IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 14, Issue 2 Ser. I (Mar. – Apr. 2022), PP 01-05
www.iosrjournals.org

Estimation of Adult Entrance Skin Dose and Effective Dose for Patients Undergoing X-ray Diagnostic Examination at Murtala Muhammad Specialist Hospital Kano State of Nigeria

M.U.Ali[1], M.AY. Hotoro[2], T.S.Bichi[3], Salisu A[4]., A Aliyu[5]., I. Muhammad[6].
[1,2,3,4,5.6]*Department of Physics Kano University of Science and Technology Wudil, Kano State of Nigeria, P.M.B 3244*
[1]*(Corresponding Author)*

Abstract:
S*tudies have proved that old X-ray machine has a tendency of failed kVp above acceptable limit of* $\pm 5\%$ *, but for* > 10 *years old machines have a tendency to failed for up to 20%. In this reaserch an old X-ray machine is used and a Caldose_X 5.0 software has been used to estimate the entrance skin doses (ESD), and the ESD with Weighing factor* (W_T) *to determined the Effective doses (ED) of Adult Patient Undergoing X-ray examinations at Murtala Muhammad Specialist Hospital(Public) at X-ray emission angle of* 17^0 *and X-ray tube filtration of 2.5mm Al. A total of 240 patients were surveyed, the imaging parameters and patient data used in the software include tube voltage(kVp), current-time per second(mAs), age, sex, type of projection, examination and focus to film distance (FFD). The mean and standard deviation ESD were found to be* $1.12 \pm 0.14mGy, 3.46 \pm 0.94mGy, 1.85 \pm 0.33mGy, 1.65 \pm 0.23mGy, 0.49 \pm 0.09mGy, 2.85 \pm 0.44mGy$ *and the mean and standard deviation ED were* $0.06 \pm 0.01mSv,\ 0.03 \pm 0.01mSv, 0.02 \pm 0.01mSv, 0.02 \pm 0.002mSv, 0.01 \pm 0.001mSv, 0.34 \pm 0.05mSv$ *for Esophagus(AP), Lumbar sacral spine(PA/LPO/RPO), Pelvis (AP), IVU/Kidney(AP), Thorax/Chest(PA/AP) and abdomen(AP) respectively. The results obtained were compared with published works also with nationally and internationally established diagnostic reference levels(NDRLs: Nov 2018, ICRP, IAEA), and found that only that of Chest/thorax among the selected examinations is not in agreement with the diagnostic reference levels. Hence further studies has is required and measures has to be implemented in order to follow ALARA principle to minimize the exposure.*

Keywords: *Dose, Entrance Surface Dose (ESD), Effective Dose (ED), Patient, Anterior to Posterior (AP), X-ray.*

Date of Submission: 01-03-2022 Date of Acceptance: 11-03-2022

I. Introduction

In radiological exposure a periodic dose assessment should be made to enhance the optimization of the radiation protection of the patients and to deliver minimum dose to the examinations. Dose measurements are required to comply with some international guidelines and regulations. The need for radiation dose assessment of patients during diagnostic X-ray examinations has been highlighted by increasing knowledge of the hazards of ionizing radiation(m.t. Taha et al, 2015).

Diagnostic x-ray radiology is a common diagnostic practice and there has been a substantial increase in the number of examinations recently (Bushong, 2001). Inspite of the increasing hazard of diagnostic x-rays to human beings, studies aimed at achieving low patient doses with sufficient image quality have continued to be of interest in research (ICRP, 1991; UNSCEAR, 2000). All exposures to ionizing radiation needs to justified and optimized in terms of the benefit and risks (ICRP, 1991). Entrance skin dose (ESD) is an important parameter in assessing the dose received by a patient in a single radiographic exposure. The European Union has identified this physical quantity as one to be monitored as a diagnostic reference level in the hopes of optimizing patient dose (Bushong, 2001; ICRP, 1991). Patient doses in diagnostic x-ray examinations can be best estimated in terms of entrance surface dose (ESD) per radiograph or dose area product (DAP) for the complete examination (European Commission, 1996). On the other hand, the effective dose is the best quantity for estimating radiation risks to the patients. The major benefit of using the effective dose is that this parameter accounts for the absorbed doses and relative radio sensitivities of the irradiated organs in the patients and, therefore, better quantifies the patient risk (ICRP, 1991. Ofori et al 2012).

