Determination and Analysis of Film Reject Rate at Eight Selected Governmental Diagnostic X-Ray Facilities in Tigray Region, Northern Ethiopian

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Abstract

Background: In radiography examination, it is common to encounter patients undergoing repeated X-ray exposure after the rejection of a film image due to poor image quality. This subjects the patients to unnecessary radiation exposure and extra cost for the facility. This fact has required to investigate the causes of film rejection in common X-ray examinations. Aims: This study aims to obtain images, which are adequate for the clinical diagnostic purpose with minimum radiation dose to the patient in X-ray radiographic examination using film rejects analysis. Methods: A prospective, cross-sectional study design was carried out for 3 months. The film rejection rate data were collected using standardized checklist as recommended by the National Radiation Protection Authority and International Atomic Energy Agency. Daily recordings were compiled by frontline radiographers and senior physicians. Statistical Analysis Used: Data were analyzed descriptively using SPSS of version 23 software. Results: Overall rejection rate was 319 (10.02%) in 3183 X-ray exposures. The rejection rates by hospitals are 33.7% in Adwa, 13% in Aksum, 9.6% in Suhul, 9.2% in AbiAdi, 7.7% in Humera, 7% in Wukro, 4.3% in Lemlem Karl, and 2.9% in Alamata General Hospitals. Conclusions: Rejected films were found to be caused by numerous factors including incorrect exposure, poor technical judgment, patient motion, and improper film processing. Hence, strategies need to be developed within medical imaging departments to improve the situation.

Keywords: Film reject, quality assurance, radiation exposure, radiation protection, X-ray examination

INTRODUCTION

Diagnostic and interventional radiology using X-rays remain among the most frequent examinations in medicine, constituting the most significant man-made source of radiation exposure to the world population.[1] Therefore, population burden in these procedures is high. Medical exposures are clearly justified for their direct benefits of exposed individuals, radiation exposure to patient in these practices should be optimized to keep the dose as low as reasonable achievable “ALARA principle” (ICRP).[2-4]

The aim of radiology is to obtain images which are adequate for the clinical diagnostic purpose with minimum radiation dose to the patient. If optimum performance is to be achieved, assessment of image quality must be made to balance it against patient dose. X-rays are known to cause malignancies, skin damage, and other side effects and therefore are potentially dangerous. It is therefore essential and mandatory to reduce the radiation dose to patients in diagnostic radiology to the barest minimum.[5] The radiation dose to a patient is linked to image quality and should not be lowered to jeopardize the diagnostic outcome of a radiographic procedure. In order to produce an adequate image quality of anatomical structures for diagnostic purposes, both quality assurance program and quality control measures are of great importance.[6]

The nature and extent of quality assurance program will vary with the size and type of the facility and the type of examinations conducted. The main goal of a diagnostic quality assurance program is to maintain image quality at an acceptable level.

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assurance program is to produce radiographs of consistent high quality (ICRP).[3] Patient radiographs, therefore, serve as a quality control check and should be factored into any departmental evaluation program.[7] Quality control techniques are those techniques used in either monitoring or testing and maintenance of the components of an X-ray system.[8] It is common to encounter patients undergoing repeated X-ray exposures after the initial X-ray examinations because radiographs have been rejected due to poor image quality, hence subjecting patients to unnecessary radiation and facility to extra cost. This has necessitated the need to explore the causes of film rejection. Film reject analysis (FRA) is the tool that provides information that would assist to achieve a sound reduction in overexposures and extra costs.

FRA has therefore become a major parameter as a quality control tool in diagnostic radiography service delivery.

According to the recommendations of Conference of Radiation Control Programme Directors recommended (CRCPD, 2009), the repeat rate of medical images obtained with film-screen technology should not be <3% or greater than 10%. Based on film-screen technology characteristics, equipment failure, and human errors, a repeat rate of less than 3% is not a realistic value for an imaging department. If the repeat rate is less than 3%, the most likely explanation would be failure to account for all repeat films or the acceptance for diagnosis of poor image quality. If either the repeat rate or rejection rate exceeds 10%, the reason would have to be identified and corrective action should be taken.[9-11]

In view of the growing call for radiological examinations, it is important that due consideration be given to the safety of patients and staff, especially in developing countries like Ethiopia, where there is no adequate regulatory control of medical uses of radiation. It is important to make every effort to reduce radiation exposure. Rejected films do not only represent an unnecessary added radiation risk for the patient and an additional cost for the facility, but thus also affect a facility’s capacity not to deliver quality services. Moreover, patients are required to wait for a longer time in hospitals to repeat the procedure and this entails additional cost and time.

