Review Article

Causes of Reject and Repeat of Digital Radiographic Images: A Literature Review to Guide the Practice of Radiography in Zambia

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ABSTRACT

Background: Radiographers aim at always improving the quality of imaging services through the production of high-quality diagnostic images, whilst minimising the radiation doses to patients and reducing healthcare costs. One strategy used in achieving this is conducting periodical reject and repeat image analysis.

Objective: The aim of this study was to review the causes of rejection and repetition of digital radiographic images to guide the practice of radiography in Zambia.

Methods: A literature search was conducted in January 2021 in PubMed/MEDLINE and ScienceDirect electronic databases. The search was extended to reference lists of eligible articles and radiography journals.

Results: Seven research studies and clinical audits were identified to be relevant and included in this review. Six causes of rejection and repetition of digital radiographic images were identified: patient positioning errors, inappropriate selection of technical exposure factors, patient motion, presence of artefacts, improper collimation of the radiographic beam, and absence of permanent anatomical side markers (ASM). Amongst these factors, patient positioning error was the most common reason for rejecting and repeating digital images.

Conclusion: The review found the overall image rejection rate to be within the acceptable range in digital radiography. This review's findings can guide the practice of radiography in Zambia as the transition takes place from traditional film-based radiography to digital radiography (DR) imaging systems.

INTRODUCTION

Radiography involves providing high-quality medical images that aid in the diagnosis and treatment of patients. To achieve this, radiographers aim at always improving the quality of imaging services. One of the strategies employed to improve the quality of imaging services is to conduct a clinical audit of current practices and compare it with the best imaging practices. This includes monitoring rejected and repeated X-ray films and digital radiographic images. Clinical auditing is a quality improvement process that seeks to improve patient care and outcomes through a systematic review of care and imaging practices against the objective standard, followed by the implementation of change if necessary.[1,2,3] In other words, clinical auditing is part of the quality assurance programme in radiology.

The move from traditional film-based radiography to digital imaging systems of computed radiography (CR) and direct digital radiography (DDR) began in the 1990s.[4] In the context of this review, these two

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terms will mean digital radiography (DR). In both imaging systems, images can be rejected due to poor quality. Holmes and Griffiths[5] state that a good quality image should have optimum contrast and density, maximum image sharpness, and minimal noise which demonstrate the anatomy or pathology of interest. A reject radiographic image is, therefore, an undiagnostic image that does not provide useful information to aid in diagnosis.[6,7] This results in repeating the image. Sherer and others[8] define a repeat image as any radiographic image that must be performed more than once because of human or mechanical error during the production of the initial image.

Repetition of radiographic images is a concern because it exposes patients to unnecessary ionising radiation with a corresponding increase in radiation dose.[6,7,9] If the patient's sensitive organs, such as gonads, were included in the imaged area, then these organs would receive a double dose.[8] Other concerns identified in the literature include increased imaging costs, longer patient waiting time, additional workload for radiographers, and reduced X-ray tube life.[6,7,8,9] It should be mentioned that repeating an image is permissible but should be within the accepted best practice. However, repeating exposures due to carelessness or poor judgment on the part of the radiographer must be avoided.[8]

Given the above, it is essential to have a reject and repeat analysis programme in place in each radiology department. Sherer *et al.*[8] identify three main benefits of such quality assurance programmes. Firstly, the programme increases awareness amongst radiographers and radiography students of the necessity to produce optimal quality images. Secondly, radiographers and radiography students generally become more careful in producing their radiographic images when aware that the images may subsequently be reviewed by experienced peers. Thirdly, when the programme identifies problems or concerns, in-service imaging education awareness programmes covering these specific topics may be designed for radiographers and radiography students.

Globally, there are several clinical audits and primary research studies conducted on the causes of rejection and repetition of digital radiographic images. However, the reviewer was unable to find any published literature review which has brought these findings together to inform evidence-based practice. The aim of this study, therefore, was to review the causes of rejection and repetition of digital radiographic images to guide the practice of radiography in Zambia. This is against the background that Zambia is changing from film-based radiography to DR imaging systems.

