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Evaluation of Repeat Analysis and Dose Burdens of Patients Examined in the Radiology Department of a Medical University Teaching Hospital in Nigeria

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ABSTRACT: The objectives of this study was to examine the repeated examinations carried out and dose burdens of patients examined in the radiology department of a tertiary institution teaching hospital in Nigeria. A standard daily record keeping method (accepted and rejected films compiled by Radiographers) was used to collect data after viewing by a Radiologist. Raw data collected were sorted with the aid of Tally Chart. Descriptive statistics was employed to analyze the data collected with the help of Excel software. The specific repeat rates (SRRs) for different examinations are as follows: chest PA (CXR-6.68 %); lumbosacral (LS-10.90%); skull/head (S/H-15.08 %); abdomen (ABD-12.97 %); pelvis/hip (PE/H-7.77 %); cervical spine/neck (SP/NK-5.56 %); thoracic spine (TS-7.14 %); extremities (EXT-1.64 %); shoulder joint (SHJ-2.22 %); knee joint (KNJ-2.99 %); elbow joint (ELB-2.53 %); ankle joint (ANK-2.77 %); and hysterosalpingography (HSG-7.35 %). The highest causal reject rates (CRRs) was found to be as a result of under-penetration (34.3%) in this study. This is followed in succession by over-collimation (22.90 %) and processing artifact (20.50 %). The excessive population doses of the exposed patients resulting from repeats for some examinations are: chest PA (CXR-103.60 mGy); lumbosacral AP (LS-23.00 mGy); skull/head PA (S/H-71.10 mGy); abdomen AP (ABD-33.48 mGy); thoracic spine AP (TS-2.52 mGy); shoulder joint AP (SHJ-1.89 mGy); knee joint AP (KNJ-2.00 mGy); ankle joint AP (ANK-0.76 mGy); hysterosalpingography (HSG-1.95 mGy). The selected exposure parameters could also be examined and adjusted to prevent under-penetration.

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Diagnostic investigation using ionizing radiation offers significant benefits to patients and is acceptable in medical practice. The desired goal of diagnostic imaging is the creation of acceptable image that can help in diagnosis. An attempt to achieve this is not without its attendant risks. The inherent risk is as a result of radiation doses deposited in the tissue and organs during the examination. These arise from the interaction of radiation with the body through Compton or photoelectric effects. During the interaction of photon energy with the tissue, ionization takes place and strands of DNA may be broken, and this could lead to immediate or late effects- hereditary effects (Lee *et al*., 2010). One of the key factors in dose reduction is quality management program. This helps to minimize the risk of obtaining sub-quality images. Quality management program includes examination of final outcomes of imaging procedures (quality of image and appropriate diagnosis) and determination of the quality of the outcome to see if further improvement can be achieved (Papp, 2002). Some of the steps involved in outcome assessment include a repeat analysis of images, artifacts analysis of images and accuracy, and specificity analysis of the diagnosis. It is important to ensure that the dose burden of a patient and extra cost of imaging are reduced. These can be achieved through elimination of any input or any activity leading to excessive patient dose and extra costs. One of the ways to achieve these is to undertake repeat analysis. This involves a sequential process of selecting and arranging the rejected film according to the causes of rejects during imaging and film processing. Regular repeat analysis helps to reduce or eliminate its future occurrence, and hence prevents extra expenses, patient dose and workload of personnel. It may be difficult to avoid

