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Prevalence of suboptimal frontal chest radiography in PSMMC

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Abstract

Background: Suboptimal frontal chest X-rays (CXRs) can impede accurate diagnosis and delay treatment, highlighting the need to assess their prevalence and identify solutions to improve image quality. This study aimed to determine the prevalence of suboptimal CXRs at a tertiary hospital and propose strategies to enhance radiographic standards.

Methods: A retrospective analysis of 505 frontal CXRs was conducted. Each image was classified as adequate or suboptimal based on criteria established by the American College of Radiology (ACR) and European guidelines. Parameters such as patient rotation and inspiratory volume were evaluated to identify technical deficiencies. Statistical analysis was performed to assess associations between patient gender and image quality.

Results: The study revealed that 25.7% of CXRs exhibited improper patient rotation, and 25.1% had inadequate inspiratory volume, indicating significant technical shortcomings. No significant association was found between patient gender and image quality. Suboptimal CXRs were prevalent, potentially compromising diagnostic accuracy and patient care.

Conclusions: Suboptimal CXRs are common and may hinder effective diagnosis and treatment. To address this, we recommend strengthening CXR acquisition protocols, implementing robust quality control measures, providing technologist re-training, and integrating artificial intelligence (AI) tools for automated quality assessment. These measures can improve radiographic standards and enhance patient outcomes.

Keywords: CXR; Radiographic techniques; Radiograph acquisition; Interpretation of a radiograph

1. Introduction

Opening the subject of poor chest radiographs (CXRs) can be achieved with a great impact by the use of Duke Ellington, the celebrated American composer from 1899 to 1974. According to him, "A problem is a chance for you to do your best." For poor CXRs, the quote calls attention to the significance of creating solutions effectively, possibly by increasing education opportunities and inventing technological developments. As we continue to adopt new technologies, It's important that we keep our critical thinking caps on.

Although many investigations have been undertaken to explore the potential benefits of various technological improvements in improving CXRs, there is also an important need to understand their limitation. There has been a host of techniques proposed and investigated that have been shown to improve radiography quality by enhancing image capture, segmentation, detection, diagnosis, risk analysis, and prediction of outcome. Additional efforts have been made

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toward achieving optimal image quality without missing interpretation errors [1-4]. However, issues have been raised about the validity and efficacy of certain methods approved by regulatory authorities [5].

This is the article that explains the factors and challenges that help contribute to standardized chest X-rays with their impact through which the potential solutions are explored for enhancing the quality of images and reducing their onset. Such similar methods are also applied for the better analysis of the different types of radiographic techniques of different body areas including different modalities of imaging. We here provide the current research overview for low-quality chest X-rays and different strategies for addressing these presented problems.

In the case of chest X-rays, or CXRs, they're one of the most common imaging tests that we order. However, numerous X-rays come out suboptimal, causing high rejection rates. Using such suboptimal images can delay patient care and make accurate interpretation difficult. This is especially relevant because CXRs are an integral part of both acute and chronic disease diagnosis and management. Poor image quality also makes radiologists differ in their opinions. Despite advances in the technology of radiography, including the transition to digital imaging, image quality remains a big issue. By improving how we acquire, analyze, and interpret images, we can solve these problems. The current knowledge of low-quality CXRs is what this paper attempts to explore while looking into different avenues of enhancing image quality and reducing the number of low-quality images.

2. Methods

2.1. Optimal and Suboptimal CXRs: The Criteria

The numerous elements that contribute to inadequate CXRs as a result of departures from these ideal imaging procedures are poor-quality (CXR) images likely to be the consequence of either under- or over-exposure, which can result in an inaccurate gray-level visibility of the lung fields. Incomplete imaging of the lungs from the apices to the costophrenic angles, inappropriate placement as a result of rotation or oblique acquisition, and blockage caused by the chin, arms, or detachable items such as lockets, zippers, coins, or watches are some of the other concerns that might arise. Inadequate visibility of lower thoracic vertebrae and retrocardiac pulmonary vessels, inadequate inspiratory effort leading to low lung volumes, excessive noise or artifacts resulting from technical limitations, improper collimation resulting in unnecessary exposure beyond the lungs, and unintended lordotic or angulated projections are some of the additional deficiencies that may be present.

