Physical Science International Journal

15(2): 1-6, 2017; Article no.PSIJ.34269
ISSN: 2348-0130

Evaluation of Radiation Doses from Paediatric Chest X-ray Examination at Three Hospitals in South-West Nigeria

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Authors' contributions

This work was carried out in collaboration between the both authors. Author BL designed the study. Authors OOD and BL participated in the measurement, data collections, data processing and analysis. Author BL wrote the protocol and the first draft of the manuscript. Authors OOD and BL managed the analyses of the study and the literature searches. Author OOD wrote the final draft of the manuscript. The two authors read and approved the final manuscript.

Article Information

DOI: 10.9734/PSIJ/2017/34269
Editor(s):
(1) Lei Zhang, Winston-Salem State University, North Carolina, USA.
(2) Christian Brosseau , Distinguished Professor, Department of Physics, Université de Bretagne Occidentale, France.
Reviewers:
(1) Mahmut Doğru, University of Firat, Turkey.
(2) S. Santhosh Kumar, Tagore Arts College, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/19829

Original Research Article

Received 22nd May 2017
Accepted 12th June 2017
Published 3rd July 2017

ABSTRACT

The aim of this study is essentially to evaluate radiation doses to paediatric patients who were referred for chest X-ray examination between April, 2015 and December, 2016 in three hospitals South-West, Nigeria. The methodology employed in this study involved measurements based on the use of exposure parameters to determine Entrance Surface Dose (ESD). A total of one hundred (100) paediatric patients randomly chosen were included in this study. ESD was determined from exposure parameters using dose calculation software (Dosecal). The results of this study show that the range of Entrance Surface Doses (ESDs) obtained for 0-1year patient is 38.00-150.00 µGy, for 1-5 years is 43.34-194.00 µGy, for 5-10 years is 74.00-223.00 µGy and for 10-15 years is 87.60-292.00 µGy. The mean ESDs obtained in this study were found to be relatively lower than the ESDs obtained in other previous studies in Nigeria but higher than the recommended reference

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dose value given by the European guidelines. This indicates that more attention needs to be given to X-ray facilities in the Country and that X-ray departments need to review their practice in terms of training and re-training of radiographers, repeated chest X-ray procedures for paediatrics, calibration of X-ray machines and standardisation of processing chemicals in order to bring dose given to patients to optimum levels. This study has also revealed the need to have dedicated X-ray facilities for paediatrics throughout the country.

Keywords: Paediatrics; entrance surface dose; exposure parameters.

1. INTRODUCTION

Diagnostic radiology utilising ionising radiation has played an important role in health care delivery since the discovery of X - rays and it has become an accepted imaging modality for the diagnosis of pathological conditions in both paediatrics and adults. But the diagnostic value of the properly conducted X-ray examination must outweigh the small risk to the patient of developing cancer in later life or any hereditary effects in the offspring of the exposed individual. The inherent health hazards are of special concern when young children are involved. Studies [1,2,3] have shown that children less than ten years of age are more sensitive to ionising radiation than middle aged adults. The higher risk of inducing malignancy is due to longer life expectancy in children for any harmful radiation effects to manifest and the fact that developing organs and tissues are more sensitive to the effect of radiation [4]. The risk of movement during X-ray procedure is greater with children which can lead to repetition of the procedure. This in turn leads to an increase of absorbed dose of radiation to the patient.

The probability of a fatal cancer being induced in a patient from a single X-ray examination although small is independent of the age of the patient and the type of examination. The United Nation Scientific Committee on Effects of Atomic Radiation [5] reported that exposure during childhood, results in a likely two or three fold increase in life time risk for certain detrimental cancers compared with adults. It is important that the radiation dose in children arising from diagnostic medical exposure is minimised. Quality Assurance Programme (QAP) and quality control initiatives in general diagnostics have been developed in several countries in the past years, mainly in Europe [6,7]. The main goals were to improve the diagnostic information and to reduce the patient dose to a minimum i.e. As Low As Reasonably Achievable: the ALARA Principle [6]. The need for special QAP for paediatric patients was first realised in 1980's [8].

The efforts towards QA in paediatric radiology were at first dominated by the principle of justification and also by the concept of efficacy/efficiency. The World Health Organization (WHO) reported 757 compilations of such principles for a number of common diseases in paediatrics and emphasised the term 'rational use of diagnostic imaging' [9]. The second important principle of optimisation is discussed in the document 'quality criteria for diagnostic radiographic images in paediatrics [10], and earlier developed document for adults 'quality criteria for diagnostic radiographic images [11].

