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COMPARATIVE STUDY OF ANTEROPOSTERIOR TRUNK DIAMETER MEASUREMENT METHODS IN ADULT PATIENT'S UNDERGOING PELVIC RADIOGRAPHY IN LAGOS STATE, NIGERIA.

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Abstract
Globally, variation in dose to patients' undergoing same radiological examination from same or other facility have been severally reported. The equipment, as well as the technique of exposure, has been scrutinized in order to find the reason for this noticeable discrepancy and reduce it. This work has considered patient's size and shape as one of the identifiable variation factor in patient dose evaluations, which has been shown to relate exponentially to the energy imparted during pelvis examination. Therefore, different approaches to measuring AP trunk thickness in patients' undergoing pelvis examination were adequately compared for accuracy purposes. Study therefore established that there is significant relation in all the methods identified for measuring patient's AP trunk diameter, except for several areas of error as may be identified as constituting to higher degree of discrepancies in the measured values. Finding showed that average AP trunk thickness ranged between 20.4cm and 24.6cm for pelvis examination in the centres studied for standard adult patients, gender wise. It is therefore suggested that these values be used as a baseline for further study in establishing AP trunk diameter for a standard adult patient in Nigeria. Consequently, predicted (20 to 30) % reduction in dose variation from radiological examinations with accurate thickness (diameter) measurement.
Keyword: Patient's parameter, Anatomical, Radiographic parameter, Trunk thickness/diameter, Dosimetry, Antero-posterior (AP)

Introduction

Over the years, the greatest source of variation in dose to patients exposed for same radiological examination using either same x-ray machine or otherwise, has been traced majorly to the size and shape of the body [Moore (1989)] which has contributed greatly to the range of the image quality. The energy imparted 'E' during examination has been identified as a factor of the thickness (T), half value layer (HVL) as well as the selected tube voltages (V) and the area exposed (A)

(Lindskoug 1992). These parameters were related using:

$E = E_i (T, HVL, V). A (cm^2)_{FSD}$ (1)

Equation (1) revealed that, thickness measurement is a vital parameter in the estimation of dose to patient and its technique of exposure during related radiological procedures Lindskoug (1992); IAEA (2004). So, be seen as relevant factor to be considered in the technical factors selection during clinical exposure of patient for routine x-ray examination, to guarantee accuracy in the level of beam penetrability and scattered radiation and for possible backscatter factor (BSF) selection.

Trunk is the main part of the body which does not include the head or the limbs, but other parts from anterior to posterior and shoulder to pelvic brim in the region below the chest and periumbilical, around the iliac wings. During antero-posterior (AP) of pelvic radiography (patient in supine or orthostatic position), beam incident on median line just above the pubic symphysis and the feet is rotated internally from 15 to 20^0, for the correction of the neck ante version angle, to avoid greater trochanter overlapping the femoral neck (Giancarlor *et al.,* 2011). Pelvis primary role is seen as supporting the weight of the upper body while sitting and to transfer this weight to the lower limbs while standing, and consequently, serves as an attachment point for trunk and lower limb muscles. Therefore, protect the internal pelvic organs as lower intestine and reproductive Knipe and Murphy (2012). The exposure of pelvis to ionizing radiation has being seen as an exposure of gonad to direct radiation, so increase possibility of risk of heredity effect of radiation, from exposure age. It has been observed that the average body density is predetermined by its weight, but not shape, while thickness has put into cognizance, the weight, height and also the average density (Moore 1989; Lindskoug 1992), which varied from one patient to the other. The desire to be corrected, especially in standard adult patient with average weight of 70kg ±10, considered. The entrance radiation doses were confirmed, to increase exponentially with body part thickness (Donald *et al.*, 2009).

Study identified two major approaches to determine patient's thickness as Direct and Indirect. These were further sub divided into different methods as patients' parameter, radiographic and anatomical. In patients' parameter, size correction allows the use of a mathematical transformation to normalize dose data to a standard weight of 70 kg for reference man equivalent diameter (Lindskoug 1992; Donald *et al.*, 2009). So, outer trunk thickness measurement (skin to skin) do not seen as correlating well with the energy imparted to the body, since this do not include any information on the constituency of the body (Lindskoug 1992; Donald *et al.*, 2009). So, assumes person to be a cylinder with the density of water. The energy imparted to an individual correlate better with the individual's equivalent diameter than with the individual's weight. Individual's equivalent diameter is calculated using:

$T = D_e = 2[\sqrt{(W / (.H.1000)}]$ (2)

where, T is patients' thickness, D_e is equivalent diameter in meter, W is weight in kilogram, and 'H' is height in meters. This is expressed in term of body mass index as

$T = D_e = 2 [\sqrt{(bH / (.1000)}]$ (3)

where, b is the body mass index. The T is considered as the AP trunk thickness/diameter for patient undergoing pelvic radiographic procedure.

