EFFECT OF EXPOSURE CHARTS ON REJECT RATE OF EXTREMITY RADIOGRAPHS

By

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Table of contents

Abstract

Purpose

This study discusses reject film analyses (RFAs) before and after the implementation of a quality improvement intervention. RFAs were undertaken to investigate the effect of the introduction and use of exposure charts (ECs) on department and student reject rates of extremity radiographs.

Methods

A quantitative comparative pre and post-treatment research design was used. Data was collected from the x-ray departments of two training hospitals in Windhoek, Namibia over a five month period. A retrospective RFA was conducted to determine the department and student reject rates for both departments before intervention. Emphasis was placed on exposure related reject films. ECs were compiled and introduced at Katutura State Hospital (venue B) by the researcher. The students were instructed to use these charts. At Windhoek Central Hospital (venue A) no ECs were used. A prospective RFA was conducted to establish department and student reject rates at both hospitals after the intervention at venue B.

Results

During the retrospective phase the department reject rate for venue A was 21% while the student reject rate was 23%. At venue B 24% and 26% were scored respectively. Students at venue A produced rejected radiographs due to overexposure (49%) and underexposure (23%), whilst 37% was recorded for both causes at venue B. At venue A, 35% of films were rejected due to incorrect mAs selection, at venue B the figure was 42%. Undiagnostic radiographs due to inaccurate kV selection comprised 62% for venue A and 59% for venue B.

During the prospective phase the department reject rate for venue A was 20% and that of the students was 19%. For venue B 12% and 11% were scored respectively. At venue A radiographs rejected due to over and underexposure were 43% and 33% respectively while those at venue B were 33% and 34%. Incorrect mAs selection caused 33% of discarded films

at venue A and 38% at venue B. The figures for inaccurate kV selection were 68% and 62% for venues A and B.

Conclusions

The introduction and use of ECs lowered the student reject rate at venue B in the prospective phase.

Keywords: Reject film analysis (RFA), reasons for rejection, reject rate, exposure factors, exposure chart (EC).

List of abbreviations used

EC: exposure chart

FFD: focus film distance

KSH: Katutura State Hospital

kV: kilovoltage

mA: milliamperes

QA: quality assurance

QC: quality control

RFA: reject film analysis

WCH: Windhoek Central Hospital

Chapter 1

Introduction

1.1 The problem and its setting

Over the last few years, public expectations and patterns of health delivery have become more challenging. Hospital services are being faced with increased demands for expenditure reduction, improved efficiency and increased throughput. In the face of these demands, the role of a hospital is identified as delivering changes in patient care and constantly improving the quality of service.

The quality of a radiographic image plays an important role in the accuracy of the diagnostic process. Diagnostic imaging provides information about the internal anatomy and physiology of the human body. Accordingly, the correct interpretation of this image is an important requirement for further action.

The primary goals of diagnostic imaging are to obtain optimal and consistent image quality and an accurate diagnosis, as well as to provide the patient with prompt, accurate, high-quality health care. In terms of these requirements, these goals will be adequately met if the following objectives are achieved: maintaining the quality of diagnostic images, minimising ionizing radiation exposure for both the patient and the staff, being cost-effective and minimising waiting time. Imaging facilities have the responsibility to constantly improve the quality of their services and to maintain superior standards of patient care.

Some radiographs are discarded because they have no diagnostic value. These are referred to as rejected films. A reject image is described as an image that does not add diagnostic information to clinical questions because of poor image quality and thus the image has to be retaken (Chu, Ferguson, Wunder, Smith, & Vanhoutte, 1982, Watkinson, Moores, & Hill, 1984, Kofler, Molke, & Vrieze, 1999; Peer, Peer, Giacomuzzi, & Jaschke, 2001). Whenever a film is rejected, the radiograph must be repeated. This repetition of radiographs presents various concerns, including unnecessary radiation exposure for the patient, increased costs, longer patient waiting time, additional workload for radiographers and reduced x-ray tube life.

Diagnostic images should be of sufficient quality and should consistently provide adequate diagnostic information. This should be achieved at the lowest possible cost and with the least patient exposure. In addressing these requirements, quality assurance (QA) comprises an organised effort by staff to achieve all the above-mentioned primary goals. QA includes periodic quality control (QC) tests, preventive maintenance procedures, administrative methods and training. It also includes continuous assessment of the efficiency of the imaging service and the means to initiate corrective action (Périard & Chaloner, 1996). In a diagnostic x-ray department, reject film analysis (RFA) forms an integral component of a QA programme (Chu *et al.,* 1982).

In order to ensure quality, service levels need to be measured. One potential measurement tool is RFA. RFA is a process where discarded films are analysed to establish the reasons for rejection.

In the identified literature, the researcher found several causes for reject films. These included, among others, the incorrect selection of radiographic exposure factors, the inaccurate positioning of the part under examination, improper processing conditions, radiographic equipment malfunction, and patient movement during an exposure (Bryan, 1987; Peer *et al.,* 2001). The researcher concentrated on exposure faults because

- exposure related errors are the most frequently recorded cause of rejection in the literature
- there were no exposure charts (ECs) available in the departments in which the research was conducted.

Radiographic examinations entail the use of exposure factors, namely (i) kilovoltage (kV), which is the potential difference between the cathode and the anode of the x-ray tube, and (ii) tube current, in milliamperes, which is applied over a set time (mAs). These result in the production of x-rays. The selection of exposure factors varies according to the size of the patient, the thickness of the area being examined, the film/screen combination and the focal film distance (FFD).

In order to produce good quality radiographs, exposure factors are determined for different anatomical parts and are then summarised in an EC. An EC is a table consisting of information, for example, kV and mAs, which enables a radiographer to select the correct exposure factors. ECs are an essential component of a QA programme in a diagnostic imaging department.

In most developed countries and several developing countries, such as South Africa, there are laws and regulations that control the use of ionising radiation, as it has potential harmful effects on cell biology. In South Africa, it is a legal requirement for licensing the equipment that every x-ray machine should have an EC. In other words, x-ray units should have written protocols for every type of standard radiographic procedure specifying the exposure factors normally used to perform each examination. The South African legislation has been adopted by the Ministry of Health and Social Services of Namibia but it is not widely implemented, thus some imaging departments in Namibia do not make use of ECs.

For the purpose of investigating the effect of ECs on reject rate, the researcher chose to study the reject films of Windhoek Central Hospital (WCH) as venue A and Katutura State Hospital (KSH) as venue B. In this study, the reject films produced by both radiographers and students during both the retrospective and prospective phases were used. At venue A there may have been a carry-over effect of exposure factor adjustments even in the absence of ECs since all students were taught to use ECs and callipers for implementation when they were allocated for clinical practice at venue B during the prospective phase. As the departments at these Namibian hospitals did not have ECs for extremity radiography, they were identified as being suitable venues for the research. Venue B is the largest radiography training hospital in Namibia, and was convenient for the study. One of the researcher's aims was to establish whether the intervention would reduce the reject rate at venue B. ECs were therefore introduced and used by students working at venue B only. Students working at venue A did not use ECs although all the students had been taught how to use them.

Approximately 10 000 and 40 000 patients are examined annually and about 20 000 and 60 000 radiographic films are used over the same period at venues A and B respectively. At the time of the study, the actual reject rate at these hospitals was not known because the previous RFA, done by Gabone, Cupido, and Bloodstaan in 2006 (unpublished), was limited to certain x-ray examinations which excluded extremity radiography.

The purpose of this study was to determine the retrospective departmental and student reject rates for use as a benchmark to design and implement a quality improvement programme to reduce the reject rate over a five-month period. During the two months (28 August to 22 October 2008) that the extremity reject films were collected for the retrospective study, ECs were compiled and were introduced at venue B after the students returned from vacation. All second and third year radiography students of 2009 were taught how to use ECs for four weeks (25 February to 25 March 2009). Following the students being taught how to use ECs the prospective phase commenced.

The study addressed exposure factor selection by compiling and introducing ECs to assist students at venue B in the production of diagnostic radiographs. Accordingly, the target population included all the departments' extremity rejected films for the retrospective and prospective RFA periods. The WCH and KSH x-ray departments were identified as the venues for the research because they are the largest training hospitals in Windhoek and were convenient for accessing data.

1.2 The statement of the problem

The purpose of this study was to conduct reject film analyses at two radiography training hospitals in Namibia, to compare the retrospective reject rates for extremity radiography produced by radiographers and students, who routinely did not use exposure charts, with the prospective reject rates for extremity radiographs, after the implementation of exposure charts used only by students at one of the hospitals, and the reject rates at the other hospital, where exposure charts were not used by students and radiographers, to determine the effectiveness of routinely using exposure charts to minimize unnecessary ionizing radiation dose to patients by students and radiographers.

1.3 Statement of sub-problems

1.3.1 Sub-problem 1a

To determine the retrospective phase departmental reject rate for extremity radiography at venue A.

1.3.2 Sub-problem 1b

To determine the retrospective phase departmental reject rate for extremity radiography at venue B.

1.3.3 Sub-problem 2

To determine if there is a difference in the mean reject rates of students at venues A and B before the introduction and use of ECs.

1.3.4 Sub-problem 3

To determine if there is a difference in the mean reject rates of students at venues A and B after the introduction and use of ECs at venue B.

1.3.5 Sub-problem 4

To determine if there is a difference in the mean reject rates of students before and after the introduction of ECs at venue B.

1.3.6 Sub-problem 5a

To determine the prospective phase departmental reject rate for extremity radiography at venue A.

1.3.7 Sub-problem 5b

To determine the prospective phase departmental reject rate for extremity radiography following the implementation and use of ECs at venue B.

1.4 The hypotheses

1.4.1 Hypothesis 1a

The retrospective phase departmental reject rate for extremity radiography is 20% at venue A.

1.4.2 Hypothesis 1b

The retrospective phase departmental reject rate for extremity radiography is 20% at venue B.

1.4.3 Hypothesis 2

There is no difference in the mean reject rates of students at venues A and B before the introduction and use of ECs.

1.4.4 Hypothesis 3

There is a difference in the mean reject rates of students at venues A and B after the introduction and use of ECs at venue B.

1.4.5 Hypothesis 4

There is a difference in the mean reject rates of students before and after the introduction and use of ECs by the students at venue B.

1.4.6 Hypothesis 5a

The prospective phase departmental reject rate for extremity radiography is 16% at venue A.

1.4.7 Hypothesis 5b

The prospective phase departmental reject rate for extremity radiography is 16% at venue B.

1.5 The delimitations

- The students were only considered for the study when they were working at venue B.
- Only rejected extremity films were analysed.
- The research did not investigate other causes of film rejection but concentrated on exposure factors only.

1.6. The assumptions

1.6.1 The first assumption

The same students rotated through the two x-ray departments selected for the study.

1.6.2 The second assumption

The student absenteeism rate was zero during the data collection phases.

1.6.3 The third assumption

All students gained the same knowledge and skills after being taught how to use ECs for implementation during the prospective phase at venue B.

1.6.4 The fourth assumption

When the students were working at venue B they applied what they had been taught in terms of using ECs and callipers.

1.6.5 The fifth assumption

When the students were allocated to venue A for clinical practice, although they did not have access to callipers and ECs, they may have made some adjustments to exposure factors based on their knowledge of ECs when they used them during clinical practice at venue B in the prospective phase.

1.6.6 The sixth assumption

The reject rate of the radiographers at both hospitals would be lower than the respective students' reject rates as the latter did not have the same level of radiographic knowledge and expertise.

1.6.7 The seventh assumption

The same radiographers and students participated in the retrospective and prospective phases.

1.6.8 The eighth assumption

The students did not share their knowledge on the use of ECs with the radiographers at venue A and B respectively.

1.6.9 The ninth assumption

The equipment used functioned optimally throughout the study period.

1.6.10 The tenth assumption

The students used manual exposures for the production of films throughout the study period.

1.6.11 The eleventh assumption

The processing chemicals used were efficient and the processors were stable.

1.6.12 The twelfth assumption

Collimation of the primary beam was standardized.

1.6.13 The thirteenth assumption

No added filters were used.

1.6.14 The fourteenth assumption

Storage of radiographic films and processing chemistry was optimal.

1.7 The importance of the study

Repeat radiographs pose potential harm to patients because of unnecessary exposure to ionising radiation. The use of ECs was expected to reduce the reject rate, which implies that less repeats were necessary and thus patients received less radiation.

The radiography community in Namibia is relatively small and very little research has been done within this domain. The researcher could only locate one RFA study that had been performed in the departments to date, thus the information gained from this study may be used as a baseline for future studies.

Namibian legislation requires x-ray facilities to provide ECs for each x-ray machine; however, this was not the case at venue B before the commencement of the current study. It was only as a result of this research study that venue B gained ECs for extremity radiography. During this research students were taught how to measure patient thickness using callipers and to use these measurements to select accurate exposure factors on a continuous basis.

1.8 Summary

This chapter discussed the problem of this study and its setting, as well as indicating the problem statements, hypotheses, delimitations and assumptions. It also explained the importance of the study.

Chapter 2 presents a review of the literature pertaining to the problem statement and gives the reasons for the study. Chapter 3 covers the data, their treatment and their interpretation. The results and findings of the study are presented in Chapter 4 and Chapter 5 discusses the conclusions, limitations and recommendations emanating from the research.

Chapter 2

Literature review

2.1 Introduction

Optimal image quality is one of the most important aspects of radiography because it is concerned with the outcome of every examination performed. Suboptimal image quality compromises patient care. Factors impacting on image quality are radiographic contrast, exposure charts (ECs), processing of films, sharpness of images, patient movement, speed of systems, etc. The EC is one of the factors with which the current research is concerned.

The aim of this chapter is to consult the literature concerning aspects which feature in the current research, for example, reject film analysis (RFA), reasons for rejection, reject rate and ECs. These topics have been well researched and the results published around the world.

This chapter serves to review different reject analyses performed on different continents. Established reject rates and acceptable reject rates will be investigated and discussed. Furthermore, reasons for rejection will be compared and the most common one, exposure faults, will be examined.

ECs have been compiled by several authors. These will be considered and their development discussed.

2.2 Reject film analysis (RFA)

In x-ray departments the production of undiagnostic films is unavoidable; however, with some effort their incidence may be minimised (Chu *et al.*, 1982). RFA is defined as a critical evaluation process in terms of which discarded radiographs are analysed with the purpose of establishing the reasons for rejection (Arvanitis, Parizel, Degryse, & De Schepper, 1991). RFA evaluates the incidence and identifies the causes of rejection. It is a well-established, inexpensive and easily performed method of quality control (QC) widely used in radiography departments (Peer *et al.*, 2001; Lau, Mak, Lam, Chau, & Lau, 2004). RFA supplies a framework for managing the use of films in an imaging department (Naqvi, n.d.).

In the literature many authors discuss different aspects of RFA. These are noted below and their relevance to the current study is stated.

Naqvi (n.d.) mentions that, by conducting RFAs, standard radiographic results can be achieved and maintained. On completion of the current study, students will be able to produce optimal image quality radiographs on a continuous basis by using ECs.

In radiography the first priority should be patient care, which is the primary objective of quality assurance (QA) and QC. Naqvi (n.d.), Scandorf and Tetteh (1998), and Dunn and Rogers (1998) agree that RFA results may give evidence of improvement after QA interventions have been introduced.

According to Scandorf and Tetteh (1998), Hardy and Persaud (2001), and Reiner, Siegel, Siddiqui, and Musk (2006), RFAs can provide results that will encourage and recommend staff development and education for the radiographers involved. According to the literature, exposure faults are the most common reason for rejection and this forms the basis for the need for in-service training of radiographers in relation to accurate exposure factor selection.

Reiner *et al.* (2006) agree that RFA may also encourage radiographers to change certain practice patterns which should result in improved quality of service for patients. The discussion of RFA in the literature underpins the present study.

Périard and Chaloner (1996) suggest that a RFA should include guidelines of documented standards to assist in the analysis and classification of rejected radiographs, as these are required for consistent classification and comparison of data. During the development of the research proposal, the criteria for data collection were established and it was established that the discussion of RFA in the literature supports the current study.

Watkinson *et al.* (1984), Arvanitis *et al.* (1991), and Meyer and Joubert (2001) all mention that the success of a RFA programme relies heavily on the preparation, structured organisation, method of implementation, type of data collected and their analysis. In addition, the programme should be simple and understandable.

Comment [AB1]: It is unclear what 'it' refers to here – is this correct?

Arvanitis *et al.* (1991), Adler, Carlton and Wold (1992), Périard and Chaloner (1996), Weatherburn, Bryan and Devise (2000), Meyer and Joubert (2001), Peer *et al.* (2001), Clark and Hogg (2003), Rawlings (2005), Saunders, Budden, Maciver, Teunis and Warren-Forward (2005) and Reiner *et al.* (2006) state that the information provided by a RFA programme can be used to evaluate the cost-effectiveness of a diagnostic department in relation to repeats and the radiation dose to a patient, as well as occupational exposure. However, these aspects have been well researched; thus the current study does not focus on them because the primary focus on ECs would be lost.

Simply carrying out a RFA may raise the standards of a department by increasing the awareness of the radiographers involved (Nixon, Thorogood, Holloway, & Smith, 1995). Kofler *et al*. (1999) add that, during such an analysis, radiographers also become aware of common problems such as recurrent positioning errors of the lateral view of the ankle or repetitive exposure faults of the anteroposterior projection of the knee.

A RFA is a helpful tool for assessing ways in which rejects can be avoided and highlights the aspects responsible for image quality in order to determine possible corrective action (Kofler *et al.,* 1999, Muhogora, Nyanda, Ngaile, & Lema, 1999; Hardy & Persaud, 2001).

Many RFAs reported in the literature were done only to establish reject rate and no further action was taken. Very few authors reported the implementation of an improvement programme. Keen (2008), however, implemented patient protection programmes which resulted in a reduction in the number of examinations necessitating repeat radiographs.

A variety of results for RFAs is stated in the literature. These results include a range of reject rates, 0.9% to 33%, with some authors including patient dose determination and several authors calculating cost-effectiveness. Such variation may be attributed to the different methods of RFA used, the various formulas applied to calculate reject rate and the different durations of studies (Adler *et al.,* 1992).

The assessment of upper and lower extremity films and EC implementation exclusively is not mentioned in the literature. It would appear from the literature that there is limited information on standards of departmental image quality; hence this is one of the reasons this aspect is addressed in the current study.

An earlier study performed at the two venues chosen for this research (Gabone, Cupido, & Bloodstaan, 2006, unpublished) was limited to certain x-ray examinations which excluded extremity radiography. At venues A and B, RFA had not been carried out to assess extremity films before the commencement of the current research, and the use of films, chemicals and other resources were not regulated.

Comment [AB2]: The two clauses in this senence do not relate to each other (there is no cause-effect). Check my change. It is also unclear why you have included this information here.

2.3 Reasons for the rejection of radiographic films

Various reasons for the rejection of radiographic films are recorded in the literature. The current study singled out exposure faults from the list because exposure related errors are the most frequently recorded cause of rejection. Exposure faults refer to images that are either too dark (overexposed) or too light (underexposed). When using film/screen systems, both under and overexposed images are undesirable since they result in undiagnostic films. In a poster presentation by Rzeszotarski (2005), it is stated that overexposures yield reduced contrast, low noise and high dose, while underexposures yield reduced contrast and increased noise.

According to Chu *et al.* (1982) exposure errors are the result of (i) improper selection of exposure parameters and (ii) a radiographer being unaware of equipment malfunction prior to making an exposure.

In addition, viewing box illumination and ambient light, which are often ignored, are aspects of RFA that should be considered when classifying exposure related rejects (Chu *et al.,* 1982). The uniformity of illumination should be maintained throughout the department and the ambient light should be consistent because these influence the subjectivity of the viewer. These two factors are important in the current study and will be discussed later.

Chu *et al.* (1982) further note that exposure related rejects can be reduced by implementing an effective QA programme. It is important to note here that the x-ray departments chosen for the study do not use any QA programme, as no programme is available owing to the Namibian Ministry of Health and Social Services not having developed such a programme for radiography departments.

It is evident from the literature that much research has been done to establish the reasons for rejection and a variety of results have proven that exposure related faults are unquestionably the most recurrent cause of rejection. Percentages of exposure related faults range from 15% of all faults, in a study done by Clark and Hogg (2003), to 50% in a study conducted by Watkinson *et al.* (1984). Positioning faults is the second most common reason for rejection, with results ranging from 9%, reported by Clark and Hogg (2003), to 47% reported by Chu *et al.* (1982).

Most researchers combine data on over and underexposure errors and state a single figure, exposure faults, in their reports. When data are interpreted, the exposure defect that in fact occurred is not identified for the reader. It is a fact that effective improvement programmes cannot be introduced unless specific results are recorded. In the literature, just a few authors gave specific details that distinguished between the two, as shown in Table 2.1.

Table 2.1: Authors stating details of over- and underexposure

Authors	Overexposure in %	Underexposure in %
Mazzoferro, Balter, and Janower (1974)	25.0	20.0
Chu *et al.* (1982)	30.7	17.5
Rogers, Matthews, and Roberts (1987)	14.4	33.1
Arvanitis *et al.* (1991)	15.0	10.32

Exceptions are encountered in the Peer *et al.* (2001) study where the main reason for rejection (43%) was technical problems and careless handling of films and chemicals, with exposure errors being the second most common reason for rejection (35.5%). Clark and Hogg (2003) disclose that 63% of rejected films in their study were undiagnostic as a result of suboptimal pattern recognition, which was the main reason for rejection.

2.4 Reject rate

The determination and reduction of the reject rate are the main aims of the current research. Over the past two decades numerous authors, for example, Rogers (n.d.), Chu *et al.* (1982), Arvanitis *et al.* (1991), Bushong (1993), Ball and Price (1995), Nixon *et al.* (1995), Dunn and Rogers (1998), Hardy and Persaud (2001) and Meyer and Joubert (2001), have used similar formulas for calculating the reject rate.

$$Reject\ rate\ (\%) = \frac{Number\ rejected\ films}{Total\ number\ of\ films\ used}\ x\ 100$$

This formula was therefore used by the researcher in this study. Reject rate has been studied widely in different parts of the world, with the values for reject rates varying considerably from 0.9%, in a study done by Muhogora *et al.* (1999) in Tanzania, to 33% in a study done by Clark and Hogg (2003) in Manchester. Watkinson *et al.* (1984) note that this variation may be due to a variety of reasons, for example differences in x-ray tube output between different rooms, etc.

