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Original Article

Assessment of Patients' Entrance Skin Dose from Diagnostic X-ray Examinations at Public Hospitals of Akwa Ibom State, Nigeria

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Abstract

Introduction
High doses of ionizing radiation can lead to adverse health outcomes such as cancer induction in humans. Although the consequences are less evident at very low radiation doses, the associated risks are of societal importance. This study aimed at assessing entrance skin doses (ESDs) in patients undergoing selected diagnostic X-ray examinations at public hospitals of Akwa Ibom State, Nigeria.

Materials and Methods
In total, six examinations were performed on 720 patients in this study. CALDose_X5 software program was used in estimating ESDs based on patients' information and technical exposure parameters.

Results
The estimated ESDs ranged from 0.59 to 0.61 mGy for PA and RLAT projections of the thorax, respectively. ESDs for the AP and RLAT projections of the cranium were 1.65 and 1.48 mGy, respectively. Also, ESD values for the AP view of the abdomen and pelvis were 1.89 and 1.88 mGy, respectively. The mean effective dose was within the range of 0.021-0.075 mGy for the thorax (mean= 0.037), 0.008-0.045 mGy for the cranium (mean= 0.016), 0.215-0.225 mGy for the abdomen (mean= 0.219) and 0.101-0.119 mGy for the pelvis (mean= 0.112).

Conclusion
The obtained results were comparable to the international reference dose levels, except for the PA projection of the thorax. Therefore, quality assurance programs are required in diagnostic X-ray units of Nigeria hospitals. The obtained findings add to the available data and can help authorities establish reference dose levels for diagnostic radiography in Nigeria.

Keywords: Entrance Skin Dose, diagnostic X-ray Examination, Akwa Ibom

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1. Introduction

Diagnostic X-rays are extensively used in medical practice. As a result, they represent by far the largest man-made source of public exposure to ionizing radiation. Each year, thousands of diagnostic x-ray procedures are performed in Akwa Ibom, Nigeria. Although radiation exposures, induced by these procedures, cannot be avoided, some measures can be taken to reduce the effects as much as possible. Patient radiation dose from conventional radiographic procedures ranges between 0.1 mSv and 10 mSv, resulting in a significant collective dose to the population. [1]

In this regard, Anoopkumar et al. concluded that cell proliferation is adversely affected by doses produced by some radiological examinations [2]. Also, Kai Rothkamm et al. reported that DNA double-strand breaks, induced by very low radiation doses (1 mGy) in cultures of non-dividing primary human fibroblasts, remain unrepaired for many days. This is in strong contrast with the efficient repair of double-strand breaks at higher doses. [3]

Today, quality and safety have become the hallmarks of efficient and successful medical procedures. The quality criteria for diagnostic radiographic images were established in 1984 when the first directives on patient radiation protection were adopted by the member states of the European Union [4]. Over the past years, patient dose has become a major issue in medical circles. Considering the increasing awareness and greater realization of the effects of ionizing radiation, X-ray users are now more demanding of dose-related information and dose reduction [5].

Recently, quality and safety measures have progressively developed in Nigeria, considering the medical use of ionizing radiation for diagnosis and treatment. The two basic principles of patient radiation protection, recommended by the International Commission on Radiological Protection (ICRP) are practice justification and protection optimization [6]. In diagnostic radiology, periodic dose assessments should be performed to optimize patient radiation protection. Dose measurements are further required to compare different radiological techniques and comply with the international guidelines and regulations.

Over the past decade, many studies have been conducted on radiation dose due to the prevalence of clinical x-ray examinations [3, 7-11]. These studies, along with extensive international research in this area, have reported wide variations in patient dose, induced by specific X-ray examinations. The reasons behind these dose variations are complicated. However, low tube potential, high mAs and low filtration have been generally known to be associated with high radiation doses at hospitals.

Therefore the purpose of this work is to assess patients' skin doses undertaking different types of diagnostic x-ray examinations at public hospitals of Akwa Ibom State. It was projected that the study will aid in the optimization of radiation protection of the patient.

