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Original Article

Radiation Dose and Risk Assessment to Patients During Thoraco-Lumbar and Lumbar Spine X-ray Procedures

Buhari Samaila[1], Mohammad Danyaro Rilwanu[2], Abdullahi Bello[3]

[1]*Department of Physics with Electronics, Federal University Birnin Kebbi, Kebbi, Nigeria.*
[2]*Department of Radiology, Federal Medical Centre Birnin Kebbi, Kebbi, Nigeria.*
[3]*Department of Physics, Kebbi State University of Science and Technology Aliero, Kebbi, Nigeria.*

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Abstract *- High doses of ionizing radiation [X-ray] received by patients can lead to adverse health outcomes such as cancer induction and other biological complications in patients. The extensive demand for X-ray examinations, an increase in the number of X-ray facilities and few radiation researches conducted in Kebbi State led to the conduct of this research. The X-ray doses received by Sixty nine (69) adult patients with a total of 8 from Sir Yahaya Memorial Hospital (SYMH) and 61 patients from Federal Medical Centre (FMC), Birnin Kebbi were analyzed using CAL DOSE_ X 5.0 version software by entering the patients' data (Age, Sex) and exposure parameters such as focus to detector distance (FDD), miliampere second (mAs), and Kilovolt (KV). The statistical distributions of Dosimetric Quantities of two examinations for two individual centres were calculated using the Minitab software and Excel spreadsheet. The average values of Entrance Skin Dose obtained for two centres (SMH and FMC) were 4.83 &7.46, 1.91 & 2.25, respectively, for the lumbar and thoraco-lumbar spine. The effective doses estimated were 0.47 & 0.74, 0.33&0.67 respectively, for the lumbar spine and thoraco-lumbar spine. Similarly, the Risk of Cancer Incidence (RCI) was found to be 1.51 & 2.91, 1.83& 3.00, and the Risk of Cancer Mortality was 0.92& 1.71, 0.99 & 5.19 for lumbar spine and thoraco-lumbar spine respectively in SMH and FMC. The entrance skin dose [ESD] and effective dose [ED] results were remarkably lower than those of international organizations and other countries. Based on the results obtained, it is concluded that the selection of proper radiological parameters can significantly reduce the absorbed dose in patients.*

Keywords *- Radiation risk, Lumbar spine, Thoraco-lumbar spine and X-ray.*

1. Introduction

Diagnostic imaging constitutes up to 78% of medical radiological exposure. The advancement in radiographic image acquisition, processing and quality allows the operator to overexpose the patient without having to repeat the radiographs [1]. Conventional X-ray diagnosis is a significant source of radiation exposure among the population. Therefore, there is a need for X-ray examinations to be conducted using techniques that keep the patients' exposure as low as possible without affecting image quality. International commission on radiological protection asserted that radiation is a major risk in diagnostic medical imaging and therapy. The problem is caused by incorrect use of radiography equipment and unnecessary radiation exposure to patients. International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA) provide publications on protection from ionizing radiation. Report-60 of the ICRP and the Basic Safety Standards that the IAEA published contained three basic principles (justification, optimization, dose limits) related to radiation protection. Exposure to different dose values for the same clinical examination is a reason to draw attention to this issue. Different dose levels are delivered to patients from different imaging techniques when performing lumbar and thoraco-lumbar spine examinations [1, 2]. Many health hazards are associated with radiation exposure, including deterministic (acute) and stochastic (chronics) effects. The acute effects include organ injuries that can possibly lead to death at a high dosage. Most diagnostics investigations do not cause acute injuries to the patients because of their low energy (less than 10 mGy). The chronic effects of radiation include the danger of cancer and genetic disorders. Measurements of the radiation doses from thorocolumbar and lumbar spine radiological examinations have been conducted globally. Most fast-changing innovations have been paired with digital radiography (DR) units [3].

1.1. Literature Review

The patient's dose has often been described by the entrance skin dose (ESD) as measured in the centre of the X-ray beam. Because of the simplicity of its measurement, ESD is considered widely as the index to be assessed and monitored [2]. Different scholars who have carried out investigations have reported large differences in radiation doses received by patients during specific X-ray procedures [30]. Studies have shown that thoraco-lumbar and lumbar spine X-ray procedures can result in varying radiation dose levels [20]. For example, a study by Smith et al. [21] found that the effective dose for lumbar spine X-rays ranged from 0.06 to 0.4 millisieverts (mSv), with an average of 0.16 mSv per examination. A study conducted by Smith et al. [22] aimed to quantify the radiation dose delivered to patients during thoraco-lumbar and lumbar spine X-ray examinations. The results showed that the mean entrance surface dose (ESD) for lumbar spine X-rays was approximately 0.34 mGy, while for thoraco-lumbar spine X-rays, it was 0.57 mGy. These values varied depending on the patient's size, age, and imaging technique employed.