Though in some area of dose and risk estimations, International Commission on Radiological Protection (ICRP) recommends the use of a size correction factor to normalize their values as expected for the reference man and was defined by the relation:

$F = \exp [k (D_e – T)]$ (4)

where, F is the size correction factor, D_e is the equivalent diameter of reference man (0.229 m or 22.9 cm), T is the calculated equivalent diameter of the subject (patient thickness) and k is a constant, determined experimentally, which reflects changes in dose for subjects of different sizes (60-80 kg), owing to changes in kVp, mAs and spectral filtration settings resulting from automatic changes in fluorographic and radiographic techniques for thicknesses of different parts of the body (Donald *et al.*, 2009; ICRP 1975).The larger the value of k, the more rapidly radiation dose increases with increasing patient thickness.

Also, radiological measurement of patient's thickness is observed during patients' clinical examination, using:

$$T = C_{AP} = y_2 - y_1 = \Delta y \quad (5)$$

where, y_2 is the focus to film distance (FFD), y_1 the focus to patient's skin distance (FSD) and $T = C_{AP} = \Delta y$, the patient's AP trunk thickness. This considers thickness as a function of the distance, vertically from the focal spot, due to patient position during examination. The anatomical measurement of patient's AP trunk thickness could be seen as a direct approach, which involves the use of a well calibrated veneer calliper. This study therefore intends to measure the AP trunk thickness (diameter) of patients during pelvic radiography and makes adequate comparison on the result deduced from the different measurement methods identified.

Materials and Methods

AP trunk thickness measurements were carefully carried out on 278 patients, monitored for entrance surface dose (ESD) during pelvic AP examination using the identified methods (Equations 3 and 5). The skin to skin measurement via the outer dimension of the lower trunk (pelvic region) during clinical examination was taken using an improvised veneer calliper (Ofori *et al.*, 2012) for a period of about 8 months in the selected 5 public and 1private hospitals within Lagos State. The criteria for hospital selection include adequate representation of the type of x-ray procedure studied, observable population of patients' attendance and availability of diagnostic procedure as well as the type of facilities available in the hospital. The hospitals were coded for identification. The average patients' characteristic information across the hospitals studied and the average measured AP trunk thicknesses using identified approaches were presented in Tables 1 and 2.

The levels of significant relationship between different approaches tested were determined using chi square and t-test statistical models at p value ≥ 0.05. True values for the AP trunk thickness (gender wise) and averaged over all sexes and adult ages were established using weighted average method, with relation given as

where (ϖ) is the weighted average, $w_i = \frac{1}{\sigma}$ is the weighted value from the error of the mean and x_i is the mean value for each of the approaches.

Results

Table1 is the summary of the patients' characteristic information by sex across each centre and averaged over all the studied centres (ALL) presented as means and standard errors while Figure 1 reflects the patients' information, averaged over sexes for each studied centre.

Discussions

Patient's size and shape have been identified as a factor contributing up to 65% of the noticeable variation in dose to patient in diagnostic dosimetry. Therefore, accurate measurement of patient's thickness, using ideal method during patients' dose monitoring becomes relevant. This is because the energy imparted during clinical examination depends on patients' thicknesses (weight, height and average body