2. Materials and Methods

Entrance surface dose (ESD) is defined as the absorbed dose by the central point of an irradiated area [12, 13]. In the present study, ESDs in routine radiographic examinations such as postero-anterior (PA) and right lateral (RLAT) projections of the thorax, PA and RLAT projections of the cranium and AP projections of the abdomen and pelvis were estimated. ESD values were measured, using CALDose_X5 program, designed by Kramer et al. in Brazil [14].

The present study was carried out at three hospitals in Akwa Ibom State, Nigeria. These hospitals were selected since they have the highest workload in this state. Three X-ray machines were included in this study (two analog and one digital device), with a total filtration of 2.5 mmAl.

Data were collected from 720 patients over two years (2011-2013). Patients' information including age and sex was recorded. Technical parameters during each radiographic exposure such as tube voltage (kV), current-time product (mAs), focus-skin distance (FSD), focus-detector distance (FDD), field size and projection were also considered. Based on the patients' information and the exposure parameters radiographic examinations were determined for each patient. The qualities of obtained images were compared among hospitals and were found to be acceptable for diagnostic purposes. However, the acceptability of diagnostic images was subjective and was assessed by radiographers.

The National Radiological Protection Board (NRPB) has introduced a nation-wide protocol for accurate dose measurements and patient dose optimization [15]. Based on this protocol, ESD should be directly measured on patient samples, using thermoluminescent dosimeters (TLD). Free-air measurement of tube radiation output, along with ESD calculation by standard parameters, may be employed under appropriate circumstances.

Use of software programs for the evaluation of patient dose in routine x-ray examinations is a modern method, widely applied at hospitals for dosimetric studies [14,16, 17]. In the present study, a windows-based program was employed for the calculation of patient dose due to lack of access to TLD chips and TLD readers in Nigeria. The results obtained in this study were compared with TLD measurements [18] and findings obtained by CalDose program in previous studies [19 - 23].

In order to increase the speed and efficiency of dosimetric processes, a windows-based computer program, known as CALDose_X5 was designed by Kramer [16]. In this program, ESD, body organ dose, effective dose, risk of cancer incidence and risk of cancer-related mortality can be determined, based on prior knowledge of factors related to examination techniques and the output data. This program is able to process large volumes of data within a short time, without the need for invasive measurements on patients [14].

For CALDose_X5 to function, it was necessary to furnish the output in mGy/mAs in all X-rays machines, used for dose evaluation. Once the tube potential, tube current, exposure time, FDD and FSD were determined, ESD could be calculated by the following formula:

$$\text{ESD} = \text{Output}\ X\left(\frac{kv}{80}\right)^2 X\left(\frac{100}{FSD}\right)^2 X\ mAs\ X\ BSF \quad (1)$$

where the output is mGy/mAs of the X-ray tube at 80 kV at a 100 cm distance, normalized to 10 mAs. BSF stands for backscatter factor for a particular examination at the required tube potential; BSF was obtained from NRPB numerical simulations [16, 24].

3. Results

In total, 720 samples were evaluated at three hospitals in the present study. At these hospitals, six common X-ray examinations were carried out. At least 40 patients were evaluated in each examination at these hospitals. It should be mentioned that both genders were included in this study.

Tables 1, 2 and 3 present the mean and range (presented in brackets) of exposure parameters, as well as the information of patients undergoing six routine examinations. Tables 4-6 present ESD values (min, max, first quartile, third quartile and median) at the evaluated hospitals. Also, the mean distribution of surface dose at these hospitals is presented in Table 7.

Distribution of entrance skin doses (ESDs) and dose reference levels. Table 8 shows the comparison between the calculated ESDs and the established international reference dose levels. All the hospitals used low tube potentials and employed a filtration of 2.5 mmAl. The filtration value (2.5 mmAL) was not measured, but provided by the radiographers.

