

Film Reject Analysis and Radiation Doses Received by Patients in Selected Hospitals in Southwestern Nigeria

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ABSTRACT

Introduction: A reject rate is the percentage of diagnostic images repeated due to errors during radiological examinations. The present study aimed to evaluate the patient radiation doses and analyze the film reject rate as part of quality assurance program in three diagnostic centers in Nigeria.

Materials and Methods: This study was conducted in three hospitals, namely Federal Medical Center (FMC), General Hospital (GH), and Sacred Heart Hospital (SHH), located in Abeokuta, Ogun State, Southwestern Nigeria. For the purpose of the study, the accepted and rejected radiographs during different X-ray examinations were recorded. A total of 376 rejected and accepted radiographs were evaluated in the three hospitals, and the economic losses due to rejected films were determined. The quality control (QC) tests, which involve kilo voltage (kV), milliamperes seconds (mAs), etc, were carried out on the facilities of two out of three hospitals using Victoreen 6000m QC kits. The results of the QC tests and exposure parameters were used to estimate the patient doses for different examinations carried out during the study.

Results: Based on the results of the study, the SHH had the highest estimated annual loss of \$225, followed by the FMC and GH with annual monetary losses of \$208 and \$166, respectively. In addition, the anteroposterior projection of the lumbosacral spine had the highest mean dose (15 ± 1.64 mGy) in this study, which was observed in the SHH. Additionally, at FMC, all the estimated doses were low.

Conclusion: Regarding the monetary loss and increase in patient dose burden involved in repeated examinations, it is essential to train personnel on the factors leading to repeated exposures.

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Introduction

Viewing of radiographs is a subjective evaluation of image quality to ascertain their suitability for diagnosis. The film reject analysis is an essential component of quality assurance (QA) program in diagnostic radiology [1]. This procedure identifies the weak areas of radiographic and radiological practices, which would help reduce the unnecessary repeats of radiological examinations contributing to the increase in radiation doses to patients. Increase in radiation doses can cause serious harmful effects, such as cancer, in patients. The probability of these effects increases with dose. The film reject analysis may also provide a platform for evaluating the improvements as it allows for the assessment of diagnostic image quality, modification of examination protocols, fulfillment of the need for in-service education, and patient radiation exposure tracking.

The QA program facilitates the investigation of the variation in tube output, potential, and current, as well as the time taken with the set values. This

program allows for checking the consistency of these values when the set values are kept constant. According to the literature, there is a reduction in the reject rate following the introduction of a QA program [2, 3]. These programs are primarily concerned with the maintenance of X-ray imaging equipment at the optimum operational conditions for providing the required diagnostic information. The World Health Organization (WHO) has defined QA as an organized effort by the staffs operating a facility to ensure that the produced diagnostic images are of sufficiently high quality for the provision of diagnostic information at the lowest possible cost and patient exposure to radiation [4].

The establishment of acceptable criteria for the benefits, costs, and risks associated with medical X-rays constitutes the basis for quality management and quality control (QC) mechanisms. The QA in diagnostic radiology involves testing the X-ray machine and the processing chemicals on regular basis to ensure optimum performance within the system [5]. Quality studies in diagnostic radiology are usually applied to X-ray production, detection,

image processing, and image viewing among others. The most efficient QA programs are those in which the patient dose reduction is balanced against the costs of staff time, material, and equipment [6, 7].

With this background in mind, the present study was conducted to perform a film reject analysis, determine the cost implications of the rejects, and estimate radiation doses delivered to the patients during all X-ray examinations implemented within the research period in selected hospitals in Abeokuta, Ogun State, Nigeria.

Materials and Methods

This study was carried out in three hospitals located in Abeokuta, Ogun State, Southwestern Nigeria. The radiological centers included in the study were Federal Medical Center (FMC), General Hospital (GH), and Sacred Heart Hospital (SHH) in Idi-Aba, Ijaiye, and Lantoro, respectively. These centers are typical of the radiological centers in Nigeria. There were no permanent radiographers in SHH, while the technologist available in this center had a diploma in science laboratory technology. The visiting radiographer came twice a week. There was also no radiologist in this center; as a result, most of the decisions on repeated X-ray examinations were solely based on the technologist's discretion on the film, when the visiting radiographer was absent.

