

# **RADIATION PROTECTION PRACTICE IN DIGITAL RADIOGRAPHY IN EASTERN CAPE GOVERNMENT HOSPITALS**

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Dissertation submitted in fulfilment of the requirements for the Degree

**MAGISTER TECHNOLOGIAE:**

**RADIOGRAPHY: DIAGNOSTIC**

in the

Department of Clinical Sciences (Radiography Programme)  
Faculty of Health and Environmental Sciences

at the

Central University of Technology, Free State

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January 2019

## DECLARATION OF INDEPENDENT WORK

### DECLARATION WITH REGARD TO INDEPENDENT WORK

I, KARIN FOURIE, identity number \_\_\_\_\_ and student number \_\_\_\_\_, do hereby declare that this research project submitted to the Central University of Technology, Free State for the Degree MAGISTER TECHNOLOGIAE: RADIOGRAPHY: DIAGNOSTIC, is my own independent work; and complies with the Code of Academic Integrity, as well as other relevant policies, procedures, rules and regulations of the Central University of Technology, Free State; and has not been submitted before to any institution by myself or any other person in fulfilment (or partial fulfilment) of the requirements for the attainment of any qualification.



\_\_\_\_\_  
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**12/01/2019**  
**DATE**

## ACKNOWLEDGEMENTS

The completion of this dissertation would not have been possible without the assistance of the following individuals.

- First and foremost I would like to thank God, for giving me the strength, perseverance and knowledge to complete this research study and dissertation.
- To my supervisor, Dr Rene Botha for his help and support throughout the completion of this research study.
- To my co-supervisor, Dr Belinda Van Der Merwe, thank you for all your assistance and encouragement throughout this study.
- To Mrs Maryn Viljoen, my biostatistician, for completing the statistical analysis of this research study.
- To Mrs Luna Berg and Leonie Munro, my language editors for completing the language editing of this research study.
- To the government hospitals radiography department as well as the department heads, thank you for your assistance in allowing me to collect my data and complete my research study at your facility.
- To Riaan Van Der Venter and Jesmean Plaatjies, my reviewers, thank you for your time and assistance in helping me to review all the images.
- To the CUT research grant, thank you for providing the financial resources which enabled me to complete my research study.

- To the assessors who will be assessing this dissertation, thank you for your time and efforts put into this dissertation.
- To my mom and dad, thank you for all your support, prayers and encouragement in getting me through this dissertation.
- Lastly, my husband, thank you for all your support, patience and efforts in helping me to get through this dissertation.

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## LIST OF ACRONYMS AND ABBREVIATIONS

|       |   |
|-------|---|
| AEC   | Automatic exposure control                          |
| ALARA | As-Low-As-Reasonably-Achievable                     |
| AP    | Anterior-posterior                                  |
| CD    | Compact disc  |
| CPD   | Continuing professional development                 |
| CPUT  | Cape Peninsula University of Technology             |
| CR    | Computed radiography                                |
| CT    | Computed tomography                                 |
| CUT   | Central University of Technology                    |
| DAP   | Dose area product                                   |
| DI    | Deviation index                                     |
| DoH   | Department of Health                                |
| DNA   | Deoxyribonucleic acid                               |
| DR    | Direct digital radiography                          |
| DRL   | Diagnostic reference levels                         |
| EC    | Eastern Cape  |
| EI    | Exposure index                                      |
| ESD   | Entrance surface dose                               |
| FFD   | Focus-film distance                                 |
| HPCSA | Health Professions Council of South Africa          |
| ICRP  | International Commission of Radiological Protection |
| ID    | Identification                                      |
| IR    | Image receptor                                      |
| IP    | Imaging plate                                       |
| IRO   | In respect of                                       |
| kVp   | Peak kilo-voltage                                   |
| LAT   | Lateral   |
| LMP   | Last menstrual period                               |
| L5/S1 | Lumbar 5 and sacral 1 joint space                   |

|      |  |
|------|--|
| LUT  | Look-up table                              |
| mA   | milliampere                                |
| mAs  | milliampere-seconds                        |
| MRI  | Magnetic resonance imaging                 |
| MRR  | Manufacturers' recommended range           |
| mSv  | millisievert                               |
| NMMU | Nelson Mandela Metropolitan University     |
| PA   | Posterior-anterior                         |
| PACS | Picture archiving and communication system |
| PMT  | Photomultiplier tube                       |
| PSP  | Photostimulable phosphor plate             |
| QA   | Quality assurance                          |
| QC   | Quality control                            |
| RSA  | Republic of South Africa                   |
| s    | Time in seconds                            |
| SID  | Source to image distance                   |
| SNR  | Signal-to-noise ratio                      |
| UFS  | University of the Free State               |

## SUMMARY

Radiation protection plays a vital role in radiography and it is necessary to ensure the safety of all patients and staff when exposed to ionising radiation.

An understanding of ionising radiation and its effects are therefore of high importance in protecting the patient from unnecessary radiation exposure, a professional issue every radiographer should be conscientious of (Carroll, 2011: 699). The basis of radiation protection revolves around ensuring that exposures to ionising radiation should be kept As Low As Reasonably Achievable (ALARA). Radiographers are required by law to provide effective and adequate radiation protection measures to all patients at all times.

The aim of the research study was to investigate radiation protection practices in digital radiography during chest and lumbar spine radiographic examinations in two Eastern Cape government hospitals and to address possible gaps in the radiographers' awareness of radiation protection using digital x-ray equipment by making recommendations.

The objectives were: to establish the awareness of diagnostic radiographers regarding effective radiation protection through a survey; to determine whether effective radiation protection was applied by diagnostic radiographers through a checklist compiled from literature completed by patients; and to determine whether the technical aspects of effective radiation protection were applied by diagnostic radiographers through a radiographic image checklist completed by three reviewers.

Results showed that professionalism, poor communication, and poor radiation protection practice, were the identified key issues. The key issues showed that: LMP was not thoroughly performed thus revealing unethical and unprofessional behaviour; patient identification was not thoroughly performed hence pointing to poor communication; and poor radiation protection practice was evident through insufficient collimation, incorrect selection of exposure factors, incorrect positioning, and insufficient usage of lead anatomical markers.

## CHAPTER 1

### OVERVIEW OF THE STUDY

---

#### 1.1 INTRODUCTION

Diagnostic imaging is used to examine a patient's body for certain signs regarding a suspected medical condition. A variety of equipment and techniques may be used to produce images of the structures and activities inside the body. The type of imaging used depends on a patient's symptoms and the body part being examined. The different types of imaging include: X-rays; computed tomography (CT) scans; nuclear medicine scans; magnetic resonance imaging (MRI) scans, and ultrasound. Many imaging examinations are painless and easy. Some examinations require one to remain still for a long period of time inside a machine, hence may be uncomfortable, and other imaging examinations i.e. diagnostic X-rays, include an exposure to a small amount of ionising radiation in order to make a diagnosis (MedlinePlus, 2016: online).

The culmination of the broad exposure latitude and LUT histogram rescaling is that there is a decline in the application of essential radiographic techniques and protection principles. The decline being due to the processing systems and programmes linked to digital radiography (DR), which can edit an original image to make it appear to be of radiographic quality. Theoretically, it may appear like any unqualified individual can perform a radiographic examination; however, in practice this is not the case, as there are fundamentals required to produce an image of radiographic quality and diagnostic value. A radiographic image produced should be such that no editing is required; therefore, it is vital that the fundamental radiographic practices are revised continuously (Carroll, 2011: 448).

It is important to remember that there are potential risks and dangers associated with the use of ionising radiation, if not applied or used correctly (World Health Organisation, 2016: online).

Safe and responsible practice of ionising radiation must therefore always be applied (World Health Organisation, 2016: online). The need for radiation protection thus exists because exposure to ionising radiation may result in harmful effects (Health Canada, 2015: online).

Radiation protection can be defined as effective measures employed by radiation workers to protect patients, employees, and the general public, from unnecessary exposure to ionising radiation (Sherer, Visconti and Ritenour, 2006: 3). Effective means producing a decided, decisive, or desired effect (Merriam-Webster, 2016: online). Effective radiation protection, therefore means that the measures and techniques employed by radiation workers to protect patients, employees, and the general public from unnecessary exposure to ionising radiation are successful and adequate in its purpose. Radiation protection plays a vital role in radiography and is of utmost importance in ensuring the safety of all patients with regard to ionising radiation (Shannoun, Blettner, Schmidberger and Zeeb, 2008: 41).

Radiation protection revolves around ensuring that exposures to ionising radiation should be kept As Low As Reasonably Achievable (ALARA) (Australian Radiation Protection and Nuclear Safety Agency, 2008: 15 and 59). The ALARA principle stipulates that it is a radiographer's duty and responsibility to protect a patient in all situations from unnecessary radiation. Radiation protection may be achieved by using lead protection, optimal collimation, checking a patient's pregnancy status, applying the correct and adequate exposure factors, and/or ensuring correct patient positioning amongst others (Australian Radiation Protection and Nuclear Safety Agency, 2008: 15 and 59).

DR may represent the ultimate technological advancement in medical imaging over the last decade. The use of radiographic films in diagnostic X-ray imaging will become outdated in a few years. A fitting comparison that is easy to comprehend is the replacement of classic film cameras with digital cameras (International Atomic Energy Agency, 2013: online).

Digital Images can be immediately acquired, deleted, modified, and sent to a network of computers. The advantages of DR are vast. DR may result in a radiography department becoming filmless. A referring physician may view the requested image on a desktop or a personal computer, and often a report in just a few minutes after the examination was completed. The images are no longer retained in a single location. They may be viewed simultaneously by physicians who are kilometres apart. In addition, a patient may be provided with the X ray images on a compact disk (CD) to take to another physician or hospital (International Atomic Energy Agency, 2013: online).

It was noted by the researcher that some radiographers working with digital imaging equipment were not applying effective radiation protection to patients due to the advances of digital system image acquisition and post-processing. Inadequate radiation protection is of great concern seeing that radiation protection is not only a moral and patient safety imperative, but is also required by law as stipulated by the Directorate Radiation Control (DoH, 2012: 1; 3). This matter raised much interest and awareness, thus resulting in the idea to conduct this study.

The purpose of this research study was to investigate radiation protection practices in DR during digital chest and lumbar spine radiographic examinations, and to address possible gaps in the radiographers' awareness of radiation protection using digital x-ray equipment in the Eastern Cape government hospitals.

The first chapter of this dissertation provides an overview of the study. It covers what the study entailed and a preview of what to expect in this study. The aim of this chapter is to introduce and interest the reader in the research study and to introduce the researcher to the reader. The chapter presents the research goal and the aim of the research study. The important literature pertaining to the study, the problem statement, the research questions, the objectives of the study and the methodology, are presented.

Also covered are: the field and scope of the study; the significance and value of the study; the research study design; the statistical analysis; the ethical considerations; the implementation of the findings; and lastly the arrangement of the dissertation.

## 1.2 SUMMARY OF IMPORTANT LITERATURE

In order to conduct a research study, one must first perform a comprehensive literature review on the proposed research topic to determine if it has been researched before and whether there are any similar studies available. Additionally, one also needs to determine what literature is available and if there is sufficient literature regarding the proposed research topic. Below is a summary of some of the important literature regarding this research study.

Ionising radiation may be defined as energy in transit from one site to another (Sherer et al., 2006: 8). Ionisation is the process when electromagnetic radiation has a high enough frequency to transfer enough energy to the electrons to remove them from the atoms to which they were attached. Ionisation is beneficial for producing X-ray images, but it has the undesirable effect of possibly producing some harm in biological material (Sherer et al., 2006: 10). There are several types of ionising radiation including x-radiation and gamma radiation. Ionising radiation protection investigated in this study is limited to x-radiation. X-rays are high energy photons and are produced artificially by the rapid slowing down of an electron beam. X-rays are similarly penetrating and, in the absence of shielding by dense materials, can deliver significant doses to internal organs (International Atomic Energy Agency, 2004: 8).

There are various image acquisition systems which may be used to produce an image of diagnostic quality, with computed radiography (CR) and direct digital radiography being the most recent imaging acquisition systems. Digital radiography includes CR and DR systems. CR uses a photostimulable phosphor plate (PSP) enclosed in a cassette. The image acquisition is a two-stage process wherein image capture and image read out are done separately (Verma and Indrajit, 2008: online).

DR systems use detectors that have a combined image capture and image read out ability. There are four different types of DR systems available, depending on the type of detectors used in the system (Verma and Indrajit, 2008: online).

During DR examinations, the exposure index (EI) is a measure of the amount of exposure that the image receptor (IR) receives after an exposure has been made. The EI value is an indication of the image quality. A recommended EI value range for optimal image quality and optimal dose is provided by the equipment manufacturer (Fauber, 2013: 170). Digital systems lack the visual signs that result in the recognition of exposure errors such as the overexposure and underexposure of an image when working with film-screen imaging systems. A radiographer must therefore monitor the EI linked with the digital imaging system (Herrmann et al., 2012: online).

The visible appearance of quantum mottle due to underexposure, together with the lack of visual appearance of overexposure, has led to an unfortunate leaning toward overexposure by radiographers known as exposure creep. Therefore, increased radiation exposure to the public is becoming a serious issue with digital imaging (Carroll, 2011: 631).

The Directorate Radiation Control of the Department of Health (DoH) in South Africa is responsible for setting out and enforcing radiation protection standards. The Directorate Radiation Control compiled a code that sets standards and requirements for radiation safety associated with the use of medical diagnostic x-ray equipment (DoH, 2012: 3). The standards and requirements are stipulated in the DoH Directorate: Radiation Control code of practice, Act 15 of 1973 and Regulations No R1332 of 3 August 1973 (RSA, 1973:5).

It is ultimately the radiographers' duty to minimise the radiation dose received by the public. The radiographers' experience, skill and patient care will determine the amount of radiation administered to the patient (Sherer et al., 2006: 7).

There are three radiation protection principles applicable to patients: the justification of the examination; the optimisation of radiation protection, and the limitation of individual dose and risk (DoH, 2012: 14). Three principles of radiation protection, namely, time, distance, and shielding must be applied to reduce ionising radiation to a patient (University of California, 2012: 6). Radiation doses of different sizes, delivered at different rates to different parts of the body may result in various sorts of health effects at different periods (International Atomic Energy Agency, 2004: 15). The higher the radiation dose received, the greater the risk for long-term damage. Diagnostic radiation exposure is officially classified as a carcinogen by the World Health Organisation's International Agency for Research on Cancer, the Agency for Toxic Substances and Disease Registry of the Centers for Disease Control and Prevention, and the National Institute of Environmental Health Sciences (The Joint Commission, 2011: 1). The need to maintain radiation doses as low as reasonably achievable is therefore of utmost importance when performing any radiographic examination.

### **1.3 THE PROBLEM STATEMENT**

The researcher found during a previous, similar research study that there was a problem with radiographers in that study not applying effective radiation protection to patients during DR, therefore possibly increasing the radiation dose to patients. The situation focused the researcher's attention on this specific matter by addressing radiation protection practice during digital chest and lumbar spine radiographic examinations in Eastern Cape government hospitals. These examinations were chosen since they were the most frequently performed general DR examinations at the given radiology departments. Both examinations require the most radiation protection measures. Radiographers' radiation protection measures and radiographic practice applied can thus be assessed in a study.

### **1.4 RESEARCH QUESTIONS**

In order to attain the overall goal of the study (see section 1.5) two research questions were formulated.

1. Are diagnostic radiographers aware of effective radiation protection measures applied in digital radiography during digital chest and lumbar spine radiographic examinations?
2. Are effective radiation protection measures applied to patients referred for routine general digital radiographic of the chest and lumbar spine?

## **1.5 THE RESEARCH GOAL**

The overall goal of this research study was to determine radiation protection practice in DR during digital chest and lumbar spine radiographic examinations in Eastern Cape government hospitals.

## **1.6 THE RESEARCH AIM**

The aim of the research study was to investigate radiation protection practices in digital radiography during digital chest and lumbar spine radiographic examinations, and to address possible gaps in the radiographers' awareness of radiation protection using digital x-ray equipment.

## **1.7 OBJECTIVES OF THE STUDY**

There were four objectives in the study.

1. To establish the awareness of diagnostic radiographers regarding effective radiation protection (includes all radiation protection variables: i.e. collimation; time; distance; shielding; the use of exposure index (EI) values; focus-film distance (FFD) and exposure factors) through a survey.
2. To determine whether effective radiation protection is applied by diagnostic radiographers through a checklist completed by patients.

3. To determine whether effective radiation protection is applied by diagnostic radiographers through a radiographic image checklist completed by three reviewers to analyse the digital radiographic images of the chest and lumbar spine with regards to the technical aspects of radiation protection.
4. To address possible shortcomings in radiographers practice by providing recommendations regarding effective radiation protection practice in digital radiography during digital chest and lumbar spine radiographic examinations.

The research study was conducted at two government hospital radiology departments, situated in the Eastern Cape. The study focused on the radiography profession with regard to radiation protection practice in DR I radiography during digital chest and lumbar spine radiographic examinations in the selected Eastern Cape government hospitals.

### **1.8.1 The researcher**

The researcher is a diagnostic radiographer registered with the Health Professions Council of South Africa (HPCSA). She was employed in a very busy private radiology department in in the Eastern Cape where she did CT, mobile radiography, fluoroscopy, general radiography including CR and DR, and operating theatre radiography. She recently relocated to Johannesburg and is currently working at a private practice providing only the latter radiographic services.

## **1.9 STUDY DESIGN**

A cross-sectional descriptive research design with quantitative elements was used in the study.

A descriptive research design refers to when data are collected without modifying the environment; it provides data about the naturally occurring health status, behaviour, attitudes or other characteristics of a certain group. A descriptive research design is performed to demonstrate links or relationships between groups. A descriptive research design that entails only a one-time interaction with groups of people is referred to as a

cross-sectional study; hence, this study is based on a cross-sectional descriptive research design (The Office of Research Integrity, 2015: online).

Quantitative data were generated through closed-ended questions included in the radiographer survey, patient checklist, and radiographic image checklist. A cross-sectional descriptive research design was used, since it was the best design for this particular research study in terms of the type of data, the participants, the aim and objectives of the study, to deliver trustworthy results.

## **1.10 METHODOLOGY**

The study focussed on DR chest and lumbar spine examinations. These two examinations were chosen since they are the most frequently performed general DR examinations at the selected radiology departments, according to the departmental statistics generated from the total number of examinations performed.

Three research tools (a radiographer survey; a patient checklist; and a radiographic image checklist) were used to collect the quantitative data. The radiographer survey (Appendix G) was used to investigate the knowledge of the radiographers regarding radiation protection practice in DR during chest and lumbar spine radiographic examinations. The patient checklist (Appendices H1-3) was used to determine from the patients whether the radiographers applied radiation protection measures during chest and lumbar spine DR examinations in the two selected Eastern Cape government hospitals, and to determine the gaps in radiation protection applied by the diagnostic radiographers.

The radiographic image checklist (Appendix I) was used to determine whether the radiographers applied effective radiation protection with regard to the technical criteria of radiation protection practice during digital chest and lumbar spine radiographic examinations. Additionally, the information was also used to determine possible gaps in radiation protection applied by the diagnostic radiographers.

## **1.11 STATISTICAL ANALYSIS**

The data obtained from the three checklists were coded and captured electronically by the researcher in Microsoft Excel. Further analysis was done by a biostatistician using SAS Version 9.2. Descriptive data (frequencies and percentages) were calculated for categorical data. Means and standard deviations or medians and percentiles were calculated for numerical data. Analytical statistics, namely, the chi-square test (or Fisher's exact test) for categorical data, was used to investigate differences between proportions for different questions in the survey. Statistical significance is a measurement used to correctly analyse the data results. Statistical significance may be defined as the likelihood that a result or relationship is triggered by something other than mere random chance (Investopedia, 2014: online). A significance level  $\alpha$  of 0.05 was used throughout this study. The results from the analysis were summarised and presented as graphs and tables. The contributions and analysis of the biostatistician also ensured for validity, reliability and credibility.

## **1.12 SIGNIFICANCE AND VALUE OF THE STUDY**

This research study reports on the quality of radiation protection provided to and received by patients, in an attempt to improve the service delivered to patients. This study should enable the researcher to determine whether radiographers are complying with that which is expected from them by law. If the radiographers do not comply with these rules, one can determine what the reasons are for such conduct.

Possible recommendations regarding good and effective radiation protection practice in DR during digital chest and lumbar spine radiographic examinations should be compiled and communicated to the diagnostic radiographers. The recommendations aim to address radiation protection practice and thereby minimise patients' radiation dose during general DR examinations, specifically the chest and lumbar spine in the Eastern Cape government hospitals. The significance of researching the quality of radiation protection applied to patients by the radiographers is that the lessons learned should

contribute to improving radiation protection measures in DR. The conclusions and possible recommendations of this can additionally be applied in similar contexts.

The researcher used a confidence level of 95%, meaning the value of 0.05 was used for  $\alpha$  during calculations. When performing a hypothesis test in statistics, a  $p$ -value helps determine the significance of the results. Hypothesis tests are used to test the validity of a claim that is made about a population. This claim is called the null hypothesis. The alternative hypothesis is the one to believe if the null hypothesis is concluded to be untrue. The evidence is the data and the statistics that go along with it. All hypothesis tests ultimately use a  $p$ -value to evaluate the strength of the evidence (Rumsey, 2018: online).

The  $p$ -value is a number between 0 and 1 and interpreted in the following way.

- A small  $p$ -value (typically  $\leq 0.05$ ) indicates strong evidence against the null hypothesis, so the null hypothesis is rejected;
- A large  $p$ -value ( $> 0.05$ ) indicates weak evidence against the null hypothesis, so the null hypothesis is not rejected;
- $p$ -values very close to the limit (0.05) are considered to be marginal (Rumsey, 2018: online).

In the majority of analyses, an alpha of 0.05 is used as the cut off for significance (The Minitab Blog, 2013: online).

If the  $p$ -value is less than 0.05, we reject the null hypothesis that there's no difference between the means and conclude that a significant difference between the percentages of the three reviewers does exist. If the  $p$ -value is larger than 0.05, we can conclude no significant difference exists (The Minitab Blog, 2013: online).

A schematic overview of the chapter presented in Figure 1 below serves to give the reader a synopsis of the research study.





**Figure 1:** Schematic overview of the study.

### **1.13 ETHICAL CONSIDERATIONS**

The proposal was submitted to the Health Sciences Research Ethics Committee of the University of the Free State (UFS) for ethical approval and clearance and approved (Appendix L). The ethics number of the project allocated is ECUFS NR is 177/2015. Permission from the Department of Health (DoH), as well as hospital management, and head of the radiology department to conduct the research at the two government hospital radiology departments in the Eastern Cape (EC), was obtained (Appendix A1-A4).

### **1.14 IMPLEMENTATION OF THE FINDINGS**

The findings of this research and recommendations may have the potential to serve as a guide to the what, why and how of radiation protection in DR. The suggested recommendations will be presented to the radiographers at the two government hospitals in the EC. Leaflets containing all the suggested recommendations will also be handed out to all the radiographers at both the government hospitals in the EC. Finally, all suggested recommendations will be emailed to the head of each radiology department to implement or use as each head of department see fit. Articles based on the research findings may also be submitted to academic journals for publication.

### **1.15 ARRANGEMENT OF THE DISSERTATION**

#### **Chapter 1: Introduction**

In this chapter the research topic is introduced. Effective radiation protection is defined. The importance of radiation protection and the purpose of the study is explained. The background to the study and its rationale which includes the problem statement, and the aim and objectives of the research study, are discussed.

## **Chapter 2: Literature review**

Based on literature, a theoretical framework, similar studies, the essential and significant aspects of radiation protection in DR during digital chest and lumbar spine radiographic examinations are presented.

## **Chapter 3: Methodology**

In this chapter a description of the research approach and research tools which were used by the researcher to gather the data that forms the answer to the research question are presented. Populations and samples, method of data analysis, validity, reliability, trustworthiness, and ethical considerations, are covered.

## **Chapter 4: Presentation and discussion of results of the research tools**

Data obtained from the radiographer survey, patient checklist and radiographic image checklist, which were analysed by the researcher with the assistance from a biostatistician, are presented and discussed.

## **Chapter 5: Conclusions, limitations and recommendations of the study**

Limitations and recommendations are presented and discussed to provide useful information for similar future studies. The lessons learned should contribute to improving radiation protection measures in DR. Final remarks and observations are made to provide a conclusion regarding the aim and objectives as set out at the beginning of the study.

## CHAPTER 2

### LITERATURE REVIEW

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#### 2.1 INTRODUCTION

In the first chapter, the reader was introduced to the study. A brief overview of what the research study entailed was presented as well as what to expect. In chapter 2 a theoretical investigation is performed and discussed, based on literature regarding effective radiation protection practices in DR during digital chest and lumbar spine radiographic examinations. Important terminology and definitions, effects, principles, responsibilities and practices of effective radiation protection in DR, are described.

A literature review may be defined as a combination of the literature on a subject. It involves finding summaries, books, journals and indexed publications on a subject; selectively choosing which literature to include; and then summarising the literature in a written report (Cottrell and McKenzie, 2010: 40). A literature review is aimed at contributing a clearer understanding of the nature and meaning of the problem that has been identified; it forms an essential and integral part of the research study (de Vos et al., 2011: 134). A theoretical literature review was conducted to investigate radiation protection practices in DR during digital chest and lumbar spine radiographic examinations, using literature and information from books, journals and online search engines. The researcher consulted the Ebscohost database, Medline database, EMBASE, SACat, Academic Search Premier, Science Direct and Best Evidence medical database, to identify relevant articles.

Based on literature a theoretical framework of the study, similar studies, the essential and significant aspects of radiation protection in digital radiography during digital chest and lumbar spine radiographic, are presented. Figure 2.1 below serves to give the reader a synopsis of the literature review and how the research tool questions were formulated.



**Figure 2.1:** A diagrammatic overview of the different aspects that will be discussed in the literature review as created by the researcher.

## 2.2 The use of ionising radiation in medical imaging

Ionising radiation may be defined as energy in transit from one site to another (Sherer et al., 2006: 8). Types of ionising radiation are x-radiation and gamma radiation. Ionisation is the process when electromagnetic radiation has a high enough frequency to transfer enough energy to the electrons to remove them from the atoms to which they were attached. Ionisation is the basis of the interactions of X-rays with human tissue. Ionisation is beneficial for producing X-ray images, but has the undesirable effect of possibly producing some harm in biological material (Sherer et al., 2006: 10). For the purpose of this study, only ionising radiation was dealt with, specifically X-rays. The latter were discovered by Roentgen in 1895 and represent a form of ionising radiation that produces positively and negatively charged ions when passing through matter. The production of these ions is the incident that may cause injury in normal biological tissue (Sherer et al., 2006: 2). X-rays are high energy photons and are produced artificially by the rapid slowing down of an electron beam. X-rays are similarly penetrating, and in the absence of shielding by dense materials, can deliver significant doses to internal organs (International Atomic Energy Agency, 2004: 8).

X-rays have the following properties.

- They can affect photographic plates.
- They are not affected by magnetic or electrical fields.
- They can cause some materials to fluoresce.
- They can cause ionisation.
- They can be absorbed by elements that have a high atomic number i.e. lead.
- They can penetrate most materials including soft tissues and bones (Seeram, 1997: 288).

The quantity of an X-ray beam is defined as the number of x-ray photons in the beam per unit of energy; the quality of the X-ray beam refers to the penetrating power of the x-ray beam (Seeram, 1997: 288).

These are some of the factors that influence radiation dose to a patient. Radiation dose may be defined as the amount of energy transferred to electrons by ionising radiation (Sherer et al., 2006: 10).

A radiographic image is produced as follows. The primary beam is attenuated by a patient's tissues; the exit or remnant radiation is composed of variable intensities; the image receptor then receives or captures the exit or remnant radiation and produces a latent or invisible image that requires processing. Image formation for DR differs from the image formation for film-screen radiography, since image receptors respond differently to the exit or remnant radiation. In DR, the digital image is stored and displayed as computer data visible on a monitor as a range of brightness levels, whereas in film-screen radiography, the film image is processed to display a range of densities on a polyester sheet (Terri and Fauber, 2014: online).

Image acquisition for film-screen radiography is as follows. Film is used to acquire, process, and display the radiographic image. An emulsion layer is adhered to a polyester sheet and serves as the radiation-sensitive and light sensitive layer of the film. Prior to the introduction of intensifying screens, a film was exposed to the primary beam and then processed to produce the required image. In an attempt to decrease the radiation exposure to a patient, intensifying screens were developed. A film is placed in a light-tight cassette that contains two intensifying screens. The film is then exposed to the light emitted from the intensifying screens in proportion to the amount of radiation exposure (Terri and Fauber, 2014: online).

Image acquisition for CR is as follows. The exit or remnant radiation interacts with the imaging plate (IP), which is composed of barium fluoride bromide crystals and is coated with europium; absorbed energy is then stored in the photostimulable phosphor material; some energy is released as visible light, but most result in electrons being released in the phosphor layer due to photoelectric interactions; electrons are then trapped in the phosphor layer until light energy is released during laser scanning (Terri and Fauber, 2014: online).

The CR latent image is digitised in three stages: scanning; sampling, and quantisation. DR is subdivided into direct and indirect conversion. Image acquisition for the former is as follows. The flat panel detector array is exposed to the exit or remnant radiation; the scintillator converts X-rays into light; the light energy is transformed into electric signals and then the electric signals are digitised. Image acquisition for direct conversion is as follows. The flat panel detector array is exposed to the exit or remnant radiation; selenium converts X-rays into electric signals and then the electric signals are digitised (Terri and Fauber, 2014: online).

The basis of the radiography profession is the creation of good quality radiographic images and patient radiation protection practices. In radiography it is essential for radiographers to comprehend the principles of electromagnetic radiation, and to effectively apply exposure techniques. Radiographers administer radiation so that patient radiation exposure is assumed safe and that occupational risk is the same as for most safe professions. In this age of technology many things are rapidly being modified in the radiology imaging speciality; nevertheless, the physical ideas of radiation exposure to produce images of diagnostic quality remain an essential part of the imaging discipline. In addition, an X-ray tube design is engineered with patient radiation protection as one of its highest criteria. Similarly, a radiographer's selection of radiographic techniques includes the highest radiation protection principles possible. Principles of radiation exposure that reduce unnecessary exposure and emphasise imaging benefits are foundation principles of the radiography profession (CEEssentials, 2018: online).

To ensure that DR is practiced safely and correctly, the Directorate Radiation Control compiled a code that sets standards and requirements for radiation safety associated with the use of medical diagnostic x-ray equipment (DoH, 2012: 3). Some of the regulations promulgated by them are discussed below.

## **2.3 Radiation protection regulations**

The Directorate Radiation Control of the Department of Health (DoH) is responsible for setting out and enforcing radiation protection standards (DoH, 2012: 3). The standards and requirements are stipulated in the DoH Directorate: Radiation Control code of practice, Act 15 of 1973 and Regulations No R1332 of 3 August 1973 (RSA, 1973:5). The code specifies that a radiographic practice must firstly obtain a license. A combined product and premises licence must be obtained for X-ray equipment before it may be installed and ordered. Licences are not transferable (DoH, 2012: 6). The licence holder must assign a responsible individual that has sufficient knowledge and experience in the field of radiation protection (DoH, 2012: 7).

A radiographer plays an essential role in linking certain vital aspects in a radiology department (Peer, 2003: 5-6). The key areas include: patient care; use of technology; quality assurance (QA); optimisation of dose; clinical responsibility; organisation and management; and education and training (Peer, 2003: 5-6). For the purpose of this study, only the radiographers' role, in terms of the code of conduct with regard to radiation protection during a digital chest and lumbar spine radiographic examination, is covered. It is ultimately the radiographers' duty to minimise the radiation dose received by the public. Their experience, skill and patient care will determine the amount of radiation administered to patients and its biological effect (Sherer et al., 2006: 7).

## **2.4 Effects of ionising radiation**

Radiation doses of different sizes, delivered at different rates to different parts of the body, may result in various sorts of health effects at different periods (International Atomic Energy Agency, 2004: 15). Patients most prone to possible risks from diagnostic radiation exposure are children and young adults, pregnant women, and individuals with medical conditions sensitive to radiation, such as diabetes mellitus and hyperthyroidism. The higher the radiation dose received, the greater the risk for long-term damage (The Joint Commission, 2011: 1).

If a patient receives small amounts of repeated doses, damage may occur, and is referred to as the cumulative effect due to the multiple doses over time. Similarly, using insufficient radiation may increase the risk of misdiagnosis, delayed treatment, and repeat examinations if the first image was inadequate, resulting in increased radiation exposure. Diagnostic radiation exposure is officially classified as a carcinogen by the World Health Organisation's International Agency for Research on Cancer, the Agency for Toxic Substances and Disease Registry of the Centers for Disease Control and Prevention, and the National Institute of Environmental Health Sciences (The Joint Commission, 2011: 1). The need to maintain radiation doses as low as reasonably achievable is therefore of utmost importance when performing a general DR examination.

#### **2.4.1 Deterministic and stochastic effect**

A deterministic effect is an effect that results in a partial function loss of an organ or tissue. It is caused by ionising radiation and manifests only above some threshold dose level. The severity of the effect depends upon the ionising radiation dose received by the person (Australian Radiation Protection and Nuclear Safety Agency, 2008: 61). Threshold dose may be defined as a dose of radiation below which an individual has a minor chance of sustaining specific biologic damage (Sherer et al., 2006: 49). Deterministic effects are produced by extensive cell damage or death. The following are examples of deterministic effects: skin erythema/necrosis/epilation; cataracts; sterility; radiation sickness and teratogenesis / foetal death (Goodman, 2010: 2).

Doses from diagnostic radiographic imaging examinations are likely to cause effects of a stochastic nature (Australian Radiation Protection and Nuclear Safety Agency, 2008: 3). A stochastic effect is a mutational and randomly occurring biologic somatic change in which the chance of incidence of the effect, rather than the severity of the effect, is proportional to the dose of ionising radiation (Sherer et al., 2006: 329).

There is no threshold below which stochastic effects cannot occur. The possibility of stochastic effects occurring is determined by:

- the age of the patient;
- the anatomical region being exposed; and
- the size of the dose (Australian Radiation Protection and Nuclear Safety Agency, 2008: 3).

According to Gofman (1995: online) there is scientific proof that demonstrates that there is no safe dose or dose-rate below which dangers disappear. Severe, deadly effects from minimal radiation doses are not "hypothetical," "theoretical," or "imaginary", they are very real and true (Gofman, 1995: online). Additionally, Frush (2009: 385-390) reports on a study that investigated radiation safety. The finding being that in radiation protection there is no safe level of exposure and that patients and medical personnel are all at risk (Frush, 2009: 385 - 390).

#### **2.4.2 Somatic and genetic effect**

Somatic effects refer to the physical effects that appear in an individual who has been exposed to radiation (Seeram, 1997: 286). Most somatic effects follow a non-linear, threshold response curve as the radiation dose increases (Carroll, 2011: 797). Most early effects are somatic; affecting the organism itself but not its offspring. Roughly 90% of somatic damage to an organism from radiation is biologically reparable. It is essential to remember that the remaining 10% of harm to an organism becomes cumulative with repeated exposures to radiation (Carroll, 2011: 803). Genetic effects refer to the biological effects of ionising radiation on future generations. Genetic effects arise as a result of radiation-induced injury to the deoxyribonucleic acid (DNA) molecule in the sperm or ova of an adult. When these germ cell mutations take place, faulty genetic information is transferred to the descendants. The impaired genetic information may manifest itself as several diseases or malformations (Sherer et al., 2006: 134).

Genetic effects do not have a threshold dose, therefore even the smallest radiation dose can cause certain genetic damage, therefore there is no such thing as a “100% safe” gonad radiation dose (Sherer et al., 2006: 135).

The total somatic and genetic biologic damage a person suffers as a result of radiation exposure depends on:

- the quantity of ionising radiation to which the subject is exposed;
- the amount of body area exposed (Sherer et al., 2006: 114);
- the specific body parts exposed; the ability of the ionising radiation to cause ionisation of the human tissue (Sherer et al., 2006: 114).

### **2.4.3 Early and late effect**

Depending on the period of time from the moment of irradiation to the first appearance of symptoms of radiation damage, the effects are classified as either early or late somatic effects. If the effects are cell-killing and directly linked to the dose received, they are called non-stochastic/deterministic somatic effects. Late effects of ionising radiation, which are mutational or randomly occurring biologic somatic modifications, independent of dose, are called stochastic somatic effects (Sherer et al., 2006: 114).

## **2.5 Radiation protection principles**

Three basic radiation protection principles applicable to patients (DoH, 2012: 14) are discussed below.

### **2.5.1 The justification of the examination**

Every radiographic examination must adhere to the radiation protection principle of justification (International Commission on Radiological Protection, 2007: 25).