Table 1. Exposure parameters and patient information at Saint Luke Hospital, Anua (Hospital A)

Type of examination	Projection	Patient age (year)	Patient weight (kg)	Patient Height (cm)	Tube potential (kVp)	Charge (Time) (mAs)
Thorax	PA	48.905 (21–80)	67.429 (60-73)	170.43 (163–176)	61.662 (60–68)	12.098 (11–16)
	RLAT	47.825 (20–78)	67.15 (60–63)	169.83 (163–176)	61.75 (60–66)	12–4 (11–14)
Cranium	AP	42.75 (20–75)	64.475 (60–73)	170.48 (163-176)	60.863 (60–63)	11.695 (10–13)
	RLAT	45.15 (20–67)	69.1 (60–73)	172.43 (163-176)	63.238 (60–68)	13.663 (11–16)
Abdomen	AP	36.075 (20–75)	63.25 (60–73)	166.25 (163– 176)	62.563 (60–67)	13.113 (11–16)
Pelvis	AP	61.00 (36–80)	60.00 (60–73)	167.00 (163–176)	70.00 (68–70)	32.00 (25–40)

Table 2. Exposure parameters and patient information at the Rehabilitation Center of Ikot Ekpene (hospital B), Nigeria

Type of examination	Projection	Patient age (year)	Patient height (cm)	Patient weight (kg)	Tube potential (kvp)	Charge (mAs)
Thorax	PA	49.74 (20–74)	168.85 (163– 176)	65.85 (60–73)	63.925 (60–70)	17.275 (12–22)
	RLAT	44.425 (20–72)	170.15 (163–176)	67.475 (60–73)	61.63 (60–66)	14.67 (11–18)
Cranium	AP	45.711 (20–78)	171.553 (163–176)	68.553 (60–73)	61.684 (60–68)	13.553 (11–18)
	RLAT	44.5 (21–71)	169.83 (163–176)	66.825 (60–68)	62.125 (60–75)	13.95 (10–20)
Abdomen	AP	58.575 (34–79)	167.88 (163–176)	64.875 (60–73)	61.775 (60–72)	13.863 (10–20)
Pelvis	AP	58.575 (34–79)	167.88 (163–176)	64.875 (60–73)	61.775 (60–72)	13.575 (12–18)

Table 3. Exposure parameters and patient information at University of Uyo Teaching Hospital (UUTH) (hospital C), Nigeria

Type of examination	Projection	Patient age (year)	Patient height (cm)	Patient weight (kg)	Tube potential (kvp)	Charge (mAs)
Thorax	PA	56.05 (35–80)	169.175 (16–176)	66.175 (60–73)	64.975 (61–70)	18.51 (12–30)
	RAT	52.575 (31–78)	167.55 (163–176)	64.55 (60–73)	64.925 (61–70)	17.1 (12–20)
Cranium	AP	41.35 (20–75)	169.83 (163–176)	66.825 (60–73)	61.80 (60–68)	15.02 (10–20)
	RLAT	48.29 (22–78)	168.07 (163–176)	65.073 (60–73)	62.75 (60–75)	15.07 (12–20)
Abdomen	AP	47.425 (20–80)	167.58 (163–176)	64.875 (60–73)	62.12 (60–70)	14.12 (12–20)
Pelvis	AP	55.45 (20–80)	168.78 (160–176)	65.85 (60–73)	63.325 (60–68)	13.575 (10–18)

Table 4. Entrance skin doses (ESDs) (mGy) at hospital A

Radiography	Projection	Sample	Min	Max	Median	First quartile	Third quartile	Mean
Thorax	PA		0.311	0.676	0.382	0.351	0.432	0.407
	RLAT		0.402	0.674	0.518	0.477	0.578	0.528
Cranium	AP		1.094	1.947	1.468	1.315	1.640	1.497
	RLAT		0.402	0.674	0.518	0.477	0.578	0.528
Abdomen	AP		1.426	2.621	1.921	1.627	2.092	1.810
Pelvis	AP		1.406	2.233	1.807	1.687	1.950	1.825