Our aim in this study was to measure the entrance skin dose (ESD) for patients undergoing diagnostic X-ray examinations by the use of caldose_x software to estimate the entrance skin doses (ESD) and effective doses (ED) of adult patients during routine x-ray examinations of the thorax (PA/PA), pelvis (AP), cervical spine (AP/LAT), thoracic spine (AP) and lumbar spine (AP/LAT) in Murtala Muhammad Specialize hospital kano State of Nigeria. The ESD is a measure of the radiation dose absorbed by the skin where the X-ray beam enters the patient. The use of ionizing radiation in medical field contributes significantly to the source of exposure of the population. In Kano State, not much work has been done for calculations of radiation dose to patients in diagnostic radiology.

II. Materials And Methods

In all, 240 adult patients were considered for the study. The study was carried out in Murtala Muhammad Specialize hospitals Kano State 'X-ray room one', each using conventional x-ray units equipped with constant potential generators (no ripple), an x-ray emission angle of 17_ and a total filtration of 2.5 mm Al. Before measurements, x-ray generators and equipment were tested for generator type, timer accuracy, HVL, kVp accuracy, output consistency, beam alignment and collimation using multi-function meter with serial number 800391-2674 and model RMI 240 A (for timer and kVp accuracy, generator type), Rad check plus ionization chamber, Nuclear Associates Div. of Victoreen, Inc., USA with serial number 0000107690 and model 06-526 (for output consistency and HVL determination) and Radiation Measurment Inc., Middleton, WI 53562 US Patent D259,406 with serial numbers 161B-5242 and 162A-4271 (for perpendicularity, alignment and collimation test) as part of the quality control test.

Measurements were concentrated on six most frequently used examinations of, pelvic (AP), Neck soft tissue/ Esophagus (AP), Chest/Thorax (PA/AP), IVU/Kidney (AP), Lumbar Sacral spine (PA/LPO/RPO) and Abdoment (AP). The entrance skin and effective doses were calculated using a software called caldose_x 5.0. The software enables the calculation of the incident air kerma (INAK) based on the output curve of an x-ray tube and of the entrance surface air kerma (ESAK) by multiplying the INAK with a backscatter factor, as well as organ and tissue absorbed doses and effective doses for posture-specific female and a male adult phantoms, using conversion coefficients (CCs) normalized to the INAK, the ESAK or the air kerma area product (AKAP) for examinations frequently performed in x-ray diagnosis (Kramer, Khoury, & Vieira, 2008). The software determines the risks of cancer incidence and cancer mortality for the examination selected by the user. The CCs have been calculated for the MASH and the FASH phantoms. The MASH and FASH have organ and tissue masses based on anatomical reference data given by ICRP89 (ICRP, 2002). MASH and FASH were modeled in standing as well as in supine posture and were used in the Monte Carlo calculations posture-specifically according to the protocol of the type of x-ray examination. It covers 24 examinations with 2.5 mm Al standard filtration for standing and/or supine posture. Caldose_x 5.0 examinations are based on focus-to-detector distance (FDD) which can be selected by the user within a given interval. The software requires the user to manually input the patient's age, sex, select type of examination, posture projections, tube potential, field position and the mAs. Other patients' information recorded were the heights and weights. The outputs of the X-ray machines (mGy/mAs) were determined based on the AAPM Task Group no. 61 Protocol (Ma et al., 2001). Once the tube potential, the tube current, the exposure time and the focus to skin distance (d) are known, ESD can be expressed as (Davies, McCallum, White, Brown, & Helem, 1997):

$$ESD = Tube\ output \times \left(\frac{V}{80}\right)^2 \times \left(\frac{100}{d}\right)^2 CTf \qquad 1$$

Where the tube output determined units of mGy/mAs, V is the tube voltage in kV, d is the focus to skin distance in cm, C is the current in mA, T is the exposure time in s, and f is the backscatter factor. The tube calibration is performed at 80 kV, 1 m distance and 10 mAs. Once the entrance skin dose is determined, the effective dose is calculated using the equation 2 below; based on the software the effective dose is then the average of the sex-specific weighted doses specified in the International Commission on Radiological Protection report 103 (ICRP, 2007).

$$E = \frac{1}{2}\left[\sum W_T H_T\ (female) + \sum W_T H_T\ (male)\right] = \frac{1}{2}[F + M] \qquad 2$$