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rejects because of different factors responsible (positioning, overexposure, underexposure, patient motion, artifacts and film processing) for it, however it is important that reject rates be kept very low -not greater than 10 % (CRCPD, 2009). Radiological Department with repeat rates exceeding 10% to 12% should be examined seriously because the department is inefficient and contributes to patient doses (Papp, 2002), and could be said to be wasteful in the use of departmental resources. An objective repeat analysis is required to enhance a better and effective performance of Radiology Department of any hospital. Asides the financial implication of rejects on the budget of radiology department, increase patient and personnel occupational doses could result in detrimental effects. A patient undergoing diagnostic imaging is expected to get better service (health) from the examination that will lead to better treatment and good health conditions. Unfortunately, as a result of increased patient dose burden resulting from repeated examination(s), the patient is exposed to additional detrimental effects in spite of the justification for the imaging procedure. The incurred health effect could lead to extra burden on the family or organizational budget in an attempt to manage the detrimental effect arising from the immediate or late effect of excess exposures. After a practice has been justified by a cost-benefit analysis, the radiation exposure of individuals and population resulting from that practice should be examined based on the principle of dose optimization. The results of repeat analysis is one of the tools that can aid in dose optimization. This stems from the fact that repeat analysis exposes the culprit responsible for substandard image quality. It therefore becomes a major parameter for quality control in diagnostic radiography service delivery (Arbese *et al*., 2018). The objective of this study was to assess the repeat analysis and dose burdens of patients examined in the radiology department of a tertiary institution teaching hospital in Nigeria.

MATERIALS AND METHODS

This study was carried out in a Tertiary Institution Teaching Hospital in Southwestern Region of Nigeria. The Hospital has the following staff: Radiologist (7); Radiographer (7); Darkroom Technician (6). Both pediatric and adult patients' data were considered in the study and the following radiographic views were examined: chest (CXR); abdomen (ABD); pelvis/hip (PE/H); thoracic spine (TS); lumbosacral joint (LS); elbow joint (ELJ); extremities (EXT); knee joint (KNJ); shoulder joint (SHJ); spine/Neck (SP/NK); hysterosalpingography (HSG); and ankle joint (ANK).

Various types of film sizes used at the Tertiary Institution Teaching Hospital include: 35 x 43 cm; 24 x 30 cm; and 18 x 24 cm films. The number of rejects were sorted from those put aside during viewing and marked for repeats. These were recorded in worksheets designed for the purpose of keeping tracks of the number and types of rejects. Manual method was used to sort out the total number of examinations carried out during the period of the study from the register of patient who were referred to the department for the period considered in this study. These were collated for further sorting and calculation by both Radiologists and Radiographers in charge. Reason for the rejects was also recorded against each one of them.

Quality Control Test (QCT): The quality control (QC) tests were carried out on the machine to ensure that the units in the department meet the required standard of exposure and it is not leaking (not faulty). This was necessary because a faulty machine might affect the image quality and leads to repeat examinations. Radiation output (mGy/mAs) and kVp value (mean, effective, maximum and minimum values) were measured to ensure that they comply with the acceptable values. Half value layer of the machine was also measured by using 1 mmAl filter and calibrated KV meter (DIAVOLT UNIVERSAL).

*Method of Analysis of Repeat Rates***:** The causal repeats rates and the total repeat rate were calculated by using equation (1) and equation (2) respectively.

$$C_R(\%) = \left(\frac{N_{RS}}{T_R}\right) 100 \qquad (1)$$

Where C_R= causal repeat rates (the percentage of repeats from a specific cause such as positioning error or technique); N_{RS} = number of repeats for specific cause and T_R = total number of repeats;

$$T_{RC} = \left(\frac{N_{RF}}{T_V}\right) 100 \qquad (2)$$

Where T_{RC} = Total repeat rates, N_{RF} = number of repeat films, and T_V = total number of views observed. Several factors influence the repeat rates, these include technical competence of personnel (Radiographers, Darkroom Technicians), quality of film processing material, population of patients examined, and Radiologist viewing ability and decision. To this end, the rejected films are classified according to the reasons for the rejects.

Financial Implication of Repeats: **T**he cost implications of repeats during the period under investigation was calculated by using equation (3)

$$C_f = \sum N_{i,j} P_{i,j} \qquad (3)$$

Where $N_{i,j}$ is the total number ($j = n$) of a particular type ($i = 3$) of film, and $P_{i,j}$ is the price of a specific type of film. Also, C_f is the cost of films used for the repeated examinations.

