ORIGINAL ARTICLE

PATIENT RADIATION DOSE ASSESSMENT IN ROUTINE X-RAY EXAMINATION AT JIMMA UNIVERSITY SPECIALIZED HOSPITAL, SOUTH WEST ETHIOPIA

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ABSTRACT

Background: *High doses of ionizing radiation can lead to such 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. Therefore, periodic dose assessments should be performed to optimize patient radiation protection. The aim of this study was to assess entrance surface dose for patients undergoing routine X- ray examinations at Jimma University Specialized Hospital.*

Methods: *A cross-sectional study was conducted on 315 patients who sought x-ray examinations at the Radiology Department of Jimma University Specialized Hospital. Patient data such as age, weight, and exposure parameters (kV and mAs) were recorded. The results of the entrance surface dose were calculated by using exposure parameters (kV and mAs), focus to surface distance (FSD), and tube output (mGy/mAs). Finally, the calculated mean entrance surface dose (ESD) was compared with the diagnostic reference level and similar internationally published studies.*

Result*: The mean ESD for chest PA examination was 0.40mGy in room 1 and 0.44mGy in room 2. This finding is higher than those of similar studies in UK, 0.23mGy and Nigeria 0.26mGy. For skull PA and abdomen PA examinations, the mean ESD was 2.09mGy and 2.27mGy, respectively, in room 1. The finding of this study revealed that mean ESD values in the present work, except for chest are mostly comparable with international Diagnostic Reference Levels like, the National Radiation Protection Board (NRPB), Commission of the European Communities (CEC), and International Atomic Energy Agency (IAEA).*

Conclusion*: Even though the radiation dose for skull, abdomen, & pelvis is within the corresponding range of reference values, the high dose obtained for chest PA is a further indication that doses delivered to patients are not as low as reasonably achievable, and there is need to optimize service and patient radiation at Jimma University Specialized Hospital.*

Keywords*: Patient, Radiation Dose, X-ray, Dosimeter, Jimma, Ethiopia*

INTRODUCTION

In medicine, diagnostic X-rays are so extensively used that they represent by far the largest man-made source of public exposure to ionizing radiation. Exposure to high radiation dose leads the patient to a risk for cancer induction or genetic detriment. Ionizing radiation which may damage Deoxyribonucleic acid (DNA) in terms of biological effect is hazardous to cell tissues (1). The prevention of the potential hazardous effect of ionizing radiation has been a critical focus and great concern despite the invaluable contribution of ionizing radiation in medical imaging to diagnosis and subsequently treat various disease entities (2). Radiation exposure either from radiation accident or medical x-ray examination at the early stage of life, usually results in a likelihood of two or three fold increase in lifetime risk for certain detrimental effects, including solid cancer, compared with that of adult (3 , 4).

Patient dose has become a major issue and because of increasing awareness and greater realization of the effects of ionizing radiation, X-ray users are now more demanding of dose information and dose reduction (5).Today, Quality and safety have become the hallmarks of efficient and successful medical proce-

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dure. In general, diagnostic patient safety and quality control initiatives have been developed in several countries in the past years, with the goal of improving diagnostic information and reducing patient dose to the minimum(the ALARA principle) (1). The two basic principles of radiation protection of patients recommended by ICRP are the justification of practice and optimization of protection (6, 7).

In diagnostic radiology, periodic dose assessments should be made to encourage the optimization of radiation protection of patients. Further dose measurements are required to compare different radiological techniques and to comply with some international guidelines and regulations. During the last ten years, many studies have been conducted on radiation dose due to clinical x-ray examinations (8-13).

These studies and to many international researches reported wide variations in patient dose arising from specific X-ray examinations. Though the reasons for these dose variations were complex, low tube potential, high mAs, and low filtration were associated with high-dose hospitals in general.

The International Commission on Radiological Protection (ICRP) introduced the term diagnostic reference level "DRL" for the first time in 1996 (14). A research done in Ireland emphasized the importance of the establishment of reference dose levels that are appropriate to countries' specific radiographic techniques and practices in order to optimize patient protection (15).

Most countries have legislations controlling the use of ionizing radiation even though the legal systems are different. In Ethiopia, there is a legal authority formed by proclamation to control the use of the country's ionizing radiation by measuring corresponding patient doses to determine whether the x-ray radiation doses to patients are as low as reasonably achieved, as required by the International Commission on Radiological Protection (1).

