Original Article

A 2-year Comparative Assessment of Film Reject Analysis and Economic Implications at Two Hospitals in South-Western Nigeria

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ABSTRACT

Introduction: Quality assurance (QA) is indispensable to assure safety and quality in radiation medicine practices. This study performed an in-depth analysis of reject radiographic films to assess the contributory factors and the related implications as a form of audit.
Materials and Methods: Data on radiographic films were obtained from the archives of two reputable hospitals in South-Western Nigeria. Information such as type of examination, reasons for rejection, film size and number of rejects were recorded on a purposely designed data collection form. The analysis of data was performed using Microsoft Excel 2016.
Results: Reject analysis (RA) performed indicated 4.54% and 3.34% reject rates at Centre 1, and 8.94% and 5.55% reject rates at Centre 2 for 2016 and 2017, respectively. The major factors contributing to film reject at Centre 1 were found to be under-exposure, 21.13%; over-exposure, 20.07%; and fog, 21.30% in 2016 while in 2017, corresponding values were 20.87%, 16.69% and 16.86%. A similar trend was obtained at Centre 2 where the same factors accounted for reject rates at 20.60%, 25.13% and 18.59%, respectively, as above in 2016 and 24.29%, 26.91% and 17.07% in 2017. This study has shown a loss in yearly productive time of up to 150 working hours per machine.
Conclusions: Repeating X-ray examinations engender wastage of time and finance as well as additional radiation exposures to the attendants. RA serves as a form of QA audit for monitoring and improving imaging services and the cost-effectiveness of diagnostic practice.

Key words: Audit, quality assurance, radiographic film, X-ray

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INTRODUCTION

Diagnostic radiology which entails medical imaging plays a crucial role in all aspects of human medicine. An integral outcome of diagnostic radiology is a radiographic image and a correct interpretation of this image is an important requirement for further action in the health-care process. The quality of a radiographic image therefore plays an important role in the accuracy of medical diagnosis which would expectedly determine the direction of health-care delivery. Radiographs that are of no diagnostic value are often discarded. These are referred to as rejected films. The number of rejected images is an indicator of image quality and unnecessary imaging at a radiology department. Hence, image reject analysis (RA) is frequent for film-screen radiology.[1] Whenever a film is rejected, the radiograph must be repeated. Repeat rate is the percentage of images that have been repeated due to errors or poor image quality.[2] A radiograph could be categorised as non-diagnostic if vital anatomical structures related to the examination type could not be seen and additional radiograph is needed to get maximum information.[3] Repetition of radiographs presents diverse concerns including unwarranted radiation exposure to patients, increased costs, longer patient waiting time, additional workload for radiographers and reduced X-ray tube life.

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The American Society for Quality defines quality assurance (QA) as the planned and systematic activities implemented in a quality system so that quality requirements for a product or service will be fulfilled. On the other hand, quality control (QC) is regarded to as the observation techniques and activities used to fulfil requirements for quality.[4] The main goal of a diagnostic QA programme is to produce radiographs of consistent high quality. RA which is a vital tool for QC provides relevant information that would help achieve an effective reduction in radiation exposure and unnecessary cost, while providing acceptable image quality.[5] Studies have shown that most radiographs are rejected because of wrong patient positioning, patient or equipment motion and selection of wrong exposure factors.[5]

QC was inherent in the screen-film imaging workflow, where rejected image rates were calculated by counting rejected films. Improperly exposed films resulted in images that were too dark or light and were repeated out of necessity.[6]

The International Commission on Radiation Protection recommends that medical exposures should be kept as low as reasonably achievable considering economic and social factors and one way of achieving this is through film RA.[7] This among many others necessitates the need to evaluate the radiographic reject rate. The objective of this study was therefore to perform an analysis of reject radiographic films to assess the contributory factors and economic implications at two reputable hospitals in south-western Nigeria.