Extra Dose Burden for Patient: The additional dose burdens of patients resulting from repeated examinations were determined from the machine output (mGy/mAs) measured at a distance of 100 cm at a tube potential of 80 kVp, tube load of 10 mAs and selected machine parameters. Backscatter factors of 1.35 (adult) and 1.30 (children) were used for dose calculation. The output was measured during the QC tests. Dose calculation method (Davies *et al*., 1997) adopted in this study has been proved to be effective in dose estimation. The total dose calculated was obtained from the mean dose calculated during quality control test and equation (4),

$$D_T = \sum_{j=1}^{N} D_{m,j} \qquad (4)$$

Where D_T = total dose burden for a specific examination, j = 1, 2, 3………N and D_m is the mean dose per film used for repeated examination.

RESULTS AND DISCUSSION

Table 1 is the result of the distribution of staff in the Radiology Department of the University Teaching Hospital investigated in this study. Table 1 shows that two team members (Physicist and Engineer) of radiological crew are missing in the department investigated in this study. This has been identified in the earlier work of Olowookere *et al.,* (2008). The missing components are responsible for quality control test/quality assurance, calibration and repairs of the machine. This is an indication that the missing roles of the two components might affect the quality assurance of the department, and could lead to additional dose burden of patients. Additional costs could also result from the processing of repeated examination films arising from suboptimal images. In Nigeria, there are few Medical Physicist (those available are in academics or in certain Teaching Hospitals) and very few equipment for quality control tests. As a result, it is very difficult to regularly carry out quality control tests. Table 2 is the range of value of exposure parameters selected during routine examination at our institution. Table 3 indicates the number of repeats for specific projection and the total number of views taken within the period of this investigation. It is evident from the table that the examination with the highest frequency is the chest x-ray (CXR-2125) and the corresponding repeated examinations is 142. This is closely followed by extremities examination (EXT). Table 2 shows a comparison of the exposure parameters selected for different examination. The result shows that the tube potentials (kVp) selected in this study are within the range of value used in UK [Hart *et al.*, 2010] in chest AP (CXR), lumbosacral AP (LS), skull AP (SH), abdomen AP (ABD), pelvis/hip AP (PE/H), thoracic spine AP (TS), shoulder spine (SHJ), and knee joint AP (KNJ) examinations. Similarly, the tube loads used in this study fall within the range selected in the UK report. Data of UK have been reviewed many times over the years. The trend in this study does not indicate the best practice, but rather it shows compliance with a standard value set by regulatory body after a series of reviews.

Table 1 Distribution of personnel at Radiology Department of the Hospital

Personnel	Radiologist	Radiographer	Physicist	Darkroom/ Technician	Engineer	Record Officer
No. of Staff	7	7	--	6	--	6
No. Qualified to Practice	7	7	--		--	6
No. on fulltime	7	5	--	6	--	6
No. on training	-	--	--	--	--	--

Table 2. Range of tube potential (kVp) and tube load (mAs) used for different examinations

Exam	CXR	LS	S/H	ABD	PE/H	SP/NK	TS	EXT	SH J	KN J	ELB	ANK	HSG
Range (kVp)	62-88	55-81	60- 92	60-80	50-80	--	65-75	--	52-75	50-68	--	50-65	68-90
(UK Value)	(65-125)	(65-109)	(69-83)	(60-94)	(62-90)	--	(65-102)		(58-69)	(52-68)	--	--	--
Range (mAs)	10-32	11-32	28-50	11-32	13-36	--	11-28	--	6-40	5.8-11.4	--	5-11	10-48
(UK Value)	(0.3-05)	(1-556)	(1-100)	(1-246)	(1-400)	--	(1-403)		(1-100)	(1-125)	--	--	--

Figure 1 shows the repeat rates for thirteen (13) different examinations considered in this study. The figure shows that the specific repeat rates ranged between 1.64 % (extremities) and 15.08% (skull). Table 4 is the identified reasons for departmental repeats in this investigation. The table indicates that under-penetration (124), over collimation (83) and the processing artifact (74) are the major culprits in succession leading to repeats in the study. Table 5 is the result of additional dose burden resulting from the repeat of examinations.