METHODOLOGY

A literature review was utilised to review the causes of rejection and repetition of digital radiographic images. In January 2021, a literature search was performed in PubMed/MEDLINE and ScienceDirect online databases using the terms "reject radiographic image", "repeat radiographic image", "computed radiography"," direct digital radiography", "digital radiography". The literature search was extended to reference lists of eligible articles and radiography journals: Radiography Journal (UK), South African Radiographer Journal, Journal of Medical Radiation Sciences, and Nigeria Journal of Radiography and Radiation Sciences. Given that DR were introduced in the 1990s,[4] the search period was from 1990 to the time of search (January 2021). All research studies and clinical audits were eligible for inclusion. Research studies and clinical audits that analysed film-based radiography were excluded as per the objective of this review. However, research studies and clinical audits which compared film-based radiography with DR were included.

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used to screen and select relevant research studies and clinical audits. This process was carried out in two stages. The first stage involved looking at the title, abstract, and keywords of the article. Based on these items, if an article was clearly ineligible, the reviewer excluded it. The second stage involved retrieving and reading each full article to make a final inclusion decision.

RESULTS

The literature search results are presented in Figure 1. A total of 173 articles were retrieved during the literature search. After removing the duplicate articles and applying the inclusion and exclusion criteria, seven articles remained for this literature review.

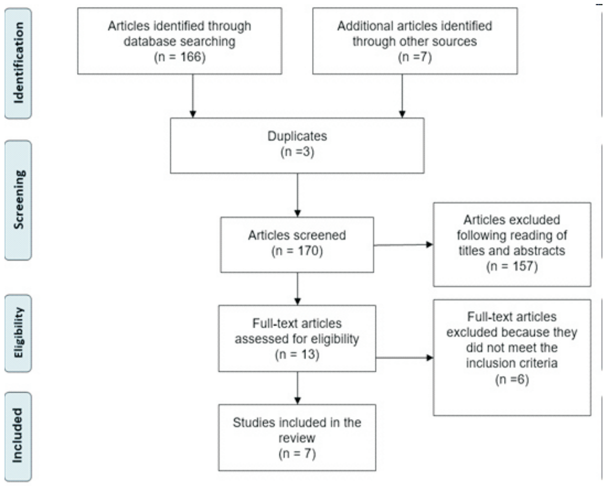

Figure 1: Literature search and selection process

Seven research studies and clinical audits were eligible for this review and their characteristics are presented in Table 1 on page 41.

Six causes of rejection and repetition of digital radiographic images were identified. These included patient positioning errors, inappropriate selection of technical exposure factors, patient motion during the radiographic exposure, presence of artefacts, improper collimation of the radiographic beam, and absence of permanent anatomical side markers (ASM).

DISCUSSION

This review found that research studies and clinical audits on reject and repeat analysis in digital imaging systems have been conducted globally. However, there was no published research study or clinical audit found in Zambia on this subject. The overall digital image reject rate ranged from 1.3% to 14.7%. Only two studies[11,14] were over the 10% acceptable image reject rate in DR.[11] This review also found that radiology departments affiliated with the schools of radiography had high rejection and repetition image rates due to radiography students' participation in the imaging of patients during their clinical training.[9,13] For this reason, radiographers who are involved in the facilitation of practice-based learning should always supervise radiography students to minimise image rejection and repetition.

This review found patient positioning errors as the main reason for rejecting and repeating digital images. Holmes and Griffiths[5] state that correct patient positioning plays a major role in determining the success of any radiographic examination. This involves including the area of clinical interest and correct patient positioning. In the Zambian radiography education system, patient positioning theory is taught in the classroom using the standard adopted textbook by K.C. Clark[16] and this is applied in the clinical area under the supervision of qualified and experienced radiographers.[17] The positioning is undertaken according to the recommended projection(s). A projection is described by the direction and location of the collimated X-ray beam relative to aspects and planes of the body.[16] There are two main radiographic projections: antero-posterior (AP)/posterior-anterior (PA) and lateral. In an AP projection, the collimated X-ray beam is incident to the anterior aspect, passes along or parallel to the median sagittal plane, and emerges from the posterior aspect of the body.[16,18] The opposite is true for a PA projection. For the lateral projection, the X-ray beam passes from one side of the body to the other along a coronal and transverse plane.[16,18] Incorrect positioning of the patient can result in rejection and repetition of the image due to distortion or obscuring of area of anatomical interest. However, it remains a challenge to image uncooperative patients, such as trauma and paediatrics. This is a reminder to radiographers to

Table 1: Characteristics of included research studies and clinical audits in this review (N = 7)

