Effective Dose Measurement from Diagnostic Radiology Procedures in Some Nigerian Hospitals

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Abstract

Conventional diagnostic X-ray examination remains the most used diagnostic tool in developing countries like Nigeria despite the technological advancement in other medical imaging technique in recent times. The need to estimate the radiological risk associated with X-ray radiography cannot be over-emphasized. Effective dose has been identified as a risk-weighted measure of radiation to organs and tissue in the body associated with radiological examination. It is considered as good indicator of radiological risk. In the present study, effective dose were estimated from entrance surface dose (ESD) measured using thermolumniscent dosimeter (TLD) in eight hospitals in southern part of Nigeria. Eight radiological procedures such as: chest PA, abdomen AP, Pelvis AP, pelvis LAT, skull AP, skull LAT, lumbar spine AP and lumbar spine LAT were included in the study. The estimated effective dose ranged from 0.02 to 0.22mSv, 0.04 to 2.82mSv, 0.17 to 2.96mSv, 0.19 to 1.84mSv, 0.018 to 0.13mSv, 0.01 to 0.09mSv, 0.10 to 2.15mSv and 0.04 to 0.22mSv for chest PA, abdomen AP, pelvis AP, pelvis LAT, skull AP, skull LAT, lumbar spine AP and lumbar spine LAT respectively. Generally the mean effective doses obtained from the present study were comparable with what was obtained in the earlier studies within Nigeria and other countries.

Key words: Effective dose, Dose optimization, Radiological risks.

1. Introduction

Assessment of patient doses in diagnostic radiology became necessary, considering the health risk associated with the use of ionizing radiation on the patients.[1,2] Diagnostic radiology imaging technique remain the most used technique in medical imaging despite recent development of other modern imaging especially in developing countries.[2,3]. It is regarded as largest contributor to the population dose from man - made radiation sources.[4-6]. Therefore, there is need to evaluate risk associated with the use of ionizing radiation in medical imaging.

In 2007, International commission on Radiological Protection (ICRP) [7] recommends the use of effective dose to determine stochastic risk assessment from non homogeneous radiation. Effective dose is defined as the sum of the weighted equivalent doses to organs. [7,8] It was introduced to express a radiation related detriment in situations where dose to the patient is not uniform. The basic aim is to express the risk from an exposure of a single organ or tissue in terms of the equivalent risk from an exposure of whole body.[9, 10].Effective dose is considered a good indicator of radiological risk but it represent a generic estimate of risk from a given procedure for a generic model of the human body. [11, 12]

Effective dose can be estimated indirectly from routine dose measurement using conversion factors appropriate to the conditions of the exposure. [13]. These coefficient can be estimated using Monte Carlo simulation techniques or derived experimentally on the basis of physical anthropomorphic phantoms.

The main aim of this study is to estimate the effective dose to patients from measured entrance surface dose (ESD) using conversion coefficients calculated by Monte Carlo methods.

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2. Materials and Methods

The ESD of two hundred and sixty patients undergoing diagnostic X – ray examinations in selected hospitals in the southern part of Nigeria were measured using Lithium Flouride thermoluminescent dosemeters LiF (TLD – 100).. The hospitals investigated in this study are: Private Hospitals, State Hospitals, University Teaching Hospitals and Federal Medical center. The hospitals investigated include University of Benin Teaching Hospital (UBTH) Benin – City, University Teaching Hospital (UTH), Ado – Ekiti, Oba Adenle Memorial Hospital (OAMH), Ilesa, Obafemi Awolowo University Teaching Hospital Complex (OAUTHC) Wesley Guild, Ilesa, Ayinke Diagnostic Center (ADC), Ilesa, Federal Medical Center (FMC), Ido Ekiti, Central Hospital (CH) Benin – City, Ladoke Akintola University Teaching Hospital (LTH), Osogbo.

A pair of highly – sensitive and tissue equivalent LiF (TLD – 100) labeled dosemeters were placed in the primary beam of X – ray where it intercept the patient surface at a right angle to the irradiated region of the patient during exposure of the patient to measure the ESD. TLD measurements, together with factors used in each case, were collected for the posterior-anterior (PA) Chest, for anterior-posterior (AP) Abdomen, Lateral (LAT), Pelvis, AP Pelvis, Skull AP/PA, Skull LAT and Extremities AP/LAT Examinations.