Table 1: Patients' characteristics by sex in mean (SEM) across centres

	OAGH		LASUTH		IIGH		AGH		GBGH		FANIC. R		ALL	
SEX	M	F	M	F	M	F	M	F	M	F	M	F	M	F
AGE(Yrs.)	42.3(4.3)	44.8(6.6)	47.6(5.2)	39.7(5.1)	46.5(5.5)	44.3(4.8)	38.7(3.9)	27.1(2.8)	44.3(3.4)	41.8(3.8)	49.6(5.2)	40.3(5.9)	44.8(3.6)	39.7(5.9)
WT(kg)	75.7(3.6)	69.4(5.4)	81.1(7.9)	72.6(4.2)	72.0(6.3)	63.5(5.1)	73.5(5.7)	63.5(3.3)	56.6(2.3)	68.3(2.6)	58.4(8.7)	75.2(8.1)	69.5(9.1)	68.8(4.3)
HT(cm)	167.9(8.2)	164.9(5.6)	170.2(5.3)	168.8(3.2)	172.1(3.9)	167.8(4.7)	173.0(5.6)	164.2(7.5)	166.0(4.7)	162.4(3.4)	163.7(3.6)	160.5(5.1)	168.9(3.3)	164.8(2.9)
BMI(kg/m^2	26.9(0.1)	25.5(1.2)	28.0(0.5)	25.5(1.3)	24.3(1.2)	22..6(1.1)	24.6(1.8)	23.6(1.5)	20.3(0.8)	25.9(0.6)	21.8(1.1)	29.2(0.6)	24.3(2.7)	25.4(2.1)

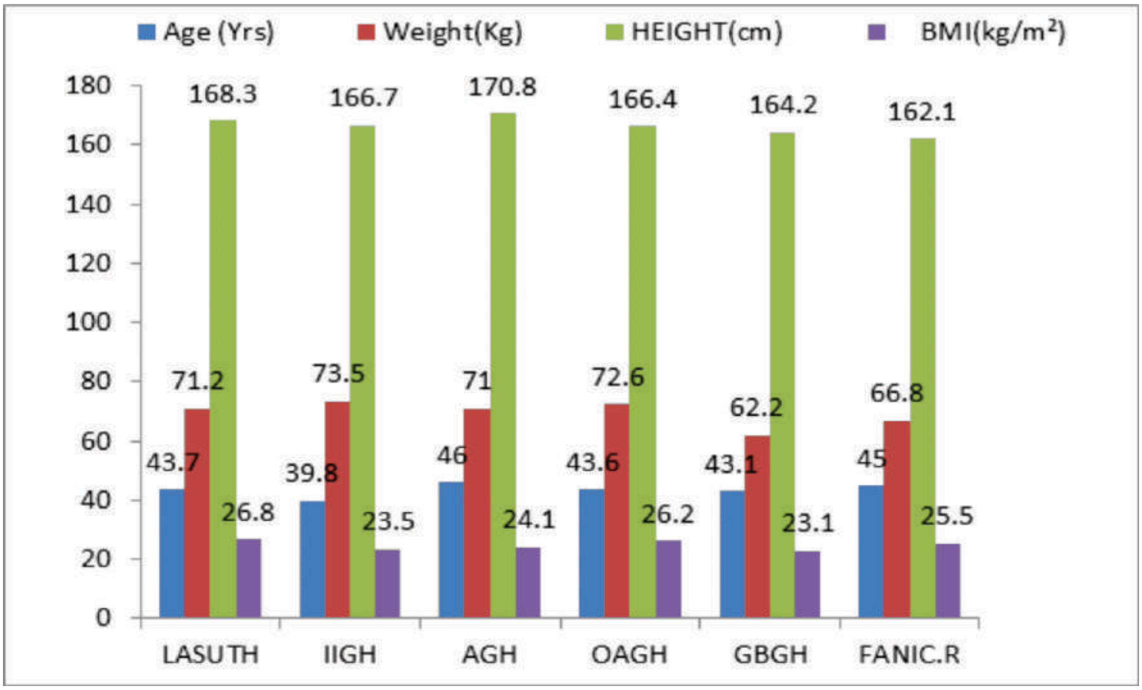

Figure 1: Patients' characteristics information averaged over sex across centre studied.

Table 2 reflects the average measured AP trunk thickness and their standard error of the mean (SEM) for each of the identified thickness measuring techniques across the centres by sex while Figure 2 shows the correlation among the values obtained from the methods used in determining the AP trunk thicknesses by gender.

Table 2: Mean AP trunk thicknesses of the identified methods and their standard errors (in parenthesis) across the centres by sex.

