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Reference Person Dose-Area Product and Organ Dose-Area Product Estimates During Pelvis Radiography in Some Selected Centres in Lagos Conurbation, Nigeria

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Abstract: *Background:* In diagnostic radiology, focus on patient's dose measurement has been on the estimation of entrance skin surface dose and its equivalent risk assessor (effective and organ doses). So, this study identified DAP's as capable of performing same function as ESD in patient dose monitoring. Thus, reported estimates on dose area product (DAP) and the equivalent risk to organ's exposed in adult patients during pelvis examination in Lagos State, Nigeria. *Patients and Methods:* Gender percentage ratio of 39.4 and 60.4 for male and female respectively, from six selected centres, exposed for both pelvis AP and LAT of the procedures were monitored using mathematical approach and dose Cal version 2.31 software, designed to monitor organ's dose and DAP. *Results:* The average DAP and it equivalent organ dose area product (ODAP) values recorded from a population of 278 adult patients studied were found to be within expected limits for a reference adult person. Though, DAP for pelvis AP was found almost twice that recorded for the pelvis LAT. High and low organ DAP recorded for both gender from urinary bladder and lungs respectively for pelvis AP whilst these were pelvis bone and lungs for male and ovaries and lungs for female from pelvis LAT respectively. High values were equally recorded for the reproductive organs (Testicles and Ovaries) during pelvis AP. *Conclusion:* This study therefore suggest that better understanding of organ anatomical position in relation to specific examination will better promote as low as reasonable practicable.

Keywords: Dose-Area Product, Organ Dose-Area Product, Reference Person, Pelvic Radiography, Antero-posterior, Lateral

1. Introduction

Dose area product is one of the relevant and significant radiation dose descriptor that revealed and confirmed the relationship between radiation-induced and bio effect magnitude of the radiation and the summative values of tissue irradiation. [1], Indeed, Dose Area Product (DAP) is seen as the product of surface area on patient exposed to irradiation at the skin entrance and the equivalent dose to the monitored surface, showing that it is an integral of the dose across the X-ray beam. This considered the area collimated on patient during medical exposure to low dose through the thickness of exposure. Thus take into account the X-ray beam area which affects the number of organs irradiated. [2],

Evidently, energy imparted during X-ray exposure has been considered a function of tube potential, Half Value Layer (filtration length), area collimated and the patients' diameter [3], given as:

$$E_I = E_I\left(kV, HVL, A_{(FSD)}, D_T\right) \quad (1)$$

Where, E_I is the energy imparted, kV the tube potential used during clinical exposure, HVL is the filtration length of the X-ray machine, $A_{(FSD)}$ is the surface area exposed and D_T, the diameters/thicknesses of patient. Thus, patient

size, X-ray machine generated output and radiographer technique becomes factors that could immeasurably constituted to the variation in dose to patient in diagnostic radiology. [4], In Nigeria, majority of the studies carried out on patient dosimetry in diagnostic X-ray examination has been on the determination of patient entrance skin surface dose (PESD) and its associated risk quantities (i.e. organ and effective doses) [5, 6] and focus were not much on patient dose-area product (DAP) received and the equivalent risk quantities arises from these, hence this study.

Lagos State, one of the Southwest combination states and a commercial capital of Nigeria which lied coordinately within Latitude 6° 27'N and Longitude 3° 24' East with about 22 millions people [7], undoubtedly constituted about (50-60) % of the accredited radio-diagnostic centres in Nigeria. Also, the activities of the Nigeria Nuclear Radiation Authority (NNRA) in term of radiation monitoring and protection services are well embraced. Thus, radiological practice among it diagnostic centres (publics and privates) seem improving in line with ALARA policy. Hence, dosimetric study as this could be considered relevant for possible prognosis, regarding exposure to low dose of ionizing radiation. Therefore, the objective of this study is to assess dose area product (DAP) and its equivalent organ dose area product (ODAP) due to pelvis procedure in a reference person from some selected centre in Lagos State, Nigeria.

Its therefore believe that this study will shed more light on the understanding of different organs that received DAP during this radiological procedure, thereby providing adequate and timely information on patient's dosimetry in diagnostic radiology.

2. Materials and Methods

The DAP and organs dose area product (ODAP) were measured on 278 adult patients exposed for both AP and LAT projections of pelvis procedure using indirect dosimetry method. These measurement were carried out in six hospitals (5 publics and 1 private), spread across five established local governments in Lagos State, with appropriate Health Research and Ethics Committee approval from Lagos State University Teaching Hospital, Ikeja, Lagos State, Nigeria (Reg. no. NHREC04/04/2008 and Ref. no: LREC. 06/10/799) issued. Study's centre selection were based on the Huge work load of patient recorded per day in pelvis examination, competent professionals on ground, status of the X-ray machine as at the time of study. Aside these criterion, the centres are equally a referral centres in Lagos State Health Service sectors. In each of the selected centres studied, the X-ray machine specific data was obtained, which include manufacturers name, X-ray machines model, year of installation, film type/speed and tube filtration. This dosimetry method was employed due to non-availability of transmission ionization chamber in all the centres. So, mathematical model as an alternative option was used, including all the quantities that are vital in establishing DAP with adequate comparison with published studies.

Patient dose assessment

Patient DAP from this study was determined using equation (2)

$$\text{DAP (mGycm}^2) = D_o \left({}^{\text{mGy}}/_{\text{mAs}}\right).\, q(\text{mAs}).\left(\frac{x}{y}\right)^2 A(y) \quad (2)$$

Where, D_o is the normalized beam output measured in the unit of mGy/mAs at 1m distance from the focal spot; q the tube loading expressed in mAs (current exposure time product); x, the focus to skin distance (FSD); y, the focus to film distance (FFD) and A(y) is the field size area collimated on patient skin. The beam output ($\frac{mGy}{mAs}$) of X-ray machine was measured using X-ray test device (Non-invasive evaluation of radiation output, model 4000^{TM} Victoreen Inc., USA) with an equivalent capacity of 6000 kV meter. As at the time of this study, the calibration of the X-ray test device as issued by the manufacturer was still valid. The reproducibility of the X-ray machines were checked at a source to detector distance of 1 metre (FDD) with tube potential value of 80 kVp (voltage at which anode current is assumed to attained stability) with tube loading value of 10 mAs. The measured beam output in $\frac{mR}{mAs}$ was converted to $\frac{mGy}{mAs}$ using conversion factor of 8.73×10^{-3} [8, 9].

