

Scattered Radiation and Entrance Skin Dose Assessment During Conventional Radiographic X-Ray Procedures

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ABSTRACT

Medical X-rays are one of the most common forms of radiation used in medicine and represent one of the largest sources of man-made radiation exposure to patients, radiology staff, and the general public. Consequently, there is a significant challenge in safely delivering radiation doses when imaging biological tissues. During the operation of an X-ray machine, if the radiation protection of X-ray room is insufficient, not only the patient but also clinical staffs as well as public are exposed to high X-ray exposures. The present study aimed to evaluate the radiation delivered [ESD] to patients and the scatter dose received to the patients and technicians, radiographers and radiologists. This research work has been carried out by the assessment of radiation (Entrance Skin Dose) delivered to the patients and the measurement of the scattered radiation dose from diagnostic X-ray examinations in Federal Medical Centre Birnin Kebbi. Both natural background radiation of the building and scattered radiation dose during exposure was measured using a portable survey meter called BR-6 Geiger Muller Radiation Detector. The radiation delivered to patients was determined using geometric and exposure factors incorporated in mathematical model for 81 patients. The natural background ionizing radiation of the radiology buildings was measured with an average effective dose rate of 0.11 $\mu\text{Sv/hr}$ using BR-6 Geiger Muller Radiation Detector. The exposure and geometric factors were recorded for different Projections in a form designed by the researcher. The scattered X-radiation for different projections was measured for each selected kVp and mAs which represents the main technique factors of abdomen supine, abdomen erect, chest, femur, forearm, leg, and skull radiographic examinations. The mean scattered radiation measured by the survey meter were found to be 0.33 $\mu\text{Sv/hr}$, 0.38 $\mu\text{Sv/hr}$, 0.32 $\mu\text{Sv/hr}$, 0.21 $\mu\text{Sv/hr}$, 0.19 $\mu\text{Sv/hr}$, 0.218 $\mu\text{Sv/hr}$, and 0.28 $\mu\text{Sv/hr}$ while ESD was calculated using mathematical equation and found to be 1.22 mGy, 1.02 mGy, 0.85 mGy, 0.38 mGy, 0.29 mGy, 0.36 mGy, and 0.77 mGy corresponding to 79, 77, 73, 64, 56, 54 kV and intensities of 20.6, 20, 18.7, 10.7, 7.6, 7.5 mAs for abdomen supine, abdomen erect, chest, femur, forearm, leg, and skull radiographic examinations. The values of scattered radiation dose obtained were remarkably higher than the natural background radiation. The excess life cancer risk was found to be in the range of 0.6×10^{-5} - 0.10×10^{-4} for scattered radiation and 0.3×10^{-5} for natural background radiation of the place which was lower than the scatter dose. Thickness of the body was in the average range of 8.60 cm to 24.29 cm. The kV, mAs, and thickness of the body affect the scattered and entrance skin dose to patients. The highest ESD were found for abdomen supine, abdomen erect, chest and Skull respectively. Similarly, the highest value of scattered radiation dose was found for the skull, abdomen erect, abdomen supine and chest x-ray procedures. All the exposure factors and body thickness affect both ESD and scatter doses, hence there's need for correct selection of exposure factors to reduce both scattered and ESD.

Keywords: X-Ray; Scattered Radiation; Entrance Skin Dose and Exposure Factors

Introduction

Over the past hundred years, X-rays have been used for diagnostic purposes. Diagnostic X-rays are used for identifying diseases and other issues during medical examinations. Indeed, X-ray diagnostics allow the exploration of internal anatomical structures by the image obtained following the patient's crossing by an X-ray beam. However, radiation exposure during diagnostic X-ray examinations can cause at

the same time harmful effects to the person undergoing exposure, if its use is not optimized. So, the radiation protection is very necessary. This is the reason why the medical use of ionizing radiation is subject to a significant regulatory control (Samaila, et al. [1]).