2.2. Suboptimal CXRs: The Problem

Not only does the interpretation of diagnostic results suffer when chest X-rays are of poor quality, but there are also cost repercussions. [8] Although the national average cost of a chest X-ray in the United States is roughly $420, costs may vary greatly based on location, even within the same area. This is the case even when comparing pricing from different regions. When you consider that chest X-rays make about forty percent of the three billion and six hundred thousand imaging investigations that are carried out all over the globe every year, the financial burden of rejected or repeated substandard X-rays is significant [9]. Imaging that is repeated results in higher radiation exposure, extra resource use, workflow inefficiencies, delays in diagnosis, and ongoing difficulties in interpretation when the picture quality is not at its ideal level.

An investigation on the rate of rejection for CXR tests was carried out by Foos et al. [16] in a research that was carried out in both university and community hospital settings. Based on their data, it was determined that chest x-rays were the most often conducted examinations, with a rejection rate of 9% in the university hospital and 8.8% in the community hospital. Clipped anatomy, positioning mistakes, patient movements, artifacts, erroneous or clipped markers, and low and high exposure index were the top causes for rejection. Other reasons included clipped markers. Additionally, the percentage of radiographs that were rejected for the shoulder, hip, and spine was found to be between 9 and 11%, 10%, and 8 to 11%, respectively [16].

Dealing with problems that are associated with substandard radiography is a difficult task. John Dewey, an American philosopher and educator who lived from 1859 to 1952, is credited with writing the following quote: "A problem well-stated is a problem half-solved." Even while acquisition mistakes are the source of a significant number of substandard X-rays, the reasons for these errors are not necessarily associated with inadequate training or a lack of accuracy on the part of radiologic technicians. It is possible that getting ideal picture quality might be challenging in some circumstances, such as when taking portable X-rays of patients who are either severely sick or immobile. This is true independent of the level of competence of the technologist or the level of complexity of the imaging gear. In a world that is driven by technological advancements, where innovations frequently seek out problems to solve or even magnify issues to justify their relevance, it is essential to first establish the true extent of the problem before considering conventional solutions or proposing advanced technologies as remedies [10-11]. As a consequence of this, every radiography method continues to be vulnerable to quality problems, which highlights the need to maintain continuous monitoring and provide quality assurance tools.

The reasons for poor chest X-rays and rejection rates are outlined in Table 1, which offers an overview of the situation. Only 4% of pediatric chest X-rays were found to meet all of the requirements for excellent picture quality, according to research that was conducted in 2015 by Tschauner and colleagues [12]. Chest X-rays were examined in the study using European criteria, with particular attention to the appropriate collimation technique—which is very essential for the lowest radiation exposure. 70 % of the identified X-rays were tilting or rotating free according to the statistics and only 49 % of them have received the inspiration of heights. Similarly, one more scientist performed his research [13], in his research he examined around 800 CXR films, and after the analysis of the sample he classified them on the basis of their quality, which depends on the identification of the patients, markers marked by anatomy experts, pertinent structure coverage, positioning of the scapula, parameters set for exposure, blurry motion, processing errors due to darkness, rotation and presence of artifacts. The standard set by the optimal quality criteria was only satisfied by 17 % of the X-rays. The inadequate collimation according to them was the most frequently faced issue that is found in more than 83 % of the participants of the study [14]

The European criteria were also used in one study for the efficient examination of the CXR, the most subsequent attention is attained by the optimal collimation technique. This technique is identified by the researcher as the most appropriate technique for the lowest radiation exposure. Likewise, Okeji et al. [13] examined 800 chest X-rays and classified image quality depending on elements including patient identification, anatomical markers, coverage of pertinent structures, inspiratory effort, artifact presence, scapular positioning, exposure parameters, motion blur, rotation, and darkroom processing errors. Only 17% of the X-rays satisfied the optimum quality criteria, according to their research; inadequate collimation was the most often occurring problem influencing 83% of the instances (n = 664/800) [23]. Every single one of the repeat rates for mammograms (16%), skull X-rays (13%), cervical spine X-rays (10%), and thoracic spine X-rays (8.3%) were higher than the norm for the department [15-17].