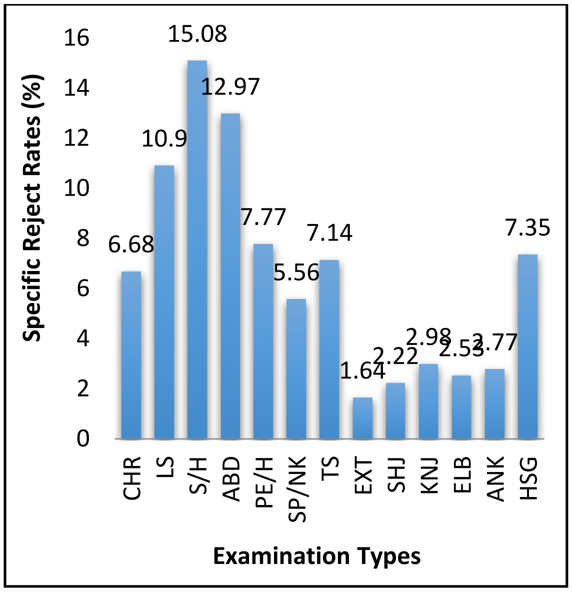

Fig 1: A plot of specific Reject Rates against Examination types

The entrance surface dose (ESD) ranges from 0.76 mGy (ankle joint- ANK) to 103.66 mGy (Chest-CXR). Radiation doses were calculated from the machine output (mGy/mAs) measured during the quality control test of the facility and exposure parameters (kVp, mAs) of the machine selected during routine examinations. Table 6 is the result of analysis of film types used, total number of films used, films used for repeated examinations, the amount (in local and foreign currencies) spent on the films used for repeated examinations. Source(s) of films used and the models are also presented in Table 6. Table 3 shows the total number of views and repeats for different examinations. The total repeat rate (as shown in the last row of Table 3-5.71%) fall within 4 to 6 % set by Federal Regulatory body (Papp, 2002) and a little above 5% recommended by World Health Organization (WHO, 1982).

This is lower than the value reported in Ethiopia (Arbese *et al*., 2018), Nigeria (Erinoso *et al*., 2017) and Ghana (Owusu- Banahese *et al.*, 2014). The repeat rate recorded in this study might not pose any cause for concern, however it is important for the department to be cautious during the imaging process. Causes of total repeat rate are multifactorial. These include the quality of equipment, quality assurance program of the department, expertise of the technical staff, viewing ability of Radiologist and population of patients examined. It is essential to note that the viewing ability of a Radiologist is subjective.

Table 3. Total number of views and Specific Repeat

Exam.	No. of Repeats for Specific Projection	Total number of views (TNV)
CXR	142	2125
LS	46	422
S/H	30	199
ABD	31	239
PE/H	38	489
SP/NK	19	342
TS	3	42
EXT	28	1709
SH J	3	135
KN J	10	334
ELB	2	79
ANK	4	144
HSG	5	68
Total	361	6327 (5.71%)

Table 4. Distribution of Causal Repeats rates among causal factors

Cause of Repeats	CXR	LS	S/H	ABD	PE/H	SP/NK	TS	EXT	Sh J	KNJ	EL	ANK	HSG	Specific Causes Total	Causal Repeat Rates (CRR) %
Over Co	31	12	9	13	12	3	0	0	0	1	0	2	0	83	22.9
Under pen	45	13	12	14	10	6	1	13	2	5	0	2	1	124	34.3
Rotation	12	0	0	1	1	0	0	0	0	0	0	0	0	14	3.9
Proc. Artifact	40	14	2	1	7	4	1	4	1	0	0	0	0	74	20.5
Poor In	4	0	0	0	0	0	0	0	0	0	0	0	0	4	1.1
Skin Ar	1	1	0	0	0	0	0	0	0	0	0	0	0	2	0.6
Poor Po	7	5	6	1	5	5	0	10	0	4	2	0	0	45	12.5
Motion Blur	1	0	0	1	0	0	1	1	0	0	0	0	0	4	1.1
Over Pe	1	0	0	0	2	1	0	0	0	0	0	0	0	4	1.1
Over ex	0	1	1	0	1	0	0	0	0	0	0	0	0	3	0.8
Poor Te	0	0	0	0	0	0	0	0	0	0	0	0	4	4	1.1
Total	142	46	30	31	38	19	3	28	3	10	2	4	5		

