An Evaluation of Entrance and Surface Doses for some Common Diagnostic X-ray Examinations in two Nigerian University Teaching Hospitals

[1]**Nworgu, O.D.**, [2]**Bamidele, L.**
[1] Department of Physics, University of Benin, Benin City, Nigeria. [2]Department of Mathematics & Statistics, Osun State College of Technology, Esa-Oke, Nigeria
Correspondence: [1]Nworgu, O.D. E-mail : dericon_7@yahoo.com

ABSTRACT

Background: The aims of this study were to estimate Entrance Surface Dose (ESDs) to patients undergoing selected diagnostic X-ray examinations in two Nigerian university teaching hospitals, to obtain the maximum to minimum ratio of ESDs for the same projections, and to compare the ESD obtained with established international reference doses.

Methods: The exposure parameters such as the tube potential (kVp), the tube current (mAs), focus-to-film distance (FFD) and the thickness of the area irradiated were obtained for each patient undergoing the specified diagnostic procedure and the entrance surface doses were estimated.

Results: Hospital mean ESD estimates ranged from 0.099 to 0.3mGy for chest PA; 0.4 mGy for chest LAT; 1.1 2.9mGy for pelvis/hip AP; 0.9 2-8mGy for skull AP/PA; 0.4 - 1.7mGy for skull LAT; 1.7 - 1.8 mGy for Abdomen AP; 1.7 - 4.1 mGy for lumbar spine AP; 3.9 - 5.8mGy for lumbar spine LAT; 0.1--0.3mGy for Extremities AP and 0.1--0.3 mGy for Extremities LAT.

Conclusions: In the two hospitals, mean ESDs were found to be within the established international reference doses.

Key-words: Entrance surface dose, the tube potential, the tube current, exposure output.

Résumé

L'arrière-plan : Les buts de cette étude étaient d'évaluer la Dose Superficielle D'entrée (DSD) aux patients subissant des examens Radiographiques diagnostiques choisi dan deux hôpitaux universitaires nigérians, obtenir la proportion maximale d'DSDs pour les mêmes projections et comparer l'ESD obtenu avec des doses de référence internationales établies.

Méthodes : Les paramètres exposes comme la potentiel du tube (kVp), le courant du tube (mAs), la distance de centre-a-film (DCF) et l'épaisseur du secteur illumine ont été obtenus pour chaque patient subissant la procédure diagnostique indiquée et les doses superficielles d'entrée ont été évaluées.

Resultats : Les estimations des DSIs moyens a l'hôpital variaient entre 0,099 et 0,3mGy pour le thorax PA; 0,4mGy pour le thorax LAT; 1,1 2,9mGy pour le bassin/la hanche AP; 0.41.7mGy pour le crane LAT; 0.92.8 pour le crane AP/PA ; 1.71.8mGy pour l'abdomen ; 1.74.1mGy pour marche pesamment l'épine AP ; 3.95.8mGy pour marche pesamment LAT, 0,1 3mGy pour les extrémités AP et 0,1 0,3mGy pour les extrémités LAT.

Les Conclusion : Dans les deux hôpitaux, on a découvert que les DSIs moyens étaient dans les limites des doses de référence internationales établies.

Key words : La Dose Superficielle D'entrée, la potentiel du tube, le courant de tube, la production d'exposition.

INTRODUCTION

It is known that, of all man-made sources of radiation, diagnostic X-rays contribute the largest part to the collective population dose [1,2] and are the most encountered radiation in diagnostic radiology leading to injurious somatic and genetic effects on human beings,[3]. Radiation dosimetry is required to asses the risk associated with X-ray exposure and to inform medical practioners of the levels of exposure. The evaluation of radiation dose in routine diagnostic X-ray examinations as a periodical or even as a standard procedure, has been increasingly adopted in hospital practice[4,5,6].

As an optimization action to reduce the risk of deterministic effects in patients undergoing diagnostic radiographic examinations, the International Atomic Energy Agency[7] recommended guideline level of dose for a typical adult in terms of entrance surface dose (ESD). The Commission of European Communities[8] also published examples of image quality criteria and good radiographic technique that include ESD levels, focus-to-detector distance (fdd), exposure time t, tube potential range V, and filtration F among others. In the "National Protocol for patient dose measurements in diagnostic radiology" adopted by National Radiation Protection Board, UK[9], the measurement of the ESD is proposed for individual radiographs rather than for complete examinations and that cumulative skin dose estimates throughout a procedure should be regarded as a realistic method in assessing deterministic risk in radiographic procedures. Furthermore, NRPB provided specific guideline values of the ESD per film for selected diagnostic X-ray examinations.