The objective of this study was to assess the rejection rate of X-ray films to obtain information for further recommendations on optimization of radiation protection of patients in X-ray radiographic examination, cost, and radiation exposure in the radiology departments of zonal hospitals in Tigray Region. The FRA method was used to assess the causes of poor image quality.

The result obtained from the study may be useful for the diagnostic radiology departments to identify problem areas, scrutinize the reasons for these problems and finding ways of rectifying them. In addition, the study has the benefits of reducing number of repeat radiographs, reduce radiation dose to the patients/public, improve the flow rate of patient in the department (throughput), maintain and improve quality of radiographs consistently, standardize processes, efficient maintenance of automatic processor and valuable information for the future equipment selection.

**Methods**

The study was conducted in eight government hospitals in Tigray Region, Northern part of Ethiopia. Before the study, ethical clearance was obtained from Health Research Ethical Committee (HRERC) office of Mekelle University’s College of Health Sciences. The collection was done over a period of 3 months from September to November 2016. All pediatrics and adult radiographs with film faults during the study period constituted the study population. Thus, all X-ray films of patients from the eight hospitals that were taken during the study period were included. The hospitals studied were Adwa, Aksum, Suhul, Abi Adi, Humera, Wukro, Lemlem Karl, and Alamata General Hospital.

Data were collected using standardized checklist as recommended by the National Radiation Protection Authority (NRPA) and the International Atomic Energy Agency (IAEA). The format contains information such as X-ray number, sex, age, type of examination, position/view, and type of film used, the number and size of films used, the number and size of films rejected, and reason for the rejections. The data were collected with the assistance of radiology staff including radiographers and darkroom technicians. Two days training was provided to data collectors about the objective of the study and the procedure of data collection and possible reasons for film rejection. Copies of the checklists were prepared for daily use in a table form and kept in each radiography room as well as in X-ray reporting rooms.

Daily recordings were compiled by frontline radiographers and senior physicians initially in the processing room and reporting room after which agreement on findings by principal investigators was reached to avoid interobserver variation. The collected data were compiled at the end of each week and entered into a computer for analysis.

**Quality control measurements**

To identify errors in equipment performance, kVp accuracy, mAs linearity, kVp, time and exposure reproducibility, HVL, and light beam/radiation beam alignment quality control measurements were undertaken. Based on these QC measurements and reject causes, corrective actions were implemented to decrease film rejection rates in each hospital. Despite the strict quality control measures observed in the hospital, image quality continues to be a problem. To identify the causes and contributory factors to poor image quality, FRA was used to assess the causes of film rejection.

**Calculation of reject and repeat rates**

The rejection rate was determined using follows equations:

\[
\text{Rejection Rate (\%)} = \frac{\text{Number of rejected films}}{\text{Total number of films used}} \times 100\% \quad (1)
\]
Causal rejection rate (\%) =
\[
\frac{\text{Number of rejected films for a specific cause}}{\text{Total number of films rejected}} \times 100\%
\] (2)

The rejected films were categorized into 11 classes according to the reasons for rejection. These included overexposure, patient motion, positioning error, underpenetration, and processing errors. Others were fog, film beam alignment, underexposure, overpenetration, multiple exposure, and artifacts. The remaining causes of film rejection rate were classified as “others,” which included causes such as mis-registration of patient and unnecessary order by the physician. These 11 classes of variables were further regrouped to five classes. Based on this grouping, over/underexposed, under/over penetration and multiple exposure were grouped to incorrect exposure factors and film beam alignment and artifact (foreign objects) were grouped into patient positioning error and dark room/storage and fog (light, chemical or aging) were grouped in processing error and Patient motion were grouped into fourth group and others (such as mis-registration of patient and unnecessary order by the physician) were grouped into fifth group. Data were analyzed descriptively using IBM SPSS Statistics version 23, Armonk, New York, United States.