Not only does reacquiring substandard CXRs raise diagnostic issues, but it also has the potential to postpone patient treatment, especially in situations that need immediate or emergency action. Especially for outpatients who may have to come back for more imaging, this delay might create a disruption in the workflow of patients and lead them to experience difficulty. In conventional radiography and computed radiography (CR), when pictures are not immediately accessible for examination, the influence is more prevalent than in other types of radiography studies. Digital radiography (DR), on the other hand, enables technicians to evaluate the quality of pictures in real time and to reacquire images before the patient departs, therefore minimizing the number of interruptions that occur. The burden of technologists is increased, however, as a result of reacquisition. Considering the significant part that CXRs play in the process of medical diagnosis, it is essential, while difficult, to lessen the number of instances in which CXRs are not ideal. Amelia Earhart (1897–1937), the first female pilot to fly solo across the Atlantic, was quoted as saying, "The most difficult thing is the decision to act, the rest is merely tenacity." This quote exemplifies the need for consistent effort in order to address this problem.

Table 1 Table that provides an overview of the CXR reject rates that were reported in earlier studies**.**

Reject Analysis	Country	Radiography	Total CXRs	Rejected CXRs	Reject Rate
Foos et al. (2009) [16]	USA	CR	102,678	5134	5%
Jabbari et al. (2011) [14]	Iran	FR	5695	626	11%
Jones et al. (2011) [17]	USA	CR & DR	27,409	1096	4%
Sadiq et al. (2017) [18]	Nigeria	FR	4171	1557	37%
Benza et al. (2018) [15]	Namibia	CR	882	88	10%
Atkinson et al. (2019) [19]	Australia	DR	39,185	2743	7%
Ali et al. (2021) [20]	Pakistan	DR	3858	579	15%
Arbese et al. (2021) [21]	Ethiopia	FR	1690	152	9%

DR stands for digital radiography, CR stands for computed radiography, Conventional is for conventional/film radiography, and FR stands for film/conventional radiography.

During the COVID-19 epidemic, Ali et al. conducted research to determine the percentage of patients who were rejected [20]. According to their findings, the total rejection rate was 17%. Positioning mistakes, artifacts, motion, collimation, labeling, exposure errors, and machine or detector failures were the most prevalent causes for rejection, in order of frequency. Other reasons included collisions, labeling, and exposure problems. Twenty-three percent was determined to be the rate of rejection for CXRs, which was fifteen percent higher than the norm for all cases. Skull radiographs had the greatest rejection rate (45%) among all other radiographs, followed by pelvic radiographs (35%), abdomen radiographs (28%), and neck radiographs (21%), according to [20].

The findings of these researches highlight the ubiquitous difficulties that adversely impact radiograph quality. Given the subjective character of the rejection criteria used by technicians at different institutions, this heterogeneity most certainly helps to explain the notable variations in reject rates shown in different research.

2.3. Suboptimal CXRs: Impact and Issues

The large difference between the incidence of mediocre chest X-rays (CXRs), reported to be as high as 83–96% in certain studies [12,13], and the reject rate of 4–15% [14,15,16,17,18,19,20,21] may most certainly be ascribed to the greater frequency of poor-quality CXRs, which results in fewer being rejected. Low reject rates may also point to problems with the CXR pictures that cannot be corrected, including low lung volumes in patients on ventilation or in critical illness. Furthermore, radiology departments may have a high tolerance for substandard computed tomography (CXR) pictures in order to minimize costs, preserve workflow efficiency, and handle the practical issues of reacquiring images. This phenomenon occurred despite the fact that we adhered to all safety measures.