2.4.1 Acceptable reject rate

Where acceptable reject rate is discussed, it is recognised that many authors recommend a 10% to 15% acceptance rate. In a presentation by Naqvi (n.d.), the author states 10% or less to be an acceptable reject rate internationally. An early study conducted by Bourne (1969) suggests that acceptable reject rate may vary between 5% and 10%. However, Watkinson *et al.* (1984), Dunn and Rogers (1998) and Hardy and Persaud (2001) consider a reject rate of between 10% and 15% to be acceptable. Arvanitis *et al.* (1991) note that assessment of RFA is based on tolerance limits but suggest that a reject rate of between 10% and 12% is acceptable for diagnostic departments where no QA programme exists.

Comment [AB3]: Is this what you mean here?

Mazzoferro *et al.* (1974) and Rogers *et al.* (1987) are the only studies where the status of a practitioner, student or radiographer was recorded in terms of reject rate. McKinlay and McCauley (1977) and Rogers *et al.* (1987) note that the presence of students in a department will increase the reject rate of that department.

Rogers *et al.* (1987) reviewed the reject rates of different departments. The reject rates for radiographers range from 3.5% to 19.3%, whereas those for students range from 7.4% to 40%. The overall repeat rate associated with student radiographers is twice that of radiographers. Another factor affecting the reject rate is the radiographers' experience (Lau *et al.,* 2004).

Following a RFA study conducted by Watkinson *et al.* (1984) the authors reported an increased reject rate. This is the only study cited in the literature where the outcome was an increased reject rate. Carlton and Adler (2001) state that high repeat rates may indicate extremely high quality standards in a department, meaning that the expected quality of the department is so high that even minor errors may lead to the rejection of radiographs. To the contrary, high reject rates may also indicate that inadequately educated radiographers work in a department, in other words, the staff is not properly trained to produce optimal quality images. The authors caution that interpretation is essential and that all aspects of analysis should be carefully studied before conclusions are drawn.

According to the World Health Organization (1982), Ball and Price (1995) and Meyer and Joubert 2001), it is almost impossible to be precise about an acceptable reject rate since standards can vary from one department to another. RFA needs to be interpreted under the circumstances or conditions in which the research is conducted. The World Health Organization (1982) and Nixon *et al.* (1995) note that it is difficult to define criteria for the assessment of RFA because the process involves a measure of subjectivity. Nevertheless, one of the aims of this study was to determine the reject rate of the selected x-ray departments in order to establish a baseline in terms of which the researcher could assess whether the rejection rate had changed following the introduction and use of ECs.

2.4.2 Reducing reject rate

The main reason for the study was to introduce ECs with the aim of improving the image quality produced with the initial exposure and thus reduce reject rate. The reduction in reject rate would consequently improve the quality of the service rendered to a patient. The following literature provides examples of situations leading to reject rate reduction.

According to Bourne (1969) an increase in image quality should lead to a decrease in reject rate.

Chu *et al.* (1982) state that the implementation of a comprehensive QA programme should greatly reduce exposure related rejects and in turn reject rate.

Arvanitis *et al.* (1991) suggest that the correct use of the film/intensifying screen, the appropriate use of an imaging system and the accurate use of exposure factors can reduce the reject rate.

Rogers *et al.* (1987), Meyer and Joubert (2001), Hardy and Persaud (2001) and Reiner *et al.* (2006) state that RFA can lead to a reduction in the cost of wasted film, thus reducing expenditure.

According to Bourne (1969) and Clark and Hogg (2003) a reject rate reduction of 1.0% will save the departments involved £45 000 and £66 000 (approximately R590 000 and R865 000) respectively per year, thus a reduction in reject rate can have a substantial effect on running costs of a department. The authors also mention that a reduction in reject rate will influence patient waiting time dramatically as well as staff productivity. In other words, if a repeat radiograph is necessary a patient has to spend twice the time in the department than would have been the case if the radiograph had been produced correctly initially. During the time that the radiographer produces a repeat radiograph a second patient could have been examined.

Comment [AB4]: What departments are you referring to here – those used in your research or those of Clark and Hogg?

Clark and Hogg (2003) are the only authors located in the available literature who highlight the importance of staff awareness of radiation dose. They state that the reject rate reduction in their study could have been influenced by the fact that staff members became more conscious of radiation safety after a RFA programme had been initiated.

2.5 Image quality and radiation dose

Films are rejected mainly because of poor image quality. Image quality in relation to radiation dose to a patient is a major concern in diagnostic radiography because when images are of poor quality they need to be repeated and thus the patient receives more than the required radiation (Muhogora *et al.,* 1999, Peer *et al.,* 2006; Tsalafoutas, Blastaris, Moutsatsos, Chios, & Efstathopoulos, 2008). Ideally, image quality should be optimal while taking into consideration that patient dose should be kept at an acceptable level.

Naqvi (n.d.), Berry and Oliver (1976), Guebert and Yochum (1994), Reiner *et al.* (2006) and Keen (2008) all discuss image quality in relation to patient dose and agree that improvements in image quality will lead to radiation dose reduction. Keen (2008) adds that patient dose is calculated using exposure parameters (kVp and mAs) and other factors. After the implementation of Keen’s (2008) improvement programme, a marked decrease in repeats was seen in most hospitals.

Comment [AB5]: Per haps you need to say where this improvement programme took place.

Périard and Chaloner (1996) mention that contaminated film processing solutions or subtle changes in developer temperature affect both image quality and patient exposure. For routine processor control to be effective, the sensitometric data must be evaluated and the necessary corrective action taken before radiographic examinations are performed on patients. This is done to ensure that radiographs are processed correctly and to minimise reject films.

2.6 Exposure factors

Exposure factors include tube current, which is referred to as mAs, and potential difference, referred to as kV.

2.6.1 mAs

When extremities are examined a small focal spot is employed which produces a detailed image of fine anatomical areas. Guebert and Yochum (1994) mention that mAs setting is usually linked to a small focal spot that produces greater image detail. A change in mAs causes a change in the intensity of the radiation emitted. The amount of blackening that occurs in the image depends on the amount of radiation absorbed by the film emulsion. The total amount of radiation emitted by the x-ray tube, operating at a certain kV, is also directly proportional to the mAs multiplied by the length of time the tube is energised (Bouma, 2004).

2.6.2 kV

The kV that is applied to the x-ray tube affects not only the intensity but also the composition of the beam. For example, by raising kV, x-rays of shorter wavelength, higher intensity and higher penetrating power will be produced (Bouma, 2004). The Office of Radiation Protection (2009) states that if kV selection is inaccurate there can be problems with image quality and an unnecessarily high patient dose may be administered.

2.7 EC

In most developed countries and several developing countries, such as South Africa, there are laws and regulations that control the use of ionising radiation, as it has potentially harmful effects on cell biology. An EC is defined as a chart that provides radiographers with a guide to select appropriate exposure factors for all patients and examinations. In South Africa, the use of ECs for every x-ray machine is a legal requirement for licensing the equipment. The South African legislation has been adopted by the Ministry of Health and Social Services of Namibia but is not widely implemented, thus some imaging departments in Namibia do not make use of ECs.

Although ECs are discussed by several authors, no evidence was found where their implementation as part of an improvement programme was discussed. Changes in reject rate in relation to the effective use of ECs have also not been established. Rogers *et al.* (1987) are the only authors who mention the use of callipers to determine patient size and ECs to maintain consistent output, and the way in which these contribute to a reduction in reject rate. As the x-ray departments involved in the research in Namibia did not have ECs for extremity radiography, they were identified as suitable venues for the research.

According to the South African Regulations Concerning the Control of Electronic Products (1971), every licence holder of a listed electronic product used for medical purposes should ensure that the product is accompanied by an EC. Bushong (1993) notes that when new radiographic equipment is purchased it is accompanied by ECs, which need to be reviewed and adjusted to suit the needs of the specific department and the processing chemistry used.

An accurate EC is essential and especially useful for training newly employed radiographers and students. It should indicate the exposure factors applicable to each of the radiographic examinations that fall within the scope of the product's licence. The chart can be used as a guideline for exposure adjustments. Watkinson *et al.* (1984), Bourne (1969), Périard and Chaloner (1996), North Western Medical Physics (2009) and Rzeszotarski (2005) support the implementation of these laws in their respective countries. Bouma (2004) mentions that the use of ECs saves a radiographer time and a department film.

Carroll (1993) states that for most adult upper and lower extremities, more than 90% of patients fall within the average range of thickness. For these radiographic procedures, a single exposure can recorded on an EC. However, a radiographer must always be observant and capable of adjusting the average exposure for exceptional circumstances. A deviation from the ECs may be necessary for various reasons, for example, in cases of decreased bone density as a result of disease or limbs being in plaster of Paris.

According to Bushong (1993) it is critical for radiographers to know how to manipulate exposure factors to produce optimal image quality with a single exposure. Rzeszotarski (2005) states that an EC is the cornerstone of QA for any radiography department and when exposure errors are made image quality suffers and repeat exposures may be necessary. Consequently, ECs and their use are important issues when considering radiation protection.

Comment [AB6]: I cannot find this in the list of references – please add.

Comment [AB7]: Is this what you mean? Am I using the right word?

According to Périard and Chaloner (1996), North Western Medical Physics (2009) and Rzeszotarski (2005) an EC should include the following:

- body part and projection
- patient size or body part thickness
- optimum kV
- optimum mA and time (mAs), or automatic exposure setting
- film/screen combination selection
- tube focal spot size

In addition, Rzeszotarski (2005) adds that ECs should give guidance on modifying exposure factors to compensate for patient size or other factors of this list.

Comment [AB8]: Have I interpreted this correctly?

As stated by Tsalafoutas *et al.* (2008), when using film/screen systems, contrast and exposure latitudes are fixed and cannot be altered after exposure. Therefore, it is important that radiographers and students have accurate ECs available so that anatomical areas of interest will be demonstrated at maximum image contrast.

2.7.1 EC compilation

Radiation Protection Services (2007), Office of Radiation Protection (2009), Van Der Plaats (1980), Bushong (1993), Carroll (1993) and De Vos (1995) provide information on the compilation of ECs. For the purpose of this study all this information was considered but the guidelines of Bushong (1993) and De Vos (1995) concerning variable kVp charts were applied. The prescribed process for EC compilation described by Online Vets (n.d.) is very similar to that prescribed by Bushong (1993) and De Vos (1995), although the document refers to veterinary services.

Radiation Protection Services (2007) reports inadequate exposure charts as one of the reasons for the non-compliance of x-ray machines and further states that ECs may be inadequate for the following reasons:

- if the chart was designed for the incorrect film/screen system

- if the values indicated on the chart are not selectable on the control panel
- if the chart has not been revised recently
- if the chart is incomplete

This source also notes solutions to the problems stated above. These reasons for inadequate ECs were taken into consideration when compiling ECs for this research and the solutions identified will be used when similar problems arise.

Comment [AB9]: Can you get away with not identifying these solutions?

Van Der Plaats (1980) states that an EC is compiled with a particular voltage form and total tube filtration in mind, since these factors greatly influence the intensity of radiation that is emitted from the x-ray tube. Venue B uses three phase generators and a total tube filtration of 2.5 mm aluminium (Al) equivalent. Bouma (2004) mentions that an EC can be developed using one type of x-ray apparatus, the same type of film and the same FFD. All the authors stated in 2.7.1 discuss important aspects of EC compilation and these were all taken into account by the researcher.

Comment [AB10]: It is unclear why you include this sentence here - you need to link it to the preceding sentence.

Comment [AB11]: It is unclear which authors you are referring to - be more specific.

2.7.2 Types of EC

Various authors, Making an exposure chart (n.d.), Bushong (1993), Carroll, (1993), Hiss (1993), De Vos (1995) and Rzeszotarski (2005), mention two types of chart, (i) fixed kVp charts and (ii) variable kVp charts.

2.7.3 Fixed kVp charts

Online Vets (n.d.), Bushong (1993) and Rzeszotarski (2005) note that a fixed kVp chart uses an optimum kVp and the mAs is changed according to the thickness of the anatomical part to be examined. According to Hiss (1993) fixed kVp charts use increased mAs, which also increase exposure time creating the possibility of a patient moving during an exposure. De Vos (1995) mentions that when fixed kVp charts are used for patients smaller or larger than average, images will have insufficient density. According to Rzeszotarski (2005), the fixed kVp chart was developed by Fuchs in 1943.

2.7.3.1 Advantages of fixed kVp charts (Rzeszotarski 2005)

The following advantages of a fixed kVp chart have been identified:

- the ease of memorising a relatively small list of kVps
- kVps are fairly high, thus patient doses are reduced compared to other EC methods
- mAs are reduced at high kVp levels, resulting in reduced patient motion artefacts
- exposure latitude is increased at high kVp to the benefit of the radiographer and radiologist
- Online Vets (n.d.) notes that fixed kVp charts are more appropriate for machines with a limited number of exposure settings because they enable changes in photon output to compensate for the restricted selection of beam energies

2.7.3.2 Disadvantage of fixed kVp charts

Rzeszotarski (2005) identifies the following disadvantage of a fixed kVp chart:

- reduced contrast due to increased scatter when compared to variable kVp charts

2.7.4 Variable kVp charts

Online Vets (n.d.), Bushong (1993) and Rzeszotarski (2005) define a variable kVp chart as one that uses a fixed mAs, while kVp varies according to the thickness of the anatomical part. Online Vets (n.d.) prefers the variable kVp chart method because it allows an operator to vary the penetration of the x-ray beam in proportion to changes in anatomical thickness. Carroll (1993) uses variable kVp and fixed mAs for radiographic extremity examinations with adjustments for patients smaller or larger than average. De Vos (1995) suggests that higher kVp than the minimum can be used for extremity radiography in order to allow lower mAs settings to reduce patient dose. Périard and Chaloner (1996) state that exposure selection based on subjective evaluation of patient size is unreliable and does not provide consistent radiographic images. The authors suggest that all patients should be measured and exposure factors adjusted according to patient’s anatomical thickness.

2.7.4.1 Advantages of variable kVp charts

Rzeszotarski (2005) states the following advantages of variable kVp charts:

- simplicity, since the kVp can be determined using callipers to measure the body part thickness

- film density is controlled because mAs is fixed for each body part
- contrast is better than with fixed kVp techniques when film/screen systems are employed

2.7.4.2 Disadvantages of variable kVp charts

Rzeszotarski (2005) identifies the following disadvantages of the variable kVp chart:

- high patient dose for thin body parts, where the kVp may be lower than optimal
- low contrast where the body part thickness is large as a result of high kVp values

Based on the information from these sources the researcher decided to compile variable kVp charts only for extremity radiography.

2.8 Summary

This chapter reviewed the literature concerning aspects of RFA published by different authors around the world.

RFA is a well-established, inexpensive and easily performed method of QC used in radiography departments. Such a RFA programme relies heavily on the preparation, structured organisation, method of implementation, type of data collected and their analysis.

Various reasons for rejection of radiographic images are cited in the literature, and it is evident that much research has been done to establish these reasons. Furthermore, a variety of results have proven that exposure related faults are the most recurrent cause of rejection.

Reject rate determination and reduction are the main aims of the current research. Several reject rates are stated in the literature and, where acceptable reject rates are discussed, several authors recommend a 10% to 15% acceptance rate. This underpins the main reason for the current study, namely, to introduce ECs with the aim of improving the image quality produced with the initial exposure thereby reducing reject rate. The authors cited provide examples of practices leading to a reduction in the reject rate.

The main reason for films being rejected is because of poor image quality. Ideally, image quality should be optimal while simultaneously taking into consideration that patient dose should be kept at an acceptable level.

ECs provide radiographers with a guide for selecting appropriate exposure factors for all patients and examinations and such charts are used as guidelines in many radiography departments. ECs and their use are important issues concerning radiation protection, because when exposure errors are made, image quality suffers and repeat exposures may be necessary.

Based on the reviewed literature, this study was justified for the following reasons:

(i) limited information was available in the selected departments relating to RFA, especially the reject rate
(ii) no ECs were available in the departments
(iii) no patient measurements were taken to obtain accurate exposure factors
(iv) there is limited evidence in the literature of improvement programmes that have been introduced after the establishment of reject rate and no EC implementation to reduce reject rate was found to have taken place
(v) no proof was found of assessment of extremity radiography rejected films
(vi) few authors have explored over and underexposure errors respectively

Many sources referred to in this chapter are outdated. Since the radiography departments in first world countries have evolved from film/screen conventional radiography to digital radiography, which is a filmless system, thus there is no need to implement RFA. A digital system is costly and most third world countries, like Namibia, cannot yet afford fully digital x-ray departments in state hospitals.

The next chapter discusses the research design and methodology.

Chapter 3

Research design and methodology

3.1 Introduction

Research design and methodology are fundamental aspects of the research process. These should be selected cautiously because the success of a research project relies heavily on them.

RFA has been performed for many years by many different people for several reasons and thus various methods of data collection for obtaining information for RFA are available. For the purpose of the current study the researcher used an approach that suited the requirements of this study.

The aim of this chapter is to describe the research design and the methodology used in the study. The chapter contains detailed information concerning sampling and the different phases of the study. In addition, it discussed reject rate calculation and EC compilation . The chapter also considers data analysis.

3.2 Research design

The current study used a quantitative, comparative pre and post-treatment design. Quantitative research has the following characteristics: it is well-defined, logically deductive, objective, uses numerical data and can be analysed statistically (Uys & Basson, 1994).

Comparative research attempts to establish cause–effect relationships among the variables in the study. Accordingly, an attempt is made to establish that the values of the independent variable have a significant effect on the dependent variable. This type of research involves group comparisons (Uys & Basson, 1994).

A pre-treatment post-treatment design involves three stages:

1. pre-treatment (retrospective) evaluation
2. treatment is administered
3. post-treatment (prospective) evaluation

This design applies to venue B only, as the student reject rate of venue A comprised the comparison group; thus pre-treatment and post-treatment are not applicable since students did not use ECs when they worked at venue A during the prospective phase. This is in accordance with the statement of the problem in chapter 1.

For the purpose of this study, the independent variable comprises the use of ECs and the dependent variable comprises reject rate. The collected data consist of the reject films obtained from venue A and B (in this document, WCH is referred to as venue A and KSH is referred to as venue B). A RFA was conducted to evaluate the reject rates of venue A and B before the intervention; ECs were then introduced and used by the students at venue B. Following a student vacation, another RFA was performed to evaluate the reject rates after the intervention. The retrospective RFA included films that had been rejected eight weeks before the introduction of ECs, while the prospective RFA involved films that were rejected during the study.

Comment [AB12]: I do not understand why you are using the 'word 'groups' here. Please clarify

Comment [AB13]: It is still unclear who or what 'groups' refers to.

During the retrospective RFA primary numeric data were collected which were used to calculate two extremity reject rates for each of the x-ray departments. During each phase at both hospitals, two reject rates were calculated: one for radiographers and students combined and one for the students only (refer to Appendix R). The following formula was used to calculate reject rate:

$$Reject\ rate\ (\%) = \frac{Total\ number\ of\ reject\ extremity\ radiographs\ produced}{Total\ number\ of\ extremity\ radiographs\ produced}\ x\ 100$$

Secondary data were collected from the literature.

The retrospective RFA study was conducted for eight weeks, from 28 August to 16 October 2008. Thereafter the students went on vacation. ECs were then introduced and used for a four week period after the students returned, from 25 February to 25 March 2009. The prospective RFA study was performed for eight weeks after the implementation period, from 25 March to 20 May 2009. Based on Durrheim's discussion (2002), the current study compared the data obtained from the retrospective and prospective reject rates to determine whether the use of ECs had resulted in a decrease in reject rate of extremity radiographs produced by students at venue B.

For the purpose of the study the following classification of data will be used:

- Pre-treatment data

All data from venue A - data A

All data from venue B	-	data B
Reject radiographs produced by the department at venue A	-	departmental data A
Reject radiographs produced by the department at venue B	-	departmental data B
Reject radiographs produced by the students at venue A	-	student data A
Reject radiographs produced by the students at venue B	-	student data B
Student reject rate at venue A	-	student reject rate data A
Student reject rate at venue B	-	student reject rate data B
Departmental reject rate at venue A	-	departmental reject rate data A
Departmental reject rate at venue B	-	departmental reject rate data B

- Post-treatment data

All data from venue A	-	data A_1
All data from venue B	-	data B_1
Reject radiographs produced by the department at venue A	-	departmental data A_1
Reject radiographs produced by the department at venue B	-	departmental data B_1
Reject radiographs produced by the students at venue A	-	student data A_1
Reject radiographs produced by the students at venue B	-	student data B_1
Student reject rate at venue A	-	student reject rate data A_1
Student reject rate at venue B	-	student reject rate data B_1

Departmental reject rate at venue A	-	departmental reject rate data A_1
Departmental reject rate at venue B	-	departmental reject rate data B_1

The study used all rejected extremity films of two x-ray departments, namely, (i) WCH x-ray department (venue A) and (ii) KSH x-ray department (venue B). The retrospective and prospective RFA studies were conducted at both hospitals simultaneously but ECs were only used at venue B so that rejected extremity films from this department could be used for the data B_1. The rejected extremity films at venue A were used to comprise data A_1. No ECs were used at venue A, thus the situation stayed constant.

Radiography students rotated between the x-ray departments, venues A and B (refer to Appendix A for clinical rosters). During 2008, all first and second year students (n = 20) participated in the retrospective RFA. As most of these students (n = 16) passed their respective examinations at the end of 2008 they became the second and third year students of 2009. Rejected extremity films produced by students and radiographers at venue A will be referred to as data A, and those produced at venue B will be referred to as data B. When students were working at venue A they contributed to data A and A_1; when working at venue B, where ECs were used, they contributed to data B and $B_{1.}$ Each student produced reject radiographs which formed part of data A for four weeks during the retrospective phase. The same students produced reject radiographs for the purpose of data B for the next four weeks.

3.3 Sampling

In order to calculate the reject rate, non-probability sampling was used. This is a method of sampling where elements are chosen from the population using non-random methods. In this study convenience sampling was used as the sample was taken from a section of the population that was easily accessible or readily available to the researcher (Uys & Basson, 1994; Brink, 2003; Leedy & Ormond, 2005). The sample used in the current study was obtained from the x-ray departments which were positioned conveniently for the researcher in terms of location, time and expense. Data were collected from the entire population, in other words, all rejected extremity films were used for data collection during the retrospective and prospective RFA phases.

3.4 Data collection

Venue B was chosen as the venue where students used ECs, while at venue A the students did not use ECs. Venue B, the largest radiography training hospital in Namibia, was particularly accessible for the researcher. The study made use of non-probability convenience sampling.

Comment [AK14]: You have already stated this and I don't really see the point of including it here. suggets you delete.

A total of twenty weeks was required for data collection: eight weeks for the retrospective RFA, four weeks for the implementation and use of ECs by the students at venue B, and eight weeks for the prospective RFA.

