SURVEY OF FILM SURFACE ENTRANCE DOSE OF PATIENTS UNDERGOING PELVIS RADIOGRAPHY IN SOME X–RAY DIAGNOSTIC CENTRES IN LAGOS METROPOLIS, NIGERIA.

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Abstract

Entrance surface dose as a good radiation dose descriptor is used in dose optimization and radiation protection. These two parameters are very important and should not be compromised during radiological examination. This study examined equivalent entrance surface dose and film surface entrance dose (E_f) in adult patients with average weight and body mass index (BMI) of 69.2±0.4 kg and 24.9±0.6 kgm^{-2} respectively. The study was carried out during routine diagnostic imaging of pelvis in some hospitals in Lagos Metropolis. Indirect dose measurement method was used to assess the dose. Entrance surface doses and patient thicknesses were determined using parametric method. The equivalent entrance surface doses were obtained with help of mathematical models which employed both homogenous and non–homogenous attenuation coefficients of the exposed tissue. Varied values of E_f were obtained for male and female subjects. The ratio factors of the calculated film surface entrance doses to the patient entrance surface doses were found to be 20.12 and 0.012 for pelvis AP and LAT when homogenous attenuation coefficient was used. The ratio factor was 23.88 and 0.004 for pelvis AP and LAT respectively when non-homogenous attenuation coefficients of the exposed tissue were used. The study showed the possible range of values expected as the dose to film, especially during pelvis examination. It also established that a substantial amount of ESD is deposited in the tissue rather than being used for image formation thereby necessitating the need for dose optimization and effective filtration.

Keywords: film surface entrance dose, attenuation coefficient radiological examination, antero-posterior, lateral, pelvis

Introduction

Entrance surface dose (ESD) is an invaluable radiation dose descriptor which relates radiation– induced bio-effects to both the intensity of the radiation dose and the equivalent summation of the tissue irradiated [(1)] ESD is also a dose index that helps in dose optimization and radiation protection. This does not only end on patient's surface but also transmission after exiting the exposed tissue to another surface where information about the spatial distribution of radiation in the area of interest is paramount. The radiation is attenuated by the intervening tissue as it traverses the tissue. This medium is equally a radiation absorber medium called the radiographic film. Therefore, radiographic film as an image receptor plays a vital role in diagnostic and therapeutic practices for radiation protection guidance. This can be seen as a radiation dosimeter with 2-D spatial resolution, very thin and do not in any way perturb the beam[2] and its definition around a reference coordinate system while the point measurement of dose on it is limited only by the resolution of the evaluation system. As a dosimeter, it requires a density measuring tool to evaluate the darkening of the film, thereby relating this to the radiation dose received. So, conventional radiographic film is equally seen as a display and archival medium which consists of a base of thin plastic with radiation sensitive emulsion (AgBr) gains, suspended in gelatin 3-D and radiation interaction with silver bromide gains form a latent image in the film that becomes visible and permanent subsequent to processing. Hence, the light transmitted during this process is seen as a function of the film opacity monitored directly in terms of optical density (OD) using densitometer. The optical density (OD) is given as:

$$OD = log_{10}\left(\frac{I_o}{I}\right) \quad (1)$$

Where, I_o is the incident radiation intensity to patient and I is the transmitted radiation intensity through it to the film. Equation (1) is a function of dose of radiation given to the film surface. The useful dose range of film is limited and the energy dependency seems more pronounced for lower energy photon while its responses depend on several parameters. Since there is scarcely any correlation between patient's average weight or height, the measurement of the ESD may be compared with the patients diameter/thickness [3, 4].

According to IAEA basic safety standard recommendation, doses are to be reduced to patient without compromising the image quality [5, 6], stipulating that all cost effective methods of reducing patients doses should be with respect to this recommendation[7]. It is essential to ensure that quality image is produced during diagnostic imaging to prevent repeated imaging this can be achieved when optimal radiation dose is received by the film. Therefore, this study sets out to evaluate the amount of radiation dose transmitted to the film surface, for all quality and reportable images during diagnostic examination using an indirect method which could further be used to estimate the range of doses required to produce quality image.

Materials and Methods

The entrance surface dose (ESD) of 278 adult patients from 6 selected hospitals (5 public and 1 private) that did routine diagnostic examinations for both antero–posterior (AP) and lateral (LAT.) projections of pelvis radiography. This was assessed using an indirect dose measurement method. Selection criteria include availability of the x–ray procedure studied, personnel, workload per day, geographical location and type of facilities available. Selected hospitals were appropriately coded for identification and differentiation. In this method, beam output of the x–ray machine $\left(\frac{mR}{mAs}\right)$ was determined at 1 metre distance from source to detector, at 80 kVp and 10 mAs x-ray machine setting (kVp value at which anode current is assumed to be stable). Reproducibility checking was conducted using x–ray test device (noninvasive survey meter model 4000™ Victoreen Inc. USA). The survey meter was cross calibrated with the facilities of National Institute of Radiation Protection and Research (NIRPR), University of Ibadan. The recorded beam output $\left(\frac{mR}{mAs}\right)$ was converted to dose in air $\left(\frac{mGy}{mAs}\right)$ using a conversion factor of 0.00873

[8]. ESD in air, using relatively Faulkner's model [9] was determined and this was subsequently converted to tissue equivalent ESD using a conversion factor of 1.06 ±1% [10]. The film surface entrance doses (E_f) was calculated using equation 2:

$$E_f = R_o . T_L \left(\frac{y^2}{x^2}\right)\left(\frac{q}{80}\right)^2 . f^{-1} . F_c e^{\mu(\Delta x - \Delta y)} \qquad (2)$$

Where, q and T_L are the tube potential (kV) and tube load (mAs) used during clinical examination. R_o ($^{mGy}/_{mAs}$) is the beam output of the x–ray machine; f is the backscatter factor and F_c, the conversion factor for entrance surface dose (ESD) in air to tissue, Δx is the focus to skin surface distance (FSD) and Δy is the focus to film distance (FFD). Since patient's size is one of the major contributing factors to variation in patient dose assessment, the patient diameter (thickness) was expressed as

$$d_t = \Delta y - \Delta x \qquad (3)$$

where, d_t is the patient thickness as determined from radiographic parameters (FFD – FSD) during examination. Putting equation (3) in (2), we have:

$$E_f = ESD_i[e^{-\mu d_t}] \qquad (4)$$

Where, ESD_i is the determined ESD to tissue and μ is the linear attenuation coefficient (radiation absorption in tissue per unit length or the attenuation of the exposed tissue).