Justification refers to the process of determining whether either a planned examination involving radiation or a planned curative action in an emergency or existing exposure circumstance is likely to be mostly beneficial in the sense that the benefits to individuals outweigh the cost and any risks or damage the action or activity may cause (International Commission on Radiological Protection, 2007: 25). All radiographic examinations must be justified in terms of a risk-benefit evaluation before starting the examination. An examination is justified when the estimated benefits surpass the predicted risks of the examination (International Atomic Energy Agency, 2009: 5). No radiation examination shall be performed unless the advantages outweigh the possible risks (DoH, 2012: 14). Justification applies in this study by certifying that every radiographic examination that was requested was checked to ensure that the advantages outweighed the possible risks. In this way justification of the study was ensured.

## **2.5.2 The optimisation of radiation protection**

The overall goal of this study related to optimisation, in terms of which radiation doses from medical exposures, and those received by the public and occupationally exposed persons, must be kept as low as reasonable achievable (ALARA principle), taking into account economic and social factors (DoH, 2012: 14). The International Commission for Radiation Protection (ICRP) recommends that as part of the optimisation process, there should be restriction on the doses to individuals, leading to the awareness of dose limits (European Commission, 2012: online). If the ALARA principle is adhered to and radiation protection principles are performed constantly then the effects of ionising radiation can be prevented or kept to a minimum (Joseph and Phalen, 2013: online).

There are numerous measures that must be taken to eliminate unnecessary radiation to a patient effectively and include the following:

- reduce risks due to unnecessary diagnostic radiation by raising awareness among staff and patients of the increased risks associated with cumulative doses (DoH, 2012: 14 – 15);

- ensure adequate awareness amongst physicians and other surgeons regarding the levels of radiation usually used and associated risks;
- sufficiently trained and competent staff (DoH, 2012: 14 – 15);
- adequate knowledge regarding typical doses;
- specific protocols stipulated that ascertain the maximum dose for each radiographic examination;
- only perform X-ray examinations with valid clinical indications (The Joint Commission, 2011: 2);
- obtain previous X-ray images to prevent and reduce unnecessary repeat x-ray images;
- collimation must be applied at all times (DoH, 2012: 14 – 15);
- use lead anatomical markers for all views done;
- select the lowest possible exposure ensuring that diagnostic quality is also kept, thus reducing radiation dose to the patient (DoH, 2012: 4);
- establish a radiation protection programme to ensure that the radiation dose delivered to a patient for diagnostic purposes is optimised;
- be aware of estimated patient radiation doses (DoH, 2012: 14 - 15).

### **2.5.3 The limitation of individual dose and risk**

All medical applications of ionising radiation must be managed in such a way that radiation doses to an occupationally exposed person and members of the public do not exceed the specified dose limits. Awareness and knowledge of the approximate patient radiation doses must be ensured. Diagnostic reference dose levels should be introduced for diagnostic X-ray examinations performed in an X-ray department. Diagnostic reference levels (DRL) refer to dose levels in diagnostic radiology departments for general radiographic examinations for average size patients using general X-ray equipment. The DRL is predicted to not be surpassed when good radiographic practice is applied (DoH, 2012: 14 - 15). The objective of a DRL is to assist in avoiding unnecessary radiation dose to a patient that does not contribute to valuable diagnostic information (Sherer et al., 2006: 26).

DRLs are necessary as a baseline to assist in producing images of diagnostic value with accurate and acceptable exposure index values, thus preventing repeats and unnecessary radiation exposure to a patient. The level of energy/beam quality (kVp) and the number of x-ray photons (mAs) are controlled by technique factors chosen by a radiographer; a radiographer is essentially responsible for the radiation dose a patient receives during a radiographic examination (Sherer et al., 2006: 26). The limitation of individual dose and risk was ensured in this study by preventing repeat examinations by applying and performing good radiographic practice techniques.

Discussed below are three basic principles of radiation protection: time, distance, and shielding, must be applied to reduce ionising radiation to a patient (University of California, 2012: 6). The three principles of radiation protection related to this study as each principle were considered to determine how each principle would have affected the radiation dose and radiation protection in terms of the overall goal of the study. In cases when radiation protection shielding measures will obscure essential anatomical details for a required radiographic examination, the other two concepts, namely, time and distance, must be applied to optimally protect the patient (U.S. Environmental Protection Agency, 2012: online).

### **2.5.3.1 Time**

Time refers to the amount of ionising radiation exposure that increases and decreases with the time that a patient spends close to the source of the radiation (U.S. Environmental Protection Agency, 2012: online). The quantity of exposure is directly related to the time that an individual is exposed to ionising radiation from a source. Exposure to ionising radiation must, therefore, be kept as short as possible. To reduce exposure, an examination must be planned in advance to reduce the amount of time spent that requires exposing a patient (University of California, 2012: 6).

Milliampere-seconds (mAs) can be defined as the product of milliamperes (mA), which refers to the X-ray tube current, and time (s), which refers to the seconds during which an X-ray tube is activated. It is the main factor that determines the amount of radiation that is directed toward a patient during a radiographic exposure. Peak kilo-voltage (kVp) may be defined as the highest energy level of photons in an X-ray beam. kVp controls the quality/penetrating power of the photons in the x-ray beam and also affects the quantity / number of photons in the x-ray beam (Sherer et al., 2006: 26). If possible, a higher kVp and lower mAs should be used to reduce the radiation exposure to a patient. When increasing the kVp, less mAs is required and thus less ionising radiation is required to achieve a desired exposure to the IR (Faubert, 2013: 85b).

### **2.5.3.2 Distance**

The inverse square law expresses the relationship between distance and the intensity of radiation. It controls the dose received. The inverse square law states: “the intensity of radiation is inversely proportional to the square of the distance from the source.” Distance is the most effective means of radiation protection (Sherer et al., 2006: 229). The further away a patient is from the source of radiation, the less the exposure will be (U.S. Environmental Protection Agency, 2012: online). The intensity of the X-ray beam is weakened as the distance from the source increases (Sherer et al., 2006: 241).

Scattered radiation, also termed secondary radiation, may be defined as a “blanket” of unwanted exposure across the image receptor which contains no information and hence adding a fixed amount of exposure to the tissue area within the image which always degrades the image, because it is random in nature and is referred to as image noise (Carroll, 2011: 327). Scattered radiation has only slightly less energy than the primary X-ray beam, and therefore is very likely to penetrate out of a patient’s body and reach the image receptor; it has a significant influence on the information reaching the image detector (Carroll, 2011: 203). The following factors increase the amount of scattered radiation produced: high kVp levels; large field sizes; and large body part thicknesses of soft tissue (Carroll, 2011: 327).

### 2.5.3.3 Shielding

Shielding was an important radiation protection measure used to protect the patient from ionising radiation in this study. It reduces the radiation dose to a patient. One can protect a patient by means of shielding; it is something that will absorb radiation between a patient and the source of the radiation (U.S. Environmental Protection Agency, 2012: online). It is used where possible to reduce radiation exposure (University of California, 2012: 6). The quantity of shielding required to protect a patient against X-rays is a thick, dense shielding, such as lead (U.S. Environmental Protection Agency, 2012: online). Lead has a high molecular density, which provides protection against scatter radiation and protection from ionising radiation during radiographic examinations. It is also effective at stopping X-rays (Radiation Protection Products, 2014: online). The greater the energy of the X-rays, the thicker the lead must be. Radiographers must therefore provide patients receiving X-rays with a lead rubber apron to shield other parts of the body that are not being x-rayed (U.S. Environmental Protection Agency, 2012: online). An important characteristic of lead is the percentage attenuation given by each of the lead equivalent thicknesses at different kVp values. As the lead equivalent thickness increases, the percentage attenuation increases for the same kVp value (Seeram, 1997: 192 - 193).

Any individual who cannot stay in the protected area during X-ray examinations must wear a protective lead rubber apron of at least 0,25mm lead equivalence for ionising examination of radiation exposures above 70 kilovoltage peak (kVp) (Virginia Tech, 2011: online). Protective lead rubber gloves must be at least 0.35mm lead equivalence (DoH, 2012: 17). Gonad shields must be at least 0.5mm lead equivalence for ionising examinations of radiation exposures of up to 50 kVp (Virginia Tech, 2011: online). Any individual standing within one meter of an X-ray tube or patient while the X-ray machine is working at tube voltages beyond 100kV must wear a protective lead rubber apron of at least 0.35mm lead equivalence (DoH, 2012: 17).

According to Australian Radiation Protection and Nuclear Safety (2008: 21) radiographers should provide a patient with radiation protection for radiosensitive organs such as the gonads, lens of the eye, breast, and thyroid, during a radiological examination.

To summarise, the three principles of radiation protection, namely time, distance, and shielding, were discussed above in terms of how each principle affects radiation dose and radiation protection.

Collimation is a subsection of shielding. Its purposes of collimation are to minimise radiation exposure to a patient and to preserve subject contrast in the remnant beam. Minimising radiation exposure to a patient should be of utmost concern to every radiographer. Restricting the size of the X-ray beam is one of the most effective ways to minimise radiation exposure. An X-ray field size must never be larger than needed to include the anatomy of interest, and must never be larger than the size of the IP. By collimating and controlling the field size, organs sensitive to radiation, such as the gonads, thyroid gland, and lenses of the eyes, may be kept outside the primary X-ray beam. The resulting decrease in dose to these organs can be significant (Carroll, 2011: 295). Collimation is performed using cones and collimators that are built into X-ray equipment. The collimator is the most versatile device for defining the size and shape of the radiographic beam (Sherer et al., 2006: 170). Collimation is also another measure to protect a patient when shielding cannot be used, as this results in a great reduction in radiation dose and improves image quality. It is the most effective ionising radiation protection measure for a patient and radiographer. It confines the primary beam before it enters the area of clinical interest, so restricting the region that the ionising radiation may strike, hence reducing the amount of scattered radiation in the tissue and preventing unnecessary exposure to tissues not under examination (Sherer et al., 2006: 168). The use of collimation can, therefore, help keep patient exposure levels in terms of ALARA (Carroll, 2011: 850).

## **2.6 Protection of patients**

Members of the public are not permitted to enter controlled areas unsupervised. Non-radiation personnel or members of the public must not stay in an X-ray room during a radiographic examination, except if they are going to be of assistance. The occasional use of non-radiation personnel to provide assistance, mainly in ward or operating theatre radiography, is acceptable, but should include the full use of protective clothing, devices and techniques to minimise radiation dose. Precaution must be taken to ensure that the same non-radiation personnel are not continually involved. Pregnant individuals may also not assist in this regard (DoH, 2012: 16).

### **2.6.1 Protection of women of reproductive age**

To minimise any chance of accidental exposure to the embryo/foetus, notices must be displayed inside a radiology department. They should contain wording similar to or having a similar meaning as the following: “If you might be pregnant notify the radiographer before your x-ray examination” (DoH, 2012: 16). It is essential, and a radiographer’s responsibility to ask all female patients of reproductive age about the possibility of pregnancy, before performing an X-ray examination (Medicine Net, 2013: online). If a patient is uncertain as to whether she is pregnant or not, the radiographer needs to ask when was the first day of her last menstrual period (LMP); by doing this one can determine if it is safe for such a patient to have an X-ray examination or not (Medicine Net, 2013: online).

LMP refers to when pregnancies are dated in weeks, starting from the first day of a woman's last menstrual period. If menstrual periods are regular and ovulation occurs on day 14 of her cycle, conception takes place about two weeks after a woman’s LMP (Medicine Net, 2013: online). A pregnant woman is seen as a radiation risk when diagnostic imaging is required due to the risk of ionising radiation to the embryo or foetus (McCollough, Schueler, Atwell, Braun, Regner, Brown and LeRoy, 2007: online).

The embryo is fairly radio-resistant during its pre-implantation phase, but extremely radiosensitive during its organogenesis (2-8 weeks) and neuronal stem cell proliferation phases (8-15 weeks). Foetal ionising radiation sensitivity decreases after this period (Goodman, 2010: 2). The possible biological effects due to radiation exposure of a developing foetus include: prenatal death, intrauterine growth restriction, small head size, mental retardation, organ malformation, childhood cancer (McCollough, et al, 2007: online) and growth retardation, specifically microcephaly (Goodman, 2010: 2). The danger of each effect depends on the gestational age at the time of radiation exposure, foetal cellular repair mechanisms, and the absorbed ionising radiation dose level (McCollough, et al, 2007: online). For ionising radiation examinations, where the primary beam inevitably irradiates the foetus, techniques minimising the radiation dose must be applied. These entail minimising the number of x-ray projections, severe x-ray beam collimation, usage of higher kV settings, and posterior anterior (PA) projections rather than anterior posterior (AP) projections (DoH, 2012: 15-16).

## **2.7 Radiographers' radiation protection responsibilities during a radiographic examination**

The radiographers' responsibilities, with regard to radiation protection during a radiographic examination, include:

- correctly verify patient identification;
- check a patient's pregnancy status;
- check a patient's clinical history to ensure that correct and appropriate examination is being requested;
- check a patient's previous X-ray examinations to ensure that the same examination is not requested again unnecessarily;
- prepare a patient by explaining the examination, positioning and or breathing instructions;
- prevent unnecessary exposure to radiation at all times by avoiding repeat examinations (Peer, 2003: 5-6);

- accurate application of radiographic techniques and positioning;
- use of accurate image processing and recording for every examination;
- striving to improve knowledge and professional competence by attending continuing professional development (CPD) activities (Peer, 2003: 5-6);
- being aware of rules governing the workplace;
- perform duties consistent with ALARA (Sherer et al., 2006: 7).

Essential, best radiographic practices, applicable to DR and radiation protection, entail the following:

- select the appropriate exposure factors for the patient's size, based on a calculated exposure system, planned in collaboration with radiologists, to ascertain acceptable image quality for diagnosis;
- include the image receptor exposure in the image data given during the image archiving process;
- carefully evaluate the examination requested to avoid possible repeats and to ensure suitability with regard to the patient's history;
- adhere to the protocols and standards set by the department, and actively take part in establishing and further developing protocols that ensure consistency of diagnostic quality images and improved radiation protection practices to decrease patient radiation dose;
- check the pregnancy status of female patients of reproductive age;
- use the highest kVp within the optimal range for the position and part of anatomy together with the lowest amount of mAs required to deliver an acceptable exposure to the image receptor;
- use automatic exposure control (AEC) when specified, and use AEC that has been adjusted to the type of image receptor to deliver a consistent exposure to the image receptor;
- use exposure technique charts that are constantly improved and pertinent to an extensive range of patient ages and sizes (Herrmann, Fauber, Gill, Hoffman, Orth, Peterson, Prouty, Woodward and Odle, 2012: online);

- collimate the X-ray beam to the anatomy of interest for the specific examination being performed;
- apply electronic masking in a way that shows the actual exposure field edge to document appropriate collimation;
- electronic masking must not be applied over anatomy that was included in the exposure field at the time of image acquisition;
- apply lead shielding to anatomy adjacent to the X-ray field;
- always use lead anatomical side markers captured on the original image during the X-ray exposure;
- use a grid with specifications suggested by the digital imaging equipment vendor, usually for body parts that exceed 10 cm;
- use immobilisation devices when necessary and avoid repeat exposures by correctly positioning each patient;
- take appropriate actions to comply with ALARA principles, radiation protection, correct positioning, immobilisation and size-appropriate exposure techniques in paediatric DR;
- become acquainted with the particular exposure indicator (EI) standards used for equipment in the department;
- effectively use the EI and deviation index to determine whether adequate exposure has reached the image receptor;
- evaluate EI values, together with image quality to determine whether the digital image adheres to departmental standards;
- identify that because the EI has limitations and other variables may affect the value, one must comprehensively evaluate whether a repeat examination is required;
- identify image artefacts and avoid future artefacts from occurring by correctly maintaining and or servicing the DR equipment;
- choose the correct processing menu for an examination to ensure image quality;
- electronically record the exposure technique factors used, EI value and radiation dose with the radiographic image to allow for evaluation and improvement of technique selection practices (Herrmann et al., 2012: online);

- implement a comprehensive quality assurance (QA) programme that includes aspects of quality control (QC) and constant quality improvement, including repeat analyses specific to the digital imaging system being used; develop a collective and supportive work team in which team members learn from one another and practice radiography safely and ethically (Herrmann et al., 2012: online).

## **2.8 Radiation dose**

### **2.8.1 Occupational dose limit**

Occupational dose limit is a dose of ionising radiation received by a person at work, where assigned duties involve exposure to ionising radiation and radioactive materials (Dictionary.com, 2013: online). Occupational effective dose limit is 20 millisievert (mSv) per annum and not more than 100 mSv over a period of five years. The dose must not be more than 50 mSv in any one year. Occupational annual equivalent dose limit is 20 mSv to the lens of the eye, 500 mSv to the skin, and 500 mSv to the hands and feet (DoH, 2012: 11). Occupational dose limit is not directly relevant to this particular study. It is however crucial for all health workers (here specifically radiographers) to avoid exposure to ionising radiation as much as possible as the same radiation effects apply them and those pertaining to patients (DoH, 2012: 5).

Occupational dose limits apply to general DR examinations where a radiographer must hold a patient for an X-ray examination. A radiation worker is an individual who may be exposed to radiation as a consequence of his/her occupation to more than three tenths of the occupational dose limit discussed (DoH, 2012: 5). A radiographer may need to hold a patient for an X-ray examination. For example, in the case of a crying uncooperative child whose mother is pregnant and there is no one else to hold the patient. In such cases radiographers need to take caution to protect themselves and to keep exposures to as low as possible to prevent them from exceeding the occupational dose limit (DoH, 2012: 16-17).

## 2.8.2 Radiation dose to the public

Public dose limit refers to a dose of ionising radiation received by an individual who is not performing assigned duties involving exposure to ionising radiation and radioactive materials (Oregon State University, 2012: online). Public effective dose limit is 1 mSv per annum; the public annual equivalent dose limit to the lens of the eye is 1 mSv, and to the skin 50 mSv (DoH, 2012: 11). Public dose limit is relevant to this particular study, since patients are the individuals undergoing radiographic examinations, and therefore will be exposed to the ionising radiation. It is essential to ensure that radiation exposure is kept as low as possible to prevent the harmful effects of radiation occurring by adhering to the public dose limits.

## 2.8.3 Digital radiography

Digital radiography includes computed radiography (CR) systems and direct digital radiography (DR) systems. CR uses a photostimulable phosphor plate (PSP) enclosed in a cassette and the image acquisition is a two-stage process wherein image capture and image read out are done separately. DR systems use detectors that have a combined image capture and image read out ability. There are four different types of DR systems available, depending on the type of detectors used in the system (Verma and Indrajit, 2008: online).

PSP screens used in CR are also called storage phosphors or imaging plates (IP). CR imaging plates are composed of a material called barium fluorohalide and is a flexible screen that is enclosed in a cassette. One IP is used for each exposure. The IP is exposed and then the CR cassette is taken to a CR reader. When a cassette is placed in the CR reader several processing steps take place namely:

1. the cassette is moved into the CR reader and the IP is mechanically removed from the cassette;
2. the IP is deciphered across a moving stage and scanned by a laser beam (Bushberg, Seibert, Leidholdt and Boone, 2002: 293 – 294);

3. the laser light stimulates the emission of trapped energy in the IP and visible light is released from the IP (Bushberg et al., 2002: 297);
4. the light released from the IP is collected by a fiber optic light guide and strikes a photomultiplier tube (PMT), where it generates an electronic signal;
5. the electronic signal is digitised and stored;
6. the IP is exposed to a bright white light to erase any remaining trapped energy; the IP is then returned to the cassette and is ready for reuse.

The digital image that is generated by the CR reader is stored temporarily on a local hard disk (Bushberg et al., 2002: 297).

Direct-capture digital radiography (DR) refers to any digital imaging system in which the image receptor plate is directly, electronically connected to a computer processing system; therefore, there is no separate “cassette” that must be carried to a processing system by a radiographer. The image receptor plate is built into the x-ray table or wall-mounted “chest” unit (Carroll, 2011: 594). DR uses small electronic X-ray detectors, and as such allows for the X-ray image to be captured directly by the electronic elements with no in-between steps (Carroll, 2011: 10).

## **2.9 Exposure latitude of digital imaging**

Exposure latitude is an indication of the amount of overexposure or underexposure used in producing an image that may still produce acceptable results (ClarkVision.com, 2008: online). Exposure latitude thus refers to the subsequent image scaling (adjustments to brightness and contrast) and post-processing, which allows an image to be manipulated for optimal viewing. Consequently, the detectors used in DR can to some degree compensate for under and overexposure and may decrease the repeats caused by incorrect radiographic techniques (Bushberg et al., 2002: 776). Digital radiography systems have exposure latitude from –50 % to +400 %, thus being a truly incredible range (Carroll, 2011: 629).

An image of diagnostic value may differ visually in density up or down by a factor of 2; however, there is no question that with the linear response of digital imaging, a far wider range of error is permitted, particularly in the direction of overexposure. A very high exposure level may saturate the system resulting in the compensating algorithms to fail, such that data are lost and totally left out of the overexposed section of the image. This section of the image will generally take on a flat, black appearance. It requires as much as eight to ten times the normal exposure to reach saturation, therefore saturation is rare and only likely to happen when a radiographer entirely forgets to change the technique from the last patient (Carroll, 2011: 629). Repeats due to overexposure or underexposure are rare, since the exposure latitude with DR systems is much wider than with screen-film systems (Bushberg et al., 2002: 297). Due to the wide exposure latitude of DR, it is crucial to ensure that the correct radiographic technique is applied to produce an image which falls within the acceptable exposure index range that is of diagnostic value (Carroll, 2011: 448).

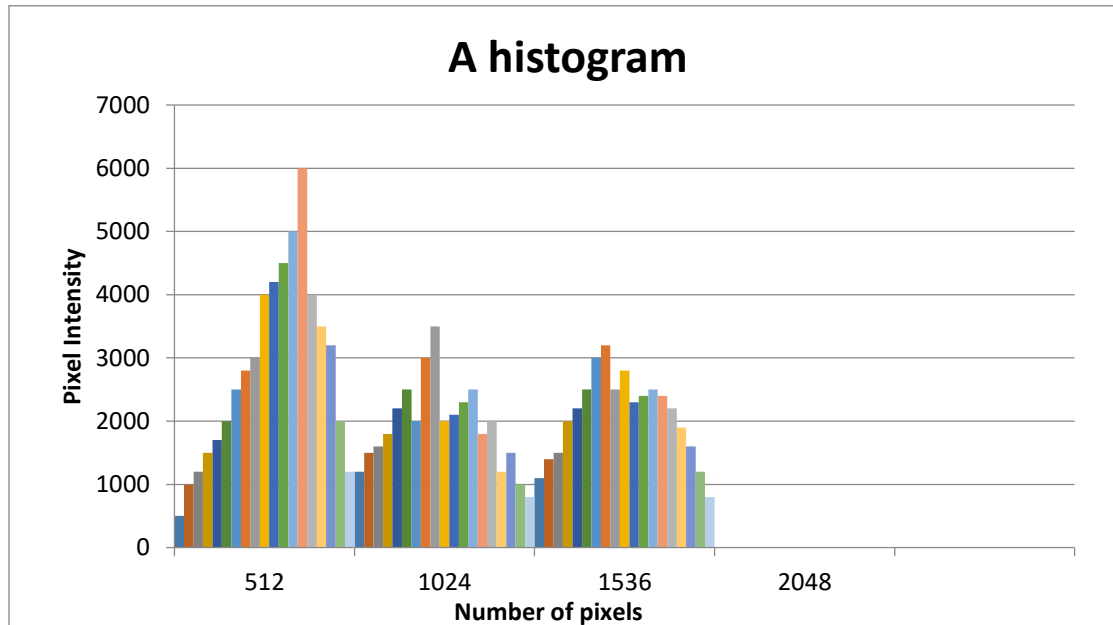
Digital imaging systems may have wide exposure latitude and may generally compensate for overexposure at the receptor plate, but they cannot compensate for information which is simply missing due to underexposure at the image receptor plate (Carroll, 2011: 448).

The wide exposure latitude of DR may produce a wide range of patient doses, from very low to very high. An appropriate patient dose is one that is necessary to deliver an image of adequate image quality required to positively make a precise differential diagnosis (Upstate Medical University, 2018: online).

If the detector is underexposed because of inadequate exposure factors, even though the image can be intensified and rescaled to show a good grayscale version, the quantum mottle in the image is equally intensified, causing a noisy and grainy radiographic image and causes the low contrast resolution sensitivity to be compromised, and often requires repeating an examination (Upstate Medical University, 2018: online).

## 2.9.1 Histogram creation and application

Figure 2.2 is a synopsis of how the histogram is constructed and how it works.



**Figure 2.2:** A histogram.

A histogram is created with the processing of each digital image. It is a graphical representation of the anatomy imaged and the exposure received within the collimated area. It is created by calculating the number of pixels within the image at each density or brightness level as the computer scans across the whole image. Each vertical bar indicates the number of pixels which hold the grey level indicated along the bottom axis of the graph (Carroll, 2011: 525).

The “peaks and valleys” of the graph indicate variations in the anatomical structures in the image and are indicated on a scale of brightness or “density” from white to black, as read from left to right; hence metallic items or contrast agents are indicated on the far left of the graph, followed by bone, then soft tissues close to the centre, fat and finally gaseous or air densities to the far right. The “spike” portion indicates the background density of the image, external to the anatomy, which is generally pitch-dark and referred to as the “tail” of the graph (Carroll, 2011: 525).

The computer identifies the “tail” portion and disregards it from the histogram analysis performed, because if the pitch-black background densities are included in the computer’s calculations, the final image produced will be tilted away from the desired brightness and contrast levels (Carroll, 2011: 525). Only data from within the anatomy need to be included during processing (Carroll, 2011: 526). Rescaling or histogram analysis errors happen due to many reasons and may result in a displayed image that is too dark, too bright, has excessive grey-scale or excessive contrast. Rescaling or histogram analysis errors are less common with DR systems, since DR systems only include the exposed pixels in the image data base, whereas CR systems start by scanning the entire IP and then attempt to separate the exposed areas from the unexposed areas of the IP (Carroll, 2011: 527).

### **2.9.2 Look-up table**

For each specific radiographic projection, the computer memory includes a pre-set reference histogram for an “ideal image” of the particular anatomy, to which the histograms of all acquired images are compared. A look-up table (LUT) lists the parameters that produce this particular shape of the ideal histogram (Carroll, 2011: 527). With the processing of each image, a table is used instead of the formula in order to save processing time in the computer. For each LUT there is an algebraic equation for converting all input pixel values into values for the output image. However, the actual calculations for all possible pixel values within the dynamic range have already been done at one point in time and the results are stored in table format within the computer. For the user’s benefit, the LUT may be denoted as a graph, plotting input pixel values against output pixel values, in which the curve is produced from the formula (Carroll, 2011: 534). This graphical data is determined by the manufacturer and signifies the combined data of an ideal image for a particular view (Carroll, 2011: 534). In order to rescale the image, various types of LUTs are created to process the data differently in order to obtain the very best results in image quality for the specific part of anatomy being radiographed (Carroll, 2011: 527).

There are essentially three general types of LUTs that are each based on particular assumptions about the histogram that will be presented for data input. Basically, each type of LUT presumes a certain shape of histogram and executes the calculations based on this. It is imperative to note that the three LUT types need to be correctly matched with the actual types of histograms acquired to prevent processing errors. It is vital that only the portion of the histogram to be analysed that is applicable to the type of LUT will be applied (Carroll, 2011: 527). The culmination of the broad exposure latitude and LUT histogram rescaling is that there is a decline in the application of essential radiographic techniques and protection principles. The decline being due to the processing systems and programmes linked to DR, which can edit the original image to make it appear to be of radiographic quality. Theoretically, it may appear like any unqualified individual can perform a radiographic examination. In practice this is not the case, as there are fundamentals required to produce an image of radiographic quality and diagnostic value. A radiographic image produced should be such that no editing is required; therefore, it is vital that fundamental radiographic practices are revised continuously (Carroll, 2011: 448).

## **2.10 Exposure Index**

An exposure index (EI) is a measure of the amount of exposure that an image receptor (IR) receives after an exposure has been made. An EI value is an indication of the image quality; a recommended EI value range for optimal image quality and optimal dose is provided by the equipment manufacturer (Faubert, 2013: 170). Digital systems lack the visual signs, which result in the recognition of exposure errors such as the overexposure and underexposure of an image when working with film-screen imaging systems. A radiographer must therefore monitor the EI linked with the digital imaging system. Radiographers should evaluate EIs as part of image evaluation, keeping in mind the variance between vendors and the limitations of the EI. The purpose of the EI is to allow a radiographer to evaluate the level of exposure the IR has received and thereby determine if the correct exposure technique for the image was used and to verify good radiographic technique (Herrmann et al., 2012: online).

It is crucial to remember that EIs are not measures of radiation dose delivered to a patient, but registers of the level of exposure to the IR. The ordinary EI values do not deliver an actual patient dose, but instead provide an estimated value of the incident radiation exposure to the detector for each acquired image (Herrmann et al., 2012: online).

Although different manufacturers have their own term for EI, such as S, LgM or DEI, the term EI is becoming standard terminology within the radiography profession, as a result of which the S, LgM, DEI and all other manufacturer terminology will be outdone with (Bowman, 2014: online). The amount of light given off by an IP is a result of the radiation exposure that it has received. The light is then converted into a signal which is used to calculate the EI number (Kerr, 2012: online). EI is therefore a function of the region of interest designated by the DR workstation for the type of examination, image processing and the exposure used (Don, Whiting, Lois Rutz and Apgar, 2014: online). EI, therefore, indirectly indicates exposure to a patient (Francique and Brownwell, 2014: online).

The effect of kVp on image contrast is less of a concern in digital imaging because computers can process digital images and alter the visibility of anatomical structures; therefore, using a higher kVp technique seems to be necessary. However, some researchers have found that using a lower kVp can improve digital image quality without an increase in patient exposure. The fact that the industry lacks a standard for digital imaging exposure techniques remains to be challenging for radiographers. CR digital image receptors are more restricted than DR flat panel detectors because they are not suitable for high kVp techniques (Fauber et al., 2018: online). In addition, in comparing exposure techniques used with film-screen, CR and DR technology, investigators found that using DR image receptors could result in decreased patient exposures. When promoting lower kVp values in routine imaging, it is essential to evaluate the benefits and the risks. Lowering the kVp value may improve image quality while maintaining patient exposure; however, the need to lower exposure may outweigh improved image quality (Fauber et al., 2018: online).

Radiographers must be more conscious of exposure technique selection and its effect on patient exposure during digital imaging. Empowering radiographers with the knowledge of how exposure techniques affect patient radiation dose will only result in improved radiation protection practices (Faubert et al., 2018: online).

Both government hospitals that participated in the study used an Agfa system. The term for EI in an Agfa system is currently the EI value; however, it was LgM originally (Long, Frank and Ehrlich, 2012: online). When the EI value falls substantially below or above the given guideline EI value, it was the practice at both hospitals to not repeat a radiographic examination when the EI value indicated high patient exposure, as long as the image quality was more than adequate.

**Table 2.1:** Exposure index guideline

| <b>Speed class</b> | <b>Target EI</b> | <b>EI min</b> | <b>EI max</b> |
|--------------------|------------------|---------------|---------------|
| 100                | 1000             | 690           | 1378          |
| 200                | 500              | 345           | 689           |
| 400                | 250              | 172           | 344           |

Table 2.1 demonstrates the EI guidelines for the Agfa CR system. Since digital image processing optimally displays the image irrespective of the exposure, rendering of an image will not change the EI value due to altered exposure levels as it would for film-screen systems. It is essential to adhere to the ALARA principle as well as maintaining good radiographic techniques. Good collimation and correct positioning will also reduce scatter absorbed by a patient. The radiation dose to a patient may therefore be kept low while still producing images of diagnostic value (Gallet, 2010: online). Deviation index (DI) expresses how far the exposure is away from a reference EI value and provides a relative indication for under-exposure and over-exposure (Gibbs, 2012: 8). In a perfect situation, the DI would be zero; however, this is rarely the case. One (1) deviation unit equals ~ 25% (+1 or -1) on an AEC and 3 deviation units equals 2x exposure or ½ exposure (+3 or -3) (Gibbs, 2012: 8).

### **2.10.1 Factors affecting EI**

Dominant factors affecting the EI in digital radiography include kVp and collimation. Image processing linked with DR allows the formation of the image using higher kVp values, while maintaining a desired image contrast. Higher kVp values result in a reduced entrance skin exposure. The careful use of collimation results in improved image quality since it decreases the amount of scatter radiation produced and thus less scatter reaches the image receptor. It also decreases the total volume of tissue irradiated and thus results in a decrease in exposure to the patient. Another factor is the source to image distance (SID). Increasing the SID may be used to decrease the entrance skin exposure (Woodward, 2012: online). Additional factors affecting EI include: positioning and centring i.e. radiographic technique, the histogram analysis and scatter (Medical Technology Management Institute, 2014: online); beam conditions namely, kVp and beam filtration; grids; the patient anatomy and the screen phosphor structure used (Cohen, Cooper, Piersall and Apgar, 2010: online).

Different types of examinations will have different target EI values based on the exposure to the body part, the sensitivity of the system and the final amount of radiation that ultimately reaches the detector (Cohen et al., 2010: online).

### **2.11 Post-processing and manipulation of digital images**

Post-processing may be defined as any adjustment made to the original image and parameters under which an image was originally recorded. These adjustments to the original image can be made in at least three different ways: by selecting a different procedural algorithm and reprocessing the image; by windowing, and by applying special features. Radiographers have discovered the convenience of simply applying the protocols for other examinations in order to make dramatic changes to an image at the touch of a button (Carroll, 2011: 506).

Even though DR systems are capable of producing images with a proper grey scale at high and low exposure levels, QA efforts must still be in place to ensure proper exposure levels are maintained. Digital images exposed to low exposure levels, while maintaining good grey scale in the image, have higher levels of X-ray quantum noise and digital images produced at high exposures have low quantum noise yet result in a higher radiation dose to the patient (Bushberg et al., 2002: 297). A lower limit for exposure is easy to distinguish since mottle becomes rapidly apparent as radiographic techniques are reduced; thus, only a slight underexposure is required to cause quantum mottle. Quantum mottle, together with the lack of any immediate consequences to overexposure, has led to an unfortunate leaning toward overexposure by radiographers known as exposure creep (Carroll, 2011: 631).

Windowing may be defined as the brightness and the contrast of the image displayed at the monitor screen which can both be adjusted upward or downward by controls on the console as the image is being viewed (Carroll, 2011: 506). This approach to modifying the image delivers more flexibility and accuracy than merely reprocessing the image under a different procedural algorithm. By visually inspecting the image as the brightness and contrast are adjusted up and down, and by going back and forth between these two controls, the image can be adjusted to the exact results preferred (Carroll, 2011: 507).

### **2.11.1 Edge enhancement and smoothing**

Smoothing algorithms, also called noise compensation, reduce the visible mottle in an image. Smoothing algorithms are particularly beneficial when applied to fairly small quantities of mottle. However, severe mottle denotes underexposure indicating a loss of small detail information within the image; using a smoothing algorithm will not restore that lost information. Radiographs displaying severe mottle as a result of underexposure must be repeated (Carroll, 2011: 583). Both kernels and low-pass frequency filtering algorithms may be used to smooth the image, and so reduce image noise and enhance the signal-to-noise ratio (SNR) (Carroll, 2011: 550).

When all of the values in a kernel are above zero and equal, smoothing takes place in the image and noise is decreased with an acquired small loss of edge contrast (Carroll, 2011: 550). Noise reduction by smoothing is a means of low-pass filtering, which eliminates the smallest details in the image. Edge enhancement, on the contrary, is achieved by high pass filtering which moderates the larger structures and background areas of the image. Smoothing and edge enhancement behave as opposites: too much noise reduction may result in a loss of detail, while too much edge enhancement may introduce visible noise in the image (Carroll, 2011: 550). Smoothing an image does result in some loss of image contrast. As a result of this, the original image should not already have low contrast as it will be made even worse (Carroll, 2011: 584).

The smoothing and edge enhancement feature must be used with utmost discretion, seeing that if an image already has very high contrast, adding edge enhancement could cause quantum mottle to become visible and even introduce further noise by means of the “halo” effect (Carroll, 2011: 584). Halo artefacts appear as dark bands at the edges of adjacent high-contrast structures such as a metal prosthesis or barium (Carroll, 2011: 609). Post-processing and manipulation of digital images, together with edge enhancement and smoothing, were relevant in this study. Post-processing, edge enhancement, and smoothing, are all features and functions of DR. They had to be considered to determine how each aspect would have affected the radiation dose and radiation protection, hence relating to the overall goal of the research study.

### **2.11.2 Lead markers and annotation**

Post-examination annotation is more prone to human error, since post-examination annotation depends on an individual’s memory. Physical lead markers, such as “left” and “right” markers in particular, must therefore be used in the radiographic room during the examination to reduce errors (Carroll, 2011: 638).

