Repeat Analysis Program As A Quality Assurance System For Radiology Management: Causal Repeat and Challenges

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Abstract. Rejected or repeated images analysis remains a significant challenge, particularly in digital imaging. Despite the expectation that the transition from conventional to digital systems would reduce repetition rates, the reality is that repetition rates still exceed established standards. This literature review aims to shed light on the identification of causes and barriers in the reject/repeat program. We conducted a systematic review of this program in radiography units over several decades, examining the causes of repetition, types of examinations, and data sources used. We also described the methods employed to analyze reject/repeat instances in both conventional and digital systems. The study found that computed or digital radiography was the primary data source for image analysis. Despite the use of digital systems, repetition rates persisted, with chest radiography being the most significant contributor, accounting for over 30% of cases. Technical factors, particularly positioning errors, contributed to more than 30% of repetitions. Notably, determining the causes of rejection proved subjective. However, one study highlighted that artificial intelligence (AI) could accurately predict image rejection with a sensitivity of 93%. Thus, the incorporation of AI can greatly assist in classifying rejection causes, resulting in more efficient and streamlined radiology management

Keyword: reject repeat analysis program, radiology, management, AI

1 Introduction

Quality assurance has become a priority in healthcare services as it improves customer satisfaction and the sustainability of healthcare organizations. In the radiology imaging department, service quality for patients and diagnostic images is the main output. With many factors involved, if not controlled, it can result in suboptimal image quality [1]. This can lead to repeated exposure, which will inevitably result in additional radiation dose to the patient and decreased accuracy of image interpretation. Errors caused by misinterpretation of an image can have a significant impact. Medical errors are a substantial cause of morbidity and

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mortality, with estimates ranging from 44,000 to 400,000 per year. In radiology, most medical errors are categorized as diagnostic errors [2]. Therefore, a quality assurance program related to image quality is necessary.

One important aspect of quality management programs is the reject, retake, or repeat analysis procedure. The reject/repeat analysis program is a systematic process of collecting rejected images and determining their causes so that actions can be taken to minimize or eliminate them in the future [1]. The reject/repeat analysis is useful for monitoring and improving diagnostic imaging services and can be used to prospectively evaluate cost-effectiveness and the quality assurance of the services provided [3]. This program contributes to the root of problem-solving related to unnecessary patient dosages and potential factors that can slow down the workflow of diagnostic imaging [4]and decision-making in the diagnostic imaging department [5]. The results of rejection/repeat analysis will provide information for technician training program planning and potential workflow changes. Repeating radiology examinations increases the risk of radiation exposure to patients, wastes medical resources, and decreases the quality of radiology services [6]. With the implementation of this reject/repeat program, it is expected to reduce the rejection rate, which will also lead to a decrease in the dosage received by patients [7].

For these reasons, concrete and continuous efforts are needed to reduce the rejection/repeat rate. One of them is the establishment of a quality assurance program in the radiology department, which is very important [8]. Personnel involved in the management of this reject/repeat program are usually carried out by the quality control team established by radiology management. Decisions regarding image quality depend on the technologist's subjectivity, and they must act as autonomous practitioners and be able to make decisions regarding image quality [9]. Technologists/radiographers routinely take many initiatives to obtain good image quality with low radiation dosage (optimization) [10]. The basic guidelines for reject/repeat decisions are based on European Guidelines for image quality criteria. In practice, differences in assessment regarding reject/repeat decisions are still found. There are differences in perception and assessment of image quality, where radiologists pass more images (related to positioning errors) than radiographers [11]. This article aims to provide an overview of the reject/repeat analysis research method in both conventional and digital radiography examinations as part of quality management in radiology. Additionally, we provide an overview of the challenges in implementing image reject/repeat in the radiology department

In Table 1, we present the research questions formulated in our review of existing literature, along with the reasons that drove these questions. This table serves as a helpful resource for future researchers, allowing them to concentrate on overviews causal reject/repeat and the challenges.