Medical X-ray is most common forms of radiation in medicine, and is one of the largest manmade sources of radiation exposure to patients, radiology staff (workers), and the general populace, hence

there exists the problem of safely delivering radiation dose when imaging biological tissues. For example, conventional radiography accounts more than 80 % of X-ray-based imaging, and it is considered a responsible for the most of the radiation exposure associated with all medical imaging techniques (Abdullah [2]). Therefore, there is a need to reduce scattered radiation dose to protect patients and radiology workers in an X-ray room from unnecessary Radiation exposure (Abdullah [2]). When a beam of X-ray strikes any object or inner cladding of X-ray room, it is scattered, absorbed, transmitted or reflected to backward. Scattered radiation photons are radiation that changes in direction due to interaction with some materials (Abdullah [2]). Scattered radiation arises from the interaction of the primary beam photons with the exposed materials causing a portion of the primary (incident) X-rays photons to be redirected in different directions. The scattered radiation photons can cause a serious radiation exposure hazard in diagnostic radiography, a large amount of X-ray photons can be scattered from the patient during radiography and fluoroscopy. Hence, scattered radiation is the source of most of the occupational radiation dose exposure that radiography's staff received (Abdullah [2]).

The longer a person is exposed to radiation, the more energy the body will be absorbed from the radiation. This is not to be mistaken with the idea that the radiation will somewhat stay in the body causing other health effects. The energy will immediately affect the body by breaking bonds in molecules or affecting the cells in the body. It is the absorption of energy that may lead to health effects. Any time radiation interacts with the body, it has the potential to damage the cells in the body, possibly leading to health effects. As more and more energy is transferred to the body by the radiation, the chances of causing a health effect also increases (Owusu-Banahene et al., 2018). The scattered photons negatively affect radiographic image contrast thereby hindering accurate representations of human anatomy, and increase radiation dose that patients and medical personnel are exposed to (Denise [3]). X-ray scatter is one of the foremost factors that negatively affect image quality by causing the underestimation of attenuation

coefficient in image reconstructions. The scattered radiation reduces image sharpness and contrast, which makes the image hazy and indistinct (Abdullah [2]).

Material and Method

This research work has been carried out by the assessment of radiation (Entrance Skin Dose) delivered to the patients and the measurement of the scattered radiation dose from diagnostic X-ray examinations in Federal Medical Centre Birnin Kebbi. The data [kV, mAs, and Geometric factors (FFD, FSD)] was collected prospectively and 81 patients were involved in the study. The ESD were determined by the exposure factors (kV, mAs) and geometric factors (FFD, FSD and filtration) incorporated into mathematical model given in equation (1)

$$ESD(EntranceSkinDose) = C \left(\frac{kV}{FSD} \right)^2 \times \left(\frac{mAs}{mmAl} \right) \quad (1)$$

Where C is constant 0.2771, mmAl is the filtration given as 3mm, FSD is focus to Skin Distance, and mAs is mili-ampere second. The measurement of scattered radiation and natural background radiation dose rate at the Radiology Department of the hospital were measured using a portable survey meter called BR-6 Geiger Muller Radiation Detector. For each projection, the corresponding scattered radiation was recorded by the meter.

Results and Discussion

The background ionizing radiation reading of the survey meter was taken and it was found to be 0.11 μ Sv/h. The Dark room and HOD's office have the least dose rate of 0.1 μ Sv/hr while exposure room has the highest natural background radiation as shown in the Figure 1 below. The highest radiation doses delivered to the patients were found for abdomen supine, abdomen erect, chest and Skull respectively. Similarly, the highest value of scattered radiation dose was found for the skull, abdomen erect, abdomen supine and chest x-ray procedures as shown in the Table 1.

Table 1: Average results for entrance skin dose and scattered radiation dose.

