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Entrance Skin Dose of Patients Undergoing Chest X-Ray in Selected Hospitals in Jalingo, Taraba State, Nigeria

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Abstract

This study serves as a method of ensuring the quality of radiation exposure by examining the entrance skin doses of patients who undergo Chest X-ray procedures at three prominent diagnostic institutions - Federal Medical Center, Taraba State Specialist Hospital, and Am-Pat Diagnostic Center, all located in Jalingo, Taraba State. Radiation exposure acquired by patients during normal x-rays is known to enhance the risk of cancer. This was the key motivation for this investigation. The Entrance Skin Dose (ESD) for sampled individuals was computed using the 1984 Edmond's formula. The research utilized a sampling population of 80 patients, divided into 20 samples each machine and subsequently categorized into 10 according to age groups. The average Entrance Skin Dose (ESD) for individuals aged 0-18 years ranged from 0.120 mGy recorded at FMC1 to 0.188 mGy at FMC2. Also the mean ESD for patients in the 19 and above age category had a range from 0.258 mGy at FMC2 to 0.400 mGy at TSSHJ. The Taraba State Specialist Hospital in Jalingo recorded a maximum mean Entrance Skin Dose (ESD) of 0.4mGy for adult patients which surpasses the standard of 0.30 mGy for a year set by the IAEA. From the results obtained, an immediate review of exposure parameters of the FMC2 and TSSHJ is recommended in order to reduce the ESD especially for the adult population so as to reduce the probability of cancer incidence and other radiation-induced side-effects.

Keywords: Chest X-ray, Ionizing Radiation, Entrance Skin Dose

INTRODUCTION

Medical practitioners are increasingly relying on diagnostic imaging modalities, including CT, MRI, ultrasound, classic radiography, and nuclear medicine (Pepe et al., 2023; Abhisheka et al., 2024; Gambo and Shehu, 2024). Amongst these modalities, Ionizing radiation is a prevalent feature of radiography, computed tomography, and nuclear medicine (Luan *et al.*, 2021; Greco et al., 2023; Sharma, 2024). Ionizing radiation is a type of radiation that has sufficient energy to dislodge electrons from their atomic or molecular orbital shells in the tissues it penetrates (Parke, 2020; Chaudhary et al 2023; Apte and Bhide, 2024). The molecular level functions of cells can be disrupted and tissues can be damaged when these ionizations are received in sufficient quantities over a period of time (Iseh *et al.*, 2018; Elgazzar, 2023). Ionizing radiation is employed in medicine for two primary objectives: diagnosis and therapy (Jargin, 2023; Gambo and Shehu, 2024). Consequently, both individuals and the overall community are exposed to significant amounts of radiation (Winters et al., 2023). Diagnostic radiology is a primary source of radiation exposure caused by human activity for the general population (Ibrahim et al., 2014; Stephens *et al.*, 2024). The dose of ionizing radiation absorbed by tissue can be categorized as either acute, meaning the energy is absorbed over a short period of hours or days, or chronic, meaning the energy is absorbed over a longer period of months, years, or a lifetime. Although, for radioactive materials with half-lives longer than a day, even if they are only taken in for a short period of time (minutes to a few days), deposit their energy in tissue where it stays for longer than a few days. This results in a prolonged exposure of the surrounding tissue, known as chronic duration (Iseh *et al.,* 2018 and Fisher *et al.*, 2017).

The function of ionizing radiation techniques in enhancing the overall health of the population through the detection of disease and treatment of trauma cannot be overemphasized. Nevertheless, there is no excuse for complacency because it is a basic assumption of radiation protection practice that any exposure should be justified by evaluating the potential harm against the perceived advantage (Ibrahim *et al.,* 2014; McBride and Schaue, 2020).

In both industrialized and developing nations, X-rays are the most commonly utilized ionizing radiation for diagnostic imaging, and they are essential to the efficient provision of healthcare (Endo, 2021; Othman et al., 2023; Othman, 2023). According to Teles et al. (2020), X-rays are reported to be the most significant contributor to the overall effective dose of ionizing radiation to the general population (personal and public). The need for radiation dose evaluation of patients during diagnostic X-ray examinations has been underlined by increased knowledge of the risk of ionizing radiation (Joseph *et al.,* 2014; Zira et al., 2021). Protection of patients during diagnostic and therapeutic procedures is imperative due to the deleterious effects of X-rays. Images of optimal quality and sufficient quality are the objective of any diagnostic X-ray examination (Al Khudairi *et al.,* 2023; Dudhe et al., 2024). Nevertheless, a radiograph of high quality is not necessarily the most visually appealing; rather, it is the one that readily elicits the necessary details (Iseh *et al.*, 2018 and Luan *et al.,* 2021).