Table 5. Entrance skin doses (ESDs) (mGy) at the Rehabilitation Center (hospital B)

Radiograph	Projection	Sample	Min	Max	Median	First quartile	Third quartile	Mean
Thorax	PA		0.382	0.959	0.594	0.503	0.759	0.634
	RLAT		0.412	0.887	0.613	0.492	0.757	0.637
Cranium	AP		1.155	2.553	1.652	1.394	1.806	1.681
	RLAT		1.066	2.301	1.477	1.258	1.701	1.484
Abdomen	AP		1.305	4.457	1.894	1.586	2.082	2.077
Pelvis	AP		1.647	3.619	1.879	1.687	2.342	2.048

Table 6. Entrance skin doses (ESDs) (mGy) at University of Uyo Teaching Hospital (UUTH) (hospital C)

Radiograph	Projection	Sample	Min	Max	Median	First quartile	Third quartile	Mean
Thorax	PA		0.412	0.968	0.672	0.604	0.744	0.690
	RLAT		0.513	1.101	0.775	0.684	0.845	0.777
Cranium	AP		1.044	2.412	1.789	1.466	1.922	1.734
	RLAT		1.145	2.515	1.698	1.185	1.920	1.618
Abdomen	AP		1.556	3.545	1.847	1.648	2.092	2.006
Pelvis	AP		1.406	3.168	2.183	1.910	2.233	2.125

Table 7. Entrance skin doses (ESDs) (mGy) at the evaluated hospitals (A, B & C)

Radiography	Projection	Sample	Min	Max	Median	First quartile	Third quartile	Mean
Thorax	PA		0.311	0.968	0.594	0.588	0.751	0.577
	RLAT		0.402	1.101	0.613	0.667	0.801	0.647
Cranium	AP		1.044	2.553	1.652	1.722	1.862	1.637
	RLAT		0.402	2.515	1.477	1.140	1.811	1.210
Abdomen	AP		1.305	4.457	1.893	2.086	2.092	1.993
Pelvis	AP		1.406	3.619	1.878	2.091	2.287	1.998

Table 8: Comparison between entrance skin doses (ESDs) (mGy) and the established international dose reference levels (DRLs) (mGy)

Radiography	Projection	Present Study	International DRLs	
		ESD (mGy)	IAEA (1994)	NRPB (2000)
Thorax	PA	0.59	0.4	0.2
	RLAT	0.61	1.5	1.0
Cranium	AP	1.65	5.0	3.0
	RLAT	1.47	3.0	1.5
Abdomen	AP	1.89	10.0	6.0
Pelvis	AP	1.88	10.0	4.0