Examination	kV	mAs	FFD (cm)	FSD (cm)	T (cm)	ESD (mGy)	SR (μ Sv/hr)	SR AED (mSv/y)	ELCR $\times 10^{-3}$
Abdomen Supine	79.64	20.68	137.86	116.07	21.79	1.22	0.334	0.003	0.01
Abdomen Errect	82.86	20.29	134.29	110	24.29	1.02	0.376	0.002	0.008
Chest	77.78	18.68	150.56	130.37	20.19	0.85	0.32	0.003	0.01
Femur	55.71	10.68	101	87	14	0.38	0.21	0.002	0.006
Forearm	53.5	7.557	94.286	85.714	8.571	0.29	0.196	0.002	0.006
Leg (Tibia/Fibula)	64.375	7.625	105	91.25	13.75	0.36	0.218	0.002	0.007
Skull	73.125	18.5	153.75	126.25	27.5	0.77	0.28	0.004	0.013
NBIR							0.11	0.001	0.003

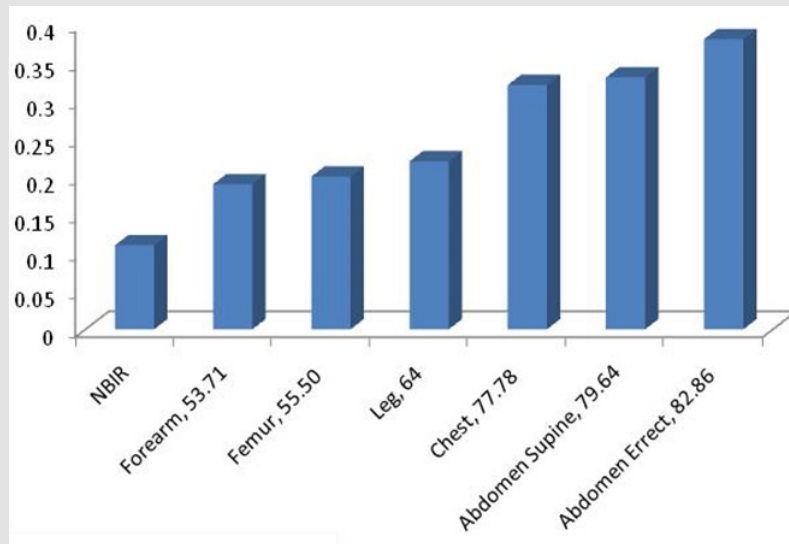


Figure 1: Effect of kV on scattered radiation.

Effect of kV and mAs on Entrance Skin Dose (ESD) and Scattered Radiation

The effect of incident X-ray energy on delivered and scattered dose was evaluated by measuring scattered dose rate at different applied voltage of X-ray tube (kVp) for different anatomical region such as abdomen, chest, femur, leg and forearm. The ESD and scattered radiation Dose rate vary depending on the voltage, for an average 53.50 kVp the corresponding ESD and scattered radiation was 0.297 mGy and 0.19 μ Sv/h, and for 82.90kVp it was 1.02mGy & 0.38 μ Sv/h for Forearm and abdomen x-rays in the erect position. Figure 2 and

Figure 3 shows the ESD and scattered X-ray dose versus kVp. The ESD and scattered radiation increased with increasing X-ray tube voltage (kVp) due to the fact that more scatter photons occur at higher energy. The change between 53.50 and 82.9kVp from the figure may be due to the transition between the Compton Effect and photoelectric effect. More ESD and scattered dose was recorded for high X-ray energy, X-ray photons interaction with matter increases by increasing photon energy (kVp). This finding is in line with Vlachos, et al. [4,5] who illustrated the effect of x-ray tube voltage on dose rate due to the scatter radiation.