The entrance surface dose (ESD) has been defined as the absorbed dose to the entrance skin of the patient at a centre point of the exposure area. ESDs can be determined by Thermoluminescence Dosemeter (TLD) measurements and Monte Carlo (MC) simulations. In the absence of appropriate dosemeter to measure ESD a reliable estimate of the ESD could be obtained by recording exposure data for each X-ray projection using measurements of absorbed dose to air in combination with literature data on back scatter factors (BSFs)[10].

Several major dose surveys have been reported, especially from advanced countries. In UK, between 1983 and 1985, a national survey on patient dose was carried out. There were very wide variations in the patient dose for the same types of X-ray examinations in different hospitals[11]. For the same types of radiographic examinations surveyed, the maximum to minimum ratios of entrance surface dose (ESD) per film in the UK were up to 100 for individual patients and over 20 for X-ray room mean values[12]. In Italy, the European Directive was implemented in the year 2000 and by December 2002 the ESDs for the examinations indicated by law were measured and compliance with the national dose reference levels (NDRLs) were verified[13]. However in developing countries like Nigeria such information does not exist to our knowledge.

The present study is an attempt to evaluate the current levels of patient radiation dose in our hospitals, estimate the entrance surface dose (ESD) for each projection, obtain the maximum to minimum ratio of ESDs for the same projections and compare the ESD obtained with established international reference doses.

MATERIALS AND METHODS

The dose distributions used in the study were from three different X-ray units, two units are in Ladoke Akintola Univeristy of Technology Teaching Hospital (LAUTECHTH) Osogbo while the other unit is at Obafemi Awolowo University Teaching Hospital, Complex (OUATHC) Wesley Guild, Ilesa.

Ten standard projections: Posterior-anterior (PA) chest, Lateral (LAT) chest, Antero-posterior (AP) abdomen, AP/PA Skull, LAT skull, AP pelvis/hip, AP Lumber spine, LAT Lumber spine, AP extremities and LAT extremities. A total of three hundred and fifty (350) patients from both sexes with ages ranging from 18 to 95 years were investigated. The patients' weights range from 58kg to 83kg which is within 70 ±13kg recommended by Commission of European Communities [CEC] as standard weight[18].

The X-ray machines investigated, are: a three-phase Siemens machine in OAUTHC, Ilesa; a three phase Phillips machine, and a three phase Neo diagnomas machine at LAUTECHTH Osogbo.

An initial Quality Control (QC) check was performed on each machine which was used to show the linearity of exposure current-time product [mAs] and kVp accuracy and reproducibility. The QC performed showed that the kV of the machines used were within the acceptable limit of 10%. The quality control tests were aimed at diagnosing any equipment malfunction. Table 1 lists the characteristics of these machines.

The following parameters were obtained and recorded for each projection. Sex, age, weight, focus-to-film distance (FFD), the tube potential kVp, the thickness of area examined, the tube

current (mAs) and back scatter factor.(BSF)
The entrance surface dose was determined using the Faulkner model[14] expressed as:

$$ESD = output \left\{ \frac{KV^2}{80^2} \right\} \left\{ \frac{100^2}{FSD^2} \right\} \frac{mAs}{BSF}$$

(Faulkner k et. al. 1999).
Where output is the output of the X-ray tube at 80kV at a distance of 1m normalized exposure time, FSD is the focus-to-skin distance and BSF is the back scatter factor.by mAs (μGy/mAs). kV is the tube potential, mAs is the product of the tube current and time