Also, the organ dose-area product (ODAP) may be determined using:

$$\text{ODAP} = \text{Do}\left(\frac{mGy}{mAs}\right).\, q\,(\text{mAs}).\,(\text{Ao})\text{FSDo}\,(\text{cm}^2) = H_{(T,o)}A_o\,(y) \quad (3)$$

Where, $(A_o)_{FSDo}$ is the noticeable cross-sectional area of the beam on the organs irradiated during patient specific radiological examination. Thus, it may be represented as:

$$(\text{Ao})\text{FSDo} = \left(\frac{FSD_o}{FFD}\right)2.\,\text{Ao}\,(y) \quad (4)$$

Where, A_o (y) is the organ's field size area.

Due to abstract nature of FSD_o, Dose-Cal version 2.31 software, designed by radiation protection centre, London in conjunction with National Radiation Protection Board (NRPB), to monitored both ESD and DAP in patient and also it equivalent in the organs exposed due to diagnostic radiology, was employed. This software contain NRPB recommended procedure and so make possible the estimation of both equivalent organ dose ($H_{(T,o)}$) and the organ dose area product (ODAP) at the radiation field, based on the software requirements as patient characteristics information, radiographic/exposure parameters and calculated DAP. Thus, the organs DAP equivalent for this procedure was estimated. Assumption was made in line with the existing correlation between this dose descriptor (DAP) and the entrance surface dose patient (ESD) [10], of which values from these dose descriptors could be used alongside a conversion factor to estimate a theoretically calculated quantity, Effective dose (ED). But it is evidential by definition that both ED and DAP are integral of doses either over radiosensitive organ or across

the area collimated for X-ray beam for protection purposes. Thus, DAP from this study was defined and estimated in a reference person, based on the mean doses in organs/ tissues of the human body as designed in ICRP recommendation for effective dose estimate [11], to provides a value which takes account of the given exposure conditions. Critical observation shows that DAP to patient from a specific procedure can equally be calculated theoretically, knowing the area of each organ exposed and their equivalent dose. Hence, DAP was estimated for individual reference male and female and made averaged over sexes for the reference person using:

$$D_S\,(\mathrm{D_A}, \mathrm{D_B}, \Delta T) = \int_{D_A}^{D_B} D\left[\frac{dN}{dD}\right] dD \qquad (5)$$

Where, $\mathrm{D_S}$ is seen as the collective DAP due to individual group's DAP between $\mathrm{D_A}$ and $\mathrm{D_B}$ from X-ray source within a specified time period ΔT. Since $\mathrm{D_S}$ will not be appropriate in the calculation of risk to organs, the average individuals DAP was determined using the relation:

$$(\mathrm{D_A}, \mathrm{D_B}, \Delta T) = \frac{1}{N(D_A, D_B, \Delta T)}\left[\int_{D_A}^{D_B} D\left[\frac{dN}{dD}\right] dD\right] \qquad (6)$$

Where, A and B are the combined number of the selected centres for studies, fragmented into two researchable groups [publics (A) and private (B)]. So, DAPs for Individual male and female were calculated using deduction from Eqn. 5 as:

$$DAP^{M}_{ind.} = \frac{1}{N_M}\Sigma\left(DAP^{M}_{(A+B)}\right) \qquad (7)$$

$$DAP^{F}_{ind.} = \frac{1}{N_F}\Sigma\left(DAP^{F}_{(A+B)}\right) \qquad (8)$$

Where, $DAP^{M}_{ind.} and\ DAP^{F}_{ind.}$ are the DAP for individual reference male and female whilst $\mathrm{N_M}$ and $\mathrm{N_F}$ are the respective male and female population in the study. Consequently, DAP for study reference person was calculated using Eqn. 7 as:

$$DAP_{Ref.} = \frac{1}{2}\left(DAP^{M}_{ind} + DAP^{F}_{ind}\right) \qquad (9)$$

These values (DAPs for individual reference male and female) was established to enable the possibility of cancer induction (cancers combined) estimate at exposure age due to specific radiological procedure as a function of age (a), sex (s), age at exposure (e) and the radiological procedure (l) for a population size specific (p) without the knowledge of the background risk. Values was inputted alongside other requirements in the software (Dose Cal) to estimate organ DAP for study's individual reference person and averaged (sex-average) for reference person organ's DAP. Radiographic film used in all the selected centres as observed was mainly Carestream (CR) 800 except for FANICR, using Agfa with nominal speed of 400. Data from patients and X-ray machines were analysed with excel spread sheet using descriptive and inferential statistics.

