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The causes of reject images in a radiology department at a state hospital in Windhoek, Namibia

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Abstract

Purpose Reject film analysis (RFA) is a well-established method of quality assurance (QA) in diagnostic radiology that gives an indication of the sources of imaging errors and highlights areas where improvements can be made. Despite the adoption of computed radiography (CR) which has a wide dynamic range and image post-processing capabilities, radiographic images are still rejected thereby emphasising the role of regular RFA in any radiology department. Regular RFA can reduce radiation exposure to patients and personnel as well as decreasing departmental operational costs. Therefore, this study aimed to identify the causes of reject images and to calculate the rejection rates at a state radiology department in Windhoek, Namibia.

Methods Using a quantitative, explorative, non-experimental and descriptive research approach, reject images obtained over a two-month period were retrieved from the computer radiography system. The images were then assessed to identify the reasons for rejection; reject rates were calculated.

Results Of the 2258 images reviewed, 181 were reject images, resulting in an overall departmental reject rate of 8%. Positioning (63%), exposure (24.9%), gridlines (1.7%), collimation (2.2%), absence of anatomical markers (2.8%), and artefacts (5.5%), were identified as the causes for image rejection. Chest and skull radiographs had the highest reject rates of 48.1% and 9.9%, respectively.

Conclusion Positioning error was the highest contributor to reject images. Even though the overall reject rate in this study was within the IAEA 5-10% recommended range, reject rates associated with individual anatomical areas require further investigation.

Keywords reject film analysis, reject rate, X-ray images

Introduction

A reject image in radiography is an undiagnostic image, as it does not provide the necessary information to aid clinical diagnosis due to its poor quality.[1,2] Repeating radiographs due poor quality of the initial images increases the radiation dose received by patients and personnel.[3] An increase in the dose to patients also increases the probability of the occurrence of cancer.[4] For a radiographic image to be deemed diagnostic, it must demonstrate the radiographic anatomy under examination; be properly marked with anatomical markers to show patient orientation; and include patient details as well as date of examination.[5-7] A radiographer must therefore correctly position a patient and choose correct exposure factors to obtain optimal radiographic images.

Reject film analysis (RFA) is a well-established method of quality assurance (QA) in diagnostic radiology,[1,8] that gives an indication of the sources of imaging errors and highlights areas where improvements can be made.[2]

Previous studies conducted on conventional radiography systems identified exposure, followed by positioning, as the leading causes of image rejection.[1,3,9-12] Recent adoption of computed radiography (CR) that has a wide dynamic range and image post-processing capabilities[13,14] enables rectification of under- or overexposure errors. In spite of CR image post-processing capabilities, the International Commission on Radiation Protection (ICRP),[8] notes that the role of RFA is to provide relevant information that would reduce cost and radiation exposure to both patients and personnel. In addition to identifying the causes of reject images, RFA includes calculating the reject rate. Reject rate is defined as the percentage of images that are repeated due to errors or poor image quality.[3]

In 2009, a RFA study was conducted in the same radiology department in Namibia to assess the effect of exposure charts on the reject rate of extremities on the conventional radiography system.[15] The study recorded decreased reject rates for extremities due to adherence to exposure chart factors. The recent upgrade from conventional to CR at the state radiology department necessitated this current study to identify the causes for reject images, and to calculate the reject rates thereof so as to establish areas for corrective action.

Materials and methodology

This was a quantitative, explorative, non-experimental and descriptive study conducted from June to August 2015 at a radiology department of a teaching state hospital in Windhoek, Namibia. Permission to conduct the study was obtained from the Ministry of Health and Social Services of Namibia as well as the principal radiographer of the radiology department.