Table 1. The research inquiries presented in our systematic literature review

Research question	Motivation
1. Can the implementation of digital radiography imaging technology convincingly reduce the proportion of film or image rejections/repeats	Analyzing whether the transition from conventional to digital modalities still yields reject/repeat rates.
2. Are there similarities in the factors causing film or image rejections/repeats?	Identifying the causes of rejection between conventional and digital systems.
3. How can the factors causing rejections/repeats be analyzed in both softcopy and hardcopy images to find effective solutions?	Describing the methods for analyzing reject/repeat image instances from conventional and digital systems.

The transformation of medical imaging modality from analog to digital provides various conveniences and advantages for radiography technologists and radiologists in carrying out their professional duties related to radiology procedures. These implications have sparked many arguments and questions about the rationale for the need for film rejection analysis or rejected/repeated analysis (RRA) programs in radiology departments, leaving behind the analysis methods of analog film performance and quality.

1.1 Contribution to Knowledge

This systematic literature review has following contributions:

1. This study examines 20 original articles or papers that elaborate on the reject/repeat analysis program conducted using various sources of radiological modalities. These findings can serve as a foundation for researchers to expand their understanding of the topic.
2. The major research findings are presented in a detailed manner and divided into four sections: (i) the modalities used, (ii) identification of the causes of repetition or rejection and the percentage of the largest causes, (iii) the total reject rate, and (iv) the types of examinations evaluated
3. Based on our discoveries, we provide advice and recommendations to assist future studies in this field.

2 Method

In our narrative review, we conducted a critical and objective analysis of the current knowledge regarding the reject/repeat analysis program. This study follows the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) and adheres to the PRISMA Checklist. We performed a search using the Google Scholar and Scopus databases, using the search terms "Reject or Repeat and Analysis and in and Diagnostic and Imaging" to include relevant articles on the topic. Additionally, we reviewed the reference lists of relevant publications for further studies. After conducting a thorough literature review, we established specific search parameters. The final search query included terms such as "reject analysis radiography," "repeat analysis radiography," "retaken radiography," "reject repeat analysis in radiography," and "quality assurance image program in radiology." Only English-language literature was considered in the search. Inclusion criteria focused on diagnostic imaging within the domain of conventional radiography that provided insights into the causes of repeated images. Among several articles, those relevant to the topic and criteria, specifically about reject/repeat analysis in diagnostic imaging, were chosen, resulting in a total of 20 selected articles, as shown in Figure 1. The extracted information pertaining to the topic is presented in Table 1. Over the past two decades, research on reject/repeat analysis has been carried out to assess performance in the radiology imaging field, encompassing both traditional film-screen-based conventional radiography and digital radiology.

Figure 1 shows the flow diagram based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) outlines the steps taken during the review of the search strategy. It provides information about the removal of duplicate chapters, reviews, and papers. Additionally, it includes details about the screening process for titles and abstracts, papers that were screened and excluded in full, as well as the final selection of papers included in the comprehensive search query. An infographic representing a conceptual framework that provides a concise overview of the sections of the study as shown in Figure 2. Table 1 presents the characteristics of radiographic image analysis that have been rejected or repeated. The table include information such as the reason for rejection or repetition, the

number of times the analysis has been rejected or repeated, and the corresponding action taken to resolve the issue.