**Results**

A total of 3183 X-ray exposures for all types of examinations were performed in eight public hospitals in Tigray Region over a period of 3 months. Of these, 319 (10.02%) X-ray films were rejected and considered for repeat exposures.

The rejection rates by hospitals were 33.7% in Adwa, 13% in Aksum, 9.6% in Suhul, 9.2% in Abi-Adi, 7.7% in Humera, 7% in Wukro, 4.3% in Lemlem Karl, and 2.9% in Alamata Hospital.

Table 1 shows total X-ray films exposed and total X-ray films rejected for each radiological examination type by hospital. Chest X-rays (CXR) were the most frequent exposures in many hospitals. Rejection rates for CXR were high at Adwa General Hospital at 31.6%, Aksum General Hospital at 10.4%, and Abi-Adi at 9.8%. The rates were reasonably low in Suhul Hospital at 6.8%, Alamata General hospital at 3.6%, and Wukro and Humera hospitals at 3.4% and can be considered as acceptable level of rejection.

Extremities X-ray were the most frequent examination in the hospitals next to CXR examination. The rejection rates for this examination type were high at 27.9% in Adwa, 14% in Aksum, 12.9% in Suhul, 8.7% in Humera, and 6.7% in Wukro hospitals, respectively, while the other three hospitals had rates within the accepted range.

Rejection rates for skull, exposures were high at 43.8% in Adwa, 19% in Aksum, 14% in Abi-Adi, 13.6% in Wukro, and 13.3% in Humera hospitals, respectively, while the other three hospitals had rates within the accepted range.

Cervical and thoracolumbar (CTL) spine X-ray exposures showed high rejection rates for Adwa (61.9%), Aksum (60%), Humera (36.8%), and Suhul (18.6%) hospitals, respectively, while the other three hospitals had rates within the accepted range.

Abdominal X-ray exposures were limited in number but rejection rate was rather high in Humera at 50%, 25% in Abi-Adi, 18.2% in Adwa, Wukro, and 14.3% in Suhul while the other three hospitals had rates within the accepted range. Pelvic X-ray exposures again showed

| Table 1: Rejection rates by radiographic examination type and by hospital, Tigray Zonal Hospital, September-November, 2016 |
|-----------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| **Examination type**        | **Abi-Adi**    | **Adwa**       | **Aksum**      | **Alamata**    | **Humera**     | **Lemlem**     | **Suhul**      | **Wukro**      |
| **General Hospital**        | **General**    | **General**    | **General**    | **General**    | **General**    | **General**    | **General**    | **General**    |
| **Total rejected film number** | (%)            | (%)            | (%)            | (%)            | (%)            | (%)            | (%)            | (%)            |
| CXR                         | 132            | 152            | 213            | 197            | 233            | 250            | 424            | 319            |
| Extremities                 | 70             | 61             | 100            | 72             | 69             | 145            | 233            | 219            |
| Skull                       | 14             | 16             | 47             | 25             | 15             | 59             | 79             | 22             |
| Abdomen                     | 11             | 12             | 20             | 20             | 8              | 30             | 43             | 8              |
| Pelvic                      | 8              | 8              | 8              | 9              | 0              | 27             | 19             | 2              |
| HSG                         | 2              | 1              | 1              | 0              | 27             | 4              | 6              | 1              |
| **Total**                   | 239            | 270            | 350            | 351            | 541            | 832            | 200            | 140            |
| **CXR:** Chest X-ray, **CTL:** Cervical and thoracolumbar, **HSG:** Hysterosalpingogram |
rejection rates of 25%, 37.5%, and 14.3% for Abi-Adi, Adwa, and Wukro General Hospital, respectively, but there was zero rejection rate for pelvic X-ray in the other five hospitals. As shown in Table 1, the HSG examination has a low frequency, and for this reason, it is not possible to provide a rejection rate.

Figures 1 and 2 summarize the frequency of rejection causes for all hospitals and examination types. As shown in Figure 2, the most frequent cause of rejection in almost all hospitals and for almost all types of examinations was exposure factors followed by incorrect patient positioning, patient motion, and nonoptimal film processing.