Data were retrieved from the NX Viewer, type 8700 SU1 (build-9.0.1813) system (Agfahealthcare N.V. Septesstraat 27, 2640 Mortsel Belgium); a system with an inherent reject tracking software that allows radiographers to indicate reasons for image rejection, as well as identify who rejected an image. All reject images were retrieved from the computer system during the research period on a weekly basis. The reject images were then grouped as performed by either a student or a radiographer. The anatomical areas imaged, as well as the reasons for rejection, were also recorded. The departmental and student reject rates were calculated.

Data analysis

Data were analysed using Statistical Package for the Social Sciences (SPSS) version 22. Graphs were created using Microsoft Office Excel 2007/2010. The causes of reject images were determined using descriptive statistics presented by means of frequency distributions.

Calculation of reject and repeat rates

The reject or repeat rate was determined as follows[16]:

$$\text{Reject Rate (\%)} = \frac{\textit{Number of rejected images}}{\textit{Number of examinations}} \times 100$$

Results

A total of 181 reject images were included in the study.

• *Causes of reject images*

Causes of reject images in this study included patient positioning, exposure, presence of grid lines, collimation, absence of anatomical markers and presence of artefacts accounting for reject rates of 63% (114), 24.9% (45), 1.7% (3), 2.2% (4), 2.8% (5) and 9.9% (18), respectively, as shown in Figure 1. Regarding exposure factor errors, underexposure, overexposure and double exposure contributed 16.6%, 5.5% and 2.2%, respectively.

• *Reject rates*

To calculate a departmental reject rate, the number of reject images is divided by the total number of images performed. Of the 2258 radiological examinations performed during the period of this study, 181 were rejected as shown in Table 1. This resulted in departmental reject rate of 8% (181) and student reject rate of 4.5% (102).

• *Reject rates per anatomical area*

Mammograms (16.4%), skull (15%), pelvis (12.7%), cervical spine (C-spine; 11.1%), chest x-ray (CXR) (9.9), and thoracic spine (T-spine; (8.3%) recorded reject rates higher than the departmental reject rate of 8.0%. The T-spine, pelvis, (CXR), C-spine and skull radiographs were the five most rejected examinations by students at 8.3%, 7.9%, 6.8%, 6.7% and 5.0%, respectively, as shown in Figure 2.

• *Student and departmental reject rates per anatomical area*

Positioning and underexposure were the commonest causes of rejects. For positioning, 57 images were rejected for the chest, and 12 images were rejected for the skull. The chest still recorded the highest rejects for underexposure as shown in Table 1.

Discussion

Akintomide et al[3] and Waaler and Hofmann[10] emphasise radiation safety measures must be applied for all radiation utilised in medical facilities including periodical RFA. The authors established that RFA identifies the causes of image rejection and allows a proactive approach to reduce errors that result in radiographic examinations being repeated. Subsequently, diagnostic or optimal radiographic image qualities or standards can be established and maintained. The aim of this study was therefore to identify the causes of image rejection at a state radiology department, and calculate the reject rates thereof.

The total number of rejected images during this study was 181 out of 2258 exposed images, of which 102 were rejected by students. The student reject rate was 4.5% while the overall departmen-