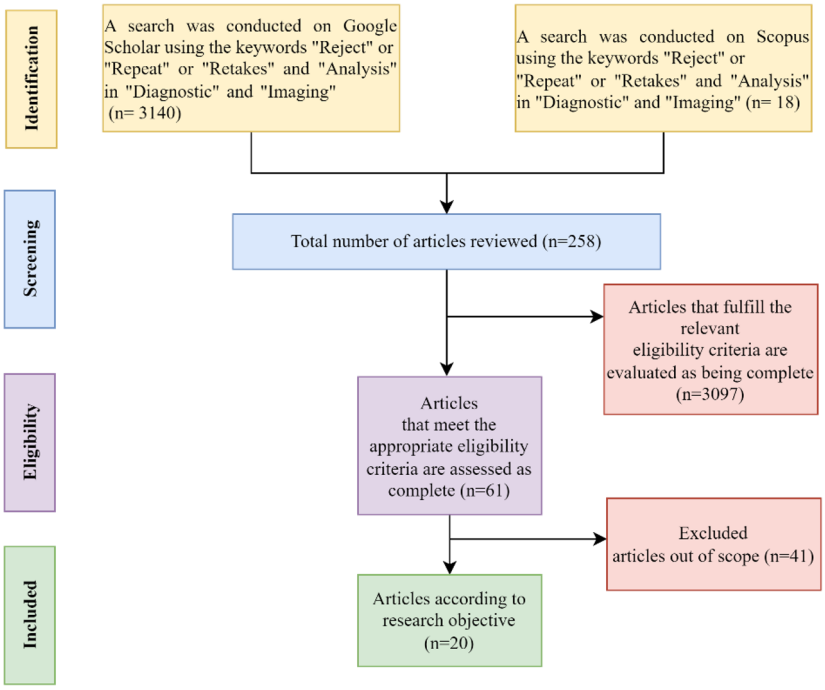

Fig. 1. Literature Search Prism Diagram

3 Overview of Reject Repeat Analysis: Modality, Causal Reject and Method

Evolution of X-ray technology for diagnostic imaging purposes has progressed remarkably rapidly. This evolution can be seen through several examples of advancements and technological developments in imaging, starting from analog imaging in conventional radiography using intensifying screens and film technology, Computer Radiography (CR), Direct Digital Radiography (DDR), Digital Fluoroscopy (DF), Dual X-ray Absorptiometry (DXA), and up to Multislice Computed Tomography (MSCT). These technologies have been widely applied in the medical field to achieve increasingly accurate diagnoses [12]. The need for a Quality Assurance Program within the framework of Radiology RFA activities is still a topic of interesting discussion to this day. It has been explained in numerous literature and scientific studies that due to the transition from conventional imaging technology to digital, the existence of reject film analysis activities is questionable. This is because advanced CR-DR technology is filmless, digital images are created using reusable imaging plates (IP), and image interpretation can be directly performed by clinicians through display monitors [13]

3.1 Reject Repeat Analysis in Digital Radiography

General radiography is commonly employed as the primary method for addressing clinical inquiries. However, when low-quality radiographic images are deemed acceptable, it can

significantly diminish the standard of care. This may necessitate the need for repeat radiographs, extend the time required to establish a diagnosis, compromise patient safety, and lead to increased healthcare costs [3]

The use of digital radiography systems, which started replacing conventional systems in the 1980s, has had a significant impact on radiography services. With the use of digital systems, the use of radiographic film has begun to be abandoned. The use of imaging plates (IP) in computed radiography systems and/or detectors in digital radiography systems enables technologists to make modifications to enhance the quality of the resulting images. This certainly has an impact on the quality of the images produced.