It is not known or there is no report showing the level of x-ray radiation doses currently used by hospitals in Ethiopia are according to the ICRP 1977 or not. Again, in Ethiopia there is shortage of information on patient radiation dose in diagnostic medical radiology. Similarly, in the Radiology Department of Jimma University Specialized Hospital (JUSH), there is no report or published studies on patient radiation dose so far. Therefore, this study was conducted to estimate the dose by using an indirect method of ESD measurement to adult patients undergoing routine x-ray examinations at JUSH.

METHOD

Study Design: A cross-sectional study was conducted to assess patient radiation dose on adult patients who visited to seek X-ray examinations at JUSH between February and August 2015. The hospital was chosen because in addition to being the only functional radio diagnostic center during the study period and by implication, the dose values obtained from this study, to a large extent, represent a good estimate of population dose in southwest Ethiopia at the time of the study.

The common X-ray examination studied included, Chest posterioranterior (PA), Skull Anteriorposterior (PA), Skull lateral (LAT) Abdomen (AP) and Pelvic (PA). For each patient examined, data like age, weight, and body part thickness were obtained. The exposure parameters used for each patient included kilovoltage peak (kVp), product of tube current and time (mAs), and focus-film distance (FFD).

Sample Size: The sample sizes were determined based on the International Commission of Radiation Protection Recommendations (ICRP, 1990) to conduct such a study (16). It recommends determining the sample size based on the total number of target population visiting the X-ray departments of this hospital in the previous year. According to data available in the hospital, a total of 6000 radiographs were taken in Room 1 and Room 2 for adult patients in the year. By considering this number as the target population, the total sample size of the study was determined using the following equation,

$$n = \frac{N}{1 + Ne^2}$$

where,

N is target population

n is sample size

e is the level of precision ($3\% \leq e \leq 10\%$).

In this study a total of 315 radiographs were taken by considering a 5% level of precision; a 5% level of precision was taken to find a sufficient sample size.

Data Collection method: To collect data two X-ray machines were investigated in two X-ray rooms. The X-ray sections that were investigated were equipped with stationary X-ray units. Both X-ray machines were shimadzu manufactured in 1992 and were constant potential generators with 1 mmAl total equivalent filtration. Both were manual exposure mode with power rating of40-125kVp.Two manufacturers' cassettes (Agfa and Kodak) were used with a screen-film combination speed of 400.

X-ray tube output measurement: The tubes outputs of all X-ray equipment were measured by dosi-time dx digital dosimeter and exposure time meter. Normalization at 80 kVp, 20mAs and focus to skin distance (FSD) of 100cm were used because the potential across the X-ray tube and anode current are highly stabilized at this point (23). Before the actual data collection, dx dosimeter was calibrated for sensitivity and linearity. Finally, tubes output was calculated in units of mGy/mAs for both X-ray tube by using the equation below.

$$O/_{P} = \frac{\textbf{Average Dosimeter Readings}}{\textbf{tube current time product (mAs)}}$$

Accordingly, the tube output of the X-ray machine found in room 1 was found to be 0.73mGy/mAs and 0.93mGy/mAs for X-ray machine found in room 2.

ESD calculation method: Patient's dose has often been described by the entrance surface dose (ESD) as measured in the center of the X-ray beam. Because of the simplicity of its measurement, ESD is widely considered as the index to be assessed and monitored. ESD is measured directly using thermoluminiscent dosimeter (TLD) placed on the skin of the patient. Because of the unavailability of TLD in the study area and due to its limitation, the indirect method of ESD measurements using digital Dosimeter (Model 05-526-2200, Sweden) and exposure factor were used. This dosimeter was calibrated by the manufacturer and reported to have more than 5% accuracy. This equation provides an easy and more practical means of estimating skin dose even before exposure.

The entrance surface doses for adult patients were determined in terms of the entrance surface air kerma on the basis of X-ray tube output measurements and X-ray exposure parameters, and it was determined by multiplying the incident air kerma to the patient's skin with an appropriate backscatter factor

(BSF). In the present work, however, ESD values were determined by using the following equation derived based on inverse square law.

Where (O/P) is the tube output mGy/ mAs measured at a distance of 100 cm from the tube focus along the beam axis. kVp is the peak tube voltage recorded for any given examination. mAs is the tube current and time product; FSD is the focus-to-patient entrance surface distance, and BSF is the backscatter factor used with a value of 1.35.

Data Analysis: Both quantitative and descriptive statistic was used for data analysis. Quantifiable information collected from each radiographic examination was analyzed and presented using mean, range, maximum, minimum, SD, 1st Quartile, 3rd and illustrated using tables.

The calculated mean ESD was compared with internationally recommended values (17, 25, 26) and with similar internationally published studies. The analysis of dose distributions within the rooms under study was also performed.

