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Patient dosimetry during chest, abdomen, skull and neck radiography in SW Nigeria

C.J. Olowookere [a], R.I. Obed [b,1,*], I.A. Babalola [c], T.O. Bello [d]

[a] Department of Physics with Electronics, Ajayi Crowther University, P.M.B 1066, Oyo, Nigeria
[b] Department of Physics, University of Ibadan, Ibadan, Oyo State, Nigeria
[c] Department of Physical Sciences, Bells University of Technology, Ota, Ogun State, Nigeria
[d] Department of Radiology, Ladoke Akintola University of Technology Teaching Hospital, Osogbo, Osun State, Nigeria

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ABSTRACT

The technique factors and X-ray output from the X-ray units of three Nigerian hospitals were obtained and used to calculate doses delivered to patients during chest, abdomen, skull and neck examinations. DoseCal software was used to calculate the entrance skin dose (ESD) and effective dose (E) based on the values of technique factors employed. The result obtained for inter-hospital comparison showed wide variation of mean hospital ESD, from a factor of 1.3 for chest posteroanterior (PA) in hospital 2 (H2) to a factor of 63 for the same chest X-ray projection in hospital 1 (H1). A comparison of ESD obtained in this work with established reference doses in the United Kingdom (UK 2005 review), International Atomic Energy Agency (IAEA), Community of European Commission (CEC), Ghana and Sudan shows that the values of ESD obtained in H1 for five examinations; namely: chest (PA) and lateral (LAT), abdomen anteroposterior (AP) and skull (PA and LAT) are higher. In H2, the dose value for chest PA is about 50% higher than that of UK but comparable with CEC and less than IAEA and Ghanaian values. The dose values obtained in H3 chest PA are higher than UK, IAEA and CEC values but comparable with that of Ghana. For abdomen AP, the dose is a factor of 1.2 less than IAEA and CEC values but greater than the UK, Ghanaian and Sudanese values by a factor of 2.1, 1.2 and 4.5, respectively. Reference data for abdomen LAT and neck AP were not available for comparison. Higher effective doses are being delivered to patients in chest PA (H1 and H3) and abdomen AP (H1) when compared with the range of values reported in the literature. This trend is an indication that patients examined are at higher health risks.

Introduction

Due to the continual leading role of X-rays as an important diagnostic tool in modern healthcare, it serves as a significant source of radiation exposure to both patient and medical personnel.[1] It is estimated that diagnostic radiology and nuclear medicine contributed 88% to the collective effective dose from man-made source in the US,[2] while in the UK similar contribution was 96%.[3] The need for determination or at least a realistic estimation of radiation dose to patients during X-ray examinations in every hospital as well as compared with reference doses established by competent regulatory authorities has been emphasized in the literature.[4,5]

Based on the important knowledge of the dose absorbed and the consequences of the absorbed dose, National Occupation Health and Safety Commission (NOHSC, 1995)[6] indicated that dose assessment of employees and members of the public is required and appropriate to ensure compliance with recommendation. Although diagnostic imaging using X-rays produces a net benefit, the potential for radiation induced injury to the patient exists. Therefore, understanding absorbed doses and the factors that affect them is very important.[7–11] Earlier publications have indicated that radiation doses are affected by technique factors, patient characteristics, filtration, projection type and age of the machine.[10] Therefore, through proper choice of technique factors, dose reduction is possible while maintaining the image quality during radiographic examinations.

The classification of United Nations Scientific Committee on the Effects of Atomic Radiation[12] shows that, Nigeria is in healthcare level IV category. This is an indication that the physician–patient ratio is higher than in healthcare level II countries with 1000–3000 persons per physician; consequently, there is no adequate

* Corresponding author. Tel.: +39 348 5141017.
E-mail address: rachelobed@yahoo.com (R.I. Obed).
[1] Present address (until September, 2010): Department of Physics, University of Trieste, Via Valerio 2, 34127 Trieste, Italy.

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information on patient doses in healthcare level IV countries as required by the international regulatory bodies. Earlier dose measurements in Nigeria have been carried out by few researchers[13–15] using direct method of dose assessment. However, only Ogundare et al. documented the technique factors, patient characteristics and attempted calculating the effective doses while others dwelt on entrance skin doses. As far as we know all these researchers obtained part of their data from University College Hospital, Ibadan and few hospitals within and outside Ibadan. More recent studies on dose measurements have been carried out in southeastern Nigeria using thermoluminescent dosimeters (TLDs)[16] and a mathematical method.[17]

The aim of this study is to evaluate the radiation doses to patients undergoing some common diagnostic X-ray examinations in three large hospitals in SW Nigeria. Part of the aim is to assess the radiographic techniques used during the different examinations. It was anticipated that the study will help in the optimization of radiation protection of the patient. Information from this dose evaluation will serve as a useful baseline against which assessment at an individual X-ray department may be compared. The doses and technique factors reported in this work will be useful for the Nigerian Nuclear Regulatory Authority (NNRA) and other regulatory bodies when exploring the possibility of dose reduction and the assessment of radiographic practices in Nigerian hospitals. The patient dose was estimated in the present study in terms of entrance skin dose (ESD) and effective dose (E). Estimated ESDs and Es were compared with the reference doses found in Africa and Europe. Analysis of dose distributions among different radiological departments under study was also performed.