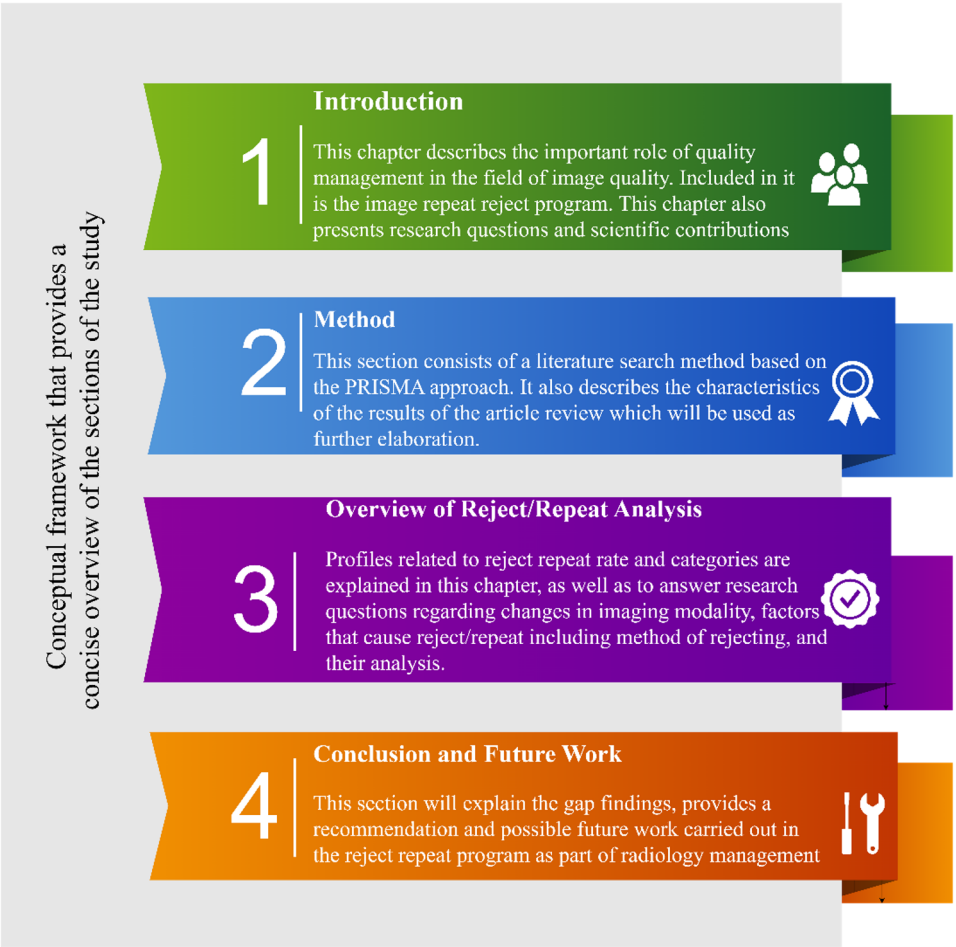

Fig. 2. Framework the study

Figure 3 describes the various image sources used in this study. The use of conventional systems still involves film-screen (FS) technology. The most widely used modalities are based on Computed Radiography (CR) and Digital Radiography (DR). Picture Archiving and Communication System (PACS) is also utilized as a system for storing digital images from various modalities. It is mentioned in several literature sources as a combination of conventional-digital variations, based on FS, CR/DR.

As the conventional film-screen radiography system was replaced by digital systems, there was a significant decrease in the reject/repeat rate. In one study, the reject/repeat rate

decreased from 2.1% to 1.3% [14] The reject/repeat rate of conventional radiography images often exceeds the established requirements, with a range of 2.1%-29.4% [14]–[17]According to the AAPM, in general radiography procedures, the reject rate is not allowed to exceed 8%, while for pediatric radiography, it is 5% with a deviation of ±2%, whereas for mammography, it is not more than ±2% [1]. The limit for mammography radiography is lower than for others because it is a sensitive organ and requires high-quality images with high detail. In one study, the reject rate was still above the threshold, namely 3.85% [8]. If it exceeds 10%, this is already a serious concern because it causes the department to work inefficiently and contributes to an increase in patient dose. By emphasizing the reject/repeat rate, it can reduce the radiation dose received by patients, as well as other factors such as cost and time [17].

