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Research Paper

Entrance Surface Dose Determination for Common Adult Radiography Examination in Selected Tertiary Hospitals in North Eastern Nigeria

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Abstract

Patients dose survey is critical in ascertaining the dose received by patients in radiography practice especially with increasing practices and technological advances. The objective of the study is to determine the radiation doses received by patients from radiography examinations in two teaching hospitals in Nigeria. Prospective cross-sectional study was conducted in two Nigerian teaching hospitals located in North Eastern Part of Nigeria. One thousand two hundred patients participated in with 60 patients for each procedure. "Thermoluminiscent" dosimeter chips were used to determine the doses received by patients for each examination. Mean and standard deviation for each examination were obtained and student T-test was used to determine the relationship between the doses received by patients in the two hospitals. Statistical significance was set at $p < 0.05$. Mean weight and age were 60.01±9.0kg and 38.10±9.3 years. The total mean dose and standard deviation for major radiographic examinations were 0.45±0.36mGy for posterior anterior chest x-ray, 0.82±0.44 lateral chest, 0.77±0.41posterior anterior skull, 0.69±0.73 lateral skull, 0.40±0.25, 0.46±0.34 for anterior posterior shoulder and 0.50±0.24 lateral shoulder. There is no statistical significant relationship $P>0.05$ between doses and technical parameters. Entrance surface doses for radiography examinations were high when compared to that of other regions in Nigeria and African countries. Therefore dose surveys are recommended with the objective of improving exposure optimization and technical procedure in Radiography examination.

Keywords: Entrance skin dose; Radiation, dose Survey; "Thermoluminiscent" dosimeters; Radiography

Introduction

Radiation dose surveys from radiography examinations provide valuable information about human health and play an important role in helping the physicians to make accurate diagnosis.The medical field over the years has benefited enormously from the use of x-ray radiation with various new developments associated with diagnosis and therapy [1]. Radiation can be a major risk in radiology and the growing use and increasing complexity of examination have been accompanied by public health concerns resulting from radiation exposure to both patients and personnel [2]. It is known that of all "man made" sources of radiation, diagnostic x-rays contribute the largest part to the collective population dose, and are the most encountered radiation in diagnostic radiology leading to injurious somatic and genetic effects on human beings [3].

X-ray is the most frequently used ionizing radiation for diagnostic imaging and it plays a significant role in effective health care delivery both in developed and developing countries [4]. X-ray is said to be the major contributor to the collective effective dose of the general public [5]. The need for radiation dose assessment for the patient during diagnostic x-ray examinations has been highlighted with the increasing knowledge of hazard of ionizing radiation [5].Increasing concerns over radiation doses received by patients and the associated radiation risks have become a major issue in recent years[6].Reducing radiation dose in radiological examination is of utmost importance particularly in the light of continued increase in the number of new modalities and examinations performed annually [7,8]. In Nigeria, in spite of the large number of x-ray examinations carried out yearly, the dose information available is grossly inadequate [10,20].The need for optimization of patient protection through implementation of measures to keep doses to patients undergoing radiology examination within acceptable ranges for the clinical purpose of each examination has been a topic of global recognition[12].

