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PATIENT ENTRANCE SKIN DOSES AT MINNA AND IBADAN FOR COMMON DIAGNOSTIC RADIOLOGICAL EXAMINATIONS

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ABSTRACT
Entrance surface dose from two diagnostic x-ray centers in Nigeria for three common radiological examinations is presented in this study. Entrance surface doses for 294 patients drawn from Niger state hospital Minna and Two-Tees x-ray centre, Ibadan are included in this dose survey. The air kerma for each patient was measured using thermoluminescent dosimeter chips (TLD-100). The air kerma for each patient was then multiplied by a back scatter factor of 1.35 to obtain the Entrance surface dose. Generally doses obtained in this study were found to be higher than those in published works and International Atomic Energy Agency recommended limits for chest examination. The range factor at Niger State General Hospital was as high as 12 in some cases but as low as 1 in most cases at Two-Tees X-ray center. The doses obtained for skull and abdomen examination were found to be within acceptable International Atomic Energy Agency recommended limit.

Key words: patient dosimetry, x-ray, thermoluminescent dosimeter, air kerma, back scatter factor

INTRODUCTION

In medicine ionizing radiation is used for two main purposes; diagnosis and therapy. Consequently, individuals and the populace at large receive significant exposure to radiation. Diagnostic radiology is a leading cause of man made radiation exposure to the population. It was estimated that diagnostic radiology and nuclear medicine contributed 96% to the collective effective dose from man made sources in the U.K (National Radiological Protection Board, (NRPB), 1993). Similar estimate showed that this contribution was 88% in the U.S.A (National Council on Radiation Protection and Measurement (NCRP), 1987). The health of the population would decline if ionizing radiation techniques were not available to diagnose disease and detect trauma. Nevertheless, there is no excuse for complacency and it is a basic premise of radiation protection practice that any exposure should be justified by weighing the potential harm against the perceived benefit In view of the significant benefits from properly conducted medical exposures, the principal concern in radiological protection is the reduction of examinations that are either unlikely to be helpful to patient management or involve doses that are not as low as reasonably achievable in order to meet specified clinical objectives. In order to do this, there is a need to optimize x-ray equipment and radiological techniques (NRPB 1990). Patient dose measurement is an integral part of this optimization procedure (Faulkner et al 1999). Such measurements will reveal x-ray facilities with high doses after which possible dose reduction measures may be specified. Dose measurement is also necessary so as to: establish dose constraints, determine risk to patient and to justify the examination.

There are two categories of doses to patient which are important in diagnostic radiology; the effective dose E which takes into account of dose equivalent to radiosensitive organs and the entrance skin dose. Most interest in diagnostic radiology is concern with effective dose since this relates to the risk of stochastic effect such as cancer induction. Effective dose or effective dose equivalent combines a set of organ or tissue equivalent dose into one single quantity. For this, the organs equivalent dose (H_T) are multiplied by organ weighing factors (w_T) and then summed.

$E = \sum H_T . w_T$ 1

However evaluation of E involves calculations which are not trivial.

Simple Entrance Skin Dose (ESD) is defined as the absorbed dose to air where the x-ray beam intersects the skin surface of the patient. It is a quantity that can be measured directly and can easily be compared with previous measurements and with measurement obtained at other practices and countries. It can also be used as an indicator of effective dose for particular radiographic projections. Another reason for evaluating skin doses is that the dose is greatest at the surface where radiation enters the body of the patient and the skin is therefore the main organ for which there is a possibility of deterministic effect i.e. skin burn. More over E can be calculated from ESD to various organs using tables published by the international commission on radiation units and measurement (ICRU), (ICRU, 2005) or the International Commission on Radiological Protection (ICRP), (ICRP, 1982) .

The European Union (EC) introduced the use of diagnostic reference levels (DRL) as an efficient standard for radiation of patients (see EC 1997). The physical parameter recommended for monitoring the DRL in convention radiography was the ESD (EC, 1996). Also, in the national protocol for patient dose measurements in diagnostic radiology (NRPB, 1992), the measurement of the ESD was proposed for individual radiograph.

ESD measurements are easy to perform, provided that appropriate dosimeters are available. In the absence of such dosimeters, an estimate of the ESD can be obtained by using measurement of absorbed dose to air, such as those performed during the quality control procedure of an x-ray unit (NRPB, 1992).

Several dose surveys have been reported, especially from advance countries (Tung *et al.* (2001), Kia *et al*. (1998), Serro *et al*. (1992) and NRPB, 1992). Few patient dose studies (Ogundare *et al*. (2004); Ajayi and Akinwumiju, 2000) completed had shown large variation in entrance dose for the same diagnostic procedure between one radiological centre and another in Nigeria.. This report represents the latest published dose survey in Niger State Hospital (NGH), Minna and Two-Tees X-ray centre (TTX) Ibadan.