In this study, six different sizes of films were used as shown in Table 2. The 35 cm × 35 cm film was the most frequently rejected size (36.4%). The frequent causes of film rejection were incorrect exposure (46%), patient positioning error (21%), patient motion (14%), and nonoptimal film processing (11%). These account for 92% of all rejection causes. Table 2 gives a brief summary of the causes of reason for rejection and film size used.

Table 3 shows the total cost of exposed and rejected films together with the proportion of wasted resources in radiography examination. In spite of CXRs were the most frequent exposures in all hospital, the highest wastage was for chest size films (35 cm × 35 cm) at 9.4%. The overall resource wastage was 11.8% of the total cost of all exposed films for the months of the studied period.

In the entire study period, in the eight general hospitals in Tigray region, the total cost of films for all categories was 111,275 Birr ($5,300), while that of the rejected films was 13,090 Birr ($624). This figure was for the 3 months study period which amounted to an annual cost of 56,723 Birr ($2800).

**Discussion**

FRA has been used to investigate the adequacy of image quality, reduction of radiation dose to patient as well as cost efficiency in clinical practice of X-ray facilities. Analysis of rejection data, therefore, becomes a simple yet powerful tool to provide information that helps to monitor and rectify...
problems regarding the above-mentioned facts in providing X-ray services.

As the information in our results showed the total rejection rate of all the hospitals studied was 10.02%. This figure was lower (14.1%) and (11.15%) than those obtained from an earlier study done in the radiology department of a teaching hospital in Ghana in 2014[12] and radiology departments in Mazandaran Province, Iran, 2007.[13] However, it was higher (3.1%) than the study done in Addis Ababa, Ethiopia, in 2010[14] and 8.9% in radiodiagnostic center in Benin City, Nigeria, in 2016.[15] Overall, the figure was well within the internationally accepted range.[13-16]

Analysis of total rejection for each hospital showed varying values with the highest rate for Adwa and Aksum General Hospital is at 33.7% and 13%, respectively, and the lowest for Alamata Hospital, having a value of 2.9%. Both values appear to be at the extreme ends of the spectrum. Values below 3% should be under the spotlight as they would indicate failure to account for rejection cases that are bound to occur in any busy X-ray radiology department and might even suggest deliberate withholding of actual incident reports. Values above 10% would indicate problems causing rejection that would necessitate corrective measures.[17-19] During the quality control measurement program for each hospital, we observed a problem in some of the hospitals. For example, the high rejection rate in Adwa General Hospital was found due to the fact that the chest stand Bucky was without grid, and this had its own impact on image quality in CXR. This problem was found in Aksum hospital also. The X-ray machines in these hospitals were installed many years ago.

In this study, CXRs were the most frequent examinations in all the hospitals studied. Rejection rates were in the acceptable range in four hospitals and Abi-Adi and Suhul hospital were at 9.8% and 6.8%, respectively, which warranted monitoring. Adwa hospital, which had 31.6% and Aksum Hospital, which had 10.8% require further investigation to identify corrective actions. Incorrect exposure, wrong patient positioning, patient motion, and other causes could explain the high figure for Adwa while a possible underreporting should be checked for the Aksum General Hospital.

Extremities were the second most frequent exposures in all the hospitals studied, but rejection rates were normal in three hospitals and in two hospitals, the values were found to be acceptable but with further monitoring in quality control and maintenance. However Adwa, Aksum, and Suhul hospitals which had values of 31.6% and Aksum Hospital, which had 10.8% require further investigation to identify corrective actions. Incorrect exposure, wrong patient positioning, patient motion, and others.

Skull was the most frequent exposures next to extremities in all the hospitals studied, and the rejection rates were normal