Over Co –over collimation; Under pen –under penetration; Rotation; Proc. Artifact -processing artifact; Poor In- Poor; Inspiratory effort; Skin Ar. Skin artifact; Poor Po – Poor part positioning; Motion Blur; Over Pe – Over penetration; Over exp.- Over exposure; Poor Te - Poor Technique.

Table 5. Examination types and total dose burden due to repeated examination

Examination	**No. of Repeats**	**Total dose (D_T) (mGy)**
CXR	142	103.60
LS	46	23.00
S/H	30	71.10
ABD	31	33.48
PE/H	38	DNA
SP/NK	19	DNA
TS	3	2.52
EXT	28	DNA
SH J	3	1.89
KN J	10	2.00
ELB	2	DNA
ANK	4	0.76
HSG	5	1.95

DNA= Data not available

Table 6. Analysis of financial implication of repeats

Film sizes used (cm)	Price per film =N= ($)	No of films used for all views (No. used for repeats)	Amount spent on films for all views =N= ($)	Amount spent on repeat =N= ($) (Source(s) of film)
35 x 43	400 (0.79)	3385 (265)	1,354,000 (2,691.8)	106,000(210.7) Fu/Pr)
24 x 30	390 (0.76)	2600 (77)	1,014, 000 (2,015.9)	30,030(59.7) (Fu/Pr)
18 x 24	250 (0.49)	342 (19)	85,500 (164.9)	4,750 (9.4) (Fu/Pr)
Total		6327 (361)	2, 453,500 (4,877.6)	140, 780 (280.1)

Fu/Pr = Fuji /Primas films

This is dependent on the ability of the Radiologist to recognize pattern, and this varies from one person to another and is premised on the judgment of each person. Certain reasons for rejecting a films may not be adequate because a film deemed to be of poor quality and rejected by an individual may be accepted by another viewer as a good one. Consequently, certain institutions have decided to classify the films in the following grades (i) acceptable without reservation (ii) acceptable with some reservation and (iii) reject quality (Rehani, 1995). The grading method was found to be effective in daily practice in India. In order to quantify the quality of film and to be more objective, a parametric scoring approach has been developed which involves physical criterion, anatomical criterion and overall score (each is based on scale of 100) as reported in Rehani (1994). The specific repeat rates (SRR) as shown in Figure 1 indicates that it ranged between 1.64 % (EXT) and 15.08 % (SKH). The highest specific repeat rates (SRR) was recorded in SKH (15.08 %) examination. This could be as a result of under penetration (causal repeat rates-CRR) as shown in Table 4. The underpenetration could be as a result of poor selection of adequate exposure factors for SKH. Additionally, the nature of the skull bone and its composition calls for care in the selection of the parameter during imaging process to obtain quality image. In this study the range of tube potential and tube load selected are: 60-92 kVp and 28-50 mAs respectively. The range of mean exposure factors used during SKH in UK [Hart *et al.*, 2010] are 72(62-83) kVp and 20 (1-246) mAs respectively. It implies that the value recorded in this study fall within those found in the literature (UK-HPA-CRCE-034). However, the value of filtration used in the document of HPA (UK) cannot be less than 2.5 mm Al as against a lower (0.9 mmAl /75) value used in the machine investigated in this study. This could be the source of under-penetration since filters remove low energy photon that are not used for image production, but contribute to patients' exposures.