Ethical consideration*:* Ethical clearance was obtained from the Ethical Review Board of Jimma University, College of Health Sciences. Each participant was well informed about the aim and potential benefit of the study, and their consent and confidentiality was ensured.

RESULT

Results from analysis of radiographic parameters and patients' information: A total of 315 radiographs were included in this study. Patient information and exposure parameters for selected examinations are shown in Table 1. The mean age of the study sample ranged from 33 to 46 years and the mean weight ranged from 73kg to 76kg. The range of patient thickness for both rooms was from 10cm to 15cm. It can be seen from Table 1 that low kVp was used for all types of examination by the hospital. The kVp used for Skull PA ranged from 80kVp - 85kVp, with a mean of 84kVp in room1 and 65- 95kVp, with a mean of 86kVp in room 2. Similarly, low kVp was used for skull LAT ranged from 80kVp- 85kVp with mean of 82kVp in room 1 and 70kVp-85kVp with mean of 80kVp in room 2. Lower kVp was used for abdomen PA which ranged from 78 – 86kVp, with mean of 84kVp in room 1 and 85 -95kVp, with mean of 92.7kVp in room 2. For Pelvic AP, a similar mean of 83.5kVp and 83.7kVp was used rooms1 and 2, respectively.

In this study, a very large mAs was employed in both rooms 1 and 2. The mean mAs used for chest PA examination were 9mAs and 6mAs in room 1 and room 2, respectively. Almost similar mean mAs were employed for skull PA examination in both rooms which were 16.2mAs and 17mAs at room 1 and room 2, respectively. There is a large variation between the mean mAs employed for Abdomen PA examination in room1 and room 2 *i. e* 17.6mAs in room 1 and 21.2mAs in room 2.

Distribution of mean ESD (mGy): Tables 2 and 3 show the mean, the 1st quartile, and 3rd quartile values of the ESD estimated for individual examinations for both rooms. In addition, the Range Factor (RF) defined as the ratio of maximum to minimum dose for the same type of examination was calculated and presented (Table 2 and Table 3).

Table 1: Mean, SD, Maximum, Minimum sample size and patient data in JUSH, 2015.

Radiography	Room 1					Room 2				
	Age (yrs)	**Weight (kg)**	**Kv_p**	**mAs**	**FFD (cm)**	**Age (yrs)**	**Weight (kg)**	**Kv_p**	**mAs**	**FFD (cm)**
Chest PA										
Mean	46	76	74	9	150	43	73.6	83.9	6	150
SD	17	9	3.3	1.7	0	8	9	6.8	1.5	0
Max	60	80	80	14	150	62	80	95	10	150
Min	28	70	68	5.6	150	29	70	76	5	150
S/size	54	54	54	54	54	71	71	71	71	71
Skull PA										
Mean	33	74	84	16.2	100	42	74	86	17	90
SD	7	8	1.5	0.5	0	10	8	6.7	2	0
Max	62	80	85	18	100	67	80	95	22	90
Min	26	70	80	16	100	30	70	65	10	90
S/size	17	17	17	17	17	28	28	28	28	28
Skull LAT										
Mean	35	73.6	82	16	100	39.4	73	80	10	90
SD	6.5	6	1.3	0	0	7	7	6	3	0
Max	59	80	85	16	100	59	80	85	15	90
Min	30	70	80	16	100	29	70	70	12	90
S/size	15	15	15	15	15	26	26	26	26	26
Abdomen PA										
Mean	41.3	73.4	84	17.6	100	40	73	92.7	21.2	100
SD	7	8	3	5	0	8	5	2.9	1.3	0
Max	60	80	86	20	100	70	80	95	25	100
Min	28	70	78	14	100	30	70	85	20	100
S/size	32	32	32	32	32	27	27	27	27	27
Pelvic AP										
Mean	39.6	75	83.5	17.8	100	39	71	83.7	20	100
SD	10	7	5	1.8	0	8	9	5	1.8	0
Max	60	80	88	20	100	69	74	90	22	100
Min	25	70	79	14	100	29	66	72	18	100
S/size	29	29	29	29	29	16	16	16	16	16

Table 2: Distribution of Mean ESD (mGy) values for individual patients in room 1 in JUSH 2015.