3.4.1 Retrospective study phase

- On 4 June 2008, permission was obtained from the Ministry of Health and Social Services of Namibia to use its premises, staff and material to collect data for the study (refer to Appendix B).
- Before embarking on this research, the researcher facilitated a comprehensive discussion with the staff and students of the departments concerned in order to familiarise them with the study and to explain its purpose in detail.
- For further reference, the researcher pasted a written document containing the same information on the notice boards of the departments (refer to Appendix C). It was important for students to understand that the purpose of the study was not to identify incapable students but rather to assess the conditions in the department at the time and to facilitate improvement.
- The use of coloured stickers enabled the researcher to differentiate between reject films produced by students and those produced by radiographers. Stickers were placed at each viewing area prior to the commencement of the retrospective study.
- Students were requested to identify the rejected films they had produced by placing a sticker on all rejected films produced by them throughout the research period.

- Students were requested to place another sticker, together with the total number of films used for the examination, on the darkroom cards of the patients examined by them. Darkroom cards are patient identification cards incorporating patient name, gender, age, x-ray registration number, date, etc. They are completed by the reception staff when a patient enters the x-ray department and are used with a patient identification camera to identify each radiograph (refer to Appendix D).

Comment [AB15]: Perhaps you need to explain this. What is 'a patient identification camera'? Do you mean 'marker'?

- A container was placed next to the patient identification camera in which the cards were stored.

- An information and reminder notice was placed at the patient identification camera (refer to Appendix E).

- The cards were collected by the researcher on a weekly basis during the retrospective and prospective study phases.

- When calculating student reject rate the total number of extremity films produced by students was obtained from darkroom cards by adding all the numbers of films produced as indicated by students on the darkroom cards.

- All extremity radiography reject films were collected from both hospitals for the eight weeks of the retrospective RFA.

- A specially marked bin was provided for collecting the reject films. An information and reminder notice was placed at each collection bin (refer to Appendix F).

- The researcher collected these films weekly.

- All the data collected, for example the number of rejected films, the total number of films produced, etc. were recorded on a weekly data collection sheet (refer to Appendix G).

- Standardisation in the use of the datasheet was achieved using predetermined criteria (refer to Appendix H) to ensure that data were collected under identical conditions every time.

3.4.2 Calculation of reject rates

The departmental reject rates for extremity radiography for both departments were calculated using the following formula:

$$Departmental\ reject\ rate$$

$$= \frac{Total\ number\ of\ reject\ extremity\ radiographs\ produced\ by\ the\ department}{Total\ number\ of\ extremity\ radiographs\ produced\ by\ the\ department} x\ 100\%$$

Rejected extremity films were counted physically by the researcher to obtain the number of rejected films, while the total number of films produced was obtained from the darkroom cards.

Reject films produced by radiographers and those produced by students were separated, as the latter were identified by stickers. The researcher then quantified the two sets of reject film. The total number of films produced by students was obtained by adding all the numbers written on the darkroom cards marked with stickers. Thereafter, the reject rate for the students was calculated using the following formula:

$$Student\ reject\ rate$$

$$= \frac{Total\ number\ of\ reject\ extremity\ radiographs\ produced\ by\ students}{Total\ number\ of\ extremity\ radiographs\ produced\ by\ students} x\ 100$$

The researcher separated the films discarded as a result of exposure faults from those rejected because of other factors. From the collected data the researcher obtained the total number of extremity radiographs rejected as a result of exposure factors and used this information to calculate the percentage of rejects produced by students owing to this error. This calculation was done for every week, and eventually for each phase. Refer to Chapter 4, Tables 4.1 and 4.2 for results.

The current study singled out exposure faults because exposure related errors are the most frequently recorded cause of rejection (Carlton & Adler, 2001). The exposure fault reject films produced by students were then evaluated and sorted according to overexposure and underexposure faults. The researcher used these data to determine the percentage of rejects produced as a result of over and underexposure for each week and eventually for each phase. Percentages were calculated using the following formula:

$$Over\ or\ underexposure\ rejects\ (\%) = \frac{Number\ of\ films\ rejected\ due\ to\ over\ or\ underexposure}{Total\ number\ of\ films\ rejected\ due\ to\ exposure\ errors} x\ 100$$

Refer to Chapter 4, Table 4.5 for results.

Subsequently, films rejected due to exposure problems were sorted according to inappropriate mAs or kV selection (refer to Appendix I for data handling). This was accomplished by means of a visual inspection conducted by a panel. If the differentiation between mAs and kV was not very clear, a densitometer was used to measure film density (blackness), as this is predominately related to mAs selection. The rejects were evaluated by a panel, consisting of a radiologist, a student and the researcher. The panel members were chosen so that the panel comprised a range of expertise. The researcher used the data collected to calculate the percentage of films rejected as a result of both mAs and kV for each week and also for each phase. The following formula was used:

$$mAs\ or\ kV\ related\ rejects\ (\%) = \frac{Number\ of\ films\ rejected\ due\ to\ mAs\ or\ kV}{Number\ of\ films\ rejected\ due\ to\ exposure\ faults} x\ 100$$

Refer to Chapter 4, Table 4.6 for results.

Viewing box illumination and ambient light, which are often ignored, are aspects of RFA that should be considered when classifying exposure related rejects (De Vos, 1995). Illuminator uniformity should be maintained throughout the department and ambient light should be consistent because these influence the subjectivity of a viewer. To ensure reliability, the researcher ensured that the panel worked under the same viewing conditions throughout the study period.

De Vos (1995) adds that a researcher should ensure that optimal focal film distance (FFD) and collimation are used when producing radiographs. Throughout the study period, the researcher encouraged students to use optimal FFD and collimation at all times. The researcher assumes that students complied with this requirement as she was unable to scrutinise every examination performed by every student.

Over the eight weeks during which the retrospective RFA films were collected, the researcher compiled ECs which were implemented on 25 March 2009 after the students returned from vacation.

3.4.3 Compilation of ECs

Bushong (1993), Hiss (1993) and De Vos (1995) initially use the same method to obtain kVp when compiling variable kVp ECs. Carlton and Adler (2001) state that the basic characteristic of this chart is short scale contrast. However, short-scale contrast was considered undesirable for the current research because in extremity radiography, long-scale contrast provides optimal visibility of the bony anatomy and surrounding soft tissue.

De Vos (1995) proceeds to add 20 to 25 kV for extremities to produce long scale contrast, while the other authors do not state any specifications. High kV settings allow for use of lower mAs. The use of high kV is beneficial for the patient because radiation dose is reduced. In addition, the use of high kV will increase the number of high energy photons and the penetration ability of the x-ray beam, as high kV results in short wavelength photons. X-ray emission is affected by the quantity and composition of the materials through which it must pass in order to exit the x-ray tube and housing, in other words, the filtration material (Carlton & Adler, 2001). As the beam passes through the filtration material, some low energy photons are absorbed. This decreases the intensity of the beam but increases the average photon energy. When filtration is used exposure factors must be increased to maintain optimal density, which means that, although the exposure is increased, there is a great decrease in patient exposure. When low mAs is used the number of electrons striking the target is reduced and patient dose is also decreased. This research is specifically concerned with the extremities. Therefore De Vos's (1995) method was preferred by the researcher. Finally, an EC for each x-ray room at venue B was compiled (refer to Appendix J).

Pelvis phantom:

Hip:

1. The hip and upper femur of the pelvis phantom (refer to Appendix K for photograph) was used as the body parts for calculating exposure factors using x-rays to simulate an actual radiographic examination of the pelvis and hips of a patient. It would be contrary

to professional ethics to irradiate a patient unnecessarily in order to calculate exposure factors.

2. The thickness of the anteroposterior (AP) hip was measured with callipers midway between the upper border of the symphysis pubis and the anterosuperior iliac spine (ASIS). The measurement obtained was 20 centimetres.
3. The minimum kV was determined by multiplying the body part thickness by 2 (20 centimetres x 2) and then adding 30. In other words, 20 centimetres x 2 + 30 = 70 kV. The researcher evaluated the first radiograph produced using 70 kV and decided that it was incorrect owing to insufficient penetration. Thus a repeat film was produced using 73 kV which revealed optimal image quality.
4. mAs was determined using a moving grid of grid factor 5 in conjunction with the established 73 kV. It is not possible to use measurements to determine the mAs, as there are many factors that impact on its selection. It is standard practice for radiographers to use their personal experience to establish the initial value. Based on De Vos's (1995) method, three radiographs were produced using three different mAs selections. The initial mAs for the first radiograph was based on the researcher's knowledge of what would probably be appropriate. For this reason 73 kV and 50 mAs were used. The remaining two films were produced using the same calculated kV (73 kV), but the mAs was increased by 30% for each film. For the second and third exposures 63 mAs and 80 mAs respectively were used. A 200 speed imaging system (film/screen combination) was employed with a FFD of 100 centimetres.
5. The radiographs were compared using a digital densitometer to determine which of the three films had the acceptable amount of radiographic density. The researcher calibrated the densitometer prior to the commencement of the study, using the manufacturer's instructions. An acceptable radiograph should have a range of densities from 0.25 to 2 to ensure that there is sufficient visualization of the body part. The density reading of the film produced with 73 kV and 50 mAs complied with this criterion.

By following the above procedure the researcher established the following exposure factors for the phantom's hip. Hip AP: thickness 20 centimetres, 73 kV, 50 mAs, grid ratio 10:1, grid factor 5, 100 centimetres focal film distance, 200 speed imaging system.

The methodology used to obtain the hip exposures was repeated to obtain exposure factors for the upper femur. The initial exposure of 64 kV was found to be incorrect and 70 kV was used instead. The resulting exposures were as follows: upper femur AP: thickness 17 centimetres, 70 kV, 40 mAs, grid ratio 10:1, grid factor 5, 100 centimetres focal film distance, 200 speed imaging system.

Since it would be professionally unacceptable to irradiate a patient unnecessarily, the researcher calculated exposure factors for all extremity examinations based on the measurements of a volunteer (refer to Appendix L for informed consent) and the baseline exposure factors of the pelvis phantom. The volunteer was not subjected to ionising radiation since only measurements (using callipers) for different anatomical parts of the upper limb (for example, hand, forearm and humerus) and lower limb (third toe, ankle, tibia and fibula) were taken to calculate the kV required. When compiling the EC, the mAs was adjusted accordingly as outlined below.

Volunteer:

Callipers were used to measure the volunteer's anatomical part, for example, hip AP, midway between the upper border of the symphysis pubis and the ASIS. Exact measurement positions for each anatomical part and views are stated in Appendix M.

1. Measurements obtained from the volunteer are available in Appendix N.
2. kV was established by increasing or decreasing kV by 2 kV for each centimetre difference. For example, phantom hip AP: thickness 20 centimetres requires 73 kV, volunteer hip thickness = 17 centimetres, 73 kV – 6 kV = 67 kV. When the exposure chart was put on trial the researcher recognised that 70 kV produced optimal image quality.
3. The phantom hip mAs was converted to a non-grid exposure by dividing the established mAs by the grid factor. For example, 50 mAs ÷ 5 = 10 mAs.
4. To determine kV the volunteer's distal femur was measured 5 centimetres superior to the middle of the upper border of the patella and a measurement of 13.5 centimetres was obtained. The kV was decreased by 2 kV for each 2 centimetres difference. For example, hip = 20 centimetres and distal femur = 13.5 centimetres. 20 – 13.5 = 6.5 centimetres ÷ 2 = 3.25 x 2 kV = 6.5 kV. Whenever the kV value was impossible to select on the control panel of the x-ray equipment, the kV closest to it was used.
5. The proposed kV for the distal femur = 73 kV – 6.5 kV = 66.5 kV.
6. The mAs used should be half of that used for the hip, 10 mAs ÷ 2 = 5 mAs, when not using a grid. If a grid is used this mAs value is multiplied by 5, 5 mAs x 5 = 25 mAs.

By following the above procedure the researcher established the following exposure factors: (i) volunteer's hip AP: thickness – 20 centimetres, 66 kV, 10 mAs, no grid, 100 centimetres focal film distance, 200 speed imaging system, and (ii) volunteer's distal femur AP: thickness – 13.5 centimetres, 66 kV, 5 mAs, no grid, 100 centimetres focal film distance, 200 speed imaging system or 25 mAs using a grid.

7. The rest of the EC was compiled according to the different thicknesses of the extremities measured in centimetres. Measurements were obtained from a volunteer with average body build, height and weight. All the volunteer's extremities were measured using callipers and exposure factors were calculated as stated above.

The completed EC was put on trial prior to its introduction and informed consent in terms of the research was obtained from patients (refer to Appendix O). Patients were informed about the test exposures and the possibility of repeats during which they might be subjected to unnecessary dose if the EC exposures were incorrect. Fortunately this did not happen.

The EC exposure factors for each view were tested on three patients, with a different patient being used for each test exposure. Patients who had been referred by physicians for extremity examinations were chosen, for example three patients requiring ankle examinations were radiographed using the EC exposure factors for the different radiographic projections. Measurements were taken as prescribed using callipers. Radiographs were evaluated using a densitometer and the researcher's subjective opinion. As radiographers are experienced in visually assessing film density it is impractical to use a densitometer for every film.

Comment [AB16]: Repetition

The EC was found to be accurate. Every film produced was evaluated by the researcher using a densitometer. Exposure latitude was evaluated.

3.4.4 Introduction of ECs and instruction for use

The compiled ECs were displayed on the walls next to the control panel in each x-ray examination room at venue B. Prior to the current study, all students were unfamiliar with the use of ECs. The focus of this study was on the role of ECs in reducing the reject rate. Accordingly, the researcher trained all second and third year students to use ECs effectively by selecting exposure factors according to body part thickness measured. All students were trained because every student was scheduled to work at venue B every alternate week. Training took place at venue B with the researcher facilitating a detailed discussion with the students on the use of ECs.

In terms of this training, the students were firstly told that all patients requiring extremity examinations were to be included in the research. Secondly, before commencing with the procedure students were requested to measure the thickness of the extremity to be radiographed at the centring point using callipers for every view requested. In addition, they were asked to measure all the patients who came for extremity examinations. Refer to Appendix M for exact patient measurement positions. Thirdly, they were instructed to compare the thickness measured with the thickness stated on the exposure chart. Fourthly, the students were informed that for every one centimetre difference, they should increase or decrease the exposure chart kV by one kV. The students were requested to record these measurements and the exposure factors used on a form (refer to Appendix P) which was provided by the researcher.

For example: For the PA hand with thickness 2 centimetres, the EC exposure is 52 kV and 3.2 mAs. If the patient's hand measures 3 centimetres, kV will increase to 52 + 1 = 53 kV. If the patient's hand measures 1 centimetre, kV will decrease to 52 – 1 = 51 kV. If the kV value obtained is impossible to select on the control panel of the x-ray equipment, the kV closest to it can be used. The mAs remained the same. The students were then given a chance to ask questions. After the detailed explanation of how to use ECs the researcher demonstrated the procedure to the students using the pelvis phantom and a patient. Instructions for using ECs were also displayed at each control panel for easy reference (refer to Appendix Q). The researcher then instructed the students to use ECs. Every student was requested to examine at least two patients using the EC instructions while being observed by the researcher, who made suggestions and gave advice. This training process took place over four weeks, from 25 February to 25 March 2009. During this time, the researcher conducted unannounced random verifications on students in order to ensure that they were using the ECs accurately and consistently.

ECs were used as a guide for average sized patients. In general, radiographers are confronted with different patient sizes on a daily basis and based on their experience they categorise patients into different groups, namely small, average or large, and then choose the exposure factors to use accordingly.

3.4.5 Prospective study phase

A prospective RFA study was conducted for eight weeks. During this time the rejected extremity films were collected on a weekly basis, but analysis was only done at the end of the prospective study period. The methodology applied in the prospective RFA study was identical to that used in the retrospective study.

According to annual departmental statistics, the number of x-ray examinations performed at venue B is double that of venue A. For this reason, the rejected films collected from venue B were used for data collection. The method used for data collection in both the retrospective and the prospective studies was identical. Data were collected for the prospective phase from both venue A and venue B.

Comment [AB17]: Is thi what you mean here?

3.5 Data analysis

The purpose of data analysis is to categorise, organise, manipulate and summarise the data that have been collected (Brink, 2003). The current study used a quantitative design and statistical strategies. In this context, quantitative data refer to numbers that are collected and then interpreted using statistics. Numerical data are described in a meaningful manner thereby enabling any researcher to understand interrelationships that exist. Data analysis aims to describe statistical analysis results but does not comment on them. The present study deals with the evaluation of the use of ECs and their effect on reject rate.

For the purpose of this study, departmental reject rate is defined as the reject rate for radiographers and students obtained from both venue A and B respectively. Refer to Appendix R which illustrates the eight different reject rates calculated.

3.6 Formulated hypotheses

According to Berg and Latin (1994), research hypotheses entail scientific instincts that a researcher has about the expected outcome of a study. Decisions to accept or reject hypotheses were based on objective and logical statistical processes called hypothesis testing. Hypothesis tests are strict statistical operations that make probability statements. The following hypotheses were formulated for this study:

Hypothesis 1a

The retrospective phase departmental reject rate for extremity radiography is 20% at venue A.

Hypothesis 1b

The retrospective phase departmental reject rate for extremity radiography is 20% at venue B.

Hypothesis 2

There is no difference in the mean reject rates of students at venues A and B before the introduction and use of ECs.

Hypothesis 3

There is a difference in the mean reject rates of students at venues A and B after the introduction and use of ECs at venue B.

Hypothesis 4

There is a difference in the mean reject rates of students before and after the introduction and use of ECs by the students at venue B.

Hypothesis 5a

The prospective phase departmental reject rate for extremity radiography is 16% at venue A.

Hypothesis 5b

The prospective phase departmental reject rate for extremity radiography is 16% at venue B.

For data analysis purposes the above-mentioned hypotheses were tested using the statistical methods presented in Table 3.1.

Table 3.1: Statistical methods used

Hypothesis number	Statistical method
Hypothesis 1a and 1b	Descriptive statistics, inferential statistics, one sample *t*-test and independent samples *t*-test
Hypothesis 2	Descriptive statistics, inferential statistics, independent samples *t*-test and weighted means
Hypothesis 3	Descriptive statistics, inferential statistics, independent samples *t*-test and weighted means
Hypothesis 4	Descriptive statistics, inferential statistics and independent samples *t*-test
Hypothesis 5a and 5b	Descriptive statistics, inferential statistics, one sample *t*-test and independent samples *t*-test

3.7 Statistics used for data analysis in the current study

3.7.1 Parametric statistics

This study adopted a parametric statistics methodology. Parametric statistics can be defined as statistical tests which make certain assumptions about the parameters of the full population from which the sample is taken (Brink, 2003). The Statistical Package for Social Sciences (SPSS) program version 15 and the Weighted Comparison of Means were used for data entry and analysis.

3.7.2 Descriptive statistics

Descriptive statistics are defined as statistics that organise and summarise numerical data (Brink, 2003) and explain such data (Leedy & Ormrod, 2005). According to Portney and Watkins (2000) these statistics are used to categorise the shape, central tendency and variability within a set of data with the intention to describe a population. Numerical data collected from this study exist in raw data form and a structure was therefore required that would allow the researcher to recognise averages and trends. Descriptive statistics entail measures of central tendency and measures of dispersion (Macfie & Nufrio, 2006). The two most commonly used measures of central tendency are the mean and the median. Measures of dispersion provide information that describes individual differences, with the standard deviation being the most important measure of dispersion. For the purpose of the current study these statistics were used to calculate means and standard deviations for different reject rates.

The mean comprises the sum of a set of scores divided by the number of scores (Portney & Watkins, 2000) and is often referred to as the average. Standard deviation is a descriptive statistic reflecting the variability of scores around the mean (Portney & Watkins, 2000) and was used in this study as a basis for comparing samples. The standard deviation was reported together with the mean so that the data could be categorised according to both central tendency and variability.

3.7.3 Inferential statistics

The type of data collected indicates the type of statistics to apply (Tarling & Crofts, 2003). Inferential statistics are defined as a process applied in order to draw information from the sampled observations of a population and to make conclusions about the population. These statistics are used to make generalisations about results (Tarling & Crofts, 2003). According to Leedy and Ormrod (2005) these statistics are concerned with numerical data and have two main functions:

1. to establish a parameter from a sample
2. to test hypotheses

Based on information obtained from Research Methods (2004) and Leedy and Ormrod (2005), the researcher concluded that inferential statistics provided the most accurate expression of the reject rate.

Sample data were used to make inferences about the population. These data were collected from a small sample over a 16 week period, but reject rates were inferred for the entire population. Inferential statistics helped the researcher to ascertain whether the differences that were found between data A and data B were significant.

The student reject rates for data B and data B_1, pre and post-intervention, were compared to establish how successful the introduction of ECs had been in reducing reject rate. The prospective phase used the same methodology as was used for the retrospective RFA.

Inferential statistics assisted the researcher in testing hypotheses 1a, 1b, 2, 3, 4, 5a and 5b as stated previously.

3.7.4 *t*-test

The *t*-test is defined as a statistical test involving the means of normal populations with unknown standard deviations and for which small samples are used (Berg & Latin, 1994). The *t*-test is used to test hypotheses and is an example of a parametric test. The test involves data expressed in absolute numbers, and its purpose is to compare two mean scores that are related. In this study, the *t*-test was used to determine whether there was a statistical significance between the reject rates of the retrospective and prospective RFAs. There are two forms of the *t*-test namely, (i) dependent samples and (ii) independent samples, as discussed in section 3.7.5.

3.7.5 Independent samples *t*-test

This version of the *t*-test determines whether the means of the two different groups are significantly different (Berg & Latin, 1994). According to Berg and Latin (1994) the following assumptions are drawn when this test is used: (i) the two groups have approximately equal variance on the dependent variable, and (ii) the two groups are independent of one another. The present study complies with these assumptions. The difference between the means was calculated. In other words, the reject rates of the retrospective and prospective RFAs were compared. Independent samples were used for this study because separate groups were used: the reject films from venue A and venue B. There was no association between the two groups.

3.7.6 Levene's test for equality of variance

The independent *t*-test is based on the assumption that the variance of two groups does not differ (Portney & Watkins, 2000). This is called the assumption of equality of variance. This assumption is routinely tested as part of the *t*-test in a computer analysis. The two tests used most often for this purpose are Bartlett's test and Levene's test. The latter test informs a researcher whether the two groups have approximately equal variance on the dependent variable (Portney & Watkins, 2000). If this test is significant (< 0.5), the two variances are significantly different. For the purpose of the current study, the reject rates for venue A and venue B were compared using Levene's test to determine whether they had equal variance.