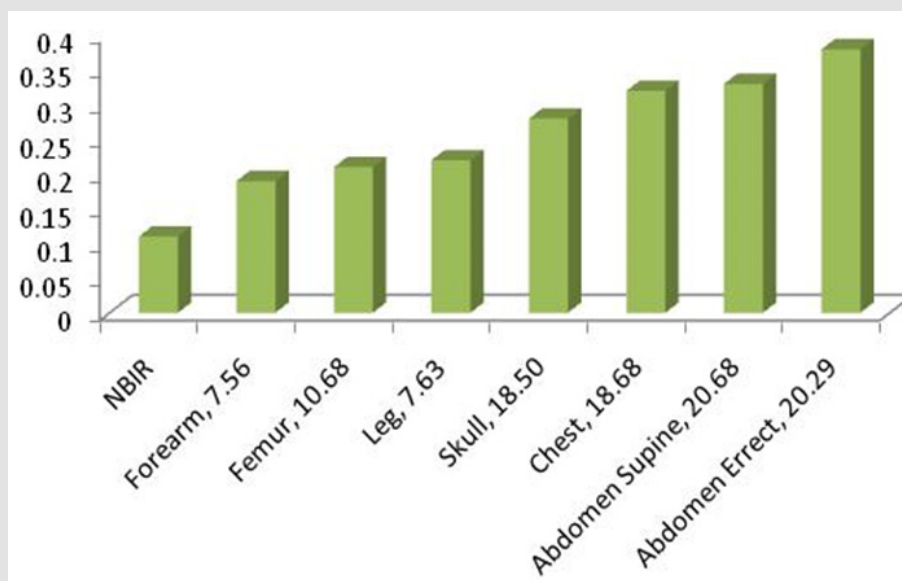


Figure 2: Effect of mAs on radiation.

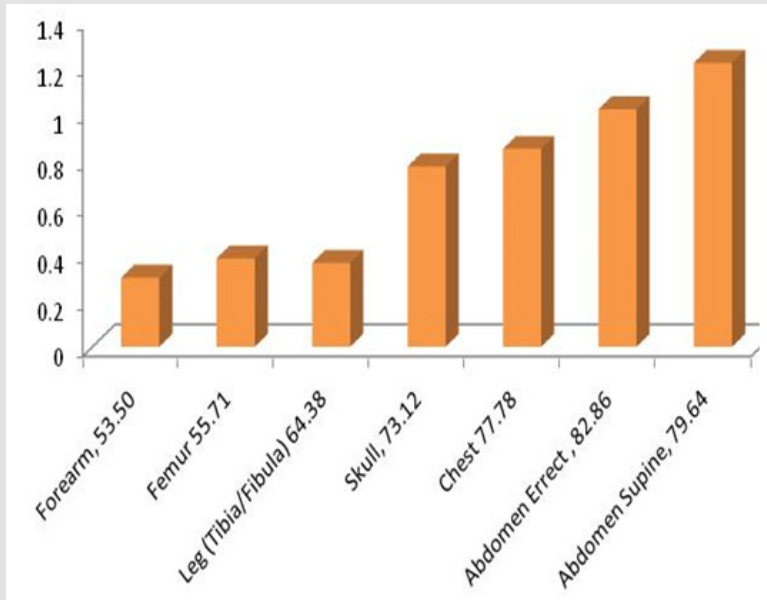


Figure 3: Effect of kV on delivered radiation (ESD).

The effect of radiation exposure intensity which referred to as mAs (product of X-ray tube current and exposure time) on the scattered radiation dose was evaluated. The delivered and scattered radiation Dose rate varies depending on the current time product. It was observed that an increase of delivered and scattered radiation was associated with the increase of current-time product. For an average of 7.56 mAs, the corresponding delivered and scattered radiation was 0.297mGy & 0.19 μ Sv/h, and for 20.68 mAs was 1.22mGy & 0.33 μ Sv/h for the forearm and Abdomen in supine position. Figure 4 and Figure

5 shows direct proportionality between ESD and scattered radiation dose and exposure intensity (mAs) due to the number of incident photons increased proportionally with mAs increase, so there is a clear relationship between the entrance skin dose, scattered radiation dose and mAs. Chiang, et al. [5] similarly reported the dependence of scattered radiation dose on the radiation exposure intensities. Therefore, one of the most effective methods to reduce scattered radiation dose is by reducing radiation intensity (Figure 6).