At FMC, qualified radiographers, radiologists, and dark room technicians were present. At GH, there was no radiographer as the technologist played the role of a radiographer; however, the hospital had a visiting radiologist who came three times a week. For the purpose of the study, the model as well as the manufacture and installation years of the X-ray machines were recorded during the investigation. Table 1 presents the equipment information of the investigated hospitals regarding the year of manufacture, model of machines, and year of installation. The age of manufacture ranged within 7-28 years. The effects of age on the output of X-ray machine have been adequately documented [8, 9].

The film evaluation was carried out within a period of three months (i.e., one month in each hospital, February 2015-April 2015). The population

studied in each hospital depended on the number of the patients undergoing X-ray within the research period. A total of 376 rejected and accepted radiographs were evaluated in the three hospitals. During each radiological examination, we recorded the tube potential (kV), tube load (mAs), focus to skin distance (FSD), and focus to film distance. Other data collected in this study were the patients' age and gender. Both adult and pediatric patients were included in the study. Any patient with the age of ≤ 15 years was regarded as pediatric patients.

The number of the rejected films, accepted films, and the reasons for rejection were noted after the processing and reading the films. The acceptance and rejection of the films were based on the observations of a team of radiologists, who examined the produced images to ensure that the films contained the required diagnostic information. The film reject rate was obtained using the following equation (1):

$$R_R = \left(\frac{R_f}{R_T} \right) 100 \quad (1)$$

Where signifies the film reject rate for a month, indicates the number of the rejected films, and denotes the total number of the films used.

The X-ray tube output (mGy [mAs]⁻¹) was measured using the QC kit (kV meter, NEROTM 6000M, manufactured by Victoreen, INC, Cleveland, Ohio, USA). This was used to test the consistency and accuracy of tube potential (kV) and the radiation output (mGy [mAs]⁻¹). The consistency of tube potential and dose output were measured, and the coefficient of variation (CV) was evaluated. The coefficient of variation serves as a relative measure of dispersion; in other words, it assesses the dispersion degree of mean tube potential or output to mean value. The voltage ripple, defined as the amount of variation in the applied X-ray tube voltage waveform relative to the peak voltage during X-ray production, was calculated using the following equation (2):

$$V_{\phi(\%)} = \left(\frac{V_{\max} - V_{\min}}{V_{\max}} \right) \times 100 \quad (2)$$

Where and are the maximum and minimum recorded kVp, respectively.

Table 1. Information of X-ray equipment in the three hospitals under investigation

Name of Hospital	X-ray model	Year of manufacture	Model	Year of installation
Federal Medical Centre	GEBE Private LTD	September, 2009	2185226 D2651P	2010
Sacred Heart Hospital	International Medico Scientifica (IMS)	December, 2004	RTM90H	2010
General Hospital Abeokuta	TOSHIBA	December, 1988	DRX-1403B	-

The outputs of two machines in the SHH and FMC were measured at a voltage of 80 kV and a current of 10 mAs [10]. However, the X-ray machine in the GH was faulty at the time of carrying out the QC program. The X-ray beam was collimated to about 7×7 cm and focused to the middle of the detector prior to the initiation of exposure. This procedure was repeated for other values of voltage and mAs. In order to calculate the entrance skin dose (ESD), such data as selected kV, mAs, and FSD were entered into an Excel spread sheet and applied to the following equation [11]:

$$ESD = output \times mAs \times BSF \times \left(\frac{kV}{80}\right)^2 \times \left(\frac{100}{FSD}\right)^2 \quad (3)$$

Where BSF is the backscatter factor (taken as 1.30 and 1.35 for pediatrics and adults, respectively) [1].