In a research article by Johnson et al. [23], effective dose estimates were determined for thoraco-lumbar and lumbar spine X-ray procedures. The study revealed that the average effective dose for lumbar spine X-rays ranged from 0.6 to 1.3 mSv, whereas for thoraco-lumbar spine X-rays, it ranged from 1.0 to 1.6 mSv. It was also observed that the effective dose varied according to factors such as patient size, imaging technique, and X-ray equipment used.

Exposure to ionizing radiation during X-ray procedures carries a small risk of radiation-induced cancer. The International Commission on Radiological Protection (ICRP) has estimated the risk coefficient for cancer incidence to be 5% per sievert. According to a study by Johnson et al. [18], the estimated lifetime attributable risk of cancer from a single lumbar spine X-ray is approximately 1 in 10,000. Efforts have been made to optimize radiation dose in thoraco-lumbar and lumbar spine X-ray procedures while maintaining image quality. A study by Lee et al. [25] explored the use of low-dose protocols for lumbar spine X-rays, resulting in a 50% reduction in effective dose compared to standard protocols.

A similar study by Davis et al. [26] emphasized the importance of collimation and beam filtration in reducing unnecessary radiation doses to patients. An investigation conducted by Brown et al. [27] aimed to assess the radiation-related risks associated with thoraco-lumbar and lumbar spine X-ray examinations. The study utilized the Biological Effects of Ionizing Radiation (BEIR) VII report to estimate the lifetime attributable risk (LAR) of cancer incidence. The findings indicated that the LAR for cancer due to lumbar spine X-rays ranged from 1 in 50,000 to 1 in 10,000, while for thoraco-lumbar spine X-rays, it ranged from 1 in 30,000 to 1 in 7,000. The study emphasized the importance of radiation optimization strategies to minimize these risks.

2. Materials and Methods

A total of 69 adult patients were considered for the study. The research was conducted in two public hospitals, each using conventional X-ray units equipped with constant potential generators, an X-ray emission angle of 17^0 and total filtration of 2.5 mm Al. An indirect measurement was conducted on two frequently used thoroco-lumbar and lumbar spine examinations. The entrance Skin and effective Doses were calculated using Cal dose_x 5.0 software [1].

The software 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 male and female 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. The software requires the user to manually input the patient's age, sex, and select type of examination, posture projections, tube potential, field position and the mAs [1]. The ESAK and BSF are determined by software and then converted to ESD using the equation below:

$$ESD = ESAK \times BSF \quad (1)$$

The effective dose (ED) is one of the parameters used to assess the relevance of examinations involving ionizing radiation. The ED value was obtained using CALDose_X 5.0. The effective dose based on CALDose_X 5.0 is then the average of the sex-specific weighted doses

$$\text{Effective Dose} = \frac{1}{2}\,[F + M] \quad (2)$$

CAL Dose_X 5.0 calculates a weighted female dose (F) and a weighted male dose (M) given at the end of the result. After getting ED, then the risk of cancer incidence and mortality incidences determine for each projection [1]

3. Results and Discussion

The results of radiation dose assessment, together with comparisons and risk of cancers and mortality.

Table 1. Comparison of ESD with other studies

Centres/Other studies	ESD (mGy)
SMH (this study)	4.83
FMC (this study)	7.46
[4]	0.58
[6]	3.05
[7]	9.99
[8]	3.14
[9]	6.00
[10]	6.00
[11]	2.37

Table 2. Comparison of effective dose with other studies

Examination	SMH	FMC	[12]	[13]	[14]	[15]
Lumbar Spine	0.47	0.74	1.67	1.90	0.41	0.38
Thoraco lumbar	0.33	0.67	--	---	--	--