In this study, both homogenous and non-homogenous attenuation coefficient were determined within the range of kV used during the routine diagnostic examination and also used to obtain film entrance surface dose (E_f) from ESD which should correlate with patient diameter [4] if exposure parameters are properly chosen during exposure. The values of attenuation coefficients obtained were substituted into equation for further comparison. All centres studied use x-ray machine with total filtration between 2.5 and 2.7 mm Al except for one (FANICR) with 0.7 mmAl tube filtration which falls below minimum levels recommended for good radiological practice. Grid with r = 12(40 cm^{-1}) and screen- film system with nominal speed value of 400 was equally used during this radiological examination but different types of film such as Carest cream, Fuji, Agfa and Retina were used in the centres. In addition to the ESD, patient characteristics (weight, height and body mass index- BMI), patient diameter and exposure parameters used during the examination were recorded.

Results

The results of 278 patients examined during the routine examinations of both pelvis AP and LAT procedures from six selected centtres in Lagos metropolis are presented as follows:

Table 1: Radiographic & technical data of x–ray machines used during examination

Centre	X–Ray Tube	Model	Year of Installation	Film Type	Total Filtration	Beam Output at 80kVp (µGy/mAs)
OAGH	Toshiba	IME–100L	09 – 2016	CAREST REAM	2.7mmAl	49.72
LASUTH	Toshiba	IME–100L	08 – 2016	FUJI	2.7mmAl	49.91
IIGH	Toshiba	IME–100L	10 – 2016	CAREST REAM	2.7mmAl	50.11
AGH	Sedecal/ Generic	A6861–01	12 – 2007	AGFA	2.5mmAl	45.35
GBGH	Siemen	10093895	04 – 2009	RETINA	2.5mmAl	40.10
FANICR	GE. Med;	2236420–2	02 – 2013	AGFA	0.7mmAl	35.47
						STD = 6.12

All the selected centres used anti-scatter grid of r =12 ($40cm^{-1}$), STD= Standard deviation

Table 2: Mean Patient characteristics and range in different hospitals (centres)

Centres	Measured Parameters	Pelvis Examination	
		Male	Female
OAGH	N	30	40
	Age (Yrs.)	42.3 (23 – 52)	44.8 (20 – 49)
	Weight (Kg)	75.7 (57 – 80)	69.4 (51 – 84)
	Height (cm)	167.9 (153 – 182)	164.9 (148 – 178)
	BMI (Kgm^{-2})	26.9 (24.4 – 27.3)	25.5 (22.0 – 25.9)
LSUTH	N	35	45
	Age (Yrs.)	47.6 (26 – 71)	39.7 (18 – 55)
	Weight (Kg)	81 .1 (65.5 – 104)	72.6 (46 – 88)
	Height (cm)	170.2 (168 – 179)	168.8 (140 – 176)
	BMI (Kgm^{-2})	28.0 (26.5 – 28.7)	25.5 (22.0 – 25.9)
IIGH	N	20	33
	Age (Yrs.)	46.5 (22 – 64)	44.3 (24 – 60)
	Weight (Kg)	72.0 (68 – 77)	63.5 (54.5 – 78.0)
	Height (cm)	172.1(154.5-176)	167.8 (158 – 174)
	BMI (Kgm^{-2})	24.3 (21.6 – 25.8)	22.6 (20.7 – 24.2)
AGH	N	10	18
	Age (Yrs.)	38.7 (19 – 43)	27.1 (28 – 52)
	Weight (Kg)	73.5 (43 – 77)	63.5 (51 – 70)
	Height (cm)	173.0 (153 – 177)	164.2(158-172.5)
	BMI (Kgm^{-2})	24.6 (19.7 – 25.6)	23.6 (21.7 – 24.3)
GBGH	N	8	17
	Age (Yrs.)	44.3 (31 – 49)	41.8 (30 – 61)
	Weight (Kg)	56.0 (51 – 69.5)	68.3 (48 – 74)
	Height (cm)	166.0 (161 – 168)	162.4 (151 – 169)
	BMI (Kgm^{-2})	20.3 (19.3 – 22.1)	25.9 (23.6 – 26.1)
FANICR	N	7	15
	Age (Yrs.)	49.6 (38 – 60)	40.3 (25 – 65)
	Weight (Kg)	58.4 (47 – 94.5)	75.2 (68 – 82)
	Height (cm)	163.7 (158 – 171)	160.5(149-168.5)
	BMI (Kgm^{-2})	21.8 (20.3 – 22.7)	29.2 (27.8 – 31.1)
ALL	N	110	168
	Age (Yrs.)	44.8 (19 – 71)	39.7 (18 – 65)
	Weight (Kg)	69.5 (43 – 104)	68.6 (46 – 88)
	Height (cm)	168.9 (149 – 182)	164.8 (140 – 178)
	BMI (Kgm^{-2})	24.3 (19.3 – 28.7)	25.4 (20.7 – 31.1)