RESULTS
Analyses were performed on the data obtained from 350 adult patients. Patient information and exposure factors for Ladoke Akintola University Teaching Hospital (LAUTECHTH) Osogbo and Obafemi Awolowo University Teaching Hospital (OAUTHC), at Wesley Guild, Ilesha are shown in tables 2 and 3 respectively.
The study sample is younger (mean age 25-66 years) than that of the 1983 UK survey (ages 47-66)[15]. The range of tube potential for most projections are within the range reported in UK survey.
The distribution and mean values of ESDs for individual patient exposure calculated by using the Faulkner model are reported in tables 4 and 5 respectively.
For all projections in the two hospitals the value of mean ESDs are below the corresponding IAEA reference values.
Table 6 shows the maximum/minimum ratio of ESD of individual patients, the mean ESD value, the median value and interquatile range. Each hospital has a wide range of ESD for individual patients for each projection and the mean ESD for a given projection varied greatly between the two hospitals. For example the mean ESD for chest PA projection in LAUTECH Osogbo is 0.2 while that of OUATHC, Ilesa is 0.3. For lateral lumbar spine that of LAUTECH Osogbo was found to be 5.8 while that OAUTHC Ilesa was 3.9.
In some projections the variation for individual patients are higher than the 1983-1985 UK survey while some are smaller[12]. For example, Chest PA projection has a maximum / minimum ratio of 60.3 compared with the corresponding UK values of 47.7; Lumbar spine antero posterior (AP) projection has a maximum/minimum ratio for individual patients of 4.5 in the present study but a maximum/minimum ratio of 71.2 in the UK survey.
Table 7 compares the median ESD values of this survey with established reference dose values from USA (CRCPD/CDRH)1992[14], NRPB 1992[10], IAEA basic safety standard 1996[7], and NRPB 2002[17]. These reference dose values are based on the use of 200 speed class film-screen combinations. It should be noted that the USA survey was carried out using a set of standard phantoms to simulate an average sized patient. The reference dose values set forth in the IAEA basic safety are based on those of the Commission of the European Communities (CEC) (EURI6260EN 1996)[18].
The median ESD values for all projections are below the IAEA reference levels except that the skull LAT is higher than the IAEA reference levels. Both pelvis/hip AP and Lumbar spine LAT projections have lowest value of doses which are only 5.7% and 12.2% of that of IAEA reference levels respectively. Both skull AP/PA and Chest PA have largest number of doses which are 93.4% and 58% that of the IAEA reference values. Chest LAT, lumbar spine AP, and Abdomen AP are 23.3%, 15.3% and 14.9% lower than that of IAEA reference values respectively. Skull AP has a value of 5.28 mGy which is 28% higher.
Comparison of both extremities are not possible as there are no available reference dose values.
Only cases with diagnostically acceptable images were used in the study

DISCUSSION
The result of this study provides a base line for local diagnostic reference levels (LDRLs) in the two hospitals considered. The very wide variation in patient dose for the same type of X-ray examination carried out on similar patients in the two hospitals suggest that significant reductions in the dose from these exposures would be possible without adversely affecting image quality. Such reductions should always be pursued in line with the ALARA (as low as reasonably achievable) principle.
However, the results from the study using exposure factors to determine dose of X-rays to patients undergoing diagnostic X-ray procedure was found to be in good agreement with

standard values.
This suggests that dose to patients could be determined using this approach where thermoluminiscence dosimetry (TLD), film badges or dosemeters are not available.

Table 1 : X-ray Machines used in the study

Type	X-ray tube type	Rectification (Phase)	Focalspot (mm)	Target angle
Phillips	RO 3050	3	1.2/2.0	16^0
Neo diagnomas	DR-125/30150	3	1.3	16^0
Siemens	NR1152503V2053	3	0.6/1	16^0

Fig. 2 Patients Information and Exposure Parameters for Six Routine X-Ray Examination (10 Projections), Mean Values and Range (In Parentheses)

Radiography	Projection	Number	Patient age (years)	Patient weight (Kg)	FSD (cm)	kVp	MAS
Chest	PA	86	30 (18-95)	61 (58-83)	94 (80-113)	66 (61-73)	14 (10-30)
	LAT	5	66(28-70)	66 (60-72)	88 (79-98)	61(56-70)	20 (15-28)
Pelvis/Hip	AP	9	43 (22-76)	65 (58-74)	89 (79-107)	73 (71-76)	112(100-125)
Skull	AP/ PA	4	33(20-64)	61(70-72)	83(73-98)	75(71-80)	96 (85-100)
	LAT	4	34(20-65)	61 (70-72)	83(75-99)	72(71-75)	53(50-64)
Lumber spine	AP	13	44(18-81)	65(58-81)	90(71-104)	75(71-90)	134(85-160)
	LAT	10	50(18-81)	71 (58-83)	81 (69-105)	76 (53-90)	112(50-200)
Abdomen	AP	6	25(19-50)	61 (60-82)	91 (87-96)	70 (63-81)	70(50-80)
Extremities	AP	24	50(18-94)	66(60-78)	106 (54-113)	61 (53-71)	15 (5-30)
	LAT	19	49(14z-88)	64 (58-83)	88 (76-99)	60 (53-71)	14(5-30)

Table 3: Patients Information and Exposure Parameters for Six Routine X-Ray Examination (10 Projections), Mean Values and Range (In Parentheses) are given for Obafemi Awolowo University Teaching Hospital Complex (OAUTHC) Wesley Guild, Ilesha.