2.1 Preparation of TLD Chips and Calibration

Direct dose measurement was carried out using TLD - 100™ (Lif; Mg, Ti) chips of dimension 3x3x1 mm obtained from Stanford Dosimetry, LLC (Bellingham, United States). A total of 100 chips were acquired and pre- annealed using an oven obtained from the Centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile Ife to empty any residual electrons trapped in the metastable state during the previous exposures. The chips were annealed under the temperature of 400° C for 1 hour and allowed to cool down in the oven for between 17 hours. The chips were packed in black polythene pouch to prevent the effect of visible light.

The chips were labeled for easy identification and presented for calibration at the Secondary Standard Dosimetry Laboratory (SSDL) of National Institute for Radiation Protection and Research (NIRPR), University of Ibadan. During the calibration, each chip was exposed to a uniform radiation (80 kV), 1 mA, 142 s or 142 mA s and FSD of 200cm, dose rate of 50.2 mGy hr1) in turn from a standard unit. The chips were taped to a water phantom placed at a distance of about 200cm from the focus before irradiated. During the calibration of the TLD chips, element correction coefficients (ECC) and reader calibration factors (RCF) were calculated using Harsaw TLD Reader Model 4500 (manual) and WinRems software (Saint - Gobain Crystals & Detector, Wermelskirchen, Germany). Golden chips (reference chips) were selected and bad dosimeters were discarded while the field dosimeter were made available for use

2.2 The Quality Control Test.

The quality conttrol test (QC) for each machine was carried out using QC kit (NEROTM 6000m, manufactured by victoreen, INC, Cleveland, Ohio, USA). The QC test was carried out by positioning the QC kit at the centre of the bean axes at focus to image distance (FID) of 100cm [14]. Although 100cm FID is a known and accepted distance used in most conventional radiography studies depending on region of the body to be imaged, the parameter that was used to arrive at 100cm FID was from a study by Welander and Wickman [15] who in their work determined the mean energy imparted into a uniform phantom. The QC test carried out on each machine are: kVp accuracy, kVp reproducibility, time reciprocity, exposure linearity and exposure reproducibility. The results obtained were within the range recommended by American Association of Physics in medicine [16].

2.3 Effective Dose Estimation

In this study, the Effective Dose (E) was estimated using NRPB – SR262 Monte Carlo Simulation to calculate effective dose from measured dose (ESD) for each individual radiograph in each individual examination. NRPB – SR262 Monte Carlo simulation data were calculated by the National Radiological Board (NRPB) of the UK using Monte Carlo techniques on a mathematical hermaphrodite phantom [17].

3. Results and Discussions

In this study 720 adult patients undergoing rotine diagnostic examinations in 8 hospitals in southern part of Nigeria were investigated. Table 1 shows the specific features of each X-ray unit considered in the study. The date of installation of the machine in each unit, to the time when the study was carried out ranged between 3 and 7 years. All the machines were installed in less than 10 years. The table also shows the total filtration (Inherent and added) of each unit. The filtration of machines in FMC and UBTH are 2.0 and 1.6 mm Al respectively, fell below the required standard of 2.5 mm Al for machine being operated at peak tube voltage above 70 kVp [18, 19]

The technical data (FFD, tube potential (kVp), and the tube loading (mAs) employed in some of the examinations in this hospital were inconsistent with international recommended values for good practices by European Union and the NRPB – HPA 2010 Review [18, 20].

Table1: Specific features of units in the investigated centre

Hospitals	Model/ Type	Manufacturer	Year of Installation	Filtration (mmAl)	Output (mGy/mAs)
OAUTHC	Silhouette	G.E Haulum Medical system	2010	2.7	0.061
OAMH	LEXRAY 500	R. Liecati A. G R. Liecati A. E	2013	3.0	0.065
UTH	Allengers	NA	2012	2.5	0.035
FMC	Giladonia Ri05	Ralco	2013	2.0	0.0347
ADC,	Ketron 300	Kehrli Rontgen Inc.	2013	2.5	0.048
CH	Siemens	Siemens Healthineers USA	NA	3.0	0.034
LTH	Toshiba Rotande	Toshiba medical system	2014	2.5	0.032
UBTH	RAD-12 G.E	General Electric Company	2010	1.6	0.068