The objectives of this study are, to obtain typical ESD values for adult patients for three different examinations, to compare the doses at NGH to that at TTX where regulation has been more, and with international reference doses and dose survey from other countries, and to compare the radiological parameters used for each examination with those found in literature. The result of this study is presented along with explanation of the main findings with specific reference to radiographic technique. The information from this study will be useful in many ways. It will serve as a contribution to a baseline against which future measurements of patient dose may be compared in Minna. The result from this work will also provide a useful contribution to knowledge of patient dose in Nigeria and to other countries in health care level IV as Nigeria according to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) classification (UNSCEAR, 2000).

MATERIALS AND METHOD

The ESD received by 294 patients were included in this study. This dose survey was conducted between August 2007 and March 2008. The patients were randomly selected from adult patients of both sexes attending medical investigations in two radiological centers. Critically sick patients were excluded from this investigation. The x-ray centers used for this study are: NGH, Minna (located in the North central part of Nigeria) and TTX, Ibadan (in western Nigeria). NGH is a state government owned hospital while TTX is owned by an individual. NGH was chosen as one of the study area because of the fact that most people in Minna prefer to make use of government health care facility. The implication of this is that dose values obtained from this study for Minna to a large extent represents a good estimate of population dose of patients in Minna. Furthermore the inclusion of NGH will, to the best of our knowledge, be the first time this kind of measurements is being reported from a radiological centre in the northern part of Nigeria. The inclusion of TTX located in the region of Nigeria where regulatory activities have been generally known to be more frequent than in the northern region where NGH is located, especially before the establishment of Nigeria Nuclear Regulatory Authority, may indicate the advantage of past regulatory activities.

For each center, available machine specific data such as type, model, waveform, filtration, year of manufacture were recorded. These data are presented in table 1. The following three routine types of x-ray examinations were studied: skull (AP), chest (PA), and abdomen (AP). For each patient the following parameters were recorded: sex, age, weight and height. These information about the patients together with body mass index (BMI) derived from weight/ (height) ^{2}, which is a useful classification scheme for size and shape of a person (Gibson 1990) are presented in Table 2. The weight of each patient was measured with a personal bathroom scale with a maximum capacity of 120 kg and error of ±1.2 kg for weight below 60 kg and ±2.0 kg for weight above 60 kg. Patient height was taken with two meter rule marking on the wall.

Summary of the technical parameters used for the patients included in this work is presented in Table 3. The kVp, and mAs values for each examination was read directly from the control panel of the x-ray machine. Machine specific data such as model number, inherent filtration and manufacturer was read from the manufacturer information written on the machine and other data such as year of manufacture and installation of machine, and added filtration were supplied by the radiologist where available.

ESD for each patient were calculated by multiplying the patient's air kerma by a back scatter factor of 1.35 suggested in European guidelines (EC, 1996). Following standard procedure, air kerma measurements were carried out using LiF thermoluminescent dosimeters (TLD), (TLD-100) which have been calibrated at the secondary standard dosimetry laboratory of the National Institute of Radiation Protection and Research (NIRPS), University of Ibadan. The chips were annealed at 400 ^oC for 1 h and cooled inside the oven at 80ºC for 17 h before being used for measurements. Air kerma measurement was carried out for each set of kVp, FSD and mAs used for the patients.

The TLD reader (Harshaw 6600) was used at the NIRPR, University of Ibadan, Ibadan, Nigeria for obtaining the air kerma from the TLDs.

RESULTS AND DISCUSSION

A total of 294 patients from two different x-ray centers, were included in this study. Table 3 shows that 145 patients are from NGH and 149 patients from TTX. Patient information such as age, weight and BMI are also presented in Table 3.

The summary of the technical parameters (tube voltage, mAs and FFD) used for the patients included in this study is given in Table 2 under the two centers. For abdomen examination, the technical parameters used in NGH are generally lower than those used in TTX. The same is true for skull examination except that mean FFD in both centers are almost the same. Comparison of the parameters used in the NGH and TTX with those obtained in similar surveys (Tung *et al*. 2001, Kia *et al*. 1998, Serro *et al*. 1992 and NRPB, 1992) are presented in Table 5.