Table 1. Characteristics of Rejected/Repeated Analysis of Radiographic Image

Researcher / Year	Modality	Identification cause of rejection	Total reject/ repeat rate (%)	biggest reject/ repeat anatomy (%)	Causes of reject/ repeat (%)
PA Clark, et al [17] /2003	FS	Position, anatomy, exposure factors, film, tools, fog, patient	Before and after interventi on 50.8 to 12	Before and after interventio n: Pelvic:12.7 to 4	Before and after interventio n: error anatomy (63%)→ex posure factor (38%)
Sheung-ling Lau, et al 14 [14]/2004	FS, CR, PACS	Exposure, position, patient movement, artifacts, processing, stich errors, incorrect tomographic level, others	Film-Screens: 2.1 CR: 1.3	NA	FS: Exposure 38.6% CR: Position (55.4%)
David H. Foos [18], /2008	CR/DR	Anatomy, position, patient, under and over exposure, tests, Artifacts, markers, tools, high/low index exposure	A: 4.4 B: 4.9	A: facebone (20.5) B: head (16.3)	Position A: 4 B: 5
A Kyle Jones, et al [19]/2011	CR/DR	Position, patient ID, exposure, test, artifact	9.08	Abdomen, lateral decubitus (13.7)	Position: 77.3
Florian Fintelmann, et al [20]/2012	CR/DR	Position, Movement, Techniques, Artifacts, Tools	CR3.6 to1.8 DR13.3 to 8.2	Chest (specific)	Position DR: 84.8 CR: 84.7
Wen-Sheng Tzeng, et al [21]/2012	CR/DR	Position, Artifacts, Patient, Tools, Parameters of other causes	4.61	Thoracic vertebrae (5.29)	Position (35.59)
Usha, et al [16]/2014	FS	Exposure, parameters, position, rotation, collimation, centering, film size, artifacts, movement	22.12	Bone back (31.41)	Over exposure (84)
J. Owusu-Banahene, et al[22]/2014	FS	Under-over-exposure, position, patient, technical factor artifact, cause other	14.1	Cervical vertebrae (57.1)	Over-exposure (78.6)

Researcher / Year	Modality	Identification cause of rejection	Total reject/ repeat rate (%)	biggest reject/ repeat anatomy (%)	Causes of reject/ repeat (%)
Bjorn Hofmann, et al [23]/2015	DDR	Position, collimation, exposure, Artifacts and reason other	11	Knees (20.6)	Position (52.3)
Mercieca N., et al [9]/2016	FS, CR, DDM	Position, patient, artifacts, exposure, machine / tool, detector	3.85	Mammae (specific)	Position (71.6)
A. A. Sadiq, et al[15] /2017	FS	Under and over exposure, cut-off, rotation, artifacts, fog, position, double exposure, patients, blurring, other causes	29.34	Chest (12.19)	Under-exposure (36.21)
Mohd Yusmiaidil Mohd Yusof, et al [24]/2017	intraoral DR	Operators (angulation and artifacts), Engineering/ machinery (blur and artifacts other than operator and patient), patient	34.4	Dental 54.4 (specific)	Operators (56.1)
Aysegul Yurt, et al [8]/2018	CR/DR	Position, centering, technician, exposure, collimation, patient, other reasons	1.2	Chest (38)	Position (36.11)
Omar S. Alahmadi, et al[25]/2019	CR/DR	Position, artifacts, collimation	14.67	Chest (specific)	Position (9.33)
Kevin J. Little, et al [26]/2020	CR/ DR	Position / collimation, Artifacts, Movement patient, exposure, technical factors, other reasons	13	Chest (37.7)	Position / collimation (67.5)
Samantha Atkinson, et al [27]/2020	CR/DR	Positions, cut-offs, artifacts, no There is image, movement patient, under exposure, less inspiration, test, image processing, software, machine, over exposure, electricity and other reasons	9	Hip with wireless horizontal beam (38)	Position (49)
Khalid A. Alousef et al [28]2020	CR/DR	Label, procedure / protocol, position, processing, error documentation, exposure, and other reasons	0.25	Extremity 43	Labelling (22)
Brittany Stephenson-Smith, et al [29]/2021	CR/DR	Position, cut-off, artifacts, detector, less inspiration, movement patient, exposure, device, software	10.3	Chest AP (18.1)	Position (67.1)
Yazeed Alasban, et al [30]/2022	CR/DR	Position, Cut-off, movement patient, exposure, collimator, gridline	8.96	Thoracic vertebrae (66)	Position (41.4)
Dimas S Joseph [31]/2022	CR	Cut-off, exposure, position, movement patients, artifacts, machines, other causes	9.77	Chest (51.76)	Cut-off (37)