NA – Not Avaliable

Table 2: The results of Quality Control test of the X - ray units

Parameters	Measurements	Acceptable Limits	Hospitals							
			LTH	OAUTHC	UTH	UBTH	FMC	OAMH	CH	ADC
KVp	Accuracy kVp	≤±5%	0.32	0.96	0.84%	0.52	0.65	0.75	0.78	0.85
	Reproducibility %	≤±5%	0.14	0.48	0.42%	0.25	0.45	0.58	0.65	0.53
	Consistency %	≤±10%	0.30	0.95	0.85%	0.50	0.64	0.45	0.75	0.74
Exposure	Accuracy %	≤± 10%	0.30	0.50	0.50%	0.96	0.65	0.76	0.05	0.45
Time	Reproducibility	≤ 0.05	0.03	0.03	0.03	0.04	0.03	0.04	0.03	0.03
Output	Linearity	≤0.10	0.07	0.09	0.04	0.06	0.08	0.06	0.05	0.07
	Reproducibility	≤ 0.05	0.04	0.04	0.02	0.03	0.04	0.03	0.04	0.03
Remarks			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

It can be seen from Table 2 that the X –ray machine at these hospitals were performing self consistently when the quality control results were compared with standard recommended by the American Association of Physicists in medicine [16].

Table 3 shows, summaries of the mean and range of the patient's age, patient's weight, focus – to – film (FFD), tube potential (kVp), and tube load (mAs) . The FFD employed in this hospital are in agreement with criteria except in few cases where FFD were outside the stipulated ranges. PA examinations the FFD as low as 100.0cm was used instead of the FFD of 140.0 – 200.0cm with mean FFD of 180.0cm recommended by European Commission for quality radiography [18]. For other projections the FFD of 100.0 – 150.0cm with mean value of 115.0cm were recommended but not totally adhered to by the hospital. The use of optimum FFD is considered very important since a direct relationship between shorter FFD, higher patients' dose and decreased geometric sharpness is well established [21, 22]. Some of the kVp employed in this hospital are comparable with the NRPB – HPA UK – 2010 review [20] especially in abdomen AP the kVp in UK – 2010 survey ranges between 60 and 94 with mean kVp of 76 and in OAUTHC the kVp employed ranges between 70 and 81 with mean value of 75. Although there is no consensus among radiologist regarding the appropriate tube potential to be used, both high and low tube potential techniques are commonly used in radiographic examinations [23]. The commission of European communities recommended an applied voltage in the range of 125 kVp [24] but in many hospitals lower tube potentials of 60 kVp – 90 kVp are used [25].

Table 3: Patients' information exposure parameters for eight routine examinations mean values and range in all X – ray units in this study

Examinations	Projection	No. of Patients	Patient Age mean (range) (years)	Patient weight mean (range) kg	FFD mean (range) (cm)	kVp mean (range)	mAs mean (range)	KVp UK Hart et al (2012)
Chest	PA	276	42 (20-80)	67 (67-72)	149 (90-182)	69 (57-80)	25 (10-40)	88(65-125)
Abdomen	AP	75	63 (49-79)	70 (68-72)	124 (70-131)	81 (80-81)	49 (40-64)	76(60-94)
Pelvis	AP	74	42 (19-70)	69 (68-84)	118 (80-124)	75 (55-81)	40 (25-63)	75(62-92)
Pelvis	LAT	64	40 (19-70)	68 (69-72)	115 (80-125)	73 (60-81)	36 (10-50)	NA
Skull	AP/PA	60	38 (30-45)	71 (70-74)	112 (70-153)	74 (70-80)	38 (32-40)	72(69-83)
Skull	LAT	56	39 (30-46)	70 (61-74)	110 (70-150)	72 (63-85)	28 (25-32)	NA
Lumbar Spine	AP	58	75 (38-90)	67 (60-75)	117 (90-160)	78 (73-96)	91 (40-125)	78(65-109)
Lumbar Spine	LAT	57	75 (38-90)	67 (60-75)	114 (90-130)	90 (81-96)	110 (64-125)	NA