Table 3: Exposure parameters and radiographic technique by sex and examination

Centre	Measured Parameters	Radiological Examinations			
		Pelvic (AP)		Pelvic (LAT)	
		Male	Female	Male	Female
OAGH	kVp	89.3 (88 – 90)	88.0(86 – 90)	89.0(86-90)	87.4(88-90)
	mAs	34.7 (32 – 36)	36.0(32 – 40)	35.4(32-40)	35.4(32-40)
	FSD (cm)	87.1(84.7-91.5)	88.3(83.6-93.0)	77.6(75.1-84.5)	79.8(74.0-83.4)
	FFD (cm)	110.0(110–110)	110.0 (110-110)	110.0 (110 -110)	110 (110 – 110)
	FIELD SIZE(cm^2)	1494	1627	528	726
LSUTH	kVp	86.7 (85 – 90)	84.0(80 – 90)	91.7(85 – 100)	92.0 (85 – 100)
	mAs	34.7 (32 – 40)	33.6 (32 – 40)	40.0 (40 – 40)	40.0 (40 – 40)
	FSD (cm)	85.8(83.2– 87.6)	86.5(83.7– 89.3)	75.0(71.6 – 77.1)	75.4 (71.4 – 78.8)
	FFD (cm)	110.0(110–110)	110.0(110–110)	110.0(110–110)	110.0(110–110)
	FIELD SIZE(cm^2)	1622	1607	1026	1023
IIGH	kVp	98.0 (96 – 100)	100.0(100-100)	110.0 (100-120)	110.0 (100-120)
	mAs	20.0 (20 – 20)	20.0(20 – 20)	20 (20 – 20)	20.0 (20 – 20)
	FSD (cm)	95.7(95.5– 96.4)	102.3(98.5-106)	86.5(84.5-88.4)	93.2 (90.5 – 95.8)
	FFD (cm)	120.0(120–120)	120.0(120-120)	120.0 (120-120)	120.0 (120 – 120)
	FIELD SIZE(cm^2)	1430	1012	975	1012
AGH	kVp	91.7 (80 – 93)	85.3(80 – 90)	90.3 (85 – 95)	90.0 (90 – 90)
	mAs	40.0 (40 – 40)	40.0 (40 – 40)	34.7 (35 – 40)	40.0 (40 – 40)
	FSD (cm)	81.8(79.3– 83.0)	79.3 (77.0 – 82)	72.3(71.5 – 75.0)	68.3 (67.5 – 69.8)
	FFD (cm)	105.0(105-105)	105.0(105–105)	110 (110 – 110)	105.0 (105 – 105)
	FIELD SIZE(cm^2)	1505	1505	750.0	750.0
GBGH	kVp	84.0 (81 – 90)	82.5 (81 – 90)	85.6 (77 – 90)	90.0 (90 – 90)
	mAs	35.0 (25 – 40)	37.3 (24 – 45)	67.7 (40 – 100)	74.3 (40 – 100)
	FSD (cm)	79.6(78.5– 81.0)	80.3 (79 – 81)	65.3(62.7 – 67.1)	62.7 (60.5 – 64.7)
	FFD (cm)	100.0(100–100)	100.0(100–100)	100.0(100– 100)	100.0 (100 – 100)
	FIELD SIZE(cm^2)	1505	1505	750.0	750
FANICR	kVp	82.5 (80 – 85)	80.5 (76 – 90)	85.0 (85 – 85)	83.8 (80 – 90)
	mAs	36.1 (32 – 40)	34.0 (32 – 40)	40.0 (40 – 40)	40.0 (40 – 40)
	FSD (cm)	85.6(84.4– 86.8)	85.8(83.3– 88.5)	75.9(74.8 – 76.9)	75.4 (70.7 – 78.5)
	FFD (cm)	110.0 (110-110)	110.0(110-110)	110.0(110– 110)	108.8 (105 – 110)
	FIELD SIZE(cm^2)	1349	1209	870	845
ALL	kVp	88.7 (80 – 100)	86.7 (76 – 100)	91.9 (77 – 120)	92.2 (80-120)
	mAs	33.4 (20 – 40)	33.5 (20 – 45)	39.6 (20 – 100)	41.6 (20 – 100)
	FSD (cm)	85.9(78.5– 96.4)	87.1 (75 – 96.4)	75.4(71.5 – 88.4)	75.8 (60.5-95.8)
	FFD (cm)	109.5(100–120)	109.2(100–120)	110 (100 – 120)	109.8 (100 – 120)
	FIELD SIZE(cm^2)	1484.2	1410.8	816.5	845
Hart et al, 2012 NRPB	kVp mA FFD(cm)	75 – 90 <400 115 (100 – 150)	Film-Screen Speed – 400		

Note: values are presented in mean and range (in parenthesis)

Table 4: Estimated mean ESD (mGy) by gender, averaged over sexes and examinations

Centre	Radiological Examinations						
	Pelvic(AP) ESD (mGy)			Pelvic(LAT) (mGy)			
	Male	Female	Mean for both sexes	Male	Female	Mean for both sexes	Difference factor of LATandAP
OAGH	2.547(0.05)	2.496(0.02)	2.522(0.03)	3.686(0.02)	3.361(0.01)	3.524(0.01)	1.41
LSUTH	2.484(0.03)	2.221(0.02)	2.353(0.02)	4.751(0.01)	4.731(0.01)	4.741(0.01)	2.13
IIGH	1.756(0.00)	1.601(0.02)	1.679(0.01)	3.070(0.02)	2.645(0.01)	2.858(0.01)	1.78
AGH	2.917(0.02)	2.686(0.01)	2.802(0.01)	3.907(0.03)	4.569(0.02)	4.238(0.02)	1.61
GBGH	1.814(0.00)	1.833(0.01)	1.824(0.00)	6.151(0.04)	8.076(0.08)	7.114(0.06)	3.90
FANICR	1.671(0.06)	1.491(0.10)	1.581(0.02)	2.541(0.02)	2.730(0.02)	2.636)(0.01)	1.66
ALL	2.198(0.05)	2.055(0.03)	2.127(0.03)	4.018(0.11)	4.352(0.14)	4.185(0.09)	1.97

Note: values are presented in mean and range (in parenthesis)

Table 5: Estimated mean thicknesses (cm) of radiation penetration on patients by gender