Materials and Methods

Experimental set up

Figure 1. **Procedure for TLD set up**

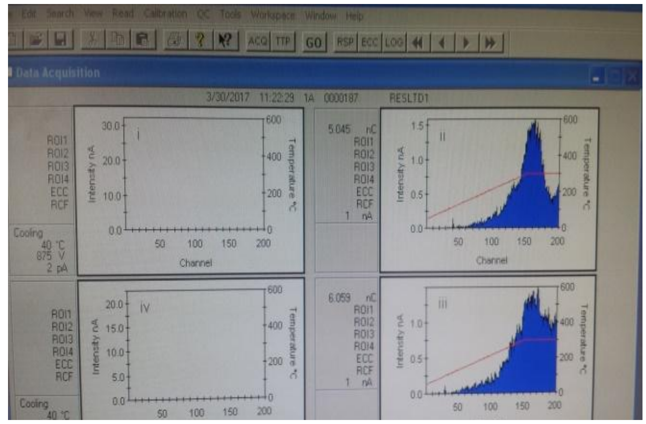

Figure 2. **Glow curve for the TLDs**

Procedure

This study is a prospective cross-sectional study conducted in two Nigerian teaching hospitals located in North Eastern Nigeria. One thousand two hundred patients participated in the study with 50 patients for each radiography examination in the two hospitals. Dosimeters chips "Thermoluminiscent" (LiF) were used to determine dose received by the patients for each examination. Thermoluminiscent dosimeter (TLD) chips were placed at the central axis where the x-ray beam strikes the patient's skin and then exposures were made at 100-150cm focus to skin distance depending on the examination. The exposed TLDs were labeled for proper identification and kept in black nylon before and after exposure. Information contained in the dose data capture sheet includes age, gender, weight, height, body mass index, focus to film distance tube voltage and tube current. Data were entered by the researcher and assisted by two senior radiographers in each facility and then checked by a medical physicist, ethical approval was obtained from the research ethics committee of the hospital under study. Informed consent form was filled by each (volunteer, Patient) participant.

Data Analysis

Data was obtained and saved on Microsoft excel spread sheet and categorized for each examination and imaging modality respectively. Statistical package for social sciences version 21.0 was used to analyze the mean, median, standard deviation, range of the anthropometric variables, technical parameters and radiation dose received. 75th percentile (3rd quartile) value of the total mean of the examinations and or procedures were obtained at 95% confidence interval. Using Kolmogorov- Smirnov test it was verified that, for 95% of confidence level, there was a normal distribution. Therefore we used a parametric test that was suitable for the set of data and analysis. Pearson's correlation was used to determine the relationship between radiation dose and weight at statistical significance of $p<0.05$.

Processing of the TLD

The TLD reader is Harshaw Model 4500. It has a hardware comprising the following system.

1. The model 4500 Harshaw TLD reader which contains data processing electronic, a sample drawer assembly, a precision light measurement system, a detector heating system, a light voltage power supply and data storage facilities.

2. A video display unit (VDU) for the display of data graphics, operating instruction and messages.

3. Keyboard that provides the interactive central interface with the TLD reader Harshaw model 4500.

4. A set of floppy disk for backup.

The model 4500 Reader is capable of reading a number of forms of thermo luminescence dosimeters, such as the whole body and the environmental dosimeter.

The Harshaw Model 4500 Manual TLD Reader with WINREMS is a state-of-art; tabletop instrument used for thermo luminescence dosimetry (TLD) measurement of a wide variety of TL materials in many forms and sizes. This model incorporates two Photomultiplier Tubes in a sliding housing, with both planchet and hot gas (nitrogen or air) heating methods. The TL element may be heated by hot gas or by a planchet. Hot gas is used for whole body and Environmental TL cards and extremity Dosimeters (Chipstrates and Ringlets), while the planchet is used for the unmounted TL elements: chips, disks, rods, and powders. The system consists of two major components: the TLD Reader and the Windows Radiation Evaluation and Management System (WinREMS) software resident on a personal computer (PC), which is connected to the Reader via a serial communications port.

WinREMS Application software

The data architecture of the system includes both a host computer in the Reader and a Windows based PC connected through an RS-232-C serial communication port. The dosimetric functions divided between the Reader and the HarshawWinREMS (Windows Radiation Evaluation and Management) software on the PC. All dosimetric data storage, instrument control, and operator inputs are performed on the PC, transport subsystem control, gas and vacuum controls, and signal acquisition and conditioning are performed in the Reader.