3.7.7 Weighted means

The weighted mean can be defined as an average that is computed with extra weight given to one or more elements of the sample (Wilcox, 2001). It is also referred to as the weighted average. The weighted mean is similar to an arithmetic mean but instead of each of the data points contributing equally to the final average, some data points contribute more than others. The notion of weighted means plays a role in descriptive statistics and is commonly used in population studies. According to Wilcox (2001) the weighted mean entails multiplying each by a constant and adding the results. When the goal is to estimate the population mean, the weights are chosen so that they sum to one. To attribute average scores their proper degree of importance, it is necessary to assign them weights (Macfie & Nufrio, 2006).

Comment [AB18]: Each what? This is unclear.

For the purpose of the current study, weighted means were used to calculate student reject rates for data A_1 and data B_1 after the use of ECs. They were also used to calculate the student reject rate B and B_1 before and after the use of ECs at venue B.

A statistician assisted the researcher with the analysis, interpretation and conclusions. The results and conclusions were scrutinised and internal validity secured. It is believed that the population selected gave a true indication of the extremity reject rates since all rejected extremity radiographs were included in the study.

3.8 Summary

A quantitative comparative pre and post-treatment research design was used for this study and non-probability, convenience sampling was used to calculate the reject rate.

The retrospective and prospective RFA studies were conducted at both hospitals simultaneously, but ECs were used only at venue B. The reject rates for extremity radiography produced by radiographers and students in both departments were calculated. Thereafter, the reject rate for the students was calculated.

The researcher then compiled the ECs, which were implemented after the students had returned from vacation. A prospective RFA was conducted at both venues.

The data analysis that was carried out consisted of formulated hypotheses and statistical methods. The next chapter covers data presentation and a discussion of the results.

Chapter 4

Results presentation and discussion

4.1 Introduction

This chapter involves the interpretation and exhibition of analysed data in order to display these data as evidence. This is achieved in terms of the sub-problems and hypotheses.

The aim of this chapter is to present data effectively, using tables and figures, to enable the reader to understand patterns of data and exceptions. The results are presented in a simple, understandable manner.

The second purpose of this chapter is to discuss the data presented in a meaningful way. Data are interpreted and explained in the discussion of the results

4.2 Results presentation

Refer to Chapter 3, 3.2 Research design, for the classification of data.

4.2.1 Student rotation

Radiography students rotated through the x-ray departments, venues A and B (refer to Appendix A for clinical allocation rosters). During 2008, all first and second year students (n = 20) participated in the retrospective RFA. As most of them (n = 16) passed their examinations at the end of 2008 they became second and third year students in 2009.

Rejected extremity films produced by students and radiographers at venue A will be referred to as data A and those produced at venue B will be referred to as data B. When students were working at venue A they contributed to data A and data A_1. When they worked at venue B, where the ECs were used, they contributed to data B and data $B_{1.}$ Each student produced reject radiographs which formed part of data A for four weeks during the eight week retrospective phase. The same students produced reject radiographs for the purpose of data B for the next four weeks of the eight week retrospective data collection phase. The same applied for the prospective phase.

4.2.2 Weekly rejected radiographs

Tables 4.1 and 4.2 represent detailed results obtained from the first weeks of the retrospective and prospective phases respectively. These tables provide information about departmental, student and radiographer reject rates for venues A and B. The percentages of rejects resulting from exposure faults produced by students are also stated for each phase. Refer to Appendix S for tables representing results for weeks two to eight of each phase. All values stated have been rounded up or down to one decimal point.

Table 4.1: Weekly rejected radiographs retrospective phase, week 1

Retrospective phase Week 1		
Weekly rejected films	Venue A	Venue B
Total number of extremity radiographs produced by the x-ray department, i.e. radiographers and students combined	50	263
Total number of extremity reject radiographs produced by the x-ray department	12	56
Department reject rate in %	24.0%	21.3%
Total number of extremity radiographs produced by the students	31	103
Total number of reject extremity radiographs (n^a) produced by the students	8	20
Student reject rate	25.8%	19.4%
Radiographer reject rate	21.1%	22.5%
Total number of reject extremity radiographs (n^b) due to exposure factors	6	16
Final percentage rejects, produced by students, due to exposure factors in %	75.0%	80.0%

*Final percentage rejects due to exposure factors was calculated as follows: $n^b \div n^a \times 100$

The total number of extremity films produced at venue A during the retrospective phase ranged from 52 to 74, while departmental data A ranged from 9 to 19. The films produced by students at venue A during this phase ranged from 14 to 52, while student data A ranged from 5 to 14. Films rejected as a result of inaccurate exposure selection scored a range of 54.6% to 90.9%.

Results obtained for all weeks except week two appear similar. Refer to Appendix S for tables representing results for weeks two to eight. During week two of the retrospective phase, the number of films produced by students at venue A, as well as those rejected by them, was considerably fewer than that for the other weeks. The researcher assumes that this occurred because the students had a spring vacation (5–14 September 2008) at the University of Namibia at that time. During vacations students are not obliged to do clinical practice but some students use this time to gain clinical hours.

For the same phase, the ranges for venue B results were as follows:

- total number of extremity films produced by the department = 263 to 397
- departmental data B = 56 to 88
- total number of films produced by students at venue B = 103 to 223
- student data B = 35 to 58
- percentage of films rejected owing to exposure faults = 55.2% to 82.9%

Week one of this phase differed from the other weeks because the results obtained for this week, namely the number of films produced and the number of films rejected by both radiographers and students, were lower than those for the other weeks.

When comparing the student and radiographer reject rates of the prospective phase, the student reject rate ranged between 6.6% and 16.0% while the radiographer reject rate ranged between 7.1% and 29.8%. Averages of 10.8% and 16.8% were scored for students and radiographers respectively.

Comment [AB19]: IS this what you mean here?

Weeks one and three of the retrospective phase and weeks five, seven, and eight of the prospective phase presented higher radiographer reject rates than student reject rates. During the prospective phase the researcher observed that the overall radiographer reject rate (16.8%) at venue B was higher than that of the students (10.8%). The reason for this was that the students used ECs whilst the radiographers did not, resulting in the student reject rate being lower. Another factor that could have caused the radiographers to score a higher reject rate was the fact that students rotated between the two hospitals. With reference to the fifth assumption stated in Chapter 1, the researcher assumed that students retained the knowledge they obtained from the training on the use ECs and used it when working at venue A; thus they produced a lower reject rate. Under normal circumstances, taking clinical experience into account, it would be reasonable to assume that the radiographers' reject rate should have been lower than the students'.

Table 4.2: Weekly rejected radiographs prospective phase, week 1

Prospective phase Week 1		
Weekly rejected films	Venue A	Venue B
Total number of extremity radiographs produced by the x-ray department, i.e. radiographers and students combined	46	376
Total number of extremity reject radiographs produced by the x-ray department	10	73
Department reject rate in %	21.7%	19.4%
Total number of extremity radiographs produced by the students	41	282
Total number of reject extremity radiographs (n^a) produced by the students	8	45
Student reject rate	19.5%	16.0%
Radiographer reject rate	40.0%	29.8%
Total number of reject extremity radiographs (n^b) due to exposure factors	6	25
Final percentage rejects, produced by students, due to exposure factors in %	75.0%	55.6%

The total number of extremity films produced at venue A during the prospective phase ranged from 36 to 60, while departmental data A_1 ranged from 7 to 11. The films produced by the students at venue A during this phase ranged from 25 to 43, while student data A_1

ranged from 5 to 8. Films rejected as a result of inaccurate exposure selection scored a range of 66.7% to 83.3%.

During week six the number of films produced (60) and rejected (11) by the department was more than that obtained for other weeks. For this phase, some weeks, for example, weeks one (46 and 10), two (52 and 10), seven (40 and 8) and eight (42 and 9) scored similar results. Weeks three (39 and 8), four (38 and 7) and five (36 and 7) were also very similar. Refer to Appendix S for the results. The researcher does not have a reasonable explanation for these phenomena.

For the same phase, the ranges for venue B results were as follows:

- total number of extremity films produced by the department = 268 to 435
- departmental data B_1 = 18 to 73
- total number of films produced by students at venue B = 183 to 294
- student data B_1 = 12 to 45
- percentage of films rejected due to exposure faults = 53.9% to 83.3%

Weeks four, six and eight show low reject rates, which can be attributed to the fact that students rotated between the two departments. When observing tables 4.1 and 4.2, as well as Appendix S, the reader should take student rotation into consideration because it did influence the results.

Each sub-problem is stated below together with the results.

4.2.3 Sub-problem 1

4.2.3.1 Sub-problem 1a

To determine the retrospective phase departmental reject rate for extremity radiography at venue A.

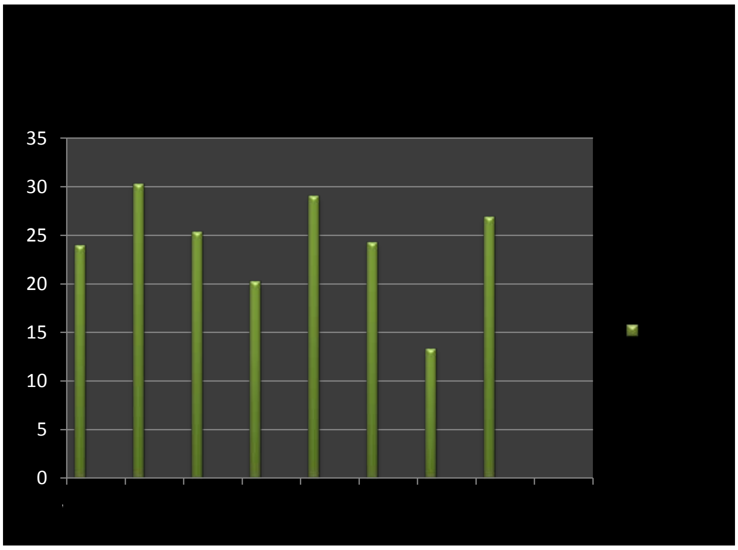

Figure 4.1 Retrospective phase departmental reject rate for extremity radiography for venue A

The retrospective departmental reject rate for data A ranges from 13.3% in week seven to 30.4% in week two. The average reject rate was 24.3% for this phase. Weeks two, five and eight showed the highest reject rates, while week seven showed the lowest. The researcher does not have a reasonable explanation for this occurrence.

4.2.3.2 Sub-problem 1b

To determine the retrospective phase departmental reject rate for extremity radiography at venue B.

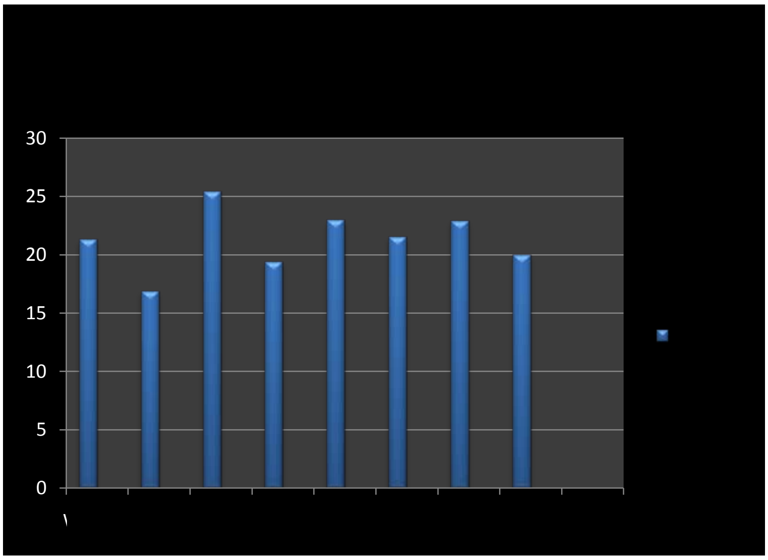

Figure 4.2 Retrospective phase departmental reject rate for venue B

The departmental reject rate for data B ranged from 16.9% in week two to 25.4% in week three. The average obtained during this phase was 21.3%. The values for week two, four and eight were below average while week three showed the highest value.

4.2.4 Sub-problem 2

To determine if there is a difference in the mean reject rates of students at venues A and venue B before the introduction and use of ECs

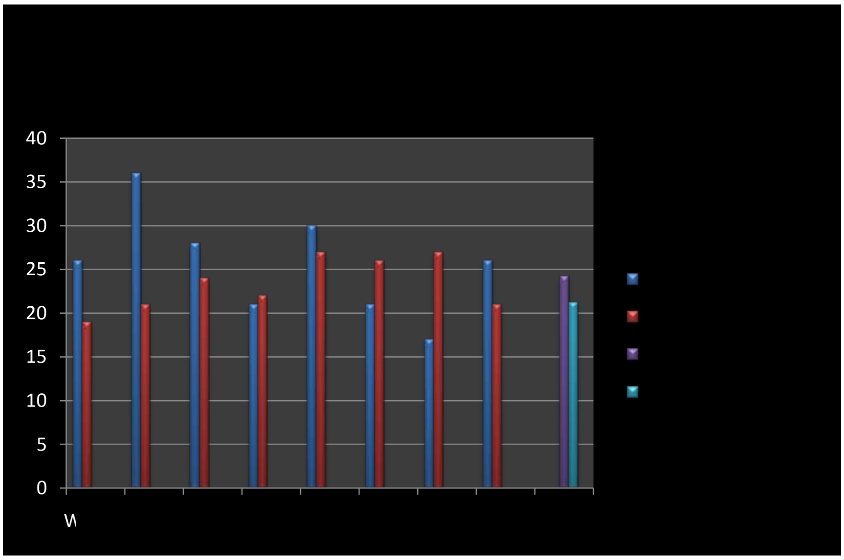

Figure 4.3 Retrospective phase student reject rate for venues A and B

Figure 4.3 demonstrates that student reject rate data A ranged between 35.7% in week two to 16.7% in week seven. A range of 19.4% to 27.4% was obtained for student reject rate data B. Averages of 23.4% and 25.6% were established for data A and B respectively. There is no statistically significant difference between these figures, thus either of these departments could have been used as the venue for introducing ECs. In the retrospective phase the reject rate obtained for week two was much higher than the remainder of the weeks for this phase.

4.2.5 Sub-problem 3

To determine if there is a difference in the mean reject rates of students at venues A and B after the introduction and use of ECs at venue B.

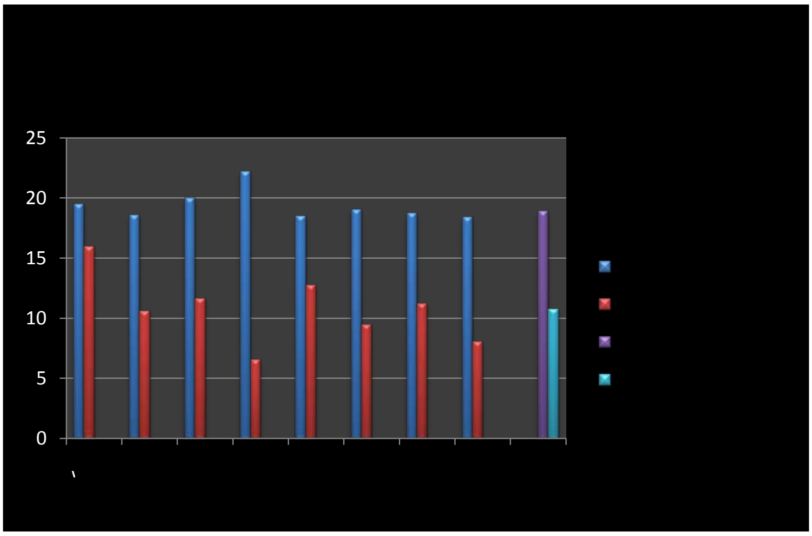

Figure 4.4: Prospective phase student reject rate for venues A and B

The prospective phase student reject rate data A_1 ranged from 18.4% to 22.2%, while student reject rate data B_1 ranged from 6.6% to 16.0%. An average of 18.9% was scored for the student data A_1 while the student reject rate data B_1 scored 10.8%. When comparing student reject rate data A_1 and B_1 during the prospective phase, the results obtained from student data A_1 are consistently higher than those of B_1. The reason for is this that students allocated to venue B used ECs to select exposure factors, while those at venue A did not.

4.2.6 Sub-problem 4

To determine if there is a difference in the mean reject rates of students before and after the introduction and use of ECs at venue B.

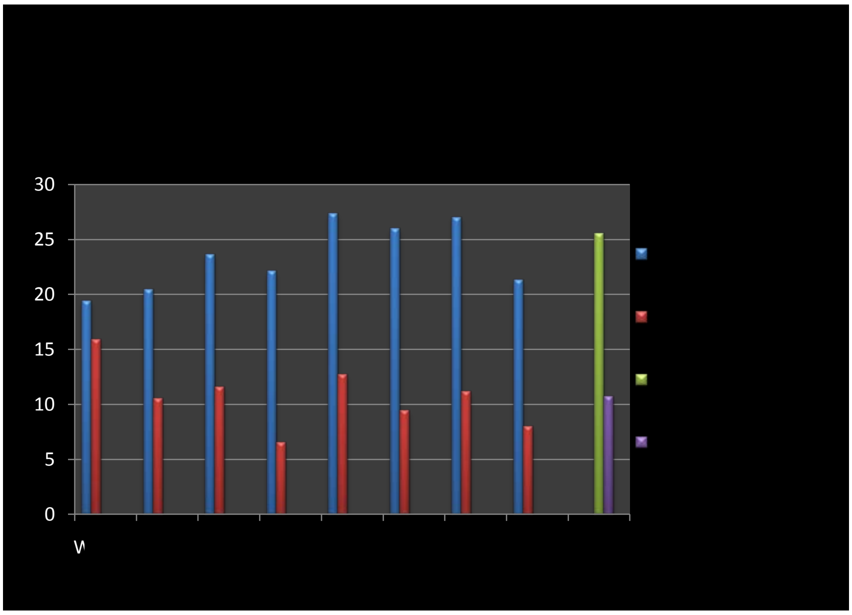

Figure 4.5: Student reject rates for venue B before and after intervention

During the retrospective phase the student reject rate for data B scored between 19.4% and 27.4% with an average of 25.6%. For the prospective phase the student reject rate for data B_1 ranged between 6.6% and 16.0% with an average of 10.8%.

When comparing the results of the retrospective and prospective phases the researcher recognised that the reject rates obtained during the retrospective phase were statistically significantly higher than those of the prospective phase. The reason for this is that students used ECs during the prospective phase and not during the retrospective phase.

4.2.7 Sub-problem 5

4.2.7.1 Sub-problem 5a

To determine the prospective phase departmental reject rate for extremity radiography at venue A

Table 4.3 Prospective phase departmental reject rate for venue A

	Venue A (reject rate in %)
Week 1	21.8
Week 2	19.2
Week 3	20.5
Week 4	18.4
Week 5	19.4
Week 6	18.3
Week 7	20.0
Week 8	21.4
Average reject rate for prospective phase	19.5

The prospective departmental reject rate data A_1 ranged from 18.3% to 21.8% and averaged 19.5%. In the prospective phase the departmental reject rate for data A_1 was consistent. The reject rate situation at this hospital remained constant.

4.2.7.2 Sub-problem 5b

To determine the prospective phase departmental reject rate for extremity radiography following the implementation and use of ECs at venue B.

Table 4.4: Prospective phase departmental reject rate for venue B

	Venue B (reject rate in %)
Week 1	19.4
Week 2	11.0
Week 3	12.0
Week 4	6.7
Week 5	10.7
Week 6	12.0
Week 7	13.7
Week 8	9.4
Average reject rate for prospective phase	11.8

The prospective departmental reject rate for data B_1 ranged from 6.7% to 19.4% and averaged 11.8%. The reject rates obtained during this phase covered a wide range.

4.2.8 Over and underexposure related rejected films

When conducting an RFA, discarded films are analysed to establish the various reasons for rejection. In the literature, a variety of results are mentioned resulting from the different methods used (Adler *et al.*, 1992) (refer to chapter 2, 2.2 Reject film analysis). The RFA conducted in the current study was modified for the purpose to cover exposure factors, that is, mAs and kV, over and underexposure, and the introduction and use of ECs. Following the use of ECs by students, the student reject rate decreased from 23.4% to 18.9% at venue A and from 25.6% to 10.8% at venue B. Tables 4.5 and 4.6 represent the data obtained after exposure related rejects produced by students had been scrutinised by the panel (refer to chapter 3, 3.4.2 Calculation of reject rates).

Table 4.5: Results for over and underexposure related rejected films

Retrospective phase						
	Venue A			Venue B		
Week	**Overexposure related rejects in %**	**Underexposure related rejects in %**	**% of films rejected due to exposure faults**	**Overexposure related rejects in %**	**Underexposure related rejects in %**	**% of films rejected due to exposure faults**
1	50.0	25.0	**75.0**	65.0	15.0	**80.0**
2	40.0	20.0	**60.0**	39.0	41.5	**80.4**
3	58.3	16.7	**75.0**	27.8	52.8	**80.6**
4	50.0	30.0	**80.0**	34.3	48.6	**82.9**
5	54.6	0.0	**54.6**	15.2	58.7	**73.9**
6	63.6	27.3	**90.9**	37.9	17.2	**55.2**
7	28.6	42.9	**71.4**	43.4	26.4	**69.8**
8	44.4	22.2	**66.7**	31.7	31.7	**63.4**
Average	**48.7**	**23.0**	**71.7**	**36.8**	**36.5**	**73.3**
Prospective phase						
	Venue A			**Venue B**		
Week	**Overexposure related rejects in %**	**Underexposure related rejects in %**	**% of films rejected due to exposure faults**	**Overexposure related rejects in %**	**Underexposure related rejects in %**	**% of films rejected due to exposure faults**
1	50.0	25.0	**75.0**	15.6	40.0	**55.6**
2	37.5	37.5	**75.0**	35.5	22.6	**58.1**
3	40.0	40.0	**80.0**	51.5	21.2	**72.7**
4	50.0	33.3	**83.3**	25.0	58.3	**83.3**
5	40.0	40.0	**80.0**	28.0	52.0	**80.0**
6	50.0	25.0	**75.0**	30.8	23.1	**53.9**
7	33.3	33.3	**66.7**	42.4	24.2	**66.7**
8	42.9	28.6	**71.4**	38.1	33.3	**71.4**
Average	**43.0**	**32.8**	**75.8**	**33.4**	**34.4**	**67.7**

*percentages for over or underexposure were calculated as follows:

$$Over\ or\ underexposure\ rejects\ (\%) = \frac{Number\ of\ films\ rejected\ due\ to\ over\ or\ underexposure}{Total\ number\ of\ films\ rejected\ due\ to\ exposure\ errors}\ x\ 100$$

During the retrospective phase, the percentage of films rejected as a result of overexposure ranged from 28.6% to 63.6% at venue A, while underexposure accounted for a range of 0.0% to 42.9%. Combined exposure related rejects averaged 71.7%. The percentage of undiagnostic radiographs resulting from overexposure ranged from 15.2% to 65.0% at venue B while underexposure constituted a range of 15.0% to 58.7%. Combined rejects resulting from exposure faults averaged 73.3%.