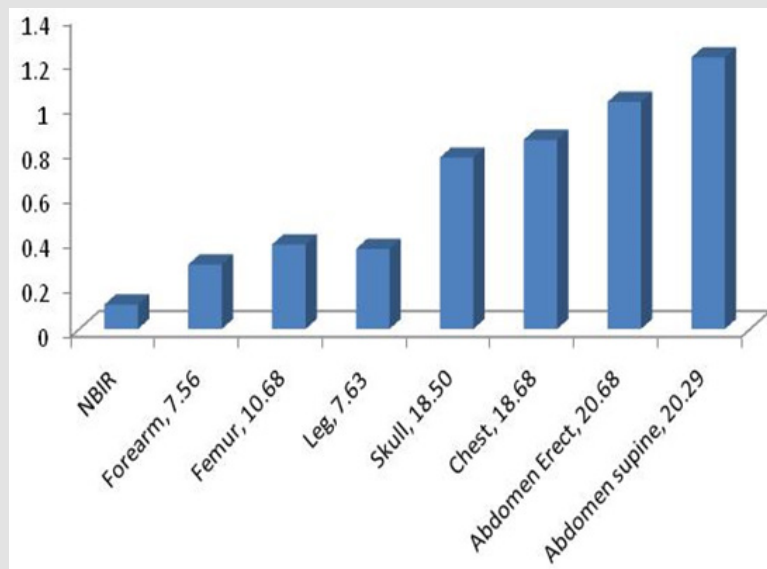


Figure 4: Effect of mAs on delivered radiation (ESD).

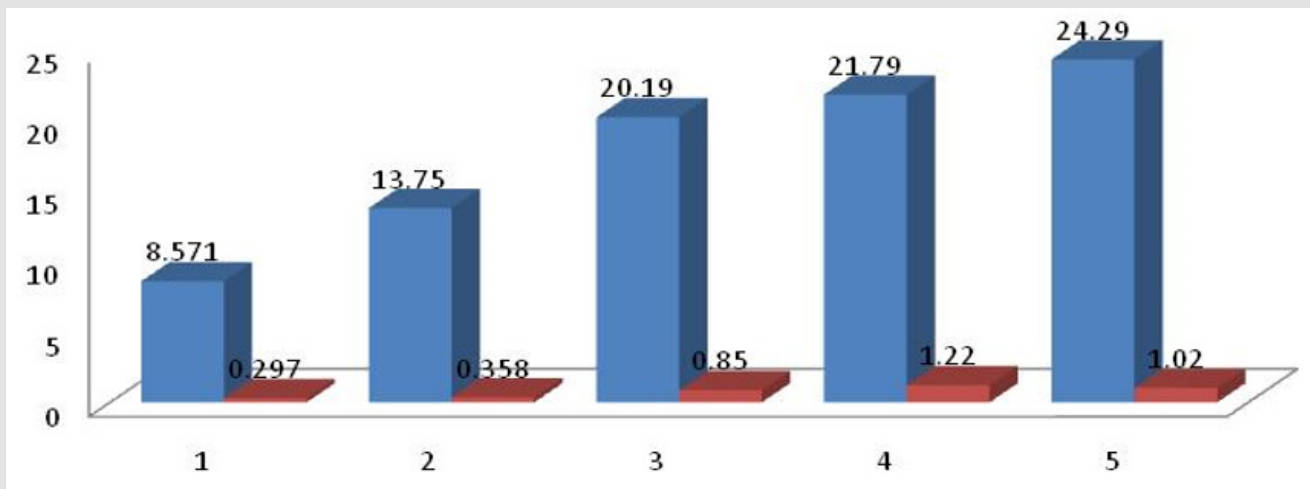


Figure 5: Effect of body thickness on ESD.