In total, 72 and 82 patient doses were evaluated in the SHH and FMC, 42 and 51 cases of which were obtained from the males, respectively. The discussion was based on the age range of the patients. In this regard, the patients with less than 16 years of age were categorized as pediatric. In the SHH and FMC, 6 and 16 patients fell within the pediatric group, respectively. The radio-sensitivity level of this age group was put into consideration.

Results

The distribution of the radiological personnel involved in the delivery of radiological services at the three investigated hospitals is illustrated in Table 2. The results of the reject rates of X-ray films in each hospital during routine X-ray examinations (for the period of three months) are presented in Table 3. According to the results, the GH had the overall highest percentage reject rate (18.8%), followed by SHH (17.8%). On the other hand, the FMC recorded the lowest reject rate (11.5%). All of these values were higher than the total percentage reject rate of 10% recommended by the Conference of Radiographic Control Program Directorate (2006) [12].

The distribution of the reasons for rejected radiographs in the three hospitals is presented in Figure 1. The percentage rates of underexposed radiographs were 29.6%, 15%, and 5.6% for the FMC, SHH, and GH, respectively. Underexposed films prevent good diagnosis, and consequently defeat the goal of diagnostic imaging. Furthermore, the SHH recorded the highest rate (35%) of rejected films due to darkroom faults, followed by GH and FMC with 33.3% and 23.5%, respectively.

Table 2. Distribution of workers in the three hospitals under investigation

Hospitals	Radiographer	Radiologist	Technologist	Dark technician room	Physicist
SHH	1*	NA	3	NA	NA
FMC	6	3	NA	5	NA
GH	NA	1	1	3	NA

SHH: Sacred Heart Hospital, FMC: Federal Medical Center, GH: General Hospital, NA: not available, *Play dual roles of radiographer and dark room technician

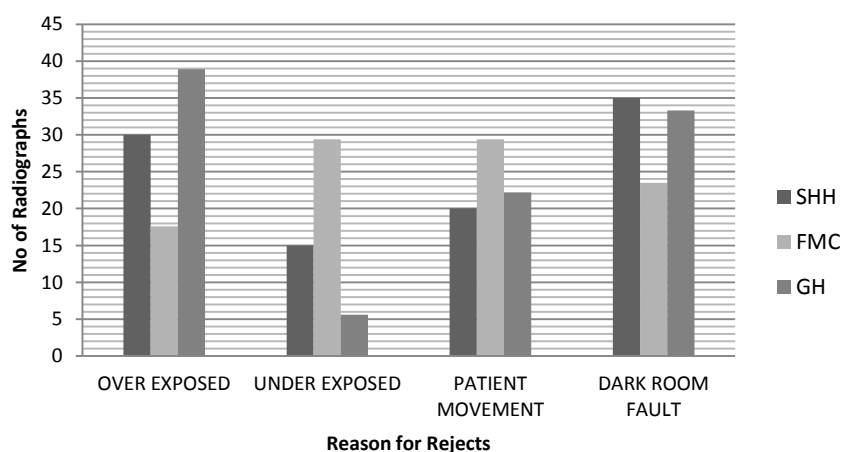


Figure 1. Reasons and number of rejected radiographs in the hospitals under investigation

Table 3. Summary of reject film rates in the three studied hospitals

Examinations	SHH (%)	FMC (%)	GH (%)
Chest	6.8	5.1	8.9
Lumbosacral	2.5	2.5	3.0
Head	1.7	1.9	1.0
Leg	1.7	—	—
Foot	—	1.3	1.0
Hand	—	—	2.0
Neck	—	—	—
Pelvis	1.7	—	3.0
Femur	1.7	—	—
Knee	1.7	0.6	—
Total	17.8	11.5	18.8

SHH: Sacred Heart Hospital, FMC: Federal Medical Center, GH: General Hospital

Table 4. Monetary losses due to rejected films in the three hospitals (film sizes indicated)