MATERIALS AND METHODS

The data on radiographic films used in years 2016 and 2017 were obtained from the archives of the radiation facilities at Centre 1, a public hospital and Centre 2, a private medical centre, both in south-western Nigeria. Permission to undertake the task on QA audit was received from the respective authorities of the hospitals in view of the overall benefits that would be derived from the study. The work involved the major X-ray equipment at the facilities being a digital floor-mounted X-ray unit (Varian, USA) and the analogue (floor to ceiling) type (Siemens, Germany) at Centres 1 and 2, respectively.

Data collection of radiographic films rejected was performed and rejection rate data were collected using standardised checklist as recommended by the National Radiation Protection Authority and International Atomic Energy Agency. Daily recordings were compiled by frontline radiographers and senior physicians. Relevant information such as type of examination, reason for rejection, film size and number of reject was recorded on a purposely designed data collection form for each rejected radiograph. The radiographic films differ in dimensions based on examination types which cover several anatomical regions including skull, neck, arm, ankle, abdomen, pelvis, spine, lumbar-sacral spine and the extremities amongst others.

The rejected radiographic films were analysed and counted according to size, reason for rejection and the anatomical part being examined. The reasons for the rejection were also categorised as overexposure, underexposure, rotation, positioning error, poor breathing, fogging, artefacts, anatomical cuts, rollers, processing and projection error. The sizes of the reject radiographs included 43 cm × 35 cm, 35 cm × 35 cm, 30 cm × 24 cm, 24 cm × 18 cm, 20 cm × 18 cm. The examination types of rejected films included chest, pelvis, abdomen, skull, neck and hip though these were found to slightly differ in both hospitals each year.

The reject rate was calculated using equation 1.0[8] as follows:

$$\text{Reject Rate}(\%) = \frac{\text{Number of rejected films}}{\text{Total number of films used}} \times 100\% \quad (1)$$

Causal reject rate was evaluated as follows:

$$\text{Causal Reject Rate}(\%) = \frac{\text{Number of rejected films for specific cause}}{\text{Total number of films rejected for a specific type of examination}} \times 100 \quad (2)$$

The average time taken to perform a repeat radiograph has been estimated to be approximately 15 min. [8]Therefore, the minimum time (hour) wasted by staff in producing the repeat radiographs during the assessment at the two centres was calculated using the equation below:

$$\frac{\text{Number of films rejected} \times 15\,\text{min}}{60\,\text{min}} \quad (3)$$

Similarly, the cost analysis of rejected radiographs by type and sizes at the two study centres for the 2 respective years was performed. The total cost of rejected radiographs was calculated using the following equation:

$$\text{Number of films rejected} \times \text{Corresponding unit cost of radiograph} \quad (4)$$

The total costs of rejected radiographs, the unit prices of which vary with film sizes were also expressed in the United States Dollars ($) using the prevailing exchange rate of N305 to $1 as of 2016. Data analysis was performed using Microsoft Excel 2016, generating frequency distribution tables from variables. Furthermore, a paired *t*-test was performed at 95% confidence interval using Statistical Package for Social Scientists (SPSS version 22, IBM Corp., Armonk, NY, USA). The statistical test was aimed at comparing the means of film rejects across various causative factors to determine if there are any differences between the 2 successive years at each of the hospitals involved in this study. This assessment was also extended to length of time wasted due to the quantity of films rejected. The types of radiographic examinations performed

on the X-ray units at Centre 1 and Centre 2 during the study period were 14 and 7 respectively while the causative factors for film rejects were classified into 6.

RESULTS

A total of 12,524 and 16, 934 X-ray films were used at Centre 1 in 2016 and 2017 respectively with corresponding reject rates of 4.54% (568 films) and 3.54% (599 films). The classifications of the rejected films according to radiographic examinations and causative factors at the government hospital for the 2 years are presented in Table I. Cost analysis of reject films by type and sizes at this hospital for the 2 successive years is comparatively presented in Table II. The highest and least monetary loss associated with rejected radiographs was found for chest and foot radiographic examinations, respectively. The highest film rejection rates were found for chest radiographic examinations. Similar to Tables I and III lists number of reject films per specific examination and cause at the private hospital (Centre 2) for the 2 years. A total of 6680 X-ray films were used at Centre 2 in 2016 while 597 (8.94%) radiographs were rejected. In the following year, corresponding values were 8227 with a reject rate of 5.55% (457 films). The total number of rejected films had reduced between 2016 and 2017 for almost all the examination types. Table IV presents cost analysis of reject films by type and sizes in the private health institution (Centre 2) for the years under review.