### **2.11.3 Collimation**

The purpose of pre-examination collimation is to minimise radiation exposure to a patient, and to maintain subject contrast in the remnant beam (Carroll, 2011: 295). Over-collimation may also be of concern if the anatomy of interest is cut off by collimating too tightly and thus requiring a repeated exposure. Every repeat doubles the radiation dose to the patient for acquisition of a specific view (Carroll, 2011: 825). Collimation is a lot more critical and of extreme importance in DR. It may so easily affect the histogram analysis and the final technical quality of the image (Carroll, 2011: 622). Digital radiography splits image acquisition, processing and display, which allows a radiographer to produce an image that has adequate diagnostic quality, but can be overexposed or underexposed. Adjustments to compensate for poor technique may be done at the time of display. The computer automatically modifies an image that is overexposed to ensure that the image is of diagnostic quality. This modification, separation of image acquisition and display, and absence of available dose information, may contribute to increased patient radiation exposure. Thus, the effect of post-processing due to poor technique results in an increased radiation dose to the patient (Herrmann et al., 2012: online).

### **2.12 Similar studies**

Amirzadeh and Tabatabaie (2005) report on a study that investigated radiation protection awareness in DR radiography among radiation workers in Shiraz hospitals. Data were collected by survey and analyses were performed by EPI6 software. The findings were that there was a meaningful relation between the level of education and the awareness of the employees about the principles of radiation protection. The employees had acceptable knowledge regarding the use of film badges; however, they lacked adequate awareness regarding other issues of radiation protection, such as proper and periodic educational courses for radiation workers are required (Amirzadeh and Tabatabaie, 2005: online).

Their study was relevant to the current study in the way that adequate awareness is also assumed to be lacking and that recommendations will be of great value.

Eze, Abonyi, Njoku, Irurhe and Olowu, (2013) report on a study that investigated the assessment of radiation protection practices in DR among radiographers in Lagos, Nigeria. Their study was a prospective cross-sectional survey; a convenience sampling technique was used to select four X-ray diagnostic centres in four tertiary hospitals in Lagos metropolis. They found that radiographers within Lagos metropolis displayed an excellent knowledge of radiation protection within the study period, but that adherence to radiation protection practices during the study period was poor. Radiographers in Lagos should embrace modern advances in radiation protection and make more serious efforts to apply their knowledge in protecting themselves and patients from harmful effects of ionising radiation (Eze et al., 2013: online).

Zhang and Chu (2012) report on a study that investigated the optimisation of the radiological protection of patients undergoing DR. The goal of their study was optimisation of the image quality and radiological protection of patients undergoing DR. The study involved the measurement of the dose area product (DAP), and entrance surface dose (ESD) received by a reference group of patients, for eight common radiographic procedures using the DR system before and after optimisation. Image rejection data were collected and sorted according to reasons for repeats during a two (2) month period. The study found that basic training in the management of image quality and patient dose in DR was necessary for radiologists, medical physicists, and radiographers involved in the use of new techniques. Training should include, amongst others, basic aspects of radiation protection for patients and staff, details of the operation of the installed x-ray systems, use of visualisation units, post-processing capabilities, and the operation of PACS (Zhang and Chu, 2012: online). Their study underscores the same concerns in this research study, namely, that knowledge regarding radiation protection in DR is not fully comprehended yet and thus assistance is necessary.

Warren-Forward, Arthur, Hobson, Skinner, Watts, Clapham, Lou and Cook, (2006), report on a study, which investigated the assessment of exposure indices in CR for the posterior-anterior chest and the lateral lumbar spine. The aim was to investigate whether radiographers were producing images with exposure indices within the manufacturers recommended range (MRR); the phenomenon of exposure creep, and the relationship between exposure indices (EIs) and radiation dose. It was a retrospective analysis of exposure indices over an 18-month period for the posterior anterior (PA) chest and lateral (LAT) lumbar spine at two centres using Kodak 800 and 850 CR systems. The findings were there was a potential to reduce the MRR and optimise patient dose. There was also evidence to suggest that EI was not a reliable indicator of patient dose. They recommended staff training is essential on the newer digital systems (Warren-Forward et al., 2006: online).

It follows from the above studies that the topic of radiation protection in DR is of great concern. This validates the need for further investigation into the topic to provide useful results that may be used to compile and provide recommendations regarding effective radiation protection practice in DR in order that patient radiation dose is minimised and the many unnecessary implications thereof. Future effects of unnecessary radiation dose to a patient should to be avoided or be kept to a bare minimum.

## **2.13 CONCLUSION**

The literature review covered a comparison of similar studies. It included basic background terminology and information necessary for this study.

It is evident in the literature that DR is a technology that is advancing rapidly and will soon impact on hundreds of millions of patients. If vigilant attention is not paid to the radiation protection problems of DR, radiation exposure of patients will raise significantly and without concurrent advantage (Kwan-Hoong, 2014: online).

The methodology used in study is presented in the next chapter.

## CHAPTER 3

### METHODOLOGY

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#### 3.1 INTRODUCTION

The theoretical framework of the study was presented in chapter 2. It provided the foundation for the chosen methodology. In chapter 3 the methodology used in this is discussed. The research design, the study location, the research tools, the information session, the permission and consent, the sample selection and the research methods and procedure, are described. Methodology is a very important part of a research study; it describes the technique used by a researcher to gather the data that form answers to a research question.

#### 3.2 RESEARCH DESIGN

A cross-sectional descriptive research design may include both qualitative and quantitative elements. A descriptive research design refers to when data are collected without modifying the environment. It provides data about the naturally occurring health status, behaviour, attitudes or other characteristics of a certain group. This type of research design is performed to demonstrate links or relationships between groups (The Office of Research Integrity, 2015: online). A descriptive research design is a statistical study concerned with describing the characteristics of a certain individual, or of a group (Kothari, 2004: 37). A cross-sectional study entails only a one-time interaction with the groups of people thus making comparisons between different population groups at a single point in time (The Office of Research Integrity, 2015: online). This study was thus based on a cross-sectional descriptive research design).

Quantitative elements apply in this study with regard to the type of data collection system used.

Quantitative research is conclusive in its purpose as it attempts to calculate a problem and understand how prevalent it is by looking for projectable results to a larger population. Quantitative research collects data in numerical form that can be placed into categories, rank order or measured in units. This type of data collection system may be used to create graphs and tables of raw data (Mora, 2010: online). For this research study, the quantitative data were generated through closed-ended questions in the radiographer survey, patient checklist, and radiographic image checklist, since the questions produced either numerical data or data that could be put into categories (e.g. “yes”, “no” answers).

Qualitative research on the other hand is as a research technique that focuses on collecting data through open-ended and conversational communication. Qualitative research methods pertain to the behaviour and opinion of a target audience with reference to a specific subject. There are several types of qualitative research methods: in-depth interviews, focus groups, ethnographic research, content analysis, and case study research, are generally used. The results of qualitative methods are more descriptive and the conclusions can be made fairly easily from the data that is attained. Qualitative data collection permits gathering data that is non-numeric and helps explore how choices are made and provide comprehensive insight (Bhat, 2018: online). This study did include some open-ended questions. For example, participants in the radiographer survey were asked to provide explanations in questions. Their responses were however grouped and quantified into percentages.

### **3.3 RESEARCH METHODS AND PROCEDURE**

The research methods and procedure used in the study are discussed. The general DR examinations included in this study were the chest and lumbar spine. They are the most frequently performed general DR examinations at the selected study sites.

### **3.3.1 Study location**

The study was conducted at two government hospitals in the Eastern Cape province of South Africa. Only government hospitals were used for this study as the study is a reflection on the radiation protection practices experienced by most of the population.

### **3.3.2 Permission from the hospital manager and head of the radiology department**

Before commencing the study it was imperative to obtain permission from the Department of Health Eastern Cape and then each of the hospitals managers and heads of the radiology departments at the two government hospitals in the Eastern Cape (Appendix A1-A4).

The permission letter mentioned: the title of the research study; the goal of the research study; the objectives of the research study, and what the research study entailed, to ensure that the Department of Health Eastern Cape, each head of department, and hospital management, fully understood what was required of them. Once permission was approved and obtained by the necessary government authorities, then the signed permission letters were submitted to the Health Sciences Research Ethics Committee of the University of the Free State (UFS) as requested.

### **3.3.3 Information session and consent**

Prior to the completion of the radiographer survey, patient checklist, and radiographic image checklist, potential participants were informed about the study and consent had to be given by them. Participants for the radiographer survey (Appendix G) included diagnostic radiographers employed at the two government hospitals' radiology departments. Participants for the patient checklist (Appendix H1-3) included patients referred to the two government hospitals' radiology departments for digital chest and lumbar spine radiographic examinations projections.

The reviewers for the radiographic image checklist (Appendix I) included the researcher, a diagnostic radiographer at one of the hospital's radiology department, and a lecturer employed at a university located in the Eastern Cape.

### **3.3.3.1 Information session and consent for the radiographers**

Each participant received an information document (Appendix B), which explained the purpose of the research study and what was required of them. The information document was available only in English since the participating radiographers had completed a three-year national diploma in diagnostic radiography in English. They had a good understanding of English. The participants also received a consent form in English (Appendix C), which had to be signed before they participated in the research. Participation was voluntary and could be withdrawn at any time. The participants also received a consent form in English (Appendix D) that had to be signed to gain their full consent to use the information gathered from the patient checklist and the radiographic image checklist.

Prior to signing the consent document, participants took note of the following guidelines associated with consent.

- Each participant had the right to refuse to participate in the research study or at any time
- Each had the right to withdraw and not continue to participate in the research study
- None of the participants received any remuneration for participation nor did it cost them anything to participate in the study
- Radiographers who were willing to participate in the research study were given a consent form to sign (Appendix C and D). The content of the consent form was discussed with each one
- All collected information was treated in a strictly confidential way and no name of any participant was mentioned when findings were reported

- Ethical clearance for the study was requested from the ethics committee of the University of the Free State (UFS).

### **3.3.3.2 Information session and consent for the patients**

Each patient participant received an information document in English, Afrikaans, or Xhosa (Appendices E1-E3), which explained the purpose of the research study and what was required of them. They also received a consent form in these languages (Appendices F1-F3), which had to be signed to gain their full consent to participate in the research. Similar to 3.3.3.1, they also took note of the guidelines related to participation in the research study. The researcher waited in the viewing room area at the government hospital radiology department and observed to see what DR examinations were being requested to determine what radiographic examination was going to be performed for each patient. If the radiographic examination included a chest or lumbar spine radiographic examination, the researcher waited for the radiographer to exit the X-ray room, and then went in to speak to the patient to explain the study and to obtain consent to complete the patient checklist.

Each patient participant was given an information document which explained the purpose of the study as well as a verbal explanation. Each had the opportunity to decline participation. They were informed that they were by no means obliged to participate.

### **3.3.3.3 Reviewers**

The reviewers' details are presented in 3.3.3. They all had ready access to assess the images in view of their location. They all completed the radiographic image checklist (Appendix I).

### **3.3.4 Procedure**

Three research tools (a radiographer survey; a patient checklist, and a radiographic image checklist) were used to collect the necessary data.

#### **3.3.4.1 The radiographer survey**

The questions for the radiographer survey (Appendix G) were based on radiation protection parameters in the literature (see Chapter 2); more specifically radiation protection measures as stipulated in the code of practice for users of medical X-ray equipment (DRC, 2012: 7). The survey consisted of questions based on the radiographers' knowledge of radiation protection in DR that they should have had. The radiographer survey was used to investigate the knowledge of the radiographers regarding radiation protection practice in DR during digital chest and lumbar spine radiographic examinations. The questions related to: radiation protection measures; EI values and ranges; radiation dose; radiation effects; and exposure factors.

#### **3.3.4.2 The patient checklist**

The patient checklist (Appendices H1-3) consisted of questions with "Yes" / "No" options that had to be marked with an X. The questions were based on the radiation protection practice applied by a radiographer during the chest and lumbar spine radiographic examinations that each participating patient underwent. The replies to the questions informed the researcher just how effectively radiation protection measures were applied to address radiation protection practice during digital chest and lumbar spine radiographic examinations in the Eastern Cape government hospitals and thereby improve radiation protection. There were also some personal and general questions regarding gender and age as this helped analyse the results more efficiently. No radiographer was aware of or had any knowledge on the content of the checklist distributed to the patients. The validity and reliability of the research study was ensured.

The researcher ensured that the content of the checklists was not obtainable by radiographers. This was done by personally keeping the copies of the checklist and personally handing a copy to each patient. The researcher waited to collect the checklist from the patient once the checklist was completed. However, the radiographers were asked to consent (Appendix D) to use the information gathered from the patients' checklist and the radiographic image checklist after the data were gathered.

### **3.3.4.3 The radiographic image checklist**

The radiographic image checklist (Appendix I) had to binary options (yes or no) that the reviewers had to choose between using an X. The statements were based on the technical criteria of radiation protection practice as applied by radiographers during the digital chest and lumbar spine radiographic examinations.

The checklist was used to investigate the behaviour of the radiographers regarding the technical criteria of radiation protection practice in DR as seen on the digital images of the chest and lumbar spine radiographic examinations. The results of the questions informed the researcher just how effectively the technical criteria of radiation protection practice were applied to address radiation protection practice in DR during the digital chest and lumbar spine radiographic examinations. The radiographer participants had no accessibility to the content of the radiographic image checklist, as this would have affected the validity and reliability of the research study. The researcher ensured that the content of the radiographic image checklist was only available to the reviewers. However, the radiographers were asked to consent (Appendix C and D) to use the information gathered from the radiographic image checklist after the data were gathered.

The three reviewers reviewed the chest and lumbar spine x-ray images produced by the radiographer participants before the images were subjected to post-processing to determine how effectively radiation protection measures was applied.

There were at least four image quality control measures that had to be considered, namely:

- beam collimation - electronic shutters may be used to reduce glare from unexposed areas of the final image. Electronic shutters were used to compensate for poor collimation in the x-ray room;
- anatomical lead markers - all CR/DR images had to show anatomical markers since it is very easy to accidentally flip/rotate an image during post- processing. Unless the original markers are visible, there is no way of truly knowing which side is which;
- exposure quality - it is easy to determine when an image is under-exposed by viewing the numerical sensitivity index and level of noise present. However, it was difficult to determine when an image was over-exposed since the EI value was the only indicator, thus the actual exposure factors used for image had to be checked;
- image quality - must be checked for artefacts, uniformity and patient positioning (Adams, 2015: 5).

The raw radiographic images on the workstations were examined by the researcher and used to just check each image for collimation and centring of anatomy in relation to the imaging plate. These were the only two technical criteria not observable from the images on the compact disks (CDs). Each checked radiographic image checklist was then ticked and marked accordingly for the other two reviewers to see. Once the raw radiographic image is processed and the examination has been completed by the radiographer, it gets automatically sent to the picture archiving and communication system (PACS). Each workstation stores five hundred (500) images and when the storage capacity is reached, the images are automatically deleted. They are still accessible on PACS if required in the future. Completion of the radiographic image checklists was done in privacy, using digital images of the chest and lumbar spine radiographic examinations which were transferred onto CDs.

The data obtained through and collected from the survey, patient checklist, and radiographic image checklist, were used to compile and provide recommendations regarding effective radiation protection practice in DR during digital chest and lumbar spine radiographic examinations.

### **3.4 SAMPLE SELECTION**

Sample selection relates to the research tools used in the research study. Each research tool is discussed further and divided into the target population, the sample size, the description of the sample, the pilot study, and the data collection.

#### **3.4.1 Radiographer survey**

##### **3.4.1.1 Target population**

The target population of the survey was diagnostic radiographers who worked in government hospitals in the Eastern Cape.

##### **3.4.1.2 Description of sample**

Diagnostic radiographers were included in this study because they perform digital chest and lumbar spine radiographic examinations. Consequently, they were the ones who effectively provided radiation protection to the patients.

##### **3.4.1.3 Sample size**

There were only thirty five (35) radiographers employed at the two specific radiology departments. The sample size included all of them.

##### **3.4.1.4 Pilot study of the radiographer survey**

A pilot study was conducted at a government hospital that was not in the study. The pilot study included a convenient sample of five diagnostic radiographers (n=5). A preliminary survey was given to a similar sample not involved in the final survey.

The purpose of the pilot study was to determine whether the information gathered from the research tools would answer the specific research question. It allowed for corrections to be made to unclear questions, as well as missed grammar mistakes.

#### **3.4.1.5 Data collection**

The survey was personally distributed by the researcher. The radiographers (n=35) had approximately thirty (30) minutes to complete the survey. The survey was completed independently by each participant. The radiographers were divided into two groups which ensured that there was staff available to work in the department.

Half of the radiographers at each department completed the survey at a time to prevent a disturbance of workflow within the department and on a day and time which was suitable for all, to prevent discussion of the questions between participants. On completion of the survey, the researcher collected all completed surveys. In this way, the validity and reliability of the survey collection were ensured. The memorandum of the survey (Appendix K) was used as a reference to the answers of the radiographer survey questions to determine the radiographers' behaviour regarding effective radiation protection practice in DR during digital chest and lumbar spine radiographic examinations.

#### **3.4.1.6 Data analysis**

Data from the radiographer survey were captured electronically in Microsoft Excel by the researcher. Further analysis was done by a biostatistician (Appendix J) using SAS Version 9.2. Descriptive statistics, namely, frequencies and percentages were calculated for categorical data. Medians and percentiles were calculated for numerical data.

### **3.4.2 Patient checklist**

The patients completed the checklist and were included in the research study because they were the only ones, besides radiographers, who could indicate the radiation protection measures taken during the examination.

#### **3.4.2.1 Target population**

The target population for the checklist were patients referred for general digital radiographic examinations, specifically the chest and lumbar spine at the two government hospitals in the Eastern Cape. These examinations were chosen because they were the most frequently performed general digital radiographic examinations at the two government hospital radiology departments.

#### **3.4.2.2 Sample size**

The sample size for the checklist was originally intended to include 100 patients per anatomical region. As there were two (2) anatomical regions the total sample size was going to be two hundred (200) patients. The 200 patients were going to be equally divided between the two government hospitals in the Eastern Cape. However, permission was not granted to complete the patient checklist at one of the hospitals participating in this study, the sample of the hospital that did grant full permission was increased. The sample size was increased to seventy (70) patients per anatomical region, giving a total sample size of one hundred and forty ( $n= 140$ ) patients. The patients were divided equally among the radiographers to ensure that each radiographer's radiation practices were evaluated the same amount of times to ensure results were more reliable and accurate.

#### **3.4.2.3 Description of sample**

The sample included all the patients who were referred for general DR examinations of either the chest and/or the lumbar spine.

#### **3.4.2.4 Pilot study of the patient checklist**

A pilot study was conducted at the same hospital as the radiographer survey (cf. 3.4.1.4) and was not part of the main data collection group. The pilot study included a sample of five patients (n=5). The checklist was given to a similar sample, who were not involved in the final checklist. The purpose of the pilot study was to determine whether the information gathered from the research tools answered the specific research question. The pilot study enable all unclear questions, as well as missed grammar mistakes, to be corrected.

#### **3.4.2.5 Data collection**

After a chest and/or lumbar spine examination was performed by a participating radiographer (i.e. one who completed the surveys), the patient completed the checklist which was handed out by the researcher.

The checklist allowed the participating patients to inform the researcher on the radiation protection measures they received during the examination. Each patient was given roughly fifteen (15) minutes to complete and return the checklist to the researcher. To limit misunderstandings, the researcher was available to clarify questions while each patient completed the checklist.

#### **3.4.2.6 Data analysis**

Data from the patient checklist were captured electronically in Microsoft Excel by the researcher. As was previously the case, further analysis was done by a biostatistician using SAS Version 9.2. Descriptive statistics, namely, frequencies and percentages were calculated for categorical data.

### **3.4.3 Radiographic image checklist**

The radiographic image checklist was included in the research study because there were certain technical criteria regarding radiation protection practice i.e. collimation, EI, lead markers etc., which had to be analysed.

These could not be answered by patients. The sample included all general digital images of completed chest and lumbar spine radiographic examinations, in particular, the PA and lateral views of the chest, and the AP and lateral views of the lumbar spine. The sample size for the radiographic image checklist comprised two anatomical regions: the chest and lumbar spine. There were 100 chest radiographic images and 100 lumbar spine radiographic images (n=200).

#### **3.4.3.1 Pilot study of the radiographic image checklist**

A pilot study was conducted at the same hospital used for the other two pilot studies above. The data collected were also not used as part of the main data collection group. The pilot study included a convenient sample of six digital images of the chest and lumbar spine (n=6).

A preliminary radiographic image checklist was used by the researcher and head radiographer to determine whether the information gathered from the radiographic image checklist answered this specific research question. The pilot study allowed for corrections to be made to all unclear questions, as well as missed grammar mistakes.

#### **3.4.3.2 Data collection**

The collection of data was done by the completion of a radiographic image checklist completed by three reviewers. They assessed all chest and lumbar spine radiographic examinations over a period of three months. The digital chest and lumbar spine radiographic examinations had to have been performed by the radiographers who completed the surveys. The radiographic image checklist was completed only on completion of the radiographers' survey and the patients' checklist. The radiographic image checklist informed the researcher on the technical aspects of radiation protection practice applied during the digital chest and lumbar spine radiographic examinations. Each reviewer completed all 200 radiographic image checklists from the government hospitals' radiology department. They did so over a period of seven months.

As stated in 3.3.4.3 measures were taken to ensure the validity and reliability of the data. Each reviewer completed the radiographic image checklist in privacy, using digital images of the chest and lumbar spine radiographic examinations which were transferred onto CD. Reviewer 2 was given CDs containing the digital images of the chest and lumbar spine radiographic examinations and completed the radiographic image checklists in privacy. The sampling of the radiographic images was completely random. The researcher went to each workstation and selected either a chest or lumbar spine radiographic examination to access a list of the completed chest or lumbar spine radiographic examinations. The researcher then started at the top of the list and worked down until sufficient examinations for the necessary radiographic image checklist were reviewed. This prevented an association being made by the reviewers between the radiographer who performed the examination and the radiographic images produced.

#### **3.4.3.3 Data analysis**

Data from the radiographic image checklists were captured electronically in Microsoft Excel by the researcher. Any further analysis was done by a biostatistician using SAS Version 9.2. Descriptive statistics, namely, frequencies and percentages, were calculated for categorical data. Medians and percentiles were calculated for numerical data. Analytical statistics, namely the chi-square test, was used to evaluate if there were any significant differences between the three reviewers. A significance level  $\alpha$  of 0.05 was used.

### **3.5 CONCLUSION**

Chapter 3 addressed the methodology used during this study. This research study was based on a cross-sectional descriptive research design.

The methodology included three research tools to obtain data to answer the research questions (see 1.4) and the research objectives (see 1.7).

Also discussed were the research design, the study location, the information session, ethics permission and informed consent, the sample selection, and the research methods.

In the next chapter, the results of the research tools used in the study are presented. An analysis of the results of the three research tools (radiographer survey, the patient checklist and the radiographic image checklist) is presented.

## CHAPTER 4

### RESULTS AND DISCUSSION OF THE RESEARCH TOOLS

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#### 4.1 INTRODUCTION

The methodology of the study presented in chapter 3 described the technique used by the researcher to gather data that answers the research questions. The results of the three research tools, namely, the radiographer survey, the patient checklist, and both the radiographic image checklist of the lumbar spine radiographic examination and the radiographic image checklist of the chest radiographic examination, are presented in chapter 4.

Each tool is dealt with individually by analysing the responses to each question or statement within the specific research tool. The results are presented as figures and tables. The results are interpreted and analysed. The results of the research tools are comprehensively discussed.

#### 4.2 THE RADIOGRAPHER SURVEY

The first objective of the study was to establish the awareness of diagnostic radiographers regarding effective radiation protection (including radiation protection variables i.e. collimation; time; distance; shielding; the use of EI values; SID and exposure factors) through a survey (Appendix G). This objective was addressed and achieved through the compilation and completion of the radiographer survey.

## **4.2.1 Radiographer survey results**

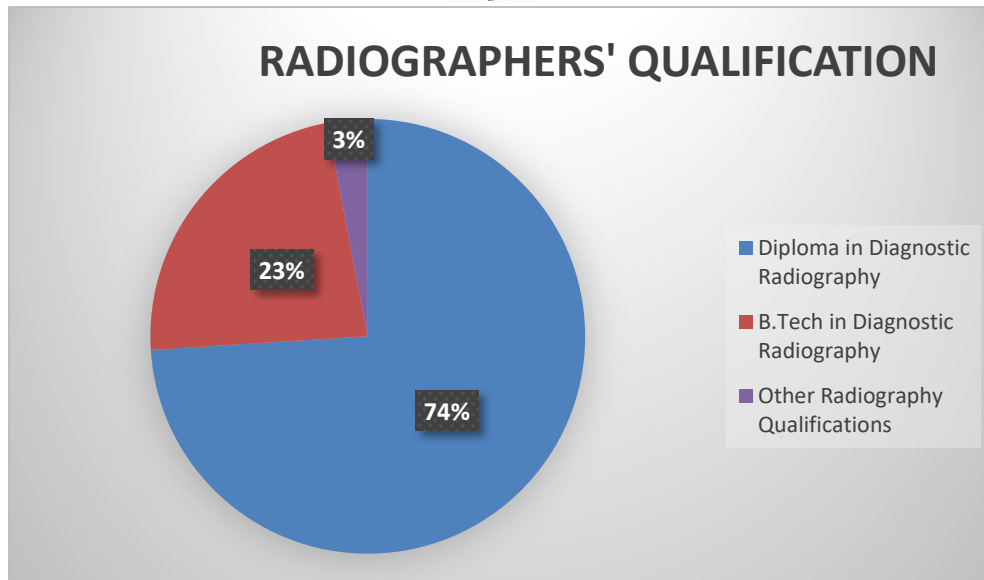
Forty copies of the survey questionnaire were generated for distribution to diagnostic radiographers who perform digital chest and lumbar spine radiographic examinations, and were employed at two government hospitals in the Eastern Cape. The hospitals in this study are referred to as hospital 1 and hospital 2. The survey comprised twenty-two (22) questions on radiographers' knowledge of radiation protection when using digital radiography. Twenty (20) copies of the survey were distributed to each of the selected hospitals for completion by radiographers. There was a 100% return rate from hospital 1 as 20 completed questionnaires were received. Only 15 completed questionnaires were received from radiographers at hospital 2 which resulted in a 75% return rate was achieved.

### **4.2.1.1 General background questions**

Three general questions (A, B and C) covered the participants' qualifications, academic training institution, and number of years of radiographic experience.

#### **4.2.1.1.1 The radiographers' highest qualification level**

Question A covered highest qualification level. The results are presented in Figure 4.1.

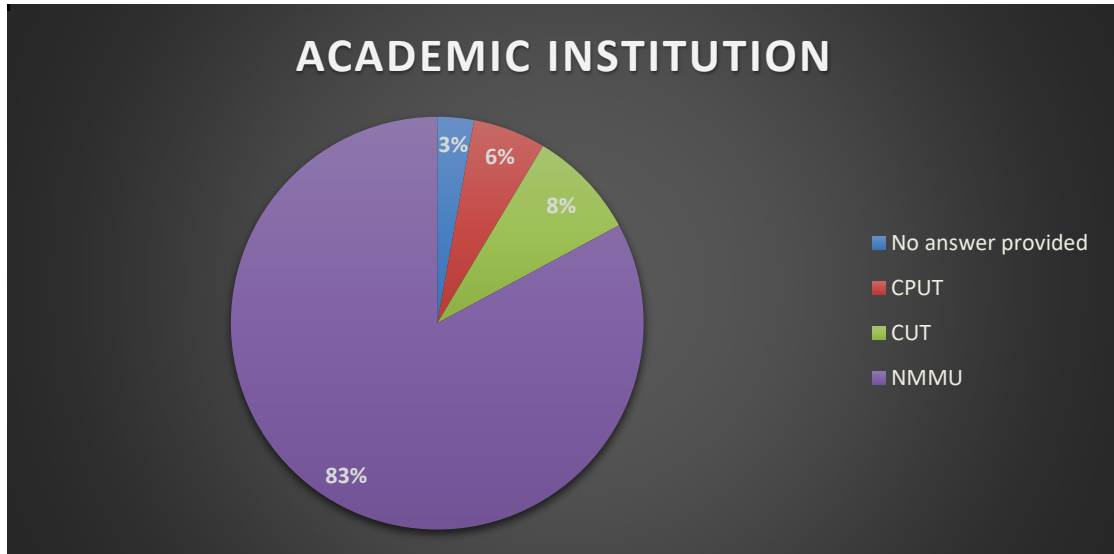


**Figure 4.1:** Graphical distribution of the different levels of qualifications of participating radiographers (both hospitals).

As shown in Figure 4.1, 74% of the participants have a diploma in diagnostic radiography, and 3% have other qualifications in radiography, which were not stated. None of the 35 participants were in possession of a master's degree in radiography. The different levels of qualifications of participating radiographers may have influenced the overall results obtained a radiographer with a B.Tech or other higher qualification in diagnostic radiography may have received additional formal training and theory on digital radiography (DR).

#### 4.2.1.1.2 Academic institution training

The participants were required to state the name of the institution where they underwent radiographic training. The results of question B are presented in Figure 4. 2.



**Figure 4.2:** Institutions at which participating radiographers from both hospitals completed their studies.

Figure 4.2 shows that 97% of the participants qualified at one of three South African institutions: Cape Peninsula University of Technology (CPUT), Central University of Technology (CUT) or Nelson Mandela Metropolitan University (NMMU); 3% did not answer the question, Most of the participants (83%) completed their studies at NMMU. This probably is because NMMU serves the local Eastern Cape community.

#### **4.2.1.1.3 The number of years qualified**

Question C covered years of qualification as a radiographer. The results are presented in Figure 4.3.

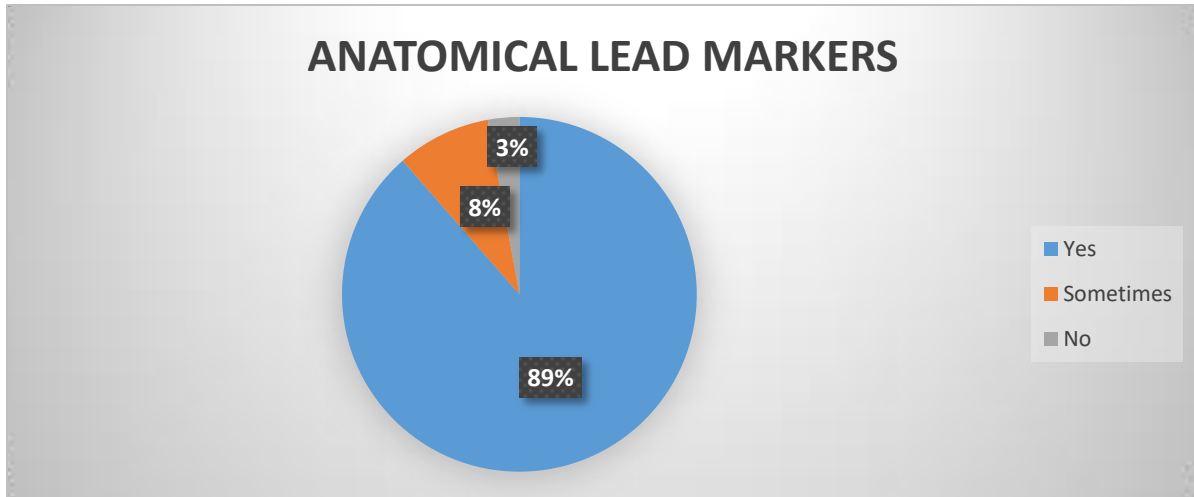


**Figure 4.3:** Graphical distribution of the number of years the participating radiographers have been qualified.

Figure 4.3 shows that 20 of the 35 participants had between three and nine years' experience as a radiographer. The mean was 6 years; the minimum was one year, and the maximum was 22 years. The varying working experience of the participants may have influenced the overall results obtained. The number of years of radiographic experience and the content of the formal theory received by the participants may have affected their knowledge regarding DR.

#### 4.2.1.2 Question 1: Anatomical lead markers

Question 1 asked whether anatomical lead markers should be present on all images. The answers to this question are presented in Figure 4.4.



**Figure 4.4:** Graphical distribution of whether anatomical lead markers must be present on all images taken of a patient.

As shown in Figure 4.4 the majority (89%) of the participants correctly answered yes. The Directorate Radiation Control (DoH, 2012: 4) states lead anatomical markers must be used for all views. Adams (2015: 5) emphasises that all CR/DR images must show anatomical lead markers since it is very easy to accidentally flip/rotate an image during post-processing. Unless the original markers are visible, there is no way of truly knowing which side which is (Adams, 2015: 5). The participants were also requested to provide a reason for their answer as seen in Table 4.1 below.

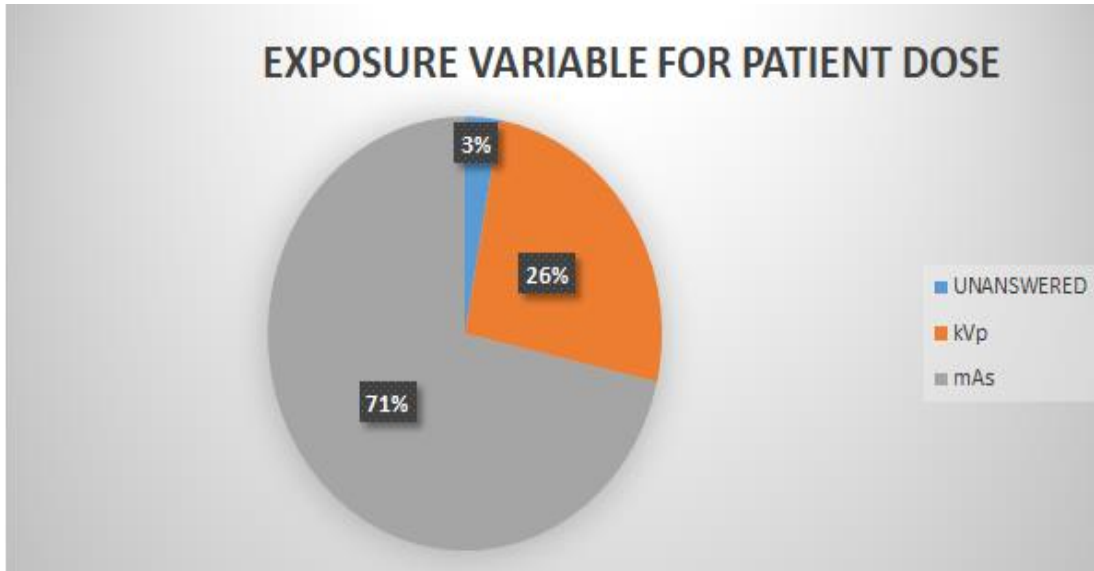
**Table 4.1:** Answers to whether anatomical lead markers must be present on all images taken of a patient

|           | Percentage | Reason 1 (R1)   | Reason 2 (R2)                        | Reason 3 (R3)  |
|-----------|------------|---|--------------------------------------|--|
| Yes       | 89%        | To ensure the correct side is being examined (R1 = 59%).  | For medico-legal reasons (R2 = 37%). | As it is law as stated by the Directorate Radiation Control (R3 = 4%). |
| Sometimes | 8%         | Anatomical lead markers do not need to be present on lateral spine and skull projections (R1 = 8%). |                                      |  |
| No        | 3%         | Not necessary to use anatomical markers for lateral spine and skull projections (R2 = 3%)           |                                      |  |

The answers in Table 4.1 show that the majority of the participants were aware that anatomical lead markers must be present on all images taken of a patient, as suggested in the literature (see sections 2.5.2, 2.11.2, 2.7 and 3.3.4.3). Although the reasons “sometimes” and “no” are incorrect in theory, in practice, depending on the clinical environment or patient condition, it is not always possible to apply markers. The majority of the participants responded yes anatomical lead markers must be present on all images taken of a patient to ensure that the correct side is being examined and for medico-legal reasons.

#### 4.2.1.3 Question 2: Exposure variable influencing patient dose

The answers given by the participants regarding the exposure variable that influences dose to a patient are seen in Figure 4.5.



**Figure 4.5:** Graphical distribution of the exposure variable which is under the control of the radiographer on which dose to a patient is primarily depended on.

It is thus evident from the results above that the majority of participants (71%) are aware that mAs is the exposure variable on which dose to a patient primarily depends. This is underscored by Sherer et al. (2006: 26) who state “the number of x-ray photons (mAs) is controlled by technique factors chosen by the radiographer; therefore, the radiographer is essentially responsible for the radiation dose the patient receives during a radiographic examination.”