Materials and methods

In this study, technique factors, that is, kVp, mA s, FSD and patient characteristics such as weight, height, age, and thickness of the irradiated regions were obtained for chest, abdomen, skull and neck radiographic examinations. These data were recorded for each patient undergoing the specified diagnostic examinations. The data were collected in three different hospitals which include one teaching hospital (H1), one private hospital (H2) and one state hospital (H3), all located in three large cities of southwestern Nigeria namely Osogbo (Osun state), Ibadan (Oyo state) and Ijebu Ode (Ogun state). A total of 209 adult (above 16 years) patients undergoing routine X-ray examinations were considered in this study.

Three different X-ray units were included in this study. They were all analogue systems installed at different times as presented in Table 1. The films were examined and considered acceptable to the radiologists/radiographers after exposure and film processing. This ensured that all dose levels used were representative of diagnostic image.

Table 1
Specific data of machines used at selected hospitals

Hospital code	Name of machine	Year of installation	X-ray output (mGy/mA s) $\times 10^{-2}$	Effective kVp	Filtration (mm Al)
H1	Neo Diagnomax	1982	7.9	89.8	3.0
H2	Aicoma	2005	5.6	97.1	1.0
H3	GEC Apollo	1984	2.7	94.5	2.0

The output of the X-ray machines (in mGy/mA s) at 80 kVp at a distance of 1 m normalized to 10 mAs[10] was measured using a calibrated KV meter (Victoreen invasive X-ray test device model 4000 m+).

Indirect measurement of entrance skin dose (ESD) and effective dose (E) was carried out in this study. This involved the use of technique factors, output of the X-ray machine and the backscatter factors for adult. The DoseCal software[18] was used to calculate ESD and E based on the values of technique factors employed, that is, the X-ray tube output and the projections. This method of dose calculation is a realistic alternative to dosimetry methods such as thermoluminescence dosimetry (TLD).[10] The DoseCal software was developed in the Radiological Protection Centre of Saint George's Hospital (London) and plays an essential role in the evaluation of radiation doses for a great number of patients. For the operation of the software, X-ray outputs in mGy/mA s at 80 kV at a distance of 100 cm normalized to 10 mA s were entered and when kVp (in kilovolts), mA s (product of tube current and exposure time), FSD (focus to skin distance in cm), BSF (backscatter factor) are known, Eq. (1) demonstrates the ESD.[19]

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

The DoseCal software uses the conversion factors included in tables NRPB-SR262[20] to convert ESD to effective dose.

Results

The data were collected in three major hospitals in SW Nigeria, comprising three X-ray facilities. Table 1 shows the specific data of the three X-ray units used for this study. The filtration of the X-ray units in H2 and H3 was found to be lower than 2.5 mm Al prescribed by the National Radiological Protection Board (NRPB). Patient information and technique factors for chest posteroanterior (PA) and lateral (LAT), abdomen anteroposterior (AP) and LAT, skull PA and LAT and neck AP examinations in the three hospitals (H1, H2 and H3) investigated are shown in Table 2. All the three X-ray units

Table 2
Patient information and technique factors for different X-ray examinations (range in parentheses)

Radiograph (hospital)	Projection	Thickness (cm)	Height (cm)	Weight (kg)	Body mass index (kg m^{-2})	Tube potential (kVp)	Mean (mA s)	FSD (cm)
Chest (H1)	PA	20 (12–30)	166 (133–192)	62 (35–91)	23 (14–36)	66 (16–80)	20 (8–100)	105 (55–100)
Chest (H2)	PA	21 (17–25)	167 (148–182)	61 (46–77)	22 (17–28)	80 (constant value used)	15 (constant value used)	129 (125–133)
Chest (H3)	PA	23 (20–26)	164 (116–181)	68 (48–170)	26 (19–48)	85 (75–90)	9 (constant value used)	125 (66–157)
Chest (H1)	LAT	26 (15–33)	165 (149–176)	61 (37–91)	23 (14–41)	71 (63–90)	23 (15–40)	96 (63–114)
Abdomen (H1)	AP	23 (16–34)	169 (157–176)	68 (55–97)	24 (18–39)	76 (70–90)	131 (100–250)	85 (60–110)
Abdomen (H3)	AP	24 (20–28)	163 (151–173)	65 (52–82)	25 (19–27)	106 (100–120)	27 (16–45)	91 (47–178)
Abdomen (H1)	LAT	34 (19–48)	167 (157–176)	73 (55–95)	27 (18–39)	83 (67–100)	150 (80–200)	69 (49–111)
Skull (H1)	PA	21 (16–27)	165 (152–182)	71 (48–109)	26 (18–43)	76 (60–85)	106 (82–160)	95 (67–132)
Skull (H1)	LAT	16 (11–23)	162 (152–182)	71 (48–100)	28 (18–43)	74 (60–100)	69 (10–100)	98 (66–118)
Neck (H1)	AP	12 (10–14)	160 (154–170)	72 (59–91)	28 (18–43)	70 (67–72)	28 (16–40)	91 (74–104)