3. Results

The result of the DAP received by adult patients during radiographic examination studied are presented in Tables 1 to 8 and two figures inclusive. The X-ray machine specific data and the measured beam output (mGy/mAs) determined during reproducibility and linearity checked at 80 kVp (tube potential value, where anode current of an X-ray machine seem to be highly stable) and 10 mAs for each selected centre is presented in Table 1. It could be noted that the age parity in year between the time X-ray machine was installed to the time of study were approximately (4.5, 5.25, 4.5, 12, 14 and 17) years respectively for OAGH, LSTH, IGH, GBGH, AGH and FANICR. Patient's anthropometrical information such as age, weight, height, and the body mass index (BMI) by gender and radiological examination for each selected centres (groups) studied are presented in Table 2. The overall age and weight ranged of patient were (18-71) years and (43-104) kg respectively. Table 3 indicates the summary of exposure parameters such as kVp, mAs, FSD (cm), FFD (cm) and the field size area (cm^2) with groups in bracket. The radiographic technique applied during this procedure was equally specified for each centre. Deduction from this table, shows that the overall range factor of selected kVp and mAs during examinations across centre studied were 1.62 and 1.57 for male and female kVp and 4.25 and 4.65 for male and female mAs for pelvis AP whilst it was 1.71 for male and female kVp and 5.00 and 1.20 for male and female mAs for pelvis LAT. Figure 1 shows the study reference person characteristics information and the technical factors selection during radiological examination. Simple deduction from this showed that the study reference person characteristic information reflects those for standard adult patient. Table 4 shows comparison in the measured DAPs value obtained across the centres as presented in mean and range factor. This was compared with published DAP recorded from other studies. The overall average estimated DAP by sex were approximately (1377.5 and 1360.6 $mGycm^2$) and (657.2 and 699.0 $mGycm^2$) for male and female pelvis AP and LAT respectively. Table 5 depicts the statistical parameters for the study reference person DAP distribution by examination and some relevant subject characteristics as determined. Figure 2 presented reference person estimated DAP ($Gycm^{-2}$) and some relevant statistical distributions with max. DAP values and UK reference DAPs. The ranges and range factors for both individual and among the selected centres (mean DAP values) from study compared with other studies are presented in Table 6. The range factors of the estimated DAP were 2.12 and 1.78 (among the centres) and 3.18 and 4.36 (across individual patient) for pelvis AP and LAT respectively for this study. Tables 7 and 8 reflects the average estimated organs DAP distribution by sex and examination projections. The range factors between organ's DAP recorded were 693.1 and 699.4 respectively for male and female pelvis AP whilst for pelvis LAT, it was 86.1 and 96.3 for male and female respectively.

Table 1. *X-ray machines radiographic technical data studied.*

Centre	X-ray tube	Model	Yr. of Inst.	Total filtration (mmAl)	Beam Output @ 80 kVp (mGy/mAs)
OAGH	Toshiba	IME-100L	09/2016	2.7	0.04992
LSTH	Toshiba	IME-100L	12/2015	2.7	0.04991
IGH	Toshiba	IME-100L	10/2016	2.7	0.05011
GBGH	Siemen	10093895	04/2009	2.5 + 1.0 mmCu	0.04010
AGH	Generic	A6861-01	12/2007	2.5	0.04535
FANIC. R	GE. Medical System	2236420-2	02/2001	1.7	0.03547
OAUTH [12],	Shimadzu	R-20	1981	1.7	0.00520
NHA [12],	Phillips Optimus	98011519	1999	1.0 + 0.1 mmCu	0.01210
OTH [13],	Shimadzu	Radiotex	2004	3.3	0.04820
KTH [13],	Shimadzu	Radiotex	2004	2.5	0.06610

Table 2. *Patient anthropometrical information by sex presented in mean and range (in bracket).*

Centres (Groups)	Patient characteristics	Male	Female	Both
	Sex	30	40	70
	Age (yrs.)	42.3 (23 - 52)	44.8 (20 - 49)	44.6 (20 - 52)
OAGH (A)	Weight (kg)	75.7 (57 - 80)	69.4 (51 - 84)	72.6 (51 - 84)
	Height (cm)	167.9 (153 - 182)	164.9 (148 - 178)	166.4 (148 - 182)
	BMI (kgm^{-2})	26.9 (24.4 - 27.3)	25.5 (22.0 - 25.9)	26.2 (22.0 – 27.3)
	Sex	35	45	80
	Age (yrs.)	47.6 (26 - 71)	39.7 (18 - 55)	43.7 (18 - 71)
LSTH (A)	Weight (kg)	81.1 (65.5 - 104.0)	72.6 (46 - 88)	76.9 (46 - 104)
	Height (cm)	170.2 (168 - 179)	168.8 (140 - 176)	169.5 (140 – 179)
	BMI (kgm^{-2})	28.0 (26.5 - 28.7)	25.5 (22.0 - 25.9)	
	Sex	20	33	53
	Age (yrs.)	46.5 (22 - 64)	44.3 (24 - 60)	45.4 (22 - 64)
IGH (A)	Weight (kg)	72.0 (68.0 - 77.0)	63.5 (54.5 - 78.0)	67.8 (54.5 – 78.0)
	Height (cm)	172.1 (154.5 - 176.0)	167.8 (158.0 - 174.0)	170.0 (154.5 – 176.0)
	BMI (kgm^{-2})	24.3 (21.6 - 25.8)	22.6 (20.7 - 24.2)	23.5 (20.7 – 25.8)
	Sex	8	17	25
	Age (yrs.)	44.3 (31 - 49)	41.8 (30 - 61)	43.1 (30 – 61)
GBGH (A)	Weight (kg)	56.0 (51.0 - 69.5)	68.3 (48.0 - 74.0)	62.2 (48.0 – 74.0)
	Height (cm)	166.0 (161.0 - 168.0)	162.4 (151.0 - 169.0)	164.2 (151.0 – 169.0)
	BMI (kgm^{-2})	20.3 (19.3 - 22.1)	25.9 (23.6 - 26.1)	23.1 (19.3 – 26.1)
	Sex	10	18	28
	Age (yrs.)	38.7 (19 - 43)	27.1 (28 - 52)	32.9 (19 - 52)
AGH (A)	Weight (kg)	68.5 (43.0 - 77.0)	63.5 (51.0 – 70.0)	66.0 (43.0 – 77.0)
	Height (cm)	173.0 (153.0 - 177.0)	164.2 (158.0 - 172.5)	168.6 (153.0 – 177.0)
	BMI (kgm^{-2})	24.6 (19.7 - 25.6)	23.6 (21.7 - 24.3)	24.1 (19.7 – 25.6)
	Sex	7	15	22
	Age (yrs.)	49.6 (38 - 60)	40.3 (2s5 - 65)	45.0 (25 - 65)
FANIC. R (Group B)	Weight (kg)	58.4 (47.0 - 94.5)	75.2 (68.0 - 82.0)	66.8 (47.0 – 94.5)
	Height (cm)	163.7 (158.0 - 171.0)	160.5 (149.0 - 168.5)	162.1 (149.0 – 171.0)
	BMI (kgm^{-2})	21.8 (20.3 - 22.7)	29.2 (27.8 - 31.1)	25.5 (20.3 – 31.1)
	Sex	110	158	278
	Age (yrs.)	44.8 (19 - 71)	39.7 (18 - 65)	42.3 (18 - 71)
ALL [(ΣA+ΣB)/6]	Weight (kg)	69.5 (430.0 - 104.0)	68.8 (46.0 - 88.0)	69.2 (43 - 104)
	Height (cm)	168.9 (149.0 - 182.0)	164.8 (140.0 - 178.0)	166.9 (140 - 182)
	BMI (kgm^{-2})	24.3 (19.3 - 28.7)	25.4 (20.7 - 31.1)	24.9 (19.3 – 31.1)

NOTE: Group A (Public Hospitals), Group B (Private hospital) and ALL (Groups A&B).