Centre	Type of Examinations					
	Pelvic (AP): patient thickness			**Pelvic (LAT) : patient thickness**		
	Male	**Female**	**Both**	**Male**	**Female**	**Both**
OAGH	22.9 (18.5 – 2 5.3)	21.7 (17.0 – 26.4)	22.3 (17.0 – 26.4)	32.4 (25.5 – 34.9)	30.2 (26.6 – 36.0)	31.3 (25.5 – 36.0)
LSUTH	24.2 (22.4 – 26.8)	23.5 (20.7 – 26.3)	23.9 (20.7 – 26.8)	35.0 (32.9 – 38.4)	34.6 (31.5 – 38.6)	34.8 (31.5 – 38.6)
IIGH	24.3 (23.6 – 25.0)	17.7 (14.0 – 21.5)	21.0 14.0 – 25.0)	33.5 (31.6– 3 5.5)	26.8 (24.2 – 29.5)	30.2 (24.2 – 35.5)
AGH	23.2 (22.0 – 25.7)	20.4 (19.0 – 21.5)	21.8 (19.0 – 25.7)	37.7 (35.0 – 38.5)	36.7 (35.2 – 37.5)	37.2 (35.0 – 38.5)
GBGH	20.4 (19.0 – 21.5)	19.4 (19.0 – 21.0)	19.9 (19.0 – 21.5)	34.7 (32.9 – 37.3)	37.3 35.3 – 39.5)	36.0 (32.9 – 39.5)
FANICR	24.4 (23.2 – 25.6)	24.2 (21.5 – 26.7)	24.3 (21.5 – 26.7)	34.1 (33.1 – 35.2)	33.4 30.3 – 38.1)	33.8 (30.3 – 38.1)
ALL	23.2 (18.5 – 26.8)	21.2 (14.0 – 26.7)	22.2 (14.0 – 26.8)	34.6 (22.5 – 38.5)	33.2 24.2 – 39.5)	33.9 (25.5 – 39.5)

Table 6: Estimated equivalent mean film surface entrance doses (E_f) by gender using non–homogeneous attenuation coefficient (μ) of the exposed tissue,

Centre	Type of Examinations						Percentage of doses deposited in patient in Pelvis AP (%)
	Pelvic(AP)			**Pelvic(LAT)**			
	E_f (mGy)			E_f (mGy) **x 10^{-3}**			
	Male	**Female**	**Both**	**Male**	**Female**	**Both**	
OAGH	0.268 (0.05)	0.932 (0.03)	0.600 (0.04)	0.320 (0.06)	0.170 (0.04)	0.250 (0.06)	89.4
LSUTH	0.230 (0.04)	0.764 (0.02)	0.497 (0.03)	0.200 (0.05)	0.060 (0.01)	0.130 (0.03)	78.9
IIGH	0.161 (0.03)	0.717 (0.05)	0.439 (0.04)	0.197 (0.05)	0.410 (0.11)	0.310 (0.08)	73.9
AGH	0.298 (0.09)	1.064 (0.05)	0.681 (0.07)	0.070 (0.01)	0.030 (0.00)	0.050 (0.01)	75.7
GBGH	0.244 (0.05)	0.760 (0.03)	0.502 (0.05)	0.280 (0.05)	0.040 (0.00)	0.160 (0.03)	72.5
FANICR	0.152 (0.05)	0.497 (0.04)	0.325 (0.04)	0.140 (0.04)	0.050 (0.00)	0.100 (0.03)	79.5
ALL	0.226 (0.05)	0.789 (0.18)	0.508 (0.11)	0.200 (0.08)	0.130 (0.01)	0.170 (0.05)	76.1

Table 7: Estimated equivalent average film surface entrance dose (E_f) by gender using homogenous coefficient (μ) of the exposed tissues

Centre	Radiological Examinations						Percentage of doses deposited in patient in Pelvis AP (%)
	Pelvic (AP)			**Pelvic (LAT)**			
	E_f (mGy)			E_f (mGy) **X 10^{-3}**			
	Male	**Female**	**Both**	**Male**	**Female**	**Both**	
OAGH	0.490 (0.02)	0.517 (0.02)	0.504 (0.02)	0.510 (0.13)	0.850 (0.38)	0.680 (0.26)	80.0
LSUTH	0.429 (0.03)	0.403 (0.03)	0.416 (0.03)	0.320 (0.08)	0.360 (0.13)	0.340 (0.11)	82.3
IIGH	0.301 (0.09)	0.443 (0.06)	0.372 (0.07)	0.319 (0.05)	0.170 (0.06)	0.245 (0.61)	77.8
AGH	0.541 (0.05)	0.611 (0.08)	0.576 (0.04)	0.130 (0.04)	0.200 (0.07)	0.170 (0.06)	79.4
GBGH	0.413 (0.03)	0.448 (0.03)	0.431 (0.02)	0.450 (0.10)	0.290 (0.09)	0.370 (0.15)	76.4
FANICR	0.284 (0.03)	0.257 (0.01)	0.271 (0.02)	0.220 (0.06)	0.287 (0.06)	0.260 (0.06)	82.9
ALL	0.410 (0.09)	0.447 (0.11)	0.428 (0.09)	0.330 (0.13)	0.620 (0.53)	0.480 (0.29)	79.9

Table 8: Comparison between mean estimated equivalent individual mean film surface entrance doses (E_f) from homogeneous and non–homogeneous values (μ) of the exposed tissues

Approach	Radiological Examinations					
	Pelvic (AP)			**Pelvic(LAT)**		
	Male	**Female**	**RF**	**Male**	**Female**	**RF**
Homogenous	0.410	0.447	1.09	0.00033	0.00062	1.88
Non-Homogenous	0.226	0.789	3.49	0.00020	0.00013	0.65
RF	1.81	0.57		1.65	4.76	

Values are presented in mean and SEM (parenthesis)

Table 9: Comparison of entrance film surface doses determined from Homogeneous and Non-homogenous attenuation coefficient

Examinations	E_f calculated (homogeneous)	E_f calculated (Non-homogeneous)	TOTAL
Pelvis AP	0.428	0.508	0.936
Pelvis LAT	0.00048	0.00017	0.0065
TOTAL	0.42848	0.50817	0.93665

