PRE AND POST COMPUTERIZED RADIOGRAPHY
FILM REJECT ANALYSIS
IN A PRIVATE HOSPITAL IN KENYA

by

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Submitted in partial fulfillment of the requirements for the degree

MA: HEALTH AND WELFARE MANAGEMENT

in the

FACULTY OF HEALTH SCIENCES

at the

NELSON MANDELA METROPOLITAN UNIVERSITY

JANUARY 2011

DEDICATION

This study is dedicated to all those going through a difficult situation, which, appears like it will never go away. All difficult situations do come to an end; it is usually just a matter of time. The important thing is to learn a lesson from the situation, that way it becomes a stepping stone to better and bigger things.

ACKNOWLEDGEMENTS

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ABSTRACT

The production of good quality radiographs is a complex process, given the high level of image quality required (Sniureviciute & Adliene, 2005: 260). Exposure of patients to x-rays, a factor in the production of quality radiographs also entails a risk of radiation injury.

In 2006, computerized radiography (CR) was introduced at The Nairobi Hospital to try and reduce the film reject rate, decrease repeats, reduce financial costs of consumables like x-ray films and processing chemicals. However, to date, no formal film reject analysis has been conducted at The Nairobi Hospital.

Four years after the incorporation of CR, there is apparently, still a significant number of film rejects, implying operational costs may still be high. The cause of film rejects and overall reject cost is not known. This has led to the research question: "Has the film reject rate in the A & E x-ray unit at The Nairobi Hospital reduced following incorporation of CR?"

A quantitative, retrospective, descriptive study involving a reject film analysis of rejected radiographs in the Accident and Emergency (A&E) x-ray unit in the Nairobi Hospital, Kenya was conducted. The researcher collected data for a period of 6 months between 2/12/07 and 28/05/08 using a purpose-designed data collection form. All rejected x-ray films during the study period were included.

Capture and analysis of the collected data was completed by the researcher using SPSS 10 and EPINFO computer packages.

Permission to conduct the study was obtained from The Nairobi Hospital Education Committee and due consideration to patient and radiographer confidentiality was maintained throughout the study.

A total of 851(2.5%) x-ray films were collected during the study period. Four hundred and fourteen (2.6%) radiographs and 437 (2.5%) radiographs were rejected prior to and after the incorporation of CR respectively. Chest radiographs were the most frequently rejected accounting for 277(66.9%) and 123 (28.1%) prior to and after the incorporation of CR respectively.

The most frequently rejected film size was 35x35cm prior to the incorporation of CR (61.6%) and 26x35cm film size after the incorporation of CR (91.3%).

The most frequent cause of film rejects was radiographer causes both prior to and after the incorporation of CR accounting for 496 (58.3%).

The film reject rate did not significantly reduce after the incorporation of CR, suggesting that there are other factors which contribute to reject rate, other than CR. The study also shows that higher film consumption does not necessarily lead to high reject rates.

The percentage value on annual rejects did not change after the incorporation of CR and a demonstrated increase in the annual cost of purchasing x-ray films was

attributed to an increase in annual consumption after the incorporation of CR, and also to the higher cost of digital x-ray films.

Despite some identified limitations to this study, some recommendations, which included conduction of regular reject analyses and regular continuing professional development with respect to radiographic technique amongst others, were suggested.

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ABBREVIATIONS

ALARA	"As Low As reasonably Achievable"
CR	Computerized Radiography
CT	Computerized Tomography
DEXA	Dual X-ray Absorptiometry
DICOM	Digital Imaging and Communications in Medicine
DR	Digital Radiography
HIS	Hospital Information Systems
MRI	Magnetic Resonance Imaging
PACS	Picture Archiving and Communications System
PET	Positron Emission Tomography
RIS	Radiological Information Systems
SPECT	Single Photon Emission Computed Tomography
SFR	Screen Film Radiography
US	Ultrasound

CHAPTER 1

INTRODUCTION TO A FILM REJECT ANALYSIS CONDUCTED

IN A PRIVATE HOSPITAL IN KENYA

Computerized imaging systems are rapidly replacing conventional film-screen radiography (Rajani *et al*., 2008: 18). The aim of this development is to extend the diagnostic capabilities but also deliver the least radiation possible to patients (Monfared *et al.*, 2007: 37).

In 2006, computerized radiography (CR) was introduced at the Nairobi Hospital in order to try and reduce the film reject rate, improve image quality, decrease repeat exposures and reduce financial costs of consumables like x-ray films and processing chemicals. This introduction also had the potential to improve work flow for radiographers and radiologists, since the process of producing a radiograph, including a written report, is shortened with CR. Improved workflow could also reduce the patient waiting times which are a major problem at the hospital. (Fang *et al.*, 2006: 44)

Since the initial installation costs are high, CR was incorporated in phases. The positioning and execution phases are already in place. The acquisition phase which comprises of Picture Archiving and Communications System (PACS) is

presently being installed. Therefore, becoming a "filmless" department is not expected until December 2010. Until then, hard copy images will still be produced.

Even with a quality control programme operational in the radiology department, no formal film reject analysis has been carried out at the hospital, either prior to or after the incorporation of CR.

This study, a quantitative, comparative, descriptive study was therefore conducted at the Nairobi Hospital. The purpose of the study was to determine if incorporation of CR in a unit of the hospital, reduced the film reject rate and consequently reduced unnecessary patient exposure to radiation. The study also included a determination of the total film reject cost per annum.

An in-depth review of the appropriate literature in Chapter 2 of this dissertation will provide a theoretical framework for the study. The research question, study hypotheses and objectives are outlined in Chapter 3. Chapter 4 provides a comprehensive account of the methodology employed in the study. The results and a discussion thereof is provided in Chapter 5, and the conclusions, limitations and recommendations are presented in Chapter 6.

CHAPTER 2

OVERVIEW OF THE LITERATURE RELATING TO

REJECT FILM ANALYSIS

2.1 MEDICAL IMAGING

Medical imaging started over a century ago, when Wilhelm Conrad Roentgen accidentally discovered x-rays in 1885 (Bansal, 2006: 425). Medical imaging is used for the diagnosis of diseases, assessing acute injuries, assessing severity of diseases or response to therapy, for guiding interventions, and for screening as in virtual colonoscopy and mammography.

This is all possible because since the discovery of x-rays in 1885, there has been an evolution in medical imaging with the development of x-ray imaging through film screen radiography (SFR), computerized radiography (CR) and direct radiography (DR) and the development of other imaging modalities like fluoroscopy, computer tomography (CT), mammography, dual x-ray absorptiometry (DEXA), nuclear medicine, positron emission tomography (PET), single photon emission computed tomography (SPECT), magnetic resonance imaging (MRI) and ultrasound (US) (Schaefer–Prokop *et al.*, 2008: 1818).

The literature review will predominantly focus on SFR and CR, since the study is about the transition from a SFR system to a CR system.

2.1.1. SCREEN FILM RADIOGRAPHY (SFR)

Although there has been significant progress in the development of new imaging modalities since the discovery of x-ray by Roentgen in 1895, SFR still constitutes 60-70% of all imaging diagnostic examinations carried out in hospital departments (Reiner *et al.*, 2000: 163). Over the years, the technology has evolved, with improvement in the characteristics of both film and screens, but the basic principles remain the same.

In SFR, x-rays pass through the patient's body and fall onto a traditional radiological cassette which contains intensifying screens and x-ray film. The intensifying screens, covered with a luminophore, change most of the x-radiation into visible light, which falls onto the x-ray film covered with emulsion, causing it to blacken and thus produces an image (Sozanski et al, 2009: 642).

The advantages of SFR include; a relatively low cost of the system, capability of rendering excellent image quality and since the cassettes are portable, great flexibility in positioning of the image receptor is possible.

Limitations of the SFR system to be considered when evaluating whether to use this system in clinical practice include;

1. Limited dynamic range: Conventional SFR relies on a combination of exposure factors and characteristics of the film and screen utilized to determine contrast and density levels. This range is limited and all pertinent information in the image may not be displayed.

2. Image manipulation: Once processed, the contrast and density levels present on an x-ray film are fixed. The user does not have the ability to adjust these values to display additional diagnostic information.

3. Processing variations: The radiographic film is subject to variables in processing conditions; variations in temperature, chemical activity and transport time result in an inconsistent display of images.

4. X-ray exposure factors: The contrast and density on SFR systems are determined by the tube current - milliamperage (mA) and the potential difference between the film and anode – kilovoltage (kV), factors utilized. Relatively minor variations in these factors may render the radiograph non-diagnostic. The resultant repeat exposures increases radiation dose to the patient and operator, increases material costs and results in an inefficient use of radiographer's time.

5. Distribution cost: X-ray films are bulky and the cost of handling and distributing to areas where they are required for diagnosis is high.

6. Storage cost: Achieved x-ray films requires a significant amount of space for storage

7. Clerical or administrative cost: The system requires the use of ID cards to imprint pertinent patient information, the film, file jackets to store and transport film files, clerical time to file patient jackets and time to retrieve folders when prior images are needed for comparison to a current examination.

8. Lost film: Lost x-ray films result in substandard patient care if prior examinations are not available for comparison and in the worse case, may have negative legal implications.

9. Environmental impact: Processing solutions contain chemicals that may be detrimental to the environment. (Deaver, 2008; Bansal, 2006: 425; Lanca & Silva, 2009a:134)

Screen film radiography is a reliable method to record images but the above problems have led the industry to search for alternatives. The two basic digital systems developed as alternatives to SFR are computerized radiography (CR) and direct radiography (DR)

2.1.2. COMPUTERIZED RADIOGRAPHY (CR)

Computerized radiography, also known as indirect radiography uses cassettes in which the conventional x-ray film has been replaced by a special charged plate covered with crystalline phosphorus compounds (Lanca & Silva, 2009b: 58). The plate functions as a multiple–use intensifier enabling the image of the investigated object to be read, stored on a computer hard disk, and then erased. The cassettes used in CR are compatible with the traditional, currently used radiological units. There is therefore no need to replace the whole diagnostic device, but only one of its elements (Sozanski *et al*., 2009: 642).

Electrons in the phosphorus crystalline network are moved to a higher, unstable energy level under the effect of x-radiation, creating a hidden image. To view the image special scanners are used. The radiographer carries the cassette to a viewing station, and following input of the patient's identifying demographic data, the plate is scanned line by line, with a helium-neon laser (Reiner *et al.*, 2005:413). This makes the electrons transit from a higher energy level to a lower one, a process which is accompanied by the emission of electromagnetic radiation in the range of blue visible light. The intensity of the emitted radiation is directly proportional to the stream of electrons, which in turn is converted into digital x-ray picture. The digital image is transferred to a diagnostic workstation

and is transferred and stored digitally or recorded as an image on a laser printed film. (Sozanski et al, 2009: 642)

Computerized radiography offers significant advantages in diagnostic quality over SFR systems. The latest enhancements include energy subtraction, which makes it possible to view bone and or soft tissue only of an image, and dynamic control which makes it possible to study both the soft tissue and bone on the same image.

Another advantage of CR is that the images are readily available immediately on the monitor for evaluation and post processing enhancement. Computerized radiography is also a portable system that can be used at the patient's bed side or in the emergency room. (Moore *et al.*, 2007: 724)

2.1.3 DIRECT RADIOGRAPHY (DR)

In the direct radiography systems, x-rays pass through the patient's body and fall onto a flat digital panel which converts x-rays into electrical impulses which in turn are converted into a digital image. The panel is permanently integrated with the x-ray unit and the obtained image is transferred directly to the workstation without the radiographer's participation. (Sozanski et al, 2009: 642) There are

two types of direct radiography detectors available; indirect conversion and direct-conversion detectors. (Cowen *et al.*, 2008:487) Direct radiography offers superior contrast resolution to CR, immediate readout and considerable time saving. (Williams *et al*., 2007: 371)

2.1.4. INFORMATION SYSTEMS

The large numbers of diagnostic images produced in radiology units requires the engagement of a large number of accessory staff, radiographers and administrative personnel. The process is time and cost consuming therefore there is a need for information systems which enable the sending of images and text by computer network to numerous places within and outside of a hospital. (Hood & Scott, 2006:70)

Digital imaging uses computer systems for sending, processing and archiving data, including radiology images; examples of these include: Picture Archiving and Communication Systems (PACS), Radiological Information Systems (RIS) and Hospital Information Systems (HIS).

2.1.4.1 PICTURE ARCHIVING AND COMMUNICATION SYSTEMS (PACS)

Picture archiving and communication systems (PACS) are used primarily for the storage, distribution, and viewing of diagnostic images in the digital imaging and communications in medicine (DICOM) format. (Sozanski *et al.*, 2009:645; Strickland, 2000: 82; Hood & Scott, 2006: 71)

2.1.4.2 RADIOLOGICAL INFORMATION SYSTEMS (RIS)

A radiological information system (RIS) is a computerized data base used for the storage and transmission of text information in radiology departments, such as patients' data, registration and scheduling details, reports and statistical data. (Sozanski *et al.*, 2009: 645)

2.1.4.3. HOSPITAL INFORMATION SYSTEMS (HIS)

Hospital information systems enable the efficient storage and distribution of all data between departments and diagnostic units in a hospital, including diagnostic images. Hospital information systems can communicate with PACS and RIS, providing for a comprehensive means of managing images and data within the hospital environment. (Sozanski *et al.*, 2009: 645)

Evolution of technology has made it easy to acquire and record x-ray images but the ionizing radiation used is detrimental to living cells. It is therefore important to ensure radiation exposures are kept as low as reasonably achievable (ALARA).