#### 4.2.1.4 Question 3: ALARA

Question 3 asked what the acronym ALARA stands for. The responses were: 94% of the participants stated that ALARA stands for “As Low As Reasonably Achievable” which is the correct answer; 3% incorrectly stated “as low as reasonably possible.”

Since 3% did not provide an answer this was considered to be incorrect as decided by the researcher and the biostatistician. The results show that majority of the participants answered correctly as they did know the full wording of the acronym ALARA. This finding is important within the context of this study as radiation protection revolves around ensuring that exposures to ionising radiation should be kept As Low As Reasonably Achievable (ALARA).

#### 4.2.1.5 Question 4: Verification of patient identification

The results of the question pertaining to the above question are presented in Table 4.2 below.

**Table 4.2:** Answers regarding how to correctly verify patient identification

| <b><u>Answers:</u></b>  | <b><u>Percentage:</u></b> |
|---|---------------------------|
| <b><i>Correct (37%)</i></b>   |                           |
| Verbally request the patient's name & DOB & Address                       | 26%                       |
| Verbally request the patients' name & DOB & address & type of examination | 3%                        |
| Verbally request the patients' name & DOB & ID number                     | 5%                        |
| Verbally request the patients' name & DOB & type of examination           | 3%                        |
| <b><i>Incorrect (63%)</i></b>   |                           |
| Verbally request the patients' date of birth (DOB) & address              | 3%                        |
| Verbally request the patients' name & address                             | 6%                        |
| Verbally request the patients' name & age                                 | 3%                        |
| Verbally request the patients' name & DOB                                 | 14%                       |
| Unanswered  | 37%                       |

As shown in Table 4.2 only 37% of the participants correctly indicated the use of two identifiers. The routine of having patients identify themselves, and by using two patient identifiers, is vital in improving the reliability of a patient's identification procedure. The use of two identifiers also helps ensure that a correct match is made between the service or treatment and the individual. This method assists in eliminating errors and enhancing patient care (Infection Prevention and You, 2017: online). For the purpose of this study it was decided to use a minimum of three patient identifiers when verifying the correct patient identification (ID).

The results indicate that patient verification is not performed sufficiently. Patient verification thus requires some attention.

#### **4.2.1.6 Question 5: Family members and acquaintances in the X-ray room**

Question 5 asked if patients' acquaintances or family members are allowed to stay in the X-ray room during a radiographic examination. The Directorate Radiation Control (DoH, 2012: 16) states that members of the public are not permitted to enter controlled areas unsupervised. The occasional use of non-radiation personnel to provide assistance, mainly in ward or operating theatre radiography, is acceptable, but should include the full use of protective clothing, devices and techniques to minimise radiation dose. Precaution must be taken to ensure the same non-radiation personnel are not continually involved. Pregnant individuals may also not assist in this regard (DoH, 2012: 16). Seventeen percent (17%) of the participants stated yes that patients' acquaintances or family members are allowed to stay in the X-ray room during an ionising radiation examination; 9% replied in the negative; and sometimes was given by 74% of the participants. Based on what the literature states with regards to members of the public, the most correct answer is sometimes. Non-radiation personnel, or members of the public, must not stay in the X-ray room during a radiographic examination, except if they are going to be of assistance.

The results show that the majority of the participants are aware that patients' acquaintances or family members must not stay in the X-ray room during a radiographic examination. The exception is if a radiographer has an incoherent or challenging patient and requires assistance. If this is the case, an acquaintance or family member must then also be provided with a full lead rubber apron or any other radiation protecting apparel to deliver the best possible radiation protection measures (see 2.6).

#### 4.2.1.7 Question 5.1: Explanation of question 5

The answers given by the participants regarding question 5 are presented in Table 4.3 below.

**Table 4.3:** Explanations of question 5

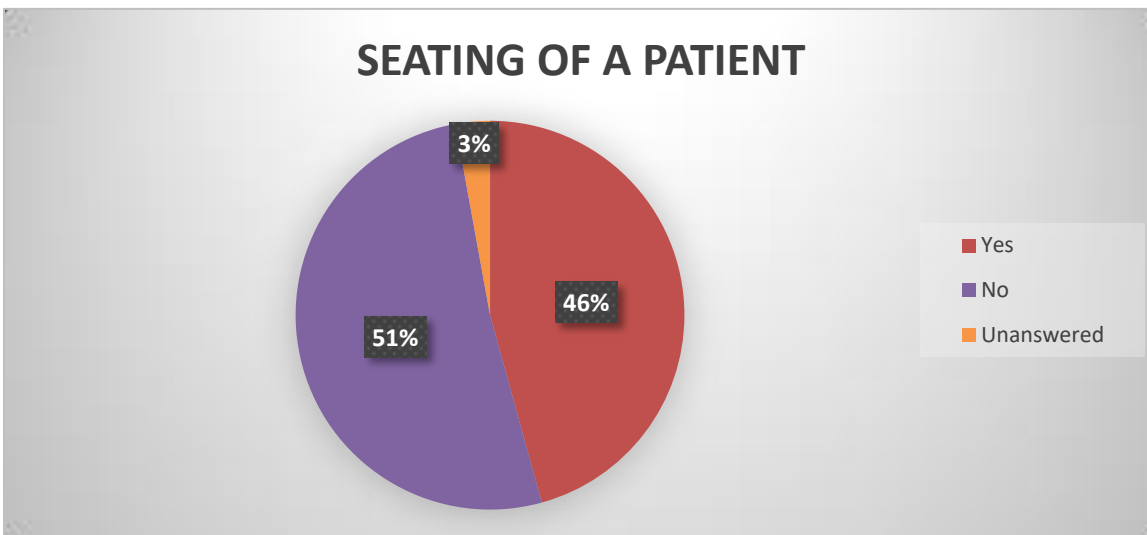
|                  | <u>Percentage</u>                   | <u>Reasons</u>   |
|------------------|-------------------------------------|--|
| <b>Yes (17%)</b> | <b><i>Correct explanation</i></b>   |  |
|                  | 25.5%                               | For support and assurance, but a lead apron must be given to the escort.         |
|                  | 49%                                 | To help with paediatric patients.  |
|                  | 25.5%                               | To assist with the patient.  |
|                  | <b><i>Incorrect explanation</i></b> |  |
|                  | 100%                                | To assist in moving patients on and off the x-ray table.                         |
| <b>No (9%)</b>   | <b><i>Correct explanation</i></b>   |  |
|                  | 50.7%                               | Radiation is harmful.  |
|                  | 49.3%                               | To assist with the patient, but a lead rubber apron must be given to the escort. |
|                  | <b><i>Incorrect explanation</i></b> |  |

|                            |                                   |  |
|----------------------------|-----------------------------------|--|
|                            | 100%                              | Unanswered.  |
| <b>Sometimes<br/>(74%)</b> | <b><i>Correct explanation</i></b> |  |
|                            | 38%                               | To help with paediatric patients.  |
|                            | 4%                                | To help with paediatric patients and for translation purposes.   |
|                            | 4%                                | To help with paediatric patients and to assist with the patient.   |
|                            | 4%                                | To help with paediatric patients and to assist with the patient, but a lead apron must be given to the escort. |
|                            | 4%                                | To help with paediatric patients and agitated or confused patients.  |
|                            | 4%                                | To help with paediatric patients and confused patients, but a lead apron must be given to the escort.          |
|                            | 4%                                | To help with paediatric patients and psychiatric patients, but a lead apron must be given to the escort.       |
|                            | 19%                               | To assist with the patient.  |
|                            | 11%                               | To assist with the patient and for translation purposes.   |
|                            | 4%                                | To assist with the patient, but a lead apron must be given to the escort.                                      |
|                            | 4%                                | To assist with the patient provided the patient is not pregnant.   |

It should be noted that although the most correct answer to question 5 is sometimes, yes or no, based on the provided reasoning, may also be correct, as decided by the researcher in terms of the literature (see DoH, 2012: 16). The reasons provided show the participants are well aware of possible reasons/circumstances to allow patients' acquaintances or family members to stay in the X-ray room during a radiographic examination.

#### 4.2.1.8 Question 6: Parallel seating for upper extremity

Question 6 asked if seating a patient parallel to the X-ray table for an upper extremity examination (i.e. hand, wrist, forearm and elbow) is a sufficient means of radiation protection for the patient. Figure 4.6 presents the answers to this question.



**Figure 4.6:** Graphical distribution of whether seating a patient parallel to the x-ray table for an upper extremity examination is sufficient means of radiation protection for the patient.

It is evident from Figure 4.6 that apart from the 3% of participants who did not answer the question, 46% indicated seating a patient parallel to the X-ray table for an upper extremity examination is a sufficient means of radiation protection for a patient.

American Society of Radiologic Technologists (ASRT) explains that during an upper extremity examination, a patient should be given a lead equivalent rubberised apron to place on their lap. This apron will protect their reproductive organs from unnecessary radiation. A radiographer requests a patient to sit on a chair and to place their arm on the X-ray table. Sponges or other equipment may be positioned around the arm to help keep it still during the examination to prevent repeating the examination and thus minimising radiation exposure to a patient (American Society of Radiologic Technologists, 2003: online).

To ensure maximum radiation protection, a patient should be seated at the side or end of the table with the lower limbs and gonads away from the primary beam, i.e. with the legs to the side of the table rather than under it; the X-ray beam should be collimated within the margins of the cassette (Whitley *et al.*, 2005: 39). Based on the literature presented above the most correct answer was no to seating a patient parallel to the x-ray table for an upper extremity examination as it is not a sufficient means of radiation protection for a patient.

#### 4.2.1.9 Question 6.1: Explanation of question 6

The answers given by the participants regarding question 6 are in Table 4.4 below.

**Table 4.4:** Explanations of question 6

|            | <u>Percentage</u>                          | <u>Reasons</u>   |
|------------|--|--|
| <b>Yes</b> | <b><i>Incorrect explanation (100%)</i></b> |  |
|            | 31%  | There is less direct radiation to the gonads.                    |
|            | 31%  | There is no radiation to the legs.                               |
|            | 38%  | No explanation / answer provided.                                |
| <b>No</b>  | <b><i>Correct explanation (100%)</i></b>   |  |
|            | 6%   | Collimation must still be applied.                               |
|            | 17%  | A lead apron should still be used.                               |
|            | 22%  | Lead protection and collimation is still needed.                 |
|            | 55%  | There is still scatter radiation thus a lead apron must be used. |

The reasons provided for answering “no” show that the participants are aware of and have some knowledge regarding radiation protection.

This result shows that the participants may have received some form of training or knowledge on radiation protection measures in digital radiography (DR) at some point.

#### **4.2.1.10 Question 7: Define EI**

Question 7 asked the participants to indicate what the term EI stands for. The responses given by the participants were: 91% stated it stands for “Exposure index,” 3% stated it stands for “Exposure indicator,” and 6% stated it stands for “Exposure indices”. According to Fauber (2013: 170) the term EI stands for exposure index/exposure indices (plural). Therefore, based on the literature in this study 97% of the participants provided the correct answer by stating that EI stands for “Exposure index” or the plural “Exposure indices”.

#### **4.2.1.11 Question 8: Purpose of EI**

Herrmann et al. (2012: online) explain that the purpose of the EI is to allow a radiographer to evaluate the level of exposure the IR has received and thereby to determine if the correct exposure technique for the image was used and to verify a good radiographic technique.

The purpose of EI in DR was covered in question 8. Table 4.5 presents the results to this question.

**Table 4.5:** The purpose of EI

|                            | <u>Percentage</u> | <u>Purpose</u>  |
|----------------------------|-------------------|---|
| <b>Correct<br/>(77%)</b>   | 16%               | To indicate the amount of radiation exposure received by the image receptor.                            |
|                            | 18%               | To help with the acceptability of the image and exposure factors.                                       |
|                            | 26%               | To determine if the correct exposure was given.   |
|                            | 4%                | To determine if the correct exposure was given and to determine if the image was over or under exposed. |
|                            | 14%               | To determine if the image was over or under exposed.  |
|                            | 22%               | To ensure that the exposure given is within the EI range  |
| <b>Incorrect<br/>(23%)</b> | 13%               | To measure the radiation dose to the patient.   |
|                            | 87%               | Question left unanswered and no purpose / answer given.   |

Literature (see 2.10) was used to determine the validity of the purpose of EI provided by the participants. It is thus evident in Table 4.5 that 76% of the participants provided the correct purpose of EI in DR.

#### **4.2.1.12 Question 9: DR affected exposure factors**

The answers given by the participants, in terms of how DR has affected / adapted exposure factors, are depicted in Table 4.6 below.

**Table 4.6:** How digital radiography has affected / adapted exposure factors

|                            | <u>Percentage</u> | <u>Answer</u>   |
|----------------------------|-------------------|---|
| <b>Correct<br/>(60%)</b>   | 28%               | DR has led to a lower kV and higher mAs values being used (see 2.10.2).   |
|                            | 28%               | DR has led to wider exposure latitude.  |
|                            | 19%               | DR has led to wider exposure latitude and less repeats of x-rays.   |
|                            | 15%               | DR provides an image of diagnostic quality with a lower dose as compared to conventional radiography.   |
|                            | 5%                | DR allows the use of a lower mAs which lowers the radiation dose to the patients.   |
|                            | 5%                | With DR one does not use or need a higher mAs whereas by conventional radiography one does.   |
| <b>Incorrect<br/>(40%)</b> | 20%               | DR has led to the increase in exposure dose to the patient.   |
|                            | 7.5%              | DR has led to a higher kV and lower mAs.  |
|                            | 7.5%              | DR has led to less radiation to the patient because the image can still be adjusted on the computer and one does not need to repeat all the time if the exposure is not acceptable. |
|                            | 7.5%              | DR has led to lower exposures due to the IP plates being more sensitive and post processing is also more accepting of low exposures.  |
|                            | 57.5%             | Question left unanswered.   |

According to Bushberg et al (2002: 308) CR imaging systems require about twice the exposure of an equivalent 400-speed screen-film detector to obtain similar image quality. A CR system is therefore equal to a 200-speed screen-film system for most general radiographic examinations. Digital radiography, according to ClarkVision.com (2008: online), has modified exposure factors by allowing an exposure latitude to occur, which is an indication of the amount of overexposure or underexposure used in producing an image that may still be considered acceptable. Based on literature (see 2.9 - exposure latitude of digital imaging) the answers were considered to be correct or incorrect. The results in Table 4.6 show that exposure factors may require some attention as 40% of the answers were incorrect.

#### 4.2.1.13 Question 10: Adapting exposures to combat deviation from EI

Table 4.7 presents the answers given by the participants regarding how to adapt exposure factors to ensure that the EI value falls within the acceptable range.

**Table 4.7:** Adapting exposures to combat deviation from EI

|                          | <u>Percentage</u> | <u>Answer</u>  |
|--------------------------|-------------------|--|
| <b>Correct<br/>(23%)</b> | 61%               | If the EI is too high, then one must decrease the exposure and if the EI is too low then one must increase the exposure. |
|                          | 26%               | Increase or decrease the exposure depending if it is lower or higher than the recommended EI value.                      |
|                          | 13%               | Increase or decrease the exposure or collimate and check the SID.  |

|                            |     |  |
|----------------------------|-----|--|
| <b>Incorrect<br/>(77%)</b> | 18% | A low EI value means the image is over-exposed and therefore one must lower the exposure, and a high EI value means the image is under-exposed and therefore one must increase the exposure. |
|                            | 82% | Question left unanswered.  |

Gibbs (2012: 8) explains deviation index (DI) expresses how far the exposure is away from a reference EI value and it provides a relative indication for under-exposure and over- exposure. In a perfect situation, the DI would be zero; however, this is rarely the case. One (1) deviation unit equals ~ 25% (+1 or -1) on an AEC and 3 deviation units equal 2x exposure or ½ exposure (+3 or -3) (Gibbs, 2012: 8). Based on literature (see 2.5.3.1, 2.10 and 3.3.4.3) the answers were considered to be either correct or incorrect.

It is evident from Table 4.7 that 23% of the participants correctly stated how one could adapt exposure factors to ensure that the EI value falls within the acceptable range; 77% incorrectly stated how one could adapt the exposure factors to ensure that the EI value falls within the acceptable range. Since the majority (77%) answered incorrectly this suggests they do not know how to adapt the exposure factors to ensure that the EI value falls within the acceptable range in terms of the literature (see 2.10). This finding of deviation from EI may require some attention.

#### **4.2.1.14 Question 11: EI range for optimum image quality for an extremity**

Participants were required to state in question 11 the manufacturers' suggested EI range for optimum image quality for an extremity. Their answers are presented in Table 4.8 below.

**Table 4.8:** EI range for optimum image quality for an extremity

|                        | <u>Percentage</u> | <u>Answer</u>   |
|------------------------|-------------------|---|
| <b>Correct (29%)</b>   | 100%              | Manufacturer's suggested EI range is 690 – 1378.                        |
| <b>Incorrect (71%)</b> | 13%               | Manufacturer's suggested EI range is 1000.                              |
|                        | 4%                | Manufacturer's suggested EI range is 1200 – 1800.                       |
|                        | 15%               | Manufacturer's suggested EI range is 200.                               |
|                        | 4%                | Manufacturer's suggested EI range is 400.                               |
|                        | 7%                | Manufacturer's suggested EI range is 400 – 1200.                        |
|                        | 20%               | Manufacturer's suggested EI range is 100 – 300.                         |
|                        | 8.5%              | Manufacturer's suggested EI range is 100 – 400.                         |
|                        | 8.5%              | Manufacturer's suggested EI range is between negative 4 and positive 4. |
|                        | 20%               | Question left unanswered.   |

According to Gibbs (2012: 8) the exposure index guideline range for the Agfa CR system, for optimum image quality for an extremity, is between the  $EI_{min}$  of 690 and  $EI_{max}$  of 1378. As shown in Table 4.8, 29% of the participants correctly stated the manufacturer's suggested EI range for optimum image quality for an extremity; 72% provided incorrect answers to the question. In view of the latter finding this suggests that they did not know or were unaware of the manufacturer's suggested EI range for optimum image quality for an extremity as presented in the literature (see 2.10). The values are available and placed in the viewing area at both hospitals therefore application of the EI values may require some attention.

#### 4.2.1.15 Question 12: Four factors that affect EI

Question 12 required the participants to name four factors that would affect the EI. The answers given by the participants are in Table 4.9. From the 35 participants, 29 participants did not answer the question. A possible reason for this is that they were unaware of the possible factors which may affect the EI value.

**Table 4.9:** Factors affecting EI

|                | <b><u>Factors</u></b>   | <b>Frequency (n = 35)</b> |
|----------------|---|---------------------------|
| <b>Correct</b> | Collimation   | 24                        |
|                | Correct centering point   | 3                         |
|                | KVp   | 11                        |
|                | kVp & mAs   | 16                        |
|                | MAs   | 16                        |
|                | SID or FFD  | 15                        |
|                | Size of cassette used relative to size of anatomical part under examination | 4                         |
|                | Size of patient   | 17                        |
|                | Type of examination: in-bucky / out of bucky (Grid selection)               | 4                         |

Woodward (2012: online) states that the factors affecting the EI in DR include: kVp: collimation; and source to image distance (SID). The results in Table 4.9 indicate that there were nine (9) identified factors that influence the EI. According to literature all nine factors are correct. It should be noted that FFD and SID were used interchangeably and since they refer to distance the researcher decided to group them together.

#### 4.2.1.16 Question 13: Determine exposure

The answers given by the participants regarding how to determine what exposure to set for a patient are in Table 4.10 below.

**Table 4.10:** How to determine what exposure factors to set for a patient

|                       | <u>Percentage</u> | <u>Answer</u>  |
|-----------------------|-------------------|--|
| <b>Correct (96%)</b>  | 30%               | Size of the patient.   |
|                       | 6%                | Size and age of the patient.   |
|                       | 3%                | Size of patient and density of the anatomical part under examination.                          |
|                       | 6%                | Size and pathology of the patient.   |
|                       | 25%               | Size of the patient and type of examination.   |
|                       | 3%                | Size of the patient, type of examination and density of the anatomical part under examination. |
|                       | 6%                | Size and pathology of the patient and type of examination.                                     |
|                       | 3%                | Density of the anatomical part under examination.  |
|                       | 3%                | Density of the anatomical part under examination and pathology of the patient.                 |
|                       | 15%               | Checking the exposure chart and applying the necessary adjustments to that.                    |
| <b>Incorrect (4%)</b> | 100%              | Question left unanswered.  |

According to Herrmann et al. (2012: online) one must: select the appropriate exposure factors for a patient's size to ascertain acceptable image quality for diagnosis; use the highest kVp within the optimal range for the position and part of anatomy together with the lowest amount of mAs required to deliver an acceptable exposure to the image receptor; and use exposure technique charts that are constantly improved and pertinent to an extensive range of patient ages and sizes. It is evident from Table 4.10 that 96% of the participants correctly explained how one would determine what exposure to set for a patient; 4% failed to provide a correct explanation. The vast majority provided correct answers showing they were aware of and did know how to determine what exposure to set for a patient. This result is in keeping with literature (see 2.7).

#### 4.2.1.17 Question 14: Adjusting exposure factors

Question 14 asked the participants to state how one would adjust exposure factors to reduce the radiation exposure to a patient. Their replies are in Table 4.11.

**Table 4.11: Adjusting exposure factors to reduce radiation exposure**

|                                       | <u>Percentage</u> | <u>Answer</u>                                 |
|---------------------------------------|-------------------|---|
| <b>Correct (72%)</b>                  | 64%               | Reduce the mAs.                               |
|                                       | 36%               | Use an increased kVp and lower mAs technique. |
| <b>Question left unanswered (28%)</b> | 100%              |   |

According to Sherer et al. (2006: 26) mAs is the main factor that determines the amount of radiation that is directed toward a patient during a radiographic exposure. Fauber (2013: 85b) states that if possible a higher kVp and lower mAs should be used to reduce radiation exposure to a patient. When increasing the kVp, less mAs is required and thus less ionising radiation is required to achieve a desired exposure to the IR (Fauber, 2013: 85b).

Table 4.11 shows that 72% of the participants correctly stated how one would adjust the exposure factors: reduce the mAs in order to reduce the radiation exposure to a patient. It is evident that most of the participants answered correctly. This suggests they were aware how to adjust the exposure factors in order to reduce the radiation exposure to a patient.

#### **4.2.1.18 Question 15: Broad exposure latitude**

The participants were requested to select and comment on the influence of broad exposure latitude of digital imaging on their selection of exposure factors. Carroll (2011: 448) explains that due to the wide exposure latitude of DR, it is crucial to ensure the correct radiographic technique is applied to produce an image that falls within the acceptable EI range that is of diagnostic value; although digital imaging systems may have a wide exposure latitude and compensate for overexposure at the receptor plate, it cannot compensate for information which is simply missing due to underexposure at the image receptor plate. The answers of the participants were: 11% did not answer the question; 49% stated that broad exposure latitude of digital imaging has a positive influence on the selection of exposure factors; 34% stated that broad exposure latitude of digital imaging has a negative influence on the selection of exposure factors; and 6% were of the opinion that broad exposure latitude of digital imaging has no influence on the selection of exposure factors.

#### **4.2.1.19 Question 15.1: Explanation of question 15**

The answers given by the participants with regard to question 15 are presented in Table 4.12 below.

**Table 4.12:** Explanation of question 15

|                           | <b><u>Frequency</u></b>             | <b><u>Reason</u></b>   |
|---------------------------|-------------------------------------|--|
|                           | <u>(n = 35)</u>                     |  |
| <b>Unanswered</b>         | 4                                   | Question left unanswered.  |
| <b>Positive influence</b> | 17                                  | Question left unanswered.  |
| <b>Negative influence</b> | <b><i>Correct explanation</i></b>   |  |
|                           | 2                                   | A broad exposure latitude makes it easy to overlook certain pathology (incorrect exposures). |
|                           | 3                                   | A broad exposure latitude allows for a wider range of (exposure) manipulation.               |
|                           | 2                                   | A broad exposure latitude effects image quality & sharpness (incorrect exposures).           |
|                           | 1                                   | A broad exposure latitude allows for over-exposure effects to be masked.                     |
|                           | 3                                   | A broad exposure latitude could result in the patient being over-exposed.                    |
|                           | <b><i>Incorrect explanation</i></b> |  |
|                           | 1                                   | Question left unanswered.  |
| <b>No influence</b>       | <b><i>Incorrect explanation</i></b> |  |
|                           | 2                                   | Question left unanswered.  |

It should be noted that based on literature (see 2.9), and how one looks at the situation, the most correct answer to this question was that the broad exposure latitude of digital imaging may have a positive influence or a negative influence on the selection of exposure factors. The reasons were considered to be correct or incorrect irrespective of whether the main answer was correct.

#### 4.2.1.20 Question 16: 15%kVp rule

This question asked the participant to explain the 15%kVp rule. The results are presented in Table 4.13 below.

**Table 4.13:** 15% kVp rule

|                   | <u>Percentage</u> | <u>Answer</u>                                       |
|-------------------|-------------------|---|
| <b>Correct</b>    | 43%               | If kVp is increased by 15% then mAs must be halved. |
| <b>Unanswered</b> | 57%               |   |

According to Carroll (2007: 104) a 15% change in kVp will result in a change in image density by a factor of 2. As shown in Table 4.13 a correct explanation for the 15% rule was provided by 43% of the participants correctly. The question was not answered by 57% of the participants and this indicates that this rule may require some attention.

#### 4.2.1.21 Question 17: Scatter affects image quality

This question asked participants to state how scattered radiation affects the image quality in DR. Their replies are presented in Table 4.14 below.

**Table 4.14:** How scatter affects image quality in digital radiography

|  | <b><u>Percentage</u></b>            | <b><u>Answer</u></b>  |
|--|-------------------------------------|---|
| <b>Unanswered</b>                        | 3%                                  | Question left unanswered.   |
| <b>Improves image quality</b>            | <b><i>Incorrect explanation</i></b> |   |
|  | 3%                                  | Scattered radiation improves the image quality in digital radiography.      |
| <b>Deteriorates image quality</b>        | <b><i>Correct explanation</i></b>   |   |
|  | 94%                                 | Scattered radiation produces a poorer image quality in digital radiography. |
| <b>Does not affect the image quality</b> | 0%                                  |   |

Scattered radiation, according to Carroll (2011: 327 & 203), may be defined as a “blanket” of unwanted exposure across the image receptor which contains no information. The addition of a fixed amount of exposure to the tissue area within the image always degrades the image, because it is random in nature and referred to as image noise (Carroll, 2011: 327). Scattered (secondary) radiation has only a little less energy than the primary X-ray beam, and therefore is very likely to penetrate a patient’s body and reach the image receptor, thus, it has a significant influence on the information reaching the image detector (Carroll, 2011: 203). The results in Table 4.14 show that 94% of the participants correctly stated how scattered radiation affects the image quality in DR.

#### **4.2.1.22 Question 17.1: Explain question 17**

The answers given by the participants for question 17 are presented below in Table 4.15.

**Table 4.15:** Explanations of question 17

|   | <u>Percentage</u>                   | <u>Answer</u>  |
|---|-------------------------------------|--|
| <b>Improved image quality (33%)</b>     | <b><i>Incorrect explanation</i></b> |  |
|   | 100%                                | Question left unanswered.  |
| <b>Deteriorates image quality (67%)</b> | <b><i>Correct explanation</i></b>   |  |
|   | 9%                                  | Scattered radiation decreases the image quality by introducing unwanted noise. |
|   | 9%                                  | Scattered radiation causes quantum mottle.                                     |
|   | 5%                                  | Scattered radiation causes quantum mottle, which decreases the image quality.  |
|   | 68%                                 | Scattered radiation decreases the image quality.                               |
|   | 9%                                  | Scattered radiation decreases the image quality because it reduces contrast.   |
|   | <b><i>Incorrect explanation</i></b> |  |
|   | 100%                                | Question left unanswered.  |

Scattered radiation produces poorer image quality in DR was the correct explanation of 22 participants as shown in Table 4.15. None stated that scattered radiation does not affect the image quality in DR. The results show that most of the participants were aware that scattered radiation results in poorer image quality in DR and why this is so.

#### **4.2.1.23 Question 18: Collimation**

In question 18 the participants were asked to state why collimation is a lot more critical and of extreme importance in DR. Their answers are presented in Table 4.16 below.

**Table 4.16:** Collimation of extreme importance in digital radiography

|                                       | <u>Percentage</u> | <u>Answer</u>  |
|---------------------------------------|-------------------|--|
| <b>Correct (78%)</b>                  | 33%               | Collimation improves the image quality.  |
|                                       | 12%               | Collimation improves the image quality and EI values.  |
|                                       | 12%               | Collimation reduces the radiation dose to the patient.   |
|                                       | 6%                | Collimation reduces scattered radiation.   |
|                                       | 4%                | Collimation reduces scattered radiation and radiation dose to the patient.   |
|                                       | 29%               | Collimation reduces scattered radiation, therefore improving image quality.  |
|                                       | 4%                | Collimation reduces scattered radiation therefore improving image quality and reduces radiation dose to the patient. |
| <b>Question left unanswered (22%)</b> |                   |  |

Woodward (2012: online) explains that careful use of collimation results in improved image quality. It decreases the amount of scatter radiation produced and thus less scatter reaches the image receptor. Collimation also decreases the total volume of tissue irradiated which results in a decrease in exposure to a patient (Woodward, 2012: online). As shown in Table 4.16 the majority of participants (78%) correctly stated why collimation is a lot more critical and of extreme importance in DR. This suggests they were aware as to why collimation is a lot more critical and of extreme importance in DR as covered in the literature (see 2.5.3.3; 2.11.3 and 2.10.1).

#### 4.2.1.24 Question 19: Producing an image of diagnostic quality

The answers given by the participants, regarding how DR allows one to produce an image of adequate diagnostic quality, but yet may be overexposed or underexposed, are presented Table 4.17 below.

**Table 4.17:** Producing an image of diagnostic quality

|                                       | <u>Percentage</u> | <u>Answer</u>   |
|---------------------------------------|-------------------|---|
| <b>Correct (52%)</b>                  | 44%               | Due to post-processing, digital radiography allows one to manipulate the image. |
|                                       | 56%               | Due to the broad exposure latitude in digital radiography.                      |
| <b>Question left unanswered (48%)</b> |                   |   |

According to Bushberg et al. (2002: 776), the detectors used in DR can, to some degree, compensate for under and overexposure and may decrease the repeats caused by incorrect radiographic techniques. Herrmann et al. (2012: online) explain that DR splits image acquisition, processing and display, which allows a radiographer to produce an image that has adequate diagnostic quality, but the image can be overexposed or underexposed. The computer automatically modifies an image that is overexposed to ensure that the image is of diagnostic quality. It is thus evident from the results in Table 4.17 that 52% of the participants correctly stated how DR allows one to produce an image of adequate diagnostic quality, but yet the image may be overexposed or underexposed. The question was not answered by 48% of the participants and in this study was considered incorrect.

#### 4.2.1.25 Question 20: Edge enhancement not favourable

Question 20 focused on why too much edge enhancement is not favourable during post-processing of a digital image. The participants' answers are present in Table 4.18 below.

**Table 4.18:** Edge enhancement not favourable

|                                       | <u>Percentage</u> | <u>Answer</u>  |
|---------------------------------------|-------------------|--|
| <b>Correct (66%)</b>                  | 26%               | Too much edge enhancement degrades the diagnostic image quality.   |
|                                       | 60%               | Too much edge enhancement results in a loss of image quality.  |
|                                       | 14%               | Too much edge enhancement causes a loss in image quality and thus may result in a misdiagnosis of the image. |
| <b>Question left unanswered (34%)</b> |                   |  |

According to Bushberg et al. (2002: 85) medical images often have a grainy appearance, called quantum mottle, caused by the statistical nature of the acquisition process. The visibility of quantum mottle can be reduced by a spatial filtering operation called smoothing. In most spatial smoothing algorithms, each pixel value in the smoothed image is attained by a weighted averaging of the corresponding pixel in the unprocessed image with its neighbours. Although smoothing decreases quantum mottle, it also blurs an image. Images must not be smoothed to the point that clinically important detail is lost. Spatial filtering can also enhance the edges of structures in an image. Edge-enhancement increases the statistical noise in the image.

The results shown in Table 4.18 indicate that 34% of the participants incorrectly stated why too much edge enhancement is not favourable during post-processing of a digital image.

#### 4.2.1.26 Question 21: Mottle

The participants were asked in question 21 why image mottle is produced on a digital image. Their answers are presented in Table 4.19 below.

**Table 4.19:** Image mottle

|                                       | <u>Percentage</u> | <u>Answer</u>  |
|---------------------------------------|-------------------|--|
| <b>Correct (74%)</b>                  | 19%               | Image mottle is produced on a digital image due to scattered radiation.          |
|                                       | 81%               | Image mottle is produced on a digital image due to the incorrect exposure given. |
| <b>Question left unanswered (26%)</b> |                   |  |

According to Bushberg et al. (2002: 297) digital images that are exposed to low exposure levels, while maintaining good grey scale in the image, have higher levels of X-ray quantum noise. Those produced at high exposures have low quantum noise yet result in a higher radiation dose to a patient (Bushberg et al., 2002: 297). Severe mottle denotes underexposure and indicates a loss of small detail information within an image. Using a smoothing algorithm will not restore that lost information. As shown in Table 4.19 the majority of participants (74%) correctly stated why image mottle is produced on a digital image.

#### 4.2.1.27 Question 22.1: Reasons for non-measuring

Question 22.1 required the participants to provide reasons for non-measuring an anatomical part to be examined. They were asked to provide an opinion. The results are shown in Table 4.20 below.

**Table 4.20:** Reasons for non-measuring

| <b><u>Reasons</u></b>   | <b><u>Percentage</u></b> |
|---|--------------------------|
| Question left unanswered.   | 37%                      |
| With experience, a radiographer is able to judge density appropriately. | 31%                      |
| Digital radiography allows for manipulation during post-processing.     | 11%                      |
| No equipment is available.  | 6%                       |
| Time consuming.   | 15%                      |

It is obvious from these results that the majority of the participants did not measure the anatomical part to be examined. The reasons for not measuring the anatomical part to be examined include: with experience, a radiographer is able to judge density appropriately; digital radiography allows for manipulation during post-processing; no equipment is available; and measuring the anatomical part to be examined is time consuming. As shown in Table 4.20, 31% of the participants were of the opinion that with experience, a radiographer is able to judge density appropriately. This is however a poor reason; it means that incorrect radiographic technique and practice were carried out. Literature explains that technique charts are based on the measurement of the body part to be radiographed. A radiographer must therefore measure the body part accurately to select the correct exposure from the technique chart or obtain the correct exposure with a programmable computerised control (Radiology Key, 2016: online).

#### 4.2.1.28 Question 22.2: Exposure chart utilisation

This question covered the utilisation of exposure charts. Participants were asked to explain what the reasons were for not using exposure charts. Their replies are presented below in Table 4.21.

**Table 4.21:** Exposure chart utilisation

| <b><u>Reasons</u></b>  | <b><u>Percentage</u></b> |
|--|--------------------------|
| Comes with experience as to what exposures to give.  | 63%                      |
| Exposure charts acts as a guideline, each patient is different and needs an individual assessment. | 14%                      |
| Exposure charts are inaccurate.  | 9%                       |
| Question left unanswered.  | 6%                       |
| Exposure charts are inaccurate and radiographers are too lazy to use them.                         | 3%                       |
| Can post-process images.   | 3%                       |
| Radiographers are too lazy to use them.  | 3%                       |

Best practice, according to Herrmann et al. (2012: online), is to select the appropriate exposure factors for a patient's size, based on a calculated exposure system by making use of exposure technique charts that are constantly improved and pertinent to an extensive range of patient ages and sizes. They also state it is best practice to take appropriate actions to comply with ALARA principles, radiation protection, correct positioning, immobilisation and size-appropriate exposure techniques in digital radiography (Herrmann et al., 2012: online). As shown in Table 4.21 the reason provided by 63% of participants for not using exposure charts was that with experience they know what exposures to give.

Such a reason is not ideal and indicates that incorrect radiographic practice was being performed. The other reasons provided for not using exposure charts are also unacceptable and are cause for concern.

#### 4.2.1.29 Question 22.3: Not utilising collimation

This question focused on the usage of collimation. The participants were asked to explain what the reasons were for not using collimation or other forms of beam limiting devices. Their answers are provided in Table 4.22 below.

**Table 4.22:** Not utilising collimation

| <u>Reasons</u>                                      | <u>Percentage</u> |
|---|-------------------|
| The fear of “chopping off” anatomy of interest.     | 40%               |
| Laziness and bad habits.                            | 20%               |
| Post-processing collimation is available.           | 11%               |
| Question left unanswered.                           | 9%                |
| Laziness and is time consuming.                     | 9%                |
| Faulty / broken collimators.                        | 3%                |
| Laziness and unaware of proper centering points.    | 3%                |
| Laziness and poor knowledge of collimation effects. | 3%                |
| Poor attitude to radiation protection.              | 3%                |

Table 4.22 indicates that the major reasons for not using collimation or other forms of beam limiting devices were: fear of “chopping off” anatomy of interest and having to repeat; “laziness” and bad habits; and that post-processing collimation was available. However, such reasons for not using collimation or other forms of beam limiting devices are inadmissible and require much attention.