III. Results And Discussions

Table 1 shows the patients' Parameters for the selected examination protocols for the various examinations for the hospitals selected for this study. It shows the total number of patients with approximately 67.5% being males with the rest being females. The patients considered for the study were those with a mean weight of 60kg representing an estimation of typical dose to an average patient. Patients of excessive body weights have been excluded from the study. The means values for the ranges of ages, kVp, mAs and FDD for all the six selected examinations have calculated and reported in Table 1 below. For all the examinations, the ages ranged from the minimum of 24 years to the maximum of 66 years. For the kVp, from the least of 63 kV to the highest of 100 kV, for the mAs, from the minimum of 8 mAs to the maximum of 25 mAs were used and for the FDD, from minimum of 102 cm to the maximum of 180 cm. The mean ranges for the ages, kVp, mAs, FDD were 31.65–56.35yrs, 65.5-96.75kV, 8.95-23.25mAs, 107.65-175.45cm respectively as in Table 1 below. The wide ranges of the kVp, mAs, FDD were as a result of various patient weights, heights, thicknesses and radiographic techniques employed by operators.

Table 1- Summary of patients' parameters for the selected examinations protocol

S/N	Examinations	Projection	Male Patient	Female Patient	Total Patient	Age Mean/Range	KVp Mean/Range	mAs Mean/Range	FDD (cm) Mean/Range
1	Esophagus/ Neck soft tissue	AP	16	24	40	39.45 (24 - 51)	65.5 (63 - 68)	9.2 (8 - 10)	110.85 (108 - 115)
2	IVU/Kidney	AP	30	10	40	52 (35 - 65)	71.8 (73 - 80)	8.95 (8 - 10)	109.75 (105 - 115)
3	Pelvic	AP	34	6	40	39.75 (25 - 65)	72.75 (65 -77)	10.5 (8 - 13)	107.65 (102 - 115)
4	Abdomen	AP	32	8	40	29.3 (24 - 35)	96.75 (93 - 100)	9.65 (8 - 12)	109.1 (104 - 115)
5	Chest/Thorax	PA/AP	20	20	40	31.65 (24 - 39)	70.8 (64 - 77)	10.2 (8 - 12)	175.45 (150 - 180)
6	Lumbar Sacral Spine	PA/LPO/RPO	30	10	40	56.35 (40 - 66)	78.35 (72 - 80)	23.25 (20 - 25)	109.45 (108 - 116)

Table 2 Below is the estimated entrance surface dose (ESD) and calculated effective dose (ED) for all the projections and examinations. For all examinations and projections, the estimated ESD ranged from a minimum of 0.36 mGy to the maximum of 5.21 mGy and the effective doses were 0.0010 mSv to maximum of 0.756 mSv with the respective mean ESD and ED ranges as 0.49 - 3.56 mSv and 0.0014 – 1.157 mSv.

Table 2- Estimated entrance surface dose (ESD) and Calculated effective dose (ED) for the selected Examination protocols

S/N	Examinations	Projection	Entrance surface dose (mGy)		Effective dose (mGy)	
			Range	Mean	Range	Mean
1	Esophagus Neck soft tissue	AP	0.90 - 1.34	1.12	0.003 - 0.005	0.004
2	IVU/Kidney	AP	1.2 - 2.11	1.645	0.42 - 0.756	0.486
3	Pelvic	AP	1.33 - 2.65	1.853	0.153 - 0.306	0.214
4	Abdomen	AP	2.13 - 3.68	2.85	0.70 - 1.56	1.157
5	Chest/Thorax	PA/AP	0.36 - 0.64	0.49	0.05 - 0.09	0.07
6	Lumbo Sacral Spine	PA/LPO/RPO	2.04 - 5.21	3.56	0.001 - 0.002	0.0014

Table 3. The mean and standard deviation for ESD is compared with published works elsewhere and internationally established diagnostic reference levels (European Commission, 1996; UNSCEAR, 2000; m.t taha et al. 2015; Ofori et al. 2014) is shown in Table 3 below. Except for thorax (PA/RLAT) with values of 0.27 mGy and 0.43 mGy which were slightly higher than the published work of Shrimpton et al. (1986) and Padovani et al. (1987) respectively, the other values were in agreement with other published works and internationally established diagnostic reference levels (European Commission, 1996). Variations in the patient doses may be due speed class of film screen combinations, manual exposure control settings, patient size and other equipment-related factors.