No	Author	Year	Title	Type of study	Main findings	Country
1	Lau et al. [10]	2004	Reject analysis: a comparison of conventional film-screen radiography and computed radiography with PACS	Research	• Overall reject rate was 1.3% • The main reason for rejection was positioning errors (55.4%) • Other reasons were exposure, patient movement, artifacts, and processing errors	China
2	Hofmann et al. [11]	2015	Image rejects in general direct digital radiography	Audit	• Overall reject rate was 11.0% • The main reason for rejection was positioning errors (51.3%), followed by centring errors (31.0%)	Norway
3	Mercieca et al. [12]	2017	Mammographic images reject rate analysis and cause- a national Maltese study	Research	• Overall reject rate was 2.6% • The main reasons for rejection were positioning errors, patient motion, artefacts, improper exposure, equipment failure, and improper detector exposure	Malta
4	Benza et al. [13]	2018	The causes of reject images in a radiology department at a state hospital in Windhoek, Namibia	Research	• Overall reject rate was 8% • The main causes of rejection were positioning errors (63%), followed by exposure (24.9%) • Other causes were collimation, absence of anatomical markers, and artefacts	Namibia
5	Alahmadi et al. [14]	2019	Evaluation of reject analysis of chest radiographs in diagnostic radiology	Research	• Overall reject rate was 14.7% • The main cause of rejection was positioning errors (16%), followed by artifacts (11.3%) • The other cause was incorrect collimation	Saudi Arabia
6	Rastegar et al. [9]	2019	Reject analysis in digital radiography: a local study on radiographers and students' attitudes in Iran	Audit	• Overall reject rate was 8% • The main causes of rejection were positioning errors and improper patient preparation	Iran
7	Atkinson et al. [15]	2020	Reject rate analysis in digital radiography: an Australian emergency imaging department case study	Research	• Overall reject rate was 9% • The main causes of rejection were positioning errors (49%) and anatomy cut-off (21%) • Other causes were collimation, absence of anatomical markers, and artefacts	Australia

maintain this basic radiography knowledge and skill through continuous professional development (CPD) learning activities.

Inappropriate selection of technical exposure factors was one of the causes for rejection and repetition of digital radiographic images identified in this review. Literature reports that under and overexposure of X-ray film is the main cause of image rejection in film-screen radiography due to a short dynamic range.[6,7,13] This is reduced in digital imaging systems because of a wide dynamic range and image post-processing capabilities which enables rectification of the under or overexposure errors.[4,11,13,14] For both imaging methods, the selection of appropriate technical exposure factors for each imaging examination is essential to ensure a diagnostic image.[8] The five prime factors of radiographic exposure are the kilovoltage (kVp), exposure time (T), milliamperage (mA), milliampere-second (mAs), and source-image distance (SID).[8,16,19] Their definitions are stated in Table 2.[19]

Table 2: Definitions of prime factors of radiography

Factor	Definition
Kilovoltage (kVp)	A measure of the potential difference across the X-ray tube. An increase in kVp results in a more penetrating X-ray beam and a greater degree of exposure to the image receptor producing a darker image.
Exposure time (T)	A measure of how long the X-ray exposure will continue. When all other factors are equal, a longer exposure time will produce more exposure and a darker radiographic image, whilst a shorter exposure time will result in less radiation exposure and a lighter image.
Milliamperage (mA)	A measure of the tube current in the X-ray tube circuit. It determines the number of electrons available to cross the tube and thus the rate at which X-rays are produced.
Milliampere-second (mAs)	This is the product of the mA and duration of the exposure (exposure time). It is an indicator of the total quality of radiation produced in the exposure.
Source-image distance (SID)	This is the distance between the tube target and the image receptor. According to the inverse square law, there is a relationship between the radiation intensity and SID: radiation intensity is inversely proportional to the square of the SID.

Given the above, knowledge and correct use of appropriate radiographic exposure factors is necessary because they have a considerable impact on the image quality.[5] When automatic exposure control (AEC) is not used, an efficient radiology department uses standardised technique charts for each piece of X-ray equipment to ensure uniform selection of technical exposure factors.[8,19] Radiographers neglecting to use the exposure charts necessitates estimating the exposure factors, which may result in repeating an examination.[8] In obese patients, more exposure is required. The use of manual exposure factors for body parts like the abdomen, pelvis, and middle and lower spine should be avoided because it can result in an underexposed image containing image noise and undiagnostic image.[16,18] A radiographer should use an AEC if available on the equipment which can appropriately determine the correct mAs for larger patients.[16,18]