During the prospective phase, ranges of 33.3% to 50% and 25.0% to 40.0% were established for over and underexposure errors respectively at venue A. Ranges between 15.6% and 51.5% and 21.2% and 58.3% were obtained for these errors respectively during the prospective phase at venue B. Averages of 75.8% and 67.7% were determined for the retrospective and prospective phases respectively.

When comparing the results of exposure errors, venues A (71.7%) and B (73.3%) were on a par during the retrospective phase. When the same comparison is made in the prospective phase a difference is observed, with venue A scoring an average of 75.8% while venue B obtained 67.7%. The researcher suggests that this difference was as a result of the intervention.

In the retrospective phase the range of overexposed films is much higher than that for underexposed ones at venue A. However, at venue B the range was within close limits. The averages compare well.

During the prospective phase the ranges for over and underexposure for both phases are comparable. When comparing the retrospective and prospective phases, the researcher realised that although the reject rate had reduced (23.4% to 18.9% at venue A and 25.6 to 10.8% at venue B), the number of films rejected due to inaccurate mAs or kV selection did not vary much after the intervention. Thus, during the prospective phase, exposure errors were still the most common reason for rejection even though ECs were in use.

4.2.9 mAs and kV related rejected films

Table 4.6: Results for mAs and kV related rejected films

Retrospective phase				
	Venue A		Venue B	
Week	mAs related rejects in %	kV related rejects in %	mAs related rejects in %	kV related rejects in %
1	33.3	66.7	37.5	62.5
2	33.3	66.7	42.4	57.6
3	33.3	66.7	51.7	48.3
4	50.0	50.0	37.9	72.4
5	33.3	66.7	44.1	55.9
6	30.0	70.0	31.3	68.8
7	60.0	40.0	40.5	59.5
8	33.3	66.7	50.0	50.0
Average	**34.6**	**61.7**	**41.5**	**59.4**
Prospective phase				
	Venue A		**Venue B**	
Week	**mAs related rejects in %**	**kV related rejects in %**	**mAs related rejects in %**	**kV related rejects in %**
1	50.0	50.0	32.0	68.0
2	33.3	66.7	68.0	32.0
3	0.0	100.0	25.0	75.0
4	20.0	80.0	40.0	60.0
5	0.0	100.0	25.0	75.0
6	66.7	33.3	35.7	64.3
7	50.0	50.0	36.4	63.6
8	40.0	60.0	40.0	60.0
Average	**32.5**	**67.5**	**37.8**	**62.2**

*percentages for mAs or kV were calculated as follows:

$$mAs\ or\ kV\ related\ rejects\ (\%) = \frac{Number\ of\ films\ rejected\ due\ to\ mAs\ or\ kV}{Number\ of\ films\ rejected\ due\ to\ exposure\ faults} x\ 100$$

During the retrospective phase, the percentage of mAs related rejects at venue A comprised 30.0% to 60.0% over the eight week period, while at venue B these ranged from 31.3% to 51.7% for the same period. Averages achieved were 34.6% and 41.5% respectively.

Films rejected as a result of inaccurate kV selection contributed between 40.0% and 66.7%, with an average of 61.7% at venue A. The data B scored an average of 59.4%, ranging from 48.3% to 72.4%. The prospective phase mAs related rejects averaged 32.5% at venue A and 37.8% at venue B, while 67.5% and 62.2% were obtained respectively by kV related rejects.

When comparing the retrospective and prospective phases, it is apparent that the averages obtained for both mAs and kV related rejects are very similar. As mentioned earlier, although the reject rate was decreased, the percentage rejected as a result of these errors remained the same after the intervention.

4.3 Data analysis presentation

In order to highlight the meaning of the findings, it was decided to present the data analysis in the following ways:

- compare the retrospective phase departmental reject rates for venues A and B
- illustrate the differences between the two reject rates at the two hospitals using statistical testing, specifically *t*-test analysis, for both the retrospective and prospective phases
- compare the departmental reject rates for venues A and B after the introduction and use of ECs at venue B

These differences will be explored and summarised in tabular form (refer to 4.3.5 Comparison of student reject rates before and after intervention at venue B and Table 4.27).

4.3.1 Comparison of retrospective phase departmental reject rates for venues A and B against 20%

The departmental reject rate for data A and B were compared to determine the difference in reject rates between the two departments.

Descriptive statistics for the retrospective phase before the introduction and use of ECs are presented in Table 4.7.

Table 4.7: Means and standard deviations for departmental reject rate scores for venues A and B

Hospital	n	$\overline{x}$	s
Venue A	8	24.3	5.3
Venue B	8	21.3	2.6

*where n is the sample size, $\overline{x}$ is the sample mean and s is the sample standard deviation

Table 4.8: One sample *t*-test for the reject rate for venue B

One-sample *t*-test	Test value = 20				
				95% confidence interval of the difference	
t	df	p	Mean difference	Lower	Upper
1.4	7	0.2	1.3	–0.9	3.4

*where *t* is the Students' *t* variable, df is the degrees of freedom and p is the attained level of significance

Table 4.9: One sample *t*-test for the reject rate for venue A

One-sample *t*-test	Test value = 20				
				95% confidence interval of the difference	
t	df	p	Mean difference	Lower	Upper
2.3	7	0.1	4.3	–0.2	8.7

Thus for departmental reject rate data B the t-value t(7) = 1.4, p = 0.2, d = 1.3 and for departmental reject rate data A the t-value t(7) = 2.3, p = 0.1, d = 4.3. It can be deduced that there was no difference between the hypothesised value of 20% and the departmental reject rates of both hospitals before the intervention. The 95% confidence intervals show that 0 $\in$ (–0.9; 3.4) as well as 0 $\in$ (–0.2; 8.7) and confirm that there were no differences from the 20%.

4.3.2 Comparison of retrospective phase departmental reject rates for venues A and B

The departmental reject rates for data A and data B were compared to obtain the difference between the reject rates for the two departments.

Table 4.10 presents the descriptive statistics for the retrospective phase before the introduction and use of ECs.

Table 4.10: Means and standard deviations for department reject rate scores for venues A and B

Hospital	n	$\bar{x}$	s
Venue A	8	24.3	5.3
Venue B	8	21.3	2.6

Table 4.11: Independent samples *t*-test analysis.

	Levene's test for equality of variances		*t*-test for equality of means					
							95% confidence interval of the difference	
	F	p	t	df	p	Mean difference	Lower	Upper
% Reject rate: equal variances assumed	1.7	0.2	1.4	14	0.2	3.0	-1.5	7.5

*where F is the F statistic for testing equal variances in this study

Thus t(14) = 1.4, p = 0.2, d = 3.0. It can therefore be deduced that there was no difference between the departmental reject rates at the two hospitals (p > 0.05) before the intervention. The 95% confidence interval shows that 0 $\in$ (–1.5; 7.5) and confirms that there was no difference.

It can therefore be stated that the radiography departments in each of the two hospitals performed similarly with regard to reject rates.

4.3.3 Comparison of retrospective phase student reject rates for venues A and B

The student reject rates for data A and B were compared to determine the difference in these reject rates during the retrospective phase.

The researcher expected there to be no significant differences between the two hospitals with regard to student reject rates since no ECs had been used at either venue prior to the study. The reject rates were analysed by means of a *t*-test, the results of which are indicated in Table 4.13, and with the use of a weighted means *t*-test, the results of which are indicated in Table 4.14.

Table 4.12 shows the descriptive statistics for the retrospective phase before the introduction and use of ECs.

Table 4.12: Means and standard deviations for student reject rate scores for venues A and B

Hospital	n	$\bar{x}$	s
Venue A	8	23.4	3.1
Venue B	8	25.6	5.9

Table 4.13 Independent samples *t*-test analysis

	Levene's test for equality of variances		*t*-test for equality of means				95% confidence interval of the difference	
	F	p	t	df	p	Mean difference	Lower	Upper
% reject rate: equal variances assumed	1.9	0.2	0.9	14	0.4	2.2	–2.8	7.3

Thus t(14) = 0.9, p = 0.4, d = 2.2. From this it can be deduced that there was no difference between the student reject rate at both hospitals (p > 0.05) before the intervention. The 95% confidence interval shows that $0 \in (-2.8; 7.3)$, which confirms that there was no difference.

Thus, the students performed similarly with regard to the reject rates at the two hospitals and the intervention, to prove that the use of ECs would actually improve the performance of the students and thus lower the reject rate, could have taken place at either of them.

Bland and Kerry (1998) suggest that the weighted means should be used in order to prove the assumption that equal variances would produce a worthwhile reduction in the size of the confidence intervals. Accordingly, this test procedure was used and the results are presented in Tables 4.14 and 4.15.

Table 4.14: Weighted means for the retrospective phase before intervention

Hospital	n	$\overline{x}$	s
Venue A	302	23.4	3.0
Venue B	1392	25.6	5.2

*where n is the total number of x-ray films produced at both hospitals. Thus the means are weighted by the total number of films used to find the reject rates for the two hospitals.

Table 4.15: 95% confidence interval of the difference

95% confidence interval of the difference	
Lower	Upper
–0.1	1.5

This confidence interval does not reject the hypothesis that the mean reject rates are the same (no difference); however, the size of the interval is drastically reduced.

4.3.4 Comparison of prospective phase reject rates for students for venues A and B

As indicated in Table 4.16 and Table 4.17, a significant difference was found in the mean reject rates of students at the two hospitals during the prospective phase.

Table 4.16 displays the descriptive statistics for the prospective phase after the intervention.

Table 4.16: Means and standard deviations for student reject rate scores for venues A and B

Hospital	n	$\overline{x}$	s
Venue A	8	18.9	2.9
Venue B	8	10.8	0.6

Table 4.17: Independent samples *t*-test analysis

	Levene's test for equality of variances		*t*-test for equality of means					
							95% confidence interval of the difference	
	F	p	t	df	p	Mean difference	Lower	Upper
% reject rate: equal variances not assumed	6.8	0.0	7.8	7.5	0.0	8.2	5.7	10.6

(p = 0.000 is interpreted as p < 0.001)

Thus, t(7.5) = 7.8, p < 0.0, d = 8.2. From the *t*-test it can be deduced that there was a significant difference between the reject rates of students at the two hospitals, (p < 0.0). The 95% confidence interval shows that $0 \notin (5.7; 10.6)$ after the intervention and confirms this difference.

Table 4.18: Weighted means for the prospective phase after intervention

Hospital	n	$\overline{x}$	s
Venue A	275	18.9	2.8
Venue B	2067	10.8	0.5

* where n is the total number of x-ray films produced at both hospitals. Thus the means are weighted by the total number of films used to find the reject rates for the two hospitals.

Table 4.19 95% confidence interval of the difference

95% confidence interval of the difference	
Lower	Upper
5.1	9.6

This confidence interval also rejects the hypothesis that the mean reject rates of students are the same (no difference); however, the size of the interval is reduced drastically.

4.3.5 Comparison of student reject rates before and after intervention at venue B

As indicated in Tables 4.20 and 4.21, a significant difference was found in the mean reject rates of students for the retrospective and prospective phases at venue B.

Table 4.20: Means and standard deviations for student reject rate scores, retrospective and prospective phases, for venue B

Test	n	$\overline{x}$	s
Retrospective	8	25.6	3.0
Prospective	8	10.8	2.8

Table 4.21: Independent samples *t*-test analysis

Paired samples *t*-test					
				95% confidence interval of the difference	
T	df	p	Mean	Lower	Upper
-6.9	7	0.0	-9.5	–12.7	–6.2

(p = 0.000 is interpreted as p < 0.001)

Thus t(7) = 6.9, p < 0.0. From the *t*-test it can be deduced that there was a significant difference between the student reject rate during the retrospective and the prospective phases for venue B (p < 0.0). The 95% confidence interval shows that 0 $\notin$ (12.7; 6.2) and confirms the difference. This therefore proves that the intervention, namely the introduction and use of ECs, lowered the student reject rate and shows a statistically significant difference in performance between the students allocated to venue B before the intervention and after the intervention.

4.3.6 Comparison of prospective phase departmental reject rates for venues A and B

As indicated in Tables 4.22 and 4.23, a significant difference was found in the mean departmental reject rates between the radiography departments of the two hospitals during the prospective phase.

Descriptive statistics for the prospective phase that took place after the intervention are presented in Table 4.22.

Table 4.22: Means and standard deviations for departmental reject rate scores for venues A and B

Hospital	n	$\overline{X}$	s
Venue A	8	19.5	3.7
Venue B	8	11.8	0.7

Table 4.23: Independent samples *t*-test analysis

	Levene's test for equality of variances		*t*-test for equality of means					
							95% confidence interval of the difference	
	F	p	t	df	p	Mean difference	Lower	Upper
% Reject rate: equal variances	0.9	0.4	5.3	14	0.0	7.7	4.6	10.9.

(p = 0.0 is interpreted as p < 0.0)

Thus t(14) = 5.3, p < 0.0, d = 7.7. It can thus be deduced that there was a significant difference between the reject rate of the two hospitals; (p < 0.0). The 95% confidence interval shows that 0 $\notin$ (4.6; 10.9) and confirms the difference that was evident after the intervention.

4.3.7 Comparison of prospective phase departmental reject rates for venues A and B against 16% after intervention

Departmental reject rate data A_1 and B_1 were compared to determine the prospective reject rates for the two departments.

Descriptive statistics for the prospective phase, namely after the introduction and use of ECs, are presented in Table 4.24.

Table 4.24: Means and standard deviations for departmental reject rate scores for venues A and B

Hospital	n	$\overline{X}$	s
Venue A	8	19.5	3.7
Venue B	8	11.8	0.7

Table 4.25: One sample *t*-test for the reject rate for venue A

One-Sample *t*-test Test value = 16					
				95% confidence interval of the difference	
t	df	p	Mean difference	Lower	Upper
5.2	7	0.0	3.3	1.9	5.1

Table 4.26: One sample *t*-test for the reject rate for venue B

One-sample *t*-test	Test value = 16				
				95% confidence interval of the difference	
T	df	p	Mean difference	Lower	Upper
3.3	7	0.0	4.2	1.2	7.3

For departmental reject rate data $B_{1,}$ the *t*-value t(7) = 3.3, p = 0.0, d = 4.2, thus the hypothesis that the mean reject rate = 16% is not supported; for departmental reject rate data $A_{1,}$ the *t*-value t(7) = 5.2, p = 0.0, d = 3.3; thus the hypothesis is rejected. It can thus be deduced that there was a difference between the hypothesised value of 16% of both hospital departments' reject rates after the intervention. The 95% confidence intervals show that $0 \notin (1.2; 7.3)$ for venue B as well as $0 \notin (1.9; 5.1)$ for venue A and confirm that there were variations from the 16%.

The purpose of the following table is to summarise the results of the study for comparison purposes.

Table 4.27: Summary of means, standard deviations and *t* and *p*-values between retrospective and prospective scores for reject rates of the students at the two hospitals

	Retrospective phase							Prospective phase											
	Venue A			Venue B				Venue A			Venue B					Difference in means: posttest–pretest for venue B			
Reject rates	n	$\overline{X}$	s	n	$\overline{X}$	s	p	n	$\overline{X}$	s	n	$\overline{X}$	s	p	n	'$\Delta\overline{X}$'	n	'$\Delta\overline{X}$'	p
	8	23.4	3.1	8	25.6	5.9	0.4	8	18.9	0.6	8	10.8	2.9	0.0	8	10.6	8	23.4	0.0

(p = 0.0 in SPSS is interpreted as p< 0.0)

4.3.8 Summary of hypotheses

Hypothesis 1a

The retrospective phase departmental reject rate for extremity radiography is 20% at venue A.

This hypothesis is rejected by the results obtained, as the retrospective phase department reject rate at venue A is 24.3%.

Hypothesis 1b

The retrospective phase departmental reject rate for extremity radiography is 20% at venue B.

This hypothesis is rejected by the results obtained, as the retrospective phase departmental reject rate at venue B is 21.3%. Thus, both reject rates exceed 20% at the 5% level of significance.

Hypothesis 2

There is no difference in the mean reject rates of students at venues A and B before the introduction and use of ECs.

This hypothesis is supported by the results obtained, as the retrospective student reject rates for the hospitals were not significantly different (venue A = 23.4%; venue B = 25.6%) for the retrospective phase.

Hypothesis 3

There is a difference in the mean reject rates of students at venues A and B after the introduction and use of ECs at venue B.

This hypothesis is supported by the results obtained, as the prospective student reject rates for the hospitals were significantly different (venue A = 18.9%; venue B = 10.8%). This therefore proves that the intervention lowered the reject rate; in addition there is a statistically significant difference in performance between the students at the two hospitals. The students at venue A had a higher reject rate than students at venue B.

Hypothesis 4

There is a difference in the mean reject rates of students before and after the introduction and use of ECs by the students at venue B.

This hypothesis is supported by the results obtained, as the student reject rates for the retrospective and prospective phases for venue B were significantly different. In fact, the reject rates were significantly lower which would indicate that the introduction and use of ECs was effective (retrospective student reject rate = 25.6%; prospective student reject rate = 10.8%).

Hypothesis 5a

The prospective phase departmental reject rate for extremity radiography is 16% at venue A.

This hypothesis is rejected by the results obtained, as the prospective phase departmental reject rate at venue A was reduced from 24.3% to 19.5%.

Hypothesis 5b

The prospective phase departmental reject rate for extremity radiography is 16% at venue B.

This hypothesis is rejected by the results obtained as the prospective phase departmental reject rate at venue B was reduced from 21.3% to 11.8%. The departmental mean reject rates after intervention did not differ significantly from 16%.

4.4 Discussion

4.4.1 Comments on results

4.4.1.1 Sub-problem 1a

To determine the retrospective phase departmental reject rate for extremity radiography at venue A.

The departmental reject rate data A was high for all weeks except week seven. The average of 24.3% is, however, higher than the hypothesised value of 20%.

4.4.1.2 Sub-problem 1b

To determine the retrospective phase departmental reject rate for extremity radiography at venue B.

The departmental reject rate data B displayed a small range (16.9% to 25.4%) and no exceptions were observed. The average of 21.3% is, however, higher than the hypothesised value of 20%.

4.4.1.3 Sub-problem 2

To determine if there is a difference in the mean reject rates of students at venues A and B before the introduction and use of ECs

The student reject rate data A and B compare well except for week two, where data B scored much higher than all the other values. The researcher is unable to offer an explanation for this. However, this was the ideal situation since the intervention could be introduced in either department.

4.4.1.4 Sub-problem 3

To determine if there is a difference in the mean reject rates of students at venues A and B after the introduction and use of ECs at venue B.

Student reject rate data A_1 is consistently higher than B_1, with averages of 18.9% and 10.8% being obtained respectively. This is due to the fact that the students used ECs when selecting exposure factors. The hypothesised significant difference between these reject rates is thus confirmed.

4.4.1.5 Sub-problem 4

To determine if there is a difference in the mean reject rates of students before and after the introduction of ECs at venue B

When comparing student reject rate data B and B_1 for the retrospective and prospective phases it is recognised that the use of ECs was in fact effective because the reject rates obtained during the prospective phase were significantly lower than those of the retrospective phase.

4.4.1.6 Sub-problem 5a

To determine the prospective phase departmental reject rate for extremity radiography at venue A.

The results of the prospective phase departmental reject rate data A_1 obtained were within close limits ranging from 18.33 to 21.8%. An average of 19.5% was achieved which is higher than the hypothesised 16%.

4.4.1.7 Sub-problem 5b

To determine the prospective phase departmental reject rate for extremity radiography following the implementation and use of ECs at venue B.

The retrospective phase departmental reject rate data B varied between 6.7% and 19.4%, however, the researcher is unable to provide a valid reason for this variation. An average of 11.8% was scored, which is lower than the hypothesised 16% and within the internationally approved acceptable limits for reject rates.

4.4.2 RFA

Naqvi (n.d.) mentions that, by conducting an RFA, standard radiographic results can be achieved and maintained. The results of the current study reveal that, if students use ECs on a continuous basis, optimal image quality radiographs will be produced.

Naqvi (n.d.), Scandorf and Tetteh (1998) and Dunn and Rogers (1998) agree that RFA results may give evidence of improvement after QA interventions have been introduced. The present study provides substantial evidence that the student reject rate decreased after the introduction and use of ECs.

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According to Scandorf and Tetteh (1998), Hardy and Persaud (2001) and Reiner *et al.* (2006), RFAs can provide results that will encourage and recommend staff development and education for the radiographers involved. In the current study, exposure errors were scrutinised and discussed. These have also been identified as being the most common reasons for rejection in the literature. The researcher recognises that there is a need for in-service training for radiographers, particularly with regard to accurate exposure factor selection.

Reiner *et al.* (2006) agree that RFAs may encourage radiographers to change certain practice patterns which should improve the quality of service supplied to a patient. In the past, for example, students did not measure the thicknesses of body parts or use ECs, but the current study changed this practice at venue B.

Many RFAs reported in the literature were done only to establish reject rate and no further action was taken. Only a few authors, for example Keen (2008), subsequently implemented improvement programmes after conducting a RFA. By conducting a modified RFA, identifying exposure faults as the main reason for rejection and introducing ECs to reduce reject rate, the present study added valuable information to the literature.

The assessment of upper and lower extremity films and EC implementation are not specifically mentioned in the cited literature; nor have these topics been addressed in previous research carried out at venue A and B. Accordingly, these aspects of the current study made it unique and will provide valuable information for the managers of these departments.

4.4.3 Reasons for rejection of radiographic films

It is evident from the literature that much research has been undertaken to establish the reasons for radiographic film rejection and a variety of results have proven that exposure related faults are unquestionably the most frequent cause of rejection. The present research study revealed that averages of 71.7% and 73.3% of the films rejected were as a result of exposure errors. These values were obtained from venues A and B respectively during the retrospective phase, while averages of 75.8% and 67.7% were obtained during the prospective phase. Thus the introduction and use of ECs at venue B reduced the percentage of films rejected as a result of exposure errors.