Table 1 shows the radiographic and technical data of the x-ray machines used at different selected centres. This consists of x-ray tube model, year of installations, total filtration, film type used and the machine beam output measured at 80 kVp and 10 mAs for each centre. The total output and filtration of the machine ranged between 35.47 and 50.11 μGy/mAs, 0.70 mm Al and 2.7 mm Al respectively. The anthropometric information of patient such as sex distribution, age, weight, height and BMI are presented in Table 2. The range of mean age, weight and BMI of the study samples were 18-71yrs, 43-104 kg and 19.3 - 31.1 kgm^{-2}. Summary of the exposure factor parameters and radiographic techniques such as kVp, mAs, FSD, FFD and field size used for pelvis examinations at different centres studied are presented in Table 3. The overall ranges of kVp and mAs selected for pelvis AP are 76-100 kV and 20-45 mAs, and for pelvis LAT the values were 77-120 kVp and 20-100 mAs respectively. Table 4 shows the estimated mean entrance surface dose (ESD) by sex and examinations for pelvis procedure (presented in mean and standard error of mean SEM, in brackets). The overall mean (SEM) of the calculated ESD are 2.198(0.05) mGy and 2.055(0.03) mGy for male and female pelvis AP and 4.352 (0.14) mGy and 4.185 (0.09), mGy for male and female pelvis LAT examination respectively. However, the summary of the estimated average patient thickness recorded during examination are also presented in Table 5. The overall estimated averaged thickness (averaged over sexes) and range were 2.2cm (14.0-26.8) and 33.9cm (25.5–39.5) for pelvis AP and LAT respectively. In comparison, EC-criteria for ESD calculations assume patient AP trunk thickness of 20.0 cm and the weight range of 70±10 (60-80) kg for a standard adult patient while for this study; it was 22.2cm and (69.2±0.4) kg. Table 6 shows equivalent average film surface entrance doses (E_f) for AP and LAT examinations calculated from the assumed non-homogenous attenuation coefficient (μ_{NH}). The overall average E_f estimated by examinations (averaged over sexes) was 0.508 (0.11) and 1.7x 10^{-4} mGy (5x10^{-5}) respectively for pelvis AP and LAT. The summary of the estimated equivalent mean film surface entrance doses (E_f) calculated from assumed Homogenous attenuation coefficient (μ_H) are presented in Table 7. The overall mean by examinations is 0.428 mGy (0.09) and 4.8 x10^{-}4 mGy (2.9 x10^{-4}) for pelvis AP and LAT respectively. Table 8 presents the comparison between the overall mean E_f estimated from Homogenous and Non–Homogenous attenuations coefficient (μ). The range factors by sex and examinations were recorded as 1.81 and 1.77 for male and female pelvis AP respectively and 1.65 and 4.77 for male and female pelvis LAT. Table 9 shows a comparison of E_f determined from ESD with the use of homogeneous and non-homogeneous attenuation coefficients. Figures 1-6 illustrate the correlation between ESD and the patient thickness. The solid line in the figures indicates a line of best fit of the measured ESD against the patient size. The figures show the relationship between ESD and the patient thickness. The obtained low value of coefficient of determination, R^2 indicated that there was no strong relationship between ESD and patient thickness d_t.

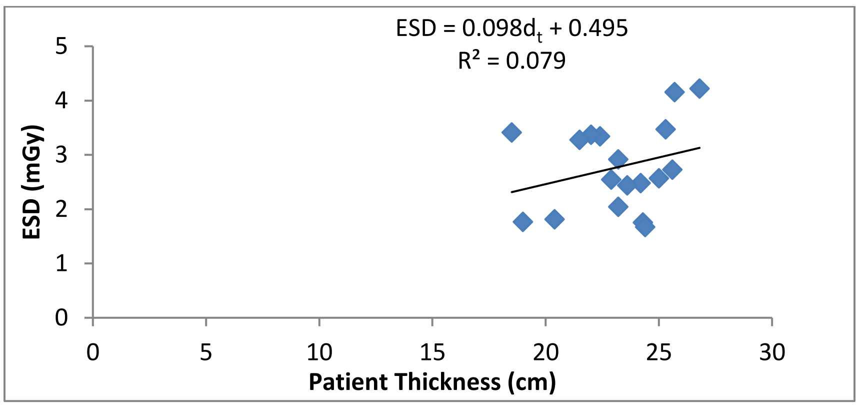

Figure1: Plot of ESD versus patient thickness for pelvis AP (male)

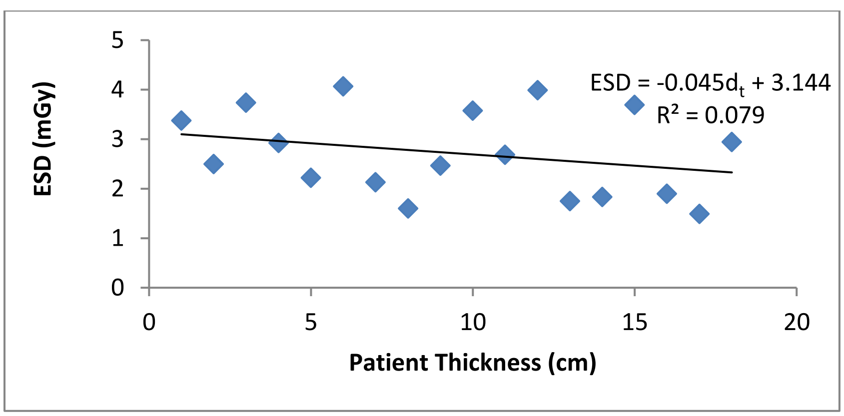

Figure 2: Plot of ESD versus patient thickness for pelvis AP (female)