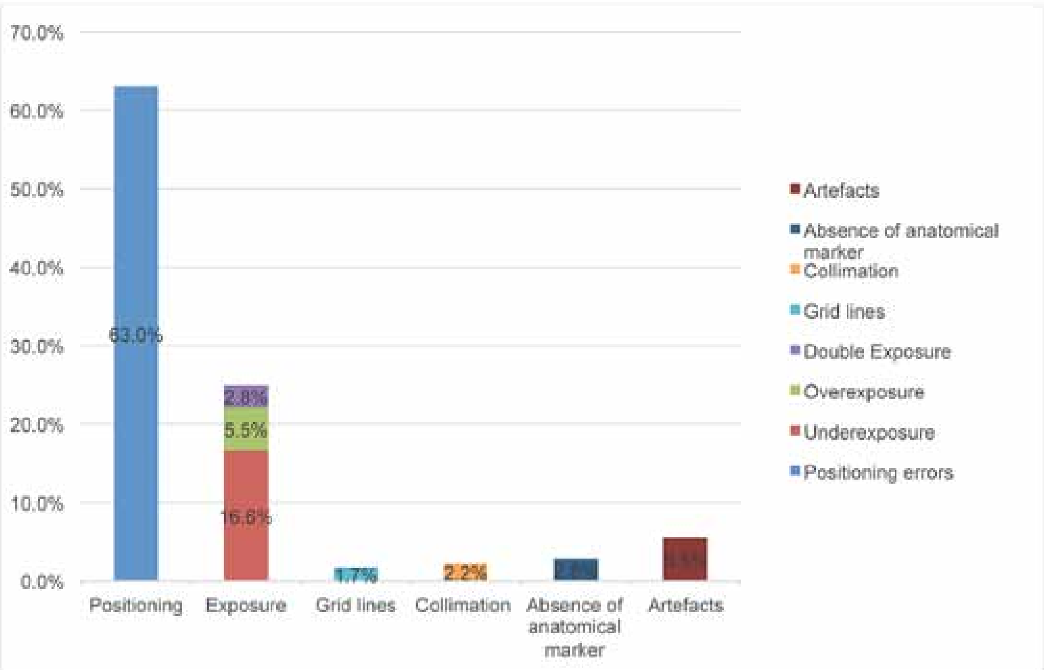

Figure 1. Causes of reject images.

Table 1. Causes of reject images per anatomical area

ANATOMICAL AREA	POSITIONING	EXPOSURE			GRIDLINES	COLLIMATION	ANATOMICAL MARKER	ARTEFACTS	TOTAL NO. OF REJECTED IMAGES	TOTAL NO. OF EXAMINATIONS PERFORMED
		OVER EXPOSURE	UNDER EXPOSURE	DOUBLE EXPOSURE						
Chest	57	3	12	3	2		5	4	86	882
Abdomen	2		1						3	75
Pelvis	2	1			2			3	8	63
Extremities	8	2	4						14	418
C-spine	5		4					1	10	19
T-spine	2								2	24
L-spine	7							2	9	127
Hip, Knee, Ankle, Shoulder, Elbow, Wrist Joints	8	3	2	1		2			16	325
Skull	12	1	4	1					18	121
Mandible	2								2	39
Mammograms	9		3						12	73
IVP[i]	0				1				1	21
TMJ[ii]										1
Total	**114**	**10**	**30**	**5**				**10**	**181**	**2258**