The Table shows that while the mean kVp used in NGH is almost the same with those used in the other surveys that of TTX are more by 10 for chest examination. The kVp in this work is higher for abdomen examination compare to other surveys in table 5. The mAs values used in NGH and TTX are higher than those from these four published works. The ratio of the mAs presented in this work to those from the published works is in some cases as high as 5. This is an indication that patients' doses may be very high for patients in NGH and TTX than it is obtained in the published works. The use of high mAs for chest examination in NGH and TTX is further indication that for this examination patients' doses are likely to be higher in these centers. The ESD obtained from TTX and NGH are comparable with those obtained in the published works for abdomen examination, but higher for chest examination.

Table 4 gives the ESD summary respectively for skull, chest and abdomen examination at the two centers. The range of ESD in the tables shows that in a given centre the range factor (maximum entrance dose divided by the minimum entrance dose) is mostly between 1 and 2. There are very large variations in about twelve cases in NGH and only in one case for TTX. These large variations sometimes have range factor as high as 12. The fact that most of the large variations occurred in NGH is an indication that patients' examination is less optimized in this centre compared to what is obtained in TTX. This may be because regulatory in the past were very much regular at TTX due to its proximity to Federal Radiation Protection Service (FRPS). Until the establishment of Nigerian Nuclear Regulatory Authority in 2001, FRPS, located in the same city as TTX, used to be the designated regulatory authority. Hence the fact that examinations are better optimized in TTX is an indication of the effectiveness of regulatory activities. The tables also showed that entrance doses are generally higher in NGH than in TTX for abdomen examination while the reverse is the case for skull and chest examinations. The other factors, as listed in Table 3, which further determines the extent of the difference between the doses in the two centers, are kVp and FFD. In the case of abdomen examination, the use of lower FFD will further make doses in NGH to be higher with a lowering of dose coming from the use of lower mAs. The fact that the doses in NGH are significantly higher than in TTX indicates that the use of lower mAs in NGH did little in reducing ESD in the centre. For skull examination, mean FFD in the two centers are similar. The slight variation in the ESD for this examination between the two centers may therefore be explained by taking it that the effect of increase in dose with the use of lower kVp was almost cancelled out by the decrease in dose from the use lower mAs. The not too much difference between the doses in the two centers for chest examination may be an indication that the use of higher FFD significantly reduced the higher doses from the use of lower kVp and higher mAs.

A comparison of doses from this work and with those from the work of Tung *et al*. (2001), Kia *et al*. (1998), Serro *et al*. (1992) and NRPB, (1996) is presented in Table 8. The table shows that: the doses in this work are generally higher than those in these published works. The fact that doses in this work are higher may be due to differences in the technical parameters used. For example, as indicated before higher mAs are used in this work when compared to those from the four published works. Sometimes, doses reported in this work are twenty times larger than those from the published work. This large variation should be expected because of the large variations between the mAs values used in this work and those used in these other works. This comparison showed that there is need for patient dose reduction in the two centers used in this work. Patient dose reduction has been a long standing issue, this work shows that despite all the effort there still exist centers where patients' doses can be very high especially in the developing countries.

Table 1: Personnel and specific data of x-ray machines used in the hospitals.

	NGH	**TTX**
Manufacturer	G.E.C. Medical Matchlet x-ray U.K	G.E.C. Medical Matchlet x-ray U.K
Model/Type	Dynamax 40	Roentgen 201
Year of manufacture	-	-
Year of installation	-	1993
Inherent filtration	1.0 mmAl	1.5 mmAl
Added filtration	1.5mmAl	-
Film Type	Agfa	Kodak
Processor	Manual	Manual
No. of radiographer	2	2
No. of radiologist	2	2
Use of Grid	yes	No
Target angle	12^{o}	16^{o}

Table 2: Mean (range) of radiographic data used in the x-ray centers

Examination	x-ray center	kVp	mAs	FSD (cm)
Abdomen AP	NGH	89 (70-90)	76 (35-80)	90.4 (90-92)
	TTX	94 (90-94)	90	120
	ALL	91 (70-94)	78 (35-80)	106 (90-120)
Chest PA	NGH	77.7 (70-80)	45.4 (45-50)	181 (180-184)
	TTX	87.9 (83-90)	24 (19-24)	147 (120-150)
	ALL	85.4 (70-90)	34 (19-50)	152(120-184)
Skull PA	NGH	79.2 (70-90)	63 (50-80)	90 (90-100)
	TTX	93.3 (90-94)	75	89.9 (89-91)
	ALL	83 (70-94)	70 (50-80)	90 (90-100)

Table 3: Sex distribution, mean (range) of age, weight and BMI of the patients used for the organ dose measurement.