Dose Algorithms

a. Glow curve analyzer which determines the quality of the glow curve. See appendix K for dose curve profile of TLD-100 (LiF-TLD).

b. Glow curve deconvulation which segregates the glow curve into their individual glow peaks

c. Chain of custody and health physics record system, which updates and maintains dose data

d. The peak value of the glow curves produced (plate 1) were automatically converted to dose using the formula

$$\mathbf{Dose} = \frac{\mathbf{Q \times ECC}}{\mathbf{RSF}} \qquad (1)$$

where:

Q = Charge (the glow peak value, in nano -columb).

ECC = Element correction coefficient = 3749

RCF = Reader calibration factor = 0.0171

Calibration of Dosimeters

Thermoluminescent dosimeters TLD100 dosimeters were used for dose measurements of ESD. They are round, small, white in colour with dimension of 4.5mm x 0.9mm thick with sensitivity of 1 which can be adjusted. The TLD has active layer thickness with isotropic composition.

Results

Table 1 shows patients total mean value for anthropometric parameters (age (years), weight (kg), height (m), body mass index (kg/m^2), focus to skin distance (FSD), anterior posterior (AP) thickness (cm) and compressed breast thickness (CBT) in (cm) for mammography) and technical parameters (Tube potential kVp and tube current mAs). The mean and standard deviation of the age weight, height, BMI,AP thickness, CBT, FSD, kVp and mAs for the whole patient population are 38.10±93, 60.00±1.0, 1.65±0.10, 24.32±3.30, 17.12±0.13, 19.88±0.11, 98.34±3.00, 60.11±1.00 and 30.1±0.1. The mean weight recorded in this study was 60.01±9.0kg while the mean patient age was 38.10±9.3 years.

Table 1. Total mean and standard deviation of anthropometric and technical parameters for radiographic and dental examination

Examination	Age (years)	Weight (kg)	Height (m^2)	BMI (kg/m^2)	Thickness (cm)	FSD (cm)	kVp	mAs
Chest x-ray PA	37.18±13	66.25±6	1.67±0	26.32±16	14.15±2.6	129.50±16	61.86±4	14.23±2
Chest x-ray Lateral	41.63±12	66.67±6.4	1.64±0.	25.18±7.	18.93±3.0	119.17±20	84.40±5.	34.09±7
Hand Dorsi Palmar	41.17±13	68.56±6.3	1.74±0	23.23±2	1.07±0.25	86.33±7.5	53.70±8	2.33±0.3
Hand DP Oblique	40.82±15	68.60±6.1	1.74±0	23.21±2	1.03±0.14	92.00±9.9	58.00±5.	2.38±0.5
Abdominal x-Ray	43.06±15	68.20±6.1	1.75±0.	22.72±24	20.67±3.8	94.00±4.7	81.02±7.	39.32±7
Pelvic x-Ray	47.70±18	69.12±6.5	1.76±0.	22.23±3.	17.15±3.1	80.00±9.4	77.00±5.	37.22±7.
Skull x-Ray PA	45.07±17	67.87±6.2	1.70±0	24.73±6	13.78±3.3	88.42±12	72.09±9	29.43±9
Skull Lateral	43.43±15.	66.26±2.9	1.75±0	22.86±2	10.57±1.4	87.10±3.8	66.00±7	34.75±3
AP Dorsal Spine	48.30±9.6	64.30±5.5	1.64±0	22.41±3	19.88±2.9	86.00±4.9	67.08±5	34.42±3
Lat. Dorsal Spine	48.30±9.6	64.12±5.5	1.65±0	22.27±3	26.65±3.4	95.67±5.0	75.00±6	36.42±3
AP C/Spine	42.15±13	65.40±5.8	1.63±0	23.56±3	5.48±0.72	105.00±5	60.34±3	21.87±2
Lateral C/ Spine	42.15±13	65.40±5.8	1.63±0	23.56±3	5.32±0.62	105.00±5.	60.34±3	21.87±2
AP Lumbosacral	46.20±11	68.30±5.5	1.64±0	22.41±3	19.13±1.4	92.00±9.9	61.83±2	31.50±2
Lateral LSS	46.20±11	84.93±5.4	1.65±0	22.13±3	24.83±4.2	91.33±10	68.33±8	33.33±5
Dental x-Ray	42.04±11	65.30±5.8	1.65±0	23.36±3	2.07±0.25	73.50±4.0	47.49±4	11.47±1

Key: DP-Dorsi-plantar, AP-Anterior posterior, PA- Posterior anterior, C/S- Cervical spine, LSS-lumbosacral spine.