2.2 "AS LOW AS REASONABLY ACHIEVABLE" PRINCIPLE

The "As Low As Reasonably Achievable" (ALARA) principle is a safety principle, recommended by national and international radiation protection agencies for radiation workers, to address the growing concerns of radiation induced somatic and heritable mutations. (Prasad *et al*., 2004: 97; Anonymous ICRP, 1991: 1)
The initial concept of radiation protection involves three physical principles;

1. reduction of time exposure,

2. increased distance between radiation source and radiation worker or patient,

3. shielding non exposed body areas especially radiosensitive organs like the bone marrow, gonads and thyroid gland by lead (Prasad et al., 2004: 97).

The ALARA principle means that every reasonable effort must be made to keep radiation workers and the public, as far below the required limits of radiation, as possible (Shaw *et al.*, 2010:401) The above three physical principles do have

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limitations, implying the ALARA principle may not be adhered to by radiation workers at all times. During fluoroscopy for example, it may not be possible to protect the gastrointestinal tract against radiation damage by lead shielding. Increasing the distance between the radiation source and exposed individuals may also not be practical for many radiation workers or patients. Reducing exposure time may not be pertinent to all populations, except those that are involved in taking care of patients who have received gamma-emitting radioisotopes for medical purposes or who are responsible for radioactive decontamination as a result of accidents or attacks. (Prasad *et al.*, 2004: 97)

In a review article entitled "Radiation protection in humans: extending the concept of ALARA from dose to biological damage", Prasad and colleagues (2004:98) suggested it would be important to identify biological or chemical agents, which when given before radiation exposure, could protect all normal tissues. Such radio-protective agents would protect patients against radiation damage during diagnostic procedures. The search for radio-protective agents began soon after World War II but the numerous agents identified during extensive radiobiological research have been toxic to humans. (Prasad *et al.,* 2004: 98; Anne, 2002: 80)

Whereas many radiobiologists believe that diagnostic doses of ionizing radiation should not be considered of insignificant risk for somatic and heritable mutations, neoplastic and non-neoplastic diseases in humans (Anonymous ICRP, 1991:1; Prasad *et al.,* 2004: 98), others have suggested that diagnostic doses of radiation do not contribute to health risks in humans. (Cohen, 2002: 1137)

Prasad and co-workers (2002:79) in a study giving consideration to the positive and negative aspects of anti-oxidant use during radiation therapy found a combination of dietary anti-oxidants was more effective in normal tissue during radiation therapy than any of the agents used on their own. Furthermore Prasad and colleagues (2004: 98), in a review article on radiation protection proposed a combination of dietary antioxidants and glutathione-elevating agents could be useful in protecting normal tissue against radiation damage, no matter how small the damage might be. The use of antioxidant preparations can extend the concept of ALARA from dose to biological damage for radiation workers. In addition such antioxidants can provide protection against radiation damage, for patients receiving diagnostic doses. The authors also suggested a clinical study to evaluate the radio protective value of antioxidants in patients receiving diagnostic radiation, using measures of oxidative stress and frequency of mutations. (Prasad *et al.,* 2004: 98)

2.3 REJECT FILM ANALYSIS

To determine the extent to which the ALARA principle is being adhered to, radiology departments usually conduct, amongst other things, a reject film analysis. Reject film analysis is an important component of a Quality Assurance (QA) programme. (IAEA, 2003; Eze *et al*., 2008:355) It involves the periodic critical evaluation of radiographs which are used as part of the imaging service but do not play a useful part in the diagnostic process. (Prieto *et al.*, 2009: 104; Weatherburn *et al.,* 1999: 653)

Film reject analysis is a relatively inexpensive, simple and practical means of identifying areas where patient service can be improved. From an analysis it is easy to obtain and interpret the film reject rate and determine its economic impact in terms of wasted resources like consumables, staff time and radiation burden to the population. (Eze *et al*., 2008: 358; Dunn & Rogers, 1998: 29)

The consumables required for SFR include both x-ray films and chemicals to process the x-ray films. In CR images may be printed on a film or stored in PACS. From a reject analysis it is possible to determine the number of wasted films, causes for rejection and the cost of wasted film. Estimation of the annual cost of rejects in a given department can be obtained by determining the average

weekly cost of rejects in a given period and multiplying by 52, the number of weeks in a one year period.

After exposure the x-ray film has to be processed because the image produced is a latent one. This may be manual or automatic process and involves development, fixing, washing and drying. The whole process takes between 30 and 200 seconds when done automatically. The developer reduces silver halide to metallic silver which has a dark appearance and is responsible for darkening the film, and then fixer solution neutralizes the reduction process to stop the development process thus fixing the film when the darkening is at an acceptable level. The fixer prevents the film from becoming totally black. The fixer also removes unreduced silver halides, which would otherwise cause brown staining of the film over time. Washing is done to remove developer and fixer. The final step in film processing is the blowing of dry air over the x-ray film so that a dry film is ejected from the processor. (Ritenour, 1996: 913) Processing chemicals can only be used within a certain time frame, and fresh stock has to be obtained and used chemicals disposed of. The cost of purchasing and maintaining processing chemicals is therefore expensive. The amount of money spent on purchasing chemicals depends on how often the processing chemicals are changed.

Time is an important resource in a radiology department, since many of the cost drivers are directly related to time. Radiology staff produce a large number of radiographs necessary for diagnosis daily, and the time necessary to produce diagnostic images can often delay the entire treatment process, thus throughput of patients in a radiology unit has an important impact on the treatment process. This requires the engagement of a large number of accessory staff, radiographers and administrative personnel.

In a SFR system, when an x-ray is taken, the radiographer submits the cassette with the exposed film for processing and then passes the processed film to a radiologist, or in case of an emergency, directly to the referring clinician (Sozanski *et al.,* 2009; 645). In most cases the referring clinician will send the radiograph back for interpretation and report. The interpreted radiograph and report are then sent back to the referring clinician, a consultant, given to the patient or stored in the archives (Sozanski *et al.,* 2009; 645). This work process demonstrates how SFR systems can be time consuming and costly.

In the case of DR and PACS, the image is sent electronically thus significantly shortening the work process time. This system also enables reduction in hospital staff and leads to a substantially lower costs (Sozanski *et al*., 2009; 643). The use of PACS improves the efficiency of a radiology department (Reiner & Siegel,

2002: 34; Reiner *et al.*, 2002: 22). It reduces the time which it takes for images and interpretations thereof to be made available to the referring clinicians. Picture archiving and communication systems allows for immediate access to imaging studies by physicians and also decreases delays in work (Reiner *et al.*, 2003: 324).

The time taken by radiographers in a radiology department can be determined by an analysis of patient throughput. The time spent by patients in a radiology unit varies and also depends on the modality of examination. For this reason patient throughput can be defined as the time a patient spends in the modality room (Tolkki *et al.*, 2004:156). The time from when the radiographer receives a patient up until the patient is discharged with the radiograph and report, can be recorded for each modality. Time taken by radiographers also depends on the number of necessary procedures per examination, the competence of the radiographer and how ill the patient is. Varying times can therefore be expected for each radiographer and the average time per modality can be obtained by dividing the sum of the different radiographer times by the how often each modality is performed. (Tolkki *et al.*, 2004:156)

Exposure to ionizing radiation during diagnostic radiological procedures is not without damage to living cells (Lockwood *et al.*, 2006: 583). The benefits of exposure should therefore outweigh the risk of exposure to ionizing radiation. The dose received from a single exposure may not be problem but the cumulative dose resulting from repeat exposures increases the risk of developing stochastic effects (Kim *et al*., 2004: 510). Protecting patients from unnecessary exposures thus reducing the radiation burden to the public can be achieved by quantifying the radiation dose received by a patient during an exposure. This is however not simple because the energy and quantity of photons used, the size of patients and the vulnerability of exposed tissues must be factored into any estimate (Lockwood *et al.*, 2006:584). Medical physicists often undertake extensive calculations to accurately estimate the dose of radiation received by a specific patient during a radiograph. The concept of effective dose, measured in millisieverts (mSv), allows many of the above mentioned factors to be compared and controlled (Lockwood *et al.*, 2006:584; Fazel *et al*., 2009:851). The effective dose is a measure designed to represent the overall detrimental biological effects of radiation exposure. It is calculated by weighting the concentrations of energy deposited in each organ from a radiation exposure with the use of parameters that reflect the type of radiation and the potential for radiation-related mutagenic changes in each organ in a reference subject. (Einstein, 2009: 545; Martin, 2008: 1).

The effective dose allows for useful population-level comparisons across different types of population exposure (IRCP, 2007: 129).

Effective dose is represented by the following equations:

$$E = \sum_T W_T \sum_R W_R D_{TR} \quad \text{or} \quad E = \sum_T W_T H_T$$

Where H_T or $W_R D_{TR}$ is the equivalent dose in a tissue or organ, T and W_T is the tissue weighting factor. The unit for the effective dose is the same as for the absorbed dose, Jkg^{-1}, and its special name is sievert (Sv). A typical effective dose per study for each type of plain film radiograph can then be used to calculate the cumulative effective dose.

The results of a film reject analysis can be an effective indicator of quality assurance in radiology departments. The information obtained can also assist in achieving a reduction in operational costs and radiation exposure to both patients and radiation health workers. It also helps identify specific problem areas for which interventions can be designed and implemented.

2.3.1 FILM REJECT ANALYSIS AND COMPUTERISED RADIOGRAPHY

The need for a quality assurance program after the incorporation of CR in a radiology department has been questioned by some (Honea *et al.,* 2002: 41; Stearns, 2004: 45) , since CR images are acquired on reusable image media,

which can be erased and imaged repeatedly, eliminating the need for films and chemicals (Honea *et al.,* 2002: 41; Stearns, 2004: 45). However, it is important to remember that even with CR the rejection rate does not fall to zero because mispositioning, patient motion, inadequate inspiration, wrong examination performed, wrong patient examined, improper collimation and double exposure, all causes of film reject with conventional screen film radiography (SFR) systems, can still happen with CR.

Whilst the most common causes of film rejects in institutions using SFR are wrong exposures (under or over exposure) and mispositioning, the commonest documented cause of rejection with the computerized system is mispositioning. (Stearns, 2004:56; Minningh & Gallet, 2009: 86; Weatherburn *et al.*, 1999: 656; Waseem *et al*, 2008: 151; Redlich *et al*, 2005: 272; Peer *et al*, 1999:1693;   Lau *et al*, 1999: 653)

2.3.2 FILM REJECT RATES

A film reject rate is obtained from a film reject analysis and is defined as the number of rejected films, expressed as a percentage of the total number of films used;

$$\frac{\text{Number of rejected films}}{\text{Total number of films used}} \times 100\%$$

(Zewdeneh *et al.*, 2008: 64). Film reject rates can represent the quality of a radiology department but as many studies have shown, they can also be sensitive to examination type (Dunn & Rogers, 1998). They should therefore not be used to compare departments; but relevant information obtained can be used to monitor and improve services within a radiology department.

The Conference of Radiographic Control Programme Directorate's (CRCPD's) committee on quality assurance recommended that an overall film reject rate of up to 10% can be considered acceptable. However, the World Health Organization (WHO) recommends an acceptable film reject rate of 5% (Zewdeneh *et al.,* 2008: 66). The ideal film reject rate recommended by the Royal Australian College of Radiologists is even lower at 2% although a rate of < 5% is considered acceptable (Rajani *et al*., 2008: 18).

The findings of some studies concerning film reject rates found in the literature are summarized below.

A university hospital in Pakistan was able to reduce its x-ray retake rate from 5.5% to 1% after converting to digital x-ray. The study high lighted efficiency gains possible through filmless x-ray imaging, even at imaging facilities in developing countries. Ahmed and colleagues cited by Casey noted that their

analogue retake obtained was within the range of 3.2% - 11. 6% published in literature (Casey, 2008). The lower reject rate was with CR was due to the ability of radiographers to post process images on preview monitors. The high retake rate related to

positioning error with CR indicated the importance of advanced training for radiographers (Casey, 2008).

Waseem and colleagues (2008: 151), in their study on film retakes in digital and conventional radiography, also done in Aga Khan Hospital, Karachi, found that digital radiography is associated with a significantly lower rate of film retakes (1%), compared to conventional SFR (5.5%), hence minimizing exposure of patients to unnecessary radiation due to x-ray re-takes. Positioning errors were a major problem in both systems, emphasizing the need for training of technologists. Under-exposure was the most frequent cause of retakes in the conventional radiography system accounting for 38% of retakes.