Table 3. Incidence of cancer risk

Examination	Lumbar Spine	Thoroco-Lumbar Spine
SHM	1.51	1.83
FMC	2.91	3.00

Table 4. Mortality cancer risks

Examination	Lumbar Spine	Thoraco-lumbar Spine
SHM	0.92	5.19
FMC	1.71	5.19

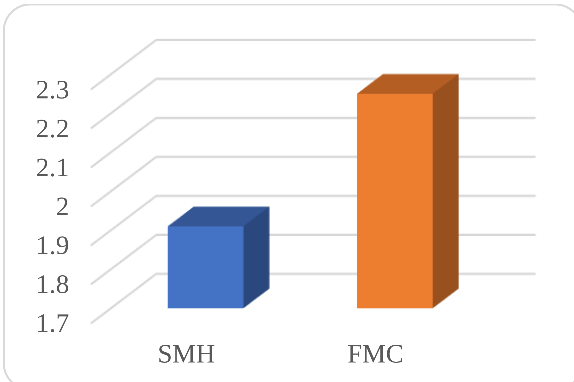

Fig. 1 ESD for Thoraco-lumbar AP X-ray

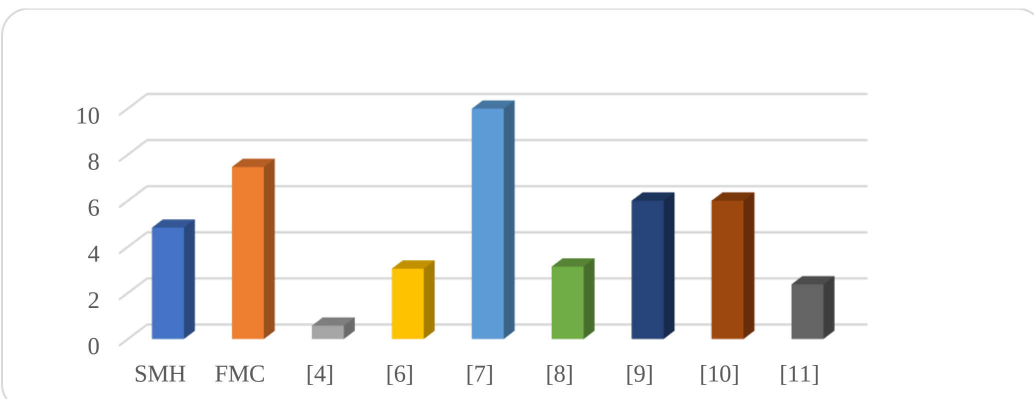

Fig. 2 ESD for Lumbar spine AP X-ray

The mean entrance skin dose results were determined and compared with other studies within and outside the country. For each type of examination, ESD values for each patient were calculated for each set of dose measurements in both hospitals. Therefore, the comparisons of the results of ESD in this study were tabulated in Table 1. The effective doses were estimated using Cal Dose_X 5.0 software. While the mean of the effective dose was estimated using statistical software. The results obtained were tabulated in Table 2 and compared with national and international studies. Figure 1 showed that the highest ESD of 6.98 mGy was obtained for thoracolumbar spine X-ray in FMC compared with SYHM 4.21mGy. This variation in the results was due to the improper selection of exposure parameters. Al-Kinani *et al.* obtained an ESD result of 13.30 mGy, presented in Figure 2 while conducting research on the lumbar spine AP X-ray procedure. Their results are much higher than the results obtained in this study, with an average value of 4.83 mGy and 7.47 mGy for SYHM and FMC, respectively. The same research was conducted by Rasuli *et al.* [17] and Hart *et al.* [2] obtained average ESD of 3.09 mGy, 4.60 mGy, and 3.72 mGy, respectively. These results were lower compared to the result obtained in this study. The effective doses estimated were 0.47 & 0.74, 0.33&0.67 for the lumbar spine and thoraco-lumbar spine in SMH and FMC. Similarly, the risk of cancer incidence (RCI) was found to be 1.51 & 2.91, 1.83& 3.00, and the Risk of Cancer Mortality was 0.92 & 1.71, 0.99 & 5.19 for lumbar spine and thoraco-lumbar spine respectively in SMH and FMC. The range of incidence cancer risks was 0.83- 4.61 (~1-5) for the lumbar spine and 0.76 – 8.99 (~1-9) for the thoraco-lumbar spine. This indicates that out of every one hundred thousand populations who underwent these examinations, 1-9 people will be affected with cancer. In the same vein, the range of risk of cancer mortality was 0.58 -5.01 ($\sim 1-5$). This range indicates that in every one hundred thousand (100,000) population, 1-5 patients will die due to radiation exposure from the procedures. Finally, the ESD and ED results obtained in our study were remarkably lower than those earlier documented by international.

4. Conclusion

The ESD and ED results were remarkably lower than that of international organizations and other countries' results. Based on the results obtained, it is concluded that the selection of proper radiological parameters can significantly reduce the absorbed dose in patients. Hence, the two centres have tried their best to select appropriate exposure factors for patients' dose limitation and optimization.

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