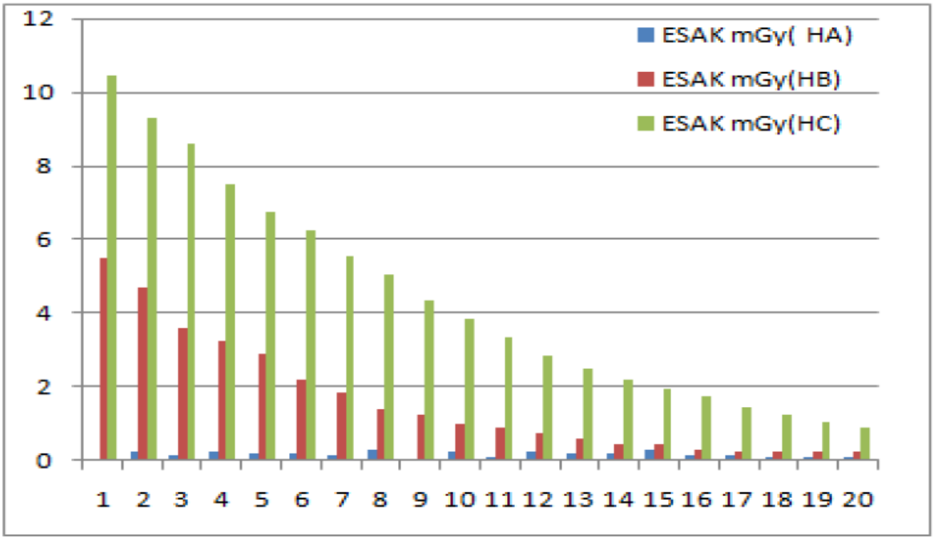

Figure 3. ESAK variations for pelvis exam among hospitals

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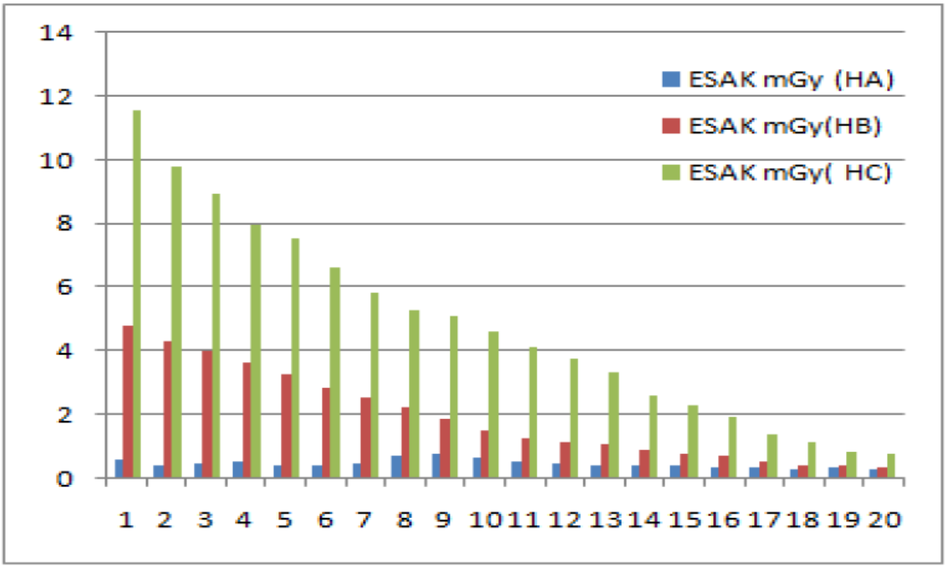

Figure 4. ESAK variations for lumbar spine exam among hospitals

Conclusion.

Most ESAK values measured for 3 common radiographic examinations in Red Sea State are comparable to those reported in other countries and are below reference dose levels suggested by European Dose (DataMed2) Project and the UK Health Protection Agency (HPA, formerly NRPB). However, hospital A, B and C exhibited a higher dose level for chest exam when compared to the DRLs. In additional In conventional x-ray examinations, wide variations in patients' doses within and between hospitals were observed. Reasons for such variations may be attributed to multifactors such as: patient weight, exposure factors, radiographic technique, FFD, equipment type and processing performance.

The Local diagnostic reference levels (LDRLs) are suggested as a further step for patient dose optimization. Besides their use in quality assurance and optimization, the results of the current dose survey provide valuable patient exposure information that will be used in formulation of national diagnostic reference levels in Sudan.

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