[i] *Intravenous Pyelogram*
[ii] *Temporomandibular joint*

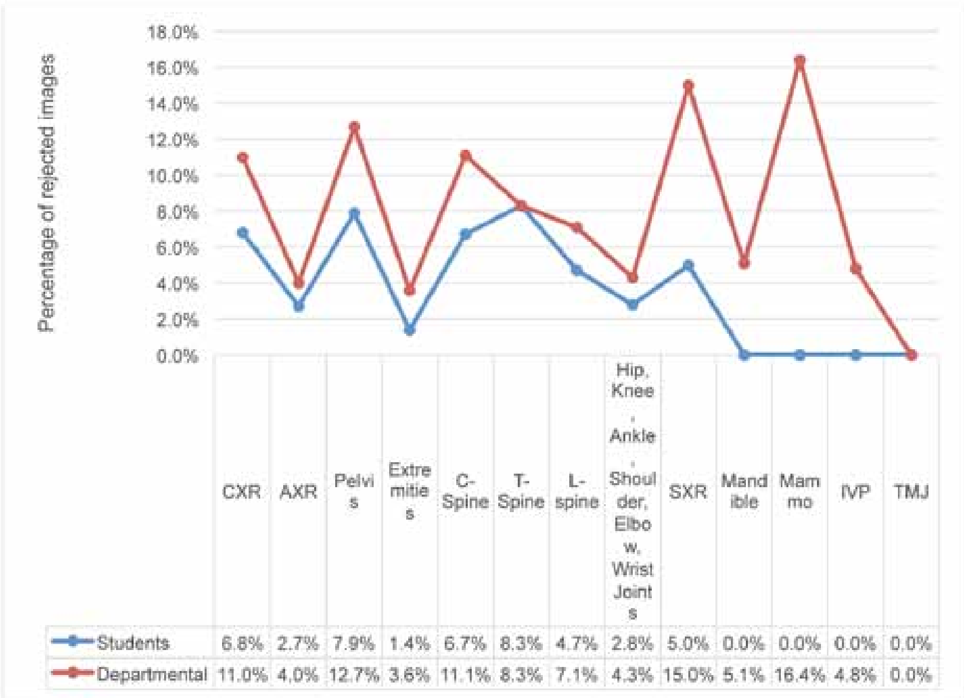

Figure 2. Student and departmental reject rates per anatomical area.

tal reject rate was 8%. This departmental reject rate is similar to the 8.6% obtained by Akintomide et al[3]; but higher than the 4.94% of Zewdeneh et al,[11] 2.3% by Peer et al[1] and 4.9% by Foos et al[17] as recorded in previous studies. Although the departmental reject rate is higher than some of the studies reviewed, it is still within the 5% and 10% range recommended by the IAEA.[11] It is important to note that even though the overall reject rate obtained in this study is within the acceptable range, it should be a departmental objective to lower it further.

There is evidence that advancement from film screen radiography (FSR) to CR imaging system can reduce departmental reject rate, due to the latter's employment of automated exposure control (AEC), post-processing and wide dynamic range capabilities.[18] The results of RFA conducted by Peer et al[1] proved the expected reduction to be true. The current study was conducted on a CR system. Thus reject rates were expected to be similar as those recorded in the respective studies of Peer et al[1] and Foos et al.[17] However, when juxtaposed against other RFAs, this study showed a reject rate higher than those of the CR studies reviewed. The findings of the current study could be an indication that CR does not necessarily result in a reject rate lower than that of FSR; there could be other factors that contribute to image rejection other than the radiographic imaging system in use. Therefore, the findings should be interpreted with caution because this study included students in the study cohort, which could have influenced the reject rates.

Positioning and exposure were the main causes of image rejection in previous studies.[1,3,8-12] Similarly, positioning and exposure were the main causes identified during this study, with fewer rejects resulting from presence of grid lines, collimation, absence of anatomical markers and presence of artefacts. Earlier literature recorded that exposure (underexposure, overexposure or both) had the highest reject rate ranging from 19.2% to 54%; while positioning had the second highest reject rate ranging from 23.8% to 56%.[3,9,11-12] Contrary to those findings, positioning had the highest reject rate of 63.0% followed by exposure (24.9%) in this study. This is an expected trend in CR due to its wide dynamic range and post-processing capabilities.

The 24.9% reject rate recorded due to underexposure, overexposure, double exposure contributed 16.6%, 5.5% and 2.8%, respectively. These findings are lower than those found by Akintomide et al[3] (41.67% due to underexposure),[3] and Yousef[8] (26.8% and 19.2% reject rates due to under and overexposure, respectively). Unlike in FSR, where exposure factors must be precise to produce optimal radiographic images, CR has a higher exposure tolerance[13] coupled with its image post-processing capabilities such as contrast enhancement, collimation, annotation of images with anatomical markers as well as positioning orientation which may be responsible for the lower reject rates due to exposure factors in this study.

In this study, underexposure recorded the highest reject rate after positioning. The exposure tolerance in CR is manned by the exposure index (EI). EI is a "measure of the signal level produced by a digital detector for a given incident exposure transmitted through the patient, it is proportional to the signal-to-noise ratio squared (SNR[2]), and it is related to image quality".[19] The inherent equipment EI results in higher recognisable noise content for underexposed radiographs compared to overexposed radiographs due to the high signal recorded by the detectors from the latter. As such, overexposed radiographs that would be clearly evident in FSR appear of diagnostic quality in CR resulting in high radiation dose exposure to patients. The RFA measurements for overexposure may then become inaccurate due to the overexposed radiographs appearing diagnostic. This may be responsible for the lower number of overexposed radiographs compared with underexposed in the current study.