The transition from analog to digital systems still finds reject/repeat images [13], even though the reject rate has decreased compared to the use of film-screen [25]. Some studies

mention that the reject rate in digital radiography is higher than in computed radiography [32]. This will certainly become a focus for continuous and consistent reject/repeat analysis, where the data obtained can be used to make decisions in improving performance and increasing work efficiency in the radiology imaging field. In the use of digital systems, a significant reject/repeat rate is still found, with most still above 5%. Although in this case, it does not affect the use of film, the cost incurred is quite significant, in terms of labor, time, machine usage, electricity consumption, and so on. There is a decrease in the reject rate with digital systems, but with the acquisition of a reject rate above 5%, it is a consideration that the digital system has not been able to reduce the reject/repeat rate. Even in digital-based intraoral dental examinations, the reject rate was 34.4% [24].

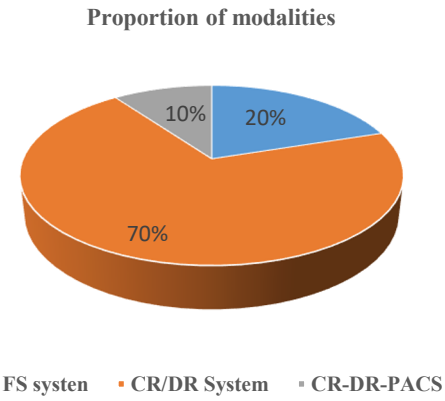

Fig. 3. Proportion of modalities used as image sources in reject/repeat analysis program

3.2 Reject/Repeat Rate Group by Examination Radiography

In terms of examination types, chest radiography contributed the highest reject rate overall as shown in Table 1, even reaching 51.67% [31], followed by vertebral examinations with the highest reject rate of 66% [32]. Research is not limited to conventional radiology units in general but is also carried out for specific areas, as done by Clark [17], who studied orthopaedics examination, stating that the largest reject rate was in pelvic radiography, which reached a reject/repeat rate of 12.7%. If related to patient radiation dose, the pelvic area is a sensitive organ to radiation because there are reproductive organs in that area. After an audit, improvements were made to radiology service management, resulting in a significant decrease in the rejection rate to 4%. Based on the review of the article, Table 1 mentions that thoracic examinations contribute the most to the reject/repeat rate, as shown in Figure 4

Chest radiography is the major factor in the category of anatomical rejects because a significant number of radiographic examinations are performed. In the implementation within hospitals, chest radiography is commonly conducted for screening purposes, institutional requirements, and preparation for further interventions such as surgeries and procedures. Additionally, this examination is also used for advanced identification of patients with metastasis to gather information about the overall condition and spread of malignant diseases. It is crucial to provide education and training (formal/informal) to technologist staff on various aspects. These include instructing them on equipment operation, building confidence in equipment performance, reducing cost wastage due to high image rejection rates, and promoting quality service improvements within the context of radiology services.