In this situation, the suboptimal CXRs display a significant influence. The identified problems including the overlapping architecture and clipped apices of lungs might make it difficult to diagnose pneumothorax, apical pneumonia, or other anomalies in individuals who are in a severe condition or who are unstable. Similar to how underexposed photos or photographs with low lung volumes may obscure lung bases and make it difficult to evaluate lines and tubes, underexposed images can also obscure lung bases. The examination of lung architecture, hila, and cardiomediastinal characteristics can be altered after an excessive amount of patient rotation. Artifacts on pictures may be misconstrued for disease, leading to unneeded further testing, repeated radiography, and patient worry.

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Even though there are criteria on CXR picture quality [6,7], lowering the percentage of substandard and rejected images continues to be a difficult task due to many variables. It takes a substantial amount of time and effort to implement quality control processes, which often include manual picture checks. Even though DR makes it possible to immediately reject and re-acquire the image, patients are nevertheless subjected to more radiation when they undergo repeated imaging. It is possible to minimize disturbances to the workflow by performing a short review and rejection analysis when using DR; however, this method is more complicated when used for traditional radiography and CR. The capacity to improve and edit pictures after they have been acquired is one of the benefits of DR. This capability may make it possible to recover certain radiographs that are not as good as they might be.

Efficiency and the number of patients seen by a provider are often prioritized above quality control measures in clinical settings. In most cases, radiographs that are rejected are not kept; instead, they are used only as statistical data for monitoring purposes. In spite of the fact that these figures are helpful for audits and evaluations, they also represent possibilities for education that were not taken advantage of. Utilizing rejected pictures as a learning tool might be beneficial to radiographers since it would assist them in recognizing and avoiding mistakes that occur repeatedly [22].

Not only does examining rejected and substandard photographs give documentation of radiation exposure, but it also provides insights into the reasons for rejection and whether or not reacquired images effectively resolved the problem. The provision of individual feedback may assist in the improvement of technique without the imposition of punitive repercussions [23]. This is due to the fact that radiographs are often associated with the specialist who got them. It is essential to identify the fact that inadequate CXRs are often the consequence of a combination of circumstances rather than the result of individual mistakes. For instance, acquiring pictures that are correctly exposed may be especially challenging for individuals who are morbidly obese, and hyperinflated lungs may result in the clipping of the bases of the lungs. Motivating technicians to concentrate on improving image acquisition may be accomplished by providing them with positive reinforcement and recognition while they are working.

In addition to this, it is of the utmost importance to record the percentage of rejects for both portable and fixed radiography equipment. It is nevertheless required to conduct routine audits and reviews in order to determine the amount of substandard CXRs and the effect they have. As our organisation has proved, these issues may be addressed with the assistance of continuous education and feedback on picture quality, which is backed by extra workers dedicated to quality assurance.

2.4. Ethical Approval and Informed Consent Waiver

This study received ethical approval from the Research Ethics Committee at Prince Sultan Military Medical City (PSMMC), approval number [11285], dated [13/ 5/ 2024]. This research was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Given the retrospective nature of this study, anonymized patient data were retrieved from the Picture Archiving and Communication System (PACS) database at PSMMC. No direct patient interaction occurred, and no identifiable personal information was used. Therefore, the requirement for informed consent was waived by the PSMMC Research Ethics Committee.

2.5. Descriptive statistics

The dataset consists of 505 rows, though the focus of the analysis is on 505 patients, accounting for user-defined missing values. The analysis includes the frequencies of four variables: age, rotation, volume, and gender. Age distribution shows the range and count of patients within various age brackets. The frequency with which certain rotation values are observed is referred to as the rotation frequency. The distribution of volume (proper inspiration) measurements among patients is that which is referred to as volume frequency. Finally, the gender frequency refers to the proportion of male and female patients who are included in the sample..

Table 2 Frequency distribution of chest radiographs according to rotation adequacy, inspiratory volume adequacy, and patient gender (n=505).