The primary tenet of the International Commission on Radiological Protection (ICRP) in medical practice is that the utilization of radiation must be justified by sound rationale. After going through the process of justification, it is essential to improve and perfect the procedure. In radiography, radiation dose optimization is the method of minimizing the amount of radiation used while yet obtaining a high-quality diagnostic image (Ibrahim *et al.,* 2014; Tsapaki, 2020; Ng, 2022; Rabiu *et al.,* 2023; Alhorani et al., 2024).

In diagnostic radiology, there are two categories of patient doses that are central: the Entrance Skin Dose (ESD) and the Effective Dose (E) which accounts for the dose equivalent to radiosensitive organs. (Harrison *et al.,* 2023). The Entrance Skin Dose (ESD) has frequently been employed to characterize the patient's dose, which is measured in the center of the X-ray beam. The ESD is a metric that quantifies the radiation dose that the skin absorbs when the X-ray beam penetrates the patient. It is widely regarded as the index that should be evaluated and monitored due to the ease of its measurement. The thermo-luminescent dosimeter (TLD) is used to directly measure ESD on the patient's skin, or it is measured indirectly by measuring the dose area products using a large area transmission ionization (Joseph *et al.,* 2014 and Iseh *et al.,* 2018).

Effective dose is a mathematical construct, concept or surrogate of risk, used in radiation protection as the basis for calculating annual radiation limits to the public and radiation workers from intakes of radiation. It is widely and increasingly utilized in medical practice to quantify the potential harm to health caused by radiation exposure, despite not being originally intended for this purpose. The main objective of effective dose, as defined by the International Commission on Radiological Protection (ICRP 2007), is to measure the amount of radiation that workers and the general public are exposed to. This is done to ensure that the dose limits are met and to enhance protection against potential health risks, particularly cancer, resulting from low-level exposure to radiation (i.e. low doses or low dose-rates) (Bolch et al., 2020; ICRP, 2021, 2022).

Recommended dose assessments should be conducted periodically for radiological exposure in order to optimize protection for patients and minimize radiation exposure during tests. Dose measurements are necessary to comply with international standards and regulations (Harrison *et al.,* 2021 and Lange *et al.,* 2023).

This study aimed to estimate the Entrance Skin Doses (ESDs) for patients receiving chest X-rays at three diagnostic institutions in Jalingo, Taraba State. The X-rays output factors approach was used to obtain these measurements.

MATERIALS AND METHODS

This study utilized data from four X-ray machines located in three diagnostic centers in Jalingo, Taraba State. Specifically, two machines were from the Federal Medical Center, while Taraba State Specialist Hospital and Am-Pat Medical Diagnostics Center each contributed one machine.

Details of each machine is expressed in Table 1. The survey approach employed adhered to the parameters set forth by the International Atomic Energy Agency (IAEA). The skin dose to patients was calculated using the Edmonds (1984) skin dose formula, which takes into account the X-ray tube characteristics and exposure radiography factors. The formula is given as:

$$Skin\ Dose\ (\mu Gy) = 418(kVp)^{1.74} \times mAs\,\frac{(\frac{1}{T}+0.114)}{(SSD)^2} \quad (1)$$

The peak voltage, kVp, determines the quality of penetration in X-ray imaging. The tube current, mAs, along with the exposure period, controls the quantity of electrons emitted from the filament. The total filtration, T, remains constant for each type of X-ray machine, and the source to skin distance, SSD, is the distance between the X-ray source and the patient's skin (Iseh *et al.,* 2018).

The research utilized a sampling population of 80 patients, divided into 20 samples each institution and subsequently categorized into 10 according to age groups. Table describes the make of the X-ray machines used while tables 2, 3, 4 and 5 presents Entrance Skin Doses (ESDs) obtained from the x-ray machines.

Table 1: Description of X-ray Machines Used

	FMC1	**FMC2**	**TSSHJ**	**AM-PAT**
Manufacturing date	2014	2010	1985	1981
Manufacturing company	Eschmed Medical	Gulfexmedical and scientific	Philips	General electrical company
Place of manufacturing	England	England	Italy	USA
Model number	PLD5000B	YZ-300	PEI98270130004	4616560G14
Filtration thickness	1.5	2.0	1.5	2.0
Year of installation	2016	2012	2006	2016

RESULTS AND DISCUSSION

The results of ESDs obtained from this study are expressed in Tables 2, 3, 4 and 5.