#### 4.2.1.30 Question 22.4: Anatomical lead markers utilisation

This question focused on the utilisation of anatomical lead markers. Participants were to provide reasons for not using them. Their answers are presented below in Table 4.23.

**Table 4.23:** Anatomical lead markers utilisation

| <b><u>Reasons</u></b>                                    | <b><u>Percentage</u></b> |
|--|--------------------------|
| Post-processing markers are available.                   | 37%                      |
| Laziness and bad habits.                                 | 20%                      |
| Does not have or own anatomical lead markers.            | 14%                      |
| Negligence.  | 9%                       |
| Question left unanswered.                                | 9%                       |
| Time consuming.  | 6%                       |
| No excuse anatomical lead markers should always be used. | 3%                       |
| Forgetfulness.   | 3%                       |

These results show that the majority of the participants did not use anatomical lead markers. Reasons for not doing so include inter alia: post-processing markers are available; laziness and bad habits; participants did not have their own anatomical lead markers; and its time consuming. The reasons provided for not using anatomical lead markers in Table 4.23 are inexcusable and concerning. The Directorate Radiation Control (2012: 4) states that lead anatomical markers must be used for all projections done (DoH, 2012: 4).

#### 4.2.1.31 Question 22.5: The utilisation of EI values

Reasons for the incidence of some radiographers' practice of not using EI values as reference during normal practice was covered in Question 22.5. The answers given by the participants are in Table 4.24 below.

**Table 4.24:** The utilisation of EI values

| <b><u>Reasons</u></b>   | <b><u>Percentage</u></b> |
|---|--------------------------|
| Question left unanswered.   | 34%                      |
| Not understanding how EI actually works.  | 20%                      |
| EI values may be manipulated during post-processing to fall within the acceptable EI range.                         | 17%                      |
| EI is a useful guideline that may be used to correct an incorrect exposure.   | 11%                      |
| Laziness and radiographers that resist change and development, as it is regarded as an effort and will not be done. | 6%                       |
| Due to experience, if the image looks acceptable, then one may pass it.   | 3%                       |
| Forgetfulness.  | 3%                       |
| Laziness.   | 3%                       |
| Laziness and one does not want to repeat an image that might look acceptable.                                       | 3%                       |

It is best practice to effectively use the EI to determine whether an adequate exposure reached the image receptor, together with image quality to determine whether the digital image adheres to departmental standards (Herrmann et al., 2012: online). As shown in Table 4.24 the question was not answered by 34% of the participants.

According to 20% of the participants not actually understanding how EI works was a reason for not using EI values as reference during normal practice. Experience was the answer given by 3% of the participants; if an image looks acceptable, then one may consider it of diagnostic value and send it through for reporting, hence the reason for not using EI values as reference during normal practice. The results show that most of the reasons provided for not using EI values as reference during normal practice are alarming and thus may need some attention.

#### 4.2.1.32 Question 22.6: No patient protection

Question 22.6 asked the participants to give an opinion what the reasons were for some radiographers not protecting a patient with lead shielding. Their answers are in Table 4.25 below.

**Table 4.25:** No patient protection

| <u>Reasons</u>   | <u>Percentage</u> |
|--|-------------------|
| No lead shielding available.                                   | 29%               |
| Laziness and bad habits.                                       | 17%               |
| Laziness and ignorance.  | 12%               |
| Laziness and negligence.                                       | 12%               |
| Question left unanswered.                                      | 12%               |
| Negligence and is time consuming.                              | 12%               |
| Not acceptable to not protect the patient with lead shielding. | 6%                |

The Directorate Radiation Control (DoH, 2012: 17) states that any individual standing within one meter of the X-ray tube or patient while the X-ray machine is working at X-ray tube voltages beyond 100kV must wear a protective lead rubber apron of at least 0.35mm lead equivalence.

Radiographers must provide patients receiving X-rays with a lead rubber apron to shield other parts of the body that are not being X-rayed (DoH, 2012: 17). The results in Table 4.25 indicate that the main reason for not protecting a patient with lead shielding is that no lead shielding was available. Other reasons for not protecting a patient include: laziness; bad habits; ignorance; and negligence. These reasons are inexcusable. It seems therefore that most participants were unaware of how essential it is to protect a patient with lead shielding, as suggested in the literature.

In summary it is evident from the radiographer survey results that there is a lack of knowledge and information regarding the technical aspects of DR and the effective radiation protection measures applicable to DR. Much attention and encouragement are required to fill this information gap.

It is apparent that the different variables of the each question influence each other. For example, incorrect selection of exposure factors may influence the EI value, the density and the contrast evident on a radiographic image. Since the different variables of each question are interlinked, it is crucial to ensure that every radiographer is well informed to deliver the best possible radiation protection service to every patient.

It is thus evident that objective 1 of the study: to establish the awareness of diagnostic radiographers regarding effective radiation protection measures in DR through a survey, was effectively accomplished through the completion and analysis of the radiographer survey results. Objective 2 of the study is discussed in the section below.

### **4.3 PATIENT CHECKLIST RESULTS**

Objective 2: to determine whether effective radiation protection is applied by diagnostic radiographers by a checklist completed by patients. For this study the checklist was compiled from literature. The data of the completed checklist are presented, analysed and discussed below.

Hospital 2 denied permission to hand out the checklist to the patients, therefore the sample size at hospital 1 had to be increased. The sample size for the patient checklist was therefore increased to seventy (70) patients per anatomical region: chest and lumbar spine. The total sample size for completed patient checklists was one hundred and forty (n=140). The checklist allowed patients to inform the researcher on the radiation protection measures they received during their respective examination. Each patient was given approximately fifteen (15) minutes to complete and return the checklist to the researcher. The return rate was 100% (n=140). The researcher was available to provide clarification and address questions while each patient completed the checklist to limit misunderstanding. The patient checklist (Appendices H1-3) consisted of thirteen (13) questions with “Yes” / “No” options that had to be marked with an X. Questions 1 – 10 were answered by all patients. Questions 11-13 were aimed at female patients of reproductive age only. The questions were based on the radiation protection practice applied by a radiographer during chest and lumbar spine radiographic examinations. There were also personal and general questions regarding gender and age. The patient checklist was available in English, Afrikaans or Xhosa (Appendices H1-3).

#### **4.3.1 Patient demographics**

There were 27 females and 43 males who had chest X-rays (n=70). The 70 patients referred for lumbar spine radiographic examinations comprised 31 females and 39 males. Gender participation in the study: 58 females/82 males.

#### **4.3.2 Section one: Question 1 to 10**

Questions 1 - 3 relate to patient identification (ID). Their data are presented in Table 4.26. The routine of having patients identify themselves and using “two patient identifiers” is vital in improving the reliability of a patient’s identification procedure (Infection Prevention and You, 2017: online).

Patient identifier possibilities include: name; assigned identification number; date of birth (DOB); phone number; address and a photo” (Infection Prevention and You, 2017: online). In this study three or more patient identifiers were used to verify correct patient ID. In Table 4.26 question 1 verification data are for name, question 2 verification data are surname, and question 3 verification data for DOB.

**Table 4.26:** Patient identification (n=140)

| <b><u>Question</u></b>             | <b><u>Chest (n=70)</u></b> |           | <b><u>Lumbar spine (n=70)</u></b> |           |
|------------------------------------|----------------------------|-----------|-----------------------------------|-----------|
|                                    | <b>Yes</b>                 | <b>No</b> | <b>Yes</b>                        | <b>No</b> |
| <b><u>Question 1 (name)</u></b>    | 90%                        | 10%       | 96%                               | 4%        |
| <b><u>Question 2 (surname)</u></b> | 89%                        | 11%       | 76%                               | 24%       |
| <b><u>Question 3 (DOB)</u></b>     | 9%                         | 91%       | 13%                               | 87%       |

As shown in Table 4.26 the majority of patients confirmed that the radiographers asked for verification of their names (90% for chest radiographic examinations, and 96% for lumbar spine examinations).

The majority (89% of the patients who came for chest radiographic examinations, and 76% of lumbar spine examinations patients) confirmed they were asked by a radiographer to verify their surname. The results indicate that most of the participants were asked to verify their respective name/ surname. In other words one patient identifier was verified, compared to what is suggested in literature (see Infection Prevention and You, 2017: online).

The data in question 3 show that radiographers did not ask the majority of patients to verify their respective DOB. Only 9% of chest patients and 13% of lumbar spine patients confirmed that radiographers asked them to confirm their DOB. In other words this patient identifier was not verified in the majority of patients.

Questions 4 - 9 cover patient communication; the data for each question are presented in Table 4.27.

**Table 4.27:** Patient communication

| <u>Question</u>   | <u>Chest</u> |     |            | <u>Lumbar spine</u> |     |            |
|---|--------------|-----|------------|---------------------|-----|------------|
|   | Yes          | No  | Unanswered | Yes                 | No  | Unanswered |
| <b>Question 4:</b> Did the radiographer ask why you came for an examination?  | 21%          | 79% | 0%         | 19%                 | 81% | 0%         |
| <b>Question 5:</b> Did the radiographer ask you if you recently had the same x-ray examination done?  | 33%          | 67% | 0%         | 14%                 | 86% | 0%         |
| <b>Question 6:</b> Did the radiographer ask you to get undressed in a cubicle and put a hospital gown on?   | 79%          | 20% | 1%         | 57%                 | 43% | 0%         |
| <b>Question 7:</b> Did the radiographer ask you to remove all jewelry, any other metallic objects and or foreign objects from the area of interest? | 91%          | 9%  | 0%         | 73%                 | 27% | 0%         |
| <b>Question 8:</b> Did the radiographer explain the examination to you?   | 50%          | 50% | 0%         | 31%                 | 69% | 0%         |

|  |     |    |    |     |    |    |
|--|-----|----|----|-----|----|----|
| <b>Question 9:</b> Did the radiographer tell you exactly what to do? | 97% | 3% | 0% | 97% | 3% | 0% |
|--|-----|----|----|-----|----|----|

As shown in Table 4.27 the majority of the participants (79% chest/81% lumbar spine) were not asked why they came for an examination. The correct radiation protection practice is to carefully evaluate the examination requested and only perform X-ray examinations with valid clinical indications. This is achieved by communicating with a patient to ensure suitability with regard to the patient's history and thereby avoid possible repeats (DoH, 2012: 14 – 15). This was not performed with most of the participants.

As evident in Table 4.27 the majority participants (67% chest/86% lumbar spine) were not asked if they had recently had the same X-ray examination done. The correct radiation protection practice is to check a patient's previous x-ray examinations, to ensure that the same examination is not requested again unnecessarily (Peer, 2003: 5-6). This was not performed for most of the participating patients.

Feedback from participants as to whether the radiographer asked them to get undressed in a cubicle and put a hospital gown on indicates that most of the participants were asked to do so (79% of the 70 chest patients, and 57% of the 70 lumbar spine patients). In terms of being requested to remove all jewelry, any other metallic objects and or foreign objects from the area of interest, affirmative responses were: 97% chest patients, and 73% lumbar spine patients. It is radiographers' radiation protection responsibility during a radiographic examination to prevent unnecessary exposure to radiation at all times by avoiding repeat examinations (see Herrmann et al., 2012: online). These results show this was usually done by radiographers at hospital 1 in this study.

Half of the chest patients received an explanation of the examination, but only 31% of lumbar spine patients were given an explanation.

Radiographers' radiation protection responsibility during a radiographic examination is to prepare a patient by explaining the examination, positioning and or breathing instructions (Peer, 2003: 5-6). This was not effectively done for all patients in this study.

The vast majority of patients (97% for each examination) were told by radiographers exactly what to do.

In other words the latter's radiation protection responsibility during a radiographic examination to prepare the patient by explaining the examination, positioning and or breathing instructions, and accurate application of radiographic techniques and positioning, was efficiently performed, as suggested in literature (see Herrmann et al., 2012: online).

#### **4.3.2.1 Patient immobilisation**

Question 10 covered patient immobilisation. According to Herrmann et al. (2012: online) a radiographer's responsibility, with regard to radiation protection during a radiographic examination, is to use immobilisation devices when necessary and avoid repeat exposures by correctly positioning a patient.

The majority of chest patients (66%) confirmed the radiographer provided them with support as they were unable to hold a certain position during the examination; 19% stated no to this question, and 16% stated not applicable (N/A). Less than half (44%) of patients who came for lumbar spine radiographic examinations gave an affirmative reply; 3% stated no, and 53% stated not applicable (N/A). It is not unreasonable to assume that those patients who stated N/A did not require support. The results show that most were provided with support if they were unable to hold a certain position for their X-ray examination.

### 4.3.3 Section two: Questions 11 to 13

Section two had three questions which were specific to female patients of reproductive age. A total of 42 female patients of reproductive age participated in the study. Feedback from them in relation to these questions is presented and discussed below.

It is a radiographer's responsibility, in terms of radiation protection during a radiographic examination, to check the pregnancy status of female patients of reproductive age (cf. 2.7). Reproductive age refers to those years of life between the first occurrence of menstruation and menopause, roughly from ages 12 to 49 (The Free Dictionary, 2017: online). International Atomic Energy Agency, (2018: online) states the 10-day rule was established to reduce the potential for performing X-ray examinations on pregnant women. The basis of the rule is to perform X-ray examinations only during the 10 days following the onset of menstruation. Therefore if a patient is uncertain as to whether she is pregnant, a radiographer needs to ask when was the first day of her last menstrual period (LMP) and by doing this one can determine if it is safe for the patient to have an X-ray examination or not (International Atomic Energy Agency, 2018: online).

The 42 female participants were asked in question 11 whether the radiographer asked them if they could be pregnant. The results were: 74% of chest patients confirmed they were asked, and 61% of lumbar spine patients also confirmed they were asked this question. However, as evident from these replies not all female participants were asked if they could be pregnant. This is of concern.

In question 12 they were asked if they were uncertain about their respective pregnancy status. The question stated: did the radiographer asked when the first day of your last menstrual period was? The results were: 32% of the patients who came for chest radiographic examinations stated yes, and only 4% of the lumbar spine patients stated yes, and 4% left the question unanswered. The results show that the majority of the participants, when uncertain about their pregnancy status, were not asked when the first day of their last menstrual period was.

From the results it is clear that the radiographers' radiation protection responsibility during a radiographic examination was not performed, as suggested in literature (see 2.6.2).

All female participants (100%), who came for chest radiographic examinations, replied to question 13 that the radiographer did not explain the risks involved with an X-ray being taken if a patient might be pregnant; only 4% of those who came for lumbar spine radiographic examinations, confirmed they were explained the risks; 4% left the question unanswered. The results reveal that the majority of the participants, did not receive an explanation of the risks involved with an x-ray being taken while they might be pregnant. From the results it is clear that the radiographers' radiation protection responsibility during a radiographic examination was not performed, as suggested in literature (see 2.6.2).

To summarise, it is evident from the patient checklist results above that there is room for improvement regarding patient identification and communication. Patient immobilisation was efficiently performed and was satisfactory. The respective results in terms of checking the pregnancy status female patients of reproductive age, and also checking each patient to in terms of not being pregnant are concerning and need much attention. It is thus apparent that the objective of the study to determine whether effective radiation protection was applied by diagnostic radiographers through the compilation and completion of the patient checklist was effectively achieved.

It may however be argued that since the data were collected at one hospital that this may have influenced the results of the study. Most of the radiographers in this study trained at the same institution, and the sample was from the same catchment area means these results do not allow for generalisability.

The following section unpacks and discusses the results of the image checklists as related to objective 3.

## 4.4 THE RADIOGRAPHIC IMAGE CHECKLIST

Objective 3 was to determine whether effective technical radiation protection is applied by diagnostic radiographers through a radiographic image checklist. The radiographic image checklist was completed by three reviewers to analyse the digital radiographic images of the chest and lumbar spine.

As discussed previously (see 3.4.3), the radiographic image checklist (Appendix I) consisted of statements with blocks which were marked with an X. Each block consisted of either yes or no answers. The radiographic image checklists were completed by three reviewers: the researcher; a diagnostic radiographer employed at a government hospitals' radiology department and a lecturer employed at the radiography training institutions. The questions and statements for the lumbar spine and chest radiographic examinations are presented and discussed in section 4.4.1.

### 4.4.1 Image checklist – lumbar spine and chest

The sample size for the lumbar spine radiographic image checklist comprised 90 images. The chest radiographic image checklist comprised 100 images. The reason for the difference in sample sizes for these two examinations was that only 90 lumbar spine radiographic examinations were available during the time of collecting data.

#### (a) The EI value – AP and lateral lumbar spine and AP / PA and lateral chest

The exposure index guideline range for the Agfa CR system for optimum image quality for the chest radiographic examination AP/PA and lateral projection is between the  $EI_{\min}$  of 345 and  $EI_{\max}$  of 689 (Gibbs, 2012: 8). The answers given by the reviewers are in Table 4.28.

The exposure index guideline range for the Agfa CR system for optimum image quality for an in-bucky examination, such as lumbar spine AP, lateral and a lumbar 5 and sacral 1 joint space (L5/S1) projection is between the  $EI_{min}$  of 172 and  $EI_{max}$  of 344 (Gibbs, 2012: 8). It should be noted that reviewers 1, 2 and 3 reviewed the same AP/PA and lateral images of the chest and lumbar spine radiographic examinations. The EI values for each AP/PA and lateral projections are also the same.

**Table 4.28:** EI values: AP / PA and lateral chest and AP and lateral lumbar spine

| <b><u>EI Value</u></b> | <b><u>Lumbar spine</u></b> |                       | <b><u>Chest</u></b>   |                       |
|------------------------|----------------------------|-----------------------|-----------------------|-----------------------|
|                        | <b><u>AP</u></b>           | <b><u>Lateral</u></b> | <b><u>AP / PA</u></b> | <b><u>Lateral</u></b> |
| <b>Median</b>          | 454                        | 531                   | 263                   | 370                   |
| <b>Minimum</b>         | 88                         | 89                    | 30                    | 77                    |
| <b>Maximum</b>         | 1831                       | 1866                  | 969                   | 1134                  |

The EI value (b) stated that reviewers should indicate the EI value for the AP and lateral projections of the lumbar spine radiographic examination, and the AP/PA and lateral projections of the chest radiographic examination and are presented as part of the information on the image. The results of all the reviewers for the lumbar spine radiographic image checklist revealed that for the EI values of the AP projections only 37 of the 90 AP projections fell within the EI value range. The EI values of the lateral projections of only 25 of the 90 reviewed lateral projections of the lumbar spine radiographic examinations fell within the EI value range. The results of the chest radiographic image checklist from Table 4.28, together with literature (see Gibbs, 2012: 8), showed that the minimum EI value for the AP/PA and lateral projections was very low and therefore underexposed. The maximum EI value for the AP/PA and lateral projections was extremely high and therefore overexposed. The results also indicated that for the EI values of the AP/PA projections only 36 of the 100 reviewed chest radiographic examinations fell within the EI value range.

The EI values of the lateral projections were that only 46 of the 100 lateral projections of the chest radiographic examinations reviewed fell with the EI value range. These results show there was a problem regarding the incorrect selection and usage of exposure factors which resulted in the EI values falling out of the range and thus require attention.

Statement (c) stated indicate the EI value for the lumbar 5 and sacral 1 joint space (L5/S1) projection of the lumbar spine radiographic examination being reviewed. Only five lumbar spine radiographic examinations were in the sample ( $n=90$ ) that included this projection. The reviewers evaluated five EI values (115; 125; 129; 373; 503). The EI value range indicated that three of the EI values were below the  $EI_{min}$  and thus underexposed, and two EI values were above the  $EI_{max}$  and thus overexposed. It is of concern that there were only five images for this projection as it is part of the lumbar spine imaging protocol.

#### **4.4.1.1 Section one: Statement 1 to 18**

Section one of the lumbar spine and chest radiographic image checklist had eighteen (18) statements. Feedback from the reviewers in relation to these statements is discussed below. The researcher used a confidence level of 95%, meaning the value of 0.05 was used for  $\alpha$  during calculations. When performing a hypothesis test in statistics, a  $p$ -value helps determine the significance of the results. Hypothesis tests are used to test the validity of a claim that is made about a population. This claim is called the null hypothesis. The alternative hypothesis is the one to believe if the null hypothesis is concluded to be untrue. The evidence is the data and the statistics that go along with it. All hypothesis tests ultimately use a  $p$ -value to evaluate the strength of the evidence (Rumsey, 2018: online).

The  $p$ -value is a number between 0 and 1 and interpreted in the following way.

- A small  $p$ -value (typically  $\leq 0.05$ ) indicates strong evidence against the null hypothesis, so the null hypothesis is rejected (Rumsey, 2018: online);

- A large  $p$ -value ( $> 0.05$ ) indicates weak evidence against the null hypothesis, so the null hypothesis is not rejected;
- $p$ -values very close to the limit (0.05) are considered to be marginal (Rumsey, 2018: online).

In the majority of analyses, an alpha of 0.05 is used as the cutoff for significance. If the  $p$ -value is less than 0.05, we reject the null hypothesis that there is no difference between the means and conclude that a significant difference between the percentages of the three reviewers does exist. If the  $p$ -value is larger than 0.05, we can conclude no significant difference exists (The Minitab Blog, 2013: online).

Statement 1 stated the original lead anatomical marker was present on the radiographic image. The answers given by the reviewers are in Table 4.29.

**Table 4.29:** Lead anatomical markers present

| <u>Projection</u>                                |     | <u>Reviewer 1</u> | <u>Reviewer 2</u> | <u>Reviewer 3</u> |
|--|-----|-------------------|-------------------|-------------------|
| <b>AP / PA chest</b>                             | Yes | 33%               | 33%               | 37%               |
|  | No  | 67%               | 67%               | 63%               |
| <b>Lateral chest</b>                             | Yes | 29%               | 29%               | 19%               |
|  | No  | 71%               | 71%               | 81%               |
| <b>AP Lumbar</b>                                 | Yes | 33%               | 32%               | 38%               |
|  | No  | 67%               | 68%               | 62%               |
| <b>Lateral lumbar</b>                            | Yes | 28%               | 32%               | 31%               |
|  | No  | 72%               | 68%               | 69%               |
| <b>Lumbar 5 and sacral 1 joint space (L5/S1)</b> | Yes | 0%                | 0%                | 0%                |
|  | No  | 100%              | 100%              | 100%              |

The  $p$ -value for statement 1 of the lumbar spine radiographic image checklist is 0.1854 therefore there is no significant difference between the percentages of the three reviewers. The results indicate a correlation of finding between the reviewers; this was to be expected as they reviewed the same images. The  $p$ -value for the results of statement 1 of the chest radiographic image checklist (see Table 4.29) is 0.0013; indicating there is a significant difference between the percentages of the reviewers.

The answers show that the original lead anatomical marker was not present on most of the lumbar spine and chest radiographic images reviewed, which is alarming and contravenes the directives of the Directorate Radiation Control, which states: “lead anatomical markers must be used for all projections done” (DoH, 2012: 4).

**Table 4.30:** Post-processing marker present

| <u>Projection</u>     |     | <u>Reviewer 1</u> | <u>Reviewer 2</u> | <u>Reviewer 3</u> |
|-----------------------|-----|-------------------|-------------------|-------------------|
| <b>AP/PA chest</b>    | Yes | 73%               | 73%               | 64%               |
|                       | No  | 27%               | 27%               | 18%               |
| <b>Lateral chest</b>  | Yes | 77%               | 77%               | 64%               |
|                       | No  | 23%               | 23%               | 18%               |
| <b>AP Lumbar</b>      | Yes | 66%               | 66%               | 61%               |
|                       | No  | 34%               | 34%               | 39%               |
| <b>Lateral lumbar</b> | Yes | 66%               | 66%               | 61%               |
|                       | No  | 34%               | 34%               | 39%               |

Table 4.30 shows that reviewers 1 and 2 stated a post-processing marker was present on 66% of the AP and lateral projections of the lumbar spine radiographic examination. However, reviewer 3 saw a post-processing marker on 61% of the images.

The answers of the reviewers regarding statement 2 of the chest radiographic image checklist were: reviewers 1 and 2 indicated that a post-processing marker was present on 73% of the AP/PA chest projections and 77% of the lateral chest projections, and reviewer 3 stated that a post-processing marker was present on 64% of the AP/PA and lateral chest projections of the chest radiographic examination. The  $p$ -value for statement 2 of the chest radiographic image checklist is 0.0023; hence there is a significant difference between the percentages of the reviewers.

A post-processing marker was present on most of the chest and lumbar spine radiographic images reviewed. This is concerning because Adams (2015: 5) explains that all CR/DR images must show anatomical lead markers since it is very easy to accidentally flip/rotate an image during post- processing. Unless the original markers are visible, there is no way of truly knowing which side is which.

The answers given by the reviewers regarding statement 3, which asked if the correct anatomical marker was used, are in Table 4.31 below.

**Table 4.31:** Anatomical markers

| <b><u>Projection</u></b> |     | <b><u>Reviewer 1</u></b> | <b><u>Reviewer 2</u></b> | <b><u>Reviewer 3</u></b> |
|--------------------------|-----|--------------------------|--------------------------|--------------------------|
| <b>AP/PA chest</b>       | Yes | 100%                     | 100%                     | 100%                     |
|                          | No  | 0%                       | 0%                       | 0%                       |
| <b>Lateral chest</b>     | Yes | 100%                     | 100%                     | 100%                     |
|                          | No  | 0%                       | 0%                       | 0%                       |
| <b>AP Lumbar</b>         | Yes | 93%                      | 93%                      | 97%                      |
|                          | No  | 7%                       | 7%                       | 3%                       |
| <b>Lateral lumbar</b>    | Yes | 93%                      | 93%                      | 97%                      |
|                          | No  | 5%                       | 7%                       | 1%                       |

|  |            |    |    |    |
|--|------------|----|----|----|
|  | Unanswered | 2% | 0% | 2% |
|--|------------|----|----|----|

Table 4.31 shows that the correct anatomical marker was used on the lumbar spine radiographic images reviewed with percentages ranging between 93% and 97%. Reviewers 1 and 3 both left 2% unanswered. The  $p$ -value for statement 3 is 0.2375 indicating good correlation between all reviewers.

The answers given by the reviewers, regarding statement 3 of the chest radiographic image checklist, show that all reviewers indicated that the correct anatomical marker was used on 100% of the AP/PA and lateral chest projections of the chest radiographic examinations reviewed. In other words the correct anatomical marker was used on the majority of chest and lumbar spine radiographic images reviewed. This is an ideal result.

Statement 4 stated collimation was performed during the examination. The answers given by the reviewers are in Table 4.32.

**Table 4.32:** Pre-examination collimation

| <u>Projection</u>     |     | <u>Reviewer 1</u> | <u>Reviewer 2</u> | <u>Reviewer 3</u> |
|-----------------------|-----|-------------------|-------------------|-------------------|
| <b>AP/PA chest</b>    | Yes | 40%               | 40%               | 40%               |
|                       | No  | 60%               | 60%               | 60%               |
| <b>Lateral chest</b>  | Yes | 37%               | 37%               | 37%               |
|                       | No  | 63%               | 63%               | 63%               |
| <b>AP Lumbar</b>      | Yes | 90%               | 90%               | 88%               |
|                       | No  | 10%               | 10%               | 13%               |
| <b>Lateral lumbar</b> | Yes | 86%               | 87%               | 84%               |
|                       | No  | 14%               | 13%               | 17%               |

|  |     |    |    |    |
|--|-----|----|----|----|
| <b>Lumbar 5 and sacral 1 joint space (L5/S1)</b> | Yes | 0% | 0% | 0% |
|  | No  | 0% | 0% | 1% |

As shown in Table 4.32 collimation was performed on the lumbar spine radiographic images reviewed. The results ranged between 84% and 90%. Additionally reviewer 3 indicated that collimation was not performed during the examination on the lumbar 5 and sacral 1 joint space (L5/S1) projection. The  $p$ -value for statement 4 of the lumbar spine radiographic image checklist is 0.9480; hence there is good correlation between the percentages of all the reviewers.

The finding for the chest radiographic image checklist in Table 4.32 was of a range between 37% and 40% in terms of collimation. Collimation was not thus not routinely performed in the chest radiographic images reviewed. The  $p$ -value for statement 4 of the chest radiographic image checklist is 1.0000 indicating there is no significant difference between the percentages of all the reviewers. The results show that collimation was performed for the majority of examinations of the lumbar spine as seen on the radiographic images reviewed. Conversely, collimation was not routinely performed during the chest radiography as evident on the images reviewed. Carroll (2011: 295) explains the purpose of pre-examination collimation is to minimise radiation exposure to a patient and to maintain subject contrast in the remnant beam. Collimation is critical and of extreme importance in digital radiography since it may so easily affect the histogram analysis and final technical quality of the image. Minimising radiation exposure to a patient should be of utmost concern to every radiographer; restricting the size of the X-ray beam is one of the most effective ways to minimise radiation exposure (Carroll, 2011: 622; 295). According to Woodward (2012: online) careful use of collimation results in improved image quality; collimation decreases the amount of scatter radiation produced and thus less scatter reaches the image receptor. Collimation also decreases the total volume of tissue irradiated and a decrease in exposure to a patient.

The answers given by the reviewers regarding statement 5, which asked if collimation was performed after the examination, are in Table 4.33 below.

**Table 4.33:** Post examination collimation

| <b><u>Projection</u></b>                         |     | <b><u>Reviewer 1</u></b> | <b><u>Reviewer 2</u></b> | <b><u>Reviewer 3</u></b> |
|--|-----|--------------------------|--------------------------|--------------------------|
| <b>AP/PA chest</b>                               | Yes | 96%                      | 96%                      | 96%                      |
|  | No  | 4%                       | 4%                       | 4%                       |
| <b>Lateral chest</b>                             | Yes | 96%                      | 96%                      | 96%                      |
|  | No  | 4%                       | 4%                       | 4%                       |
| <b>AP Lumbar</b>                                 | Yes | 71%                      | 71%                      | 71%                      |
|  | No  | 29%                      | 29%                      | 29%                      |
| <b>Lateral lumbar</b>                            | Yes | 73%                      | 74%                      | 73%                      |
|  | No  | 27%                      | 26%                      | 27%                      |
| <b>Lumbar 5 and sacral 1 joint space (L5/S1)</b> | Yes | 0%                       | 0%                       | 1%                       |
|  | No  | 0%                       | 0%                       | 0%                       |

As shown in Table 4.33, the result of the lumbar spine radiographic image checklist that collimation was performed after the examination in terms of the images reviewed indicates a range between 71% and 74%. The *p*-value for statement 5 of the lumbar spine radiographic image checklist is 0.9170; hence there is good correlation between the percentages of all the reviewers.

Table 4.33 shows that all reviewers for the chest radiographic image checklist stated that collimation was performed after the examination on 96% of the AP/PA and lateral chest projections of examinations reviewed.

The  $p$ -value for statement 5 of the chest radiographic image checklist is 1.0000 indicating there is good correlation between the percentages of all the reviewers.

The results show that most of the time collimation was performed after the examination, which reveals poor radiographic practice and is thus concerning. Herrmann et al. (2012: online) state that digital radiography allows a radiographer to produce an image that has adequate diagnostic quality, but can be overexposed or underexposed, and, therefore, the effect of post-processing due to poor technique results in an increased radiation dose to a patient. The results also show that collimation was applied during the examination but, additional collimation was added during post-processing on the majority of the lumbar spine radiographic images reviewed with percentages ranging between 84% and 90%. The results also are that no collimation was applied during the examination and collimation was applied afterwards during post-processing on 10% to 17% of the lumbar spine radiographic images reviewed. The results also indicate that collimation was applied during the examination but, additional collimation was added during post-processing on between 37% and 40% of the chest radiographic images reviewed.

Of note is that the percentages are high for both statement 4, which referred to collimation being performed during the examination, and statement 5, which referred to collimation being performed after the examination, due to the fact that although collimation was applied during the examination, it was not sufficient enough; additional collimation was thus applied after the examination during post-processing. Thus, one image may have evidence of both pre and post examination collimation.

Two questions referred to patient positioning, in particular the correct centering of anatomy of interest on the IP and the correct positioning of the anatomical part. These results are discussed in detail below.

Statement 6 stated the correct centering of the anatomy of interest on the IP is evident. The answers of the reviewers are in Table 4.34 below.

**Table 4.34:** Correct centering of anatomy of interest on the IP

| <b><u>Projection</u></b>                         |     | <b><u>Reviewer 1</u></b> | <b><u>Reviewer 2</u></b> | <b><u>Reviewer 3</u></b> |
|--|-----|--------------------------|--------------------------|--------------------------|
| <b>AP/PA chest</b>                               | Yes | 27%                      | 27%                      | 27%                      |
|  | No  | 73%                      | 73%                      | 73%                      |
| <b>Lateral chest</b>                             | Yes | 17%                      | 17%                      | 17%                      |
|  | No  | 83%                      | 83%                      | 83%                      |
| <b>AP Lumbar</b>                                 | Yes | 56%                      | 56%                      | 60%                      |
|  | No  | 44%                      | 44%                      | 40%                      |
| <b>Lateral lumbar</b>                            | Yes | 49%                      | 48%                      | 56%                      |
|  | No  | 51%                      | 52%                      | 44%                      |
| <b>Lumbar 5 and sacral 1 joint space (L5/S1)</b> | Yes | 98%                      | 98%                      | 99%                      |
|  | No  | 2%                       | 2%                       | 1%                       |

It is evident from the data in Table 4.34, that the correct centering of anatomy of interest on the IP was average for lumbar spine radiographic images reviewed with percentages ranging between 48% and 60%. Additionally, all of the reviewers indicated that the correct centering of anatomy of interest on the IP was evident on the majority of the lumbar 5 and sacral 1 joint space (L5/S1) images reviewed. The  $p$ -value for statement 6 of the lumbar spine radiographic image checklist is 0.8252; hence there is no significant difference between the percentages of the reviewers.

Table 4.34 shows the reviewers indicated that the correct centering of the anatomy of interest on the IP was evident on 27% of the AP/PA chest projections, and on 17% of the lateral chest projections. The  $p$ -value for statement 6 of the chest radiographic image checklist is 1.0000 indicating there is good correlation between the percentages of the reviewers.

The answers show the correct centering of anatomy of interest on the IP ranged from poor to average. As stated by Peer (2003: 5 - 6) a radiographer's radiation protection responsibility during a radiographic examination is the accurate application of radiographic techniques and positioning. Based on the results presented it is argued that this was not effectively performed by the radiographers who performed the examinations.

**Table 4.35:** Positioning of anatomy

| <b><u>Projection</u></b>                         |     | <b><u>Reviewer 1</u></b> | <b><u>Reviewer 2</u></b> | <b><u>Reviewer 3</u></b> |
|--|-----|--------------------------|--------------------------|--------------------------|
| <b>AP / PA chest</b>                             | Yes | 4%                       | 4%                       | 88%                      |
|  | No  | 96%                      | 96%                      | 12%                      |
| <b>Lateral chest</b>                             | Yes | 6%                       | 6%                       | 87%                      |
|  | No  | 94%                      | 94%                      | 13%                      |
| <b>AP Lumbar</b>                                 | Yes | 92%                      | 82%                      | 100%                     |
|  | No  | 9%                       | 18%                      | 0%                       |
| <b>Lateral lumbar</b>                            | Yes | 86%                      | 80%                      | 98%                      |
|  | No  | 15%                      | 20%                      | 2%                       |
| <b>Lumbar 5 and sacral 1 joint space (L5/S1)</b> | Yes | 100%                     | 100%                     | 100%                     |
|  | No  | 0%                       | 0%                       | 0%                       |

Statement 7 stated the correct positioning of the anatomical part was evident. Table 4.35 data show that in most cases correct positioning of the anatomical part was evident on the lumbar spine radiographic images reviewed; percentages ranged between 82% and 100% on the AP lumbar spine projections, and 80% and 98% on the lateral lumbar spine projections.

Additionally, the reviewers stated that correct positioning of the anatomical part was evident on 100% of the lumbar 5 and sacral 1 joint space (L5/S1) projections. The  $p$ -value for statement 7 of the lumbar spine radiographic image checklist is 0.0423, indicating there is a significant difference between the percentages of the reviewers. The results, with reference to statement 7 of the chest radiographic image checklist, indicate that reviewers 1 and 2, assessed that correct positioning of the anatomical part was evident on 4% of the AP/PA chest projections, and 6% of the lateral chest projections. Reviewer 3 stated that the correct positioning of the anatomical part was evident on 88% of the AP/PA chest projections, and 87% of the lateral chest projections. The  $p$ -value for statement 7 of the chest radiographic image checklist is  $<.0001$  which indicates there is a significant difference between the percentages of the reviewers.