Frequency Table					
Rotation					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	adequate	375	74.3	74.3	74.3
	non-adequate	130	25.7	25.7	100.0
	Total	505	100.0	100.0	
Volume					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	adequate	378	74.9	74.9	74.9
	non-adequate	127	25.1	25.1	100.0
	Total	505	100.0	100.0	
Gender					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	290	57.4	57.4	57.4
	Female	215	42.6	42.6	100.0
	Total	505	100.0	100.0	

The correct measurements provide us with important information on the demographics of the patients as well as the distribution of the variables that are being assessed. understanding the features of the population is essential for making informed judgements on future analysis or therapeutic intervention, and it is also significant for understanding the characteristics of the populationThe even distribution of the three selected variables is illustrated in the above-mentioned tables, the three variables are Gender, volume, and rotation. A sample size of 505 patients was analyzed.

375 patients, or 74.3 percent, had adequate rotation, whereas 130 patients, or 25.7%, had non-adequate rotation. This information was derived from the Rotation variable. By looking at the Volume variable, it was found that 378 patients (74.9% of the total) had appropriate volume, whereas 127 patients (25.1% of the total) exhibited poor volume.

According to the gender breakdown, there were 290 male patients or 57.4% of the total, and there were 215 female patients or 42.6% of the total. The frequency distributions provide data that describes the patient group in such a manner that the majority of them have excellent rotation and volume, with the majority consisting of more male patients than female patients. The information is essential for gaining a knowledge of the baseline features of the patient group, and it has the potential to be decisive in the course of future research or therapeutic treatment.

Table 3 Crosstabulation of rotation and inspiratory volume adequacy of chest radiographs according to gender.

Gender * Rotation				
Crosstab				
Count				
		Rotation		Total
		adequate	non-adequate	
Gender	Male	212	78	290
	Female	163	52	215
Total		375	130	505
Gender * Volume				
Crosstab				
Count				
		Volume		Total
		adequate	non-adequate	
Gender	Male	216	74	290
	Female	162	53	215
Total		378	127	505

2.6. Examination of Crosstabulation Among Gender, Rotation, and Volume

The information consists of 500 entries, and any missing values that are specified by the user are handled appropriately. Within the context of the crosstabulation study, the relationship between Gender, Rotation, and Volume is investigated.

2.6.1. Gender and Rotation

In all, there are 505 patients, and the data reveals that 290 of them are male (57.4%), while 215 of them are female (42.6%). In terms of the Rotation variable, there are 375 patients who have a strong rotation, whereas there are 130 patients who do not have a good rotation. We may use chi-square statistics to investigate the link between rotation and gender in order to determine whether or not there is a significant connection between the two variables.

2.6.2. Gender and Volume

The Volume variable reveals that 378 patients, or 74.9 percent, have a good volume, whereas 127 patients, or 25.1%, do not have a good volume. When we have this information, we are able to analyze the link between volume and gender by using chi-square statistics to see whether or not there are any significant associations.

3. Result

This retrospective study was conducted at Prince Sultan Military Medical City, to evaluate the prevalence of suboptimal CXR. focusing on patients' data for a collection of variables such as gender, rotation, and volume. Data analysis was performed using SPSS. Descriptive statistics were used to summarize the demographic and clinical characteristics of the study population.

Of the 505 CXRs analyzed, 130 (25.7%) exhibited suboptimal rotation, and 127 (25.1%) had inadequate inspiratory volume. Overall, approximately 25% of radiographs were suboptimal. The gender distribution included 57.4% males and 42.6% females. Chi-square analysis showed no significant gender association with suboptimal rotation or inspiratory volume ($p>0.05$). Additionally, no significant correlation was found between rotation and volume issues occurring together in the same image.

4. Discussion

Our study confirms the prevalence of suboptimal CXRs, consistent with prior findings in the literature [12,13,16]. Tschauner et al. reported that only 4% of pediatric CXRs met quality standards [12], while another study found just 17% of adult CXRs optimal [13]. Poor-quality CXRs impair clinical outcomes by obscuring critical diagnostic features, necessitating repeat imaging, and contributing to higher healthcare costs [16].