Film sizes	SHH	Amount in ₦ (equivalent in \$)	FMC	Amount in ₦ (equivalent in \$)	GH	Amount in ₦ (equivalent in \$)
18×24 cm	—	—	—	—	2	200 (\$0.6)
24×30cm	3	360 (\$1.2)	3	360 (\$1.2)	6	720 (\$2.4)
30×40 cm	6	1050 (\$3.5)	6	1050 (\$3.5)	4	700 (\$2.3)
35×35 cm	2	300 (\$1.0)	—	—	4	600 (\$2.0)
35×45 cm	10	2200 (\$7.3)	10	2200 (\$7.3)	3	660 (\$2.2)
Total	21	3,910 (\$13)	19	3,610 (\$12.0)	19	2,880 (\$ 9.6)

SHH: Sacred Heart Hospital, FMC: Federal Medical Center, GH: General Hospital Monetary estimation was based on 1\$ = ₦ 300 (Naira)

Table 5. Results of tube voltage and dose output quality control tests in Sacred Heart Hospital and Federal Medical Center at tube load of 10 mAs

Hospital	Selected kVp	Average measured kVp	kVp accuracy (%)	kVp consistency (%)	kVp reproducibility (%)	Dose output consistency (reproducibility) (%)
SHH	80	71.6	1.12	1.79	3.56	2.11 (4.29)
FMC	80	71.6	0.067	0.13	0.28	0.33 (0.76)

SHH: Sacred Heart Hospital, FMC: Federal Medical Center

Table 6. Selected and measured tube potentials with the voltage ripples in two facilities

Hospital	Selected kVp	Measured kVp	Voltage Ripple (%)
SHH	50	46.8	2.73
	60	53.9	2.18
	70	61.3	1.92
	80	72.0	2.99
	90	81.3	3.35
	100	88.1	7.50
FMC	50	43.5	3.65
	60	58.2	1.86
	70	62.2	1.60
	80	70.9	2.58
	90	83.0	3.72
	100	90.4	2.77

SHH: Sacred Heart Hospital, FMC: Federal Medical Center

Table 7. Doses delivered to adult patients at Sacred Heart Hospital and Federal Medical Center

Examination	Single exposures at SHH			Single exposure at FMC			Repeated exposures at SHH	Repeated exposures at FMC
	AP (mGy)	LAT (mGy)	Total dose (mGy)	AP (mGy)	LAT (mGy)	Total dose (mGy)	Mean dose (mGy)	Mean dose (mGy)
Chest	1.42	—	1.42±0.54	0.16	—	0.16±0.16	2.59±0.54	0.23±0.056
Lumbosacral	7.50	7.50	15.0±1.64	1.63	1.99	3.62±1.15	18.45±2.45	2.83±0.66
Skull	4.86	4.42	9.28±1.37	0.95	1.63	2.58±0.24	—	5.48±0.91
Leg	1.77	1.77	3.54*	0.21	0.11	0.32±0.09	2.47*	—
Foot	3.09	2.08	5.17±1.81	0.12	0.08	0.2±0.048	—	0.75*
Hand	1.97	1.97	3.94±0.36	—	—	—	—	—
Neck	2.20	1.85	4.05±0.47	—	—	—	—	—
Pelvis	4.57	3.29	7.86±1.20	1.73	1.01	2.74±1.19	18.70±2.72	—
Femur	4.66	3.02	6.04±1.48	0.15	0.09	0.24±0.07	15.46*	—
Knee	3.11	3.11	6.22±0.25	0.31	0.19	0.5 ±0.15	23.41*	—

SHH: Sacred Heart Hospital, FMC: Federal Medical Center, *Estimated doses for one patient, AP: anteroposterior, LAT: lateral

The summary of the economic implications of rejected radiographs in the three hospitals during the study period based on the current price of different sizes of films in Southwestern Nigeria is presented in Table 4. Out of the three hospitals under investigation, SHH had the highest loss of \$13 due to rejected radiographs during the period of this study. This loss was due to the frequent use of large-sized films in this hospital. Regarding this, the annual loss incurred to this hospital due to the rejected radiographs was estimated to be \$225. This was followed by the FMC and GH with annual monetary losses of \$208 and \$166, respectively.