Radiography	Projection	Number	Patient age (years)	Patient weight (Kg)	FSD (cm)	kVp	MAS
Chest	PA	62	50(14-80	68 (60-78)	103(84-115)	52(46-70)	15(8-32)
	LAT	-	-	-	-	-	-
Pelvis/Hip	AP	18	50(18-85)	70(58-80)	96(88-104)	75(66-81)	42(32-64)
Skull	AP/ PA	4	31(30-32)	76(61-82)	99(92-103)	69(66-70)	40
	LAT	3	30(30-32)	76(61-82)	100(99-101)	64(63-66)	25
Lumber spine	AP	8	62(21-90)	70(58-80)	93(84-99)	79(70-96)	53(32-100)
	LAT	5	50(21-81)	69(59-75)	79(70-88)	92(85-102)	72(50-100)
Extremities	AP	35	40(18-87)	67(58-80)	99(78-117)	50(44-66)	15(2.5-30)
	LAT	30	40(18-87)	67(58-80)	99(78-117)	50(44-66)	12(2.5-25)
Abdomen	PA	5	57(19-70)	62(60-65)	101(98-109)	83(77-102)	57(40-80)

Table 4: Distribution of entrance surface dose values (mGy) for individual patients for ten projections at LAUTECHTH, Osogbo.

Radiograph	Projection	Number	Min	1st quartile	Median	Mean	3rd quartile	Max	Max/ min
Chest	PA	86	0.15	0.24	0.28	0.30	0.35	0.65	4.3
Chest	LAT	5	0.21	0.34	0.35	0.40	0.58	0.62	2.9
Pelvis/hip	AP	9	0.28	2.57	2.65	2.90	2.91	4.60	16.4
Abdomen	AP	6	1.01	1.08	1.71	1.80	2.48	2.69	2.7
Skull	AP/PA	4	2.07	2.88	2.80	3.17	3.17	3.17	1.5
Skull	LAT	4	1.49	1.49	1.65	1.70	1.65	1.66	1.1
Lumbar spine	AP	13	1.86	2.91	4.15	4.10	4.56	7.00	3.8
Lumber spine	LAT	10	3.62	4.21	5.49	5.80	6.21	9.79	2.7
Extremities	AP	24	0.07	0.16	0.22	0.30	0.58	0.88	11.4
Extremities	LAT	19	0.08	0.15	0.26	0.30	0.44	0.88	11.2

Table 5: Distribution of entrance surface dose values (mGy) for individual patients for ten projections at OAUTHC (Wesley Guild Hospital Ilesa).

Radiograph	Projection	Number	Min	1st quartile	Median	Mean	3rd quartile	Max	Max/ min
Chest	PA	61	0.01	0.09	0.09	0.20	0.19	0.66	60.3
Chest	LAT	-	-	-	-	-	-	-	-
Pelvis/hip	AP	20	0.52	0.73	1.03	1.10	1.21	1.98	3.8
Abdomen	AP	5	0.83	1.05	1.17	1.70	1.99	3.65	4.4
Skull	AP/PA	4	0.73	0.72	0.87	0.90	0.99	0.99	1.4
Skull	LAT	3	0.38	0.39	0.39	0.40	0.45	0.45	1.2
Lumbar spine	AP	8	0.73	0.91	1.06	1.70	1.39	3.73	5.1
Lumber spine	LAT	5	2.32	2.69	2.92	3.90	5.80	5.81	2.5
Extremities	AP	35	0.02	0.05	0.09	0.10	0.21	0.46	25.3
Extremities	LAT	30	0.03	0.05	0.10	0.10	0.17	0.49	17.8

Table 6: Distribution of entrance surface dose values (mGy) for individual patients for ten projections in the two University Teaching Hospitals.

Radiograph	Projection	Number	Min	1st quartile	Median	Mean	3rd quartile	Max	Max/ min
Chest	PA	147	0.01	0.12	0.23	0.20	0.31	0.66	60.3
Chest	LAT	5	0.21	0.34	0.35	0.40	0.58	0.62	2.9
Pelvis/hip	AP	29	0.52	0.89	1.22	1.30	2.28	4.66	8.9
Abdomen	AP	10	0.39	0.39	1.49	1.10	1.66	1.86	4.8
Skull	AP/PA	8	0.73	1.40	3.67	3.20	4.19	7.01	9.7
Skull	LAT	7	2.32	3.63	5.28	5.20	5.98	9.79	4.2
Lumbar spine	AP	21	0.73	0.75	1.53	1.80	2.59	3.26	4.5
Lumber spine	LAT	15	0.63	1.05	1.71	1.00	2.49	3.65	4.4
Extremities	AP	59	0.03	0.07	0.14	0.20	0.26	0.88	48.9
Extremities	LAT	19	0.03	0.07	0.14	0.20	0.26	0.88	31.5