| Reason for rejection | Film size used |
|----------------------|---------------|
|                      | 35 cm × 35 cm | 35 cm × 43 cm | 30 cm × 40 cm | 24 cm × 30 cm | 18 cm × 24 cm | 18 cm × 40 cm | Total (%) |
| Overexposed (dark)   | 11            | 3             | 15            | 9             | 11            | 1            | 50 (16)   |
| Patient motion       | 17            | 2             | 12            | 8             | 7             | 0            | 46 (14)   |
| Positioning error    | 17            | 4             | 10            | 5             | 2             | 0            | 38 (12)   |
| Underpenetration     | 8             | 2             | 9             | 7             | 4             | 0            | 30 (9)    |
| Processing error     | 15            | 0             | 9             | 8             | 3             | 0            | 35 (11)   |
| Film beam alignment  | 6             | 0             | 1             | 5             | 2             | 0            | 14 (4.4)  |
| Underexposure (light)| 9             | 3             | 13            | 4             | 1             | 0            | 30 (9.4)  |
| Overpenetration      | 9             | 1             | 9             | 2             | 5             | 0            | 26 (8.2)  |
| Multiple exposure    | 4             | 0             | 3             | 1             | 2             | 0            | 10 (3)    |
| Artifact (foreign objects) | 3 | 1 | 4 | 6 | 1 | 0 | 15 (5) |
| Other                | 17            | 0             | 5             | 2             | 1             | 0            | 25 (8)    |
| Total (%)            | 116 (36.4)    | 16 (5)        | 90 (28.2)     | 57 (17.9)     | 39 (12.2)     | 1 (0.3)      | 319       |

| Table 2: Reason for rejection and film size used in Tigray Zonal Hospitals, September-November, 2016 |
|---------------------------------------------------------------|
| Reason for rejection | Film size used |
|----------------------|---------------|
|                      | 35 cm × 35 cm | 35 cm × 43 cm | 30 cm × 40 cm | 24 cm × 30 cm | 18 cm × 24 cm | 18 cm × 40 cm | Total (%) |
| Overexposed (dark)   | 11            | 3             | 15            | 9             | 11            | 1            | 50 (16)   |
| Patient motion       | 17            | 2             | 12            | 8             | 7             | 0            | 46 (14)   |
| Positioning error    | 17            | 4             | 10            | 5             | 2             | 0            | 38 (12)   |
| Underpenetration     | 8             | 2             | 9             | 7             | 4             | 0            | 30 (9)    |
| Processing error     | 15            | 0             | 9             | 8             | 3             | 0            | 35 (11)   |
| Film beam alignment  | 6             | 0             | 1             | 5             | 2             | 0            | 14 (4.4)  |
| Underexposure (light)| 9             | 3             | 13            | 4             | 1             | 0            | 30 (9.4)  |
| Overpenetration      | 9             | 1             | 9             | 2             | 5             | 0            | 26 (8.2)  |
| Multiple exposure    | 4             | 0             | 3             | 1             | 2             | 0            | 10 (3)    |
| Artifact (foreign objects) | 3 | 1 | 4 | 6 | 1 | 0 | 15 (5) |
| Other                | 17            | 0             | 5             | 2             | 1             | 0            | 25 (8)    |
| Total (%)            | 116 (36.4)    | 16 (5)        | 90 (28.2)     | 57 (17.9)     | 39 (12.2)     | 1 (0.3)      | 319       |

Table 3: Cost of total exposed and rejects rate by film size for all radiographic images, September-November, 2016

| X-ray film size (cm) | Number of exposed films | Total price (Birr) | Number of rejected films | Total price (Birr) | Percentage of rejected films | Percentage of wasted money |
|----------------------|-------------------------|--------------------|--------------------------|--------------------|-----------------------------|---------------------------|
| 35×35                | 1397                    | 47,040             | 116                      | 4,420              | 8.3                         | 9.4                       |
| 35×43                | 161                     | 5460               | 16                       | 570                | 9.9                         | 10.4                      |
| 30×40                | 869                     | 30,140             | 90                       | 4570               | 10.4                        | 15.2                      |
| 24×30                | 472                     | 14,660             | 57                       | 1970               | 12.1                        | 13.4                      |
| 18×24                | 278                     | 13,795             | 39                       | 1530               | 14.0                        | 11.1                      |
| 18×40                | 6                       | 180                | 1                        | 30                 | 16.7                        | 16.7                      |
| Total                | 3183                    | 111,275            | 319                      | 13,090             | 10.0                        | 11.8                      |

Table 3: Cost of total exposed and rejects rate by film size for all radiographic images, September-November, 2016
only in Alamata hospital. The major causes of rejection in the skull were wrong patient positioning followed by incorrect exposure, patient motion, and nonoptimal film processing.