Table 2. Total mean and standard deviation of anthropometric and technical parameters for radiographic and dental examination

Examination	Mean ESD (mGy) Hospital A	Mean ESD (mGy) Hospital B	Mean ESD(mGy) Both
PA chest x-ray	0.34±0.05	0.55±0.43	0.45±0.36
Chest x-ray lateral	0.78±0.07	0.87±0.49	0.82±0.44
PA skull x-ray	0.79±0.32	0.74±0.50	0.77±0.41
Lateral skull	0.77±0.32	0.61±0.45	0.69±0.73
AP dorsal spine	0.87±0.33	0.86±0.318	0.86±0.32
Lateral dorsal spine	0.97±0.50	0.87±0.20	0.92±0.35
AP cervical spine	0.37±0.18	0.53±0.26	
Lateral cervical spine	0.73±0.25	0.54±0.27	0.64±0.26
AP L/S spine	0.99±0.11	0.98±0.45	0.99±0.11
Lateral L/S spine	1.43±0.10	1.28±0.33	1.43±0.10
Abdominal x-ray	0.87±0.46	0.43±0.35	0.83±0.31
Pelvic x-ray AP	0.62±0.05	0.80±0.34	0.60±0.30
Hand dorsi palmar oblique	0.21±0.03	0.58±0.28	0.25±0.20
Hand dorsi palmar	0.49±0.07	0.30±0.21	0.56±0.37
Dental x-ray (periapical view)	0.41±0.11	0.27±0.24	0.29±0.37

Key- ESD- Entrance skin dose, L/S- Lumbo sacral spine

Table 3. Relationship between doses received by patients during contrast radiographic examination and technical parameters

Examination	Technical Parameters	ESD Vs Technical Parameters		DAP Vs Technical Parameters	
		R-value	p-value		
IVU	FSD	0.534	0.002	0.077	0.686
	kVp	-0.317	0.088	-0.209	0.268
	mAs	-0.067	0.726	-0.469**	0.009
HSG	FSD	0.171	0.367	-0.096	0.613
	kVp	0.250	0.183	-0.071	0.708
	mAs	0.012	0.949	-0.132	0.488
RUG	FSD	-0.235	0.211	0.671	0.000
	kVp	-0.153	0.420	0.485	0.007
	mAs	0.213	0.259	-0.010	0.956
BA ENEMA	FSD	0.386	0.035	0.390*	0.033
	kVp	-0.086	0.650	-0.199	0.292

	mAs	-0.013	0.944	0.230	0.222
BA SWALLOW	FSD	0.174	0.357	-0.137	0.470
	kVp	0.448	0.013	-0.110	0.562
	mAs	0.678	0.000	-0.056	0.769
BA MEAL	FSD	0.139	0.465	0.185	0.327
	kVp	-0.532	0.002	-0.162	0.393
	mAs	-0.437	0.016	-0.246	0.191

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

Table 2 shows the mean and standard deviation of entrance skin doses (mGy) received by patients during radiographic examinations in both hospitals and the established diagnostic reference levels in mGy. The total mean dose and standard deviation of the radiographic examinations for the hospitals were 0.45±0.36 for PA chest x-ray, 0.82±0.44 lateral, 0.77±0.41 PA skull, 0.69±0.73 for lateral skull, 0.40±0.25 and 0.46±0.34 for AP and lateral shoulder, 0.45±0.21 for AP dorsal spine and 0.41±0.23 for lateral dorsal spine.