Radiograph	S/size	Min. ESD (mGy)	1st Quartile	Mean ESD (mGy)	3rd Quartile	Max. ESD (mGy)	Max/Min
Chest PA	54	0.25	0.32	0.40	0.55	0.67	2.68
Skull PA	17	1.92	1.98	2.09	2.31	2.33	1.21
Skull LAT	15	1.89	1.89	1.97	1.99	2.08	1.10
Abdomen PA	32	1.69	1.89	2.27	2.44	2.62	1.55
Pelvic AP	29	1.73	1.91	2.27	2.56	2.73	1.58

Table 3: Distribution of Mean ESD (mGy) values for individual patients in room 2 in JUSH, 2015

Radiograph	S/size	Min. ESD (mGy)	1st Quartile	Mean ESD (mGy)	3rd Quartile	Max. ESD (mGy)	Max/Min
Chest PA	71	0.33	0.38	0.44	0.72	0.85	2.58
Skull PA	28	1.77	2.32	3.71	4.54	5.41	3.06
Skull LAT	26	1.77	1.85	1.99	2.62	2.93	1.66
Abdomen PA	27	3.54	4.02	4.25	4.87	5.07	1.43
Pelvic AP	16	2.38	2.40	3.27	3.87	3.99	1.68

There was a considerable variation in the range factor for ESD for the same type of examination in the same room. The range factor highlights the spread/ variation in the ESD values for the same type of examination either within or between rooms (Figure 1).

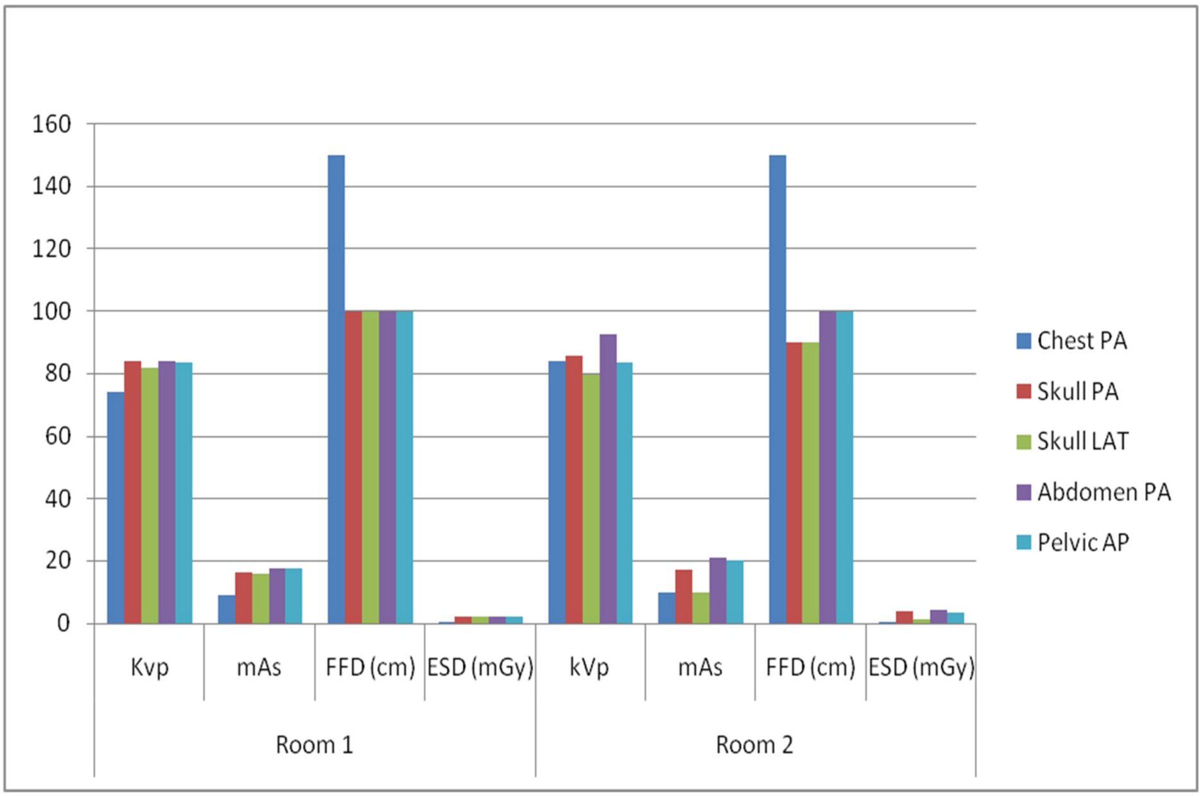

Figure 1: Comparison of mean exposure parameters and mean ESD (mGy) within the rooms, 2015.

Table 4 shows the comparison of the mean ESD (mGy) obtained in the present study with some international published studies and reference dose values. For chest PA 0.40mGy and 0.44mGy mean ESD was observed in room 1 and room2, respectively.

Table 4: Comparison of the Mean ESD (mGy) Obtained in the present Study with Some International Published Studies and Reference Dose Values 2015.