Their responses indicate that the correct positioning of the anatomical part was mostly achieved on the lumbar spine radiographic images reviewed. This implies that the radiation protection responsibility of a radiographer, during a radiographic examination in terms of accurate application of radiographic techniques and positioning, was efficiently performed (see 2.7).

The results also show that there was a discrepancy between the respective results of reviewers 1, 2 and 3 regarding the correct positioning of the anatomical part of the chest radiographic images reviewed. A possible reason for the difference between the percentages of the reviewers could be due to their respective subjective interpretation of each image.

Three questions referred to EI, in particular the target EI value and the EI value range. The results for these questions are discussed in detail below.

**Table 4.36:** Target EI value

| <b><u>Projection</u></b>                         |     | <b><u>Reviewer 1</u></b> | <b><u>Reviewer 2</u></b> | <b><u>Reviewer 3</u></b> |
|--|-----|--------------------------|--------------------------|--------------------------|
| <b>AP Lumbar</b>                                 | Yes | 1%                       | 1%                       | 0%                       |
|  | No  | 99%                      | 99%                      | 100%                     |
| <b>Lateral lumbar</b>                            | Yes | 0%                       | 0%                       | 0%                       |
|  | No  | 100%                     | 100%                     | 100%                     |
| <b>Lumbar 5 and sacral 1 joint space (L5/S1)</b> | Yes | 0%                       | 0%                       | 0%                       |
|  | No  | 100%                     | 100%                     | 100%                     |

Statement 8 stated the EI value was the same as the target EI. The answers given by the reviewers, with reference to the lumbar spine radiographic image checklist, are listed in Table 4.36. Reviewers 1 and 2 indicated that the EI value was not the same as the target EI on 99% of the AP lumbar spine projections, and reviewer 3 was of the opinion it was on 100% of the projections. In reference to the lumbar 5 and sacral 1 joint space (L5/S1), and lateral projections of the lumbar spine radiographic examination, all reviewers were of the opinion that the EI value was not the same as the target EI on 100% of the images.

In terms of the chest radiographic image checklist, reviewers 1 and 2 stated that the EI value was the same as the target EI on 1% of the AP/PA and lateral chest projections of the chest radiographic examinations reviewed. Reviewer 3 indicated that the EI value was not the same as the target EI on 100% of the AP/PA and lateral chest projections of the chest radiographic examinations reviewed. The  $p$ -value for statement 8 of the chest radiographic image checklist is 0.6045. The answers show that the majority of the time the EI value was not the same as the target EI, revealing that attention is required in this regard, since it states in literature by Herrmann et al. (2012: online) that it is a radiographer's radiation protection responsibility during a radiographic examination (see 2.7).

Statement 9 stated that if the EI value is not the target value but falls within  $EI_{\min}$  and  $EI_{\max}$ . The assessments of the reviewers are in Table 4.37 below.

**Table 4.37:** EI value range

| <u>Projection</u>                                |     | <u>Reviewer 1</u> | <u>Reviewer 2</u> | <u>Reviewer 3</u> |
|--|-----|-------------------|-------------------|-------------------|
| <b>PA chest</b>                                  | Yes | 35%               | 35%               | 37%               |
|  | No  | 65%               | 65%               | 63%               |
| <b>Lateral chest</b>                             | Yes | 47%               | 47%               | 46%               |
|  | No  | 53%               | 53%               | 54%               |
| <b>AP Lumbar</b>                                 | Yes | 38%               | 38%               | 42%               |
|  | No  | 62%               | 62%               | 58%               |
| <b>Lateral lumbar</b>                            | Yes | 27%               | 27%               | 30%               |
|  | No  | 72%               | 72%               | 69%               |
| <b>Lumbar 5 and sacral 1 joint space (L5/S1)</b> | Yes | 0%                | 0%                | 0%                |
|  | No  | 4%                | 4%                | 3%                |

Table 4.37 shows that reviewers 1 and 2 indicated that the EI value was not the target value, but was within  $EI_{\min}$  and  $EI_{\max}$  on 38% of the AP lumbar spine projections and 27% of the lateral lumbar spine projections. Reviewer 3 stated that the EI value was not the target value, but was within  $EI_{\min}$  and  $EI_{\max}$  on 42% of the AP lumbar spine projections and 30% of the lateral lumbar spine projections. As shown in Table 4.37 reviewers 1 and 2 indicated that the EI value was not the target value, but was within  $EI_{\min}$  and  $EI_{\max}$  on 35% of the AP/PA chest projections and 47% of the lateral chest projections.

Reviewer 3 stated that the EI value was not the target value but was within  $EI_{min}$  and  $EI_{max}$  on 37% of the AP/PA chest projections and 46% of the lateral chest projections. The  $p$ -value for statement 9 of the chest radiographic image checklist is 0.0984. There is good correlation between the percentages of the reviewers.

The reviewers' answers show that in instances where the EI value was not equal to the target value it also did not fall within  $EI_{min}$  and  $EI_{max}$ . This indicates there may be a problem with the selection of exposure factors. According to Herrmann et al. (2012: online) one must select the appropriate exposure factors for a patient's size, use the highest kVp within the optimal range for the position and part of anatomy, together with the lowest amount of mAs required to deliver an acceptable exposure to the image receptor, and use exposure technique charts that are constantly improved and pertinent to an extensive range of patient ages and sizes.

**Table 4.38:** EI value: over-exposed

| <u>Projection</u>                                |     | <u>Reviewer 1</u> | <u>Reviewer 2</u> | <u>Reviewer 3</u> |
|--|-----|-------------------|-------------------|-------------------|
| <b>AP/PA chest</b>                               | Yes | 64%               | 64%               | 63%               |
|  | No  | 35%               | 35%               | 37%               |
| <b>Lateral chest</b>                             | Yes | 55%               | 55%               | 55%               |
|  | No  | 45%               | 45%               | 45%               |
| <b>AP Lumbar</b>                                 | Yes | 61%               | 61%               | 58%               |
|  | No  | 39%               | 39%               | 42%               |
| <b>Lateral lumbar</b>                            | Yes | 73%               | 73%               | 69%               |
|  | No  | 27%               | 27%               | 31%               |
| <b>Lumbar 5 and sacral 1 joint space (L5/S1)</b> | Yes | 8%                | 8%                | 6%                |
|  | No  | 0%                | 0%                | 0%                |

|   |  |    |    |    |
|---|--|----|----|----|
| <b>Unanswered<br/>(all projections)</b> |  | 1% | 1% | 0% |
|---|--|----|----|----|

The results in Table 4.38, regarding statement 10 of the lumbar spine radiographic image checklist, indicate that reviewers 1 and 2 assessed that the image was overexposed on 61% of the AP lumbar spine projections, 73% of the lateral lumbar spine projections, and 8% of the lumbar 5 and sacral 1 joint space (L5/S1) projections. Reviewer 3 stated it was overexposed on 58% of the AP lumbar spine projections, 69% of the lateral lumbar spine projections, and 6% of the lumbar 5 and sacral 1 joint space (L5/S1) projections.

Table 4.38 shows that reviewers 1 and 2 indicated that the image was overexposed on 64% of the AP/PA chest projections; reviewer 3 assessed that the image was overexposed on 63% of the AP/PA chest projections. In terms of the lateral projections of the chest radiographic examination, all reviewers assessed the image was overexposed on 55% of the images.

These responses show that in the majority of cases the image was overexposed, which is worrying. Herrmann et al. (2012: online) state that digital systems lack visual signs that result in the recognition of exposure errors such as overexposure and underexposure of an image. The purpose of the EI is to allow a radiographer to evaluate the level of exposure the IR received and thereby determine if the correct exposure technique for the image was used and to verify good radiographic technique. EI, therefore, indirectly indicates exposure to a patient.

Statement 11 asked whether there was adequate spatial resolution visible in the centre of the image. Spatial resolution is the capacity for distinguishing fine detail in an image. The term used to identify spatial resolution is line pairs per millimeter (lp/mm) (Gonzalez, 2011: online). The reviewers' answers are in Table 4.39 below.

**Table 4.39:** Spatial resolution

| <b><u>Projection</u></b>                         |     | <b><u>Reviewer 1</u></b> | <b><u>Reviewer 2</u></b> | <b><u>Reviewer 3</u></b> |
|--|-----|--------------------------|--------------------------|--------------------------|
| <b>AP / PA chest</b>                             | Yes | 72%                      | 72%                      | 73%                      |
|  | No  | 27%                      | 27%                      | 27%                      |
| <b>Lateral chest</b>                             | Yes | 73%                      | 73%                      | 73%                      |
|  | No  | 26%                      | 26%                      | 27%                      |
| <b>Unanswered</b>                                |     | 1%                       | 1%                       | 0%                       |
| <b>AP Lumbar</b>                                 | Yes | 79%                      | 91%                      | 63%                      |
|  | No  | 21%                      | 9%                       | 36%                      |
| <b>Lateral lumbar</b>                            | Yes | 80%                      | 91%                      | 65%                      |
|  | No  | 20%                      | 9%                       | 34%                      |
| <b>Lumbar 5 and sacral 1 joint space (L5/S1)</b> | Yes | 1%                       | 1%                       | 2%                       |
|  | No  | 0%                       | 0%                       | 1%                       |

As shown in Table 4.39 visible spatial resolution in the centre of the lumbar spine radiographic images reviewed ranged between 63% and 91%. Reviewers 1 and 2 stated that adequate spatial resolution was visible in the centre of the image on 1% of the lumbar 5 and sacral 1 joint space (L5/S1) projections; reviewer 3 was of the opinion that adequate spatial resolution was visible in the centre of the image on 2% of the lumbar 5 and sacral 1 joint space (L5/S1) projections. The  $p$ -value for statement 11 of the lumbar spine radiographic image checklist is  $<.0001$ ; hence there is a significant difference between the percentages of the reviewers. A possible reason for this difference could be due each reviewer's subjective interpretation of spatial resolution on images.

The results for visible spatial resolution in the centre of the image on the chest radiographic images ranged between 72% and 73%. Reviewers 1 and 2 left 1% unanswered. The  $p$ -value for statement 11 of the chest radiographic image checklist is 0.0027. The responses indicate that in the majority of cases there was adequate spatial resolution visible in the centre of the image on the chest and lumbar spine radiographic images reviewed. There is a significant difference between the percentages of the three reviewers. A possible reason for the difference between the percentages of the three reviewers could be due the subjective interpretation of each individual reviewing the image. Spatial resolution is essential for the diagnosis as seen in literature (see Herrmann et al., 2012: online).

The results for statement 12 in terms of image noise are presented in Table 4.40.

**Table 4.40:** Image noise

| <u>Projection</u>                                |     | <u>Reviewer 1</u> | <u>Reviewer 2</u> | <u>Reviewer 3</u> |
|--|-----|-------------------|-------------------|-------------------|
| <b>AP / PA chest</b>                             | Yes | 2%                | 2%                | 3%                |
|  | No  | 98%               | 98%               | 93%               |
| <b>Lateral chest</b>                             | Yes | 4%                | 4%                | 15%               |
|  | No  | 96%               | 96%               | 81%               |
| <b>AP Lumbar</b>                                 | Yes | 18%               | 4%                | 31%               |
|  | No  | 82%               | 96%               | 69%               |
| <b>Lateral lumbar</b>                            | Yes | 12%               | 5%                | 26%               |
|  | No  | 88%               | 95%               | 74%               |
| <b>Lumbar 5 and sacral 1 joint space (L5/S1)</b> | Yes | 1%                | 1%                | 2%                |
|  | No  | 0%                | 0%                | 1%                |

The findings in Table 4.40 were as follows. No quantum mottle on the lumbar spine radiographic images reviewed ranged between 69% and 96% on the AP lumbar spine projections, and 74% and 95% on the lateral lumbar spine projections. The reviewers indicated no quantum mottle was obvious the lumbar 5 and sacral 1 joint space (L5/S1) projections of the lumbar spine radiographic examination images as the percentages ranged between 0% and 2%. The  $p$ -value for statement 12 of the lumbar spine radiographic image checklist is 0.0001; hence there is a significant difference between the percentages of the reviewers.

Table 4.40 also shows that there was not a quantum mottle appearance on the chest radiographic images reviewed with percentages ranging between 93% and 98% on the AP/PA chest projections, and 81% and 96% on the lateral chest projections. The  $p$ -value for statement 12 of the chest radiographic image checklist is 0.0016; hence there is a significant difference between the percentages of the reviewers.

The results show that most images did not have a quantum mottle appearance on the chest and lumbar spine radiographic images. This is an optimal finding. Carroll (2011: 631) explains that quantum mottle, together with the lack of any immediate consequences to overexposure, has led to an unfortunate leaning toward overexposure by radiographers known as exposure creep.

The answers given by the reviewers with reference to statement 13, which stated good contrast of image was evident, are presented in Table 4.41 below.

**Table 4.41:** Image contrast

| <b><u>Projection</u></b>                         |     | <b><u>Reviewer 1</u></b> | <b><u>Reviewer 2</u></b> | <b><u>Reviewer 3</u></b> |
|--|-----|--------------------------|--------------------------|--------------------------|
| <b>AP / PA chest</b>                             | Yes | 79%                      | 79%                      | 76%                      |
|  | No  | 21%                      | 21%                      | 24%                      |
| <b>Lateral chest</b>                             | Yes | 80%                      | 80%                      | 76%                      |
|  | No  | 20%                      | 20%                      | 24%                      |
| <b>AP Lumbar</b>                                 | Yes | 75%                      | 84%                      | 63%                      |
|  | No  | 25%                      | 16%                      | 37%                      |
| <b>Lateral lumbar</b>                            | Yes | 73%                      | 81%                      | 60%                      |
|  | No  | 27%                      | 19%                      | 40%                      |
| <b>Lumbar 5 and sacral 1 joint space (L5/S1)</b> | Yes | 0%                       | 0%                       | 0%                       |
|  | No  | 0%                       | 0%                       | 2%                       |

As shown in Table 4.41 good image contrast was evident on the lumbar spine radiographic images reviewed. The findings were between 63% and 84% on the AP lumbar spine projections, and between 60% and 81% on the lateral lumbar spine projections. Reviewer 3 indicated that good image contrast was not evident on 2% of the lumbar 5 and sacral 1 joint space (L5/S1) projections of the lumbar spine radiographic examination images reviewed. Good image contrast was evident on the chest radiographic images reviewed. The findings ranged between 76% and 79% on the AP/PA chest projections, and 76% and 80% on the lateral chest projections. The *p*-value for statement 13 of the chest radiographic image checklist is 0.0370; revealing there is a significant difference between the percentages of the reviewers. The responses show in most cases good image contrast was evident on the lumbar spine and chest radiographic images reviewed. Good image contrast is crucial for diagnosis and image quality.

It is achieved by using the highest kVp within the optimal range for the position and part of anatomy together with the lowest amount of mAs required to deliver an acceptable exposure to the image receptor (Herrmann et al., 2012: online).

Table 4.42 presents the answers given by the reviewers with reference to statement 14 that enhancement/windowing of the image was required.

**Table 4.42:** Enhancement / windowing

| <b><u>Projection</u></b>                         |     | <b><u>Reviewer 1</u></b> | <b><u>Reviewer 2</u></b> | <b><u>Reviewer 3</u></b> |
|--|-----|--------------------------|--------------------------|--------------------------|
| <b>AP / PA chest</b>                             | Yes | 5%                       | 5%                       | 73%                      |
|  | No  | 95%                      | 95%                      | 27%                      |
| <b>Lateral chest</b>                             | Yes | 3%                       | 3%                       | 74%                      |
|  | No  | 97%                      | 97%                      | 26%                      |
| <b>AP Lumbar</b>                                 | Yes | 19%                      | 9%                       | 78%                      |
|  | No  | 81%                      | 91%                      | 22%                      |
| <b>Lateral lumbar</b>                            | Yes | 20%                      | 10%                      | 80%                      |
|  | No  | 80%                      | 90%                      | 20%                      |
| <b>Lumbar 5 and sacral 1 joint space (L5/S1)</b> | Yes | 1%                       | 1%                       | 0%                       |
|  | No  | 0%                       | 0%                       | 0%                       |

With reference to Table 4.42 the results show that enhancement/windowing of the image was not required on the lumbar spine radiographic images reviewed; percentages ranged between 22% and 91% on the AP lumbar spine projections, and 20% and 90% on the lateral lumbar spine projections.

The  $p$ -value for statement 14 of the lumbar spine radiographic image checklist indicates there is a significant difference between the percentages of the reviewers.

Reviewers 1 and 2 stated that enhancement/windowing of the image was required on 5% of the AP/PA chest projections, and 3% of the lateral chest projections. Reviewer 3 stated it was required on 73% of the AP/PA chest projections, and 74% of the lateral chest projections. The  $p$ -value for statement 14 of the chest radiographic image checklist is  $<.0001$ .

The responses indicate that in most cases enhancement/windowing of the image was not required on the chest and lumbar spine radiographic images reviewed. According to Carroll (2011: 506, 550 and 584) the smoothing and edge enhancement feature must be used with utmost discretion, seeing that an image already has very high contrast. Adding edge enhancement could cause quantum mottle to become visible and even introduce further noise by means of the “halo” effect (Carroll, 2011: 584). The  $p$ -values for both the chest and lumbar spine radiographic image checklist show that there is a significant difference between the percentages of the reviewers. A possible reason for the difference could be the different way that each individual perceived and looked at the image.

Statement 15 stated motion/blurring of the image was evident. The answers given by the reviewers regarding statement 15 are presented in Table 4.43.

**Table 4.43:** Motion / blurring

| <b><u>Projection</u></b> |     | <b><u>Reviewer 1</u></b> | <b><u>Reviewer 2</u></b> | <b><u>Reviewer 3</u></b> |
|--------------------------|-----|--------------------------|--------------------------|--------------------------|
| <b>AP Lumbar</b>         | Yes | 4%                       | 1%                       | 4%                       |
|                          | No  | 95%                      | 99%                      | 95%                      |
| <b>Lateral lumbar</b>    | Yes | 4%                       | 0%                       | 4%                       |
|                          | No  | 95%                      | 100%                     | 95%                      |

|  |     |    |    |    |
|--|-----|----|----|----|
| <b>Lumbar 5 and sacral 1 joint space (L5/S1)</b> | Yes | 0% | 0% | 0% |
|  | No  | 0% | 0% | 0% |

As shown in Table 4.43 reviewers 1 and 3 indicated that motion/blurring of the image was evident on 4% of the AP and lateral lumbar spine projections. Reviewer 2 stated it was evident on 1% of the AP lumbar spine projections. For the lateral projections of the lumbar spine radiographic examination, reviewer 2 was of the opinion that enhancement / windowing of the image was not required on any of the images. The *p*-value for statement 15 of the lumbar spine radiographic image checklist is 0.6600; hence there is good correlation between the percentages of the reviewers.

The answers given by the reviewers, with reference to statement 15 of the chest radiographic image checklist, show that all stated that motion/blurring of the image was not evident on 100% of the AP/PA and lateral projections of the chest radiographic images. No motion/blurring was noted in all chest images and this is the ideal in chest imaging. The results of the lumbar spine radiographic image checklist reveal that in the majority of cases motion/blurring of the image was not evident.

The presence of artefacts was covered in statement 16. The results are presented below in Table 4.44.

**Table 4.44:** Artefacts

| <b><u>Projection</u></b> |     | <b><u>Reviewer 1</u></b> | <b><u>Reviewer 2</u></b> | <b><u>Reviewer 3</u></b> |
|--------------------------|-----|--------------------------|--------------------------|--------------------------|
| <b>AP / PA chest</b>     | Yes | 83%                      | 82%                      | 29%                      |
|                          | No  | 17%                      | 17%                      | 71%                      |
| <b>Lateral chest</b>     | Yes | 84%                      | 84%                      | 19%                      |
|                          | No  | 16%                      | 16%                      | 81%                      |

|  |     |     |     |     |
|--|-----|-----|-----|-----|
| <b>AP Lumbar</b>                                 | Yes | 68% | 79% | 16% |
|  | No  | 32% | 21% | 84% |
| <b>Lateral lumbar</b>                            | Yes | 67% | 80% | 8%  |
|  | No  | 33% | 20% | 92% |
| <b>Lumbar 5 and sacral 1 joint space (L5/S1)</b> | Yes | 0%  | 0%  | 0%  |
|  | No  | 0%  | 0%  | 0%  |

With reference to Table 4.44 reviewer 1 indicated that artefacts were present on 68% of the AP lumbar spine projections, and 67% of the lateral lumbar spine projections. Reviewer 2 stated that artefacts were present on 79% of the AP lumbar spine projections, and 80% of the lateral lumbar spine projections. Reviewer 3 indicated that artefacts were present on 16% of the AP lumbar spine projections, and 8% of the lateral lumbar spine projections. The  $p$ -value for statement 16 of the lumbar spine radiographic image checklist is  $<.0001$ .

Reviewer 1 stated that artefacts were present on the image on 83% of the AP/PA chest projections, and 84% of the lateral chest projections. Reviewer 2 indicated that artefacts were present on the image on 82% of the AP/PA chest projections, and 84% of the lateral chest projections. Reviewer 3 stated that artefacts were present on the image on 29% of the AP/PA chest projections, and 19% of the lateral chest projections. The  $p$ -value for statement 16 of the chest radiographic image checklist is  $<.0001$ .

The  $p$ -values for both the chest and lumbar spine radiographic image checklist indicate that there is a significant difference between the percentages of the reviewers. A possible reason for the difference could be different training received or years of experience of each individual. The results of both the chest and lumbar spine radiographic image checklist showed that in most cases artefacts were present on the image. This is concerning in view of what is in the literature.

Both Peer (2003: 5-6), and Herrmann et al. (2012: online), state that ensuring artefacts are not in images is a radiographer's radiation protection responsibility during a radiographic examination (see 2.7).

The results for statement 17 regarding image density are presented in Table 4.45.

**Table 4.45:** Image density

| <b><u>Projection</u></b> |     | <b><u>Reviewer 1</u></b> | <b><u>Reviewer 2</u></b> | <b><u>Reviewer 3</u></b> |
|--------------------------|-----|--------------------------|--------------------------|--------------------------|
| <b>AP / PA chest</b>     | Yes | 95%                      | 95%                      | 52%                      |
|                          | No  | 5%                       | 5%                       | 48%                      |
| <b>Lateral chest</b>     | Yes | 94%                      | 94%                      | 54%                      |
|                          | No  | 6%                       | 6%                       | 46%                      |
| <b>AP Lumbar</b>         | Yes | 70%                      | 81%                      | 49%                      |
|                          | No  | 23%                      | 12%                      | 52%                      |
| <b>Lateral lumbar</b>    | Yes | 66%                      | 80%                      | 45%                      |
|                          | No  | 28%                      | 14%                      | 56%                      |
| <b>Unanswered</b>        |     | 6%                       | 6%                       | 0%                       |

Table 4.45 shows that reviewer 1 stated that optimal image density was evident on 70% of the AP lumbar spine projections, and 66% of the lateral lumbar spine projections. Reviewer 2 indicated it was evident on 81% of the AP lumbar spine projections, and 80% of the lateral lumbar spine projections. Reviewer 3 stated it was evident on 49% of the AP lumbar spine projections, and 45% of the lateral lumbar spine projections. Reviewers 1 and 2 left 6% unanswered. The  $p$ -value for statement 17 of the lumbar spine radiographic image checklist is  $<.0001$ .

Table 4.45 shows that reviewers 1 and 2 stated that optimal image density was evident on 95% of the AP/PA chest projections, and reviewer 3 stated it was evident on 52% of the AP/PA chest projections, and 54% of the lateral chest projections. The  $p$ -value for statement 17 of the chest radiographic image checklist is  $<.0001$ . The  $p$ -values for both the chest and lumbar spine radiographic image checklist indicate that there is a significant difference between the percentages of the reviewers. A possible reason for the difference could be the different way in which each individual perceived and looked at the images. The results show that in most cases optimal image density was evident, which is essential and reveals good radiographic technique was achieved (see 2.7).

Statement 18 referred to factors that may have influenced the EI value and hence is listed as four subdivided statements: collimation; differences in density of anatomy; wrong anatomical processing algorithm, and other additional factors not stated. Their collective results are presented in Table 4.46 below.

**Table 4.46:** Factors influencing the EI value: chest and lumbar spine

| <b>Factor</b>                        | <b>Projection</b>         |     | <b>Reviewer 1</b> | <b>Reviewer 2</b> | <b>Reviewer 3</b> |
|--------------------------------------|---------------------------|-----|-------------------|-------------------|-------------------|
| <b>18.1 Collimation:<br/>Too Big</b> | <b>AP / PA<br/>chest</b>  | Yes | 100%              | 100%              | 96%               |
|                                      |                           | No  | 0%                | 0%                | 4%                |
|                                      | <b>Lateral<br/>chest</b>  | Yes | 100%              | 100%              | 96%               |
|                                      |                           | No  | 0%                | 0%                | 4%                |
|                                      | <b>AP Lumbar</b>          | Yes | 82%               | 90%               | 89%               |
|                                      |                           | No  | 18%               | 10%               | 11%               |
|                                      | <b>Lateral<br/>Lumbar</b> | Yes | 83%               | 92%               | 89%               |
|                                      |                           | No  | 17%               | 8%                | 11%               |
|                                      | <b>Unanswered</b>         |     | 1%                | 1%                | 0%                |

|  |  |                          |     |     |      |      |
|--|--|--------------------------|-----|-----|------|------|
| <b>18.1.1<br/>Collimation: Too<br/>Small</b> | <b>AP / PA<br/>chest</b>               | Yes                      | 1%  | 1%  | 0%   |      |
|  |  | No                       | 99% | 99% | 100% |      |
|  | <b>Lateral<br/>chest</b>               | Yes                      | 1%  | 1%  | 0%   |      |
|  |  | No                       | 99% | 99% | 100% |      |
|  | <b>AP Lumbar</b>                       | Yes                      | 1%  | 3%  | 0%   |      |
|  |  | No                       | 86% | 84% | 100% |      |
|  | <b>Lateral<br/>Lumbar</b>              | Yes                      | 1%  | 3%  | 0%   |      |
|  |  | No                       | 86% | 84% | 100% |      |
|  | <b>Unanswered</b>                      |                          | 13% | 13% | 0%   |      |
|  | <b>18.2 Differences<br/>in density</b> | <b>AP / PA<br/>chest</b> | Yes | 86% | 86%  | 96%  |
| No   |  |                          | 14% | 14% | 4%   |      |
| <b>Lateral<br/>chest</b>                     |  | Yes                      | 86% | 86% | 96%  |      |
|  |  | No                       | 14% | 14% | 4%   |      |
| <b>AP Lumbar</b>                             |  | Yes                      | 49% | 68% | 68%  |      |
|  |  | No                       | 51% | 32% | 32%  |      |
| <b>Lateral<br/>Lumbar</b>                    |  | Yes                      | 49% | 68% | 68%  |      |
|  |  | No                       | 51% | 32% | 32%  |      |
| <b>18.3 Processing<br/>algorithms</b>        |  | <b>AP / PA<br/>chest</b> | Yes | 2%  | 2%   | 0%   |
|  |  |                          | No  | 98% | 98%  | 100% |
|  | <b>Lateral<br/>chest</b>               | Yes                      | 2%  | 2%  | 0%   |      |
|  |  | No                       | 98% | 98% | 100% |      |
|  | <b>AP Lumbar</b>                       | Yes                      | 0%  | 0%  | 6%   |      |

|                   |                       |     |      |      |     |
|-------------------|-----------------------|-----|------|------|-----|
|                   |                       | No  | 100% | 100% | 94% |
|                   | <b>Lateral Lumbar</b> | Yes | 0%   | 0%   | 6%  |
|                   |                       | No  | 100% | 100% | 94% |
| <b>18.4 Other</b> | <b>AP / PA chest</b>  | Yes | 25%  | 27%  | 1%  |
|                   |                       | No  | 75%  | 73%  | 99% |
|                   | <b>Lateral chest</b>  | Yes | 25%  | 27%  | 1%  |
|                   |                       | No  | 75%  | 73%  | 99% |
|                   | <b>AP Lumbar</b>      | Yes | 63%  | 57%  | 34% |
|                   |                       | No  | 37%  | 43%  | 66% |
|                   | <b>Lateral Lumbar</b> | Yes | 63%  | 57%  | 34% |
|                   |                       | No  | 37%  | 43%  | 66% |

With reference to statement 18.1 in Table 4.46, the reviewers' answers for the E1 value of the lumbar spine radiographic image were: reviewer 1 stated that the EI value was influenced by the collimation being too big on 82% of the AP lumbar spine projections, and 83% of the lateral lumbar spine projections; reviewer 2 indicated this did occur on 90% of the AP lumbar spine projections, and 92% of the lateral lumbar spine projections; and reviewer 3 stated it occurred on 89% of the AP, and lateral lumbar spine projections of the lumbar spine radiographic examination. Reviewers 1 and 2 left 1% unanswered. The  $p$ -value for statement 18.1 of the lumbar spine radiographic image checklist is 0.4770; hence there is good correlation between the percentages of the reviewers.

In terms of the EI value being influenced by the collimation on the chest projections, reviewers 1 and 2 stated this it was too big on 100% of the AP/PA and lateral chest projections, and 96% was stated by reviewer 3.

The  $p$ -value for statement 18.1 of the chest radiographic image checklist is 0.0596; hence there is good correlation between the percentages of the reviewers.

The answers of both the chest and lumbar spine radiographic image checklist indicate that the EI value was influenced by the collimation being too big in the majority of cases. This finding is of concern since the Directorate Radiation Control (DoH, 2012: 14 – 15) states that collimation must be applied at all times. According to Carroll (2011: 295) minimising radiation exposure to a patient should be of utmost concern to every radiographer. Restricting the size of the X-ray beam is one of the most effective ways to minimise radiation exposure (Carroll, 2011: 295). The results also show that collimation being too small had a minimal influence on EI values.

Statement 18.2 stated the EI value was influenced by differences in density of anatomy. The reviewers' answers in Table 4.46 were as follows. Reviewer 1 stated that the EI value was influenced by the differences in density of anatomy on 49% of the AP and lateral lumbar spine projections, whereas reviewers 2 and 3 stated this was evident on 68% of the AP and lateral lumbar spine projections of the lumbar spine radiographic examination. The  $p$ -value for statement 18.2 of the lumbar spine radiographic image checklist is 0.0019; hence there is a significant difference between the percentages of the reviewers.

Table 4.46 shows that reviewers 1 and 2 stated that the EI value was influenced by the differences in density of anatomy on 86% of the AP/PA and lateral chest projections, and reviewer 3 indicated this was evident on 96% of the AP/PA and lateral chest projections. The  $p$ -value for statement 18.2 of the chest radiographic image checklist is  $<.0001$ , revealing there is a significant difference between the percentages of the reviewers.

These results show that for most case the EI value was influenced by the differences in the density of the anatomy.

This is of concern. According Peer (2003: 5-6), and Herrmann et al. (2012: online), it is a radiographer's radiation protection responsibility to ensure correct density on images during a radiographic examination (see 2.7). Carroll (2011:448) explains that due to the wide exposure latitude of DR, it is crucial that the correct radiographic technique is applied to produce an image which falls within the acceptable exposure index range that is of diagnostic value. Digital imaging systems may have wide exposure latitude and may generally compensate for overexposure at the receptor plate, but it cannot compensate for information which is simply missing due to underexposure at the image receptor plate (Carroll, 2011: 448).

The answers given by the reviewers with reference to statement 18.3 of the lumbar spine radiographic image checklist, and the chest radiographic image checklist, which state the EI value was influenced by the wrong anatomical processing algorithm, are presented in Table 4.46. The  $p$ -value for statement 18.3 of the chest radiographic image checklist is 0.3629; hence there is good correlation between the percentages of the reviewers. The results of both the chest and lumbar spine radiographic image checklist show that the EI value was not influenced by selection of the wrong anatomical processing algorithm, which is excellent as it shows diligence on the radiographers' behalf.

The answers given by the reviewers in reference to statement 18.4 of the lumbar spine radiographic image checklist which states the EI value was influenced by other factors are seen in Table 4.46. The other factors which influenced the lumbar spine radiographic examinations EI value include: artefacts; no pre-exposure collimation; no grid selection; incorrect exposure; incorrect centering of anatomy IRO IP; the patient condition i.e. bowel gas / faecal impaction and pathology.

Table 4.46 presents the responses given by the reviewers with reference to statement 18.4 of the chest radiographic image checklist.

The other factors which influenced the chest radiographic examinations EI value include: artefacts; foreign bodies; inadequate inspiration; the incorrect centering point; the patient condition i.e. cardiomegaly; incorrect patient positioning; incorrect exposure and pathology.

The results regarding the lumbar spine radiographic image checklist indicate the EI value was also influenced by other factors in most cases. Therefore the results indicate the radiographers' responsibilities i.e. patient positioning; exposure settings, removal of artefacts etc. with regard to radiation protection during a radiographic examination, as stated by Herrmann et al. (2012: online), were not effectively performed and achieved (see 2.7). Other factors in 18.4 include those not mentioned i.e. collimation being too big or too small; differences in density, and processing algorithms.

The results with reference to the chest radiographic image checklist show that in the majority of cases the EI values were not influenced by other factors. They show that the radiographers' responsibilities with regard to radiation protection, patient care and professionalism during a radiographic examination, as stated by Herrmann et al. (2012: online), were effectively performed and achieved (see 2.7).

#### **4.4.1.2 Section two lumbar spine checklist: Statement 22 to 24**

Section two of the lumbar spine radiographic image checklist had three statements pertaining to the evaluation criteria for the AP, lateral and lumbar 5 and sacral 1 joint space (L5/S1) projections of the lumbar spine radiographic examination. Statement 22 was subdivided into several statements. The latter were based on the evaluation criteria of the AP projection of the lumbar spine radiographic examination. Feedback from the reviewers, in relation to these statements, is presented in Table 4.47 below.

**Table 4.47:** Anatomy of interest clearly visible on projection

| <b><u>Projection</u></b> |     | <b><u>Reviewer 1</u></b> | <b><u>Reviewer 2</u></b> | <b><u>Reviewer 3</u></b> |
|--------------------------|-----|--------------------------|--------------------------|--------------------------|
| <b>AP Lumbar</b>         | Yes | 91%                      | 98%                      | 79%                      |
|                          | No  | 9%                       | 2%                       | 21%                      |
| <b>Lateral lumbar</b>    | Yes | 91%                      | 98%                      | 79%                      |
|                          | No  | 9%                       | 2%                       | 21%                      |

Statement 22.1 read: the lumbar vertebral bodies, disk spaces, spinous and transverse processes, lateral margin of psoas muscle, SI joints, and sacrum are clearly visible. It is evident from Table 4.47 that the lumbar vertebral bodies, disc spaces, spinous and transverse processes, lateral margin of psoas muscle, SI joints, and sacrum were clearly visible on the majority of the AP and lateral projections of the lumbar spine radiographic images reviewed. The *p*-value for statement 22.1 is 0.0002, indicating there is a significant difference between the percentages of the reviewers. Peer (2003: 5-6), and Herrmann et al. (2012: online), state it is the responsibility of radiographers' to prevent unnecessary exposure to radiation at all times by avoiding repeat examinations. These results show that this was performed effectively by the radiographers at the study sites.

Table 4.48 presents the results for inclusion of anatomy of interest (T12 to S1) on the projections.

**Table 4.48:** Anatomy of interest all included on projection

| <b><u>Projection</u></b>                         |     | <b><u>Reviewer 1</u></b> | <b><u>Reviewer 2</u></b> | <b><u>Reviewer 3</u></b> |
|--|-----|--------------------------|--------------------------|--------------------------|
| <b>AP Lumbar</b>                                 | Yes | 97%                      | 98%                      | 92%                      |
|  | No  | 2%                       | 2%                       | 7%                       |
| <b>Lateral lumbar</b>                            | Yes | 97%                      | 98%                      | 92%                      |
|  | No  | 2%                       | 2%                       | 7%                       |
| <b>Lumbar 5 and sacral 1 joint space (L5/S1)</b> | Yes | 99%                      | 100%                     | 99%                      |
|  | No  | 1%                       | 0%                       | 1%                       |

Statement 22.2 read: T12 to S1 are included and evident on the AP view of the lumbar spine radiographic images reviewed. As shown in Table 4.48 this was evident in the majority images as the percentages ranged between 92% and 98% on the AP lumbar spine projections. Reviewers 1 and 3 indicated that T12 to S1 was included on 99% of the lumbar 5 and sacral 1 joint space (L5/S1) projections, and reviewer 3 stated this anatomy was included on 100% of the lumbar 5 and sacral 1 joint space (L5/S1) projections. The *p*-value indicates no significant difference between the percentages of the reviewers.

Statement 22.3 was subdivided into several statements; all referred to rotation being evident. Feedback from the reviewers in relation to these statements is discussed below.