Table 4 shows the mean ESD, the mean ESD ranged from 0.13 mGy to 0.68 mGy for chest PA, it ranged from 1.01 mGy to 17.20 mGy,1.08 mGy to 16.16 mGy, 1.15 mGy to 10.06 mGy, 1.14 mGy to 6.42 mGy, 1.11 mGy to 4.71 mGy, 1.67mGy to 12.65 mGy, and 1.91 mGy to 14.26 mGy for abdomen AP, pelvis AP, pelvis LAT, skull AP/PA, skull LAT, lumbar spine AP and lumbar spine LAT respectively. From the Table, it can be seen that there are wide variations on the ESD values for the same type of projections in different X – ray units. The variations in the ESD values are due to patient sizes, radiographic equipment used and most especially the radiographic technique adopted

Table 4 :Mean ESD (mGy) for each X – ray units in the study

RADIOGRAPH PROJECTION	HOSPITALS							
	OAUTHC	UTH	CH	FMC	LTH	OAMH	ADC	UBTH
Chest PA	0.67	0.47	0.71	0.37	0.17	1.97	0.82	0.56
Abdomen AP	2.59	1.24	17.20	1.32	1.01	4.97	4.04	1.88
Pelvis AP	2.25	1.08	16.16	1.52	1.33	3.28	1.97	1.92
Pelvis LAT	2.24	1.15	10.06	1.87	1.25	3.39	1.78	2.21
Skull AP	2.36	1.14	6.42	0.88	1.19	3.65	2.13	1.89
Skull LAT	1.67	1.52	4.71	1.11	1.07	3.24	2.26	1.42
Lumbar Spine AP	5.02	2.71	12.65	5.73	1.67	4.03	4.39	2.31
Lumbar Spine LAT	6.89	3.33	14.26	3.02	1.91	2.34	4.86	4.04

by the radiographer.

Table 5 show the mean effective dose estimated from ESD in all units investigated under this study. For chest PA the mean effective dose value ranged from 0.02mSv at LTH to 0.09mSv at CH while for abdomen AP the mean value ranged from 0.04mSv at LTH to 2.82mSv at CH. For pelvis projection the mean value ranged from 0.17mSv at UTH to 2.96mSv at CH for AP projection while mean ranged from 0.15mSv at UTH to 1.84mSv at CH for LAT projection. Skull AP mean ranged from 0.01mSv to 0.13mSv at OAUTHC and UTH respectively. The skull LAT, the mean ranged from 0.01 at OAUTHC and LTH to 0.09mSv at FMC. For limber spine AP, the mean ranged from 0.10mSv at UTH to 2.15mSv at CH while the lumbar spine LAT, the mean value ranged from 0.10mSv at UTH to 0.17 at ADC.

The inter-comparison of results obtained in the present study with other previous studies show that the value of the mean effective dose obtained at LTH for Chest PA is comparable with the value estimated in NRPB [26] and similar study in Canada [7] while other hospitals have higher value than what obtained in NRPB and Canada (see Table 6).

For Abdomen AP and Pelvis AP, only CH have greater value of mean effective dose than what obtained in NRPB 1997 [26] but all the other units have mean effective dose higher than what obtained in Canada survey in 2013 [7]. For Skull AP, OAUTHC, CH, FMC and OAMH have higher value of mean effective dose when compared with corresponding value obtained by NRPB and in similar study in Canada, but comparable with the value obtained in other units considered in the

Table 5: Summary of mean effective dose for the examinations

RADIOGRAPH PROJECTTION	HOSPITALS Mean Effective Dose (mSv)							
	OAUTTHC	UTH	CH	FMC	LTH	OAMH	ADC	UBH
Chest PA	0.06	0.05	0.09	0.04	0.02	0.22	0.08	0.05
Abdomen AP	0.30	0.16	2.82	0.23	0.04	0.70	0.47	0.22
Pelvis AP	0.32	0.17	2.96	0.22	0.20	0.58	0.29	0.29
Pelvis LAT	0.33	0.15	1.84	0.28	0.19	0.59	0.27	0.33
Skull AP	0.13	0.01	0.09	0.08	0.01	0.06	0.02	0.02
Skull LAT	0.01	0.07	0.05	0.09	0.01	0.05	0.02	0.01
Lumber SpineAP	0.62	0.10	2.15	0.64	0.18	0.45	0.58	0.24
Lumber Spine LAT	0.22	0.10	0.04	0.08	0.05	0.14	0.17	0.11

Table 6: Comparison between the mean effective dose values (mSv) obtained in this work with those from other studies