Table 3- Comparison between the estimated mean and standard deviation for entrance surface dose (ESD) of present study with the examination procedures in different countries

S/N	Examinations	Projection	Present study	Mean entrance surface dose (mGy)			
				(UNSCEAR, 2000)	(European Commission,1996)	(Ofori et al, 2014)	(m.t. taha. et al,2015)
1	Esophagus Neck soft tissue	AP	1.12±0.14	–	–	–	—
2	IVU/Kidney	AP	1.645±0.23	–	–	–	—
3	Pelvic	AP	1.853±0.33	–	10	1.31	5.41±0.33
4	Abdomen	AP	2.85±0.44	–	–	–	2.5±0.14
5	Chest/Thorax	PA/AP	0.49±0.09	–	–	0.43	0.14±0.04
6	Lumbo Sacral Spine	PA/LPO/RPO	3.56±0.94	5.95	10	3.25	—

The mean effective doses compared with published works (Ciraj, Markovic & Kostitic, 2005; Wall & Hart, 1997) are shown in Table 4. The mean effective doses for the examinations were lower than those of published works elsewhere. This could generally be attributed to good radiographic techniques employed during the procedures.

Table 4- Comparison between the effective dose (ED) of present study with other articles

S/N	Examinations	Projection	Present study(mSv)	(Ofori et al, 2014. mSv)	(m.t. taha. et al,2015.mSv)
1	Esophagus Neck soft tissue	AP	0.004	–	–
2	IVU/Kidney	AP	0.486	–	–
3	Pelvic	AP	0.214	0.7	49.5
4	Abdomen	AP	1.157	–	16.8
5	Chest/Thorax	PA/AP	0.07	0.02	5.2
6	Lumbo Sacral Spine	PA/LPO/RPO	0.0014	0.41	–

IV. Conclusions

The caldose_x software was used to assess the ESD and ED of six selected x-ray examinations at Murtala Muhammad Specialist hospitals kano. Patient data and exposure parameters were captured into the software for the calculations of the doses. The values obtained compares favorably with similar works published elsewhere and internationally established diagnostic reference levels, the ESD and ED received by patients in our study does not exceed that doses reported by the international organizations, except for the entrance skin doses of thorax which was slightly higher than published works by Shrimpton et al. and Padovani et al., yet below the IDRL. This shows that when technical and clinical factors are optimized, patient doses will be reduce substantially.

Acknowledgment

The authors wish to thank Academics and Technical staff of Department of Physics Kano University of Science and Technology wudil, Kano state, together with management and staff of Murtala Muhammad Specialist hospitals for their assistance and cooperation.

REFERENCES

[1]. Akhdar, H. (2007). Assessment of entrance skin dose and effective dose of some routine X-ray examinations using calculation techniques. KSU (M.Sc thesis).
[2]. American Association of Physicist in Medicine. (1990). Standardized methods for measuring diagnostic x-ray exposures. AAPM.
[3]. Bushong, S. C. (2001). Radiologic science for technologists. St. Louis: Mosby, ISBN 0-323-01337-6.
[4]. Cameron, J. R., & Skofronick, J. G. (1978). Medical physics (2nd ed.). John Wiley and Sons.

[5]. Ciraj, O., Markovi_c, S., & Ko_suti_c, D. (2005). First results on patient dose measurements from conventional diagnostic radiology procedures in Serbia and Montenegro. Radiation Protection Dosimetry, 113(3), 330 - 335.

[6]. Davies, M., Mc Callcum, H., White, G., Broen, J., & Hlam, M. (1997). Patient dose audit in diagnostic radiography using custom designed software. Radiography, 3, 17 - 25.

[7]. Davies, M., McCallum, H., White, G., Brown, J., & Helem, M. (1997). Patient dose audit in diagnostic radiography using custom designed software. Radiography, 3, 17 - 25. Diretrizes de Protecaeo Radiologica.

[8]. European Commission. (1996). European guidelines on quality criteria for diagnostic radiographic images. EUR 16260 EN. Brussels.

[9]. International Atomic Energy Agency. (1996). International basic standards for protection against ionizing radiation and for the safety of radiation source. Vienna: IAEA Safety Series.

[10]. International Commission on Radiological Protection(ICRP). Diagnostic Reference Levels in Medical Imaging: Review and Additional Advice. A wed module produced by committee 3 of ICRP.

[11]. International Commission on Radiological Protection. (1991). Recommendations of the ICRP publication 60. Annals of ICRP. Oxford: Pergamon Press.

[12]. International Commission on Radiological Protection. (2002). Basic anatomical and physiological data for use in radiological protection reference values (pp. 3-4). ICRP Publication 89. Ann. ICRP 32.

[13]. International Commission on Radiological Protection-103. (2007). Recommendations of the international commission on radiological protection. Annals of ICRP. Oxford, UK: Pergamon Press.