A study in Germany, by Redlich and co-researchers (2005: 272), demonstrated that digital radiography provided the best quality chest x-ray (CXR) in comparison to conventional techniques for obtaining CXRs. In conventional SFR retakes were mostly due to either under-exposure or over-exposure. In digital radiography positioning errors were the main reason for repeat x-rays.

Nol, Isuoard and Mirecki (2006:159), in Australia, found that the number of repeats as a result of exposure factors was dramatically reduced when using the

CR system. The percentage of repeats as a result of positioning skills was slightly increased because some rejects in the conventional system, which may have qualified as either exposure or positioning errors, were more likely to be classified as exposure errors. The ability to digitally adjust dark or light images reclassified some of those images as positioning errors.

A comparison of image reject rates when using film, hard copy computed radiography and soft copy images on picture archiving and communication systems conducted by Weatherburn and colleagues (1999: 656), revealed a decrease in the reject rates across all examinations, from 9.9% to 8.1% when hard copy CR was used and 7.3% when picture archiving and communication systems (PACS) were used. Positioning and radiographic technique errors were the major reasons for rejects, throughout the study period, and contributed to a greater proportion of all rejects when CR and PACS were used, rather than when x-ray films were used. Examinations of the chest accounted for the majority of rejects during the study period; this was attributed to the chest being the most frequently examined body area (Wheatherburn *et al.,* 2000: 707).

In Malaysia, a study by Ranganathan and Faridah (2007: 806) revealed a decrease in the reject rate from 2.0% when using SFR to 1.98% after the

incorporation of computerized radiographic mammography (CRM). The primary change that affected both patients and staff alike was in the work flow, namely an increase in patient throughput. Time taken for film processing was reduced thus decreasing the patients' waiting time**.**

Peer and co-workers (1999: 1693), in Austria, carried out a comparative analysis of rejected radiographs in conventional and CR, investigating specifically the number of rejected images and the reasons for rejection. The findings of this study showed an overall rejection rate of 27.6% in the conventional and 2.3% in the computerized department. Whereas the main reason for rejection in the department using conventional radiography was exposure and problems related to film processing, the main reason in the department using CR was positioning.

During the literature review, no studies on comparative pre- and post- CR rejection analysis in East Africa were identified. This is because all the hospitals, except the Nairobi Hospital, Aga Khan Hospital and the Plaza Imaging and Diagnostic Center Kenya, all of which are in Kenya, are still using the conventional SFR system. No comparative study has yet been conducted.

A discussion of the findings from studies related to film wastage done in East Africa follows:

In Uganda two studies done in Mulago Hospital, the national teaching and referral hospital revealed rejection rates of 15.9% (Magala, 2004: 24) and 9.8% (Teefe, 2006: 26). In both studies the most frequent reasons for rejection were under or over exposure.

Muhoogoro and colleagues (2001: 222), in a study completed in Tanzania, found that faulty radiographic equipment, wrong exposure selection, positioning, as well as factors attributable to patient influences, contributed to over 90% of the film rejects. In a previous study, the reject rates obtained at Mbeya Consultant Hospital and Arusha Regional Hospital were 9.4% and 0.9% respectively (Muhogora et al, 1999: 302). In this study it was concluded that a large proportion of the film wastage was due to techniques and skill used and also patient factors.

In Rwanda, a study done by Senoga (unpublished data, PACORI, 2007) at King Faisal Hospital revealed an overall reject rate of 9.9%. The commonest causes were human errors (47%), resulting in wrong exposures being used, poor positioning and wrong technique. Other causes were x-ray equipment (41%) and dark room (12%) faults.

In Kenya, reject rates obtained from cross-sectional studies done in 4 hospitals in Nairobi were; 5.93% at the Kenyatta National Hospital, 3.11% at the Aga Khan Hospital (Kigo, 1993:21), 4.1% at the Department of Imaging and Radiation Medicine, University of Nairobi (DIRM-UON) and 5.05% at the Mbagati District Hospital (MDH) (Kitheka, 2007: 19). The presence of radiography students at the Kenyatta Hospital was implicated in the higher overall reject rate whilst Aga Khan Hospital, being a private hospital, was thought to be more cost conscious and therefore had a lower rejection rate (Kigo, 1993: 34).

Wrong exposures and positioning errors were the most frequent cause of rejections in both hospitals. The higher rate in MDH was also partly attributed to the absence of a radiologist for supervision and monitoring of the work done by student radiographers (Kitheka, 2007: 27). Again incorrect exposures followed by positioning errors were the most frequent causes of rejections.

This review of the literature suggests a reduction in the reject rates in institutions where CR has been incorporated. In many places with CR systems the reject rate fell to less than 5%. The literature further demonstrates that all but two hospitals in East Africa are still using conventional SFR implying the consequences of film wastage resulting from rejected films may be a problem in many countries.

2.4 REPEAT EXPOSURES

Ionizing radiation does have detrimental effects hence the need to reduce exposure during x-ray examination as low as possible. The effects of ionizing radiation may either be stochastic or deterministic. A stochastic effect is one where the probability of occurrence increases with radiation dose but the severity of the result does not vary with dose; examples include the development of cancer and leukemia and hereditary and genetic effects. Stochastic stands for something that occurs by chance and is random in nature; there is no threshold for stochastic effects (Muller, 1995:115; Edwards & Bestor, 2007: 243).

By contrast a deterministic effect is one where the severity depends upon radiation dose; examples include skin burns, infertility, hair loss and cataract formation. There is a threshold for deterministic effects; these effects occur once the threshold radiation is crossed. (ICRP, 2007: 1)

Most diagnostic procedures will not have adverse effects. However, with multiple exposures there is a potential for biological effects. It is therefore the small doses encountered in diagnostic procedures, contributing to the stochastic effects, which are a matter of concern. As the level of radiation exposure and the

absorbed dose increases, the probability of stochastic effects increases almost linearly. (Little *et al*., 2009: 6)

Besides the health related risks which may arise from repeat exposures, the cost to the health care facility also needs to be considered. The consequence of repeat x-ray examinations is an increase in the operational costs of imaging departments. Not only are time and human resources wasted, but with SFR x-ray films, processing chemicals are squandered when the radiographic images taken are discarded, thus negatively affecting budget.

A study on radiographic repeat rate data in three hospitals in Jeddah, Saudi Arabia, revealed the cost of repeat films in the entire kingdom per year was projected to be about US$1.82million (18.2 million ZAR) in the government hospitals only (Al-Maliki *et al.*, 2003: 323). The three hospital included King Fahad Hospital (KFH), King Abdulaziz Hospital (KAH), and Maternity and Children Hospital (MCH). The repeat rate in each of these hospitals was 7.44%, 7.84% and 9.57% respectively.

At Mulago Hospital, approximately 65million Uganda shillings (UGS) (about 22. 5 thousand ZAR) per year, is wasted as a result of repeat x-ray examinations. The waste includes the cost of the film, equipment, personnel and film processing (Creemers, 2007: 14).

The annual cost arising from film rejects in DIRM-UON and MDH in Kenya was 37,700 Kenya shillings (4597ZAR) and 51,662 Kenya shillings (6300ZAR) respectively representing 4.4% and 4.8% respectively of the total annual film costs (Kitheka, 2007: 29). These figures appear small but are substantially high when the cost of the x-ray tube life, chemicals and manpower are also considered.

An x-ray reject analysis done in Tikur Anbessa Hospital, Ethiopia by Zewdeneh, Teferi and Admassie (2008: 64) revealed the total cost of film for all categories during the entire study period was 27,717.83 Ethiopian Birr (15538ZAR), whilst the total reject cost was 1371.49 Ethiopian Birr (768ZAR), which gives an overall percentage of 4.95%. This would yield an approximate total reject cost of 10, 972 Ethiopian Birr (6150 ZAR) per year.

2.5 PATIENT THROUGHPUT

With increasing budgetary constraints on the health system, a further contribution that the radiology department can make to cost reduction in hospitals is to decrease the length of time taken between requesting an x-ray examination and receiving a report with or without the radiographic image.

In many medical facilities, there is a shortage of radiologists and radiographers and yet the demand for imaging services continues to grow (Greene, 2001: 52). The introduction of CR or DR with PACS in a radiology unit has been found to reduce the need for big numbers of radiographers or radiologists and reduce patient throughput time (Mariana *et al*., 2006:18; Ranganathan & Faridah; 2007: 806, Minningh & Gallet; 2009: 87; Stearns, 2004: 58).

In the case of CR with PACS there is a reduction in the film reject rates and elimination for the need of film processing chemicals, thus reducing overall operational costs (Ranganathan & Faridah; 2007: 806, Minningh & Gallet; 2009: 87; Stearns, 2004: 58; Kusakabe, 2002: 1277).

In an objective assessment and comparison of CR versus SFR for performing upright chest examinations, Andriole (2002: 161) at the University of California, Santiago, found an increased patent throughput of 12% for CR over SFR.

Wideman and Gallet (2006:29) in their study "Analog to digital workflow improvement" found that the average patient examination time reduced from 9.24 minutes to 5.28 minutes with digital imaging, indicating that a higher patient throughput could be achieved. Comparing the percent room utilization for CXR examinations, with the FSR process, the room utilization was 66%, whereas with digital imaging it was in the order of 38%. Digital imaging therefore resulted in the chest room being available almost twice as much as it is with SFR.

2.6 APPLICATIONS TRAINING

Inadequate applications training is another explanation for avoidable film wastage and possibly elevated patient radiation dose with FSR (Zewdeneh *et al.*, 2008: 66). It is however important to note that the transition from FSR to CR can also entail an increase in patient radiation doses; one of the reasons being lack of specific training in new digital techniques (ICRP, 2004). Lack of specific training in digital techniques for some radiographers, and lack of well established

methods to audit patient doses in computerized systems, can worsen the problem of patient radiation exposure with CR (Vaňo *et al*., 2007: 462).

Therefore, as institutions make the transition from conventional SFR to CR systems, it is important that radiographers undergo formal education, continuing education and training on how to use the equipment; thus ensuring proper use of the equipment, reducing wastage and improving service delivery in the process (Nyathi *et al.*, 2010: 5).

This literature shows there has been an evolution in medical diagnostic imaging since the discovery of x-rays by Roentgen in 1895. Using digital radiography x-ray images can now be taken and made available to referring clinicians for patient management, much faster than previously. It is however important to remember that ionizing radiation is detrimental to living cells thus the need for radiation workers to adhere to the "ALARA" principle. One of the ways to ensure that the "ALARA" principle is being observed is to carry out periodic film reject analyses. A film reject analysis is an effective indicator of quality assurance in a radiology unit and it helps identify specific problem areas for which solutions can be provided.

The literature review also shows that implementing CR or DR in a radiology unit can reduce the reject rate and overall operational costs. It also suggests that managers in institutions acquiring new technology need to ensure that all users of the new equipment undergo appropriate formal training on how to use the equipment.

No comparative film reject analysis has previously been done at the Nairobi Hospital since the incorporation of CR in 2006. It is therefore not known if the overall operational costs of the radiology department have reduced. The purpose of this study was therefore to determine the film reject rate before and after incorporation of CR and also estimate and compare the total annual reject costs before and after the incorporation of CR.

CHAPTER 3

PROBLEM STATEMENT, RESEARCH QUESTION AND OBJECTIVES

3.1 PROBLEM STATEMENT

The Nairobi Hospital is a private hospital located in Nairobi, the capital city of Kenya. It has a total capacity of 312 beds and offers the following services: radiology imaging, cardiac catheterization, dietary therapy, chemotherapy, diabetic clinic, physical medicine, paediatric care, surgery, general medicine, obstetrics and gynecology. The radiology department comprises of the main x-ray department and the Accident and Emergency x-ray unit (A & E x-ray). It provides several imaging facilities, which include; computerized radiography, ultrasound (US), computerized tomography (CT), fluoroscopy, magnetic resonance imaging (MRI), and mammography.

The hospital bed capacity has risen from 199 beds in 2003, to 312 beds in 2010. This means that there has been an increase in the numbers of both in- and out-patients visiting the hospital. To try and improve the radiology imaging services at the hospital, CR was adopted in 2006. Its purpose was to improve patient

throughput, cut down on film wastage and also reduce production costs, since no processing chemicals would be needed.

Since initial capital costs required to have a totally "filmless" department are high, the hospital opted to gradually replace the conventional FSR system that was in place, over a two year period. At present, Picture Archiving and Communication Systems (PACS) have not yet been incorporated; therefore, hard copy radiographic images are still produced. The PACS was expected to be installed in the whole hospital by September 2010. It is however currently only installed in the radiology department.

The machine used in the A & E x-ray unit is a ceiling suspended Diagnost C5 Type B IEC601-1 230V 50Hz-60Hz 3,5A (Phillips Medical Systems) with a Fujifilm Dry Pix7000. The system has been calibrated to print 26cm x 36cm film sizes. Smaller or larger film sizes are therefore not used.

The same ceiling suspended Diagnost C5 Type B IEC601-1 230V 50Hz-60Hz 3,5A (Phillips Medical Systems) was used prior to incorporation of CR. Exposure tables placed near the control panel are used.