The specific repeat rates (SRR) of ABD AP and LS AP follow closely behind that of SKH AP with value of 12.97 % and 10.90 % respectively. Factors responsible for high repeat rate of ABD are collimation and under-penetration. It is also evident from Table 4 that three prominent factors leading to the 10.90 % repeat rates in LS AP are: over collimation, under-penetration and processing artifact. Figure 1 shows that SHJ (2.22%), KNJ (2.98 %), ELB (2.53 %) and ANK (2.77 %) fall within the same repeat rates in our institution. Extremities (EXT) has the lowest repeat rate of 1.64 %.

The most frequently carried out examination in this study is CXR. This is closely followed by (EXT). The reason for this trend could be attributed to complications arising from lung diseases and automobile accidents among young persons who use motorbike for commercial purposes in Nigeria. Since some specific examination repeat rates (CXR, LS, SKH, ABD, PE/H, TS and HSG) are relatively higher than the recommended value, it is proposed that corrective measures be undertaken to reduce the repeat rates. This will reduce the excess dose burden, cost of films, and save time of personnel if carried out. It should be noted that the dose burden of HSG is four times (7.80 mGy) as much as the one reported in this study (1.95 mGy). This is because an average of four exposures are required during an HSG procedures. This is a relatively higher dose. Table 4 shows that under-penetration (34.3%) is the most pronounce causal repeat rates (CRR). This is followed by over-collimation (22.9 %) and processing artifact (20.5%). The result in Table 5 shows the excessive dose burden calculated from the exposure parameters and machine output. The dose burden calculated could be said to be a function of number of exposures, therefore chest has the highest excess dose of 103.60 mGy. Although LS has a larger number of repeat exposures than the SKH, its dose burden is higher than that of LS by a factor of 3.1 units. This could be attributed to the higher mean dose obtained from SKH. The higher dose must have arisen from the tube loads used during examination (Table 2 in the range of 28-50 mAs) during examinations. The density of skull bone requires higher tube load to allow more penetration of photon. The trend of dose burden recorded in the study calls for caution in selecting the exposure parameter that can give quality images and low doses as reasonably achievable. Similar trend as seen in SKH is found in ABD. The extremities population dose recorded in this study indicates that the population is exposed to extra risk that can affect health and finance of the patient, personnel and the caregiver (during imaging). This is the reason ALARA principle should be strictly adhered to. Radiographer should not only be mindful of image quality but take into cognizance the patient dose burden during imaging processes. The result of Table 6 shows the unit price of film, film types used, the total cost and extra cost of film used for repeats. In the study, cost of time spent in repeat exposures, the film processing time and the energy consumed (electricity) are not quantified monetarily. It is only the cost of the film that has been considered in the study. The fifth column shows the extra money spent on repeat examinations for each film type and the total cost. The total cost of purchasing film used during the period is =N= 2, 453, 500 ($ 4, 877.60) and the monetary value of films used for repeats examinations is =N= 140, 780 ($ 280.1). This represents 5.74 % of the actual cost. This is equivalent to three month wages of a junior staff in Nigeria. This amount could be substantial over a period of ten years. Although this appears to be small, if the cost of procuring films is the aspect considered. However, if all the cost of repeats are considered monetarily, this could be significant. It is therefore imperative to retrain both the imaging personnel and darkroom technicians on how to select exposure parameters and positioning patients to obtain quality image and low patient doses. Faulty equipment is another factor that can affect the repeat rates. This should be addressed as soon as such is detected. Regular quality control test is essential to ensure optimal functioning of facilities. In the course of diagnosis, principles such as justification, optimization and dose limitation should be adopted.

Conclusion: Repeat analysis and the attendant dose burden at our institution were examined. It was found that the total repeat rates fall within the acceptable limits. The causal repeat analysis was also conducted and the highest causal repeat is under-penetration. This is followed by over-collimation and processing artifacts in succession. As regards the specific repeats, SKH has the highest SRR. Other examinations with relatively high repeats rates include ABD, and LS. It is expected that personnel would be retrained to further reduce repeat examinations, and management advised to carry out regular quality control tests of facilities.

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