Improving CXR quality requires multifaceted solutions. Technological advances, such as AI-based real-time feedback systems, show promise by identifying technical errors immediately during image acquisition, thereby significantly reducing suboptimal imaging [1],[4]. Regular training programs, quality audits, and dedicated quality assurance personnel are also critical to maintaining imaging standards [22]. Implementing AI-driven quality checks, supported by recent evidence [23], could significantly mitigate technical errors

5. Conclusion

This study highlights the critical issue of substandard chest radiographs (CXRs) and their impact on patient management. Poor-quality CXRs can lead to delayed treatment, misdiagnosis, and inconsistencies in diagnostic performance among radiologists. Despite advancements in radiographic technology, including digital imaging, ensuring high-quality images remains a challenge. The findings emphasize the need for improved protocols in acquiring, evaluating, and interpreting radiographs to enhance CXR quality.

Our analysis showed that 74.4% of patients had appropriate rotation, while 25.6% exhibited non-adequate rotation. Similarly, 74.9% had an acceptable volume, whereas 25.1% demonstrated inadequate volume. The gender distribution indicated that 57.4% of the patients were male and 42.6% were female.

A chi-square statistical analysis was conducted to explore potential correlations between gender, rotation, and volume, which could provide valuable insights for clinical decision-making and radiographic quality improvements.

A promising solution to mitigate suboptimal CXRs is the integration of artificial intelligence (AI) in radiographic assessment. AI-powered algorithms can assist in real-time quality control, identifying poor exposures, positioning errors, and anatomical obstructions before final image acquisition. AI can also aid radiologists by enhancing image interpretation, reducing human variability, and providing automated feedback to technologists for continuous quality improvement. By leveraging AI, healthcare facilities can reduce rejection rates, minimize repeat imaging, lower radiation exposure, and improve diagnostic accuracy.

The research underscores the necessity for continuous efforts to enhance CXR quality through technological advancements, AI-driven solutions, and specialized training programs. By addressing these challenges, healthcare professionals can improve diagnostic precision, streamline patient care, and ultimately enhance clinical outcomes.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no competing interests.

Data Availability Statement

This data is available under a CC BY 4.0 license.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

References

[1] Homayounieh F, Digumarthy S, Ebrahimian S, et al. An Artificial Intelligence-Based Chest X-ray Model on Human Nodule Detection Accuracy From a Multicenter Study. *JAMA Netw Open*. 2021;4:e2141096. doi: 10.1001/jamanetworkopen.2021.41096.

[2] Suri JS, Agarwal S, Carriero A, et al. COVLIAS 1.0 vs. MedSeg: Artificial Intelligence-Based Comparative Study for Automated COVID-19 Computed Tomography Lung Segmentation in Italian and Croatian Cohorts. Diagnostics. 2021;11:2367. doi: 10.3390/diagnostics11122367.

[3] Ebrahimian S, Digumarthy S, Bizzo B, et al. Artificial Intelligence has Similar Performance to Subjective Assessment of Emphysema Severity on Chest CT. Acad Radiol. 2022;29:1189–1195. doi: 10.1016/j.acra.2021.09.007.

[4] Yoo H, Lee SH, Arru CD, et al. AI-based improvement in lung cancer detection on chest radiographs: Results of a multi-reader study in NLST dataset. Eur Radiol. 2021;31:9664–9674. doi: 10.1007/s00330-021-08074-7.

[5] Ebrahimian S, Kalra M, Agarwal S, et al. FDA-regulated AI Algorithms: Trends, Strengths, and Gaps of Validation Studies. Acad Radiol. 2022;29:559–566. doi: 10.1016/j.acra.2021.09.002.

[6] ACR-SPR-STR Practice Parameter for the Performance of Chest Radiography. 2017. Available from: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/ChestRad.pdf [Accessed on 12 August 2021].

[7] Carmichael J, Moores B, Maccia C, et al. European Guidelines on Quality Criteria for Diagnostic Radiographic Images. Luxembourg: European Commission; 2000.