Another reason for rejecting and repeating digital radiographic images identified in this review is due to patient motion during the radiographic exposure. Patient movement, which can be voluntary or involuntary results in motion artifacts or blurring of an image.[16,18] It should be mentioned that a high-quality radiographic image must be sharp.[5] Therefore, blurring due to motion will cause image unsharpness and reduce the diagnostic quality of an image.[5,16,18] For this reason, movement unsharpness should be kept to a minimum by carefully applying good radiographic technique for voluntary and involuntary motions. To reduce voluntary movements, the radiographer should make the patient comfortable, give them precise instructions on breathing technique, and plan the examination accordingly.[16,18] In extreme cases, the patient can be immobilised or sedated, as in the case of people with special needs or psychiatric patients.[19] For involuntary movements, the use of short exposure times is recommended.[5] In summary, patient movement can result in the rejection and repetition of a radiographic image.

The other reason found in this review for reject and repeat of digital radiographic images is the presence of artefacts. A radiographic artifact is an abnormal shadow which is noted on an image produced by the equipment or human error.[16] Human error also includes artifacts from the patient's clothing and jewellery. Holmes and Griffiths[5] point out that radiographic images should be free from artifacts to avoid obscuring relevant detail. However, repeating an image should only be undertaken if the artifact interferes with the diagnosis.[16] To minimise artifacts, a radiographer must ask the patient to remove all radiopaque objects covering the area of interest and where necessary change them into the hospital gown during the imaging examination. To eliminate equipment artifacts, the imaging equipment should be serviced, and quality assurance performed periodically. However, there is a lack of such programmes in Zambia.[20] To improve the quality of imaging services, there is a need to establish servicing and quality assurance programmes in Zambia.

Improper collimation of the X-ray beam is one of the causes of rejecting and repeating digital radiographic images identified in this review. Good collimation of the X-ray beam should include all relevant anatomical structures, including soft tissue. Holmes and Griffiths[5] state that good X-ray beam collimation reduces scattered radiation and hence increases the contrast of the image. Careful collimation is also one way of reducing the radiation dose to the patient as only areas of interest are irradiated. It should be mentioned that over-zealous (close) collimation can result in anatomical cut-off and necessitate a repeat image, whilst a lack of collimation can result in overexposure of a patient to ionizing radiation.[15,16,18] A lack of collimation is a potential pitfall in DR where postprocessing techniques may be used to crop the image after image acquisition.[16,18] For this reason, it is important to conduct clinical audits of X-ray beam collimation and digital image cropping. Although a certain degree of flexibility may be necessary to avoid anatomical cut-off, repeated use of the unnecessarily large field of collimation is inappropriate due to increased radiation dose.[16,21] On the other hand, a field that is too small increases the risks of a diagnostic error or may require a second exposure.[16,21] This means that correct X-ray beam collimation requires knowledge by the radiographers regarding the external anatomical landmarks which are used as a guide. However, it can be challenging for the radiographer in obese patients to identify the bony landmarks or surface markings for radiological examinations of the abdomen, spine, and pelvis. This is one area where errors in collimation mostly occur during imaging.[16]

Only two studies[13,15] in this review identified the absence of permanent ASM as one of the causes of rejecting and repeating a radiographic image. It should be mentioned that image annotation is a core imaging skill of a radiographer. Adejoh et al.[22] define an ASM as a portable radiopaque objective with capital “L” and “R” which is used to indicate the anatomical left and right. The marker must be placed in the primary X-ray beam before making an exposure,[23] but digital imaging allows the placement of electronic markers as part of postprocessing procedures. Electronic markers may attract medical-legal implications due to human error during placement.[13,22,23] If the permanent ASM is missing and the radiographer is unsure or there is any anatomical double, an image must be repeated, especially for pre-surgery images and serious cases such as non-accidental injures (NAI) and forensic radiography because of legal issues involved.[16] In Zambia, Mulenga and others[24] reported an unusual and strange case of NAI in a young child presenting with multiple sewing needles and wires in his body. This is one example that requires correctly placing permanent ASM by a radiographer. To improve and maintain the standards of radiography, each radiology department should conduct periodical clinical audits of ASM.

CONCLUSION

This review has identified the causes of rejection and repetition of digital radiographic images. To reduce these factors, each radiology department should establish and conduct periodical image reject analysis and educational awareness. The reviewer found no published research or clinical audit on this subject in Zambia. This concurs with a review conducted by Bwanga and Chanda[20] on the challenge of radiation protection which found a lack of clinical auditing in Zambia. To have a good understanding of this subject, it is recommended to conduct image reject analysis in Zambia in different medical facilities offering imaging services.

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