The QC test results are displayed in Table 5. The results of the calculated consistency of tube potential and output of the machine indicated that they fell below the tolerance limit of 5% (i.e., within the acceptable level of ± 5) [13]. The values within the tolerance are indication of good tube performances. Based on the percentage error, the accuracy fell within the acceptable level of $\leq 10\%$ [13] in both SHH and FMC. The reproducibility of tube potential and radiation output were also found to be within the acceptable level of $\leq 5\%$ in the two hospitals, where the QC tests were carried out.

The mean tube potential, maximum tube potential, and effective tube potential are demonstrated in Table 6. Table 7 presents the results of the mean and standard deviation of the total doses for adult patients for each examination. For a single exposure at SHH, lumbosacral was found to have the highest total dose of 15.0 ± 1.64 mGy, followed by the skull with a total dose of 9.28 ± 1.37 mGy. In addition, among the repeated X-ray examinations at SHH, knee examination had the highest dose of 23.4 mGy for a

single exposure, which was relatively high, since the dose was computed as the cumulative dose of all the fractional doses received by the patient for the same examination. This high dose could be due to the selection of high exposure parameters during the exposure.

The repeated mean doses delivered to the patient during the lumbosacral, pelvis, and femur examinations in the SHH were 18.45 ± 2.45 , 18.17 ± 2.72 , and 15.46^* mGy, respectively (doses with asterisk shows that only a patient was evaluated). At FMC, all the estimated doses were relatively low, except for the skull examination with the dose of 5.48 ± 0.91 mGy. The highest dose for single exposure in the FMC was found in the lumbosacral examination (3.63 ± 1.15 mGy). This could be the result of the use of training and experienced personnel responsible for the exposure of the patients during the examinations in the FMC.

The mean doses delivered to the pediatric patients at SHH and FMC are illustrated in Table 8. As indicated in this table, doses delivered to two pediatric patients in the SHH during repeated skull X-ray examination, and a patient during repeated chest X-ray examination were relatively high with mean doses of 12.71 ± 2.63 and 7.05^* mGy, respectively. Furthermore, for a single exposure at SHH, the dose delivered to a patient during the chest examination was 2.28^* mGy, which was relatively high considering the pediatric age group. At FMC, all doses delivered to the pediatric patients were relatively low. The employment of low doses for the pediatric patients is a good practice since these patients are more radio-sensitive than the adult patients.

Table 8. Mean doses received by pediatric patients at SHH and FMC

Examination	Single exposure at SHH			Single exposure at FMC			Repeated exposure	
	AP (mGy)	LAT (mGy)	Total dose (mGy)	AP (mGy)	LAT (mGy)	Total dose (mGy)	Mean dose at SHH (mGy)	Mean dose at FMC (mGy)
Chest	—	—	2.28*	0.07	—	0.07 ± 0.033	7.05*	—
Knee	—	—	—	—	—	—	—	0.51*
Hand	1.46	1.46	2.92*	0.19	0.24	0.43*	—	—
Cervix	—	—	—	0.05	—	0.05*	—	—
Shoulder	—	—	—	0.19	—	0.19*	—	—
Pelvis	—	—	—	0.97	—	0.97*	—	—
Femur	1.54	1.54	3.08*	—	—	—	12.71 ± 2.63	—

SHH: Sacred Heart Hospital, FMC: Federal Medical Center, AP: anteroposterior, LAT: lateral, *Estimated doses for one patient

Table 9. Comparison of adult mean entrance surface doses estimated in this study with those obtained in other African countries participating in the International Atomic Energy Agency

Radiographic Projection	Congo (mGy)	Ghana (mGy)	Madagascar (mGy)	Sudan (mGy)	Tanzania (mGy)	Zimbabwe (mGy)	SHH (exposures)		FMC (exposures)	
							Single (mGy)	Double (mGy)	Single (mGy)	Double (mGy)
Chest PA	0.3	0.1	0.29	0.21	0.3	0.2	1.42	2.59	0.16	0.23
Lumbosacral AP	0.4	8.3	3.92	1.63	2.1	0.7	7.5	—	1.63	—
Lumbosacral, LAT	—	14.4	6.61	3.29	4.7	2.0	7.5	18.45	1.99	2.83
Abdomen AP	0.3	10.3	3.92	1.5	0.9	0.6	—	—	—	—
Pelvis AP	0.1	7.0	3.92	0.9	1.5	1.1	4.57	18.7	1.73	—
Skull AP	—	—	2.95	1.02	—	0.8	4.86	—	0.95	5.48
Skull LAT	—	—	—	—	—	—	4.42	—	1.63	—