4.4.4 Over and underexposure

Many researchers (Peer *et al.*, 2001; Hardy & Persaud, 2001; Clark & Hogg, 2003) have combined data on over and underexposure errors and state a single figure for exposure faults in their reports, thus not making it clear which exposure fault occurred. It is important that results should be recorded in detail, otherwise effective improvement programmes cannot be introduced. Thus the present study separated the data pertaining to exposure faults on account of over and underexposed images.

During the retrospective phase, at venue A an average of 48.7% of films was rejected as a result of overexposure, a figure which differs from the results (Chu *et al.,* 1982, stated 30.7%, Rogers *et al.,* 1987 noted 14.4% and Arvanitis *et al.,* 1991, recorded 15.0%) found in the literature. For the same phase, an average of 36.8% was obtained for venue B, with the percentage published by Chu *et al.* (1982), 30.7%, being the closest to this figure. Radiographs rejected on account of underexposure scored an average of 23.0% at venue A, which is similar to the 20.0% stated by Mazzoferro *et al.* (1974), while at venue B an average of 36.5% was recorded. This value is close to the 33.1% reported by Rogers *et al.* (1987).

For the prospective phase, venue A scored an overexposure rate of 43.0% while venue B scored 33.7%. For the same phase, 32.8% of films was rejected owing to underexposure at venue A while 34.4% was obtained at venue B. The 33.1% recorded by Rogers *et al.* (1987) is the closest to these amounts.

4.4.5 kV and mAs related rejected films

As over and underexposure are a result of inaccurate exposure selection, the ECs used by students at venue B were compiled to address the selection of kV and mAs. During the retrospective phase, an average of 34.6% of exposure related reject films was discarded owing to inaccurate mAs selection at venue A. For the retrospective phase, venue B obtained an average score of 41.5%. Radiographs rejected as a result of incorrect kV selection averaged 61.7% at venue A, and 59.4% at venue B.

For the prospective phase, venue A scored a value of 32.5% for inappropriate mAs selection while venue B scored 37.8%. For the same phase, 67.5% of films were rejected at venue A owing to inaccurate kV selection, while 62.2% was recorded at venue B.

No references to mAs and kV selection were found in the literature. Therefore the results of the current study cannot be related to the literature.

4.4.6 Reject rate

Reject rate has been studied widely on different continents. The values for reject rates vary considerably from 0.9% in a study done by Muhogora *et al.* (1999) in Tanzania, to 33% in a study done by Clark and Hogg (2003) in Manchester.

The retrospective phase departmental reject rate of 24.3% found at venue A in the current study is close to the 27.6% stated by Peer *et al.* (2001). This value was reduced to 19.5% during the prospective phase. For the same phase, a reject rate of 21.3% was obtained at venue B but decreased to 11.8%. The retrospective phase student reject rate of 23.4% for venue A also declined to 18.9% during the prospective phase, while at venue B the 25.6% obtained decreased to 10.8%. These results can be compared to those recorded by Clark and Hogg (2003), who note that their baseline audit revealed a reject/repeat rate of 33% but the intervention (viewing patients' previous films) reduced it to 10.6%.

Chu *et al.* (1982) note that exposure related rejects can be reduced by implementing an effective QA programme. The results of the present study reveal that after the introduction and use of ECs as a quality control measure, the student reject rate at venue B decreased considerably from 25.6% to 10.8%. The study also revealed that the student reject rate at venue A declined from 23.4% to 18.9%. Since students rotated between the two venues (refer to the fifth assumption) this could be attributed to the fact that it was highly likely that students, following their training in the use of ECs, retained this knowledge and used it when working at venue A. This could have impacted on the reject rate.

Where acceptable reject rates are discussed in the literature, various authors (Watkinson *et al.,* 1984, Dunn & Rogers, 1998; Hardy & Persaud, 2001) recommend a 10% to 15% acceptance rate. In this study, the retrospective student reject rates obtained during the current study were high (venue A = 23.4% and venue B = 25.6%) but the intervention reduced them to an acceptable level at venue B (10.8%).

4.5 Summary

In this chapter figures and tables were used to present the data. During the retrospective phase the respective departmental reject rates for venues A and B were 24.3% and 21.3% respectively. During the same phase, the student reject rates for the hospitals were not significantly different. As a result of the introduction and use of ECs, the student reject rate at venue B was lowered during the prospective phase. The student reject rates for the two hospitals differed significantly during the prospective phase and a statistical difference in performance between the students at the two hospitals was proven during this phase. However, at venue A the student reject rate during the prospective phase also decreased, probably as a result of student rotation between the two hospitals.

At venue B, the student reject rates for the retrospective and prospective phases differed significantly with the prospective reject rate being significantly lower, thus demonstrating that the introduction and use of ECs was effective. The departmental reject rates were reduced from 24.3% to 19.5% at venue A and from 21.3% to 11.8% at venue B during the prospective phase.

The next chapter discusses the conclusions and recommendations resulting from the study.

Chapter 5

Conclusions and recommendations

5.1 Introduction

This chapter reverts to the research problem, the sub-problems and the purpose of the study and serves to draw conclusions from the results obtained. This chapter also makes recommendations for improvements in current practice in the x-ray departments of the two hospitals, and suggests possible future research opportunities.

5.2 Purpose of the study

The purpose of this study was to determine the retrospective departmental and student reject rates for use as a benchmark in designing and implementing a quality improvement programme to reduce the reject rate over a five month period. During the two months (28 August to 22 October 2008) in which the extremity reject films were collected for the retrospective study, ECs were compiled and these were introduced at the venue B after the students returned from their vacation. All 2009 second and third year students were taught how to use these ECs over four weeks (25 February to 25 March 2009). Following the students being taught how to use ECs the prospective phase commenced.

This study addressed exposure factor selection by compiling and introducing ECs to assist students at venue B in the production of diagnostic radiographs. The target population was all the rejected extremity films of the departments for the retrospective and prospective RFA periods. The WCH and KSH x-ray departments were identified as the venues for the research because they are the largest training hospitals in Windhoek and were convenient for accessing data.

5.3 The statement of the problem

The purpose of this study was to conduct reject film analyses at two radiography training hospitals in Namibia, to compare the retrospective reject rates for extremity radiography produced by radiographers and students, who routinely did not use exposure charts, with the prospective reject rates for extremity radiographs, after the implementation of exposure charts used only by students at one of the hospitals, and the reject rates at the other hospital, where exposure charts were not used by students and radiographers, to determine the effectiveness of routinely using exposure charts to minimize unnecessary ionizing radiation dose to patients by students and radiographers.

5.4 Statement of sub-problems

5.4.1 Sub-problem 1

5.4.1.1 Sub-problem 1a

To determine the retrospective phase departmental reject rate for extremity radiography at venue A.

5.4.1.2 Sub-problem 1b

To determine the retrospective phase departmental reject rate for extremity radiography at venue B.

5.4.2 Sub-problem 2

To determine if there is a difference in the mean reject rates of students at venues A and B before the introduction and use of ECs.

5.4.3 Sub-problem 3

To determine if there is a difference in the mean reject rates of students at venues A and B after the introduction and use of ECs at venue B.

5.4.4 Sub-problem 4

To determine if there is a difference in the mean reject rates of students before and after the introduction of ECs at venue B.

5.4.5 Sub-problem 5

5.4.5.1 Sub-problem 5a

To determine the prospective phase departmental reject rate for extremity radiography at venue A.

5.4.5.2 Sub-problem 5b

To determine the prospective phase departmental reject rate for extremity radiography following the implementation and use of ECs at venue B.

5.5 Hypotheses

5.5.1 Hypothesis 1

5.5.1.1 Hypothesis 1a

The retrospective phase departmental reject rate for extremity radiography is 20% at venue A.

5.5.1.2 Hypothesis 1b

The retrospective phase departmental reject rate for extremity radiography is 20% at venue B.

5.5.2 Hypothesis 2

There is no difference in the mean student reject rates of students at venues A and B before the introduction and use of ECs.

5.5.3 Hypothesis 3

There is a difference in the mean reject rates of students at venues A and B after the introduction and use of ECs at venue B.

5.5.4 Hypothesis 4

There is a difference between the mean student reject rates of students before and after the introduction and use of ECs by the students at venue B.

5.5.5 Hypothesis 5

5.5.5.1 Hypothesis 5a

The prospective phase departmental reject rate for extremity radiography is 16% at venue A.

5.5.5.2 Hypothesis 5b

The prospective phase departmental reject rate for extremity radiography is 16% at venue B.

5.6 Research methods

A quantitative comparative pre and post-treatment research design was used for this study. Non-probability, convenience sampling was used to calculate the reject rate.

The retrospective and prospective RFA studies were conducted at both hospitals simultaneously; however, ECs were used by the students at venue B only. The reject rates for extremity radiography were calculated for both departments. Thereafter, the reject rates for the students were calculated.

The ECs compiled by the researcher, and based on the RFA conducted by the panel, were introduced at venue B after the students returned from vacation. This RFA was concerned with exposure factors, that is, kV and mAs. The possible reasons for rejection that were identified by the analysis were

- over or underexposure resulting from inaccurate kV selection
- over or underexposure resulting from incorrect mAs selection

A RFA conducted at both venues during the prospective phase showed that the use of ECs by students decreased reject rates at venue B.

The methodology presented in this study is general in nature and can therefore be applied to any institution that produces radiographs. The technique used is a variation of conventional

RFA methods and allows for site specific information to be obtained and analysed. The researcher hopes that both the framework for data collection and the subsequent analysis will be useful to those intending to undertake similar investigations in this field.

5.7 Conclusions

5.7.1 Conclusions in relation to hypotheses

The following conclusions are warranted from the results of the study:

- The retrospective departmental reject rate data A was 24.3% and departmental reject rate data B was 21.3%. These were thus higher than the acceptable reject rate of 10% to 15% (Hardy & Persaud, 2001). Hypothesis 1a and 1b are therefore rejected by the results obtained.

- The retrospective student reject rate data A and data B were not significantly different. Thus, the ECs could be implemented and used at either hospital. Hypothesis 2 is therefore supported by the results obtained.

- The prospective student reject rates data A_1 and B_1 for both hospitals were significantly different. Thus, the results show that the use of ECs lowered the student reject rate during the prospective phase. These results therefore support hypothesis 3.

- The retrospective and prospective student reject rates data B and B_1 were significantly different, which indicates that the use of ECs was effective. Hypothesis 4 is therefore supported by the results obtained.

- The prospective departmental reject rate data A_1 was 19.5% and data B_1 was 11.8%. Thus, the intervention lowered the departmental reject rate at venue B during the prospective phase. Hypotheses 5a and 5b are therefore rejected by the results obtained.

5.7.2 RFA

A RFA is an invaluable tool when trying to improve radiography service. At the time Hardy and Persaud (2001) wrote their article there was no literature available that accurately described improvement measures implemented as a result of undertaking a RFA and the effect of these measures on the evaluation of reject rates. Thus, the results of the current study have provided information that will enhance the literature.

If the results of a RFA can be used as an indicator of the production of acceptable image quality radiographs, it can be said that the departments used in this study had major problems with consistency in producing acceptable image quality prior to this study. However, the study improved this situation.

In radiography, the first priority should be patient care, which is the primary objective of QA and QC. Naqvi (n.d.), Scandorf and Tetteh (1998) and Dunn and Rogers (1998) agree that RFA results may give evidence of improvement after QA interventions have been introduced. The current study has proven that the reject rate at venue B decreased after the implementation and use of ECs.

Simply carrying out a RFA may raise the standards of a department by increasing the awareness of the radiographers involved (Nixon *et al.*, 1995). Kofler *et al.* (1999) add that radiographers also become aware of common problems such as recurrent positioning errors of the lateral view of the ankle or repetitive exposure faults of the anteroposterior projection of the knee. The reduction in the overall departmental reject rates suggests that the current research has made students more aware of the accurate selection of exposure factors and of rejected films.

A RFA is a helpful tool for identifying ways rejects can be avoided and possible corrective action to be introduced, as it highlights the aspects responsible for poor image quality (Kofler *et al.,* 1999, Muhogora *et al.*, 1999; Hardy & Persaud, 2001). The retrospective RFA conducted for this research established high reject rates (24.3% and 21.3%), the reduction of which required the implementation of ECs as a remedial action.

The results of this study will be presented to the radiographic staff and students who participated, and the lessons learnt will be reflected on in order to improve the quality of radiographic services. The researcher intends to facilitate a discussion with participants in order to provide them with a platform to express their opinions and make recommendations.

5.7.3 Exposure selection

The percentage of films rejected due to inaccurate mAs selection during the retrospective phase amounted to 34.6% of exposure related errors at venue A and 41.5% at venue B, while kV related rejects scored 61.7% and 59.4% for venues A and B respectively. During the prospective phase, mAs related rejected films decreased to 32.5% at venue A and 37.8% at venue B, while kV related rejects increased to 67.5% and 62.2% respectively. This increase may be attributed to the fact that a variable kV EC was used and students had to select kV according to patient thickness. Although the researcher did offer specific guidelines for selection, the students may have experienced some difficulties. Nevertheless, with the implementation of ECs reject rates decreased (19.5% and 11.8% at venues A and B respectively). This reduction indicates that standardised ECs enable students to select accurate exposure factors confidently on a continuous basis.

From the results of this study it can be concluded that if exposure factors are standardised then the percentage of rejects could be decreased significantly to the benefit of the patient in terms of a lower radiation dose. Although the legislation concerning the use of ECs is not yet completely conformed with, this study has brought the two hospitals closer to achieving this goal.

5.7.4 Reject rate

According to Meyer and Joubert (2001) several factors can influence reject rate. These include:

- differences in the terminology used, for example, reject rate is defined in various ways
- start-up effect

- whether radiographers have been informed about the RFA
- the viewer's opinion of image quality
- the radiographers' experience
- examinations performed
- workload of the department
- use of automatic exposure control, etc.

The results of the retrospective RFA reflected the initial reject rate, whereas the prospective study was able to record the student and departmental reject rates after the intervention. From the information obtained by means of the methodology, it was possible to draw comparisons between the reject rates of the retrospective and prospective studies. Using statistical analysis, the effectiveness of the intervention was recorded and reductions in the reject rates were noted.

The results of the study indicate that the introduction and use of ECs reduced the departmental and student reject rates at both hospitals. However, the student reject rate data A_1 scored a higher reject rate (19.5%) than that of student reject rate B_1 (11.8%).

Nixon *et al.* (1995) note that the radiographer's experience plays a role when reject rates are considered. Lau *et al.* (2004) report that low reject rates can be due to the fact that the majority of radiographers have a high level of experience. One reason for the high retrospective departmental reject rates obtained by data A and B is that, unlike many other studies, the study involved students. Clark and Hogg (2003) note that less experienced radiographic staff, for example students, will produce a higher number of rejects than experienced personnel (refer to the sixth assumption).

5.7.5 QA and QC

Patients expect to receive the highest possible quality of service from a medical facility and no one wants to be exposed to unnecessary ionising radiation. As a system for evaluating performance (Bushong, 2004), QA consists of actions taken to ensure that standards and procedures are adhered to and that services meet performance requirements. QA ensures that x-ray departments will render consistently high quality images (Carlton & Adler, 2001). QA assesses all aspects affecting patient care, for example, interpretation of examinations, maintenance of equipment, performance of procedures, etc. The QA process operates as follows:

1. Identifies problems or problem areas
2. Monitors the problem
3. Resolves the problem

QC is the aspect of QA that monitors technical equipment in order to maintain quality standards (Carlton & Adler, 2001). The QC concept is to stabilise various equipment components of the imaging chain and RFAs are one of these. Erratic performance of equipment causes repeat radiographs and unnecessary radiation exposure for patients. The term QC is also used to describe the evaluation of individual radiographs according to acceptance standards, a task which was undertaken by the designated panel, which evaluated the rejected films in order to distinguish the various reasons for rejection. The fact that no QC programme or ECs have ever been used in these departments before possibly explains why the reject rates obtained in the retrospective study were so high.

5.8 Recommendations for improvements in current practice

5.8.1 RFAs

The radiographers and students of the x-ray departments involved are advised to conduct RFAs on a continuous basis in order to obtain more useful information. If the research period had been longer, more results could have been obtained from a larger sample and a more accurate reflection of the departmental reject rates could have been achieved. With the ongoing use of RFAs, the performance of the department could be monitored over a longer period. The researcher suggests that a more extensive study is required including a wider range of clinical facilities within Namibia, using both government facilities and private practices as the research population, in order to obtain a national reject rate.

RFAs form an integral component of a QA programme in a diagnostic x-ray department (Muhogora *et al.*, 1999). Muhogora *et al.* (1999) add that the establishment of a QA programme is useful where no such programme has been used previously. Reiner *et al.* (2006) state that a specially trained QA specialist is a good addition to the staff, as overall image quality and consistency could be improved as a result of a consistent set of standards being applied to all images. A QA specialist would also be able to provide radiographers with valuable educational feedback. The x-ray departments involved in the present study do not have a QA programme in place nor do they employ QA specialists. They are, however, urged to do so because such an innovation would benefit these departments in numerous ways. For example, instead of the radiographer taking the decision to repeat a radiograph alone, the QA specialist could be consulted to confirm the decision. Where students are concerned a clinical tutor could be consulted. This aspect should be added to departmental protocol as standard practice. Since Namibia does not have QA specialists or clinical tutors, the researcher suggests that x-ray departments in this country encourage willing radiographers to register for courses to qualify themselves for these purposes.

The ninth assumption of this study states that equipment used would be functioning optimally throughout the study period. It is suggested in this regard that all apparatus used should be inspected and serviced on a regular basis and processor variations should be kept strictly within tolerance limits to ensure minimal effect on image production (Watkinson, Moores & Hill, 1984). Watkinson, Moores and Hill (1984) add that, by implementing a processor QC programme, reject rates can be reduced by up to 30%.

5.8.2 Exposure selection

Results from the current study suggest that exposure errors are the most frequent cause of rejection. It is recommended that clinical practice could be improved by implementing continuous professional development for radiographers in the form of in-service training. In radiography, life-long learning is essential in creating an environment in which clinical excellence will flourish (Hardy & Persaud, 2001). Therefore, radiographers should be encouraged and motivated to, for example, attend courses and conferences to increase their knowledge and expertise. Teaching institutions in Namibia, namely, the University of Namibia and the National Health Training Center, should recognise this gap in knowledge and review their curricula accordingly.

Comment [AK21]: Should you say 'and the literature consulted' as well here

McKinlay and McCauley (1977) note that the use of automatic exposure control (AEC) should reduce exposure errors. However, AEC is not suitable for non bucky exposures. Anatomically programmed radiographic equipment will assist a radiographer when selecting exposures, who can then focus all his or her attention on patient positioning. The researcher suggests that the x-ray equipment used at both venues A and B should be programmed with accurate exposure factors for all anatomical regions.

Comment [AK22]: Is this the right word to use here?

During the current study, ECs were compiled for four x-ray rooms at venue B exclusively and only for extremity examinations. Callipers were used to measure extremities only. It is recommended that ECs should be compiled for all x-rays rooms, at both hospitals and for all examinations performed and callipers should be used for all patients. The consistent use of callipers for assessing body part thickness and hence selecting exposure factors may lead to more consistency. If used regularly, radiographers and students would be able to produce optimal image quality on a continuous basis. Thus, fewer repeats would be required and, as a result, patient radiation dose would be reduced.

According to the South African Regulations Concerning the Control of Electronic Products (1971), an EC should be updated on a yearly basis or when repairs or adjustments are made to the x-ray equipment. As Namibia has adopted this law, the researcher advises that it should be complied with.

The researcher further recommends that exposure factors be recorded in the patient file, hospital passport or x-ray envelope. This will assist radiographers during follow-up procedures and may be used when calculating the radiation dose received by a patient over a period of time.

5.8.3 Viewing boxes

It is recommended that all viewing boxes in a department are matched as uniformly as possible (Chu *et al.,* 1982). This will ensure uniformity between radiographer, radiologist and referring clinicians, and provide a reference basis for exposure selection suitable for diagnostic films.

5.9 Recommendations for future research

5.9.1 RFA

RFAs may provide information on the number and size of films used, which can be applied to determine departmental expenditure in relation to reject films. The precise square metrage of rejected film can be calculated and the price per square metre determined. The present study excluded this aspect, but it is an opportunity for future research.

5.9.2 Reject rate

The departmental reject rate identified in this study is not a true representation of the departments' overall reject rate for all examinations, as only extremities were investigated. When conducting RFAs, several reasons for rejection can be established and all examinations performed in the department should be included. However, the current research only scrutinised exposure related reject films and reject extremity films, thus a complete RFA could be conducted in future to analyse all the causes for rejection and all procedures that should be included. The reject rate for specific examinations could also be calculated, as well as for different x-ray rooms. Interventions could then eventually be implemented to reduce the reject rate in general.

5.9.3 Radiographic staff work experience

The present research did not explore the relationship between the number of rejected films and the work experience of radiographic staff. This is a possible aspect for future investigation.

5.9.4 Patient radiation dose

Another important factor that the current research did not consider is the correlation between reject films and patient radiation dose. This is an issue that could be researched in future.

5.9.5 Digital and computed radiography

Digital and computed radiography are emerging modalities that many practices are starting to use, as they replace conventional film/screen systems. With digital systems, images can be produced, evaluated, manipulated, sent to a network of computers or deleted (X-ray Newsletter Division of Environmental Health, 2006).

With digital radiography, if the radiographic detector is improperly exposed the image does not become too light or too dark, as its wide dynamic range maintains contrast and image appearance. This aspect of digital imaging enables the radiographer to take images over a wide range of exposure levels (X-ray Newsletter Division of Environmental Health, 2006). If an image is produced using too much exposure, the system will simply compensate for the overexposure. There is thus a tendency by radiographers who operate digital equipment to routinely overexpose a patient in order to obtain better images. This is referred to as dose creep (Strauss, Pitura, Spahn, & MacCutcheon, 2007). Dose creep occurs when the radiation dose delivered to the patient gradually rises in the time following digital x-ray implementation (Casey, 2007). Radiographers are advised to try to prevent dose creep.

Lau *et al. (*2004) state that with the use of this technology the need for repeat examinations resulting from exposure errors will be significantly reduced. In the Reiner *et al.* (2006) report it is mentioned that the reject rate decreased from 10% to 0.8% after the transition from film/screen imaging to digital imaging. Hardy and Persaud (2001) add that computed radiography will result in cost-effective practice as films will not be rejected, in other words, unacceptable images will be deleted from the system.

However, according to well-known radiographic equipment suppliers and engineers in Namibia, the purchase and installation of digital equipment is costly (Fidler & Van Rensburg, 2009). However, to be more specific, initial purchasing costs are high but medium to long-term costs are reasonable. The researcher suggests that the departments used for this study should consider changing to computed radiography because it would be more cost-effective.