Examinations	**Present Study Ethiopia**		**Nworgu O. *et al* (2014) Nigeria**		**Shirmpton *et al* , (1986)**	**Organization with DRLs**		
	Room 1	**Room 2**	**UBTH**	**CH**	**UK**	**NRPB (2000)**	**CEC (1996)**	**IAEA (1996)**
Chest PA	0.40	0.44	0.26	0.47	0.23	0.2	0.3	0.2
Skull PA	2.09	3.71	2.09	4.43	4.37	3.0	5.0	2.5
Skull LAT	1.97	1.49	1.67	3.28	2.33	1.5	3.0	1.5
Abdomen PA	2.27	4.25	NR	NR	8.43	6	5	10
Pelvic AP	2.27	3.27	8.38	12.04	6.57	4	10.0	5.0

UBTH: University of Benin Teaching Hospital. CH: Central Hospital. NR- not reported

DISCUSSION

The mean weight was within 70 ± 6kg which was comparable with the standard sized adult patients recommended by International Commission on Radiological Protection (16). Thus, this study complied with this recommendation; therefore, the estimate ESDs for all examinations could be considered sufficiently representative values for the specific rooms. Low kVp was observed in this study. This is lower than the kVp recommended by the European Community guidelines for quality radiographs (17). Both low and high kVp techniques were reported to be commonly used in routine radiographic examinations in Europe and the USA (18), but it has been shown that the use of a high voltage technique for routine X-ray examination has been calculated to reduce entrance surface dose by half and effective dose equivalent by 20%; therefore, values lower than the recommended tube potentials should not be used (19, 20). Using low kvp and high mAs which improves image quality, while increasing dose to the patient must be changed so that the dose should be maintained as low as reasonably achievable (ALARA) principles.

This study also revealed that there were inconsistencies in the use of the FFD as recommended in the European Community (EC) quality criteria (21). The EC quality criteria recommend for chest PA an average FFD of 180cm and for skull AP, Abdomen PA and pelvic AP an average FFD of 115cm is recommended. Both rooms used FFD values below the average values for all procedures. Since ESD is inversely proportional to the square of the FFD, for the same kVp and mAs the dose reaching the patient is expected to be high. The use of optimum FFD is considered very important since a direct relationship between shorter FFD, higher patient dose and decreased geometric sharpness is well established (22, 23).

Generally, the radiographic technique parameters recorded show that there were variations in the technique factors when compared with the recommendations in the EC quality criteria (21). In this study, varying radiographic voltages and reduced focus film distances were used. All these factors have an adverse influence on the outcome of the dose to patients. These problems could probably be partly associated with the inadequate training of imaging staff, variations in patient physical status, types of equipment, and varieties of techniques used in different rooms. Therefore, the optimization step must start with the regulatory body mandating radiographers, radiologists and medical physicists to take part in various refreshers and update courses to be aware of recent developments on how to properly and effectively select technical parameters that will not affect or compromise image quality.

In this study, a small variation of individual radiation dose was observed. The maximum/minimum ratio of chest was 2.68 in room 1 and 2.58 in room 2. This is much lower than the UK value of 47.7(24). The variations recorded in this study are an indication that operational conditions are less optimized in this hospital. The variation in patient dose for the same type of X-ray examination carried out on similar patients in this hospital compared to other established work suggests that significant reductions in the dose from such exposures would be possible without adversely affecting image quality.

Comparison between present measurements and those from internationally established reference dose levels revealed that mean ESD values in the present work are mostly comparable with and some higher than those from NRPB, CEC and IAEA (25,17, 26). The mean ESD values for chest PA are higher than the corresponding range of values that have been reported from countries like Nigeria and other studies in UK (24, 27). Therefore, still there is home for reduction in patient radiation dose without adversely affecting image quality by simple programming of education, regular provision of dose information and an approach involving collaboration between medical physicists, radiographers, and radiologists, and by establishing a culture of regular dose measurements, film reject analysis, and image quality assessment as recommended by the IAEA.

In conclusion, even though the mean ESD found in this study is mostly comparable with international DRL (17, 25, 26), the result confirmed that patients who underwent chest PA X-ray examination receive higher radiation dose compared to other international published works and international reference dose levels. The reason behind the high doses may be differences in the technical parameters used. The high dose could also be due to patient size or clinical complexity, suboptimal use of equipment or equipment problems generally because of the paucity of regular quality control and radiation protection programs.

This study provides additional data that can help the regulatory authority to establish reference dose level for diagnostic radiology in Ethiopia. The results are also useful for international and professional organizations. Finally, we recommend a large scale study at a national level to standardize radiographic techniques and to develop a national DRL.

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