Table V reports statistical analysis of rejected radiographs and the corresponding time length wasted within 2 successive years at the two study centres. Comparison of film rejects between the 2 years across the causative factors showed Pearson's correlation factors ranging from 0.986–0.998 to 0.393–0.984 respectively at the two centres. Consequently, the differences observed between the pairs of data are generally of no statistical significance ($P > 0.05$). While under-exposure was considered the most prominent factor for film rejection at Centre 1, over-exposure was identified as the major reason at Centre 2. In Table VI, the authors compared their study spanning over a 2-year period at the two hospitals with previous studies within and outside Nigeria.

DISCUSSION

RA is the critical evaluation of rejected radiographs carried out to assess average reject rates and to establish the major reasons, otherwise regarded to as the causative factors for rejected films. Considering all examination types, a total of 12,524 X-ray films were used at Centre 1 in 2016 out of which 568 radiographs were rejected for different reasons. This represents 4.54% overall reject rate with its attending increased radiation dose to the people examined. In a total of 16,934 radiographic films used in the subsequent year, 599 repeat radiographs were recorded, depicting an overall reject rate of 3.54%. At Centre 2, a total of 6,680 radiographs with 597 rejected (reject rate of 8.94%) were recorded for the year 2016 while a total of 8,227 radiographs with 457 rejected (reject rate of 5.55%) were obtained in the succeeding year. This could be attributed to problems associated with the machine and the limited technical know-how.

The overall reject rates obtained in this study are in agreement with a review of the literature[6] which revealed that repeated image rates hovered around 10% in screen-film radiography. It is readily observed that the overall reject rates obtained at the radiology department of Centre 2 were found to be higher than values obtained at Centre 1. The initial result of 8.94% obtained at **C**entre 2 however agrees with figures earlier determined in certain parts of Nigeria[7,9,10] while a reduction to 5.55% ensued in the following year. This could result from problems associated with the machine and limited experience of the staff. On the other hand, the overall reject rates found

Table I: Number of reject films per specific examination and cause of rejection at Centre 1 for 2016 and 2017

Radiographic examinations	Over-exposure 2016/2017	Under-exposure 2016/2017	Positioning error 2016/2017	Fog 2016/2017	Anatomical cut 2016/2017	Others 2016/2017	Total
Chest	58/49	61/58	68/56	76/66	51/60	37/96	351/385
Pelvis	12/16	14/18	7/4	8/8	0/2	0/3	41/51
Abdomen	2/2	3/4	4/8	7/6	2/1	0/0	18/21
Spine	15/8	13/10	5/3	6/4	5/5	3/2	47/32
Skull	8/8	12/11	2/3	7/3	0/1	3/3	32/29
Hand	1/2	2/3	0/1	3/3	0/0	3/2	9/11
Wrist	2/2	1/2	0/1	4/2	0/1	2/2	9/10
Ankle	0/1	4/3	0/0	2/1	0/1	0/0	6/6
Knees	2/2	1/1	3/3	0/0	2/1	0/0	8/7
Lumbar-sacral	7/5	5/7	3/4	4/3	0/1	3/3	22/23
Neck	2/2	1/1	2/2	1/1	0/0	0/0	6/6
Hip	3/2	1/3	2/1	1/2	2/1	1/2	10/11
Foot	2/1	0/2	0/0	1/1	1/0	0/0	4/4
Arm	0/0	2/2	2/0	1/1	0/0	0/0	5/3
Total							568/599

Others: Artefact, double exposure, wrong placement of marker, poor collimation etc., *n*: Number of rejected films for specific reason

Table II: Cost analysis of reject films by types of study and sizes of films at Centre 1 for 2016 and 2017