Table 3 (a and b) shows the T-test comparison of radiation dose and technical parameters in the two hospitals studied during radiological examination. Detail result from the table showed that when the mean doses (Entrance skin dose) and technical variables (KVp and mAs) of AP elbow, Lateral Shoulder, Dorsi plantar foot, AP Dorsal Spine, Lateral Dorsal Spine, AP Cervical Spine, Lateral Cervical Spine, and Lateral elbow of patients at hospitals were compared, there was no statistical significant differences (P>0.05) in the radiological dose and technical parameters in the both hospitals. Detail result from the table showed that when the mean doses (entrance skin dose) and technical variables (kVp and mAs) of AP elbow, lateral shoulder, dorsi plantar foot, AP dorsal spine, lateral dorsal Spine, AP cervical spine, lateral cervical spine, and lateral elbow of patients at hospitals were compared, they showed no statistical significant differences (P > 0.05) in the radiological dose and technical variables.

Discussion

This study has provided some initial baseline data on the size of average adult patient in North Eastern Nigeria and the corresponding dose for radiological examination using different imaging modalities. The mean weight recorded in this study was 60.01±9.0kg while the mean patient age was 38.10±9.3 years. This corroborates with a study by International atomic energy agency (IAEA) [12]. In the IAEA study in 2004, on patients undergoing radiographic examination in some European and Asian countries an average weight of 70±10kg was considered appropriate for the European participating countries while 65±10kg was used for the Asian countries [13]. The average age of the only African country that participated in the study, morocco was not stated but a compromise was made to enable a comparison of the measured dose to reference levels. The radiographic technical parameters recorded show that there are variations in technical factor when compared to the recommendations of European commission quality criteria [14]. Varying radiographic voltages and reduced FFD were noted in this study. All this factors have adverse influence on the outcome of the dose to patients. The above outcome is not isolated to this study, this corroborates with a study in Ghana [15], but it is common in other developing countries [16].

Entrance Skin Dose values for the same type of examination in the hospitals vary possibly due to the differences in patient size and in the radiographic technique used by different radiographers. Variation in ESD values between different x-ray rooms will additionally be due to differences in radiographic equipment, film type, processing and processing conditions. The mean ESD values for the individual examinations varied considerably across all hospitals [15]. The variation in dose among the study centers is in agreement with the findings of Shrimpton *et al.* and Olerud, who found variations in the centers to be up to 10 to 40 in UK and 8 to 20 in Norway [16, 17]. A common position among the hospitals in Nigeria is lack of regular patient dose monitoring and quality control in diagnostic radiology. A major reason for this is the cost of running a standard radiation protection and quality assurance facility. This is in consonance with a study by Egbe *et al.* in three Nigerian hospitals in South-South Nigeria [18].

There was statistical significant relationship (p=0.04) between ESD and tube current (mAs) for AP knee with ESD and tube potential (kVp) for AP shoulder. There was no statistical significant relationship (p=0.06) between technical parameters and ESD for PA skull x-ray and lateral, knee AP. Similarly, there was no statistical significant relationship (p=0.15) between ESD and technical parameters (FSD, kVp and mAs) for AP dorsal spine, lateral dorsal spine, AP cervical spine, lateral cervical spine dorsi-plantar oblique foot AP wrist and lateral wrist respectively.

Conclusions

Entrance surface doses for radiography examinations were high when compared to that of other regions in Nigeria and African countries. Therefore dose surveys are recommended with the objective of improving exposure optimization and technical procedure in Radiography examination. The study advocates the need for establishing clinical and anatomic dose reference levels for radiography examination as a panacea for achieving dose optimization.

Abbreviations

TLD: Thermoluminiscent Dosimeter; VDU: Visual Display Unit; ECC: Element Correction Coefficient; RCF: Reader Calibration Factor; FSD: Focus to Skin Distance. AP: Anterior Posterior; CBT: Compressed Breast Thickness.

Author Contributions

All authors contributed equally to this study and manuscript. All authors gave their final approval.

Competing Interests

The authors have declared that no competing interest exists.

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