Table 3. *Exposure parameters and radiographic techniques by examination sex and averaged over sexes, presented in mean and range factor (in bracket).*

Centres (Groups)	Measured Parameters	Examination (projection)		
		Pelvis (AP)		
		M	F	B
	kVp	89.3 (1.02)	88.0 (1.05)	88.7 (1.02)
	mAs	34.7 (1.00)	36.0 (1.25)	35.4 (1.04)
OAGH (A)	FSD (cm)	87.1 (1.08)	88.3 (1.11)	87.7 (1.01)
	FFD (cm)	110 (1.00)	110 (1.00)	110 (1.00)
	Field size area (cm^2)	1494 (1.03)	1627 (1.05)	1561 (1.09)

Centres (Groups)	Measured Parameters	Examination (projection)		
		Pelvis (AP)		
		M	F	B
	kVp	86.7 (1.06)	84.0 (1.13)	85.4 (1.09)
	mAs	34.7 (1.01)	33.6 (1.05)	34.2 (1.03)
LSTH (A)	FSD (cm)	77.2 (1.04)	76.5 (1.05)	76.9 (1.01)
	FFD (cm)	100 (1.00)	100 (1.00)	100 (1.00)
	Field size area (cm^2)	1622 (1.01)	1607 (1.05)	1615 (1.01)
	kVp	98.0 (1.04)	100.0 (1.00)	99.0 (1.02)
	mAs	20.0 (1.00)	20.0 (1.00)	20.0 (1.00)
IGH (A)	FSD (cm)	95.7 (1.06)	102.3 (1.08)	99.0 (1.07)
	FFD (cm)	120 (1.00)	120 (1.00)	120 (1.00)
	Field size area (cm^2)	1430 (1.02)	1012 (1.01)	1221 (1.41)
	kVp	84.0 (1.11)	82.5 (1.11)	83.3 (1.10)
	mAs	35.0 (1.60)	37.3 (1.80)	36.2 (1.70)
GBGH (A)	FSD (cm)	79.6 (1.03)	80.3 (1.03)	80.0 (1.03)
	FFD (cm)	100 (1.00)	100 (1.00)	100 (1.00)
	Field size area (cm^2)	1505 (1. 00)	1505 (1.00)	1505 (1.00)
	kVp	91.7 (1.13)	85.3 (1.13)	88.5 (1.13)
	mAs	40.0 (1.00)	40.0 (1.00)	40.0 (1.00)
AGH (A)	FSD (cm)	81.8 (1.05)	79.3 (1.07)	80.6 (1.06)
	FFD (cm)	105 (1.00)	105 (1.00)	105 (1.00)
	Field size area (cm^2)	1505 (1.01)	1505 (1.00)	1505 (1.00)
	kVp	82.5 (1.06)	80.5 (1.18)	81.5 (1.12)
	mAs	36.1 (1.26)	34.0 (1.25)	35.1 (1.25)
FANIC. R (B)	FSD (cm)	85.6 (1.03)	85.8 (1.06)	85.7 (1.05)
	FFD (cm)	110.0 (1.00)	110.0 (1.00)	110.0 (1.00)
	Field size area (cm^2)	1348 (1.03)	1209 (1.03)	1279 (1.03)
	kVp	87.7 (1.62)	87.1 (1.57)	87.4 (1.59)
	mAs	40.1 (4.25)	41.4 (4.65)	40.8 (4.65)
ALL [(ΣA+ΣB)/6]	FSD (cm)	85.0 (1.29)	85.3 (1.43)	85.2 (1.43)
	FFD (cm)	108.0 (1.20)	108.0 (1.20)	108.0 (1.20)
	Field size area (cm^2)	1484 (1.12)	1411 (1.38)	1448 (1.38)

Table 3. *Continued.*

Centres (Groups)	Measured Parameters	Examination (projection)		
		Pelvis (LAT)		
		M	F	B
	kVp	74.3 (1.10)	73.3 (1.07)	73.8 (1.01)
	mAs	40.7 (1.13)	40.0 (1.00)	40.4 (1.02)
OAGH (A)	FSD (cm)	62.7 (1.05)	61.8 (1.08)	62.3 (1.02)
	FFD (cm)	110 (1.00)	110 (1.00)	110 (1.00)
	Field size area (cm^2)	1157 (1.02)	1196 (1.01)	1177 (1.03)
	kVp	91.7 (1.18)	92.0 (1.18)	91.9 (1.18)
	mAs	40.0 (1.00)	40.0 (1.00)	40.0 (1.00)
LSTH (A)	FSD (cm)	75.0 (1.08)	75.4 (1.10)	75.2 (1.01)
	FFD (cm)	110 (1.00)	110 (1.00)	110 (1.00)
	Field size area (cm^2)	1026 (1.02)	1023 (1.03)	1025 (1.00)
	kVp	110.0 (1.20)	110.0 (1.20)	110.0 (1.00)
	mAs	20.0 (1.00)	20.0 (1.00)	20.0 (1.00)
IGH (A)	FSD (cm)	86.5 (1.09)	93.2 (1.07)	89.9 (1.08)
	FFD (cm)	120 (1.00)	120 (1.00)	120 (1.00)
	Field size area (cm^2)	975 (1.01)	1010 (1.01)	992.5 (1.04)
	kVp	85.6 (1.17)	90.0 (1.00)	87.8 (1.08)
	mAs	67.7 (2.50)	74.3 (1.00)	71.0 (1.80)
GBGH (A)	FSD (cm)	65.3 (1.07)	62.7 (1.07)	64.0 (1.07)
	FFD (cm)	100 (1.00)	100 (1.00)	100 (1.00)
	Field size area (cm^2)	750 (1.00)	750 (1.00)	750 (1.00)
	kVp	90.3 (1.09)	90.0 (1.00)	90.2 (1.05)
	mAs	34.7 (1.14)	40.0 (1.00)	37.4 (1.07)
AGH (A)	FSD (cm)	72.3 (1.05)	68.3 (1.02)	70.3 (1.05)
	FFD (cm)	110 (1.00)	105 (1.00)	108 (1.05)
	Field size area (cm^2)	750 (1.00)	750 (1.00)	750 (1.00)