[8] New Choice Health. Chest X-ray Procedure Pricing. Available from: https://www.newchoicehealth.com/procedures/chest-x-ray [Accessed on 12 August 2021].

[9] World Health Organization. Communicating Radiation Risks in Pediatric Imaging. 2016. Available from: https://www.who.int/ionizing_radiation/pub_meet/radiation-risks-paediatric-imaging/en/ [Accessed on 13 August 2021].

[10] Smith-Bindman R, Kwan ML, Marlow EC, et al. Trends in Use of Medical Imaging in US Health Care Systems and in Ontario, Canada, 2000–2016. JAMA. 2019;322:843–856. doi: 10.1001/jama.2019.11456.

[11] Bansal GJ. Digital radiography: A comparison with modern conventional imaging. Postgrad Med J. 2006;82:425–428. doi: 10.1136/pgmj.2005.038448.

[12] Tschauner S, Marterer R, Gübitz M, et al. European Guidelines for AP/PA chest X-rays: Routinely satisfiable in a paediatric radiology division? Eur Radiol. 2016;26:495–505. doi: 10.1007/s00330-015-3836-7.

[13] Okeji M, Agwuna K, Abubakar U, et al. Evaluation of Diagnostic Quality of Chest Radiographs Seen in a Nigerian Teaching Hospital. J Adv Med Med Res. 2017;23:1–6. doi: 10.9734/JAMMR/2017/35114.

[14] Jabbari N, Zeinali A, Rahmatnezhad L. Patient dose from radiographic rejects/repeats in radiology centers of Urmia University of Medical Sciences, Iran. Health. 2012;4:94–100. doi: 10.4236/health.2012.42015.

[15] Benza C, Damases-Kasi C, Daniels ER, et al. The causes of reject images in a radiology department at a state hospital in Windhoek, Namibia. S Afr Radiogr. 2018;56:37–38.

[16] Foos DH, Sehnert WJ, Reiner B, et al. Digital radiography reject analysis: Data collection methodology, results, and recommendations from an in-depth investigation at two hospitals. J Digit Imaging. 2009;22:89–98. doi: 10.1007/s10278-008-9112-5.

[17] Jones AK, Polman R, Willis CE, Shepard SJ. One year's results from a server-based system for performing reject analysis and exposure analysis in computed radiography. J Digit Imaging. 2011;24:243–255. doi: 10.1007/s10278-009-9236-2.

[18] Sadiq AA, Miftaudeen MN, Mohammed A, et al. Reject-repeat analysis of plain radiographs as a quality indicator at University of Maiduguri Teaching Hospital (UMTH). EJPMR. 2017;4:188–191.

[19] Atkinson S, Neep M, Starkey D. Reject rate analysis in digital radiography: An Australian emergency imaging department case study. J Med Radiat Sci. 2020;67:72–79. doi: 10.1002/jmrs.343.

[20] Ali A, Yaseen M. Digital radiograph rejection analysis during COVID-19 pandemic in Pakistan. Chin J Acad Radiol. 2021;4:133–140. doi: 10.1007/s42058-021-00070-6.

[21] Arbese MY, Abebe TD, Mesele BA. Determination and Analysis of Film Reject Rate at Eight Selected Governmental Diagnostic X-ray Facilities in Tigray Region, Northern Ethiopia. J Med Phys. 2018;43:270–276. doi: 10.4103/jmp.JMP_40_18.

[22] Dunn MA, Rogers AT. X-ray film reject analysis as a quality indicator. Radiography. 1998;4:29–31. doi: 10.1016/S1078-8174(98)80027-8.

[23] Dasegowda G, Kalra MK, Abi-Ghanem AS, et al. Suboptimal chest radiography and artificial intelligence: The problem and the solution. Diagnostics. 2023;13(3):412. doi: 10.3390/diagnostics13030412.

[24] Alghamdi QA et al. Prevalence of suboptimal CXRs at PSMMC [Dataset]. figshare; 2024. Available from: https://doi.org/10.6084/m9.figshare.28452449.v1 [Dataset].