RADIOGRAPH PROJECTTION	HOSPITALS Mean Effective Dose (mSv)								NRPB[a] 1997	CANADA[b] 2013	NIGERIA 2016
	OAUTTHC	UTH	CH	FMC	LTH	OAMH	ADC	UBH			
Chest PA	0.06	0.05	0.09	0.04	0.02	0.22	0.08	0.05	0.02	0.02	0.42
Abdomen AP	0.30	0.16	2.82	0.23	0.04	0.70	0.47	0.22	0.70	0.14	1.82
Pelvis AP	0.32	0.17	2.96	0.23	0.20	0.58	0.29	0.29	0.70	0.16	0.52
Pelvis LAT	0.33	0.15	1.84	0.28	0.19	0.59	0.27	0.33	-	-	-
Skull AP	0.13	0.01	0.09	0.008	0.01	0.06	0.02	0.02	0.03	0.02	0.14
Skull LAT	0.01	0.07	0.05	0.09	0.01	0.05	0.02	0.01	0.01	0.007	-
Lumber SpineAP	0.62	0.10	2.15	0.64	0.18	0.45	0.58	0.24	0.70	0.38	0.66
Lumber Spine LAT	0.22	0.10	0.04	0.08	0.05	0.14	0.17	0.11	0.30	0.13	-

study. For Skull LAT the mean effective dose obtained at FMC is greater than what obtained in both NRPB and Canada but the values obtained in other hospitals are comparable with that of NRPB and similar study in Canada. For Lumbar Spine AP, the value of mean effective dose obtained in CH is higher than value obtained NRPB and Canada while the values that obtained in all other units are comparable with what obtained in both NRPB and similar study in Canada. For Lumbar Spine LAT, the values of mean effective dose obtained were comparable with what obtained in NRPB and in similar study in Canada. When compared with similar study in Nigeria, the mean effective dose values obtained in Abdomen AP, Pelvis AP and Lumbar Spine AP were comparable with what obtained by Jibiri and Olowookere [27] but the values were relatively lower than what reported in skull AP. These results are indication that reasonably low doses could be obtained in Nigeria without losing the diagnostic information if appropriate corrective measures are put in place.

4.0 Conclusion

Monitoring and controlling patient doses during X –ray examinations procedures is of utmost importance to successive reduction of radiation doses. Optimization of diagnostic X - ray examinations can only be achieved by regular assessment of imaging procedures. The results obtained in this study represent the current state of practice of diagnostic X – ray examinations in most X – ray centers in Nigeria. The large variation of patient dose values for the same type of examination among the hospitals could be attributed to the experience of each imaging personnel, each X – ray machine performance, expected image quality, size of the patients and the nature of the film – processing chemicals. It also shows that substantial dose reduction is possible without compromising image quality.

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References

[1] ICRP (1996): Radiological protection and safety in medicine. Recommendations of the International Commission on Radiological Protection. ICRP publication 73. Oxford and New York. Pergamon Press.

[2] UNSCEAR (2000): United Nation Scientific Committee on the Effect of Atomic Radiation: Report to the General Assembly: Medical Radiation Exposure. New York .United Nations.

[3] Muhogora W. E, Ahmed N. A, Almosabihi A, Alsuwaidi J. S, Beganovic A, Ciraj-Bjelac O, Shandorf C.(2008) Patient doses in radiographic examinations in 12 countries in Asia, Africa, and Eastern Europe: initial results from IAEA projects. AJR Am J Roentgenol. 190(6):1453–1461. http://dx.doi.org/10.2214/ajr.07.3039 . [PubMed]

[4] Ajayi I.R.; Akinwumiju A (2000) Measurement of entrance skin dose to patients in four common diagnostic examinations by thermoluminscence dosimetry in Nigeria. Radiat. Prot. Dosim. 87: 217-220. ICRP.

Radiological protection in medicine. ICRP publication 105. Ann ICRP.2007; 37(6).

[5] Johnston D. A. and Brennan P. C. (2000): Reference Dose Levels for Patients Undergoing Common Diagnostic Examination in Irish Hospitals. Br. J. Radiol. 2000; 73 & 396 – 402.

[6] Jones D. G, & Wall B.F (1985): Organ Doses from Medical Examinations using Monte Carlo techniques. NRPB Report.NRPB D-186.