In terms of statement 22.3, which stated that no rotation was evident on the AP projection of the lumbar spine radiographic images, reviewer 1 indicated that no rotation was evident on 90% of the AP projections of the lumbar spine radiographic examinations; reviewer 2 stated it was not evident on 89% of the AP projections of the lumbar spine radiographic examinations; and reviewer 3 indicated it was not evident on 91% of the AP projections of the lumbar spine radiographic examinations.

Their answers show that in the majority of cases rotation was not evident on the AP projection of the lumbar spine radiographic images reviewed. This shows that correct positioning and radiographic technique was applied.

Statements 22.3.1 – 22.3.4 relate to rotation of the AP projection of the lumbar spine, and their results are presented in Table 4.49 below.

**Table 4.49:** Rotation criteria for AP projection

|  | <u>AP Lumbar</u> | <u>Reviewer 1</u> | <u>Reviewer 2</u> | <u>Reviewer 3</u> |
|--|------------------|-------------------|-------------------|-------------------|
| <b>22.3.1 Spinous processes are in the midline of the vertebral bodies</b> | No               | 1%                | 6%                | 3%                |
|  | Yes              | 99%               | 94%               | 97%               |
| <b>22.3.2 Right and left transverse processes are equal in length</b>      | No               | 9%                | 12%               | 6%                |
|  | Yes              | 91%               | 88%               | 94%               |
| <b>22.3.3 Symmetric vertebrae</b>  | No               | 10%               | 10%               | 10%               |
|  | Yes              | 90%               | 90%               | 90%               |
| <b>22.3.4 SI joints is equal distance from the spine</b>                   | No               | 12%               | 13%               | 9%                |
|  | Yes              | 88%               | 87%               | 91%               |

As evident in Table 4.49 the results indicate that in the majority examinations the spinous processes were in the midline of the vertebral bodies on the AP projection of the lumbar spine radiographic images reviewed. This is good positioning for an accurate diagnosis to be made. The  $p$ -value for statement 22.3.1 is 0.2518; there is good correlation between the percentages of the reviewers.

The results show that the right and left transverse processes were equal in length. The  $p$ -value for statement 22.3.2 is 0.2909; there is no significant difference between the percentages of the reviewers.

The results for statement 22.3.3 show that in the majority images the vertebrae were symmetrical on the AP projection of the lumbar spine radiographic images reviewed. Such positioning is essential for correct diagnosis (see Herrmann et al., 2012: online).

The responses indicate that in most of images the sacro-iliac (SI) joints were an equal distance from the spine on the AP projection of the lumbar spine radiographic images reviewed. This positioning is important for accurate diagnosis. The  $p$ -value for statement 22.3.4 is 0.6227 thus there is good correlation between the percentages of the reviewers.

Statements 22.4 and 22.4.1 related to the subjective analysis of the optimal exposure of the AP projection of the lumbar spine radiographic examination. Their results are presented in Table 4.50 below.

**Table 4.50:** Optimal exposure for AP projection

|   | <u>AP Lumbar</u> | <u>Reviewer 1</u> | <u>Reviewer 2</u> | <u>Reviewer 3</u> |
|---|------------------|-------------------|-------------------|-------------------|
| <b>22.4 Optimal exposure is evident</b>   | No               | 24%               | 13%               | 43%               |
|   | Yes              | 76%               | 87%               | 57%               |
| <b>22.4.1 Soft tissues, margins of psoas muscle and bony vertebrae are demonstrated</b> | No               | 11%               | 1%                | 36%               |
|   | Yes              | 89%               | 99%               | 64%               |

The  $p$ -value for statement 22.4 is  $<.0001$ , indicating there is a significant difference between the percentages of the reviewers.

A possible reason for the difference between their percentages could be different training received or years of experience of each individual. The results show that in most cases optimal exposure was evident on the AP projection of the lumbar spine radiographic examinations reviewed. This indicates good radiographic technique was applied.

It is evident in Table 4.50 that in most reviewed images the soft tissues, margins of the psoas muscle and bony vertebrae, were demonstrated on the AP projection of the lumbar spine radiographic examinations, with percentages ranging between 64% and 99%. The  $p$ -value for statement 22.4.1 is  $<.0001$ , hence there is a significant difference between the percentages of the reviewers. A possible reason for the difference could be their subjective interpretation of each image.

According to Herrmann et al. (2012: online) radiographers' responsibilities, with regard to optimal exposure and radiation protection during a radiographic examination, include:

- accurate application of radiographic techniques,
- select the appropriate exposure factors for a patient's size, based on a calculated exposure system, planned in collaboration with radiologists, to ascertain acceptable image quality for diagnosis.

Statement 23.1 stated the lumbar vertebral bodies, intervertebral foramina, disc spaces, spinous and transverse processes, SI joints and sacrum, were clearly visible. Reviewer 1 indicated this anatomy was clearly visible on 83% of the AP and lateral lumbar spine projections of the lumbar spine radiographic examination, reviewer 2 stated it was clearly visible on 96% of these projections, and reviewer 3 listed it as 68%. The  $p$ -value for statement 23.1 is  $<.0001$ , indicating there is a significant difference between the percentages of the reviewers.

These are ideal results for demonstrating the anatomy of interest. Peer (2003: 5-6) states it is the responsibility of radiographers to practice good radiographic techniques for optimal image quality and radiation protection during a radiographic examination.

Radiographers should prevent patients being subjected to unnecessary exposure to radiation at all times by avoiding repeat examinations (Peer, 2003: 5-6).

Statement 23.3 was subdivided into four statements. They all referred to rotation being evident on the lateral projection of the lumbar spine radiographic images. For statement 23.3, reviewer 1 stated that no rotation was evident on 82% of the lateral projections of the lumbar spine radiographic examinations, reviewer 2 listed 91%, and 77% was stated by reviewer 3. The  $p$ -value for statement 23.3 is 0.0321, indicating there is a significant difference between the percentages of the reviewers. The results show that in most images rotation was not evident on the lateral projections of the lumbar spine radiographic examinations. This points to application of good radiographic technique.

Statements 23.3.1 – 23.3.4 related to the technical criteria of rotation of the lateral projection of the lumbar spine. Their results are presented in Table 4.51 below.

**Table 4.51:** Rotation criteria for lateral projection

|  | <b>Lateral Lumbar</b> | <b><u>Reviewer 1</u></b> | <b><u>Reviewer 2</u></b> | <b><u>Reviewer 3</u></b> |
|--|-----------------------|--------------------------|--------------------------|--------------------------|
| <b>23.3.1 Nearly superimposed iliac crests when the x-ray beam is not angled</b> | No                    | 10%                      | 6%                       | 18%                      |
|  | Yes                   | 90%                      | 94%                      | 82%                      |
| <b>23.3.2 Superimposed posterior margins of each vertebral body</b>              | No                    | 12%                      | 9%                       | 18%                      |
|  | Yes                   | 88%                      | 91%                      | 82%                      |
| <b>23.3.3 Open intervertebral disc spaces</b>                                    | No                    | 7%                       | 1%                       | 13%                      |
|  | Yes                   | 93%                      | 99%                      | 87%                      |

|   |     |     |     |     |
|---|-----|-----|-----|-----|
| <b>23.3.4 Vertebrae is aligned down in the middle of the radiographic image</b> | No  | 21% | 6%  | 22% |
|   | Yes | 79% | 94% | 78% |

Table 4.51 shows that in the majority of reviewed images there was almost superimposed iliac crests when the X-ray beam was not angled on the lateral projections of the lumbar spine. Such superimposition is significant for accurate diagnosis. The  $p$ -value for statement 23.3.1 is 0.0306, indicating there is a significant difference between the percentages of the reviewers. The posterior margins of each vertebral body were superimposed on the lateral projection of the lumbar spine radiographic images reviewed. The  $p$ -value for statement 23.3.2 is 0.2002, indicating there is good correlation between the percentages of the reviewers.

The responses of the reviewers with reference to statement 23.3.3 show that in the majority of cases open intervertebral disc spaces was evident on the lateral projection of the lumbar spine radiographic images reviewed. This is important for accurate diagnosis. In other words, radiographers' responsibilities, with regard to positioning and radiation protection during a radiographic examination, were performed efficiently as propounded in the literature (see 2.7). The  $p$ -value for statement 23.3.3 is 0.0058, showing there is a significant difference between the percentages of the reviewers.

Statement 23.3.4 stated the vertebrae were aligned in the middle of the radiographic image. Table 4.51 shows that for most cases the vertebrae were aligned in the middle of the radiographic image on the lateral projection of the lumbar spine radiographic images reviewed. This suggests that good radiographic technique was applied, and that the radiographers accurately applied radiographic techniques and positioning. This is in accord with statements by Peer, (2003: 5-6), and Herrmann et al. (2012: online), in terms of radiographers' responsibilities. The  $p$ -value for statement 23.3.4 is 0.0033, indicating there is a significant difference between the percentages of the reviewers.

Statements 23.4 and 23.4.1 related to subjective analysis of the optimal exposure of the lateral projection of the lumbar spine radiographic examination.

Statement 23.4 stated optimal exposure was evident. Reviewer 1 indicated it was evident on 70% of the lateral projections of the lumbar spine radiographic examinations, 82% was stated by reviewer 2, and 47% by reviewer 3. The  $p$ -value for statement 23.4 is  $<.0001$ , indicating there is a significant difference between the percentages of the reviewers. The results indicate that optimal exposure was mostly evident on the lateral projections of the lumbar spine radiographic examinations reviewed. This is of utmost importance as it implies good radiographic technique was applied.

With reference to statement 23.4.1, reviewer 1 stated that soft tissues, joint spaces and bony vertebrae were demonstrated on 83% of the lateral projections of the lumbar spine radiographic examinations, 99% was stated by reviewer 2, and 56% by reviewer 3. The  $p$ -value for statement 23.4.1 is  $<.0001$ , showing there is a significant difference between the percentages of the reviewers. The results show good radiographic technique was applied as stated in literature (see 2.7).

Statement 24 was subdivided into two statements based on the evaluation criteria of the lumbar 5 and sacral 1 joint space (L5/S1) projection of the lumbar spine radiographic examination.

For statement 24.1, reviewer 1 indicated that the lower one or two lumbar vertebrae and upper sacrum were demonstrated on 10% of the lumbar 5 and sacral 1 joint space (L5/S1) projections, reviewer 2 stated this was evident in 90% of the projections, and 4% was stated by reviewer 3. The  $p$ -value for statement 24.1 is 0.2902, demonstrating there is no significant difference between the percentages of the reviewers. The results indicate that lumbar vertebrae 4 and 5, and upper sacrum were not demonstrated on the majority of projections. Of concern is that a separate lateral L5/S1 projection seems to not be protocol at the two study sites as images were not available during data collection.

With reference to statement 24.2, reviewers 1 and 2 stated that the lumbosacral joint was in the center of the radiographic image on 10% of the lumbar 5 and sacral 1 joint space (L5/S1) projections, and 3% was listed by reviewer 3. The  $p$ -value for statement 24.2 is 0.2285, showing there is no significant difference between the percentages of the reviewers. The results show the lumbosacral joint was not in the center of the radiographic image on the majority of the lumbar 5 and sacral 1 joint space (L5/S1) projections reviewed. Images of lumbar 5 and sacral 1 joint space (L5/S1) projection were not available for reviewing, and this is of concern.

The  $p$ -values in several results indicate a significant difference between the percentages of the reviewers. A possible reason for the difference could be their subjective interpretation of each image.

To summarise, the above discussion covered the radiographic image checklist for lumbar spine radiographic examinations. The radiographic image checklist for the chest radiographic examination is discussed below.

#### **4.4.1.3 Section two chest checklist: Statement 20 to 21**

Section two of the chest radiographic image checklist comprised statements 20 and 21, which were reviewed by all three reviewers. These statements were subdivided into several statements based on the evaluation criteria for the AP/PA and lateral projection of the chest radiographic examination. Statement 20 of the chest radiographic image checklist was further subdivided into eight statements. Feedback from the reviewers, in relation to these statements, is discussed below. Tables 4.52 to 4.54 present the results for the statements.

**Table 4.52:** Evaluation criteria for the AP / PA chest projection

| <b>Evaluation Criteria</b>  | <b>Projection</b> |     | <b>Reviewer<br/>1</b> | <b>Reviewer<br/>2</b> | <b>Reviewer<br/>3</b> |
|---|-------------------|-----|-----------------------|-----------------------|-----------------------|
| <b>20.1 Entire lung fields from apices to costo-phrenic angles are clearly demonstrated</b>   | AP / PA chest     | Yes | 98%                   | 98%                   | 92%                   |
|   |                   | No  | 2%                    | 2%                    | 8%                    |
| <b>20.2 No rotation evident</b>   | AP / PA chest     | Yes | 4%                    | 4%                    | 78%                   |
|   |                   | No  | 96%                   | 96%                   | 22%                   |
| <b>20.3 Trachea visible in midline</b>  | AP / PA chest     | Yes | 98%                   | 98%                   | 98%                   |
|   |                   | No  | 2%                    | 2%                    | 2%                    |
| <b>20.4 Scapula projected outside lung fields</b>   | AP / PA chest     | Yes | 33%                   | 33%                   | 53%                   |
|   |                   | No  | 67%                   | 67%                   | 47%                   |
| <b>20.5 Ten posterior ribs visible above diaphragm</b>  | AP / PA chest     | Yes | 80%                   | 80%                   | 72%                   |
|   |                   | No  | 20%                   | 20%                   | 72%                   |
| <b>20.6 Sharp outline of the heart and diaphragm</b>  | AP / PA chest     | Yes | 89%                   | 89%                   | 93%                   |
|   |                   | No  | 11%                   | 11%                   | 7%                    |
| <b>20.7 Faint shadow of ribs and superior thoracic vertebrae visible through heart shadow</b> | AP / PA chest     | Yes | 92%                   | 92%                   | 92%                   |
|   |                   | No  | 8%                    | 8%                    | 8%                    |

|   |               |     |      |      |     |
|---|---------------|-----|------|------|-----|
| <b>20.8 Lung markings visible from hilum to periphery of lung</b> | AP / PA chest | Yes | 100% | 100% | 94% |
|   |               | No  | 0%   | 0%   | 6%  |

The answers given by the reviewers regarding statement 20.1, which stated the entire lung-fields from the apices to the costo-phrenic angles were clearly demonstrated, are shown in Table 4.52. Reviewers 1 and 2 indicated the entire lung-fields from the apices to the costo-phrenic angles were clearly demonstrated on 98% of the AP/PA projections of the chest radiographic examinations, and 92% was indicated by reviewer 3. The  $p$ -value for statement 20.1 is 0.0439; there is a significant difference between the percentages of the reviewers. In the majority of cases the essential visualisation of the entire lung fields from the apices to the costo-phrenic angles was evident.

Peer (2003: 5-6), and Herrmann et al. (2012: online), state that the radiographers' responsibilities with regard to anatomy of interest and radiation protection during a radiographic examination include:

- collimate the x-ray beam to include all the anatomy of interest for the specific examination being performed (Herrmann, *et al*, 2012: online),
- prevent unnecessary exposure to radiation at all times by avoiding repeat examinations (Peer, 2003: 5-6).

Statement 20.2 stated no rotation was evident. Reviewers 1 and 2 stated that no rotation was evident on 4% of the AP/PA projections of the chest radiographic examinations, and 78% was indicated by reviewer 3. The  $p$ -value for statement 20.2 is <.0001 indicating there is a significant difference between the percentages of the reviewers. No rotation is important in chest images. Good collimation, and correct positioning, reduce scatter absorbed by a patient. The radiation dose to a patient may therefore be kept low while still producing images of diagnostic value.

The responses of the reviewers regarding statement 20.3, which stated the trachea was visible in the midline, showed this was evident in the majority of cases.

The trachea was visible in the midline on the AP/PA projection of the chest radiographic images reviewed, and this is important for accurate diagnosis. The  $p$ -value for statement 20.3 is 1.0000; indicating there is good correlation between the percentages of the reviewers.

Statement 20.4 stated the scapulae were projected outside the lung-fields. The results show that in most cases they were not projected outside the lung-fields. This is of concern. Adams (2015: 5) states there are image quality control measures that must be considered, namely: image quality, which must be checked for uniformity and patient positioning. The  $p$ -value for statement 20.4 is 0.0038; hence there is a significant difference between the percentages of the reviewers.

Statement 20.5 stated ten posterior ribs should be visible above the diaphragm. As evident in Table 4.52 these ribs were visible above the diaphragm. This shows the need for good inspiration was explained to most patients. The radiographers' radiation protection responsibility during a radiographic examination to prepare the patient by explaining the examination, positioning and or breathing instructions, was performed adequately, as suggested in literature (see 2.7). The  $p$ -value for statement 20.5 is 0.2961 indicating there is good correlation between the percentages of the reviewers.

Statement 20.6 stated a sharp outline of the heart and diaphragm should be evident. As evident in Table 4.52 this was evident in the majority of chest images. This is important for image quality since the DOH (2012: 4) states that one must select the lowest possible exposure ensuring that diagnostic quality is also kept and therefore reduces the radiation dose to a patient as well. The  $p$ -value for statement 20.6 is 0.3098; indicating there is good correlation between the percentages of the reviewers.

Statement 20.7 stated the faint shadow of the ribs, and superior thoracic vertebrae, were visible through the heart shadow. The results are presented in Table 4.52. The  $p$ -value for statement 20.7 is 1.0000 indicating there is no significant difference between the percentages of the reviewers.

The results show that in the majority of chest examinations the faint shadow of the ribs, and superior thoracic vertebrae, was visible through the heart shadow. This indicates good radiographic technique was applied, which is essential for image quality and accurate diagnosis, as suggested in literature (see Herrmann et al. 2012: online).

Statement 20.8 stated the lung markings were visible from the hilum to the periphery of the lung. The answers of the reviewers show that in most reviewed chest examinations the lung markings were visible from the hilum to the periphery of the lung on the AP/PA projection. This is essential. The results ranged between 94% and 100% on the AP / PA chest projections. The *p*-value for statement 20.8 is 0.0022; indicating there is a significant difference between the percentages of the reviewers. A possible reason for the difference could be the subjective interpretation of each reviewer for each image. The results indicate that excellent exposure and radiographic technique were applied, which is imperative for image quality and accurate diagnosis.

According to Herrmann et al. (2012: online), the radiographers' responsibilities with regard to optimal exposure and radiation protection during a radiographic examination include:

- accurate application of radiographic techniques, and
- select the appropriate exposure factors for the patient's size, based on a calculated exposure system, planned in collaboration with radiologists, to ascertain acceptable image quality for diagnosis.

Statement 21 of the chest radiographic image checklist was subdivided into nine statements. Statements 21.1 – 21.6 related to the evaluation criteria of the lateral chest radiographic examination. Feedback from the reviewers in relation to these statements is discussed below.

**Table 4.53:** Evaluation criteria for the lateral chest projection

| <b>Evaluation Criteria</b>                                   | <b>Projection</b> |     | <b>Reviewer 1</b> | <b>Reviewer 2</b> | <b>Reviewer 3</b> |
|--|-------------------|-----|-------------------|-------------------|-------------------|
| <b>21.1 Entire lung fields clearly demonstrated</b>          | Lateral chest     | Yes | 93%               | 93%               | 81%               |
|  |                   | No  | 7%                | 7%                | 19%               |
| <b>21.2 Arms not superimposed over lung fields</b>           | Lateral chest     | Yes | 97%               | 97%               | 78%               |
|  |                   | No  | 3%                | 3%                | 22%               |
| <b>21.3 Sharp radiographic outline is evident</b>            | Lateral chest     | Yes | 86%               | 86%               | 88%               |
|  |                   | No  | 14%               | 14%               | 12%               |
| <b>21.4 No rotation evident</b>                              | Lateral chest     | Yes | 29%               | 29%               | 81%               |
|  |                   | No  | 71%               | 71%               | 19%               |
| <b>21.5 No tilt</b>  | Lateral chest     | Yes | 89%               | 89%               | 100%              |
|  |                   | No  | 11%               | 11%               | 0%                |
| <b>21.6 Hilum is in the center of the radiographic image</b> | Lateral chest     | Yes | 99%               | 99%               | 99%               |
|  |                   | No  | 1%                | 1%                | 1%                |

Statement 21.1 stated the entire lung-fields from the apices to the costo-phrenic angles were clearly demonstrated. As shown in Table 4.53 reviewers 1 and 2 indicated that the entire lung-fields from the apices to the costo-phrenic angles were clearly demonstrated on 93% of the lateral chest projections, and 81% was stated by reviewer 3. The *p*-value for statement 21.1 is 0.0128; there is a significant difference between the percentages of the reviewers. The results are important in chest examination because as evident in Table 4.53 in most examinations the entire lung-fields from the apices to the costo-phrenic angles were clearly demonstrated.

Herrmann et al. (2012: online) explain that it is the radiographers' responsibility to accurately apply good radiographic techniques and positioning and to collimate the X-ray beam to include all the anatomy of interest for a specific examination being performed.

Statement 21.2 stated the arms were not superimposed over portions of the lung-fields. The results in Table 4.53 show that in most radiographs the arms were not superimposed over portions of the lung-fields. This is important in chest radiography. Herrmann et al. (2012: online) explain it is the radiographers responsibility to use immobilisation devices when necessary and to avoid repeat exposures by correctly positioning a patient. The  $p$ -value for statement 21.2 is  $<.0001$ , hence there is a significant difference between the percentages of the reviewers.

Statement 21.3 stated a sharp radiographic outline was evident for the outline of the diaphragm and lung markings. Most radiographs met this criterion on the lateral projection of the chest radiographic examinations. As shown in Table 4.53 the percentages ranged between 86% and 88%. The  $p$ -value for statement 21.3 is 0.3743; indicating there is good correlation between the percentages of the reviewers. The results indicate that a good exposure technique was applied, which is crucial for optimal image quality. According to Herrmann et al. (2012: online) this can be achieved by using the highest kVp within the optimal range for the position and part of anatomy together with the lowest amount of mAs required to deliver an acceptable exposure to the image receptor.

The results for statement 21.4 show that reviewers 1 and 2 stated that no rotation was evident on 29% of the lateral chest projections, and 81% was stated by reviewer 3. The  $p$ -value for statement 21.4 is  $<.0001$  which indicates there is a significant difference between the percentages of the reviewers. A possible reason for the difference could be their respective subjective interpretation of each image. The results show that in most examinations good radiographic technique was applied as rotation was not evident.

Statements 21.4.1 – 21.4.3 related to the technical criteria of rotation of the lateral projection of the chest. Their results are presented in Table 4.54 below.

**Table 4.54:** Rotation criteria for lateral projection

|   | <b>Lateral chest</b> | <b>Reviewer <u>1</u></b> | <b>Reviewer <u>2</u></b> | <b>Reviewer <u>3</u></b> |
|---|----------------------|--------------------------|--------------------------|--------------------------|
| <b>21.4.1 Ribs are superimposed posterior to the vertebral column without any separation of right and left posterior ribs and both costo-phrenic angles</b> | No                   | 66%                      | 66%                      | 19%                      |
|   | Yes                  | 34%                      | 34%                      | 81%                      |
| <b>21.4.2 Lateral aspect of the sternum forms the anterior border</b>   | No                   | 12%                      | 12%                      | 3%                       |
|   | Yes                  | 88%                      | 88%                      | 97%                      |
| <b>21.4.3 No ribs are projecting in front of the sternum</b>  | No                   | 20%                      | 20%                      | 5%                       |
|   | Yes                  | 80%                      | 80%                      | 95%                      |

Statement 21.4.1 stated the ribs were superimposed posterior to the vertebral column without any separation of the right and left posterior ribs and both costo-phrenic angles. It is evident in Table 4.54 that in most radiographs the ribs were not superimposed posterior to the vertebral column without any separation of the right and left posterior ribs and both costo-phrenic angles on the lateral projection of the chest radiographic examinations. The percentages ranged between 34% and 81%. The *p*-value for statement 21.4.1 is <.0001 which indicates there is a significant difference between the percentages of the reviewers. It is of concern that in most radiographs the ribs were not superimposed as per statement 21.4.1. This indicates poor radiographic practice and poor patient positioning.

Peer (2003: 5 - 6) states it is the radiographers' responsibilities with regard to positioning and radiation protection during a radiographic examination:

- to accurately apply radiographic techniques and positioning, and
- to prevent unnecessary exposure to radiation at all times by avoiding repeat examinations.

Statement 21.4.2 stated the lateral aspect of the sternum formed the anterior border. Reviewers 1 and 2 stated that the lateral aspect of the sternum formed the anterior border was on 88% of the lateral chest projections, and 97% was indicated by reviewer 3. The  $p$ -value for statement 21.4.2 is 0.0370, indicating there is a significant difference between the percentages of the reviewers. These are excellent percentages for the majority of radiographs showing that good and accurate radiographic techniques and positioning were carried out as stated in literature (see Peer, 2003: 5 - 6).

For statement 21.4.3 reviewers 1 and 2 stated that no ribs projected in front of the sternum on 80% of the lateral chest projections, and 95% was listed by reviewer 3. The  $p$ -value for statement 21.4.3 is 0.0028; indicating there is a significant difference between the percentages of the reviewers. In the majority of radiographs no ribs projected in front of the sternum on the lateral projection of the chest radiographic examinations reviewed. This shows that optimal radiographic technique was applied. Adams (2015: 5) explains there are certain quality control measures that must be considered; image quality must be checked for uniformity and patient positioning.

Statement 21.5 stated there was no tilt hence the thoracic intervertebral spaces and intervertebral foramina were open. As evident in Table 4.54 in the majority of radiographs there was no tilt evident hence the thoracic intervertebral spaces and intervertebral foramina were open. This is an excellent result as it demonstrates good radiographic technique and practice were applied. The  $p$ -value for statement 21.5 is 0.0026, indicating there is a significant difference between the percentages of the reviewers. A possible reason for the difference could be their respective subjective interpretation of each image.

Statement 21.6 stated the hilum was in the center of the radiographic image. All reviewers stated that it was in the center of the radiographic image on 99% of the lateral projections of the chest radiographic examinations. The  $p$ -value for statement 21.6 is 1.0000; hence there is good correlation between the percentages of the reviewers. The results indicate that in the majority examinations the hilum was in the center of the radiographic image; this is essential.

#### **4.4.2 Conclusion**

The respective data of the questions and statements in the three research tools were analysed and discussed in this chapter. The research tools were the radiographer survey, the patient checklist, the radiographic image checklist of the lumbar spine radiographic examination and the radiographic image checklist of the chest radiographic examination.

In chapter 5, limitations and recommendations of the study are discussed. Final remarks and observations are provided with a conclusion regarding the aim and objectives as set out at the beginning of the study. Specific recommendations to improve radiation protection when using DR systems are presented.

## CHAPTER 5

### CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

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#### 5.1 INTRODUCTION

In chapter 4 the results and analysis of each research tool were presented. In chapter 5 conclusions are drawn from the results, interpretation, and discussions of the quantitative data in chapter 4. Chapter 5 presents an overview of the study. In addition final conclusions, limitations, and recommendations, are presented. Two recommendations are presented: those related to the limitations during the research process; and those related to the improvement of radiographic practice.

#### 5.2 OVERVIEW OF THE STUDY

The overall goal of this research study was to determine radiation protection practice in digital radiography during digital chest and lumbar spine radiographic examinations in two Eastern Cape government hospitals. The aim of the research study was to investigate radiation protection practices in digital radiography during digital chest and lumbar spine radiographic examinations and to address possible gaps in the radiographers' awareness of radiation protection using digital x-ray equipment.

In order to attain the overall goal of the study (see section 1.5) the following research questions were formulated.

1. Are diagnostic radiographers aware of effective radiation protection measures applied in digital radiography during digital chest and lumbar spine radiographic examinations?
2. Are effective radiation protection measures applied to patients referred for routine general digital radiographic of the chest and lumbar spine?

A cross-sectional descriptive research design with quantitative elements was used. It was the best design for this particular research study with regards to the type of data, the participants, the aim, and objectives of the study, to deliver trustworthy results. Information from the different research tools were used to address three objectives of the research study.

1. To establish awareness of diagnostic radiographers regarding effective radiation protection (includes all radiation protection variables: i.e. collimation; time; distance; shielding; the use of exposure index (EI) values; focus-film distance (FFD) and exposure factors) through a survey.
2. To determine whether effective radiation protection is applied by diagnostic radiographers through a checklist completed by patients.
3. To determine whether effective radiation protection is applied by diagnostic radiographers through a radiographic image checklist completed by three reviewers to analyse the digital radiographic images of the chest and lumbar spine with regards to the technical aspects of radiation protection.

In section 5.3 the conclusions for the different research tools are discussed.

## **5.3 CONCLUSIONS FROM THE RESEARCH TOOLS**

The conclusions from chapters 4 are combined, linked and discussed in sections 5.3.1 to 5.3.3. The conclusions are drawn from the three research tools which addressed objectives 1 to 3.

### **5.3.1 Conclusions related to objective 1**

Objective 1: To establish awareness of diagnostic radiographers regarding effective radiation protection (includes all radiation protection variables: i.e. collimation; time; distance; shielding; the use of exposure index (EI) values; focus-film distance (FFD) and exposure factors) through a survey.

Participants were aware that anatomical lead markers are required on every image by law. However they did not use lead anatomical markers on lateral images since it is department's policy to omit the use of anatomical lead markers on the lateral views of the chest and skull radiographic examinations as they deem it unnecessary. The participants also provided unacceptable reasons for not using anatomical lead markers. This finding shows that lead anatomical markers are not routinely used and should be monitored.

Participants understood what the radiation protection principle ALARA is and they comprehended the importance thereof. They were aware that mAs is the exposure factor to adjust to keep radiation exposure as low as possible. Participants however had inadequate knowledge regarding exposure factors in DR. This shows that exposure factors in DR require assistance.

Participants were aware what EI stands for and they recognised the purpose of EI in DR. However they lacked knowledge of the implications of EI and were unaware of how the EI value system works, and the function thereof, as well as the factors which may affect the EI value. This finding shows that EI values were not monitored.

The participants understood that for radiation protection purposes ideally only a patient should be in an x-ray room. They provided correct reasons to allow someone to assist with patients. This shows the participants were knowledgeable on radiation protection measures in theory, but the correct application of radiation protection measures were not always applied as seen from the poor reasoning provided for not protecting a patient with lead shielding.

Participants had poor knowledge regarding wide exposure latitude and image creation in DR. They were knowledgeable regarding the cause of image mottle in DR, but they misunderstood the use of post-processing on a digital image. The participants knew how scattered radiation affects the image quality in DR and why collimation is critical in DR.

However, the unacceptable usage of collimation or other forms of beam limiting devices were noticeable. This reveals that post-processing was being relied on instead of performing good radiographic techniques where only minor post-processing would be necessary.

Unacceptable reasons were provided by the participants for not measuring the anatomical part to be examined. The reasons for this may be due to the work environment and culture. This shows that anatomical parts were not being measured and must therefore be examined

### **5.3.2 Conclusions related to objective 2**

Objective 2: To determine whether effective radiation protection is applied by diagnostic radiographers through a checklist completed by patients.

Participating patients indicated that identification was not thoroughly performed. This finding is an indication of poor communication between radiographers and patients. It was evident however that patients were informed to undress and remove foreign objects. This shows that an effort was made to prevent any artefacts from obscuring anatomy of interest. Good patient care was also evident from the responses which revealed that patients received support and help if required. LMP was not thoroughly performed thus revealing unethical and unprofessional behaviour.

### **5.3.3 Conclusions related to objective 3**

Objective 3: To determine whether effective radiation protection is applied by diagnostic radiographers through a radiographic image checklist completed by three reviewers to analyse the digital radiographic images of the chest and lumbar spine with regards to the technical aspects of radiation protection.

The L5S1(lumbar 5/sacrum 1) lateral view is not routinely performed; this is of concern and shows that it should be included in the department protocol to ensure it is performed routinely for an optimal diagnosis to be made. The responses showed insufficient usage of lead anatomical markers; correct ones are used which reveals that in the majority of cases post-processing markers are used. The results show that both inadequate and insufficient pre-collimation are generally applied. It is thus evident that pre-collimation efforts were poor due to the availability of post-processing collimation. Over usage and application of post-processing collimation was thus apparent. Inclusion of the entire anatomical area of interest was not always ensured; this shows that poor radiographic techniques were applied. Accurate selection and application of exposure factors were noted in the results. However, incorrect selection of exposure factors was also evident. This underscores that that exposure factors require monitoring. From the results it appears that the participants (radiographers) selected their own exposure factors from what they have learnt over the years. They are thus not utilising the exposure charts available as they are out dated. This shows that the exposure charts were not used even though radiographers are trained to do. The hospitals in this study also have new digital x-ray machines which use AEC hence the radiographers do not use the exposure charts. The correct selection of anatomical processing algorithm was visible which means radiographers are vigilant in selecting it. The images had optimal contrast indicating the correct usage and selection of kVp. The images showed optimal density indicating the correct usage and selection of mAs. In other words good radiographic techniques were applied.

Artefacts were present on the images which indicate that either the machinery may be faulty or the participants were negligent in ensuring that artefacts were removed. Motion or blurring of the image was not seen on the images. There was no visible rotation of the patients. Generally all anatomy of interest was clearly demonstrated revealing the accurate application of radiographic techniques and positioning.

Generally there was accurate application of radiographic techniques and positioning, but incorrect applications were also found.

Accurate positioning of the anatomical part was performed, but also evident was inadequate patient positioning, the latter points to the need for patient positioning to be assessed regularly via QA.

Accurate application of centering of anatomy of interest on the IP was apparent but not for all the images. The use of the incorrect centering point shows the application of inadequate radiographic techniques. All of the above underscore the identification of three key issues: professionalism, poor communication, and poor radiation protection practice.

## **5.4 RECOMMENDATIONS**

Recommendations related to the three objectives are presented and discussed. These recommendations were derived from the conclusion formulated from the results of the study.

### **5.4.1 Recommendations related to objective 1**

- Radiographers do not use lead anatomical markers on lateral images. It is recommended that the department protocol should be revised to include the use anatomical lead markers on all images including lateral images since this is required by law.
- Radiographers provided unacceptable reasons for not using anatomical lead markers. It is recommended that personalised lead anatomical markers should be ordered for each radiographer on the staff, and to perform regular audits to ensure anatomical markers are being used.

- Radiographers are aware of the ALARA principle. It is recommended to continuously promote this principle and its application which may be monitored by performing reject analysis and implementing and ensuring that a quality assurance programme is in place.
- Radiographers do not effectively communicate with the patients. It is recommended that radiographers speak and communicate more with patients to confirm and ensure correct identity of each patient. Poor communication can be addressed through staff development sessions, whereby staff can be encouraged and advised on how to improve communication with the patients. This can be monitored by asking patients to voluntarily complete questionnaires. Incentives can be provided if communication is improved. Incentives may refer to implementing a radiographer of the month.
- Radiographers have theoretical knowledge on radiation protection measures, but the study found evidence of inadequate application of radiation protection measures. It is recommended that training should be provided as well as information leaflets on the proper application of radiation protection measures. Radiographers should be advised that from time to time spot checks may be performed by management to ensure and monitor whether effective radiation protection measures are applied. An incentive such as radiographer of the month could be implemented to encourage radiographers to apply effective radiation protection measures at all times.
- Radiographers are aware what EI stands for and they understand its purpose in DR. The study did however find there was a lack of knowledge of its implications. There was unawareness of how the EI value system works and the function thereof as well as the factors which may affect its value. It is recommended that information leaflets and training sessions be provided to explain or remind radiographers of the DR system. In particular the function and meaning of the EI values as well as the factors which may affect the EI value.

Furthermore since EI values are not monitored it is recommended that this be done and regularly revised.

- The study did find evidence of accurate selection and application of exposure factors, but there was also evidence of incorrect selection of exposure factors. It is recommended that visible updated exposure charts are placed in each X-ray room. It is also recommended that radiographers should measure the anatomical part to be examined. Each exposure chart should include: the radiographic examination; the different views for every examination; the different sizes / thickness of the patient i.e. new born, small, medium and large; kVp; milliseconds; mAs, and the SID. The study did find that the radiographers had inadequate knowledge regarding exposure factors in DR and the 15% kVp rule thus it is recommended that a series of practical in-service training sessions should be provided.
- The study found that the radiographers had poor knowledge regarding wide exposure latitude and image creation in DR. It is thus recommended to provide training regarding DR exposure factors and wide exposure latitude.
- Radiographers in this study misunderstood the use of post-processing on a digital image. It is thus recommended to provide training on DR and post-processing techniques and the function and usage thereof as well as the pros and cons. If the department addresses and monitors the abovementioned factors, then post-processing may not be an issue.
- Radiographers in this study did understand why collimation is critical in DR. The findings show inadequate and insufficient usage of collimation or other forms of beam limiting devices. It is thus recommended to encourage radiographers to apply tighter pre-collimation by providing examples of the effects of inadequate pre-collimation and to encourage the usage of lead strips by implementing some reward system for a period of time until it becomes standard practice.