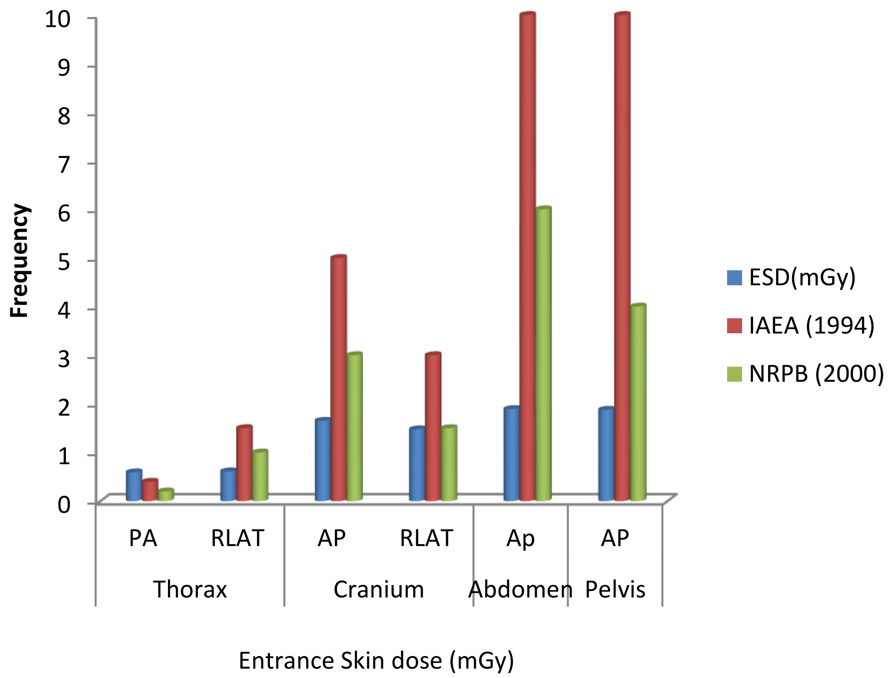

Figure 1. Distribution of entrance skin doses (ESDs) and dose reference levels

4. Discussion

Based on the obtained findings, there was a significant difference in patient dose for each projection at the evaluated hospitals; however, the mean dose did not vary greatly from one hospital to another. According to Table 9, the highest recorded ESD (mGy) was reported in PA examinations of the thorax at all hospitals and the lowest value was reported in RLAT examinations of the cranium (at the Rehabilitation Center and UUTH).

The ESD values in this study were compared with the established reference dose levels introduced by NRPB and IAEA (USA). All median values were below the basic safety standard, except for chest PA examinations; however, the values were higher than the standard IAEA reference level.

The variations in dose level for ESD may be caused by many factors, amongst which we can name the efficiency of equipments, the applied processing systems and radiographic techniques used at each hospital. Similarly, various studies have reported results regarding variations in ESD values [18-23]. Investigation of the causes of this significant dose variation suggested that further research is required to eliminate the differences and ensure the As-Low-As Reasonably Achievable (ALARA) principle. Moreover, the received doses can be reduced if radiographers strictly adhere to the guidelines to correct operative modalities.

Also, in the present study, the organ/tissue absorbed dose or body organ dose for six examinations was calculated in 720 adult patients in AP, PA and RLAT projections of the thorax, cranium, abdomen and pelvis. The estimated ESD values were as follows: 0.594 mGy and 0.613 mGy for PA and RLAT projections of the thorax, 1.625 mGy and 1.477 mGy for the AP and RLAT projections of the cranium and 1.894 mGy and 1.879 mGy for the AP projections of the abdomen and pelvis, respectively.

The mean effective dose was within the range of 0.0209-0.0748 mGy in the thorax (mean= 0.0370), 0.0083-0.0446 mGy in the cranium (mean= 0.016217), 0.2151-0.2258 mGy in the abdomen (mean= 0.2194) and 0.1009-0.1190 in the pelvis (mean= 0.112033). In total, use of low tube potentials and high mAs was common at the evaluated hospitals and was reported as the main cause of dose variations.

As stated by the radiographers, obtaining higher resolution was the main cause of dose variation. As Obed indicated, an increase in tube potential was associated with a 33% drop in ESD. Also, the increase in tube potential by 8-13 kV in lumbar and thoracic spine examinations resulted in a dose reduction of 26-39% [20]. This finding was also confirmed by a study by Esen and Obed[19].

5. Conclusion

In this study, ESD and effective dose during diagnostic x-ray examinations on adult patients were assessed at some hospitals in Akwa Ibom State, Nigeria. Patients' ESD were reported to be consistent with the range of values reported in literature review. Also, the mean ESD values in the present study were compared with the reference dose levels; these values were mostly comparable with the reference levels. This implies that radiation risk to an average patient was low at the evaluated hospitals; moreover, the risk to the hospital staff was generally low. These findings indicate a serious need for quality assurance programs and monitoring aimed at reducing patient dose in Nigeria. This purpose can be achieved by organizing regular workshops and conferences for radiographers, setting guidelines for different exposures and establishing diagnostic reference levels with which hospitals may be compared.

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