X-Ray Center	Examination		
	Abdomen (AP)	Chest (PA)	Skull (PA)
NGH			
No. Of patients	45	50	50
Age (year)	41 (21-65)	34 (20-71)	34 (20-53)
Weight (kg)	66 (46-94)	69 (52-95)	68 (51-86)
BMI	32 (23-45)	29 (18-40)	28 (20-41)
TTX			
No. Of patients	49	50	50
Age (year)	35 (20-74)	41(24-71)	41 (24-71)
Weight (kg)	67 (51-90)	76 (61-115)	68 (46-86)
BMI	28 (22-38)	31 (20-46)	30 (22-38)
All			
No. Of patients	94	100	100
Age (year)	38(20-74)	48 (20-71)	55 (20-71
Weight (kg)	29 (22-38)	30 (18-46)	29(20-38)
BMI	66(46-90)	71 (52-115)	68 (46-86)

Table 4: Distribution of individual entrance surface dose (ESD) for the three examinations from the two Hospitals

Examination	Hospital	Number of Patients	ESD (mGy)					
			Min	First Quartile	Median	Mean	Third quartile	Max.
Chest PA	NGH	50	0.90	3.84	4.62	4.44	4.62	10.97
	TTX	50	4.08	5.27	5.27	4.99	5.27	5.27
	All	100	0.90	4.08	4.62	4.71	5.27	10.97
Abdomen AP	NGH	44	2.08	6.13	6.13	6.28	6.13	16.70
	TTX	50	5.27	5.34	5.34	5.34	5.34	5.34
	All	94	2.08	5.34	5.34	5.78	6.13	16.70
Skull AP	NGH	50	3.41	4.60	4.60	4.93	6.13	6.13
	TTX	50	5.27	5.34	5.34	5.34	5.34	5.34
	All	100	3.41	4.60	5.34	5.14	5.34	6.13

Table 5: Comparison of radiological parameters used in this work and other surveys in four other countries.

Projection	Taiwan Tung *et al.* 2001	Malaysia Kia *et al.* 1998	Portugal Serro *et al.* 1992	U.K NRPB 1996	This work NGH	TTX
Chest PA						
kVp	77	79	76	76	78	88
mAs	12	9	16	8	46	24
Abdomen AP						
kVp	72	71	76	73	89	94
mAs	38	57	62	53	76	90

Table 6: Comparison of the mean value of ESD from other four countries and this work

Projection	Taiwan Tung *et al.* 2001	Malaysia Kia *et al.* 1998	Portugal Serro *et al.* 1992	U.K NRPB 1996	This work NGH	TTX
Chest (PA)	0.52	0.28	0.31	0.16	4.44	4.99
Abdomen (AP)	4.77	10	4.59	5.6	6.28	5.27

CONCLUSSION

In this study, entrance doses from two diagnostic x-ray centers in Nigeria are presented. The mean entrance dose at NGH was found to be much more than that at TTX for abdomen examination even at same radiological and geometrical parameters. The mean entrance doses, obtained from measurements carried out on 294 patients, were found to be generally higher than published values. For skull examination the mean doses are 4.93 mGy and 5.34 mGy for NGH and TTX respectively, for abdomen NGH has a mean ESD of 6.28 mGy and 5.34 mGy for TTX and for chest examination NGH has a mean dose of 4.44mGy and TTX has a mean dose of 4.99 mGy. The high doses in this work are a further confirmation of the fact that patient doses are not as low as reasonably achievable in many Nigerian hospitals. These also show that despite all the efforts towards reduction of patients' doses, there still exist centre's where patients' doses can be very high especially in the developing countries. The major contributor to the high doses reported in this work has been identified to be the use of high mAs. The mAs values are found to be sometimes 5 times the values reported in the literatures. Although in both centers the mean ESD obtained for abdomen examination is lower than the International Atomic Energy Agency (IAEA) recommended guidance level of 10mGy (IAEA, 1995), the mean ESD for chest at these two centers exceeds the recommended value of 0.4mGy.

RECOMMENDATION

These results showed that there is the need to optimize operations in NGH and TTX and probably in Nigeria at large especially for chest examination which is the commonest examination. The optimization steps may start with the regulatory mandating radiographers and radiologists to take part in various refresher courses for them to be aware of the recent developments on how to properly select technical parameters that will not compromise image quality but lead to a reduction in patient dose. There is also the need for national survey so as to set a guidance dose for these examinations so that hospitals can always compare their dose with it and take remedial action without affecting image quality if need be. A culture of regular dose measurements, film rejection analysis and image quality assessment as recommended by the IAEA need to become part of diagnostic radiology procedure in Nigeria.

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