General radiography is done by qualified radiographers who have undergone three years of training. None of the radiographers have had a formal module in CR or DR. The radiographers are taught how to use the CR equipment, on joining the organization.

With the SFR system automatic processing instead of manual processing was used. The former is faster and less prone to human error. The screen film combination used was blue light emitting intensifying screens and loading and unloading of cassettes was done in a darkroom. There is now no need for a dark room after the incorporation of CR.

Two years after the partial incorporation of CR and PACS, there is still a significant number of film rejects. Unnecessary patient radiation from re-exposures resulting from under- or over-exposure may have reduced, but operational costs are still high, since many of the non-diagnostic x-ray images are printed, contributing to film wastage. The cause of film rejects and the overall reject cost is not known.

It is therefore important to identify the possible causes of film rejection and the overall reject costs so that solutions on how to reduce film wastage, can be provided.

3.2 RESEARCH QUESTION AND HYPOTHESIS

3.2.1 RESEARCH QUESTION:

The research question for this study is:

"Has the film reject rate in the A & E x-ray unit, at the Nairobi Hospital, reduced following the incorporation of CR?"

3.2.2 HYPOTHESIS

The null hypothesis (H_o) and alternative hypothesis (H_1) are stated as follows:.

- H_o: the number of rejected films and the use of CR are independent.

- H_1: the number of rejected films and the use of CR are dependent.

3.3 OBJECTIVES OF STUDY

The primary objective of the study was to determine the film reject rate before and after the incorporation of CR in the A & E x-ray unit of the Nairobi Hospital. The secondary objectives include:

- Identifying the causes of film rejection,

- Comparing the causes of film rejection before and after incorporation of CR

- Estimating and comparing the total annual film reject cost before and after the incorporation of CR,

- Providing recommendations on how to reduce the film reject rate if found to be high.

CHAPTER 4

RESEARCH METHODOLOGY

A quantitative, comparative, descriptive study involving a reject film analysis of rejected radiographs in the Accident and Emergency (A&E) x-ray unit in the Nairobi Hospital, Kenya was conducted.

4.1   RESEARCH DESIGN

Mouton (2001: 55) defines a research design as a plan or blueprint of how you intend conducting the research. His explanation is that a research design focuses on the end product, formulates a research problem as a point of departure and focuses on the logic of research. The design of this study was a retrospective, quantitative, comparative, descriptive study.

4.1.1 QUANTITATIVE STUDY

According to Neuman (2000: 121-155) quantitative designs include experiments, surveys and content analysis. Mouton and Marais (1990: 155-156) have identified the following characteristics of a quantitative study:

- It is formalized and explicitly controlled.

- Its range is more exactly defined.

- It is relatively close to physical sciences.

In addition to the three characteristics given by Mouton and Marais (1990: 155-156), Fortune and Reid (1999: 93) suggest the following additional characteristics:

- The researcher's role is that of an objective observer whose involvement with phenomena being studied, is limited to what is being required to obtain necessary data.

- Studies are focused on relatively specific questions or hypotheses that remain constant through out the investigation.

- Plans about research procedures are developed before the study begins.

- Data collection procedures are applied in a standardized manner; with all participants being able to answer the same questionnaire.

- Measurement is normally focused on specific variables that are, if possible, quantified through rating scales, frequency counts and other means.

- Analysis proceeds by obtaining statistical breakdowns of distribution of variables and by using statistical methods to determine associations / differences between variables.

According to Creswell (1994: 1-2), a quantitative study is an inquiry into a social or human problem, based on testing a theory composed of variables, measured with numbers and analyzed with statistical procedures in order to determine whether the predictive generalizations of the theory hold true.

On the basis of the researcher's experience with non diagnostic radiographic images at the Nairobi Hospital, it was decided that a quantitative study would be suitable for this study. A specific question was being asked in this study and a hypothesis had been stated. Data collection was to be done in a standardized manner, using the same purpose-designed data collection form for all rejected x-ray films. The relationship between specific variables such as x-ray film size, cost of film, radiographer, cause for rejection, anatomical part x-rayed were to be explored.

4.1.2 DESCRIPTIVE STUDY

A descriptive study is also called an observational study; since subjects are observed without otherwise intervening. (Waning & Montagne 2001:45). In a descriptive study, no attempt is made to change behaviour or conditions; and things are measured as they are. In this study, all rejected films from the A & E x-ray unit at the Nairobi Hospital were to be collected and no attempts were intended to be made to increase or decrease the numbers or the causes of rejects.

4. 2 RESEARCH METHODS AND MATERIALS

Research methods refer to the process of data collection and analysis of any research study done (Pilot & Hungler 1995: 205). It also includes information on

the population and sample involved. Research methods describe in detail the nature of the sample and the strategy for selecting it, the specific technique to be used, specific measuring instruments to be utilized and the specific series of activities to be conducted in making measurements (de Vos 2005: 118). The research methods in terms of population, sampling method and sample and data collection method employed in this study are described below.

4.2.1 RESEARCH POPULATION

McBurney (2001: 27) refers to the research population as the sampling frame. A population is the totality of persons, events, organization units, case records or other sampling units with which the research problem is concerned (de Vos 2005: 194). The target population in this study was the rejected x-ray films in the A & E x-ray unit at the Nairobi Hospital. Data was collected retrospectively. The collection was done over a period of 6 months between 12/12/07 and 28/05/08.

4.2.2 SAMPLING METHOD

Complete coverage of the total population in order to understand a given phenomenon is seldom possible. It is also not possible to study all of the members of a population of interest (Yates 2004:25). The time and cost of

studying the entire population, even if it was theoretically possible to identify and contact the relevant entire population' make it practically impossible (de Vos 2005: 194). Sampling is therefore done and the main reason for this is feasibility (Sarantakos 2000: 139).

In this study, all films rejected in the A & E x-ray unit, for the three month period prior to the implementation of CR and for the three month period, post-implementation of computerized radiography, were included. No selection of type or film size was done.

4.2.3 CRITERIA FOR INCLUSION

All films rejected in the A&E x-ray unit during the study period were included in the study.

4.2.4 SAMPLE SIZE

A sample comprises elements of the population considered for actual inclusion in the study or it can be viewed as a subset of measurements drawn from a population which we are interested in (de Vos 2005:194). It is generally stated that the larger the population, the smaller the percentage of that population that the sample needs to be, and vice versa (Neuman 2003:232). If the population

itself is relatively small, the sample should comprise a reasonably large percentage of the population. Larger samples enable researchers to draw more representatives and make more accurate conclusions, and to make more accurate predictions, than smaller samples (Mitchell and Jolley 2001: 496- 497). For this study, a statistician was consulted about the sample size.

Using Kish and Leslie's (1965) formula for sample size calculation, a total sample size of 325 film rejects was calculated at a 95% confidence level, with an error term fixed at 5%. The formula applied was as follows:

Sample size formula:

Sample size $n = \dfrac{Z^2 p(1-p)}{e^2}$

Where n = required sample size

Z = standard normal value at the acceptable level of significance (95%)

p = proportion of the population with rejected radiographs, taken as 10%

e^2 = the permissible error to be committed, which is the estimate of the prevalence of situational trend assumed desired with an acceptable error of 0.05.

4.2.5 DATA COLLECTION

A quantitative comparative descriptive study involving the collection of rejected radiographs in the Accident and Emergency (A&E) x-ray unit in The Nairobi Hospital, Kenya was done.

The following information was recorded on a purpose designed data collection form (Appendix 1) for each rejected radiograph:-

1. Date of exposure
2. Type of examination
3. Radiographic projection
4. Film size and type
5. Reason for rejection
6. Radiographic quality (this denotes the visibility and sharpness of the images of structural details)

Radiographers are also required to include their code (initials of names) on every film exposed, making it possible to trace a radiograph to a radiographer. Also documented were the codes used by the radiographer responsible for taking the radiograph, their prior training, work experience and use of CR. For anonymity of the radiographers, codes (R1 –R17) only known to the researcher were allocated to each of the radiographers.

The duties of each of the x-rays rooms are usually predetermined and thus the films taken could be traced to the room. The CR equipment in the A& E x-ray unit is different from that in the main x-ray department. Different types of film are therefore used making it easy to identify.

The total number of films consumed each day during the study period was obtained from the x-ray department records. A total of 851 rejected films were analyzed. Thus the sample size exceeded the 325 films that were considered necessary for a meaningful analysis.

4.3   DATA ANALYSIS

The rejected radiographs were grouped in the following categories for the purposes of film fault analysis;

1. Dark room errors:
   a) Artefacts eg roller marks, finger impressions
   b) Fog eg exposure to light, chemical or aging

2. Incorrect exposures:
   a) Under exposure
   b) Over exposure
   c) Double exposure

2. Power supply to printer

3. Equipment
   a) Faulty printer
   b) Printer artifact

5. Radiographer's fault
   a) No identification
   b) Collimation
   c) Position
   d) Rotation
   e) Centering
   f) No image
   g) Marker
   h) Artefact
   i) Film size
   j) No reason

   k) Processing
      a) Weak chemicals (SFR)
      b) Post processing manipulation (CR)

   l) Dark room / storage
      a) Fog (light, chemical or aging)

4.3.1. RADIOGRAPHIC QUALITY

The criteria used for classification of the radiographic quality assessment for this study is as follows:-

1. Good – a radiograph with no obvious reason for having been rejected.

2. Fair – a radiograph with an obvious fault but could have been salvaged if proper consultation between the radiographer and radiologist and possibly

a supplementary radiograph taken or at least most of the anatomical

details is   well visualized or probably only the identity is lacking.

3. None – a radiograph with obvious radiographic fault that does not fall in

either of the above categories.

This value judgment was based on the investigators assessment. If doubt arose about the reason for rejection or radiographic quality the opinion of another consultant radiologist or that of a radiographer was sought.

4.3.2 RADIOGRAPHIC COSTING

Details of the type of film and size were used to estimate the cost of the films. The estimation of the annual cost of reject films was obtained by multiplying the cost of rejects by 52/20, where 20 weeks is the study period before and after the incorporation of CR while 52 weeks is a one year period.

Estimation of the cost of other factors like x-ray machine depreciation, chemicals and radiographer working hours before the incorporation of CR, and machine depreciation and radiographer working hours after the incorporation of CR, was not done.

4.3.3 DETERMINATION OF REJECT RATE

The film reject rate was calculated using the following equation:

$$\frac{Number\,of\,rejected\,films}{Total\,number\,of\,films\,used}\,x100\%$$

Films rejected from the A & E x-ray unit during the study period were collected and formed the numerator and the total number of films consumed during the study period formed the denominator, for purposes of calculation of the overall reject rate.

Data analysis was done by use of EPIINFO$^{®}$ and SPSS$^{®}$ computer packages. The annual estimation of reject films was done by multiplying the total number of rejects in the study period by 52/20 weeks.

The films were collected and serialized for purposes of capturing data. Analysis was done using descriptive statistics, tables, bar charts, scatter diagrams and percentages by sizes. The Chi- square test was done to determine the relationship between the number of rejects and the incorporation of CR.

4.4   ETHICAL CONSIDERATIONS

Permission was sought and obtained from The Nairobi Hospital education committee and the Head of Radiology Department (Appendix 2). Repeat films collected were those of patients who had undergone plain x-ray examinations in the A & E x-ray unit in The Nairobi hospital. The patients had been referred by their attending clinicians and the examinations were done for the benefit of the referred patients. According to Berle, (2008: 89) the taking of clinical photographs must be practiced within the contest of professional etiquette. No repeats were taken for the purpose of this study. No patient identifying details were considered or recorded.

4.5 LIMITATIONS OF THE STUDY

Some of the rejected films were disposed of before the end of the study; therefore, not all the rejected films were included in the study. Films rejected 20 weeks prior to and 20 weeks after incorporation of CR instead of the proposed 21 weeks for each period were included in the study. The reject rates obtained may have therefore been lower than the actual rates since not all the rejected films during the proposed study period were included. It is also important to note that some of the rejects may also have never been placed in the collection boxes.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 RESULTS

5.1.1 NUMBER OF REJECTS

The total number of rejected films during the study period was 851 (2.5%). The number of rejects prior to the incorporation of CR was 414(2.6%) whilst the number of rejects after the incorporation of CR was 437(2.5%). This is summarized in Table 1 below.

Table 1: Reject Rate prior to and after introduction of CR

Period	No of rejects	Total films used	Reject rate (%)
Prior to CR	414	16,100	2.6
After CR	437	17,360	2.5
Overall	851	33,460	2.5

5.1.1.1 RELATIONSHIP BETWEEN NUMBER OF REJECTED FILMS AND INCORPORATION OF CR AT THE NAIROBI HOSPITAL

The relationship between the number of rejected films and the incorporation of CR at the Hospital was determined using the Chi-square test (χ^2) of independence. Values used were the number of rejects before and after the incorporation of CR (see Table 1). Since χ^2 (1, N = 32876) = 0.018, at a 95% level of significance, the null hypothesis is not rejected. That is the number of rejects is independent of the incorporation of CR.