Table 7: Comparison of median values of ESDs with internationally established reference doses in

Radiograph	Projection	Present study (2009)	USA (1992) CRCPD/ CDRH	NRPB (1992)	IAEA Basic safety standard(1996)	NRPB (2002)
Chest	PA	0.23	0.17	0.3	0.4	0.2
	LAT	0.35	-	1.5	1.5	1.0
Abdomen	AP	1.49	5.6	10	10	6
Pelvis/hip	AP	1.21	-	10	10	-
Skull	AP/PA	3.67	-	5	5	3
	LAT	5.28	16	3	3	15
Lumbar Spine	AP	1.53	6.4	10	10	6
	LAT	1.71	-	30	30	14
Extremities	AP	0.14	-	-	-	-
	LAT	0.13	-	-	-	-

REFERENCES

1. UNSCEAR, Sources and Effects of ionizing radiation (New York: United Nations) 1993
2. National Council on Radiation Protection and measurements: NCRP, Ionizing radiation exposure of the Population of the United States. NCRP Report no 93 (National Council on radiation protection and measurements, Bethseda, Maryland USA (1987).
3. UNSCEAR, United Nations Scientific Committee on Effects of Ionizing radiation. UNSCEAR report to the General assembly with scientific Annexes Vol 1. Sources Annex d. Medical radiation exposure Untied Nations, New York (2000).
4. Calzado A, Vano E, Moran P, Castellote C, Ruiz S, Ganzalez L, Estimation of doses to patients from complex conventional X-ray Examinations Br J Radiol 1991, 64:539-46.
5. Hart D, Jones D.G. Wall BF: Normalized organ doses for medical X-ray examinations calculated using Monte Carlo techniques, 1994 NRPB SR 262 London: HMSO.
6. Parry C.K., Chu R.Y.L., Eston B.G, Chen C.Y Measurement of skin entrance exposure with a Dose Area Product meter at chest Radiography Radiology 1996; 201, 574-5.
7. IAEA, International Atomic agency: International basic safetystandards for Protection Against ionizing radiation and for the safety of radiation sources. 1994; Safety series no 115-1 Vienna.
8. Commission of the European Community (CEC): Working Document on Quality Criteria for Diagnostic Radiographic Images, CEC XII/173/90 (June 1990)
9. National Radiological Protection Board. NRPB: National protocol for patient dose measurements in diagnostic radiology dosimentry. Report of a Working Party of the Institute of Physical Sciences in Medicine Chilton (1992).
10. Yakoumakis E, Nikolaon D, Nazos I, Koulentianos E, Proukakis C.H ():
Differences in effective dose estimation from dose area product and entrance surface dose measurements in intravenous urography Br. J. Radiol, 2001; 74, 727-734.
11. Shrimpton P.C.,Wall B.F., Jones D.G., Fisher E.S., Hillier M.C. et. al.: A national survey of dose to patients undergoing a selection of routine x-ray examinations in English hospitals, 1986, NRPB-R 200. London. HMSO.
12. National Radiological Protection Board. NRPB: Patient dose reduction in Diagnostic radiology. Documents of the NRPB 1990; Vol. 1-3.
13. Gaetano Compagnone, Laura Pagan and Carlo Bergamini Local Diagnostic

Reference Levels in standard X-ray examinations. Journal of Radiation Protection Dosimetry 2004; 113(1) 54-63.

14. Faulkner K, Broadhead D.A., Harrison R.M.: Patient dosimetry measurement methods, Applied Radiation and Isotopes 1996; 50, 113-123.

15. Hart D, Hillier M.C, Wall B.F, Shrimpton P.C. and Hungay D, : Doses to Patient from Medical X-ray examinations in the UK 1995 review, NRPB Report 289, Chilton:

16. Council of Radiation Control Program Directors Center for Devices and Radiological: Health CRCPD/CDRH: Average patient exposure dose guides CRCPI0 1992, Pub 92-4 Frankfurt.

17. National Radiological Protection Board. NRPB : Doses to Patients from Medical X-ray examinations in the UK: 2000 review, Chilton. NRPB W14 (2002).