Table 2: Entrance Skin Dose Obtained from FMC1

S/N	**Age 0-18**					**Age 19 and above**				
	kVp	mAs	T	SSD	ESD (mGy)	kVp	mAs	T	SSD	ESD (mGy)
1	60	5.0	1.5	110	0.167	70	5.0	1.5	120	0.184
2	65	4.0	1.5	120	0.129	80	5.0	1.5	100	0.334
3	65	3.0	1.5	100	0.14	85	5.0	1.5	110	0.307
4	60	3.0	1.5	70	0.248	70	5.0	1.5	120	0.184
5	50	2.4	1.5	80	0.111	100	6.0	1.5	120	0.411
6	65	4.0	1.5	80	0.291	90	7.0	1.5	110	0.475
7	60	3.0	1.5	70	0.248	85	6.0	1.5	100	0.446

8	55	5.0	1.5	70	0.355	75	5.0	1.5	120	0.208
9	50	4.0	1.5	90	0.146	80	7.0	1.5	120	0.325
10	55	3.0	1.5	80	0.163	85	6.0	1.5	110	0.368
ESD(mGy)					**0.120**					**0.324**

Table 3: Entrance Skin Dose Obtained from FMC2

S/N	Age 0-18					Age 19 and above				
	kVp	mAs	T	SSD	ESD (mGy)	kVp	mAs	T	SSD	ESD(mGy)
1	90	10.2	2.0	160	0.257	75	12.0	2.0	160	0.22
2	75	9.8	2.0	160	0.18	88	10.0	2.0	160	0.242
3	90	8.0	2.0	140	0.263	80	11.0	2.0	140	0.295
4	80	7.0	2.0	160	0.144	90	10.0	2.0	160	0.252
5	75	8.0	2.0	160	0.147	100	10.0	2.0	160	0.303
6	80	7.0	2.0	160	0.144	88	11.0	2.0	160	0.267
7	70	8.0	2.0	140	0.17	80	10.0	2.0	140	0.268
8	70	10.2	2.0	160	0.166	85	11.0	2.0	160	0.251
9	85	9.0	2.0	140	0.268	75	12.0	2.0	140	0.288
10	80	7.0	2.0	160	0.144	70	12.0	2.0	160	0.195
Mean ESD(mGy)					**0.188**					**0.258**

Table 4: Entrance Skin Dose Obtained from TSSHJ

S/N	Age 0-18					Age 19 and above				
	kVp	mAs	T	SSD	ESD (mGy)	kVp	mAs	T	SSD	ESD (mGy)
1	60	3.6	1.5	80	0.228	80	6.0	1.5	100	0.401
2	70	3.2	1.5	110	0.14	80	8.0	1.5	100	0.535
3	50	3.6	1.5	70	0.217	70	6.0	1.5	110	0.263
4	75	3.2	1.5	110	0.158	80	8.0	1.5	110	0.442
5	60	3.2	1.5	110	0.107	80	8.0	1.5	110	0.442
6	50	2.0	1.5	70	0.12	70	6.0	1.5	110	0.263
7	50	4.0	1.5	70	0.241	80	6.0	1.5	110	0.332
8	75	2.8	1.5	110	0.138	70	6.0	1.5	70	0.649
9	60	4.0	1.5	110	0.134	70	5.0	1.5	80	0.414
10	65	3.2	1.5	110	0.123	70	6.0	1.5	110	0.263
Mean ESD(mGy)					**0.161**					**0.400**

Table 5: Entrance Skin Dose Obtained from AM-PAT

S/N	Age 0-18					Age 19 and above				
	kVp	mAs	T	SSD	ESD (mGy)	kVp	mAs	T	SSD	ESD (mGy)
1	50	2.4	1.5	80	0.160	80	4.0	1.5	110	0.221
2	65	2.6	1.5	100	0.140	70	4.2	1.5	120	0.155
3	70	2.6	1.5	100	0.160	75	4.0	1.5	100	0.239
4	75	2.6	1.5	100	0.190	80	4.4	1.5	90	0.363
5	55	2.4	1.5	80	0.080	75	4.6	1.5	110	0.227
6	55	2.6	1.5	80	0.190	85	4.0	1.5	110	0.246
7	70	2.6	1.5	100	0.160	70	5.0	1.5	120	0.184
8	50	2.6	1.5	100	0.110	85	5.2	1.5	100	0.386
9	60	2.6	1.5	100	0.110	80	4.0	1.5	100	0.267
10	65	2.6	1.5	100	0.140	80	5.0	1.5	120	0.232
Mean ESD(mGy)					**0.124**					**0.252**