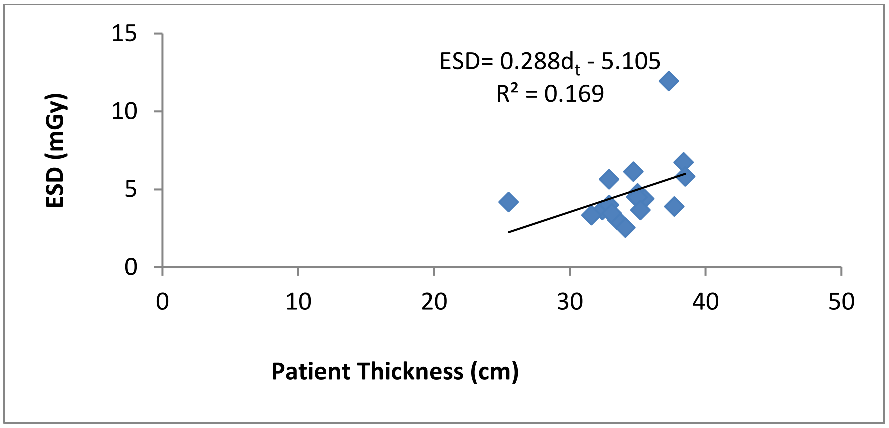

Figure 3: Plot of ESD versus patient thickness for pelvis LAT. (male)

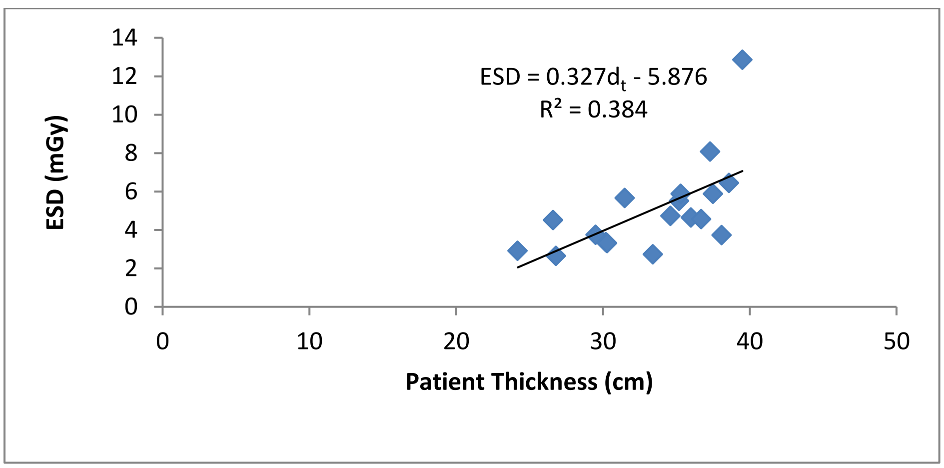

Figure 4: Plot of ESD versus patient thickness for pelvis LAT. (female)

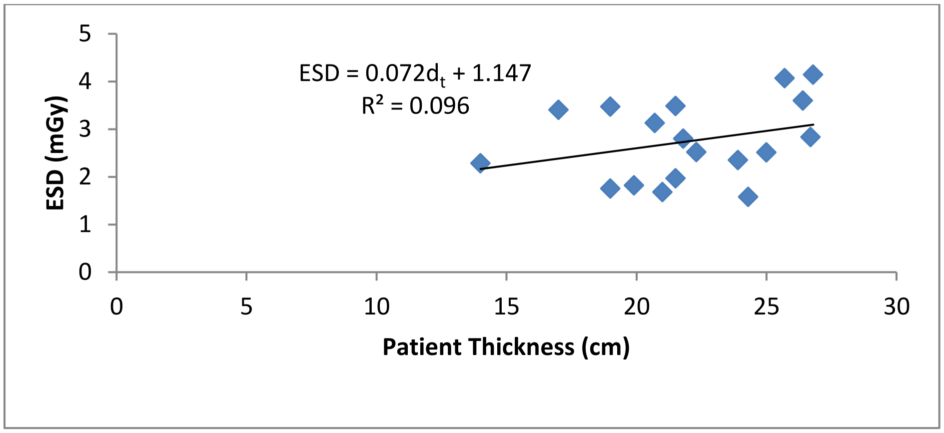

Figure 5: Plot of ESD versus patient thickness for pelvis AP (Homogenous attenuation)

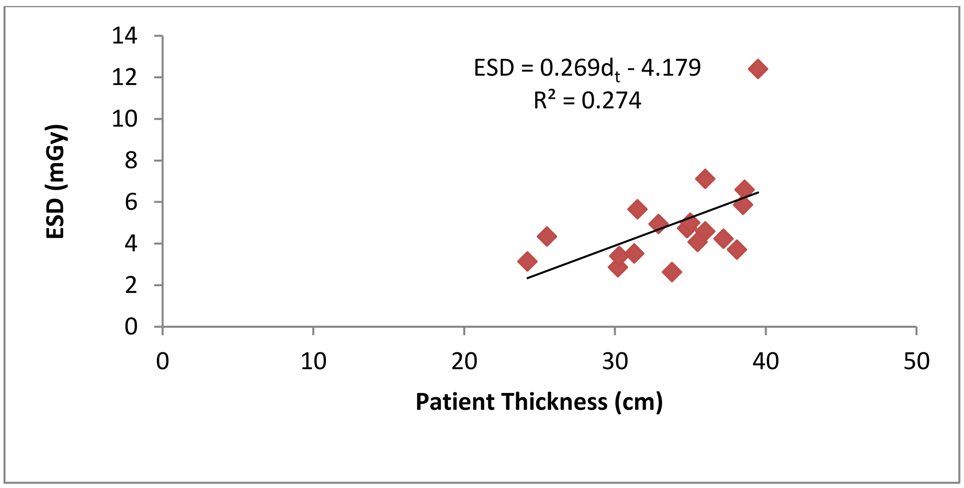

Figure 6: Plot of ESD versus patient thickness for pelvis LAT (Homogenous attenuation

DISCUSSION

The significant correlation between ESD and the radiation thickness of penetration on patient tissue has been established in earlier work (4) and also confirmed that ESD and absorbed dose are good indicator of risk to patient during routine x–ray examinations. Evidently, light transmission is a function of film thickness and also of the film opacity. So, optical density is seen as a function of radiation dose entering the surface of the film. Hence, knowledge of radiation dose (or exit dose) to films surface becomes necessary. As indicated in Table 1, most of the x–ray machines examined in the study were installed between 2009 and 2017. The total filtration of the machines range between 0.7 and 2.7 mm Al. Most of the machines have filtration within the limit of recommendation for good radiological practice (11) except for FANICR (private centre) with far less filtration value (0.7mmAl) which falls below the expected value of 2.5 mm Al (12) for good radiological practice. Low filtration could results in an elevated patient doses because of low energy photons that are not used for exposure of the film are deposited in patient's body as the beam traverse the section of the body irradiated [13] and poor image quality could results.