Regions	Radiographic film sizes (cm×cm)	Unit cost of radiographs (₦)	Number of rejected radiographs	Total price of rejected radiographs (₦) 2016/2017	Total price of rejected radiographs ($) 2016/2017
Chest	35×35	145.53	351/385	51,081.03/56,029.05	167.48/183.70
Pelvis	24×30	85.40	41/51	3501.40/4355.4	11.48/14.28
Abdomen	35×43	189.84	18/21	3417.12/3986.64	11.20/13.07
Hip	35×35	145.53	10/11	1455.30/500.83	4.77/1.64
Spine	35×43	189.84	47/32	8922.48/6074.88	29.25/19.92
Skull	18×20	79.22	32/29	2535.04/2297.38	8.31/7.53
Hand	18×20	79.22	9/11	712.98/871.42	2.34/2.86
Wrist	18×20	79.22	9/10	712.98/792.2	2.34/2.60
Knees	18×24	97.6	8/7	780.80/683.2	2.56/2.24
Foot	18×24	97.6	4/4	390.40/390.4	1.28/1.28
Ankle	18×20	79.22	6/6	475.32/475.32	1.56/1.56
Lumbar-sacral	35×35	145.53	22/23	3201.66/3347.19	10.50/10.97
Neck	18×24	97.6	6/6	477.60/585.6	1.57/1.92
Arm	24×30	85.40	5/3	427.00/256.8	1.40/0.84
Total			568/599	78,091.11/80,646.31	256.04/264.41

Cost equivalence was based on the exchange rate of $1 (USD) to ₦ 305 as of 2016

Table III: Number of reject films per specific examination and cause at Centre 2 for 2016 and 2017

Exams types	Over-exposure 2016/2017	Under-exposure 2016/2017	Positioning error 2016/2017	Fog 2016/2017	Anatomical cut 2016/2017	Rotation 2016/2017	Rollers 2016/2017	Others 2016/2017	Total
Chest	23/29	34/26	24/20	41/30	10/10	23/17	10/12	16/5	181/149
Pelvic	22/24	20/21	11/17	17/15	8/8	1/2	1/1	4/3	84/91
Abdomen	46/20	22/18	33/6	30/8	10/6	1/1	2/1	6/2	150/62
Extremities	18/16	10/13	1/2	4/6	4/0	1/1	0/2	0/0	38/40
Spine	19/16	15/14	8/8	6/4	5/4	1/0	1/0	3/2	58/48
Skull	8/10	6/8	2/2	9/12	10/0	1/2	0/0	5/4	41/38
Lumbar-sacral	14/8	16/11	3/2	4/3	3/4	0/0	2/0	3/1	45/29
Total									597/457

Others: Artefacts, double exposure, wrong placement of marker, poor collimation etc., *n*: Number of rejected films for specific reason

Table IV: Cost analysis of reject films by types of study and sizes of films at centre 2 for 2016 and 2017

Region	Radiographic film sizes (cm×cm)	Unit cost of radiographs (₦)	Number of rejected radiographs	Total price of rejected radiographs (₦) 2016/2017	Total price of rejected radiographs ($) 2016/2017
Chest	35×35	145.53	181/149	26,340.93/21,683.97	86.36/71.09
Pelvic	24×30	85.40	84/91	7173.6/7771.4	23.52/25.48
Abdomen	35×43	189.84	150/62	28,476.00/11,770.08	93.36/38.59
Extremities	35×43	189.84	38/40	7213.92/7593.60	23.65/24.90
Spine	18×20	79.22	58/48	4594.76/3802.56	15.06/12.47
Skull	18×20	79.22	41/38	3248.02/3010.36	10.65/9.87
Lumbar-sacral	35×35	145.53	45/29	6548.85/4220.37	21.47/13.84
Total			597/457	83,596.08/59,852.34	274.09/196.24