Radiology information system (RIS) and picture archiving and communication system (PACS) are also advised. However, PACS is expensive to implement and maintain (Ridley, 2009). Notwithstanding, Ridley's study proved that digital imaging is much more costly than filmless imaging.

The researcher proposes that the departments explore the possibility of changing to digital systems in future. A needs assessment and a cost-benefit analysis could be carried out in advance. When purchasing a digital radiography system it should be considered that the equipment will provide the radiographer with an exposure control index. This will inform the radiographer that the image is properly exposed.

It is advised that the Allied Health Professions Council of Namibia, University of Namibia, Ministry of Health and Social Services and private practices should provide training opportunities, such as workshops, conferences and short courses, to prepare radiographers for these new imaging systems.

5.9.6 Student rotation

During the current study students rotated between venues A and B on a weekly basis. For future research it is advised that students be allocated to a specific venue for the duration of the study.

5.10 Limitations of the study

Student rotation influenced the results of the study because all the students produced reject films for the data A, B, A_1 and B_1. The researcher assumes that the students who were working at venue A retained and used knowledge relating to the training on the use of ECs when producing reject films for data A and A_1. Thus the reject rate at venue A also decreased after the intervention. For future endeavours the students should be divided into two groups and should work at only one of the x-ray departments for the duration of the study. Refer to the first and fifth assumptions.

With reference to the second and seventh assumptions, when considering the results obtained from venues A and B the researcher can give no guarantee that the same radiographers were present during the retrospective and prospective phases, taking into account sick leave, vacation leave, resignations and new appointments. The same applies for the students. This may have had an impact on the results of the study. In a future study this should be considered.

In relation to the third assumption, all students were unfamiliar with the use of ECs prior to the start of the current study. The researcher trained the 2009 second and third year students in the use of ECs because all the students worked at both venues. The researcher cannot guarantee that all students gained the same knowledge and skills during this training. Validation in this regard should be considered in future endeavours.

With regard to the fourth assumption, the researcher cannot confirm that the students' applied knowledge and skills pertaining to the use of ECs were applied effectively and continuously when working at venue B.

Pertaining to the eighth assumption, the researcher cannot substantiate that students did not share the knowledge on use of ECs with the radiographers included in the current study.

Ideally, all equipment used in any study should be in a good working order throughout the study period. Refer to the ninth and eleventh assumptions.

With regard to the tenth assumption, the researcher cannot guarantee that the students used manual exposures for the production of all extremity radiographs throughout the study period.

With reference to the twelfth, thirteenth and fourteenth assumptions, it was impossible for the researcher to be present when every extremity radiograph was produced. Thus she could not state categorically that collimation was standardised, that added filters were not used, or that films and processing chemicals were securely stored during the study.

5.11 Summary

The purpose of this study was to determine the retrospective departmental and student reject rates. This purpose has been achieved in that, during the prospective phase, the introduction and use of ECs significantly decreased both student and departmental reject rates at venues A and B.

The conclusions have been stated in relation to the sub-problems and hypotheses. Recommendations for improvement in current practice, as well as recommendations for future research, have also been provided.

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Personal communication

Fidler, J. & Van Rensberg, O. Personal communication, September 30, 2009.

Appendices

Appendix A

Clinical rosters for students

First year students 2008

	21-25.07	28.07-01.08	04-08.08	11-15.08	18-22.08	25-29.08	01-05.09	15-19.09	22-26.09	29.09-03.10	06-10.10	13-17.10	20-24.10	27-31.10
Reception KSH			Ka	Bu	Fr	An	He	As	Co	Am	Va			
Room 1 WCH				Ka	Bu	Fr	An	He	As	Co	Am	Va		
Darkroom KSH	Va				Ka	Bu	Fr	An	He	As	Co	Am	Va	
Room 2 WCH	Am	Va				Ka	Bu	Fr	An	He	As	Co	Am	Va
Room 3 KSH	Co	Am	Va				Ka	Bu	Fr	An	He	As	Co	Am
Room 1 WCH	As	Co	Am	Va				Ka	Bu	Fr	An	He	As	Co
Room 4 KSH	He	As	Co	Am	Va				Ka	Bu	Fr	An	He	As

Darkroom **WCH**	An	He	As	Co	Am	Va				Ka	Bu	Fr	An	He
Room 5 **KSH**	Fr	An	He	As	Co	Am	Va				Ka	Bu	Fr	An
Room 2 **WCH**	Bu	Fr	An	He	As	Co	Am	Va				Ka	Bu	Fr
Room 6 **KSH**	Ka	Bu	Fr	An	He	As	Co	Am	Va				Ka	Bu
Room 1 **WCH**		Ka	Bu	Fr	An	He	As	Co	Am	Va				Ka

Van Rooyen: Va Coetzee: Co Heita: He Frederick: Fr Amuntenya: Am Ashipembe: As Anton: An Busch: Bu
Kandjala: Ka

Second year students 2008

Date	**18.02-22.02**	**25.02-29.02**	**17.03-20.03**	**31.03-04.04**	**21.04-25.04**	**28.04-02.05**	**19.05-23.05**	**26.05-30.05**	**04.08-08.08**	**11.08-15.08**	**01.09-05.09**	**15.09-09**	**06.10-10.10**	**13.10-17.10**
Room 3 **KSH**	Ka	Shin	Sa	Tj	Fr	Ts	Shi	As	Hi	Lu	Cl	Ka	Shin	Sa
EUG **WCH**	Cl	Ka	Shin	Sa	Tj	Fr	Ts	Shi	As	Hi	Lu	Cl	Ka	Shin
Screen **KSH**	Lu	Cl	Ka	Shin	Sa	Tj	Fr	Ts	Shi	As	Hi	Lu	Cl	Ka
Mobiles **WCH**	Hi	Lu	Cl	Ka	Shin	Sa	Tj	Fr	Ts	Shi	As	Hi	Lu	Cl
Room 4 **KSH**	As	Hi	Lu	Cl	Ka	Shin	Sa	Tj	Fr	Ts	Shi	As	Hi	Lu
EUG **KSH**	Shi	As	Hi	Lu	Cl	Ka	Shin	Sa	Tj	Fr	Ts	Shi	As	Hi
Screen **WCH**	Ts	Shi	As	Hi	Lu	Cl	Ka	Shin	Sa	Tj	Fr	Ts	Shi	As
EUG **KSH**	Fr	Ts	Shi	As	Hi	Lu	Cl	Ka	Shin	Sa	Tj	Fr	Ts	Shi
Room 1 **WCH**	Tj	Fr	Ts	Shi	As	Hi	Lu	Cl	Ka	Shin	Sa	Tj	Fr	Ts
Room 4 **KSH**	Sa	Tj	Fr	Ts	Shi	As	Hi	Lu	Cl	Ka	Shin	Sa	Tj	Fr
Room 2 **WCH**	Shin	Sa	Tj	Fr	Ts	Shi	As	Hi	Lu	Cl	Ka	Shin	Sa	Tj

Kahuure: Ka Cloete: Cl Ludick: Lu Hikerwa: Hi Ashipala: As Shikongo: Shi Tsauses: Ts Fransisco: Fr Tjiroze: Tj
Saunders: Sa Shininge: Shin

Second year students 2009

Date	**23-27.02**	**02-06.03**	**23-27.03**	**30.03-03.04**	**27-30.04**	**05-08.05**	**26-29.05**	**01-05.06**	**10-14.08**	**17-21.08**	**07-11.09**	**21-25.09**	**12-16.10**	**19-23.10**
Room 3 **KSH**	An						Bu	If	Am	Fr	As	An		
EUG **WCH**	As	An						Bu	If	Am	Fr	As	An	
Screen **KSH**	Fr	As	An						Bu	If	Am	Fr	As	An
Mobiles **WCH**	Am	Fr	As	An						Bu	If	Am	Fr	As
Room 4 **KSH**	If	Am	Fr	As	An						Bu	If	Am	Fr
EUG **KSH**	Bu	If	Am	Fr	As	An						Bu	If	Am
Screen **WCH**		Bu	If	Am	Fr	As	An						Bu	If
EUG **KSH**			Bu	If	Am	Fr	As	An						Bu
Room 1 **WCH**				Bu	If	Am	Fr	As	An					

Room 4 **KSH**					Bu	If	Am	Fr	As	An				
Room 2 **WCH**						Bu	If	Am	Fr	As	An			

Anton: An Frederick: Fr Amutenya: Am Ifugula: If Ashipembe: As Busch: Bu

Third year students 2009

Date	**09-13.03**	**16-20.03**	**06-09.04**	**20-24.04**	**11-15.05**	**18-20.05**	**08-12.06**	**27-31.07**	**03-07.08**	**24-28.08**	**31.08-04.09**	**28.09-02.10**	**05-09.10**	**26-30.10**	**02-06.11**
Screen WCH	Tj				Lu	Hi	As	Shik	Shin	Fr	Cl	Ka	Sa	Tj	
EUG KSH	Sa	Tj				Lu	Hi	As	Shik	Shin	Fr	Cl	Ka	Sa	Tj
Mobiles WCH	Ka	Sa	Tj				Lu	Hi	As	Shik	Shin	Fr	Cl	Ka	Sa
Room 4 KSH	Cl	Ka	Sa	Tj				Lu	Hi	As	Shik	Shin	Fr	Cl	Ka
Screen WCH	Fr	Cl	Ka	Sa	Tj				Lu	Hi	As	Shik	Shin	Fr	Cl
EUG KSH	Shin	Fr	Cl	Ka	Sa	Tj				Lu	Hi	As	Shik	Shin	Fr
Mammo/ General WCH	Shik	Shin	Fr	Cl	Ka	Sa	Tj				Lu	Hi	As	Shik	Shin
Room 5 KSH	As	Shik	Shin	Fr	Cl	Ka	Sa	Tj				Lu	Hi	As	Shik
Mobiles WCH	Hi	As	Shik	Shin	Fr	Cl	Ka	Sa	Tj				Lu	Hi	As

Room 6 **KSH**	Lu	Hi	As	Shik	Shin	Fr	Cl	Ka	Sa	Tj				Lu	Hi
General **WCH**		Lu	Hi	As	Shik	Shin	Fr	Cl	Ka	Sa	Tj				Lu
General **KSH**			Lu	Hi	As	Shik	Shin	Fr	Cl	Ka	Sa	Tj			
General **WCH**				Lu	Hi	As	Shik	Shin	Fr	Cl	Ka	Sa	Tj		

Tjiroze: Tj Cloete: Cl Shikongo: Shik Ludick: Lu Saunders: Sa Fransisco: Fr Ashipala: As Kahuure: Ka Shininge: Shin

Hikerwa: Hi

Appendix B

Approval letter

9 - 0 / 0001

REPUBLIC OF NAMIBIA

Ministry of Health and Social Services

Private Bag 13198
Windhoek
Namibia

Ministerial Building
Harvey Street
Windhoek

Tel: (061) 2032538
Fax: (061) 272286
E-mail: mzauana@mhss.gov.na

Enquiries: Ms. M. Zauana **Ref.:** 17/3/3/AP **Date:** 04 June 2008

OFFICE OF THE PERMANENT SECRETARY

Ms. Luzanne Kalondo
P. O. Box 3654
Windhoek
Namibia

Dear Ms. Kalondo

EFFECT OF EXPOSURE CHARTS ON REJECT RATE OF EXTREMITY RADIOGRAPHS

1. Reference is made to your application to conduct the above-mentioned study.

2. The proposal has been evaluated and found to have merit.

3. Kindly be informed that approval has been granted under the following conditions:

3.1 The data collected is only to be used for your Masters degree;

3.2 A quarterly progress report is to be submitted to the Ministry's Research Unit;

3.3 Preliminary findings are to be submitted to the Ministry before the final report;

3.4 Final report to be submitted upon completion of the study;

3.5 Separate permission to be sought from the Ministry for the publication of the findings.

Wishing you success with your project.

Yours sincerely,

Mr. K. Kahuure.
PERMANENT SECRETARY

Forward with Health for all Namibians by the Year 2005!

Appendix C

Notice to students and staff

TO: **All X-Ray Department Staff & Students**

FROM: **Luzanne Kalondo (Researcher)**

DATE: **30 April 2008**

RE: **RESEARCH TO BE CONDUCTED AT WCH AND KSH X-RAY DEPARTMENTS.**

Introduction

Radiographs are produced to assist medical practitioners in making a diagnosis. Some radiographs are discarded because they have no diagnostic value. These are referred to as rejected films.

Whenever a film is rejected, a repeat radiograph must be done. Repetition of radiographs causes concerns such as unnecessary radiation exposure to the patient, increased costs, longer patient waiting time, additional workload for radiographers and reduced x-ray tube life.

Reject film analysis (RFA) is a process where discarded films are analysed with the purpose of establishing the reasons for rejection. According to the literature (Bryan, 1987 & Peer *et al.* 2001) incorrect selection of radiographic exposure factors, inaccurate positioning of the part under examination, improper processing conditions, radiographic equipment malfunction, as well as patient movement during an exposure, are the most common causes of reject films.

RFA forms an integral component of a quality assurance (QA) programme in a diagnostic x-ray department. Radiographic examinations entail the use of exposure factors, namely (i) kilovoltage (kV), which is the potential difference between the cathode and the anode of the x-ray tube, and (ii) tube current, in milliamperes, which is applied over a set time (mAs), and these result in the production of ionising radiation. The selection of exposure factors varies according to the size of the patient, thickness of the area being examined, film/screen combination and focal film distance (FFD).

In order to produce good quality radiographs, exposure factors are determined for different anatomical parts and are then summarized in an exposure chart (EC). An EC is a table consisting of information, for example, kV and mAs, which enables the radiographer to select the correct exposure factors to use when exposing a patient.

In most developed countries and many developing countries, such as South Africa, there are laws and regulations that control the use of ionising radiation as this has potential harmful effects on living cells. The use of ECs for each x-ray machine is a legal requirement for licensing of the equipment in South Africa. The South African legislation was adopted by Namibia but is not widely implemented, thus some imaging departments in Namibia do not make use of ECs.

As the KSH and WCH X-Ray Departments in Namibia do not have ECs for extremity radiography it was identified as suitable venues for the proposed research. KSH is the largest radiography training hospital in Namibia, and would be convenient for accessing data for the proposed study.

Approximately 10 000 and 40 000 patients are examined, and about 20 000 and 60 000 radiographic films are used annually at WCH and KSH respectively. It is unknown how many of these films are rejected because the previous reject film analysis, done by Gabone, Cupido, and Bloodstaan, in 2006 (unpublished), was limited to certain x-ray examinations which excluded extremity radiography.

Purpose of study

The purpose of the study is to determine the current reject rate for use as a benchmark in order to design and implement a quality improvement program to reduce the reject rate over a seven and a half month period. During the three months that the extremity reject films are collected for the retrospective study ECs will be compiled, students will be taught how to use them and they will be introduced.

The study will address exposure factor selection by compiling and introducing ECs to aid students in the production of diagnostic radiographs.

The target population will be all the extremity rejected films of the departments for the retrospective and prospective RFA periods.

The proposed study will be done in two stages, namely retrospective and prospective RFAs.

Retrospective phase

- Permission was obtained from the Permanent Secretary of the Ministry of Health and Social Services before the study could commence because their premises, staff and material will be used for data collection.
- Students will be provided with stickers, prior to the commencement of the retrospective study, which they will use when producing radiographs throughout the research period. The use of these stickers will enable the researcher to differentiate between reject films produced by students and those produced by radiographers.
- Students will be requested to place a sticker as well as the number of films used on the darkroom cards of the patients. The researcher will place a container next to the daylight printer in which the cards will be stored.
- A specially marked bin will be provided to collect the reject films.
- Retrospective RFAs will be conducted on rejected extremity radiographs to determine the number that were rejected due to inappropriate exposure factors.
- ECs for extremity radiographs will then be compiled in accordance with methods used by Bushong (1993) & De Vos (1995). Accurate exposure factors will be determined by performing test exposures using a body equivalent adult pelvis phantom. Once the exposure factors have been established for the hip of the phantom they can be used to compile extremity exposure factors.
- Students will be shown how to measure patients using callipers. All extremity patients will be measured.
- Students will also be trained to use ECs effectively by selecting exposure factors according to patient thicknesses measured. Students will be requested to record these measurements and exposure factors used on a provided form.
- ECs will be introduced at KSH. Students will be instructed to use ECs when radiographing extremities. Image quality of radiographs produced will then be monitored by a panel using predetermined criteria.
- ECs will be used for four weeks before the prospective RFA is conducted because students need to become familiar with their use and the number of rejected films will be manageable.

Note: It is important that students understand that the purpose of this study, is not to identify insufficient students but merely to assess the current conditions in the department and to facilitate improvement.

Prospective phase

- A prospective RFA will be conducted for eight weeks to determine if there has been a change in the reject rate obtained during the retrospective analysis.
- The prospective RFAs will be an identical repetition of the retrospective phase.
- The student reject rate will be compared to that of the retrospective RFA to determine if the introduction and use of ECs reduced reject rate at KSH.
- The overall reject rates obtained from WCH and KSH will be compared to establish if the use of ECs at KSH reduced reject rate compared to the reject rate obtained at WCH where no ECs were used.

Conclusion

The researcher would like to urge all involved parties for your dedicated assistance with regard to the proposed study.

Thanking you in advance.

____

Luzanne Kalondo

Appendix D

Darkroom card

WINDHOEK CENTRAL HOSPITAL COMPLEX

Name: ____

Surname: ____ Age: _________

X-ray no: _________________________ Hosp:________ Sex: _________

Appendix E

Notice placed at patient identification marker

DEAR STUDENTS.

KINDLY PLACE A STICKER ON THE DARKROOM CARD.

KINDLY WRITE THE NUMBER OF FILMS USED FOR THE EXAMINATION ON THE DARKROOM CARD.

PLEASE DO NOT REMOVE ANY CARDS FROM THE BOX.

THESE CARDS WILL BE USED FOR RESEARCH PURPOSES.

THANK YOU FOR YOUR CO-OPERATION.

LUZANNE

Appendix F

Notice placed at reject bin

DEAR STAFF & STUDENTS.

KINDLY PLACE ALL EXTREMITY REJECTED FILMS INTO THIS BOX.

PLEASE DO NOT REMOVE ANY FILMS FROM THE BOX.

THESE FILMS WILL BE USED FOR RESEARCH PURPOSES.

THANK YOU FOR YOUR CO-OPERATION.

LUZANNE

Appendix G

Weekly data collection sheet

Hospital: ________________________

Department RR:

Date:____________ Week: ___________ Day: ____________________ Time: ________

Nr	Nt	RR

Exposure fault reject films produced by:

No. produced by students	No. produced by radiographers

Student RR:

Nr	Nt	RR

Student exposure fault reject films:

No. exposure faults	No. other faults

Student exposure fault reject films:

Overexposure	Underexposure

Student exposure fault reject films:

No. kV related	No. mAs related

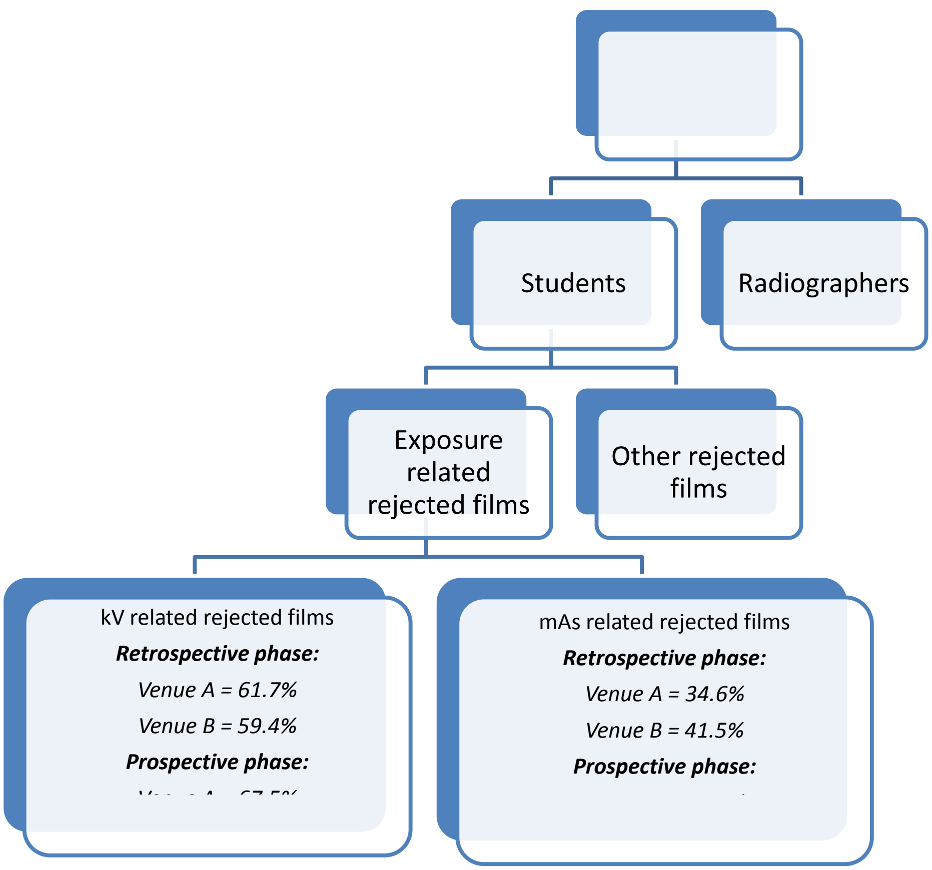
Appendix H

Criteria for data collection

- The same viewing area will be used, in other words, the same viewing box with the same light intensity. The viewing boxes used in the department in question use 15W fluorescent tubes, and consist of white enamel reflecting surfaces and Perspex screens.
- The ambient light should be the same – data collection will be done at the same time of day.
- The panel members will stand in exactly the same place when collecting data in order to prevent different light reflections.
- The same panel members will conduct data collection throughout the study period.