The beam outputs of the x–ray machines used ranged between 35.47 and 50.11 µGy/mAs. These fall within the range of values recommended by the American Association of Physicist in Medicine (AAPM) and Institute of Physics and Engineering in Medicine (IPEM) as (4.0±1.5 mR $(mAs)^{-1}$ and 6.02±2.0 mR $(mAs)^{-1}$ for single and 3–phases respectively). The acceptable beam output falls within a mean value of 5.01±1.01 mR $(mAs)^{-1}$ for good radiological practice [14],[15],[16]. The standard deviation of machine output measured at a distance of 100 cm and 80 kV was found to be 6.12 mR $(mAs)^{-1}$ The beam output could affect the radiation dose to the patient; thereby making x-ray machines require regular quality control check to ensure that the dose delivered to the patient is as low as reasonably achievable. The variation in machine output, filtration and the selected exposure parameters could lead to slightly different doses in different centres studied. In most of the centres examined, Radiographers chose the exposure parameters based on their discretion. Their choices depended on the training of the radiographer and the goals he sets out to achieve-image quality. There were no charts in the consoles that could guide the selection of exposure parameters during routine examinations. In different study centres, varied radiographic films type and processors were used, these include: Carest Ream, Fuji, Agfa and Retina, with film–screen combination of nominal speed of 400 (Table 1). Although, films of the same speed were used, but because of varied machine's output, nature of the processing chemicals and filtration, selections of different exposure parameters for similar radiographic examination are done. The type of film speed used at different centres requires a low tube load (mAs).

The range of age, weight, and BMI are 18-71 yrs, 43-104 kg and 19.3-31 kgm-^{2} respectively. The mean age range of male and female are 38.7- 49.6 yrs. and 27.1- 44.8 yrs. The age ranges observed in the study indicate that the patients are within working age of the population being examined. The BMI of patients examined in this study range between 20.3 and 28.0 kg m-^{2} (male) and 22.6 and 29.2 kg m-^{2} (female). The London school of Hygiene and Tropical Medicine has shown that BMI of an average Nigerian is 22.88 kg m-^{2} (mean male = 22.98 kgm-^{2} and mean female = 21.77 kgm-^{2}) [17.]. The overall mean for male and female for the seven centres are 24.3 kg m-^{2} and 25.4 kg m-^{2} respectively. Each of this is greater than the value for average for male and female Nigerians. The nature of BMI of the patient indicates that the selection of exposure parameters in Nigerian requires utmost cares so that quality images are obtained at low patient radiation doses.

The overall weights of patient examined in this study are 69.0 Kg and 68.8 kg for male and female patients as shown in Table 2. These fall within the weight of a reference man (70.2± 10 kg). Generally, the characteristics feature of patients examined satisfy the recommendation of EC quality criteria and IPEM report 91 for ESD measurement [16,18] for standard patient dosimetry.

Table 3 shows the overall kVp and the range for pelvis AP and LAT for male and female. The mean kVp are relatively higher than NRPB published data [19]. However, the mean value reported in the UK fall within the range of value in this study by factors which range between 1.15 and 1.22. The relatively lower kVp in UK [20, 21] must have arisen from several reviews that have been carried out since 1981 by NRPB-HPA. The mean mAs in NRPB_HPA document for pelvis AP is comparable with the values obtained in pelvis AP (male and female), but it is lower than the value obtained in pelvis LAT (male and female).

It is clear from Table 3 and row 9 that, the mAs used in pelvis LAT is higher than the pelvis AP by a factor of at least 1.24. The difference between the exposure parameters used in UK and Nigeria could be as a result of variations in patient anatomy, experience of personnel, and the nature of equipment used. This variation is a common occurrence among nations. It has been found even among machines in the same room [22, 23]. Other factors that must have informed variations in tube potential used are; filtration and the selected focus to skin distance (FSD)[24]. The mean focus to film distance (FFD) for pelvis AP and LAT (male and female) shown in Table 3 are comparable, while the mean FSD for the two projections are in the range between 75.4 and 87.1 cm for all the centres examined in this study. The range of values for FFD (100-120cm) and FSD (75.0-96.4 cm) are within the EC quality criteria (FSD [100-150 cm] and FFD [80-210 cm]) recommended for pelvis examinations for good geometric images sharpness [25].

Table 4 shows the ESD obtained from the investigation carried out in the seven centres. Results of ESD obtained as shown in Table 4 indicate that the mean values of ESD obtained for male and female pelvis AP and LAT are comparable. The only exception to this is found in GBGH (Gbagada General Hospital) where the male mean ESD is given as 6.15 mGy and female is 8.07 mGy. The relatively higher doses in male and female of GBGH could be attributed to the use of higher values of tube loads (67.7 mAs-male, and 74.3 mAs-female) as seen in Table 3. The mean tube load used in GBGH is higher than the mean recorded for ALL centres. The practice of the use of high mAs leads to higher dose. It is essential to use relatively lower mAs to optimize the dose delivered to the patient during examinations. The mean for all centres: 2.20 (1.67-2.92) mGy; female: 2.05 (1.49-2.49) mGy in pelvis AP. In pelvis LAT, the mean for all centres are given as, for male: 4.018 (2.54 -6.151) mGy; female: 4.352 (2.730-8.076) mGy. The group mean obtained in pelvis AP (Table 5) is lower than the ones determined in Southwestern Nigeria (2.84 – 2.71 mGy). The mean pelvis AP for male and female are lower than the 75th percentile (6.63 mGy-assume to be the reference dose determined earlier in Nigeria) [26]. The mean values were also found to be lower than the NRPB-HPA reference level determined in UK [19]. This implies that the ESD determined in pelvis AP are below the UK and Nigerian reference dose levels.