In a similar manner, CTL spine X-ray exposures showed high rejection rates for Adwa (61.9%), Aksum (60%), Humera (36.8%), and Suhul (18.6%) and major causes of rejection were incorrect exposure factor followed by wrong patient positioning error, patient motion, and nonoptimal film processing.

Reject rates for abdominal exposures were again found to be quite high for Humera General Hospital (50%), Abi-Adi (25%), Adwa (25%), Wukro (18.2%), and Suhul (14%). Exposure factors, patient motion, and manual processing factors were the main causes of reject. Pelvic X-rays, showed yet again high reject rates for Adwa (37.5%), Abi-Adi (25%), and Wukro (14.3%) with the main causes of rejection being exposure factors, wrong patient positioning, patient motion, and others.

All the above explanations regarding the magnitude of rejections and their causes indicated that piece-meal analysis of examination types and individual hospitals revealed more candid information which would otherwise be missed if we were to rely on the overall rejection rate obtained for all examinations and hospitals collectively.

A total of 319 films were rejected with the highest film size rejected being 35 cm × 35 cm (36.4%) and the lowest being 18 cm × 40 cm (0.3%). Consumption was also highest and lowest, respectively, for these two film sizes. Despite the high consumption of the 35 cm × 35 cm film size, the rejection rate for this film size was low at 8.3% compared to 10.4% and 12.1% for the 30 cm × 40 cm and 24 cm × 30 cm film sizes, respectively. This means that although the 35 cm × 35 cm film size was frequently used, more errors were made when using the 30 cm × 40 cm and 24 cm × 30 cm film sizes. It can therefore be concluded that higher film consumption does not necessarily lead to high rejection rates. This is also similar to the results of obtained in other studies pre- and postcomputerized radiography in a private hospital in Kenya, 2011. As shown in Table 2, the most frequent causes of film reject were incorrect exposure (46%), patient positioning error (21%), patient motion (14%), and nonoptimal film processing (11%). These accounted for 92% of all rejection causes.

FRA can lead to reduction in the cost of wasted film. In the entire study period, in the eight general hospitals in Tigray region, the total cost of film for all categories was 111,275 Birr ($5,300), while that rejected films was 13,090 Birr ($624), which gives an overall percentage of 11.8%.

Our study has explicitly shown that the main causes of rejection in almost all the hospitals studied appeared to stem from exposure factors, suboptimal human and equipment performance of X-ray. The study has given some gross and basic input into the common problems of quality of radiographic service and recommends that all hospitals must have regular quality assurance (QA) and quality control program and reduction of patient dose. In addition, policy procedure that is well documented, including regular calibration of the X-ray machines with proper attentiveness of the technologists to take care of factors leading to repetition of the X-ray films should be in place and use a proper film size.

The high number of rejection in this category suggests the radiographers at Tigray General Hospitals should be encouraged to participate in Continuous Professional Development programs such as courses, seminars, and workshops with respect to radiographic technique for operators. Finally, those hospitals should introduce digital imaging technology, which is a filmless system to replace the conventional system of processing radiologic image to eliminate darkroom related cause of film rejection and radiographer can properly calibrate automatic exposure control system in digital technology.

Therefore, by reducing the rate of rejected films, the radiation dose to the public should be as low as reasonably achievable (ALARA). Apart from the radiation dose to the public, radiographs, which must be repeated, represent additional, nonbillable costs because of increased film consumption, chemical agent for film developments and equipment use, as well as increased patient waiting time. As result, the burden of department, waiting room and undesirable financial impact is increased.

**Acknowledgments**

We gratefully acknowledge the financial support of Mekelle University’s (MU) College of Health Science (CHS), Tigray Regional Health Bureau (TRHB), Tigray Regional Government Science and Technology Bureau (TRGSTB), and all the hospitals that participated in this study and their staffs for their cooperation. The authors also express their gratitude to all radiographers who contributed to data collection.

I would also like to thank Prof. Renato Padovani, for giving me invaluable comments and suggestions about this research.

**Financial support and sponsorship**

This research was financially supported by MU CHS, TRHB, and TRGSTB.

**Conflicts of interest**

There are no conflicts of interest.

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