5.1.2 REJECT RATES BY RADIOGRAPHIC EXAMINATION TYPE

Considering the frequency of examinations rejected, chest radiographs were the most frequently rejected accounting for 277 (66.9%) and 123 (28.1%) prior to and after the incorporation of CR respectively.

The distribution of rejects according to radiographic examination is shown below in Table 2.

Table 2: Rejects according to anatomical site

Radiographic examination	Prior to CR	%	After CR	%
CXR	277	66.9	123	28.1
Joints	30	7.2	68	15.5
Lumbar spine	13	3.1	51	11.6
Extremities	19	4.6	44	10.1
Cervical spine	13	3.1	37	8.5
Abdomen	18	4.3	30	6.9
Thoracic spine	11	2.7	23	5.3
Skull x-ray	9	2.3	22	5.1
Para nasal sinuses	1	0.2	14	3.2
Pelvis	19	4.6	12	2.7
Post nasal space	0	0	6	1.4
No image	2	0.5	4	0.9
Sacral spine	0	0	2	0.5
Thoraco-lumbar spine	0	0	1	0.2
Mandible	2	0.5	0	0
Total	414	100	437	100

5.1.3   REJECT RATES BY FILM SIZE

The 35 x 35cm film was the most frequently rejected size prior to the incorporation of CR (61.6%), in other words using screen film radiography (SFR), and 26 x 35cm film size was the frequently rejected after the incorporation of CR (93.1%). (See Figure 1 below)

During both study periods these film sizes were used for CXR examinations.
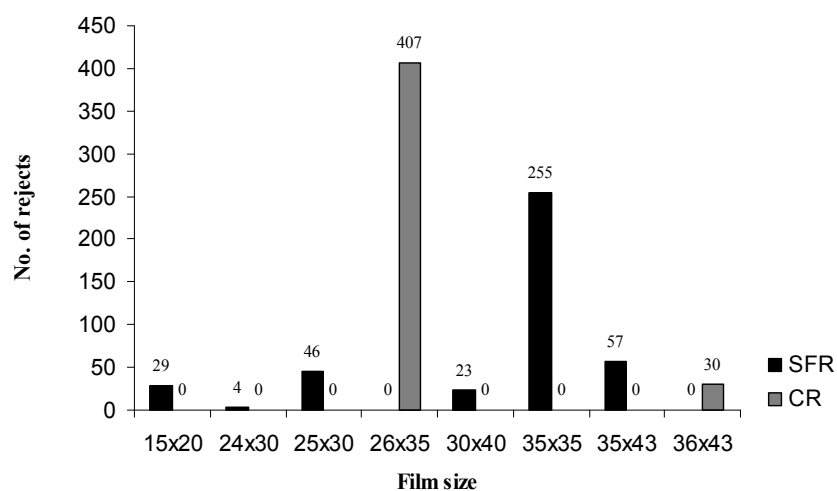
Figure 1: Number of rejects by film size

The reject rate by film size is summarized in greater detail in Table 3 below:

Table 3: Reject rates by film size

Film size (cm)	SFR				CR			
	Passed	Rejected	Consumed	Reject rate	Passed	Rejected	Consumed	Reject rate
15x20	1,295	29	1,324	2.2	0	0	0	0
24x30	152	4	156	2.6	0	0	0	0
25x30	750	46	796	5.8	0	0	0	0
26x35	0	0	0	0	16,799	407	17,206	2.4
30x40	423	23	446	5.2	0	0	0	0
35x35	10,061	255	10,316	2.5	0	0	0	0
35x43	2,545	57	2,602	2.2	0	0	0	0
36x44	0	0	0	0	0	30	30	100
Total	15,226	414	15,640	-	16,799	437	17,236	-

5.1.4 FILM FAULT CHARACTERISTICS

Film faults were classified into 6 groups; radiographer causes (58.3%), wrong exposures (27.1%), processing (10.9%), darkroom/storage (2.9%), faulty equipment (0.6%) and power supply (0.2%).

The most frequent cause for film rejects was due to radiographers' fault accounting for 496 (58.3%) followed by wrong exposure selection accounting for 231 (27.1%). The lowest cause of film rejects was no power supply accounting for 2 (0.2%). (See Table 4)

Table 4: Frequencies of causes for film reject

Cause for reject	SFR	%	CR	%	Total	%
Radiographer	204	49.3	292	66.8	496	58.3
Wrong exposure	187	45.2	44	10.1	231	27.1
Processing	2	0.5	90	20.6	92	10.9
Darkroom / storage	21	5	4	0.9	25	2.9
Faulty equipment	0	0	5	1.1	5	0.6
Power supply	0	0	2	0.5	2	0.2
Total	414	100	437	100	851	100

Further details for each of these categories is explained as follows:

1. Radiographer causes: Patient ID, collimation, position, rotation, centering, no image, no marker, artefact, film size, no reason

2. Wrong exposures: under exposure, over exposure, double exposure

3. Processing: Weak chemicals, computerized post processing

4. Dark room/ storage: Fog

5. Faulty equipment: Printer

6. Power supply: Power cut to printer

Figure 2 shows the actual reject pattern as per film fault using SFR and CR.
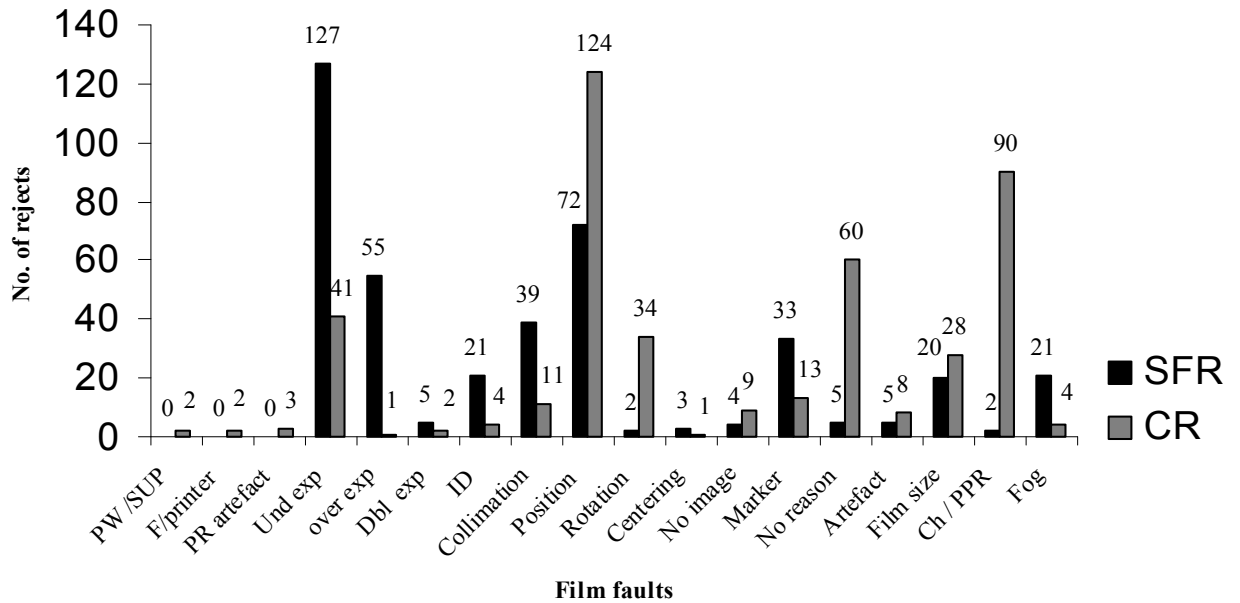
Key: PW/SUP – Power supply
F/printer – Faulty printer
PR artefacts – Printer artefacts
Und exp – Under exposure
Over exp – Over exposure
Dbl exp – Double exposure
ID – Identity
Ch/PPR – Chemicals/ Post processing
Sample size (n) = 851

5.1.5 RADIOGRAPHIC VALUE

The largest category of rejected films was due to no radiographic quality (84%) both prior to and after the incorporation of CR.

A small percentage (7.6%) of good quality radiographs were among the rejects.

The percentage of good quality radiographs was higher (92.3%) after the

incorporation of CR while the percentage of radiographs considered fair quality

was higher (87.3%) prior to the incorporation of CR (See Figure 3 below).

Figure 3: Rejection of films according to radiographic quality
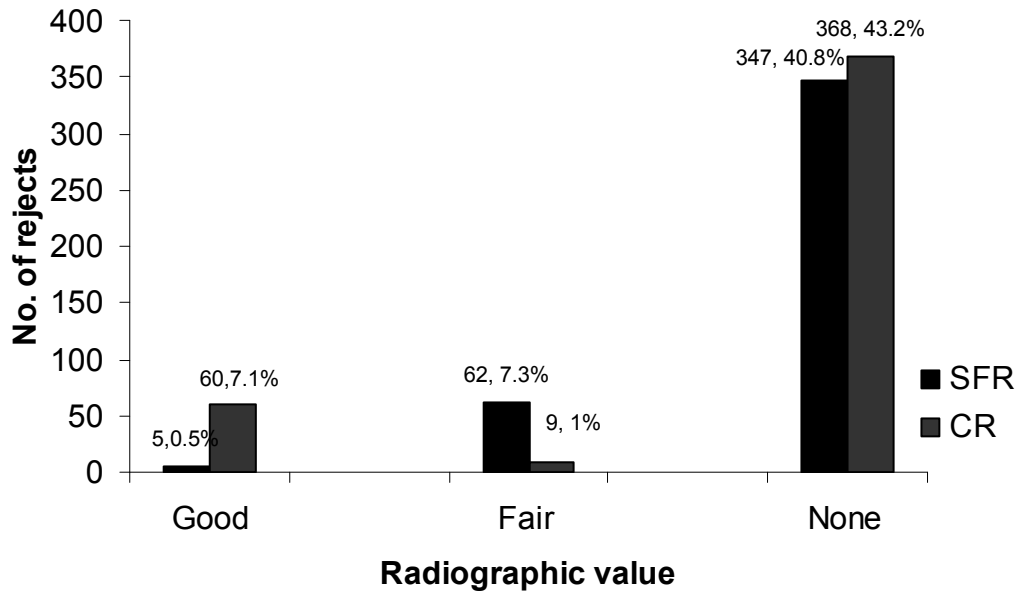
Sample size (n) = 851

The distribution of rejects according to examination type and radiographic value

is shown in Table 5 below.

Table 5: No of film rejects according to anatomical site and radiographic quality

Anatomic site	Good SFR	Good CR	Fair SFR	Fair CR	None SFR	None CR	Total SFR	Total CR
CXR	3	30	44	2	230	91	277	123
Joints	0	12	7	1	23	55	30	68
Lumbar spine	0	4	1	1	12	46	13	51
Extremities	1	6	2	0	16	38	19	44
Cervical spine	0	3	2	3	11	31	13	37
Abdomen	0	1	0	2	18	27	18	30
Thoracic spine	0	1	1	0	10	22	11	23
Skull x-ray	1	0	0	0	8	22	9	22
Para nasal sinuses	0	0	0	0	1	14	1	14
Pelvis	0	2	5	0	14	10	19	12
Post nasal space	0	0	0	0	0	6	0	6
No image	0	0	0	0	2	4	2	4
Sacral spine	0	0	0	0	0	2	0	2
Thoraco-lumbar spine	0	1	0	0	0	0	0	1
Mandible	0	0	0	0	2	0	2	0
Total	**5**	**60**	**62**	**9**	**347**	**368**	**414**	**437**

5.1.6 RADIOGRAPHIC COSTING

On the basis of the total x-ray films used over the study period, it was estimated that a total of about (15,640x52/20) 40,664 x-ray films per annum were used prior to the introduction of CR and (17236x52/20) 44,813.6 x-ray films per annum after the incorporation of CR.

Considering all types and sizes of x-ray films, about 1,609,083.22Kshs (136,667.75 ZAR) and 9,030,291.40Kshs (766,989.20ZAR) for SFR and CR respectively went into purchasing x-ray films annually.

Prior to the incorporation of CR approximately 16,230.34Kshs (1378.55ZAR) (1%), of the total value of x-ray films were rejected, whilst 88,190.50Kshs (7490.45ZAR) (1%), of the value of x-ray films were rejected annually after the incorporation of CR.

The distribution of the cost of x-ray films used prior to and after the incorporation of CR in the A & E x-ray unit is shown in Tables 6 and 7.