Centres (Groups)	Measured Parameters	Examination (projection)		
		Pelvis (LAT)		
		M	F	B
FANIC. R (B)	kVp	85.0 (1.00)	83.8 (1.13)	84.4 (1.06)
	mAs	40.0 (1.00)	40.0 (1.00)	40.0 (1.00)
	FSD (cm)	75.9 (1.03)	75.4 (1.11)	75.7 (1.07)
	FFD (cm)	110.0 (1.00)	108.8 (1.05)	109.4 (1.03)
	Field size area (cm^2)	870 (1.06)	845 (1.03)	858 (1.05)
ALL [(ΣA+ΣB)/6]	kVp	88.3 (1.71)	89.7 (1.71)	89.0 (1.17)
	mAs	44.7 (5.00)	47.1 (1.20)	45.9 (5.00)
	FSD (cm)	72.4 (1.44)	73.2 (1.59)	72.8 (1.56)
	FFD (cm)	109.0 (1.20)	108.0 (1.20)	108.5 (1.20)
	Field size area (cm^2)	921 (1.38)	929 (1.42)	925 (1.40)

All centres used anti-scatter grid of 12 cm (40^{-1}); NOTE: Group A (Public Hospitals), Group B (Private hospital) and ALL (Groups A&B).

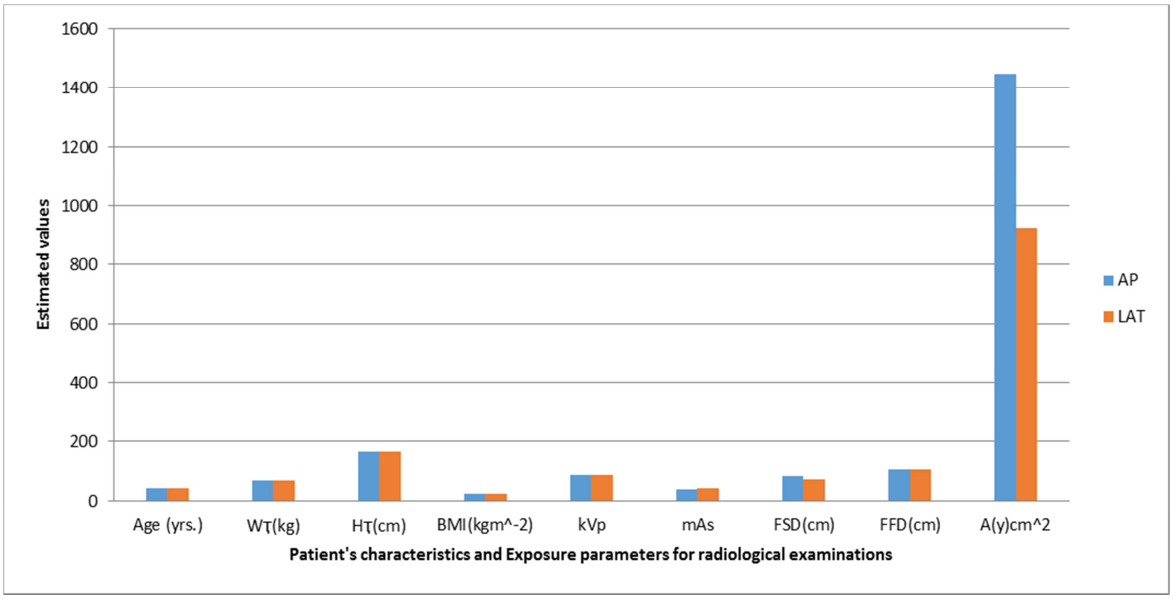

Figure 1. *Study reference person characteristics information and the technical factors selection during radiological examination.*

Table 4. *Comparison in the average estimated DAP ($mGycm^2$) by sex, averaged over sexes and examination from study presented in mean and range factor (in bracket) and some published DAP (mean values) (2dp).*

This study (Groups)		Examination / Projections	
		Pelvis (AP) ($mGycm^2$)	Pelvis (LAT) ($mGycm^2$)
OAGH (A)	Male	1616.08 (1.59)	522.09 (1.76)
	Female	1877.01 (1.44)	589.15 (1.95)
	Both	1746.55 (1.71)	555.62 (1.98)
LSUTH (A)	Male	1709.39 (1.37)	952.11 (1.44)
	Female	1666.35 (1.21)	959.52 (1.68)
	Both	1687.87 (1.37)	955.82 (1.68)
IGH (A)	Male	911.39 (1.14)	507.63 (2.65)
	Female	737.01 (1.48)	611.69 (1.80)
	Both	824.20 (1.58)	559.40 (3.03)
AGH (A)	Male	1644.03 (1.26)	505.94 (2.31)
	Female	1545.07 (1.48)	571.11 (1.89)
	Both	1594.55 (1.31)	538.48 (2.35)
GBGH (A)	Male	1338.27 (1.16)	868.10 (1.64)
	Female	1451.41 (1.10)	878.38 (2.00)
	Both	1394.84 (1.16)	873.24 (2.00)
FANIC R (B)	Male	1045.77 (1.33)	587.44 (2.48)
	Female	887.00 (1.51)	583.90 (2.03)
	Both	966.39 (1.76)	585.67 (2.44)
ALL [(A+B)/6]	Male	1377.49 (1.88)	657.20 (1.88)
	Female	1360.64 (2.55)	698.96 (1.68)
	Both	1369.07 (2.13)	678.04 (1.78)
Hart et al; [14],	Avg. Over sexes	3000	--
Hart and Wall [15],	Avg. Over sexes	2100	--