Appendix I

Data handling procedure



Appendix J

Exposure chart

Anatomical part	View	Thickness in cm	kV	mAs	FFD in cm	Film/screen combination	With/without grid
Hand	PA	2	52	3.2	100	C2	Without grid
	OBL	2	52	3.2	100	C2	Without grid
	LAT	7	55	3.2	100	C2	Without grid
Wrist	PA	2.5	55	4	100	C2	Without grid
	LAT	4.5	55	5	100	C2	Without grid
Forearm	AP	5	55	5	100	C2	Without grid
	LAT	6.5	57	5	100	C2	Without grid
Elbow	AP	5.5	57	5	100	C2	Without grid
	LAT	7	57	5	100	C2	Without grid
Humerus	AP	7	60	5	100	C2	Without grid
	LAT	7	60	5	100	C2	Without grid
Shoulder	AP	13	66	25	100	C2	With grid
	LAT	16	73	50	100	C2	With grid
Foot	DP	4.5	55	4	100	C2	Without grid
	OBL	4	55	4	100	C2	Without grid
	LAT	6	57	4	100	C2	Without grid
Ankle	AP	10.5	57	5	100	C2	Without grid
	OBL	5.5	55	5	100	C2	Without grid

	LAT	5.5	55	5	100	C2	Without grid
Tibia and fibula	AP	9	60	8	100	C2	Without grid
	LAT	8	60	8	100	C2	Without grid
Knee	AP	10	66	16	100	C2	With grid
	LAT	10	63	16	100	C2	With grid
Femur (including knee)	AP	13.5	66	40	100	C2	With grid
	LAT	13.5	66	40	100	C2	With grid
Femur (including hip)	AP	17	70	40	100	C2	With grid
	LAT	17	70	40	100	C2	With grid
Hip	AP	20	73	50	100	C2	With grid
	OBL	15	70	50	100	C2	With grid
Pelvis	AP	21.5	73	50	100	C2	With grid

Appendix K

Pelvis phantom

Appendix L

Volunteer informed consent

P. O. Box 3654

Windhoek

NAMIBIA

20 November 2008

Dear Volunteer.

RE: INFORMED CONSENT FOR RESEARCH.

I would hereby like to introduce myself. My name is Luzanne Kalondo and I am one of the radiography lecturers at the University of Namibia. I am registered as a Magister Technologiae student at the Nelson Mandela Metropolitan University in Port Elizabeth, South Africa.

My topic is *Effect of exposure charts on reject rate of extremity radiographs.*

Windhoek Central Hospital (WCH) and Katutura State Hospital (KSH) were identified as the venues for the proposed study.

Reject film analysis is used to describe a process where discarded radiographic films are scrutinized with the purpose of establishing what the reasons for rejections are. It is important to acknowledge the reasons for rejection to be able to introduce remedial measures to reduce reject rate.

A reject film analysis program as well as exposure charts will be introduced and primary data will be collected. All data required will be obtained from extremity radiography rejected films and darkroom cards. However, a volunteer is required for measurement. All extremities of the volunteer will be measured using callipers.

A retrospective reject film analysis will be conducted. The data collected will be used to calculate extremity reject rate of the department. Exposure charts will then be introduced only at KSH with the purpose of reducing reject rate. Exposure charts will not be introduced at WCH for control group purposes. A prospective reject film analysis will be conducted. The retrospective reject rate will be compared with the prospective reject rate to determine if there was any significant change after the introduction of exposure charts.

In order to compile an exposure chart measurements need to be taken of all extremities. The anatomical areas of interest will be measured using callipers.

The proposed study will have no financial implication for the patient. The patient will not be exposed to any discomfort during the course of the study and it is not a lengthy procedure.

The proposed study and the research methodology involved have been approved by the Advanced Degrees Committee of the Nelson Mandela Metropolitan University.

It is against this background that I kindly request your voluntary informed consent to take measurements of your extremities only for the purpose of the research mentioned above.

Attached please find a copy of my research proposal for further reference.

Please do not hesitate to contact me for any enquiries.

I trust that my request will receive your approval.

Kind regards

____

Luzanne Kalondo

Tel: +264 61 206 3792 (w)

+264 61 239160 (h)

+264 81 298 9065 (c)

Fax: +264 61 206 3922

E-mail: lkalondo@unam.na

Volunteer's full name in print: ________________________________

Volunteer's signature: _______________________________________

Signed at ____________________________, on the ________ day of ________________ 200 ____.

Appendix M

Patient measurement positions

Anatomical part	View	Measurement position
Third finger	PA	Proximal interphalangeal joint
	Lat	Proximal interphalangeal joint
Hand	PA	Third metacarpophalangeal joint
	Lat	Second metacarpophalangeal joint
	Obl	Third metacarpophalangeal joint
Wrist	PA	Midway between the radial and ulna styloid processes
	Lat	Radial styloid process
Forearm	AP	Midway between the wrist and the elbow joints
	Lat	Midway between the wrist and the elbow joints
Elbow	AP	2.5 cm distal to the midpoint of a line between the epicondyles of the humerus
	Lat	Lateral epicondyle of the humerus
Humerus	AP	Midway between the elbow and the wrist joint
	Lat	Midway between the elbow and the wrist joint
Shoulder	AP	Coracoid process of the scapula
	Obl	Medial boder of the scapula, centred to the head of the humerus
Third toe	DP	Third metatarsophalageal joint
	Lat	Metatarsophalageal joint
Foot	DP	Cuboidnavicular joint
	Lat	Navicularcuneiform joint
	Obl	Cuboidnavicular joint

Ankle	AP	Midway between the malleoli
	Lat	Medial malleolus
	Obl	Midway between the malleoli
Tibia and fibula	AP	Midway between the tibia and fibula
	Lat	Midway between the tibia and fibula
Knee	AP	Midway between the palpable upper borders of the tibial condyles
	Lat	Midpoint of the palpable superior border of the medial tibial condyle
Lower femur	AP	15 cm above the point midway between the palpable upper borders of the tibial condyles
	Lat	15 cm above the midpoint of the palpable superior border of the medial tibial
Upper femur	AP	9 cm below the lower border of the symphysis pubis and 11 centimeters to the right or left
	Lat	9 cm below the lower border of the symphysis pubis and 11 cm to the right or left
Hip	AP	Midway between the upper border of the symphysis pubis and the anterior posterior iliac spine
	Obl	The femoral pulse

Appendix N

Measurements obtained from volunteer

Anatomical part	View	Thickness in cm
Hand	PA	2
	OBL	2
	LAT	7
Wrist	PA	2.5
	LAT	4.5
Forearm	AP	5
	LAT	6.5
Elbow	AP	5.5
	LAT	7
Humerus	AP	7
	LAT	7
Shoulder	AP	13
	LAT	16
Foot	DP	4.5
	OBL	4
	LAT	6
Ankle	AP	10.5
	OBL	5.5
	LAT	5.5
Tibia and	AP	9

Fibula	LAT	8
Knee	AP	10
	LAT	10
Femur (including knee)	AP	13.5
	LAT	13.5
Femur (including hip)	AP	17
	LAT	17
Hip	AP	20
	OBL	15
Pelvis	AP	21.5

Appendix O

Consent for EC test exposures

P. O. Box 3654

Windhoek

NAMIBIA

28 November 2008

Dear Patient.

RE: INFORMED CONSENT FOR RESEARCH.

I would hereby like to introduce myself. My name is Luzanne Kalondo and I am one of the radiography lecturers at the University of Namibia. I am registered as a Magister Technologiae student at the Nelson Mandela Metropolitan University in Port Elizabeth, South Africa.

My topic is *Effect of exposure charts on reject rate of extremity radiographs.*

Windhoek Central Hospital (WCH) and Katutura State Hospital (KSH) were identified as the venues for the proposed study.

Reject film analysis is used to describe a process where discarded radiographic films are scrutinized with the purpose of establishing what the reasons for rejections are. It is important to acknowledge the reasons for rejection to be able to introduce remedial measures to reduce reject rate.

A reject film analysis program as well as exposure charts will be introduced and primary data will be collected. All data required will be obtained from extremity radiography rejected films and darkroom cards. However, a volunteer is required for measurement. All extremities of the volunteer will be measured using callipers.

A retrospective reject film analysis will be conducted. The data collected will be used to calculate extremity reject rate of the department. Exposure charts will then be introduced only at KSH with the purpose of reducing reject rate. Exposure charts will not be introduced at WCH. A prospective reject film analysis will be conducted. The retrospective reject rate will be compared with the prospective reject rate to determine if there was any significant change after the introduction of exposure charts.

The compiled exposure chart needs to be tested for accuracy. The anatomical area of interest will be measured using callipers. After that you will be examined.

The proposed study will have no financial implication for the patient. The patient will not be exposed to any discomfort during the course of the study and it is not a lengthy procedure.

The proposed study and the research methodology involved have been approved by the Advanced Degrees Committee of the Nelson Mandela Metropolitan University.

It is against this background that I kindly request your voluntary informed consent to take measurements of your extremities only for the purpose of the research mentioned above.

Attached please find a copy of my research proposal for further reference.

Please do not hesitate to contact me for any enquiries.

I trust that my request will receive your approval.

Kind regards

____

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Volunteer's full name in print: _________________________________

Volunteer's signature: ____

Signed at _____________________________, on the ________ day of ________________ 200 ___________

Appendix P

Form used to record patient measurements and exposure factors used

Anatomical part	View	Measurement in cm	kV selection	mAs selection

Appendix Q

Notice how to use EC

HOW TO USE EXPOSURE CHARTS

1. Measure the thickness of the anatomical part to be examined at the centring point using callipers. Callipers can be found on top of the wooden cassette storage container.
2. Compare the thickness measured with the thickness stated on the exposure chart.
3. For every one centimetre difference, increase or decrease the exposure chart kV by one kV.

E.g.

Anatomical part	View	Thickness in cm	kV	mAs	FFD in cm	Film/screen combination	With/without grid
Hand	PA	2	52	3.2	100	C2	Without grid

If the patient’s hand measures 3 cm, kV will increase to 53.

OR

If the patient’s hand measures 1 cm, kV will decrease to 51.

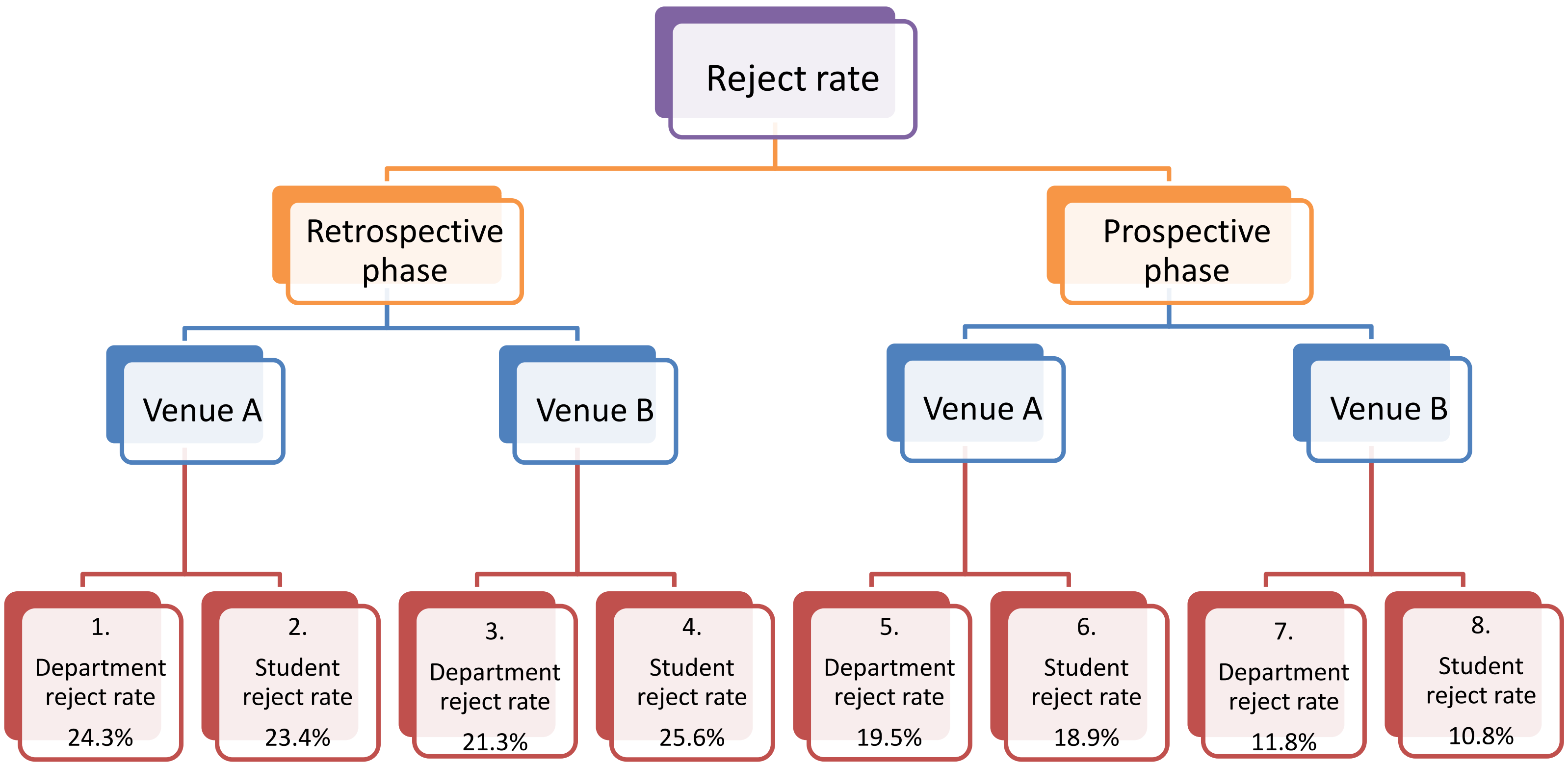
If the kV value is impossible to select on the control panel of the x-ray equipment, the kV closest to it can be used.

The mAs remain the same.

On completion of the examination please complete the patient measurement strip.

Appendix R

Reject rates calculated



Appendix S

Weekly rejected radiographs

Retrospective phase

Retrospective phase Week 2		
Weekly rejected films	Venue A	Venue B
Total number of extremity radiographs produced by the x-ray department, i.e. radiographers and students combined	62	397
Total number of extremity reject radiographs produced by the x-ray department	19	67
Department reject rate in %	30.4%	16.9%
Total number of extremity radiographs produced by the students	14	200
Total number of reject extremity radiographs (n^a) produced by the students	5	41
Student reject rate	35.7%	20.5%
Radiographer reject rate	29.2%	13.2%
Total number of reject extremity radiographs (n^b) due to exposure factors	3	33
Final percentage rejects, produced by students, due to exposure factors in %	60.0%	80.5%

Retrospective phase Week 3		
Weekly rejected films	Venue A	Venue B
Total number of extremity radiographs produced by the x-ray department, i.e. radiographers and students combined	63	311
Total number of extremity reject radiographs produced by the x-ray department	16	79
Department reject rate in %	25.4%	25.4%
Total number of extremity radiographs produced by the students	43	152
Total number of reject extremity radiographs (n^a) produced by the students	12	36
Student reject rate	27.9%	23.7%
Radiographer reject rate	20.0%	27.0%
Total number of reject extremity radiographs (n^b) due to exposure factors	9	29
Final percentage rejects, produced by students, due to exposure factors in %	75.0%	80.6%

Retrospective phase Week 4		
Weekly rejected films	Venue A	Venue B
Total number of extremity radiographs produced by the x-ray department, i.e. radiographers and students combined	64	315
Total number of extremity reject radiographs produced by the x-ray department	13	61
Department reject rate in %	20.3%	19.4%
Total number of extremity radiographs produced by the students	48	158
Total number of reject extremity radiographs (n^a) produced by the students	10	35
Student reject rate	20.8%	22.2%
Radiographer reject rate	18.8%	16.6%
Total number of reject extremity radiographs (n^b) due to exposure factors	8	29
Final percentage rejects, produced by students, due to exposure factors in %	80.0%	82.9%

Retrospective phase Week 5		
Weekly rejected films	Venue A	Venue B
Total number of extremity radiographs produced by the x-ray department, i.e. radiographers and students combined	55	383
Total number of extremity reject radiographs produced by the x-ray department	16	88
Department reject rate in %	29.1%	23.0%
Total number of extremity radiographs produced by the students	37	168
Total number of reject extremity radiographs (n^a) produced by the students	11	46
Student reject rate	29.7%	27.4%
Radiographer reject rate	27.8%	19.5%
Total number of reject extremity radiographs (n^b) due to exposure factors	6	34
Final percentage rejects, produced by students, due to exposure factors in %	54.6%	73.9%

Retrospective phase Week 6		
Weekly rejected films	Venue A	Venue B
Total number of extremity radiographs produced by the x-ray department, i.e. radiographers and students combined	74	376
Total number of extremity reject radiographs produced by the x-ray department	18	81
Department reject rate in %	24.3%	21.5%
Total number of extremity radiographs produced by the students	52	223
Total number of reject extremity radiographs (n^a) produced by the students	11	58
Student reject rate	21.6%	26.0%
Radiographer reject rate	31.8%	15.0%
Total number of reject extremity radiographs (n^b) due to exposure factors	10	32
Final percentage rejects, produced by students, due to exposure factors in %	90.9%	55.2%

Retrospective phase Week 7		
Weekly rejected films	Venue A	Venue B
Total number of extremity radiographs produced by the x-ray department, i.e. radiographers and students combined	66	345
Total number of extremity reject radiographs produced by the x-ray department	9	79
Department reject rate in %	13.3%	22.9%
Total number of extremity radiographs produced by the students	42	196
Total number of reject extremity radiographs (n^a) produced by the students	7	53
Student reject rate	16.7%	27%
Radiographer reject rate	8.3%	17.4%
Total number of reject extremity radiographs (n^b) due to exposure factors	5	37
Final percentage rejects, produced by students, due to exposure factors in %	71.4%	69.8%

Retrospective phase Week 8		
Weekly rejected films	Venue A	Venue B
Total number of extremity radiographs produced by the x-ray department, i.e. radiographers and students combined	52	330
Total number of extremity reject radiographs produced by the x-ray department	14	66
Department reject rate in %	26.9%	20.0%
Total number of extremity radiographs produced by the students	35	192
Total number of reject extremity radiographs (n^a) produced by the students	9	41
Student reject rate	25.7%	21.4%
Radiographer reject rate	29.4%	18.1%
Total number of reject extremity radiographs (n^b) due to exposure factors	6	26
Final percentage rejects, produced by students, due to exposure factors in %	66.7%	63.4%

Prospective phase

Prospective phase Week 2		
Weekly rejected films	Venue A	Venue B
Total number of extremity radiographs produced by the x-ray department, i.e. radiographers and students combined	52	435
Total number of extremity reject radiographs produced by the x-ray department	10	48
Department reject rate in %	19.2%	11%
Total number of extremity radiographs produced by the students	43	293
Total number of reject extremity radiographs (n^a) produced by the students	8	31
Student reject rate	18.6%	10.6%
Radiographer reject rate	22.2%	12.0%
Total number of reject extremity radiographs (n^b) due to exposure factors	6	18
Final percentage rejects, produced by students, due to exposure factors in %	75.0%	58.1%

Prospective phase Week 3		
Weekly rejected films	Venue A	Venue B
Total number of extremity radiographs produced by the x-ray department, i.e. radiographers and students combined	39	382
Total number of extremity reject radiographs produced by the x-ray department	8	46
Department reject rate in %	20.5%	12.0%
Total number of extremity radiographs produced by the students	25	284
Total number of reject extremity radiographs (n^a) produced by the students	5	33
Student reject rate	20.0%	11.6%
Radiographer reject rate	21.4%	13.3%
Total number of reject extremity radiographs (n^b) due to exposure factors	4	24
Final percentage rejects, produced by students, due to exposure factors in %	80.0%	72.7%

Prospective phase Week 4		
Weekly rejected films	Venue A	Venue B
Total number of extremity radiographs produced by the x-ray department, i.e. radiographers and students combined	38	268
Total number of extremity reject radiographs produced by the x-ray department	7	18
Department reject rate in %	18.4%	6.7%
Total number of extremity radiographs produced by the students	27	183
Total number of reject extremity radiographs (n^a) produced by the students	6	12
Student reject rate	22.2%	6.6%
Radiographer reject rate	9.1%	7.1%
Total number of reject extremity radiographs (n^b) due to exposure factors	5	10
Final percentage rejects, produced by students, due to exposure factors in %	83.3%	83.3%

Prospective phase Week 5		
Weekly rejected films	Venue A	Venue B
Total number of extremity radiographs produced by the x-ray department, i.e. radiographers and students combined	36	346
Total number of extremity reject radiographs produced by the x-ray department	7	37
Department reject rate in %	19.4%	10.7%
Total number of extremity radiographs produced by the students	27	196
Total number of reject extremity radiographs (n^a) produced by the students	5	25
Student reject rate	18.5%	12.8%
Radiographer reject rate	22.2%	8%
Total number of reject extremity radiographs (n^b) due to exposure factors	4	20
Final percentage rejects, produced by students, due to exposure factors in %	80.0%	80.0%

Prospective phase Week 6		
Weekly rejected films	Venue A	Venue B
Total number of extremity radiographs produced by the x-ray department, i.e. radiographers and students combined	60	318
Total number of extremity reject radiographs produced by the x-ray department	11	38
Department reject rate in %	18.3%	12%
Total number of extremity radiographs produced by the students	42	274
Total number of reject extremity radiographs (n^a) produced by the students	8	26
Student reject rate	19.1%	9.5%
Radiographer reject rate	37.5%	27.3%
Total number of reject extremity radiographs (n^b) due to exposure factors	6	14
Final percentage rejects, produced by students, due to exposure factors in %	75.0%	53.9%

Prospective phase Week 7		
Weekly rejected films	Venue A	Venue B
Total number of extremity radiographs produced by the x-ray department, i.e. radiographers and students combined	40	357
Total number of extremity reject radiographs produced by the x-ray department	8	47
Department reject rate in %	20.0%	13.2%
Total number of extremity radiographs produced by the students	32	294
Total number of reject extremity radiographs (n^a) produced by the students	6	33
Student reject rate	18.8%	11.2%
Radiographer reject rate	25.0%	22.2%
Total number of reject extremity radiographs (n^b) due to exposure factors	4	22
Final percentage rejects, produced by students, due to exposure factors in %	66.7%	66.7%

Prospective phase Week 8		
Weekly rejected films	Venue A	Venue B
Total number of extremity radiographs produced by the x-ray department, i.e. radiographers and students combined	42	330
Total number of extremity reject radiographs produced by the x-ray department	9	31
Department reject rate in %	21.4%	9.4%
Total number of extremity radiographs produced by the students	38	261
Total number of reject extremity radiographs (n^a) produced by the students	7	21
Student reject rate	18.4%	8.1%
Radiographer reject rate	50%	14.5%
Total number of reject extremity radiographs (n^b) due to exposure factors	5	15
Final percentage rejects, produced by students, due to exposure factors in %	71.4%	71.4%

List of tables and headings per chapter

List of figures and headings per chapter

Chapter 1:

None

Chapter 2:

None

Chapter 3:

None

Chapter 4:

Chapter 5:

None

List of appendices with headings