Table 6: Distribution of film cost per film size during the study period

Film size (cm)	SFR			CR		
	No (%)	Cost/100 Sheets (Kshs)(ZAR)	Cost (Kshs)(ZAR)	No (%)	Cost/100sheets (Kshs)(ZAR)	Cost (Kshs)(ZAR)
15x20	29 (7%)	1,900 (161.40)	551(46.80)	0	0	0
24x30	4 (1%)	2,371(201.40)	94.84(8.05)	0	0	0
25x30	46 (11%)	3,400(288.80)	1564(132.85)	0	0	0
26x35	0	0	0	407 (93.1%)	20,150(1711.45)	82,010.50(6965.55)
30x40	23 (5.6%)	3,900(331.25)	897(76.20)	0	0	0
35x35	255 (61.6%)	4,040(343.15)	10,302(875)	0	0	0
36x43	57 (13.8%)	4,950(420.45)	2,821.5(239.65)	0	0	0
35x43	0	0	0	30 (6.9%)	20,600(1749.65)	6,180(524.90)
Total	414 (100%)		16230.34(1378.55)	437 (100%)		88190.50(7490.45)

Table 7: Frequency of annual film consumption and cost

Film size (cm)	SFR		CR	
	Study period consumption	Cost (Kshs)(ZAR)	Study period consumption	Cost (Kshs)(ZAR)
15x20	1324	25,156.00 (2,136.65)		
24x30	156	3,698.76 (314.15)		
25x30	796	27,064.00 (2,298.70)		
26x35	0	0	17,206	3,467,009.00 (294470.95)
30x40	446	17,394.00 (1,477.35)		
35x35	10,316	416,766.40 (35,398.10)		
36x43	2,602	128,799.00 (10,939.55)		
35x43	0	0	30	6,180 (524.90)
Total	15,640	618,878.16 (52564.50)	17,236	3,473,189.00 (294995.85)
Annual consumption/cost	40,664	1,609,083.22 (136,667.75)	44,813.4	9.030,291.40 (766,989.20)

5.1.7 RADIOGRAPHERS' FILM REJECT RATES

There were a total of 17 radiographers at the hospital during the study period. After the incorporation of CR, radiographers were required to indicate their initials on the x-ray films. Only 330 (75.5%) of the 437 films rejected had initials of the radiographer who took the radiograph. Fifteen of the radiographers (coded as R1 – R15) had films amongst the rejects. Two of the radiographers (R16 and R17) did not have films amongst the rejects.

A summary of the number of rejects per radiographer and their number of years work experience is presented below in Table 8.

Table 8: Frequency of film rejects versus work experience per radiographer

Radiographer	Work experience (years)	No. of rejects	Percentage (%)
R1	3	61	18.5
R2	6	58	17.6
R3	5	51	15.5
R4	10	43	13.0
R5	10	26	7.9
R6	8	20	6.1
R7	3	18	5.5
R8	11	15	4.5
R9	11	13	3.9
R10	5	11	3.3
R11	5	6	1.8
R12	26	4	1.2
R13	13	2	0.6
R14	2.5	1	0.3
R15	24	1	0.3
R16	8	0	0.0
R17	3	0	0.0
Total		330	100

The work experience of the radiographers ranged from 2.5 – 26 years with an average of 9.03 years and range of 23.5 years (Table 7).

The number of rejects generally reduced with increase in the number of years of work experience. The relationship between number of years of work experience and number of film rejects is further presented graphically in Figure 4 below.
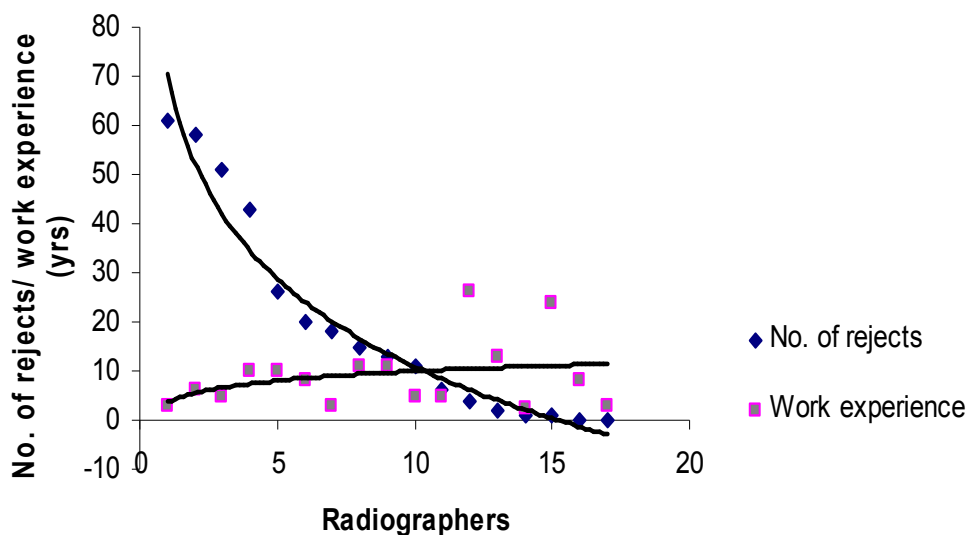
Figure 4: Frequency of rejects versus work experience

5.1.7.1. RADIOGRAPHERS' WORK EXPERIENCE AND PRIOR USE OF CR

None of the radiographers took a module in digital radiography while at school because it did not form part of the curriculum. Those who had worked longer at the hospital had at least previously used the digital equipment installed in the main x-ray department. Eight (47.1%) of the radiographers had used CR equipment at the hospital for 2 years. Only 2 (11.8%) of the radiographers, who had joined the hospital after July 2008, had not used CR equipment at all. The duration of prior use of CR did not have an effect on the number of rejects.
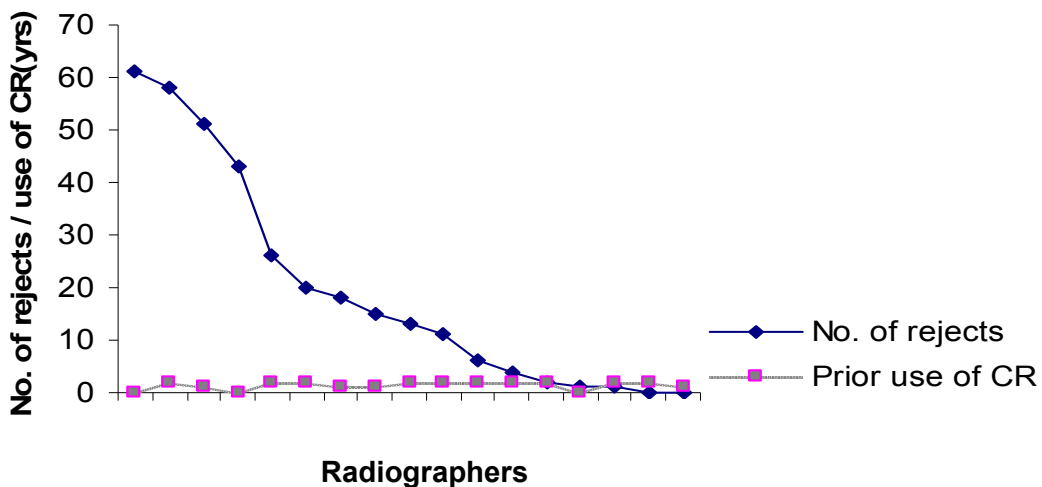
Figure 5: Frequency of rejects versus prior use of CR

Using chi-squared testing no statistically significant relationship between the number of years of experience using CR and the number of films rejected could be identified ($\chi^2(1, N = 17) = 0.3286$, at a 95% level of significance).

5.2 DISCUSSION

5.2.1 OVER VIEW

The total number of rejected films during the study period was 851 and the over all reject rate obtained was 2.5%. This would be considered an acceptable reject rate, since the Royal Australian College of Radiologists recommend that the reject rate should be less than 5% but above 2% (Rajani *et al*., 2008: 18). The reject rates obtained also fall within the 1% - 8.9% reject range identified in similar studies (Ranganathan and Faridah 2007: 806; Weatherburn *et al.,* 1999: 656; Waseem *et al.*, 2008: 151).

Considering the reject rates for the individual periods; the reject rates prior to and after incorporation of CR were 2.6% and 2.5% respectively. Both of these reject rates obtained can each be considered to be adequate. Although the reject rate reduced after the incorporation of CR, similar to that reported in many other studies (Casey, 2008; Waseem & Colleagues, 2008:151; Weatherburn & Colleagues, 1999: 656; Ranganathan & Faridah, 2007: 806; Peer & co-workers, 1999: 1693), there was no statistically significant reduction in the number of rejected films. This suggests that there are factors which contribute to the reject rate, other than computerizing radiography. These include, amongst others, good techniques, applications training and attitude of radiographers.

There is not enough evidence from this study to conclude that there is a significant (α = 0.05) relationship between the reject rate and the incorporation of CR.

5.2.2 REJECT RATES BY FILM SIZE

A total of 414 films were rejected prior to implementation of CR, with the highest film size rejected being 35 x 35cm (61.6%) and the lowest being 24cm x 30cm (1%). Consumption was also highest and lowest respectively for these two film sizes.

Despite the high consumption of the 35cm x 35cm film size, the reject rate for this particular film size was low at 2.5% compared to 5.2% and 5.8% for the 30cm x 40cm and 25cm x 30cm film sizes respectively. This means that although the 35cm x 35cm film size was frequently used, more errors were made when using the 30cm x 40cm and 25cm x 30cm film sizes. It can therefore be concluded that higher film consumption does not necessarily lead to high reject rates. This is similar to the results of Kitheka (2007:27) in a film reject analysis done in two hospitals in Nairobi, Kenya.

After the incorporation of CR only two film sizes were used; 26cm x 35cm and 36cm x 44cm. The CR post-processing equipment has been calibrated to print images on 26cm x 35cm film hence the higher consumption (99.8%) compared to 0.2% consumption of 36cm x 44cm film size. The reject rate was higher for the latter again confirming that a higher consumption of film does not necessarily lead to a higher reject rate.

The use of 36cm x 44cm film, instead of the 26cm x 36cm film the machine is calibrated to print, implies some of the radiographers did not know they had to select the calibrated film size and therefore selected the larger film size unknowingly or did know but would forget to select the right film size, for example when in a hurry to clear a patient queue.

5.2.3 REJECT RATES BY RADIOGRAPHIC EXAMINATION

The most rejected radiographic examination prior to and after the incorporation of CR was the chest followed by joint examinations. In both cases selection of wrong exposures and inappropriate positioning were the reasons for rejection.
The high frequency of rejected chest films was attributed to the chest being the most frequently performed radiographic examination.

5.2.4 REJECT RATE BY FILM FAULT CHARACTERISTICS

Overall, the most frequent film faults were those due to radiographer causes, such as: no patient identification, collimation, position, rotation, centering, no marker, artefact on film, wrong film size selection, no image, no image, and no reason for rejection.

An important factor in positioning, alignment and collimation errors is the light field or x-ray field misalignment. The high number of rejects in this category suggests the radiographers at The Nairobi hospital may need more training to perfect their radiographic techniques.

The other contributing factor may be that many of the patients sent to the A/ E x-ray unit are casualty patients referred following trauma or are very sick and therefore difficult to position. However it may also be due to radiographers giving inadequate explanations to the patients of what is required of them. The importance of maintaining the desired position whilst the radiograph is being taken is not being effectively communicated.

Lack of identification, markers, choice of film size, the presence of artefacts like earrings and the presence of diagnostic radiographs amongst the rejects may indicate a lack of concentration by the radiographers whilst performing x-ray

examinations. It may also indicate that they are overwhelmed by patient queues and they are rushing, trying to clear numbers. This is however only speculation, since the reasons for these factors occurring were not explored in this study.

The presence of exposed films without images may indicate a confusion of the cassettes by the radiographer. Although this does not directly increase patient radiation dose it leads to overall increase in the environment dose. It also results in increased machine wear and increase staff load, and wastage of chemicals when SFR is still being used.

Incorrect exposure selection, may also be classified as radiographer error, since the incorrect setting of exposure factors by radiographers may produce a non diagnostic radiograph. It is however important to note that incorrect x-ray output can also result in non diagnostic radiographs even with the proper setting of exposure factors by the radiographer.

Contrary to findings in many other similar studies, in this study, the most frequent cause of film rejects prior to incorporation of CR was radiographer causes followed by wrong exposures. In other studies, wrong exposure selection was found to be greater than radiographer causes, such as by positioning errors (Magala, 2004: 24; Kitheka, 2007: 27).

Dark room / storage errors, although not frequent, included artefacts due to roller marks and both high basic fog and light fog due to leaking cassettes. Only 2 films were rejected because of poor contrast as a result of weak chemicals.

Considering the period after the incorporation of CR and similar to many other studies (Redlich & co-researchers, 2005: 272; Noi et al., 2006: 159; Peer & co-workers, 1999: 1693), the most frequent cause of film rejects was positioning errors further emphasizing the need for training of the radiographers at The Nairobi Hospital.

Faulty equipment and power supply issues were causes of film faults only seen after the incorporation of CR. A faulty printer resulted in the printing of more than the selected number of films. For example, more than one copy of a given projection was printed, since only one copy of a particular projection was needed per patient, the rest of the printed copies were rejected.

The other reason for more than one copy of the same projection being printed was the number of desired of copies not being selected during post processing.

Interruptions in power supply to the printer resulted in incomplete printing of images. Such images had to be reprinted and the incomplete ones rejected.

5.2.5 RADIOGRAPHIC VALUE

As expected the majority of rejects were of no diagnostic value, both prior to and after the incorporation of CR. There was however a significant number of good diagnostic images among the rejects, possibly an indication that no consultation with a radiologist was done prior to films with good and fair value being rejected. With proper consultation the good value films would not have been among the rejects. Radiographs with fair radiographic value would have also been salvaged if supplementary radiographs were taken, in consultation with a radiologist.