Cost equivalence was based on the exchange rate of $1 (USD) to ₦ 305 as of 2016

at the government-owned hospital are comparable to previous results[2,8] evaluated at different hospitals in Ethiopia. However, the individual (specific to anatomical site) reject rates of most examinations at Centre 2 in 2016 were greater than the WHO criteria of 5%[11] the highest being 26.88% (558 films used and 150 rejected) for the abdomen [Table III] obtained in Centre 2 in the year 2016. A previous study[12] of this nature in Ethiopia found similar results but the largest reject rate (31.11%) was associated with pelvic examinations. Factors considered responsible for this trend in the previous study include machine faults, operator's technical limitation and lack of QA program.[12]

This study has identified fogging and under-exposure as the most prominent causes of film reject (rates at 21.30% and 20.87%) at the government hospital in years 2016 and 2017,

Table V: Statistical analysis of rejected radiographs and the corresponding time length wasted within 2 successive years at the two study centres

Causative factors for rejection and time parameter	Centre 1				Centre 2			
	Total		Paired differences Mean±SD (df=13)	*r* *t*-test (*P*)	Total		Paired differences Mean±SD (df=13)	*r* *t*-test (*P*)
	2016	2017			2016	2017		
Over-exposure	114	100	1.000±3.282	0.986 (0.275)	150	123	3.857±10.527	0.493 (0.370)
Under-exposure	120	125	−0.357±1.946	0.994 (0.504)	123	111	1.714±4.071	0.927 (0.308)
Positioning error	98	86	0.857±3.634	0.994 (0.394)	82	57	3.571±10.753	0.495 (0.413)
Fog	121	101	1.429±2.766	0.998 (0.075)	111	78	4.714±8.864	0.807 (0.209)
Cut	63	74	−0.786±2.547	0.998 (0.269)	50	32	2.571±3.823	0.393 (0.125)
Others	52	113	−4.357±15.756	0.994 (0.320)	81	56	3.571±5.623	0.984 (0.144)
Total	568	599	−2.214±10.533	0.998 (0.446)	597	457	20.000±32.624	0.984 (0.005)
Hours wasted	142	149.75	−0.554±2.633	0.998 (0.446)	149.25	114.75	9.429±15.916	0.553 (0.168)

SD: Standard deviation

Table VI: Comparisons of the present study with other previous studies

Study	Overall reject rate (%)	Place of study
Present study (2016)	4.54	Centre 1, South-West, Nigeria
Present study (2017)	3.54	Centre 1, South-West, Nigeria
Present study (2016)	8.94	Centre 2, South-West, Nigeria
Present study (2017)	5.55	Centre 2, South-West, Nigeria
Joseph *et al*.[9]	9.62	Bauchi, North-East, Nigeria
Osahon *et al*.[7]	8.90	Benin, South-South, Nigeria
Eze *et al*.[10]	8.86	Edo, South-South, Nigeria
Zawdeneh *et al*.[8]	4.94	Tikur Anbessa, Ethiopia
Teferi *et al*.[2]	3.10	Addis Ababa, Ethiopia

respectively. Conversely at the private hospital, over-exposure was identified as the most important factor in both years. Under-exposure and over-exposure had been identified by various studies[8,12,13] as the major indications for repeating X-ray examinations as about 50% of repeats could be attributed to generation of radiographs that are either too dark or too light.[12,14] The outcomes of the present study were largely within this limit as the percentages of film rejects attributable to over-exposure or under-exposures were 41.2% and 37.6% at Centre 1 while corresponding values of 45.7% and 51.2% were found at Centre 2.

Statistical analysis presented in Table V shows a general strong correlation (r ~1) between the quantities of film rejects due to the identified causative factors between the 2 years. The correlation was however less pronounced at Centre 2 which resulted in a statistically significant difference in the total number of films rejected between 2016 and 2017. This is the only exception as statistical outcomes generally indicated that the observed differences across reasons for rejections for both hospitals are of no statistical significance (>0.05). Consequently, each of the identified reasons for rejections brought about similar film reject rates between the two successive years at the hospitals. The need is therefore strongly indicated to identify and address the underlying causes of these factors with a view to achieving reduction in film rejects in subsequent years. This has further stressed the need for RA which is considered an integral part of a QA programme for radiography.[6]