[7] ICRP (2007): Radiological protection in medicine. International Commission for Radiological Protection publication 105. Ann ICRP. 37(6).

[8] Osei E. K & Darko J. A (2013): Survey of organ equivalent and effective doses from diagnostic radiology procedures. ISRN Radiol. 2013:204346. http://dx.doi.org/10.5402/2013/204346 . [PMC free article] [PubMed]

[9] Akbar Aliasgharzadeh, Ehsen Mihamdost and Mehran Mohseni (2015): Measurement of entrance slain dose and calculation of effective dose for common diagnostic X ray examinations in Kashan Iran Global Journal of Health Science. 7(5) 202 -207 [pmc free article].

[10]Darrel R. Fischer and Frederic H. Faley (2017): Appropriate use of effective dose in radiation protection and risk assessment Health Physics. 113(2): 102-109 [HHS Public Access]

[11]Jones D. G, Wall B.F.(1985): Organ doses from medical examinations using Monte Carlo techniques. NRPB Report. NRPB D-186 –

[12]Hart D, Jones D.C, Wall B.F.(1991): Normalised organ doses for medical X – ray examinations calculated using monte carlo techniques. Tech. Rep. NRPB – SR262, Chilon, NRPB.

[13]McCollough C H, Christner J.A, and Kofler J.M. (2010): "How effective is the effective dose as a predictor of radiation risk?" American Journal of Roentgenology, 194(4), 890 – 896.

[14]Chan C.T & Fung K. K (2015): Dose optimization in lumbar spine radiographic examination by air gap method at CR and DR systems: A phantom study. J Med Imaging Radiat Sci. 46: 65-71.

[15]Welander U & Wickman G (1978): Mean Energy Imparted in Relation to the Focus to Object Distance. Acta Radiol Diagn (Stockh). 19:1014-24.

[16]AAPM (2002): American Association of Physicists in Medicine: Quality Control in Diagnostic Radiology. AAPM Report No. 74. Madison: Medical Physics Publishing..

[17]Hart, D; Jones, D. G and Wall B. F (1994): Estimation of effective dose in diagnostic radiology from entrance surface dose – area product measurements. NRPB Report, NRPB – R262.

[18]European Commission(1990): Quality criteria for diagnostic radiographic images. working document cec xii/173/90.2nd edition. Commission of European Communities.Bruxelles.1990.

[19]Jibiri N. N., Olowookere C. J. (2016): Patient Dose Audit of the Most Frequent Radiographic Examinations and the Proposed Local Diagnostic Reference Levels in South-Western Nigeria: Imperative for Dose Optimization. Journal of Radiation Research and Applied Sciences. 9: 274 – 281

[20]Hart D, Hillier M, Shrimpton P (2012): Doses to patients from radiographic and fluoroscopic X-ray imaging procedures in the UK-2010 review. HPA CRCE-034.

[21]Vano E; Olite S; Gonzalez L; Guibelade E;Velasco A and Fernandez J. M (1995): Image quality and dose in lumbar spine examination: results for 5 years quality control programme following European quality criteria trial. Br. J. Radiol. 68: 1332 – 1335

[22]Brenner D, Huda W (2008):. Effective dose: a useful concept in diagnostic radiology. Radiat Prot Dosimetry. 128 (4):503–508. http://dx.doi.org/10.1093/rpd/ncn056 . [PubMed]

[23]Mark F. M., Brennan P. C. and Connor G. O (2004): The effect of tube potential on the image quality of PA chest radiographs when using digital image acquisition devices. Radiography 10:287 – 292.

[24]European Commission (1990): Working document on quality criteria for diagnostic radiographic images, CEC XII/173/90 (June 1990).

[25]NRPB (2002): National Radiation Protection Board. Doses to patients from medical examinations in the UK: 2000 Review, Chilton NRPB –W14.

[26]NRPB (1997): National Radiation Protection Board. Radiation protection and dosimetry for patients in diagnostic radiology in the UK NRPB Chilton, Didcot, Oxon, OX11 ORQ UK.

[27]Jibiri .Nnamdi N. and Olowookere Christopher J. (2016): Evaluation of dose – area product of common radiographic examinations towards establishing a preliminary diagnostic reference levels (PDRLS) in Southwestern Nigeria. Journal of Applied Clinical Medical Physics 2016; 17 (6): 392 – 404.