As was previously stated earlier, printing of more than one image for a given projection contributed to some of the diagnostic images being rejected, after the incorporation of CR.

5.2.6 RADIOGRAPHIC COSTING

One of the reasons for CR being introduced at The Nairobi Hospital was an anticipated reduction in costs of films. However, the percentage value on annual rejects did not change after the incorporation of CR. It remained at 1% implying the objective of reducing operational costs, by cutting on the cost of films was not achieved. It has to also be noted that the estimated annual cost spent on purchasing films increased more than 5 times after the incorporation of CR. This

is due to the greater cost of digital x-ray films in comparison to the cost of x-ray films used in SFR, and also the higher annual consumption after the incorporation of CR.

The higher annual consumption may be explained by increased through-put reported after the incorporation of CR in similar studies (Mariana et al., 2004: 18; Ranganathan & Faridah, 2007: 806; Minnigh & Gallet, 2009:87; Stearns, 2004:58; Andriole, 2002: 161). A further study would however be necessary to confirm or reject this suggestion.

It is also important to note that only the cost of films were taken into account and other related costs like tube life and human resource costs, amongst others, were not included in this study. This means that the estimated annual percentage value spent on rejects is much higher than the 1% obtained.

5.2.7 RADIOGRAPHERS

After the incorporation of CR radiographers responsible for taking a radiograph are expected to include their initials on the x-ray taken. With this information on

the rejects it was easy to identify the radiographers and obtain information on how long each of them had worked and for how long they had used CR.

There was a general reduction in the number of rejects with increasing years of work experience; implying people improve with time as they learn on the job. The low numbers of rejects by the most senior staff may also be because they are mainly in managerial positions, and therefore less involved in the routine general radiographic duties.

Prior use of CR and the number of rejects seemed to be independent but there isn't sufficient evidence from this study to conclude that there is a significant relationship between prior use of CR and number of rejected films. There was a radiographer who joined the organization after the incorporation of CR in the A & E x-ray department, and had never used CR previously, but had only 1 film among the rejects.

The results from this study and discussion have been presented in chapter 5. These results and discussion will all be considered together in order to draw conclusions and suggest recommendations in chapter 6.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSION

Although CR was first introduced into the Nairobi Hospital, Nairobi, Kenya, in 2006, two years after the partial incorporation of CR, there was still a significant number of film rejects. Unnecessary patient radiation due to re-exposures as a consequence of under- or over-exposure may have been reduced, but operational costs remained high. However the cause of film rejects and the overall reject cost was not known. This gave rise to the research question, "Has the film reject rate at the Nairobi Hospital reduced following the incorporation of CR?"

In order to try and answer this question, a film reject analysis, pre- and post-implementation of CR in the A&E x-ray unit, at the hospital, was conducted. This was a quantitative, comparative descriptive study which involved the collection of rejected films between the 12th of December 2007 and the 28th of May 2008, in the A & E x-ray unit.

The primary objective of the study was to determine the film reject rate before and after the implementation of CR. The reject rates prior to and after incorporation of CR were 2.6% and 2.5% respectively. Although in the context of international standards, both of these reject rates can be considered to be adequate, with the implementation of CR, there was no statistically significant reduction in the number of rejected films. Thus the null hypothesis stated in Section 3.2.2: "The number of rejected films and the use of CR are independent", cannot be rejected.

If the secondary objectives of the study are considered:

Both prior to and after implementation of CR, most rejects were due to radiographer causes. Prior to CR, the most cause of rejection was under-exposure, and post implementation the most common cause was positioning.

Although the 35cm x 35cm film size was the most frequently consumed film size, more errors appeared to be made when using the 25cm x 30cm film size.

In theory, the implementation of CR should have been a cost-saving move, however the estimated annual expense on the purchase of x-ray films increased after the incorporation of CR. This is due to the increased cost of the digital x-ray film. However no other costs were considered in the study, and costs based on x-ray film alone are not sufficient to draw a true conclusion here.

In the study the number of rejects per radiographer, generally reduced with increased work experience but the prior use of CR by the radiographers, did not seem to have any impact on the number of rejects.

Although there are limitations to this study, which include:

- the study was only conducted within one X-ray department at a single hospital, and may therefore not be easily generalisable,

- it was a retrospective study, and so the reasons for film rejections were not always easily identifiable.

- The economic implications of CR implementation cannot be based on film costs alone, other costs need to also be considered.

Recommendations arising from the study, both for further studies as well as for the management of the X-ray units at the Hospital can be made.

6.2 RECOMMENDATIONS

The following would be recommendations to the X-ray department and Hospital management:

1. A regular film-reject analysis, for example, biannually, as part of the already present quality assurance programme, is suggested. This way, problem areas can be identified for appropriate corrective measures to be initiated.

2. Although there wasn't sufficient evidence from this study to identify the exact causes of rejections after the implementation of CR, there were findings which suggest some of rejects were a result of incorrect use of the CR equipment. The department managers should therefore emphasize adequate and appropriate application training for all users whenever new equipment is installed.

3. Other causes for film rejects identified in this study, suggest on-going training in radiographic techniques is required. Regular continuing professional development with respect to radiographic technique for radiographers is suggested.

4. The hospital management should consider hastening the installation of PACS throughout the hospital, in order for the x-ray department to become completely filmless, since this study suggests that the cost of purchasing x-ray films has increased five-fold with the implementation of CR.

In terms of further studies the following can be recommended:

1. An overall annual increase in film consumption was found after the incorporation of CR. This may indicate an increase in patient throughput, a larger study to confirm or reject this is therefore suggested.

2. A cost effectiveness analysis which considers all the costs involved in both CR and SFR, and the outcomes, would provide a more accurate idea of the cost implications of CR implementation.

3. An on-going or real-time analysis, of the causes for film rejects, including direct input from the radiographers involved, would provide greater in-depth insight into the nature of interventions needed.

REFERENCES

Al-Maliki, M. A., Abulfaraj, W. H., Bhuiyan, S. I. and Kinsara, A. A. 2003. A study of radiographic repeat rate data of several hospitals in Jeddah. *Radiation Protection Dosimetry*. Vol. 103, No. 4, P: 323-330.

Andriole, K.P. 2002. Productivity and cost assessment of computed tomography, digital radiography, and screen-film for outpatient chest examinations. *J Digit Imaging.* Vol. 165, No. 3, P: 161-169.

Anne, P.R. 2002. Phase II trial of subcutaneous amifostine in patients undergoing radiation therapy for head and neck cancer. Semin Oncol. Vol. 29 (6-suppl 19), P: 80-83.

Anonymous. 1991. ICRP Publication 60: 1990 Recommendations of the International Commission on Radiological Protection. *Annuals of the ICRP*. Vol. 21, P: 1-3.

Bansal, G. J. 2006. Digital radiography: A comparison with modern conventional imaging. *Postgrad Med J.* Vol. 82, P: 425-428.

Berle, I. 2008. Clinical photography and patient rights: the need for orthopraxy. *Med Ethics*, Vol. 34, P: 89 – 92.

Casey, B. Digital x-ray lowers retake rates in study from Pakistan. AnntMinnie, June 2008,

http://www.auntminnie.com/index.aspx?sec=sup&sub=xra&pag=dis&ItemID=816 24

Creemers, E., Hagemeijer-van, B.T. & Voorn, S. 2007. Repeat analysis at Mulago hospital, plain radiographs. Unpublished Graduation project MBRT: Fontys University, Eindhoven.

Creswell, J.W. 1994. Research design: qualitative and quantitative approaches. Thousand Oaks: Sage.

Cohen, B. L. 2002. Cancer risk from low-level radiation. AJR Am J Roentgenol. Vol.179, P: 1134-1143.

Cowen, A.R., Kengyelics, S.M. & Davis, A.G. 2008. Solid-state, flat-panel, digital radiography detectors and their physical imaging characteristics*. Clin Radiol*. Vol. 63, P: 487-498.

Deaver, S.M. Computed radiography versus digital radiography. Omini Imaging. December 31st, 2008, http://www.omniimaging.com/?p=72

De Vos, A.S. 2005. <u>Research at Grass roots: For the social sciences and human service professions</u>, 3rd ed. Pretoria: Van Schaik.

Dunn, M. A., Rogers, A. T. 1998. X-ray film reject analysis as a quality indicator. *Radiography.* Vol. 4. No. 1, P: 29- 31.

Edwards, J. R., Bestor, T. H. 2007. Gene regulation: stochastic and deterministic effects in gene regulation. *Hereditary* Vol. 99, P: 243-244.

Einstein, A.J. 2009. Radiation protection of patients undergoing cardiac computed tomography angiography. *JAMA.* Vol. 301, P: 545-547.

Eze, K.C., Omodi,a N., Okegbunam, B., Adewonyi, T. & Nzotta, C.C. 2008. An audit of rejected repeated x-ray films as a quality assurance element in a radiology department. *Niger J Clinical Pract*. Vol. 11, No.4, P: 355-8.

Fazel, R., Krumholz, H.M., Wang, Y., Ross, J.S., *et al.,* 2009. Exposure to Low-dose ionising radiation from medical imaging procedures. *N Engl J Med*. Vol. 361, P: 849-857.

Fang, Y.C., Yang, M.C., Hsueh, Y.S. 2006. Financial assessment of a picture archiving and communication system implemented all at once. *J Digital Imaging*. Vol. 19, No. 1, P: 44 -51.

Fortune, A. E. & Reid, W.J.1999. Research in social work, 3rd ed. New York: Colombia University Press.

Greene, J. 2001. A developing crisis. Staffing overshadows all other challenges facing radiology departments. *Hosp Health Netw*. Vol. 75, No. 10, P: 52-4

Honea, R., Blado, M.E., & Ma, Y., 2002. Is reject analysis necessary after converting to computed radiography? *Journal of Digital Imaging*. Vol. 15, Suppl. 1, P: 41-52.

Hood, H. M., & Scott, H., 2006: Introduction to picture archiving and communication systems. *J Radiol Nur*. Vol. 25, No. 3, P: 69-74.

IAEA. 2003. Radiation protection in diagnostic radiology.

ICRP 2007. The 2007 recommendations of the International Commission on Radiological Protection: ICRP publication 103. *Ann ICRP*. Vol. 37, No. 2-4, P: 1-332.

International Commission on Radiological Protection (ICRP), Managing patient dose in digital radiology: a report of the international Commission on Radiological Protection. *Ann ICRP* 2004; 34, P: 1-73.

Kigo, A. K. 1993. A film reject analysis at two radiology departments in Nairobi. Unpublished Masters of Medicine in Diagnostic Radiology Dissertation: Nairobi University, Kenya.

Kim, P.K., Gracias, V. H., Maidment, A.D., O'Shea, M., Reilly, P.M. & Schwab, C. William., 2004. Cumulative radiation dose caused by radiologic studies in critically ill trauma patients. *Journal of Trauma-Injury Infection & Critical Care*. Vol. 57, No. 3, P: 510-514.

Kish, Leslie. 1965. Survey sampling. New York: John Wiley and sons, Inc.

Kitheka, M. D., 2007. A radiographic film reject analysis of the department of Imaging and Radiation Medicine of the University of Nairobi and the x-ray Department of Mbagathi District Hospital Nairobi. Unpublished Masters of Medicine in Diagnostic Radiology Dissertation: Nairobi University, Kenya.

Kusakabe, Y., 2002. Financial impact of introducing filmless CRT diagnosis. *Nippon*. Vol 58, No. 9, P: 1277-1281.

Lanca, L & Silva, A. 2009a. Digital radiography detectors – A technical overview: Part 2. *Radiography*. Vol.15. No. 2, P: 134 -138

Lanca, L. & Silva, A. 2009b. Digital radiography detectors- A technical overview: Part 1. *Radiography* .Vol. 15, P: 58-62.

Lau, S., Mak, A.S., Lam, W., Chao, C. & Lau, K., 1999. Comparison of conventional film-screen radiography and computed radiography with PACS. *British Journal of Radiology*. Vol. 72 No. 859, P: 653-660.

Little, M.P., Wakeford, R., Tawn, E.J., Bouffler, S.D. & Berrington de Gonzalez, A., 2009. Risks associated with low doses and low dose rates of ionizing radiation. Why linearity may be (almost) the best we can do. *Radiology*. Vol. 251, No. 1, P: 6-12.

Lockwood, D., Eienstein, D., &Davros, W. 2006. Diagnostic imaging: Radiation dose and patients' concerns. *Cleveland Clinical Journal of Medicine*. Vol. 73, No. 6, P: 583- 586.

Magala, W. 2004. A study on the cause of the commonly occurring film faults in casualty x-ray department. Unpublished Diploma Dissertation: Makerere University, Kampala.

Mariana, C., Tronchi, A., Oncini, L., Osvaldo, P., and Murri, R. 2006. Analysis of x-ray workflow in two diagnostic imaging departments with and without a RIS/ PACS system. *Journal of Digital Imaging*. Vol. 19, No. 1, P 18-28).