METHODS	OGH		LSUTH		IGH		AGH		GBH		FANIC. R		ALL	
SEX	M	F	M	F	M	F	M	F	M	F	M	F	M	F
PAT.PARAMETER	23.98	23.14	24.63	23.41	23.08	21.97	23.28	22.21	20.73	23.14	21.32	24.43	22.84	23.05
(cm)	(1.8)	(2.1)	(2.0)	(1.7)	(1.6)	(2.4)	(1.5)	(1.3)	(1.9)	(1.1)	(0.8)	(1.7)	(1.4)	(0.8)
ANATOMICAL	24.50	23.50	24.50	24.30	23.50	22.50	23.60	23.60	21.40	24.60	21.50	24.36	23.17	23.81
(cm)	(1.5)	(1.7)	(0.6)	(0.8)	(2.6)	(0.9)	(0.5)	(1.8)	(0.4)	(1.4)	(0.3)	(1.5)	(1.3)	(07)
RADIOGRAPHIC	22.95	21.77	24.20	23.50	23.37	22.43	23.20	22.25	20.40	23.60	21.40	24.20	22.59	22.96
(cm)	(1.8)	(1.1)	(1.1)	(1.1)	(2.3)	(1.4)	(1.2)	(1.3)	(0.6)	(0.9)	(0.6)	(1.3)	(1.3)	(0.9)

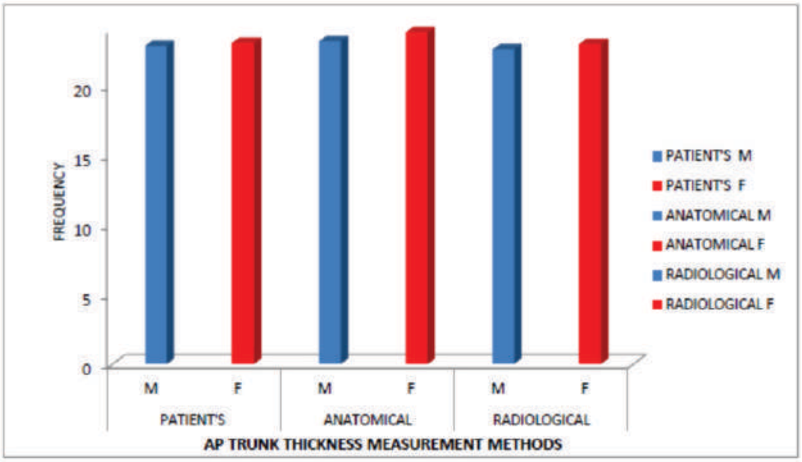

Figure 2: Comparison in the mean values recorded for each of methods adopted for the patients' AP trunk thickness at 95% confidence Level

Table 3: Hypothesis testing the significant relationship between methods employed in measuring patient's trunk thicknesses/diameters during pelvic procedure using Chi square

Sex	Observed Frequencies			Expected Frequencies			Total
	Pat. Parameter	Anatomical	Radiographic	Pat. Parameter	Anatomical	Radiographic	
Male	22.84	23.17	22.59	22.74	23.28	22.57	68.60
Female	23.05	23.81	22.96	23.12	23.70	22.98	69.82
Total	45.89	46.98	48.55	45.89	46.98	48.55	138.42

Table 3 shows the comparative study of the different methods employed for measuring AP trunk thickness/diameter of patient's during pelvis radiographic procedure. These methods were tested for their significant relation using chi square method of analysis at degree of freedom (df) = 2 and 95% confidence level (p value ≤ 0.05). The calculated value ($\chi_{cal.}$) was 0.0017 compared to table value (χ_{tab}) of 5.992, establishing a strong relationship between methods/approaches for trunk thickness/diameter determination.

Table 4: Hypothesis for establishment of significance relation tested, using T-test analytical method.

Sexes	Pat. Parameter	Anatomical	Radiographic	Mean (μ)
Male	22.84	23.17	22.59	22.89
Female	23.05	23.81	22.96	23.27
Diff.(d_i)	0.21	0.64	0.37	0.40

In Table 4, number of methods/samples considered (n) = 3, Deviation (D) = 0.40667, Standard deviation (S) = 0.21734; the calculated value at degree of freedom (df) = 2 and 95% confident level (p value ≤ 0.05) was (t_{NH}) = 3.2408 while t_{Tab} = 4.303. This equally confirmed a strong relationship between the methods.

Table 5: Comparison in the average estimated parameters by sex and averaged over sexes and age, studied for standard pt. and the available related values from literatures, exposed for pelvis radiography with standard error of the mean (SEM).