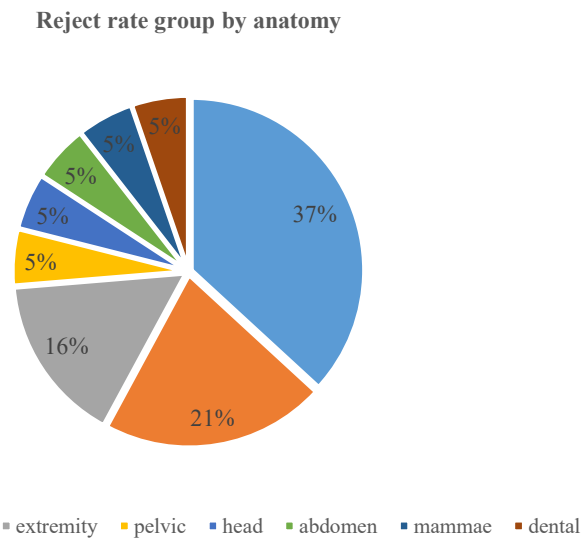

Fig. 4. Proportion of most anatomy examination in reject/repeat analysis program

3.3 Causal Reject/Repeat in Conventional and Digital Radiography

In categorizing the causes of rejection in the film-screen system, issues still arise in the digital system, such as position, exposure, patient movement, and artifacts. Most of the reasons for rejection/repeat in the use of conventional film-screen are due to exposure factors, whether it is due to inadequate or excessive exposure [15], [16], [33]. This is because the film's latitude is short, so even a slight exposure factor error will greatly affect the resulting image quality. Other factors such as film processing and film storage conditions can also cause fog [15]. The addition of rejection/repeat factors in the digital system, such as detectors [9] and processing software [34], adds to the list of rejection causes. Position remains the primary culprit for the increased rejection rate, with the majority of cases contributing more than 50% and even more than 70% of rejections [19]. Errors in position can cause anatomy to appear invisible or to be cut off and not within the collimation. This can lead to misdiagnosis. Therefore, managerial efforts are needed so that after identifying the causes of rejection, future actions or prevention can be taken to eliminate or minimize rejection/repeat rates. Increased radiology examinations due to repetition increase the risk of radiation exposure to patients, waste medical resources, and reduce the quality of radiology services [6]. From the various causes mentioned in Table 1, we simplified the grouping of reject causes based on the five main categories mentioned by Little [4] and added other causes that were not included in those categories, as shown in Figure 5.

Positioning is the biggest factor contributing to the rate of rejects/repeats. The category of reject/repeat due to positioning includes errors in positioning, collimation, rotation, and anatomical cutoff. Positioning errors can occur due to patient limitations caused by accompanying medical conditions. Non-cooperative patient conditions can make it difficult for technologists to achieve an ideal repositioning. This can be avoided by using aids, immobilization techniques, or modifying the X-ray machine settings.