Generally, the doses delivered to patient during pelvis LAT examination are higher than the dose to the pelvis AP by factors which range from 1.41 (OAGH) to 3.90 (GBGH). The values of overall mean ESD obtained from this study in pelvis AP for both male and female is lower than the [11,18, 23] value of 3.90 mGy, while the value measured in female pelvis LAT is higher than the value for AP projection.

Table 5 shows that the mean patient sizes for pelvis AP range between 18.5 and 26.8 cm for male and 14.0 to 26.7 cm for female respectively. In pelvis LAT, the mean pelvis LAT sizes range from 22.5 to 38.5 cm for male, and 24.2 to 39.5 cm for female patients. This is in agreement with the earlier works in Nigeria (23.3[18.5-26.8]) [13] and Ofori et al.[24] in Ghana.

An attempt was made to determine the dose required to produce an optimal image and the percentage dose absorbed by patient body when the radiation beam traverse the patient body. To achieve these two assumptions were made. The first is that, a non-homogeneous attenuation coefficient (μ_{NH}) was assumed (Table 6), and the second, a homogeneous attenuation coefficient μ_H was assumed (Table 7). These were determined for both pelvis AP and LAT and used to calculate the film entrance surface dose (exit dose) from the patient body. The mean film surface doses (exit doses) range between 0.152 to 0.298 mGy for male and 0.497 to 0.932 mGy for female when non-homogeneous attenuation coefficients were used during pelvis AP examinations. Moreover, during pelvis LAT examination, the range of value of exit dose determined were 0.030 x 10^{-3} to 0.410 10^{-3} mGy (male) and 0.050 x 10^{-3} to 0.310 10^{-3} mGy (female). Similarly, Table 7 (homogeneous attenuation coefficient) shows that the range of mean values for the centres range from 0.284 - 0.541 mGy (male, pelvis AP), 0.257-0.576 mGy (female, pelvis AP) and (0.130-0.510) x 10^{-3} mGy (male, pelvis LAT), (0.17-0.85) x10^{-3} mGy (female, pelvis LAT). Much smaller exit doses were obtained in pelvis LAT. This could be attributed to the fact that the beam traverse a longer distance in the body before it exited, therefore more radiation is expected to be deposited in the patient body in this regards more than when the AP section is examined.

A comparison of the entrance surface dose to the film entrance surface dose (exit dose) shows that, for pelvis AP, the percentage of radiation doses deposited in the patient body range between 72.5 - 89.4 % (Table 6) and 76.4 - 82.9% (Table 7). This is an indication that a greater percentage of radiation doses incident on patient do not contribute to image transformation, but are imparted to patient body during interaction with the muscles, fluid and denser bones. This is the reason adequate filtration is necessary to remove the spectrum of energies that are not essential for image formation. Adequate collimation is also needed to restrict the primary beam to the portion whose image is required. This would ensure dose optimization.

This work also show that a small percentage of entrance surface doses – ESD - (between 10.6 and 27.5 %) is required to produce quality image during examinations. However, the radiation beam must possess adequate energy to reach the film since a certain percentage of the beam energy is used during interaction with human body content through photoelectric and Compton interactions.

Additionally, the calculated μ_{NH} (non-homogeneous attenuation coefficient) used is inversely proportional to E_f (film entrance dose) for a given ESD and thickness. The difference between the values in Table 6 and Table 7 is as a result of the different attenuation factors used in the calculation of E_f. Table 8 shows the differences between male and female (for pelvis AP and pelvis LAT) obtained from the ESD data by using μ_H and μ_{NH}.. For male, the E_f (μ_H) in pelvis AP is higher than the E_f (μ_{NH}) by a factor of 1.81units. However, the reverse is the case for the female. In pelvis LAT for male, the E_f (μ_H) is higher than the E_f (μ_{NH}) by a factor of 1.65 and 4.76 for female. It is also clear from Table 8, that the values of female E_f (μ_H) and E_f (μ_{NH}) are higher than those of males in both pelvis AP and LAT.

To test whether there is a significant difference between the mean E_f for male and female in pelvis AP, a paired t-test was used. This was done with Graph Pad Instant software (2007 version). The result for male in E_f (μ_{NH}) and Ef (μ_H) was considered at p-value for the two-tailed is < 0.0002. The value of t = 10.080 with degree of freedom of 5 (df = 5) at confidence interval of 95%. The mean difference was found to be equals to -0.1842 (mean of paired difference). The 95% confidence interval of the difference is given as 0.2311 to -0.1372. This was considered extremely significant. In addition, the result of the t-test for female shows that the p-value is 0.0002, t = 10.183 (df =5), the mean difference = 0.3425 (mean paired difference). The 95% confidence interval of the difference is 0.2560 to 0.4290, the mean difference between non-homogeneous and homogeneous is considered extremely significant and the pairing (matching) appears to be effective (with the correlation coefficient r = 0.9770).

Figures 1-6 indicate low coefficient of determination r^2 (0.079 to 0.384), this implies that during the routine examination, radiographers did not match exposure parameters and patient sizes. Although image qualities examined in this study were said to be acceptable, but the acceptability is subjective. It is apparent that the interest of both Radiographer and the Radiologist is image quality, but this is at the expense of patient dose burden. It is therefore important for Radiographer to optimize dose during the imaging process by matching patient size and the selected exposure parameters (where the automatic exposure control is not available as it is in most centres studied) to produce acceptable quality image at low doses (ALARA principle) and still produce quality image.

Conclusion

In this study mathematical models were used to assess both entrance surface dose (ESD) and film entrance surface dose (exit dose), E_f. The mean group ESD obtained in pelvis AP is below the UK reference dose. In pelvis LAT relatively higher doses were obtained. The higher doses could be as a result of higher value of tube load used in GBGH. Low E_f values were found for pelvis AP for homogeneous and non-homogeneous attenuation coefficients used. However, extremely low E_f was obtained in pelvis LAT examination. The results of this study indicate that between 10.6 and 27.5 % of ESD are required to produce acceptable diagnostic information from the film.

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