Table 5. *Statistical parameters for study's reference person DAP (Gycm^{-2}) (2dp.), distribution for pelvis procedure and some relevant subject characteristics.*

Examinations	N	Mean Age (yrs.) (RF)	Mean BMI (kgm^{-2}) (RF)	Mean Wt.(kg) (RF)	Mean DAP (Gycm^{-2}) (SEM)
Pelvis AP	278	42.3 (3.9)	24.9 (1.6)	69.2 (2.4)	1.37 (0.21)
Pelvis LAT.	278	42.3 (3.9)	24.9 (1.6)	69.2 (2.4)	0.68 (0.10)

Table 5. *Continued.*

Examinations	Min. DAP (Gycm^{-2})	Max. DAP (Gycm^{-2})	Median DAP (Gycm^{-2})	75th Percentile DAP (Gycm^{-2})	80th Percentile DAP (Gycm^{-2})	DAP RF
Pelvis AP	0.63	2.01	1.48	1.53	1.54	3.18
Pelvis LAT.	0.27	1.17	0.73	0.76	0.76	4.36

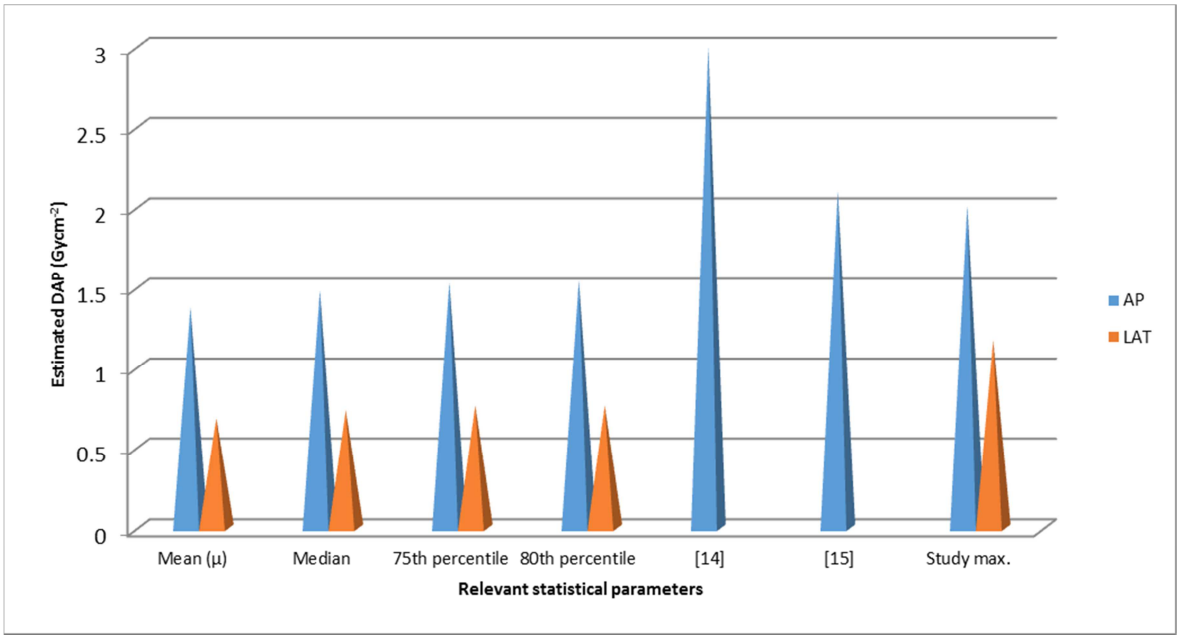

Figure 2. *Reference person estimated DAP (Gycm^{-2}) and some relevant statistical distributions with max. DAP values and UK reference DAPs.*

Table 6. *Comparison in the range and range factors across individual and mean values for centres studied by examination and the published values.*

Examination (Groups A&B)	Across centres (mGycm^2)		Across individual patients (mGycm^2)	
	Range	RF	Range	RF
Pelvis (AP)	824.2 - 1746.6	2.12	634.1 - 2013.2	3.18
Pelvis (LAT)	538.5 - 955.8	1.78	268.1 - 1169.3	4.36
[12]		7.98		3.80

Table 7. *Estimated average organ dose area product (ODAP) due to pelvis AP by sex and averaged over sexes (Reference person) presented in mean ± SD (1dp).*

Organs	Ind. reference male	Ind. reference female	Reference person
Active bone marrow	148.4 ± 1.8	61.7 ± 1.7	105.4 ± 2.6
Colon	714.7 ± 30.8	727.9 ± 26.2	721.3 ± 0.4
Liver	50.6 ± 2.2	44.7 ± 2.5	47.7 ± 0.2
Lungs	1.8 ± 0.1	1.9 ± 0.1	1.85 ± 0.1
Ovaries	--	1257.8 ± 49.2	--
Testicle	1231.6 ± 53.4	--	--
Prostrate	762.9 ± 32.7	--	--
Uterus	--	777.0 ± 30.5	--
Stomach	89.1 ± 5.0	208.4 ± 21.1	148.8 ± 35.8
Urinary bladder	1275.3 ± 55.2	1300.9 ± 50.8	1288.1 ± 12.8
Pelvis/trunk region	327.7 ± 14.2	334.3 ± 13.0	331.0 ± 0.2
Gall bladder	26.1 ± 1.1	26.6 ± 1.1	26.3 ± 0.0
Pancreas	674.9 ± 29.0.	687.4 ± 24.9	681.2 ± 0.4
Small intestine	133.6 ± 5.7	135.6 ± 5.3	134.6 ± 0.1
Kidneys	52.4 ± 2.1	137.9 ± 9.8	95.1 ± 2.6

Table 8. *Estimated average organ dose area product (ODAP) due to pelvis LAT by sex and averaged over sexes (Reference person) presented in mean ± SD (1dp).*