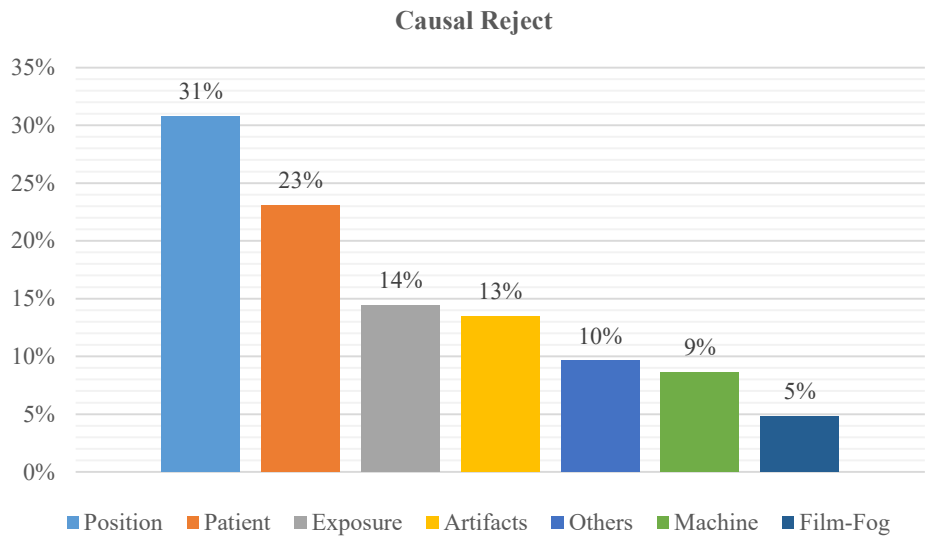

Fig. 5. Category of causal reject/repeat

3.4 Challenges Methods Reject/Repeat Analisis Program in Management Quality of Radiologic

The method of collecting data related to reject repeat analysis program (RRA), which is film-based, is done by calculating the number of physical films rejected compared to the total use of films over a certain period. For digital-based systems, whether using CR or DDR, data is pulled from the system or PACS after the radiologist assesses whether the image is rejected or suitable for radiologist reading. Or a combination of both methods [9], [35]. Some articles use Python scripts to verify data accuracy [4] Most data are processed descriptively using Microsoft Excel to find frequency ranges [36], while others use statistics with SPSS [25], [30]Although the reject/repeat analysis program in digital technology is not new, its correct and appropriate implementation is essential for radiology management, which can be held accountable both internally (structural to hospital management) and externally (accountability to the public). RRA can become a primary program that should be applied in diagnostic radiology services to plan targeted training to improve technical skills for radiography/technologist practitioners [37] Table 1 presents the characteristics of radiographic image analysis that have been rejected or repeated. The table include information such as the reason for rejection or repetition, the number of times the analysis has been rejected or repeated, and the corresponding action taken to resolve the issues.

Radiologists and technologists play a significant role in the reject/repeat program. Subjectivity in determining the justification for reject/repeat is still present. The determination of image rejection/repeat involves technologists and radiologists. Most of the image rejection and categorization processes are still directly determined by the designated team, which can cause bias. Efficiency is also a major obstacle, as the program is not always performed correctly by personnel.

With the development of science, digital modalities have been equipped with reject analysis software, but the decisions to reject and categorize images are still limited to personnel/teams. Some studies have shown differences in decision-making when assessing whether an image is acceptable or should be rejected. Radiologists tend to pass more images deemed acceptable for interpretation and do not require repetition. This is supported by

Kjelle's research, which found significant differences between radiologists and technologists in categorizing reject/repeat images. To avoid differences in decision-making due to subjectivity, efforts are needed to standardize the reject decision, including the use of artificial intelligence.

Implementation of AI-based reject/repeat programs has been developed. One study mentioned that AI improves the quality of technologists in fulfilling their responsibilities in presenting and auditing images [38]. The use of AI can also reduce workload and subjective decision-making. In Whaley's study [39], efforts were made to assess images using a neural network approach for the development of an algorithm to automatically predict the presence and degree of anatomical cutoff and patient movement in thoracic images. Exposure errors were detected using feature-based, linear model algorithms. The algorithm was evaluated by comparing its detection with technologists' detection results with or without software assistance. All images from each CR unit were configured by technologists to specifically determine the reasons for rejection. Subsequently, the images were processed using the algorithm and classified as either rejected or accepted. Other developments related to the use of intelligent systems have also been carried out by Moradi, using deep neural network algorithms to classify images with technical errors and without technical errors with a sensitivity of 93% [40]. This research can still be developed to classify reject categories into multiclass, to obtain data related to the causes of reject/repeat and to improve the program in the future.

The use of X-ray technology is focused on improving clinical diagnosis, but the number of radiographic repetitions is sometimes overlooked by personnel in the field. However, this repetition has an impact on increasing radiation doses to patients and technologists. The repetition rate is considered important because it is related to practitioners and decision-makers in diagnostic imaging departments. It is hoped that this innovation can help improve the performance of radiology departments and reduce the number of rejects/repeats, which will ultimately improve patient care.

4 Conclusion

Reject/repeat program is part of image quality management. This program can identify the root cause of image repetitions, which also affects unnecessary radiation doses to patients and hinders the performance of other radiology departments. Although technology has shifted to digital systems, the rejection rate has not been completely eliminated. The justification for rejection decisions still poses a challenge related to personnel's subjective factors, and determining the causes of rejection/repeat must also be done to obtain concrete data related to radiography performance. The use of AI in the reject/repeat program has not been extensively studied, and therefore, there is a great opportunity for development.

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