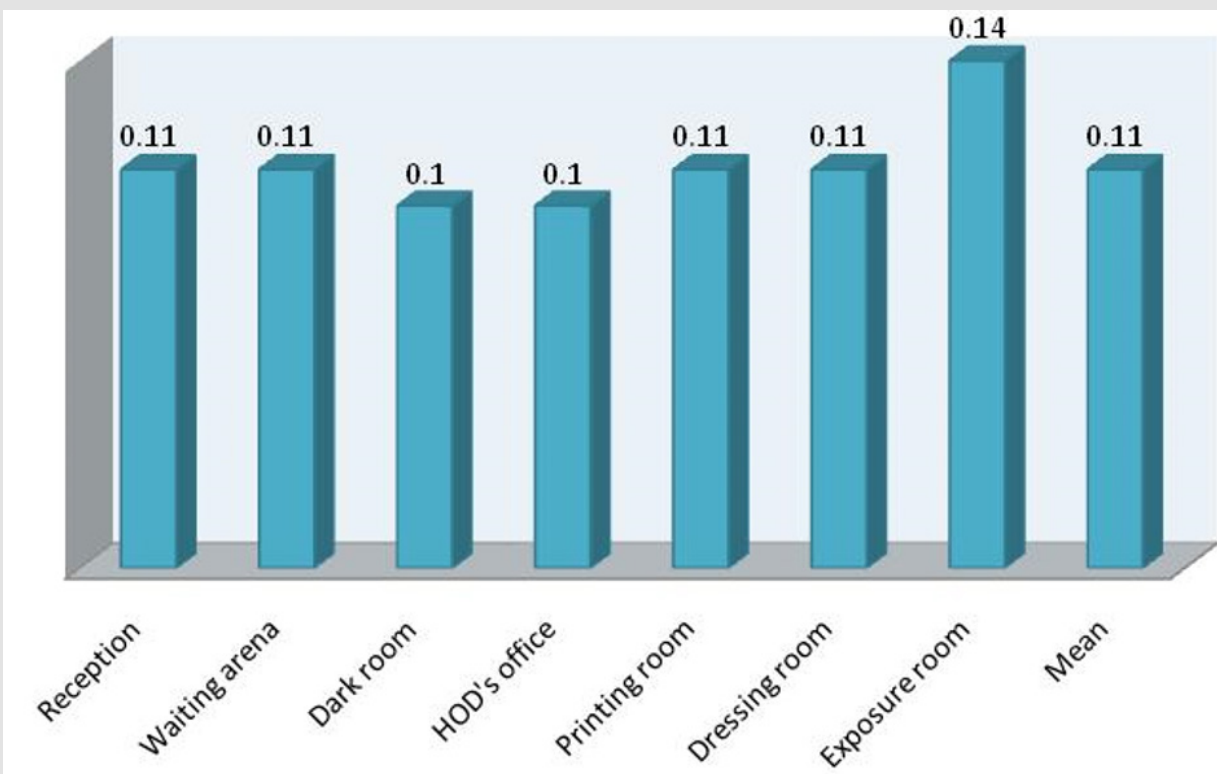


Figure 6: Natural Background Ionizing Radiation at Radiology Departmental Buildings.

Effect of Body Thickness on Entrance Skin Dose

Figure 5 shows that the body thickness has an effect on the radiation delivered to patients. The findings revealed that an increase in the body thickness of the patient correspond to the increase in the radiation delivered (ESD) to the patients. Comparatively, the ESD ob-

tained (0.85mGy) for the chest in this work was remarkably lower than ESD (1.77 mGy) obtained in the research conducted by Samaila [6] with factor of 1. The ESD in leg and forearm x-ray procedure was 0.36 mGy and 0.297mGy, which was in line with 0.22 mGy for leg recorded by Samaila [7].

Conclusion

The ESD and Scattered X-ray depends on various exposure factors, such as X-ray tube voltage, exposure intensity, and the thickness of the patients' body. The reduction of the radiation doses can be achieved by adequate and good selection of radiation exposure factors. The scattered radiation is an undesirable dose and should be kept at lowest level within the permissible occupational dose.

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