Organs	Ind. reference male	Ind. reference female	Reference person
Active bone marrow	195.7 ± 0.5	201.2 ± 0.5	198.5 ± 0.2
Colon	288.5 ± 0.9	358.4 ± 0.1	323.5 ± 2.1
Liver	143.0 ± 11.2	222.8 ± 11.2	182.9 ± 2.4
Lungs	5.0 ± 0.1	5.6 ± 0.1	5.3 ± 0.0
Ovaries	--	540.4 ± 13.1	--
Testicle	3.81 ± 0.1	--	--
Prostrate	221.9 ± 4.77	--	--
Uterus	--	239.8 ± 5.5	--
Stomach	58.3 ± 4.4	64.2 ± 4.1	61.3 ± 0.2
Urinary bladder	47.1 ± 1.0	51.0 ± 1.2	49.1 ± 0.1
Pelvis/trunk region	433.0 ± 8.3	454.5 ± 8.6	443.8 ± 0.6
Gall bladder	19.4 ± 0.9	20.8 ± 0.8	20.1 ± 0.1
Pancreas	51.1 ± 1.3	51.9 ± 1.5	53.3 ± 0.1
Small intestine	132.6 ± 17.0	189.0 ± 13.6	160.8 ± 4.7
Kidneys	40.5 ± 1.7	49.3 ± 1.4	44.9 ± 0.3

4. Discussion

Dose area product (DAP) as a good indicator of radiation risk to patient, not just the absorbed dose received during routine radiographic examinations but also reflect the area of tissue irradiated. [9], Therefore, pelvis X-ray examination as one of the commonly identified radiologic procedure inevitably involved exposure of some relevant reproductive organs to ionizing radiation. Thus, in line with the principle of keeping doses as low as reasonably achievable (ALARA), accurate patient dosimetry becomes highly significant, to ascertain an optimized exposure during this procedure. Hence, the needs to evaluate DAP and the equivalent risks to respective area of tissue irradiated during radiologic examinations particularly among adult patient (≥18 yrs.).

As far as this study is concerned, most of the X-ray machine involved is of averaged beam output values assessed to range between 35.47 and 50.11 mGy/mAs as presented in Table 1. These are related to those X-ray machines reported on, in Sudan. [13], All the X-ray machine total filtration is within the recommended range of values (2.5 - 4.3 mmAl) for good radiologic practice [13], except for FANICR (1.7 mmAl) with low beam output value. So, this could likely be traceable to a gallery age of a machine (Eighteen centuries). Thus, possibility of technological advancement involved in the recently manufactured X-ray machine may have contributed to the variation recorded in the beam output when compared to others. All the centres included in this study used Automatic film processors (Dry View 5700 laser imager and Drystar 5300, CR35. The centres evaluated in this study used Carestream 800 (CR system) films except FANICR centre, using Agfa with screen film combination system of nominal speed 400. Evidence had shown that high image quality can be achieved using Carestream 800 (CR system) with good contrast. [16-18] Since images were created, ranked in term of Signal-Noise Ratio (SNR) (figure of merit for image quality) [19], from low to high quality, it is therefore expected that if technical factors selection varied as 75 -105 kVp, 20 -50 mAs and SID/FFD (110 cm) by age or patient diameter during examination together with the identified type of films [18, 20] then high mean SNR will be generated. Hence, high quality image expected.

Population of 278 adult patients exposed for both AP and LAT of pelvis procedure from six (6) selected centres (Grp. A=5 publics and Grp. B=1 private) with gender percentage ratio of 39.6 and 60.4 for male and female respectively, studied. Thorough evaluation of this gender combination may likely reflect the demographic structure of the area under investigation. [7], In the EC quality criteria [21], and IPEM report 91 [22], it is recommended that the dose descriptors measurement among adult patient, be made on statistically significant patient's sample (≥ 10), whose weights are near the standard adult patient of average weight 70.0±10 kg (60-80 kg). Thus, study shows compliance with recommendation. As such, estimate of DAP and organs DAP for this examination, be seen as a well representative value for each selected centre and generally as a whole. The age range of patients established in this study was (18-71 yrs.) and still within studies conducted in Nigeria [12], and outside the country as reported [23-25]. The mean weight and BMI recorded in this study were (69.5; 68.8 and 69.2 kg) and (24.3, 25.4 and 24.9 kgm^{-2}) respectively for male, female and averaged over sexes. Generally for this study, the BMI's range between (19.3-31.1) kgm^{-2} as reflected in Table 2. So, reference person established weight and BMI recorded for this study becomes 69.2 kg and 24.9 kgm^{-2} respectively and closely related to the recommended values for a standard adult patient. [21, 26].

The range of kVp and mAs recorded for this radiological procedure (pelvis) were (80 -100) and (20-45) for pelvis AP and (77-120) and (20-100) for pelvis LAT respectively. Thus, generated range factors of 1.25 and 1.56 for kVp and 2.25 and 5.00 for mAs respectively for pelvis AP and LAT. These reflected high precision in the selected exposure factors for pelvis LAT than for AP. Comparison of these recorded range of values with study [12], for same examination (70-86) kVp and (45-120) mAs with range factors of 1.23 and 2.67 respectively for kVp and mAs, shows good agreement in general whilst the slight discrepancies could be ascribed to

the patient anatomical and film processing chemical differences. Though, the range factor for kVP and mAs selection in this study is a little different from those recorded in study. [12], The range factors for FSD and FFD as recorded in this study by gender were (1.29 and 1.43) for male and female FSD respectively and (1.20 and 1.20) for male and female FFD for pelvis AP while it was (1.44 and 1.59) for male and female FSD and (1.20 and 1.20) for male and female FFD for pelvis LAT. This therefore shows consistency in the FFD selection and reflected adequately, the variation in the patient's anatomy when compared with its FSD factors. The range of FFD (100-120), still fall within the recommended values proffer for pelvis procedure [(75-90) kVp, (< 400) mA and (100-150 cm) FFD and screen film speed of 400]. [21], Therefore, the range of values recorded for either FSD (60-106 cm) and FFD (100-120 cm) from this study still fall within the optimum values of FFD (80-210) required for good geometric image sharpness reported in Sudan [12, 13]. Anti-scatter grids were applied in all centres studied with a unique mode of application as shown in Table 3. As in figure 1, the study reference person characteristics information gives an indication of an accredited standard adult person [21, 26], thus justified the scope of study.