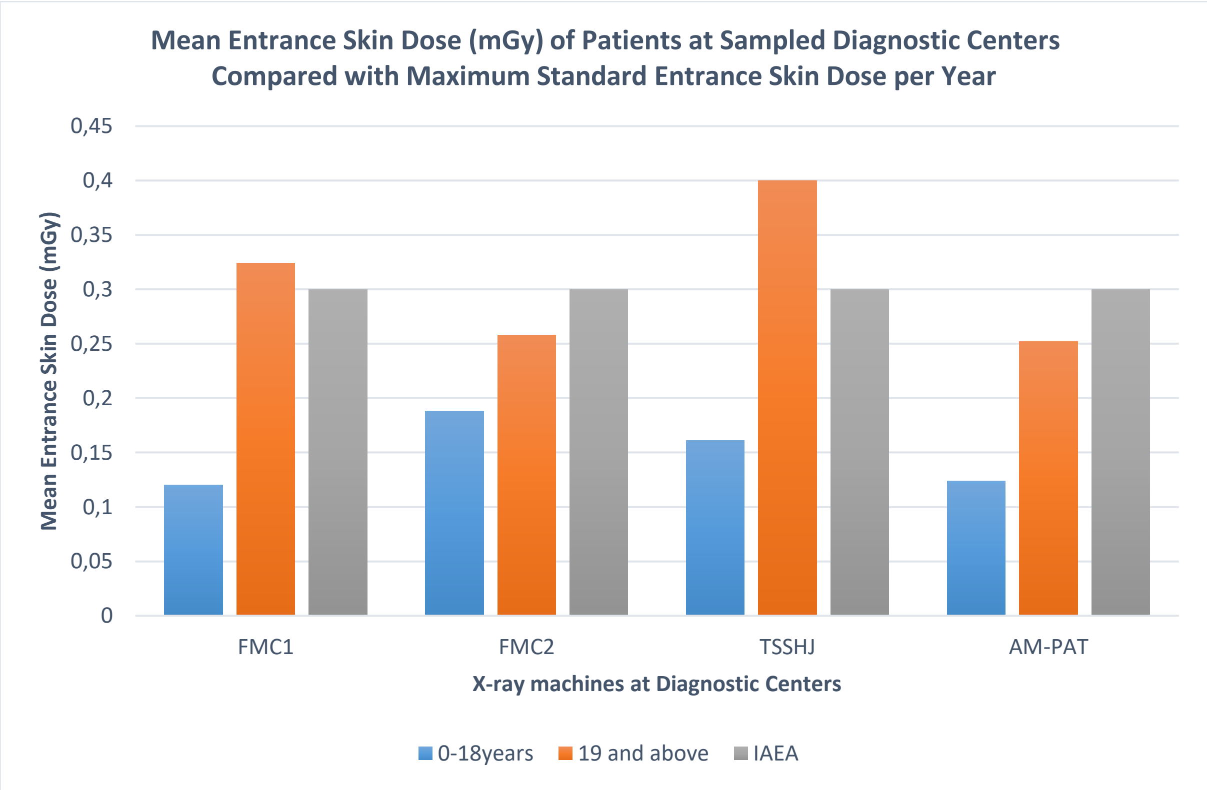

Figure 1: Chart of Mean Entrance Skin Dose (mGy) at Diagnostic Centers

The column chart in Figure 1 demonstrates a positive correlation between age and Entrance Skin Dose (ESD). The average Entrance Skin Dose (ESD) for individuals aged 0-

18 years ranged from 0.120 mGy recorded at FMC1 to 0.188 mGy at FMC2. Also the mean ESD for patients in the 19 and above age category had a range from 0.258 mGy at FMC2 to 0.400 mGy at TSSHJ.

None of the calculated average entrance skin doses (ESDs) for individuals aged 0-18 years surpass the recommended limit of 0.30 mGy per year set by the International Atomic Energy Agency (IAEA). Among individuals aged 19 and older, two mean entrance skin doses (ESDs) were measured to exceed the International Atomic Energy Agency (IAEA) threshold, while two were determined to be below it. The average Entrance Skin Doses (ESD) for the patients collected at FMC1 and TSSHJ were determined to be 0.324 mGy and 0.400 mGy respectively. It is crucial to highlight that the average ESD values for people (aged 19 and above) measured at FMC2 and AM-PAT did not surpass the IAEA limit of 0.30 mGy per year. However, they were very close to this threshold, with values of 0.252 mGy and 0.258 mGy respectively. This is highly concerning especially if a need arises for the patients to repeat the radiographs.

CONCLUSION

This study presents the results of measuring the Entrance Skin Dose (ESD) received by patients during chest X-rays using four different X-ray equipment at three diagnostic centers in Jalingo. Two machines were found to have average entrance skin doses (ESDs) that were higher than the IAEA standard of 0.3 mGy for individuals aged 19 and above, while the average ESDs of the other machines were below the IAEA limit. The Taraba State Specialist Hospital in Jalingo recorded a maximum average Entrance Skin Dose (ESD) of 0.4mGy for adult patients.

It is crucial to thoroughly review the exposure parameters of all four machines, particularly for patients aged 19 and above bearing in mind the fundamental principle of radiation exposure: As Low as Reasonably Achievable (ALARA) because the computed mean ESDs were found to be too close to the threshold for comfort.

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