[14]. Kofi Ofori, Samuel W. Gordon, Emmanuel Akrobortu, Adriana A. Ampene, Emmanuel O.Darko (2014). Estimation of adult patient doses for selected X-ray diagnostic examinations. Journal of Radiation Research and Applied Sciences 7 (2014) 459 – 462

[15]. Kramer, R., Khoury, H. J., & Vieira, J. W. (2008). CALDose_X a software tool for the assessment of organ and tissue doses, effective dose and cancer risk in diagnostic radiology. Physics in Medicine and Biology, 53, 6437 - 6459.

[16]. M.T. Taha, F.H. Al-Ghorabie, R.A. Kutbi, W.K. Saib. (2015). Assessment of entrance skin doses for patients undergoing diagnostic X-ray examinations in King Abdullah Medical City, Makkah, KSA. Journal of Radiation Research and Applied Sciences 8 (2015) 100 – 103

[17]. Ma, C. M., Coffey, C. W., DeWerd, L. A., Liu, C., Nath, R., Seltzer, S. M., et al. (2001). AAPM protocol for 40-300 kV X-ray beam dosimetry in radiotherapy and radiobiology. Medical Physics, 28(6), 868-889.

[18]. Marie, J. R., Raolina, A. M., Virginia, T., & Gfrtner, H. (2009). Survey of image quality and patient dose in simple radiographic examinations in Madagascar: Initial results HEP-MAD 09 Antananarivo (Madagascar), 8-21-28.

[19]. National Radiologic Protection Board. (2000). National protocol for patient dose measurements in diagnostic radiology. Chilton Didcot, UK: NRPB. Report of the working party of the Institute of Physics Science in Medicine.

[20]. Ofori, E. K., William, K. A., & Diane, N. S. (2012). Optimization of patient radiation protection in pelvic X-ray examination in Ghana. Journal of Applied Clinical Medical Physics, 13(4), 165.

[21]. Olivera, C., Srpko, M., & Dusko, K. (2012). Patient dosimetry patient radiation Protection in pelvic X-ray examination in Ghana. Journal of Applied Clinical Medical Physics, 13(4), 165.

[22]. Olowookere, C. J., Babalola, I. A., Olayiwola, M. O., Odina, G., Obed, R. I., & Bello, T. O. (2009). Comparison of five models for assessing patient dose from radiological examinations. Biomedical Engineering and Science, 1, 21 - 29. Afr. J.Med Phy.

[23]. Omolola Atalabi, M., Ademola, J., & Samuel Olutayo, A. (2013). Entrance surface dose from pediatric diagnostic X-ray examinations in a developing world setting: are we ALARA principle compliant. British Journal of Medicine and Medical Research, 3(4), 2288 - 2298.

[24]. Osman, H. (2013). Pediatric radiation dose from routine X-ray examination hospital based Study, Taif pediatric hospital. Scholars Journal of Applied Medical Sciences, 5, 511 - 515.

[25]. Padovani, R., Contento, G., & Fabretto, M. (1987). Patient doses and risks from diagnostic radiology in north-east Italy. The British Journal of Radiology, 60, 155-165.

[26]. Parry, R. A., Glaze, S. A., & Archer, B. R.. (1998). The AAPM/RSNA physics tutorial for residents typical patient radiation doses in RSNA scientific assembly.

[27]. Shrimpton, P. C., Wall, B. F., & Jones, D. G. (1986). Doses to patients from routine diagnostic X-ray examinations in England. The British Journal of Radiology, 59, 749-758.

[28]. Suliman, I. I., Abbas, N., & Habbani, F. I. (2007). Entrance surface doses to patients undergoing selected diagnostic x-ray examinations in Sudan. Radiation Protection Dosimeter, 123(2), 209 - 214.

[29]. United Nations Scientific Committee on the Effects of Atomic Radiation. (2000). Sources and effects of ionizing radiation. New York: United Nations.

[30]. Wall, B. F., & Hart, D. (1997). Revised radiation doses for typical X ray examinations: report on a recent review of doses to patients from medical X-ray examinations in the UK by NRPB. British Journal of Radiology, 70, 437-439

M.U.Ali, et. al. "Estimation of Adult Entrance Skin Dose and Effective Dose for Patients Undergoing X-ray Diagnostic Examination at Murtala Muhammad Specialist Hospital Kano State of Nigeria." *IOSR Journal of Applied Physics (IOSR-JAP)*, 14(02), 2022, pp. 01-05.