Justification for radiographic requests, standardisation of procedure and optimisation of protection measures are key principles in the protection of individuals exposed to ionisation, especially children. In Nigeria, there is paucity of studies [12,13,14,15] to evaluate the range of radiation dose received by paediatric patients while existing studies on patient radiation doses are mainly done on adult patients. The Commission of European Communities (CEC) has recognised the need for the special treatment of children and has published guidelines suggesting examples of good radiographic practice and present useful image criteria with the aim of producing high quality images at the lowest possible dose to the patient [16]. Good radiographic technique includes the use of optimum kilo voltage peak (kVp). The lower kVp should be avoided in paediatric chest examinations. The CEC recommends the use of 60-80 kVp for children between 0-15 years of age. The guidelines have proved to be a useful tool to unify the practice in Europe [17].

This study is aimed at evaluating the exposure parameters selected for chest X-ray examination of paediatric patients in three hospitals in South-West Zone of Nigeria and to determine the ESD delivered to the patients during the medical X-ray examination. It is hoped that the results of this study will complement the existing dearth data on paediatrics radiation dose from medical X-ray examinations in Nigeria.

2. MATERIALS AND METHODS

This study was carried out in the radiological units of three hospitals; two teaching hospitals (OAUTHC Ilesa and LTH Osogbo) and one private hospital (OAMH Ilesa) in South-West Zone, Nigeria. A total of one hundred (100) children randomly chosen from those who were referred for chest X-ray examination between April 2015 and December 2016, were included in this study. Exposure factors such as kVp, mAs, FFD and details of patients' age, weight, height and thickness of the irradiated region were obtained for patients. For available machine in each X-ray room, specific data such as type, model, output, manufacturer and year of installation were recorded. These data are presented in Tables 1 and 2. Measurements of the X-ray tube output in mGy $(mAs)^{-1}$ were performed with NERO 6000M manufactured by Victoreen, Cleveland Ohio, USA. The dosimeter was calibrated by the manufacturer and its detailed specification is as displayed in Table 6 reflecting its usage and description. An initial quality control checks of exposure parameters (kVp, mA and time) and measurements of beam output of the X- ray performed on the facilities showed that the tube potential and time of all the facilities are accurate and reproducible. As the use of thermoluminescence dosimetry (TLD) to calculate ESD is more cumbersome when compared with the use of formula, in this study, ESD received by paediatric patients undergoing chest X-ray examination was calculated using the Dosecal software on the basis of the following equation [3,18]:

$$ESD = Q_{80} \times (kV/80) \times [80/(FSD)]^2 \times mAs \times BSF$$

Where Q_{80} is the output of the X-ray tube in mGy $(mAs)^{-1}$ at 80kV and at a distance of 1 m normalised to 10 mAs, FSD the focus-to-skin distance (cm), mAs is the product of tube current (in mA) and the exposure time (in seconds) and BSF, the backscatter factor. The normalisation at 80kV and 10 mAs was used as the potentials across the X-ray tube and the anode current stabilised at this point. BSF is calculated automatically by the Dosecal software after all input data are entered manually in the programme.

3. RESULTS AND DISCUSSION

Table 1 shows the radiographic and output data of the three X-ray machines employed during this study. The table indicates that the machines in the three hospitals fall short of the minimum required filtration standard (2.5 mm Al) for X-ray machine operated at peak tube voltage above 70 kVp [11,19]. Patient's age, weight and thickness of anatomical area examined are shown in Table 2. The summary of technical data tube potential (kVp), exposure current-time product (mAs), and Focus-to-Film Distance (FFD) in all the hospitals included in this survey is given in Table 3. Quality assurance measurement performed before data collection showed that the kVp and mAs were within the acceptable limit of 10% [20]. It was also found that the kVp and mAs were reproducible. From Table 2, the overall range of kVps used for all age groups in this study was between 50-57 kVp.

Table 1. Radiographic equipment information

Hospital	Model/type	Manufacturer	Year of installation	Filtration	Output (mGy/mAs)
OAUTHC ILESA	Silhoutte V.R	GE Huallum Medical System	2010	1.5	0.0610
LTH OSOGBO	Neodiagnomax	NA	1982	3.0	0.0180
OAMH ILESA	Lexray 500	R Liecati AG	2013	2.0	0.0580

Table 2. Patients' information from the hospitals

Age group (Years)	Sample size	Age (years)	Weight (Kg)	Height (cm)	Chest thickness (cm)
0-1	20	0.85(0.12-1.00)	9.50(6.90-12.00)	48.00(23.00-65.00)	5.80(4.80-7.80)
1-5	30	3.50(1.25-4.00)	12.00(9.50-14.00)	85.00(76.00-94.00)	14.00(12.00-18.00)
6-10	25	8.50(5.00-9.50)	19.00(12.00-38.00)	120.00(80.00-143.00)	16.00(13.00-19.00)
10-15	25	13.50(11.00-15.00)	58.00(49.00-62.00)	140.00(120.00-160.00)	18.00(14.00-21.00)