A decreasing trend in film reject across the causative factors as generally observed at Centre 2, albeit not at a significant level should be aimed at. This would entail a strict compliance with post-installation acceptance tests which would help check that the X-ray equipment functions correctly as specified by the manufacturer and meets the pre-determined expectations of the end users. We opine that selection of the right combination of exposure factors for a given radiographic examination by radiographer could still result in under-exposure or otherwise if the equipment does not operate according to the chosen imaging parameters. The mandatory need for acceptance testing on purchased radiographic equipment prior to routine clinical service is therefore indispensable.[15]

Rejected X-ray examinations contribute to financial loss through wastage of films and processing chemicals, wastage of patient and staff time, increase in radiation dose to patients and personnel, wear and tear on the equipment and accessories.[12] Minimising the number of repeat films will therefore not only reduce unnecessary exposure to patient, but can also have a significant effect on imaging running cost and time.[12] The findings of this study revealed that ₦ 83,596.08 was wasted due to rejection or repeat of 597 radiographic examinations at Centre 2 in 2016. This value reduced to ₦ 59,852.34 considering the lower number (457) of films rejected in the subsequent year. Although this trend was not brought about by a prior RA, the need for a periodic appraisal of diagnostic imaging practice is further indicated. The contrary was the case at the government hospital where across the 2 years, the economic loss increased from ₦ 78,091.11 to ₦ 80,646.31 for the wastage of 568 and 599 X-ray films, respectively. These monetary values could rise significantly if radiographic film rejection is not curtailed and the cost of procurement increases due to the prevailing economic factors.

The time wastage due to radiographic rejections was similar at the two centres given the nonstatistically significant differences. The weaker correlation obtained in this regard at the private hospital could be attributed to the marked difference in the total numbers of film rejects between the 2 years. Approximately 150 h representing about 19 working days (at the rate of 8 h/day) was obtained at Centre 1 in 2017. The estimated time loss at the second hospital in 2016 was similar being 149 h. These figures each of which is for a 12-month period are lower than a value of 277 h obtained at a centre in Ethiopia where a previous study based its assessment on two X-ray units within a 4-month duration.[12]

Study limitations

Although the study centres have multiple X-ray equipment, the present study was based on one radiological machine at each of the hospitals. This implies that our findings were the minimum obtained for the evaluated parameters and greater implications could have resulted if other X-ray equipment were considered. It was also probable that not all the film rejects were duly reported through documentation. Authors could not find studies in literature involving a similar assessment over a 2-year period with which statistical values [Table V] could be further compared.

Future directions and recommendations

It is of great essence for every radiology centre to have QA committee comprising qualified medical physicists, radiologists, radiographers and biomedical engineers to develop QA programs for effective and sustained service delivery, X-ray dose reduction to patients and personnel, as well as economic management of scarce resource. These personnel should be jointly involved in the decision making process for procurement of radiological facilities. Medical physicists should mandatorily conduct acceptance testing to assure equipment operates satisfactorily according to established guidelines before clinical use of facilities is initiated. Every radiology department should aim at introducing digital radiography to replace the conventional system of radiological image processing. Rejected image rates in digital departments have been reported to range from 4% to 8%.[16,17] Digital imaging systems have picture archiving and communication systems that helps to ensure that the number of repeat images are correctly inputted and calculated. Image digitalisation significantly changed the causes of rejects. While rejects for screen-film systems were mostly exposure-related, they are mainly reported to relate to patients' positioning errors in the digital systems.[1]

CONCLUSIONS

This study has indicated that analysis of reject radiographic films is a form of QA audit in diagnostic radiology. It has also shown RA as a useful tool in monitoring and improving diagnostic imaging services. Furthermore, it could be used to monitor and evaluate prospectively the cost-effectiveness of diagnostic imaging departments. Hospitals incur high costs while setting up diagnostic imaging centres and therefore should aim at reducing wastage of resources and workforce time engendered by repeat examinations. While training and re-training for imaging staff should be encouraged, it is of prime importance that periodic rejection analysis of this nature should be part of the QA programs with necessary documentation in place.

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Conflicts of interest

There are no conflicts of interest.

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