Martin, C. J. 2008. The application of effective dose to medical exposures. *Radiat. Prot Dosimetry*. Vol. 128, P: 1-4.

McBurney, D.H. 2001. Research Methods. London: Wadsworth Thomson Learning.

Mitchell, M. & Jolley, J. 2001. Research design explained. London: Harcourt College Publishers.

Minningh, T.R. and Gallet, J. 2009. Maintaining Quality Control Using a Radiological Digital x-ray Dashboard. *Journal of Digital Imaging*. Vol. 22 no.1, P: 84-88.

Monfared, A.S., Abdi, R. & Saber, M. A. 2007. Repeat analysis program in radiology depatments in Mazandaran province- Iran; Impact on population radiation dose. *Iran J Radiat. Res*, Vol. 5 No. 1, P: 237 – 40.

Moore, C. S., Liney, G.P., Beavis, A. W., Saunderson, J. R. 2007. A method to optimize the processing algorithm of a computed radiography system for chest radiography. *British Journal of Radiology*. Vol. 80, P: 724-730.

Mouton, J. 2001. <u>How to succeed in your master's and doctorial studies: a South African guide and resource book</u>. Pretoria: Van Schaik.

Mouton, J. & Maurais, H.C. 1990. Basic concepts in the methodology of social sciences . Pretoria: Human Sciences Research Council.

Muhogora, W.E., Nyanda, A.M. & Kazema, R.R. 2001. European Guidelines on quality criteria for radiographic images in Tanzania. *Journal of Applied Clinical Medical Physics*. Vol. 2, No. 4, P: 219-226.

Muhogoro, W.E., Nyanda, A.M., Ngaile, J.E. & Leme, S.E. 1999. Film reject rate studies in major diagnostic x-ray facilities in Tanzania. *J Appl. Clin. Med. Phys*, 301-305.

Muller, W. A. 1995. Stochastic and deterministic radiation carcinogenesis. *Radiation research*. Vol. 143, No. 1, P: 115-116.

Neuman, W.L, 2000. Social research method: qualitative and quantitative approaches, 4th ed. Boston: Allyn & Bacon.

Neuman, W.L. 2003. Social research methods: qualitative and quantitative approaches, 5th ed. Boston: Allyn & Bacon.

Nol, J. Isouard, G. & Mirecki, J. 2006. Digital repeat analysis; setup and operation. *J Digital Imaging*, Vol.19. No. 2, P: 159-166.

Nyathi, T., Chirwa, T.F., van der Merwe, D.G. 2010. A survey of digital radiography practice in four South African teaching hospitals: an iluminative study. *Biomed Imaging Interv J*, Vol 6, No. 1, P: 1-5.

Peer, S., Peer, R., Walcher, M., Pohl, M. & Jaschke, W. 1999. Comparative reject analysis in conventional film-screen and digital storage phosphor radiography. *Eur Radiol* Vol.9, P: 1693-96.

Pilot, D.F. & Hungler, B.P. 1995. Nursing research principles and methods. Philadelphia: JB Lippincott.

Prasad, K.N., Cole, W.C., Hasse, G.M. 2004. Radiation protection in humans: extending the concept of as low as reasonably achievable (ALARA) from dose to biological damage. *The British Journal of Radiology*. Vol. 77, P: 97-99.

Prasad, K.N., Cole, W, C., Kumur, B., Che Prasad, K. 2002. Pros and cons of antioxidant use during radiation therapy. Cancer Treat Rev. Vol. 28, P: 79-91.

Prieto, E., Vano, E., Ten, J.N., Fernandez, J.M., Iňiguez, Arevalo, N., Litcheva, A., Crespo, E., Floriano, A., Martinez, D. 2009. Image retake analysis in digital radiology using DICOM header information. *J digit Imaging.* Vol 22, No. 2, P: 104-113.

Rajani, A., Sajjid, Z., Masroor, I., Parveen, A., Mansoor, N. 2008. "Should we stop improving when benchmarks are met?" *Pakistan Journal of Radiology*. Vol. 18 No.1, P: 18-19.

Ranganathan, S. & Farida, Y. 2007. Moving into digital era: a novel experience with the first full-field digital mammography systems in Malaysia. *Singapore Med J*. Vol. 48 No. 9, P: 804-807.

Redlich, H., Hoeschen, C., Effenberger, O., Fessel, A., Preuss, H., Reissburg, S. *et al.,* 2005. Comparison of four digital and one conventional radiographic image systems for the chest in a patient study with subsequent system optimization. <u>*Rofo*</u>, Vol. 177, P: 272-78.

Reiner, B.I. & Seigel, E.L. 2002. Technologists' productivity when using PACS: comparison of film based versus film radiograph. *Am J Roentgenol*. Vol 179, P: 33-37.

Reiner, BI., Seigel, E.L., Flagle, C. 2000. Effect of filmless imaging on the utilisation of radiology services. Radiology. Vol. 215, P:163-167.

Reiner, B.I., Seigel, E.L. & Scanlon, M. 2002. Changes in technologist productivity with implementation of an enterprise-wide PACS. *J Digit Imaging*. Vol. 15, P: 22-26.

Reiner, B.I., Seigel, E.L., Siddiqui K., 2003. Evolution of digital revolution: a radiologits perspective. *J Digit Imaging*. Vol. 16. No. 4, P: 324-330

Ritenour, E. R. 1996. Physics overview of screen-film radiography. *Radiographics*. Vol. 16, P: 903-916.

Sarantakos, S. 2000. Social research. Sydney: Macmillan.

Schaefer-Prokop, C., Neitzel, U. & Venema, H. W. 2008. Digital chest radiography: an update on modern technology, dose containment and control of image quality. *Eur Radiolo*. Vol. 18, No. 9, P: 1818- 1830.

Senoga, J. 2007. Reject-Repeat films: an ongoing quality assurance program in King Faisal Hospital, Kigali. Pan African Congress of Radiology and Imaging (PACORI).

Shaw, P., Croŭail, P. & Drouet, F. 2010. Risk- assessment and continuous improvement programmes. *Radioprotection*. Vol. 25, No. 3, P: 401-408.

Sozanski, T., Sokolska, V., Gomulkiewicz, M., Magdalan, J., Trocha, M., Bladowska, J., Merwid-Lad, A. 2009. Filmless radiology –digital radiography systems*. Adv Clin Exp Med.* Vol. 18, No. 6: 641-648.

Stearns, E.D. 2004. Computerized radiography in perspective. *The NAVTA Journal* no. 4, P: 53-58.

Sniureviciute, M. & Adliene, D. 2005. Problems with film processing in medical x-ray imaging in Lithuania. *Radiat Prot Dosimetry*, Vol.114, No. 1-3, P: 260-263.

Strickland, N.H. 2000. PACS (picture archiving and communication systems): filmless radiology. *Arch Dis Child*. Vol. 83, P: 82-86.

Teefe, J. D. 2006. Reject analysis x-ray unit of Uganda cancer institute. Unpublished Diploma Dissertation: Makerere University, Kampala.

Tolkki, O., Ahovuo, J., Kauppinen, T., Fyhr, N., Kujala, J. & Parvinen, P. 2004. Patient in Process, Benefits of Reduced Throughtput Time-Case HUSpacs. EuroPACS-MIR (2004), Edizioni Università di Trieste: 155–158, 2004.

Vaňo E., Femandez, J. M., Ten, J.I., Prieto, C., Gonzalenz, L., Rodriguez, L., de Las Heras, H. 2007. Transition from film- screen to digital radiography: evolution of radiation doses at projection radiography. *Radiology*. Vol. 243, no. 2, P: 461-466.

Waseem, A., Mubashir, A., Arif, A., Kashir, M., Nadeem, A. 2008. Film retakes in digital and conventional radiography. *Journal of College of Physicians and Surgeons Pakistan*. Vol. 18, No 3, P: 151-153.

Waning, B., Montagne, M. 2001. Observational study designs. In: Pharmacoepidmiology principlesx and practice. McGraw-Hill.

Weatherburn, G.C., Bryan, S. & West, M. 1999. A comparison of image reject rates when using film, hard copy computed radiography and soft copy images on picture archiving and communication systems (PACS) workstations. *The British Journal of Radiology*, Vol. 72, P: 653 – 660.

Weatherburn, G.C. Bryan, S. & Davies, G. J. 2000. Comparison of doses for bedside examinations of the chest with conventional screen-film and computed radiography: Results of a randomized controlled trial. *Radiology*. Vol. 217, P: 707-712.

Wideman C. & Gallet J. 2006. Analog to digital workflow improvement: A quantitative study. *J Digital Imaging*. Vol. 19, No. 1, P: 29-34.

Williams, M. B., Krupinksi, E. A. & Strauss, K. J. 2007. Digital radiography image quality: image acquisitions. *J Am Coll Radiol*. Vol. 4, No. 6, P: 371-388.

Yates, S. J. 2004. Doing Social Science Research. London: Sage

Zewdeneh, D., Teferi, S., & Admassie, D. 2008. X-ray reject analysis in Tikur Anhessa and Bethzatha Hospitals. *Ethiop J Health Dev*. Vol. 22, No. 1, P: 63-67.

BIBLIOGRAPHY

Bahari, S., Morris S., Broe D., *et al*. 2006. Radiation exposure of the hands and thyroid gland during percutaneous wiring of hand and wrist procedures. *Acta Orthop Belg.* Vol. 72, No. 2, P: 194-8.

Christensen, G. J. 2004. Why switch to digital radiography? *J Am Dent Assoc*, Vol. 135, No. 10, P: 1437- 1439.

Clark, P. A., Hogg, P. 2003. Reject repeat analysis and the effect prior film viewing has on a departments reject/ repeat rate. *Radiography*, Vol 9, P: 127- 137.

Reiner, B.I., Seigel, E.L., Hooper, F.J., Siddiqui, K.M., Musk, M,, Walker, L.,Chacko, 2005. A. Multiple-institutional analysis of computed and direct radiography. Part 1. technologist productivity*. Radiology*. Vol. 236, P: 413-419.

Sieber, J.E. 1982. <u>The ethics of social research: surveys and experiments</u>. New York: Springer.

Tomasz, S., Violetta, S., Marek G., Jan, M., Malgorzata, T. Joanna, B. Merwid-Lad, A. 2009. Filmless radiology- digital radiography systems. *Adv Clin Exp Med*. Vol. 18, No. 6, P: 641- 648.

APPENDIX I

DATA COLLECTION FORM

X-ray film code …………………………………..

System of radiography   1] Conventional film screen radiography (FSR)

           2] Computerized radiography (CR)   [ ]

Date of exposure: ……………………………………………

Invoice No. : …………………………………………………..

Film size	FSR	1]	8 x10cm	
		2]	15 x 20cm	
		3]	24 x 30cm	
		4]	25 x 30cm	
		5	30 x 40cm	
		6]	35 x35cm	
		7	35 x 43cm	[ ]
	CR	1]	26 x 35cm	
		2]	36 x 44cm	[ ]

Cost of film: …………………………………………………

Examination	1]	Chest x-ray (CXR)
	2]	Skull x-ray (SXR)
	3]	Para nasal sinuses (PNS)
	4]	Abdomen
	5]	Pelvis
	6]	Spine

7]   Extremity

8]   Joints   [   ]

Radiographic quality

1]   Good

2]   Fair

3]   None   [   ]

Reason for rejection 1]   Under penetrated

2]   Over penetrated

3]   Positioning

4]   Artifacts

5]   Processing

6]   Motion blurr

7]   Double exposure

8]   Collimation / Centering   [   ]

Radiographer (Code)   …………………………………………………..

Radiographer experience   1]   < 1year

2]   1-5years

3]   6-10years

4]   > 10years   [   ]

Radiographer training in CR   1]   Yes

2]   No   [   ]

Form of CR training   1]   Radiography module

2]   On the job

3]   Both   [   ]

THE NAIROBI HOSPITAL

Our Ref: TNH/ADMIN /CEO/15/12/10

15 August 2010

Dr. Nabaweesi Jennifer Batuka
Consultant Radiologist
Radiology Department
The Nairobi Hospital
P.O. Box 30026-00100
NAIROBI

Dear Dr. Nabaweesi,

STUDY PROPOSAL: "PRE & POST COMPUTERISED RADIOGRAPHY FILM REJECT
ANALYSIS AT THE NAIROBI HOSPITAL"

Reference is made to your letter dated 6 August 2010 on the above subject matter.

This is to inform you that approval of the study has now been granted. You are further
advised to maintain confidentiality at all time and ensure that any printed images do not
bear names of identity of a patient. Kindly liaise with Dr. Ravi Bowry, our Chief Radiologist
on logistics.

We also request you to forward your findings to our Education & Research Committee for
record purposes.

Yours sincerely,
FOR: THE NAIROBI HOSPITAL

Dr. Cleopa Mailu, EBS
CHIEF EXECUTIVE OFFICER

cc:
- Chief Radiologist, The Nairobi Hospital
- Human Resources Manager, The Nairobi Hospital
- Chairman, Education & Research Committee,
  The Nairobi Hospital

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