Table 3. Mean and range of radiographic data used in the hospitals

Age group (Years)	Tube potential (kVp)	mAs	FFD (cm)
0-1	53.00(50.00-55.00)	5.20(5.00-6.30)	117.0(109.0-123.0)
1-5	54.50(54.00-56.00)	5.40(5.00-6.30)	120.0(114.0-125.0)
6-10	56.5(56.00-58.00)	6.00(6.00-6.50)	130.00(120.0-140.0)
10-15	64.50(64.00-67.00)	15.20(14.00-16.00)	140.0(130.0-165.0)

Table 4. Summary of entrance surface dose in µGy

Age group (Years)	Range (µGy)	Mean (µGy)	S.D
0-1	38.00-150.00	91.55	0.350
1-5	43.34-194.00	125.64	0.550
6-10	74.00-223.00	150.25	0.056
10-15	87.60-292.00	226.00	0.650

Table 5. Comparison of mean ESD (µGy) this study, UNSCEAR, similar studies carry out in Nigeria and some other international reference doses

Age	This study	UNSCEAR	Nigeria (2004)	Nigeria (2013)	DRLs	
					UK (2000)	CEC (1996)
0-1	91.55	20	350	330	50	0-1
1-5	125.64	20	520	527	70	1-5
5-10	150.25	30	490	742	120	5-10
10-15	226.00	_	_	_	_	_

Table 6. Specification of NERO dosimeter

Quantities	Description	Values
Kilovoltage	Accuracy	Within 3% or 3 kVp, whichever is greater (Tungsten target X-ray\ tubes) Within 3% or 1 kVp, whichever is greater (Molybdenum target X-ray tube)
	Precision	±0.5%
	Range	Tungsten Target Tube: 27-155 kVp in the five ranges (27-42, 35-60, 50-85, 70-120, 100-155) Molybdenum Target Tube: One range, 21-150 kVp.
Time	Accuracy	Within *2%* or 2 ms, whichever is greater
	Precision	±o.3 ms
	Range	1 ms to 10 sec
Exposure	Accuracy	It has programmable correction factor. Without correction ±15%
	Precision	±lmR
	Range	10 mR to 10 R (could display air kerma in µGy)

Tube potential below 60 kVp was used for paediatric patients of age 0-1, 1-5, and 5-10 years, but CEC recommend the use of 60-80 kVp for infants aged 0-1 years and 100-120 for imaging 5 years old child onwards. As high doses are generally associated with the use of low kVp, high mAs technique, the use of reverse i.e. high kVp low mAs technique can have a significant reduction of patient doses.

Table 3 shows a summary of the entrance surface dose in µGy. The ranges of dose are 38.00-150.00 µGy for 0-1 yr, 43.34-194.00 µGy for 1-5 yrs, 74.00-223.00 µGy for 5-10 yrs and 87.60-292.00 µGy for 10-15 yrs with mean ESD of 91.55, 125.64, 150.25 and 226.00 µGy respectively. ESDs obtained in the present study were lower than the values obtained in previous studies in Nigeria [12,13]. Also, the doses are higher when compared with some international reference doses recommended by the Commission for European Community (CEC), National Radiological Protection Board (NRPB) of the UK. For example, ESD to 0-1 yr paediatric patient in this study is 83% higher than UK reference dose and 12% higher than CEC reference dose. ESD to 1-5 yrs, is 79% higher than UK reference dose and 26% higher than

CEC reference dose and for 5-10 yrs, ESD obtained is 25% higher than both UK and CEC reference doses.

The mean ESDs obtained in this study were relatively low compared to previous studies in Nigeria due to the use of lower mAs by the radiographers, though the tube potential used was lower than the recommended level. Some improvements were evident in the choice of technical parameters used but not yet accurate. The high ESDs recorded in this study were due to the use of low kilovolts, the absence of added filtration and state of the equipment, for example, the X-ray machine used in LTH was installed more than two decades ago.

4. CONCLUSION

In conclusion, this study has shown that from the ESD measurement on paediatric patients undergoing chest X-ray examinations in the three hospitals in South-West Nigeria, the doses obtained are much higher than recommended values by international established Dose Reference Levels (DRLs). Based on the analysis of doses and radiographic parameters, several factors can be attributed for this result. These are due to the use of low kilovolts; filtration used is below the minimum required standard of 3.0 mmAl for the equipment operated with kVp greater than 70. To this end, there is need for dose reduction during X-ray examinations. The general practice of high kilo voltage technique and lower mAs should be encouraged. The development of a Quality Assurance (QA) programme to address the lapses in equipment and technical performance is also recommended. In addition, owing to radiosensitivity of breast attention must also be paid to the frequency of radiation exposure to chest region especially in female paediatric patients to avoid radiation induced breast cancer in their later years in life.

ACKNOWLEDGEMENT

The authors would like to thank management and members of staff of the hospitals that were included in this study for their cooperation and assistance. The authors also express their gratitude to the Radiological Protection Centre of Saint George's Hospital, London, for assisting us with the Dosecal software.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/19829