DAP as a dose descriptor, had been shown to uniformly related to entrance surface dose (ESD) to patient from diagnostic radiology [10, 18] and so, be seen as an essential tool to assess effective dose (ED) to patient. Generally, the average DAP value recorded for AP seem almost twice that for LAT in all the centres except for IGH. This is traceable to patients' anatomical difference and the consistent used of technical factors selection in conformity with the recommended values for As Low As Reasonably Practicable (ALARP). Comparison in the average estimated DAP from study shows that (OAGH) recorded the high mean DAP, approximated at 1747 mGycm^{-2} (approximately 1.75 Gycm^{-2}) whilst IGH recorded low mean DAP (0.824 Gycm^{-2}) for AP and for LAT, approximately it was LSUTH (0.96 mGycm^{-2}) and AGH (0.54 Gycm^{-2}) respectively (Table 4). Further comparison of DAPs from this study with DAPs reported in some literature [12, 14, 15] for same radiologic procedure for adult patients as equally shown in Table 4, shows good agreement in general but the slight differences could be ascribed to patient anatomical and technical factors variances. The overall average DAP recorded for individuals male, female and reference person for this radiologic procedures were an approximate values (1.38, 1.36 and 137 Gycm^{-2}) respectively for pelvis AP and (0.66, 0.70 and 0.68 Gycm^{-2}) for pelvis LAT. The average value of DAPs recorded from [12], as determined were (0.41, 0.52 and 0.46 Gycm^{-2}) for male, female and averaged over sexes respectively while for [9], averaged over sexes was recorded as 3.0 Gycm^{-2} and the UK National reference DAP as 2.1 Gycm^{-2} [15],. Above reference results showed that the result of DAPs recorded from this study, were still within recommended values for good radiologic practice. Generally, the low DAP's values recorded in pelvis LAT compared to it AP counterpart is traceable to possible increased homogeneity attenuation that may be recorded for lateral projection of the X-ray beam. Hence, possibility of low stochastic health effect may be recorded for AP pelvis compared to LAT, if determined.

The overall average age, weight and BMI for the study reference person used for this procedure was (42.3 yrs, 69.2 kg and 24.9 kgm^{-2}) with reference individual persons (male and female) BMI factor of 1.05 (across the mean) Table 5. The statistical comparison of the reference person mean DAP across the centre's mean range (minimum and maximum obtainable average DAP values), showed that the DAPs value from each centre studied can still be further optimized, thus reducing the average DAP recorded for study reference person (Table 5 and Figure 2).

The estimated range factors in this study for individual minimum and maximum values by examination were recorded as 3.18 and 4.36 for pelvis AP and LAT respectively and for across the mean values (among centres), it was 2.12 and 1.78, showing wide spread between individual DAPs (DAP values across patients) recorded for pelvis LAT than for pelvis AP and for DAPs range factors (among centres), the DAPs values recorded for LAT are closely related compared to pelvis AP (Table 6). DAPs across the mean values for pelvis LAT are closely related (0.54-0.96 Gycm^{-2}) and so values cluster around the mean (true values) when compared to pelvis AP (0.82 -1.75 Gycm^{-2}). The variation recorded may be ascribed to the difference in the X-ray thickness of penetration during clinical examination. The variation recorded between estimated DAPs for same X-ray examination gives a suggestive of possibility for reductions in DAPs value for this examination without compromising the image quality. Comparison of the individual and among centres minimum and maximum DAP values by examination from this study with other published DAPs range factor in the literature shows good agreement but the observable differences are traceable to patient anatomy, radiographer's and dosimetry techniques. Further comparison showed that values from this study are more closely related compared to [12], with range factor among centres and individual patient recorded as (7.98 and 3.80), though estimates by examination projections was not clearly recorded.

The average estimated organs DAPs distribution by gender and examination using dose Cal software are presented in Table 7. This indicates the product of the dose of radiation (mGy) given to measureable area on a specified organ irradiated during examination. It is therefore evident that for every uniformly irradiated area during X-ray examination, some organs are exposed to specific level of risk due to the dose of exposure, since they fell within the area collimated on the patient. Hence, knowledge of organ DAPs for a specific examination procedure becomes indispensible. In this study, DAPs to some organs exposed in adult patient during pelvis examination were estimated using recommended software (Tables 7 and 8). So, the organ that received high and low DAP during pelvis AP examination were Urinary bladder and Lungs with values recorded as (1288.1 ± 12.8 and 1.85 ± 0.1 mGycm^{-2}) averaged over sexes and for pelvis LAT, different values

recorded gender-wise as Pelvis bone and Testicles (433.0 ± 8.3 and 3.81 ± 0.1 $mGycm^{-2}$) for male's high and low DAP respectively whilst it was Ovaries and Lungs (540.4 ± 13.0 and 5.61 ± 0.1 $mGycm^{-2}$) for female. Successively, organs as Testicles and Prostate (male) and Ovaries and Uterus (female) equally recorded high DAPs values during AP examination. It is evident that organ as Ovaries and Lungs are independent of the projections during this procedure while Testicles in male is projection dependent for an exposure to either high or low values for either of the dose descriptors. Generally, the variation in DAPs values recorded from this study and others in the literature emphasised the needs for greater awareness creation on the irrational used of the atom in radiating patient and the surrounding environment. Thus, measure to optimized dose to patients and the environment should be given a prompt attention, so as to reduce possible risks of exposure inducement to cancer.

5. Conclusion

The study showed variation in exposure factors and DAPs values recorded for same types of examination, both within and between centres studied. Thus, revealed the need for further optimization and awareness creation among radiographic staff. All the hospitals studied gave considerably lower DAP to patient when compared with UK recommended diagnostic reference (2100 - 3000 $mGycm^{-2}$). Thus, results from this study compare favourably with those published report within and outside the countries. So, the differences recorded could be ascribed to possible differences in dosimetry techniques, patient anatomy, the technical parameters selection and the exposure condition.

6. Suggestion/Recommendation

Based on the methodology employed in this study, the author deem it fit that same could be applied in risk and average risk per area estimates on patient over a specific population, approaching linear non-threshold (LNT) model as advocated in BEIR VII phase 2 and ICRP.

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