AVERAGE ESTIMATED PARAMETERS									
STUDIES	THICKNESS (CM)			WEIGHT (KG)			HEIGHT (CM)		
	M	F	BOTH	M	F	BOTH	M	F	BOTH
This Study	22.95 (1.41)	23.25 (0.70)	23.10 (0.73) (20.4 – 24.6)	69.20 (9.10)	68.85 (4.33)	69.24 (0.46)	168.9 (3.34)	164.8 (2.90)	166.92 (1.35)
IAEA., (2004)			20.00	-	-	70.0 (10.0)			170.0
CEC., (1989)			20.00			65.0 (10.0)			170.0
(Ofori et al., 2012)			(20-40)			80.1 (5.0)			163.7
Lindskoug (1992)			22.90			70.0			170.0

density). Identified methods of AP trunk thickness measurement in patients were established and carefully used on 278 adult patients monitored for entrance surface dose (ESD) during pelvic examination from selected hospitals within Lagos State, Nigeria.

As reflected in Table 1 and Figure 1, the average patient's characteristic factors studied were observed as a gender ratio of 1.13, 1.01, 1.03 and 1.05 for age, weight, height and body mass index respectively and averaged over all sexes values of (42.3±2.6) yrs., (69.2±0.4) kg, (166.9±2.1) cm and (24.9±0.6) kg/m^2. This showed that the above listed patient's factors agreed with the accredited values for a standard adult patient (70±10 kg and 1.7± 0.1 m) [IAEA (2004); Ofori *et al.,* 2012].

Different methods of AP trunk thickness measurements were identified and used in determining the subjects' thickness for adequate comparison (Table 2 and Fig.2). Anatomical method recorded higher values generally for both sexes and above others, with a gender factor of 1.03, while the other two methods were 1.02 and 1.01 for radiographic and patients' parameters respectively. Similar difference was observed in the gender factors recorded when compared. This could be as a result of measurement/experimental error. Both radiographic and patients' parameters seem to be more closely related compared to anatomical. Generally, AP trunk thicknesses for female were found higher than their male counterparts.

The comparison of these methods for (significant differences) using chi-square and t-test analytical methods, indicated that values recorded gender wise were statistically related. Hence, values from all the methods correlated with each other (Tables 3 and 4). This confirmed that either of the methods could be adopted as being relevant for AP trunk thickness determination during dosimetric exercise, provided all errors either random or systematic, which may account for overall uncertainty in the process, are adequately taken care of.

The average patient's AP trunk thicknesses established in this study (using weighted average method) were 22.95 cm and 23.25 cm for male and female respectively. These agreed with the values suggested and supported by (IAEA 2004; Donald *et al.*, 2009; ICRP 1975). The value was made averaged over all sexes and age of standard patient as 23.10 cm. There was also a strong indication that the AP trunk thicknesses (diameters) of average standard patients in Lagos State and Nigeria as a whole could be between the average of 20.40 cm and 24.60 cm (factor difference of 1.21 approximately).This, in line with the International Atomic Energy Agency (IAEA) and Commission of the European Community (CEC) criteria for estimating patient entrance surface dose (ESD) due to pelvic procedure, AP trunk thicknesses serve as a major factor for dose variation and so, for As low As Reasonably Practicable (ALARP), in the exposure of patient for pelvic examination.

Comparison of this study's average values with Asia and Europe acceptance of an average value of 20 cm trunk thickness for a standard adult patient for pelvic examination (Lindskoug, 1992; IAEA 2004; CEC 1989; CEC 1996). As far as Africa is concern, Ghana has established AP trunk thickness/diameter value, range between 20 cm and 40 cm (Ofori *et al.,* 2012) and of which this study value fell within as in Table 5. Observable difference in the range of value may be traceable to the patient's BMI (studied BMI range between (23.1 and 26.8) kg/m^2 and a range factor of 1.16, indicating that this value could therefore serve as a baseline for comparison in the AP trunk thickness/diameter measurement for standard patient pelvic in Nigeria and so a baseline for further evaluation and comparison of a standard patient globally.

Conclusion

The agreeable sources of variation in dose to patient monitoring, either at different facilities/centres location, same centres and even for same x-ray machine have been the patient's size and shape. This has contributed enormously to absorbed dose to patient and image quality. As part of the efforts to improve the quality of the procedure and reduce the possible variation in dose to patient estimation, patient's thickness measurement during dose monitoring should be given a priority using either of the identified methods with adequate concentration for accuracy to reduce degree of uncertainty errors. This is because variability in patient thickness may be the greatest single contribution, unless this is achieve, then we can proceed to examine other technical factors that may account for this anomaly.

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