SHH: Sacred Heart Hospital, FMC: Federal Medical Center, PA: posterioranterior, AP: anteroposterior, LAT: lateral

Discussion

As indicated in this study, physicists were missing in all the centers under investigation. This trend could affect the QC program of these facilities, thereby increasing the dose burden of the patients in these centers. A similar trend was found in an earlier investigation carried out in Nigeria [14]. The dual role, performed by the radiographer as seen in SHH could adversely affect the dose received by the patients and image quality, especially in facilities visited by a large number of patients.

According to the findings, the percentage reject rate of each examination, except the chest radiography examination, fell within the recommended maximum value of 5% by the WHO [4]. The percentage reject rate for the chest examination was higher than the recommended value, which may be due to the complexity of the chest, considering the overlying and underlying tissues. In addition, the procedure is very technical as patients were advised to hold their breath for few seconds, while some patients with chronic diseases (e.g., asthma) might not be able to hold their breath for the specified time. These reasons might affect the quality of radiographs.

The results demonstrated that the GH had the highest percentage of overexposed radiographs (38.9%), followed by SHH and FMC rendering rates of 30% and 17.6%, respectively. This trend at GH and SHH could be due to the lack of adequately trained radiographers or the selection of inappropriate

technical factors for producing quality radiographs. The overexposed films could also result from faulty X-ray units, film processing condition, and film type. It is essential to regularly perform QC testing of the facilities used for radiological examination. This aim is achieved by using the expertise of medical physicists or health physicists.

The dark room faults at both SHH and GH may be due to the lack of qualified darkroom technicians in the two hospitals and the chemical used for imaging. Another reason for darkroom failures could be the film processing condition. In this study, the highest reject rate due to darkroom faults was obtained in the SHH, which can be attributed to the dual role of the technicians (as darkroom technician and radiographer) since they were diploma holders in science laboratory technology rather than qualified radiographers. It was observed that the chest X-ray had the most rejected radiographs in the three hospitals. Although the GH had the highest rejected film rate, it recorded the least loss due to rejected radiographs. On the other hand, the FMC had the lowest rejected film rate. Furthermore, the SHH had the highest loss due to rejected radiographs.

The voltage ripples obtained in this study were within the experimentally determined values of 13-25% (for 3-phase 6pulse) and 3-10% (3-phase 12pulse) [15]. The comparison of doses obtained in this study with those determined in other African countries participating in the International Atomic Energy Agency project is presented in Table 9. It was

observed that at SHH, the doses delivered to the patients during the chest examinations were relatively higher for single exposures than those obtained in other African countries. Accordingly, the mean dose was estimated to be 1.40 mGy, compared to 0.30 mGy recorded in Congo, which was the highest dose recorded in other African countries. In addition, the SHH had the highest mean dose (4.48 mGy) delivered during the skull examinations as compared to other African countries.

All other doses for single exposures in the investigated hospitals in this study were within the range of values obtained in other African countries. Among the repeated exposures, the knee examination had the highest dose of 23.41 mGy for a single patient in SHH, which was considerably high, compared to that of other African countries. Additionally, the repeated doses for lumbosacral, pelvis, and femur examinations were greater than the values obtained in other African countries.

Based on the findings of this study, it is essential to optimize the radiological practices in Nigeria. In this regard, the technical factors leading to relatively higher doses in the studied hospitals should be identified and adjusted. Furthermore, qualified personnel should be employed in these centers in order to reduce the film reject rates.

Conclusion

As the findings of this study revealed, the reject rates were relatively high in both SHH and GH. Therefore, some special considerations are necessary for these radiology departments.

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