In radiography, anatomical markers must be present in the primary x-ray beam in order to identify the anatomical right and left.[20] Digital annotation of anatomical markers may attract medico-legal implications in case of human error during their placement resulting in surgery to wrong side, incorrect chest drain placement, and in situs inversus.[5,12] In studies conducted in Nigeria,[3] Iran,[9] and Ethiopia,[11] it was evident that as the anatomical area increased in size and complexity, so did reject rates. Spinal, pelvic and skull radiographs were classified as complex radiographic examinations.[3,9,11] Jabbari et al[9] recorded their highest anatomical reject rate of (14.01%) from pelvic images; Akintomide et al[3] recorded their highest reject rate from the lumbar spine (53.06%), followed by that of the skull (50%) and abdomen (25%). In this current study, skull (15%), pelvis (12.7%), C-spine (11.1%), chest x-ray (CXR) (9.9%) and T-spine (8.3%), recorded the highest reject rates for general radiography studies as shown in Figure 2. Additionally, the skull and spines recorded high reject rates due to positioning compared to exposure, presence of grid lines, collimation, absence of anatomical markers and presence of artefacts as shown in Table 1. Although chest radiography is not considered a complex procedure, it is one of the examinations that contributed to a high number of repeated examinations in this study. This could be attributed to the high incidence of performing chest radiography examinations at the study site thereby increasing their frequency of rejection. For most of the studies reviewed, extremities had the lowest reject rate of upper limb radiography (4.17%),[9] and lower limb radiography (2%).[3] This study obtained similar results of 3.6% for extremities as shown in Figure 2. The findings of this study corroborated that a reject rate may be dependent on the complexity of the anatomical region under examination.

Conclusion

The overall departmental reject rate in this study was 8% and it thus complies with the IAEA recommended range of 5%-10%. The causes of reject images included positioning, exposure, presence of grid lines, collimation, absence of anatomical markers and artefacts. Despite employment of CR, with its image post-processing capabilities, regular RFA remains an important activity in the radiography department. It identifies causes of reject images and allows a department to correct these errors in order to reduce the radiation exposure to patients and personnel, as well as decrease departmental operational costs. The wide dynamic range of the CR system resulted in a low number of images being rejected due to exposure compared to positioning error that could not be corrected by the system. Radiographers must be wary of the additional radiation dose exposure to patients with overexposed radiographs that the CR system identifies as diagnostic; and as well as the medical legal aspects following annotation of digital anatomical markers.

Recommendations

Even though the overall reject rate obtained in this study was within the acceptable range, it should be a departmental objective to lower it further. Positioning was the highest contributor to reject images; this suggests a need for staff and students to continuously attend refresher courses or continuing professional development activities in imaging anatomical areas that pose the highest challenges. Radiographers should be trained on the importance of consistent and precise use of exposure charts with a CR system, as overexposed images reflect as diagnostic images resulting in higher radiation doses to patients. Furthermore, standardised quality assurance measures should be used to overcome the factors contributing to image rejection.

Limitations of the study

The study was conducted at one state hospital. Thus, the results cannot be generalised to the rest of Namibia. Another limitation was the omission of operator names for some reject images thereby compromising the calculation of the true reject rates of both radiographers and students. This is because the reject images could have been performed by either students or radiographers.

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Competing interests

The authors declare that they did not have competing interests and the research was not funded.

Contributions of authors

Guarantor of integrity of entire study – CN: Study design and concept – CB: Literature review – CB, CDK, ED, CN: Statistical analysis – CB, CDK, CN: Manuscript preparation and editing – CB, CDK, ED, MA, CN

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