- The radiographers in this study were unaware of the reasons for not measuring the anatomical part to be examined. The study found the relevant part of anatomy was not measured efficiently. It is recommended that this be included in the department protocol in order to encourage radiographers to measure the anatomical part to be examined and to explain the importance thereof. Reasons provided for not using exposure charts may be due the work environment and culture, thus it is recommended to ensure there are visible updated exposure charts up in each X-ray room. Every radiographer should have access to such charts.
- Radiographers in the study did know that they have to protect a patient with lead shielding. Reasons provided for not protecting patients with lead shielding may be due to the work environment thus it is recommended that additional lead rubber aprons should be purchased, and that all mandatory QC tests are performed.

#### **5.4.2 Recommendations related to objective 2**

- The study found that patient identification was not thoroughly performed. It is recommended that every radiographer implements patient-centered communication for every patient. This will entail ensuring patient identification by cross checking with each patient to ensure any three specific patient details are correct.
- LMP was not thoroughly performed thus revealing unethical and unprofessional behaviour. It is recommended that an informed consent form should be routinely used, and that each female patient of reproductive age should be requested to sign the form. The form should include possible pregnancy, if patients are uncertain about their LMP, to ensure they are not pregnant.

Posters that cover the dangers/risks involved when X-ray examinations are performed should be prominently displayed in the reception / waiting area. Staff training should be provided.

#### **5.4.3 Recommendations related to objective 3**

- The study found that the L5S1 projection was not routinely performed. In a lateral lumbar spine examination the X-ray beam deviates on a lateral projection of the lumbar spine and produces a distorted image of L5S1. It is recommended that the L5S1 view should be routinely performed in all lumbar spine radiographic examinations.
- Poor communication and poor radiation protection practice were key issues identified under professionalism. It is recommended that to achieve improved communication skills, and to prevent additional factors (e.g. collimation) from influencing the EI value negatively that training should be provided on the correct radiation protection practices when using DR.
- Artefacts were present on the images thus it is recommended that each patient should be requested to remove all artefacts in the relevant regions of interest and to undress and use a provided gown. It is also recommended that all necessary QC tests are performed when due to prevent any machinery artefacts from occurring. A good QA programme should be in place.
- Although accurate application of radiographic techniques and positioning was evident. The study did however find incorrect application of radiographic techniques and positioning. It is recommended that an information leaflet/training session should be provided regarding accurate and latest radiographic techniques and positioning. There should be a protocol that allows a QC staff member to monitor the images by randomly checking the images on a weekly basis.

- Accurate, as well as inaccurate application of centering of anatomy of interest on the IP was evident in the study. It is recommended that an information session is provided regarding the correct centering points of the anatomy of interest for each examination, and the accurate and latest radiographic techniques and practice. It is also suggested that the QA team should monitor this issue by regularly performing reject analysis.

## **5.5 RESEARCH DESIGN**

A cross-sectional descriptive research design with quantitative elements was used in this research study as discussed in section 1.9. The quantitative data were generated through closed-ended questions included in a radiographer survey, patient checklist, and radiographic image checklist. The cross-sectional descriptive research approach was the best design for this particular research study with regards to the type of data, the participants, the aim and objectives of the study, to deliver trustworthy results.

## **5.6 VALIDITY, RELIABILITY AND CREDIBILITY**

Validity refers to how well a scientific test or piece of research actually measures what it sets out to do, or how well it reflects the reality it claims to represent (The Association for Qualitative Research, 2018: online). Reliability refers to the repeatability of a particular set of research results; that is, how precisely they would be duplicated in a second identical piece of research (The Association for Qualitative Research, 2018: online).

None of the radiographers at the study sites were aware of or had any knowledge on the content of the checklist distributed to the patients, as this would have affected the validity and reliability of the research study, since it would not have been a valid assessment of what radiographers usually did. The researcher ensured that the content of the checklists was not accessible by personally keeping the checklists to hand to each patient. The researcher collected the completed checklist from each patient.

The radiographer survey questionnaire was distributed after all 140 patients' checklists were completed. A pilot study was conducted prior to the real study. In this way the validity and reliability of the checklist collection were ensured.

Credibility involves establishing that the results of quantitative research are credible or believable from the perspective of a participant in a research study (Social Research Methods, 2006: online). It is thus evident from the results that each research tool that was used to meet each objective of the research study did accurately measure what it was supposed to measure; reliability and credibility were achieved. The contributions and analysis by the biostatistician also ensured credibility. A pilot study was conducted prior to the actual study which also ensured credibility. It was also done to determine whether the information gathered from the research tools would answer the research question. All unclear questions, as well as grammar mistakes, were corrected. In this way the validity, reliability and credibility of the research tools was ensured.

Three research tools (a radiographer survey; a patient checklist and a radiographic image checklist) were used to collect the data in this study. A radiographer survey (Appendix G) was used to investigate the knowledge of the participating radiographers regarding radiation protection practice in digital radiography during chest and lumbar spine radiographic examinations. A patient checklist (Appendices H1-3) was used to determine from the patients whether the radiographers applied radiation protection measures during chest and lumbar spine digital radiographic examinations in the two selected Eastern Cape government hospitals. A radiographic image checklist (Appendix I) was used to determine whether the participating radiographers applied effective radiation protection with regard to the technical criteria of radiation protection practice during digital chest and lumbar spine radiographic examinations. It is thus evident that each research tool measured what it was supposed to as stated above. The patient checklist was translated into Xhosa by a Xhosa student and each question was exactly the same as the questions from the English patient checklist. The majority of the radiographer participants were Xhosa speaking.

The researcher, as well as the radiographer performing the patient's examination, was available for clarification and questions while each patient completed the checklist to limit misunderstanding. It is thus apparent that the triangulation of the results from the research tools was achieved.

## **5.7 SIGNIFICANCE OF THE STUDY**

This research study reported on the quality of radiation protection provided to and received by patients, therefore the service delivered to the patient may be improved. This research study enabled the researcher to determine radiographers' practices and the reasons for such practices were determined. The objectives aimed to address radiation protection practice and thereby minimise patients' radiation dose during general digital radiographic examinations, specifically the chest and lumbar spine. The significance of this research study is that it should allow the two radiology departments that participated in the study, and other radiology departments, to enhance the quality of radiation protection applied to patients by the radiographers.

## **5.8 LIMITATIONS OF THE STUDY**

The limitations and recommendations may be used to provide useful information for similar future studies.

Limitations in this study include:

- a) there was a limited number of participants available to take part in the radiographers survey, thus it is may be argued that the study may have been more accurate if a larger number of radiographer participants were available;
- b) the radiographer participants were not very willing to answer the radiographer survey;
- c) hospital 2 denied permission to hand out the patient checklists to patients, therefore the sample size at hospital 1 had to be increased.

## **5.9 RECOMMENDATIONS TO THE LIMITATIONS OF THE STUDY**

The recommendations below are related to the limitations and are presented in the same above order.

- a) Increase the number of hospitals to increase the number of radiographer participants.
- b) Make it more worthwhile to take part in the research study and to complete the radiographer survey.
- c) Troubleshooting possible issues related to data collection will require a researcher to consult with possible sites to see if the research methods in their entirety can be employed.

## **5.10 FINAL REMARKS**

Based on the literature review, the results from the questionnaires and checklists, the researcher was able to determine how effectively radiation protection was applied during chest and lumbar spine radiographic imaging procedures.

The study's value enabled the researcher to determine whether radiographers do adequately comply with the radiation protection laws required to protect patients from ionising radiation and its potential negative effects.

The results of this study can now be communicated to the participating radiographers in the form of an information session to attend to the key areas found lacking in the questionnaire and checklists. This may stimulate radiographers' awareness towards effective radiation protection and hence improve the effectiveness of radiation protection to patients. It is thus evident that all of the above mentioned objectives for this research study were achieved (see 1.7). This confirms that the research question was comprehensively covered and answered to make a difference.

This research study allowed the researcher to make a difference by improving the quality of radiation protection received by patients, because as stated in the literature (see 2.4.3) there is no radiation that is considered to be low enough.

This research study has been a wonderful learning experience and has given me great insight into digital radiography and how radiographers comprehend this new era in radiography.

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## APPENDIX A1

2/2/16  
Refer to well known  
for facilitation  
Thanks  
X-Ray  
Leona

**PERMISSION TO CONDUCT A RESEARCH PROJECT FROM THE CEO OF THE DORA  
NGINZA HOSPITAL**

P.O. Box 29029  
Sunridge Park  
Port Elizabeth  
6001

01 February 2016

Dora Nginza Hospital  
Spondo Street  
Zwide Ext 3  
Ibhayi  
Port Elizabeth  
Eastern Cape  
South Africa  
6205

To Dr N. Qangule,

**STUDY TITLE:** Radiation protection practice in digital radiography in Eastern Cape government hospitals.

Radiation protection plays a vital role in radiography and is of utmost importance in ensuring the safety of all patients with regard to ionising radiation. The basis of radiation protection revolves around ensuring that exposures to ionising radiation should be kept As Low As Reasonably Achievable (ALARA).

This letter serves to request permission to conduct a research project to fulfil the requirements for M.Tech Radiography (Diagnostic) at the Radiology facilities located at Dora Nginza Hospital.

The aim of the research study is to investigate radiation protection practices in digital radiography, thereby minimising the patients' radiation dose during general digital radiographic examinations in specific the chest and lumbar spine and to address possible gaps in the radiographers' awareness of radiation protection using digital x-ray equipment.

The research study's objectives are to establish the awareness of diagnostic radiographers regarding effective radiation protection through a survey; to determine whether effective radiation protection is applied by diagnostic radiographers through a checklist compiled from literature completed by patients; to determine whether effective radiation protection is applied by diagnostic radiographers through a radiographic image checklist completed by three reviewers to analyse the digital radiographic images of the chest and lumbar spine with regards to the technical aspects of radiation protection and to compile and provide recommendations regarding effective radiation protection practice in digital radiography during digital chest and lumbar spine radiographic examinations.

Access to the picture archiving and communication system (PACS) will be required to obtain the exposure index (EI) values and to evaluate the technical aspects (number and examinations). No patient data or personal information will be captured or disclosed. Arrangements for the days and times to conduct the data collection will be made with the radiology manager, Mrs Witbooi, thus to prevent any disturbance of workflow within the department.

Prior to the completion of the survey and checklist participants will be informed about the study by means of an information document and consent will be obtained from the participants to participate in the study. Once participants have been informed and consent is given, the radiographer participants will receive a survey and the patient participants will receive a checklist. The answers from the completed survey and checklist will then be analysed to determine the results of the study.

You may contact Karin at 083 641 5328 any time if you have questions about the research study or you may contact the Ethics Committee of the Faculty of Health Sciences, UFS at telephone number (051) 4052812 if you have questions about your rights as a research participant.

I \_\_\_\_\_, hereby grant permission to Karin Fourie to conduct the  
research project: at the named facility.

\_\_\_\_\_  
Signature of CEO

\_\_\_\_\_  
Date

\_\_\_\_\_  
Signature of Witness  
(Where applicable)

\_\_\_\_\_  
Date

## APPENDIX A2

**PERMISSION TO CONDUCT A RESEARCH PROJECT FROM THE HEAD OF THE  
RADIOLOGY DEPARTMENT DORA NGINZA HOSPITAL**

P.O. Box 29029  
Sunridge Park  
Port Elizabeth  
6001

01 February 2016

Dora Nginza Hospital  
Spondo Street  
Zwide Ext 3  
Ibhayi  
Port Elizabeth  
Eastern Cape  
South Africa  
6205

To Mrs Witbooi,

**STUDY TITLE:** Radiation protection practice in digital radiography in Eastern Cape government hospitals.

Radiation protection plays a vital role in radiography and is of utmost importance in ensuring the safety of all patients with regard to ionising radiation. The basis of radiation protection revolves around ensuring that exposures to ionising radiation should be kept As Low As Reasonably Achievable (ALARA).

This letter serves to request permission to conduct a research project to fulfil the requirements for M.Tech Radiography (Diagnostic) at the Radiology facilities located at Dora Nginza Hospital.

The aim of the research study is to investigate radiation protection practices in digital radiography, thereby minimising the patients' radiation dose during general digital radiographic examinations in specific the chest and lumbar spine and to address possible gaps in the radiographers' awareness of radiation protection using digital x-ray equipment.

The research study's objectives are to establish the awareness of diagnostic radiographers regarding effective radiation protection through a survey; to determine whether effective radiation protection is applied by diagnostic radiographers through a checklist compiled from literature completed by patients; to determine whether effective radiation protection is applied by diagnostic radiographers through a radiographic image checklist completed by three reviewers to analyse the digital radiographic images of the chest and lumbar spine with regards to the technical aspects of radiation protection and to compile and provide recommendations regarding effective radiation protection practice in digital radiography during digital chest and lumbar spine radiographic examinations.

Access to the picture archiving and communication system (PACS) will be required to obtain the exposure index (EI) values and to evaluate the technical aspects (number and examinations). No patient data or personal information will be captured or disclosed. Arrangements for data collection times will be made prior to each visit with yourself, thus to prevent any disturbance of workflow within the department.

Prior to the completion of the survey and checklist participants will be informed about the study by means of an information document and consent will be obtained from the participants to participate in the study. Once participants have been informed and consent is given, the radiographer participants will receive a survey and the patient participants will receive a checklist. The answers from the completed survey and checklist will then be analysed to determine the results of the study.

You may contact Karin at 083 641 5328 any time if you have questions about the research study or you may contact the Ethics Committee of the Faculty of Health Sciences, UFS at telephone number (051) 4052812 if you have questions about your rights as a research participant.

I \_\_\_\_\_, hereby grant permission to Karin Fourie to conduct the  
research project: at the named facility.

*Qosi*

\_\_\_\_\_  
Signature of Mrs Witbooi

*4/2/2016*

\_\_\_\_\_  
Date

\_\_\_\_\_  
Signature of Witness  
(Where applicable)

\_\_\_\_\_  
Date

## APPENDIX A3

### PERMISSION TO CONDUCT A RESEARCH PROJECT FROM THE LIVINGSTON HOSPITAL MANAGER

P.O. Box 29029  
Sunridge Park  
Port Elizabeth  
6001

14 October 2015

Livingston Hospital  
Stanford Road  
Korsten  
Port Elizabeth  
Eastern Cape  
South Africa  
6020

To the Livingston hospital manager

**STUDY TITLE:** Radiation protection practice in digital radiography in Eastern Cape government hospitals.

Radiation protection plays a vital role in radiography and is of utmost importance in ensuring the safety of all patients with regard to ionising radiation. The basis of radiation protection revolves around ensuring that exposures to ionising radiation should be kept As Low As Reasonably Achievable (ALARA).

This letter serves to request permission to conduct a research project to fulfil the requirements for M.Tech Radiography (Diagnostic) at the Radiology facilities located at Livingston Hospital.

The aim of the research study is to investigate radiation protection practices in digital radiography, thereby minimising the patients' radiation dose during general digital radiographic examinations, specifically chest and lumbar spine and to address possible gaps in the radiographers' awareness of radiation protection using digital x-ray equipment.

The research study's objectives are to establish the awareness of diagnostic radiographers regarding effective radiation protection through a survey; to determine whether effective radiation protection is applied by diagnostic radiographers through a checklist compiled from literature completed by patients; to determine whether effective radiation protection is applied by diagnostic radiographers through a radiographic image checklist completed by three reviewers to analyse the digital radiographic images of the chest and lumbar spine with regards to the technical aspects of radiation protection and to compile and provide recommendations regarding effective radiation protection practice in digital radiography during digital chest and lumbar spine radiographic examinations.

Access to the picture archiving and communication system (PACS) will be required to obtain the exposure index (EI) values and to evaluate the technical aspects (number and examinations). No patient data or personal information will be captured or disclosed.

Prior to the completion of the survey and checklist, participants will be informed about the study by means of an information document and consent will be obtained from the participants to participate in the study. Once participants have been informed and consent is given, the radiographer participants will receive a survey and the patient participants will receive a checklist. The answers from the completed survey and checklist will then be analysed to determine the results of the study.

If you agree to give permission, a signed copy of this document as well as the information document, which is a written summary of the research will be provided to you.

You may contact Karin at 083 641 5328 any time if you have questions about the research study or you may contact the Ethics Committee of the Faculty of Health Sciences, UFS at telephone number (051) 4052812 if you have questions about your rights as a research participant.

I \_\_\_\_\_, hereby grant permission to Karin Fourie to conduct the research project: at the named facility.

\_\_\_\_\_  
Signature of Hospital manager

\_\_\_\_\_  
Date

\_\_\_\_\_  
Signature of Witness  
(Where applicable)

\_\_\_\_\_  
Date



Eastern Cape Department of Health

Enquiries: Zonwabele Merile  
Date: 18 December 2015  
e-mail address: zonwabele.merile@echealth.gov.za

Tel/No: 040 608 0830  
Fax No: 043 642 1409

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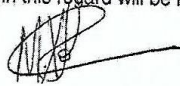
Dear Ms. K. Fourie

**Re: Radiation Protection Practice in Digital Radiography in Eastern Cape Government Hospitals  
(EC\_2015RP59\_960)**

The Department of Health would like to inform you that your application for conducting a research on the abovementioned topic has been approved based on the following conditions:

1. During your study, you will follow the submitted protocol with ethical approval and can only deviate from it after having a written approval from the Department of Health in writing.
2. You are advised to ensure, observe and respect the rights and culture of your research participants and maintain confidentiality of their identities and shall remove or not collect any information which can be used to link the participants.
3. The Department of Health expects you to provide a progress on your study every 3 months (from date you received this letter) in writing.
4. At the end of your study, you will be expected to send a full written report with your findings and implementable recommendations to the Epidemiological Research & Surveillance Management. You may be invited to the department to come and present your research findings with your implementable recommendations.
5. Your results on the Eastern Cape will not be presented anywhere unless you have shared them with the Department of Health as indicated above.

Your compliance in this regard will be highly appreciated.



SECRETARIAT: EASTERN CAPE HEALTH RESEARCH COMMITTEE



*Ikanva eliqaqambileyo!*

**APPENDIX B**  
**INFORMATION DOCUMENT FOR RADIOGRAPHERS**

**STUDY TITLE:** Radiation protection practice in digital radiography in Eastern Cape government hospitals.

To whom it may concern:

I, Karin Fourie, am doing research on radiation protection in digital radiography applied to patients during digital chest and lumbar spine radiographic examinations. Qualified radiographers are hereby invited to participate in this research study.

Radiation protection plays a vital role in radiography and is of utmost importance in ensuring the safety of all patients with regard to ionising radiation. Radiography uses the ALARA principle, which makes it evident that it is the radiographer's duty and responsibility to protect the patient from unnecessary radiation by keeping exposure to radiation as low as reasonable achievable in all circumstances. This raised the question as to whether radiographers are effectively applying radiation protection measures as stipulated by the Directorate Radiation Control when imaging a patient.

The aim of the research study is to investigate radiation protection practices in digital radiography, thereby minimising patients' radiation dose during general digital radiographic examinations, specifically the chest and lumbar spine and to address possible gaps in radiographers' awareness of radiation protection using digital x-ray equipment.

A quantitative study will be done; this involves the answering and participation in a survey. The participant is expected to be involved in the study for approximately 30 minutes just for answering the survey.

The results from the study will be presented at the annual M.Tech presentation day of the Central University of Technology, Free State (CUT) in Bloemfontein in November 2016 as well as at a Continuous Professional Development (CPD) seminar at the Central University of Technology (CUT). The results may also be published as an article in a professional, related journal. No personal information will be disclosed in such an article.



All information will be kept confidential. For further information/reporting of study-related adverse events, contact: **Ethics Committee of the Faculty of Health Sciences, University of the Free State** – for reporting of complaints/problems: Telephone number (051) 4052812.

You may contact Karin at 083 641 5328 any time if you have questions about the research study.

## APPENDIX C

### CONSENT TO PARTICIPATE IN RESEARCH FOR RADIOGRAPHERS

**STUDY TITLE:** Radiation protection practice in digital radiography in Eastern Cape government hospitals.

You have been asked to participate in and informed about the research study by Karin Fourie.

Participation is voluntary and refusal to participate will involve no penalty or loss of benefits to which the participant is otherwise entitled;

The participant may discontinue participation at any time without penalty or loss of benefits to which the participant is otherwise entitled;

No remuneration will be given for participation nor will it cost the participant anything to participate in the study;

Efforts will be made to keep personal information confidential. Absolute confidentiality cannot be guaranteed;

Personal information may be disclosed if required by law;

Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the Ethics Committee for Medical Research and the Medicines Control Council (where appropriate).

You may contact Karin at 083 641 5328 any time if you have questions about the research or if you are injured as a result of the research.

The research study, including the above information, has been described to me verbally. I understand what my involvement in the study means and I voluntarily agree to participate.

---

Signature of Researcher

---

Date

---

Signature of Radiographer

---

Date

---

Signature of Witness

---

Date

## APPENDIX D

### **CONSENT FROM THE RADIOGRAPHER TO USE THE INFORMATION GATHERED FROM THE PATIENT CHECKLIST AND RADIOGRAPHIC IMAGE CHECKLIST**

**STUDY TITLE:** Radiation protection practice in digital radiography in Eastern Cape government hospitals.

You have been asked to give consent to use the information gathered from the patient checklist and radiographic image checklist and informed by Karin Fourie.

Efforts will be made to keep personal information confidential. Absolute confidentiality cannot be guaranteed;

Personal information may be disclosed if required by law;

Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the Ethics Committee for Medical Research and the Medicines Control Council (where appropriate).

You may contact Karin at 083 641 5328 any time if you have questions about the research or if you are injured as a result of the research.

The research study, including the above information, has been described to me verbally. I understand what is required of me and I voluntarily agree to give consent.

\_\_\_\_\_  
Signature of Radiographer

\_\_\_\_\_  
Date

**APPENDIX E1**  
**INFORMATION DOCUMENT FOR PATIENTS**

**STUDY TITLE:** Radiation protection practice in digital radiography in Eastern Cape government hospitals.

To whom it may concern:

I, Karin Fourie, am doing research on how effectively radiation protection is applied to patients during digital chest and lumbar spine radiographic examinations.

Research is just the process to learn the answer to a question. In this study, we want to investigate radiation protection practices in digital radiography, thereby minimising the patients' radiation dose during general digital radiographic examinations, specifically the chest and lumbar spine and to address possible gaps in the radiographers' awareness of radiation protection using digital x-ray equipment by compiling and providing recommendations to improve the radiographers' awareness on radiation protection practice in digital radiography during digital chest and lumbar spine radiographic examinations.

All information will be kept confidential. We are asking/inviting you to participate in a research study.

A quantitative study will be done; this involves the answering and participation in a checklist. The participant is expected to be involved in the study for approximately 15 minutes just for answering the checklist.

For further information/reporting of study-related adverse events, contact: **Ethics Committee of the Faculty of Health Sciences, University of the Free State** – for reporting of complaints/problems: Telephone number (051) 4052812.

You may contact Karin at 083 641 5328 any time if you have questions about the research study.

## APPENDIX E2

### INLIGTINGSDOKUMENT VIR PASIËNTE

**STUDIE TITEL: Bestralingsbeskerming in digitale radiografie in die Oos-Kaapse regerings-hospitale.**

Aan wie dit mag aangaan:

Ek, Karin Fourie, doen navorsing oor hoe effektief die bestralingsbeskerming is wat aan pasiënte gedurende digitale borskas en lumbale werwels radiologiese prosedures toegedien word.

Navorsing is net die proses om die antwoord op 'n vraag te leer. In hierdie studie wil ons die bestralingsbeskerming in digitale radiologiese prosedures ondersoek, en sodoende die bestralings- dosis tydens 'n algemene digitale radiologiese prosedure, spesifiek die borskas en lumbale werwels minimaliseer en moontlike leemtes in radiografiste se bewustheid oor bestralingsbeskerming van digitale x- straaltoerusting te bespreek deur die opstel en beskikbaarstelling van aanbevelings om die radiografiste se bewustheid oor bestralingsbeskerming in digitale radiografie te verbeter.

Alle inligting sal vertroulik hanteer word. Ons vra / nooi u om deel te neem aan 'n navorsingstudie.

'n Kwantitatiewe studie sal gedoen word; dit behels die beantwoording van en deelname in 'n kontrolelyns. Die deelnemer word verwag om vir ongeveer 15 minute in die studie betrokke te wees, net vir die beantwoording van die kontrolelyns.

Vir verdere inligting / rapportering van studie-verwante nuwe-effekte, kontak: **Etiëkkomitee van die Fakulteit van Gesondheidswetenskappe, Universiteit van die Vrystaat** - vir verslagdoening van klagtes / probleme: Telefoonnommer (051) 4052812.

U kan Karin op 083 641 5328 enige tyd kontak indien u vrae het in verband met hierdie navorsingstudie.

## APPENDIX E3

### INKCUKACHAEZENZELWE IZIGULANE

**UPHANDO OLUNZULU:** Ukhuseleko logqatso igesi xana kusenziwa iradiography yobuchwepheshe kwizibhedlele zikarhulumnte eMpuma Koloni.

Kulowo imchaphazelayo:

Mna Karin Fourie ndenza uphando ngendlela eyiyo yokhuselo logqatso ngegese elwenziwa ngayo kwizigulane xa kusenziwa iradiography.

Uphando yindlela yokufumana impendulo yombuzo. Koluphando sifuna ukujonga indlela eyiyo yokunika izigulana ukhuseleko logqatso gesi, ukuze kunciphe umlinganiselo wogqatso gesi ngexesha lohlobo lwe igesi ngokukhulisa uqeqesho ukuze kuphuhle ulwazi lwee radiographers kukhuseleko logqatso igesi kwi iradiography yobuchwepheshe.

Siyakumema ukuba uthabathe inxaxheba koluphando. Zonke iincukhaca zomntu kuzakuqinisekiswa zikhuselekile.

Uphando olunzulu luzokwenziwa; iquka ukuphendulwa nokuthatha inxaxheba kwichecklist. Umntu othatha inxaxheba kulindeleke ukuba abeyinxalenye yoluphando imizuzu elishumi elinesihlanu ukuphendula isiqinisekiso kuphela.

Ukuba unencukacha okanye ufuna ukuchaza ingxaki ethe yabakho ngenxa yoluphando, ungatsalela i**Ethics Committee of the Faculty of Health Sciences, University of the Free State**-ukuba ufuna ukuxela ingxaki/ isikhalazo ungafownela (051) 4052812.

Ungatsalela uKarin ku 083 641 5328 nangaliphi ixesha ukuba unemibuzo mayela noluphando.

## APPENDIX F1

### CONSENT TO PARTICIPATE IN RESEARCH FOR PATIENTS

**STUDY TITLE:** Radiation protection practice in digital radiography in Eastern Cape government hospitals.

You have been asked to participate in and informed about the research study by Karin Fourie.

Participation is voluntary and refusal to participate will involve no penalty or loss of benefits to which the participant is otherwise entitled;

The participant may discontinue participation at any time without penalty or loss of benefits to which the participant is otherwise entitled;

No remuneration will be given for participation nor will it cost the participant anything to participate in the study;

Efforts will be made to keep personal information confidential. Absolute confidentiality cannot be guaranteed;

Personal information may be disclosed if required by law;

Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the Ethics Committee for Medical Research and the Medicines Control Council (where appropriate).

You may contact Karin at 083 641 5328 any time if you have questions about the research or if you are injured as a result of the research.

The research study, including the above information, has been described to me verbally. I understand what my involvement in the study means and I voluntarily agree to participate.

---

Signature of Patient

---

Date

## APPENDIX F2

### TOESTEMMING OM DEEL TE NEEM IN NAVORSING VIR PASIËNTE

**STUDIE TITEL: Bestralingsbeskerming in digitale radiografie in die Oos-Kaapse regerings-hospitale.**

Jy is gevra om deel te neem in en deur Karin Fourie ingelig oor die navorsingstudie.

Deelname is vrywillig, en die weiering om deel te neem sal geen boete of verlies van voordele waarop die deelnemer andersins geregtig is, behels nie;

Die deelnemer mag teeniger tyd en sonder boete of verlies van voordele, deelname staak;

Deelnemers in die navorsing studie sal geen vergoeding ontvang nie. Daar sal ook geen kostes vir die deelnemer wees nie;

Pogings sal aangewend word om persoonlike inligting vertroulik te hou. Absolute vertroulikheid kan egter nie gewaarborg word nie;

Persoonlike inligting kan openbaar gemaak word indien dit deur die wet vereis word;

Organisasies wat van die navorsingsrekords vir gehalteversekering en data-analise kan inspekteer en / of kopieer, sluit groepe soos die Etiekkomitee vir Mediese Navorsingsraad en die Medisynebeheerraad in (waar toepaslik).

Jy kan Karin op 083 641 5328 enige tyd kontak as jy vrae het in verband met hierdie navorsingstudie of as jy beseer is as 'n gevolg van die navorsing.

Die navorsingstudie, met inbegrip van die bogenoemde inligting mondelings is aan my beskryf. Ek verstaan wat my betrokkenheid by die studie beteken en ek stem vrywilliglik in om deel te neem.

\_\_\_\_\_  
Handtekening van Deelnemer

\_\_\_\_\_  
Datum

## APPENDIX F3

### ISIVUMELWANO SEZIGULANE SOKUTHATHA INXAXHEBA KOLUPHANDO

**UPHANDO OLUNZULU:** Ukhuseleko logqatso ingesi xana kusenziwa iradiography yobuchwepheshe kwizibhedlele zikarhulumnte eMpuma Koloni.

Uceliwe ukuba uthathe inxaxheba koluphando waze wanikwa inkcukacha ezimayelana noluphando ngu Karin Fourie.

Ukuthatha inxaxheba akunyanzelisi kwaye ukungavumi ukuthatha inxaxheba akuthethi ukuba umntu akazolifumana uncedo amele ukulifumane;

Umntu angangaqhubekiki nokuthatha inxaxheba nangaliphi ixesha, angafumani sohlwayo kwaye angaxuthwa uncedo amele akulifumane;

Akukho ntlawulo ezakunikwa umntu othathe inxaxheba kwaye umntu akukho nto ekumele ayibhatale ngokuthatha inxaxheba koluphando;

Iinzame zokukhusela iinkcukacha zabantu zizakwenziwa. Ukufihlwa kwencukacha okukuko akuqinisekiswa;

Iinkcukacha zabantu zingavezwa ukuba umthetho uyanyanzelisa;

Imibutho enokuthi ihlole okanye ikhuphele iinkcukacha zophando lwakho ukuqinisekisa uphando olululo iquka amaqela anjenge Ethics Committee for Medical Research and the Medicines Control Council (xa kufanelekile).

Ungagqagamshelana no Karin ku 083 641 5328 nangaliphi na ixesha ukuba unemibuzo ngoluphando okanye uye wonzakala ngenxa yoluphando.

Oluphando, kunye nezincukacha zingentla ndizicacisewe ngomlomo. Ndiyaqonda ukuba ukathatha kwam inxaxheba koluphando kuthetha ntoni kwaye ndiyavuma ukuthatha inxaxheba.

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Usayino lwesigulane

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Usuku

## APPENDIX G

### THE SURVEY FOR THE RADIOGRAPHER

**STUDY TITLE:** Radiation protection practice in digital radiography in Eastern Cape government hospitals.

The survey will be used to gather data for this research study to analyse and draw conclusions regarding radiation protection practice in digital radiography during digital chest and lumbar spine radiographic examinations. The survey will take roughly 30 minutes to complete.

#### INSTRUCTIONS:

- **Select and mark the appropriate box with a X.**
- **Please comment when asked.**
- **See example for correct method:**

| <b>EXAMPLE</b> |   |
|----------------|---|
|                | <b>Questions</b>  |
| <b>1.</b>      | <b>State whether exposure charts are available in each x-ray room?</b>                |
|                | Yes, there is an exposure chart at the console for each x-ray room in the department. |

Please indicate your highest qualification.

|                                      |  |
|--------------------------------------|--|
| Diploma in Radiography (diagnostic)  |  |
| B.Tech in Radiography (diagnostic)   |  |
| Master's in Radiography (diagnostic) |  |
| Other                                |  |

At which institution did you complete your studies?

|          |  |
|----------|--|
| CPUT     |  |
| CUT      |  |
| NMMU     |  |
| PRETORIA |  |
| DUT      |  |
| Other    |  |

For how many years have you been qualified? \_\_\_\_\_years.

Please answer the following questions:

|  |  |
|--|--|
| <b>Question 1</b>  |  |
| <b>Must anatomical lead markers be present on all images taken of a patient?</b> |  |
| YES  |  |
| SOMETIMES  |  |
| NO   |  |
| <b>Please explain your answer:</b>   |  |
| _____  |  |
| _____  |  |
| _____  |  |
| _____  |  |

|  |  |
|--|--|
| <b>Question 2</b>  |  |
| <b>Which exposure variable is under the control of the radiographer on which dose to a patient is primarily depended on?</b> |  |
| KVp  |  |
| Ma   |  |
| Mas  |  |
| S  |  |

**Question 3**

**Define ALARA.**

---



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**Question 4**

**State how you would correctly verify patient identification.**

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**Question 5**

**Do you allow patients' acquaintances or family members to stay in the x-ray room during an x-ray examination?**

YES

NO

SOMETIMES

**5.1 Please explain your answer above:**

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**Question 6**

**Is seating a patient parallel to the x-ray table for an upper extremity examination (i.e. hand, wrist, forearm and elbow) sufficient means of radiation protection for the patient?**

YES

NO

**6.1 Please explain your answer above:**

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**Question 7**

**Define the term EI.**

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**Question 8**

**State the purpose of EI in digital radiography.**

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**Question 9**

**State how digital radiography has affected / adapted exposure factors.**

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**Question 10**

**State how you would adapt the exposure factors to ensure that the EI value falls within the acceptable range.**

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**Question 11**

**State your manufacturers suggested EI range for optimum image quality for an extremity.**

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**Question 12**

**Name four factors that would affect the EI.**

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**Question 13**

**Explain how you would determine what exposure to set for a patient.**

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**Question 14**

**State how you would adjust the exposure factors if you want to reduce the radiation exposure to the patient.**

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**Question 15**

**Select and comment on the influence of broad exposure latitude of digital imaging on your selection of exposure factors.**

POSITIVE INFLUENCE

NEGATIVE INFLUENCE

NO INFLUENCE

**15.1 Please explain your answer above:**

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**Question 16**

**Explain the 15%kVp rule.**

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**Question 17**

**State how scattered radiation affects the image quality in digital radiography.**

IMPROVE THE QUALITY

POORER QUALITY

DOES NOT AFFECT THE QUALITY

**17.1 Please explain your answer above:**

---

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**Question 18**

**State why collimation is a lot more critical and of extreme importance in digital radiography.**

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**Question 19**

**State how digital radiography allows one to produce an image of adequate diagnostic quality, but yet may be overexposed or underexposed.**

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**Question 20**

**State why too much edge enhancement is not favourable during post processing of a digital image.**

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**Question 21**

**State why image mottle is produced on a digital image.**

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**Question 22**

**In your opinion what are the reasons for the incidence of the following phenomena in some radiographers' practice:**

**22.1 Not measuring the anatomical part to be examined.**

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**22.2 Not using exposure charts.**

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**22.3 Not using collimation or other forms of beam limiting devices.**

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**22.4 Not using anatomical lead markers.**

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**22.5 Use EI values as reference during normal practice.**

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**22.6 Not protecting the patient with lead shielding.**

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Thank you for your participation in this research study!

Checklist number: 

|  |  |
|--|--|
|  |  |
|--|--|

**APPENDIX H1**

**THE CHECKLIST**

- Please be so kind as to complete all areas within the checklist.
- There is an additional section for females of reproductive age, thus male participants may leave section 11 onwards out.
- The checklist will take roughly 15 minutes to complete.

**Instructions:**

- Mark the appropriate box with a X.
- See example for correct method:

| Question              | Yes | No |
|-----------------------|-----|----|
| The sky is blue today | X   |    |

| What is your gender?  | Female | Male         |
|---|--------|--------------|
| For which x-ray examination are you here for?   | Chest  | Lumbar spine |
| Question  | Yes    | No           |
| <b>ALL PATIENTS</b>   |        |              |
| 1. Did the radiographer ask you to verify your name?  |        |              |
| 2. Did the radiographer ask you to verify your surname?   |        |              |
| 3. Did the radiographer ask you to verify your date of birth?   |        |              |
| 4. Did the radiographer ask you why you are here for the examination?   |        |              |
| 5. Did the radiographer ask you if you recently had the same x-ray examination done?  |        |              |
| 6. Did the radiographer ask you to get undressed in a cubicle and put a hospital gown on?   |        |              |
| 7. Did the radiographer ask you to remove all jewelry, any other metallic objects and or foreign objects from the area of interest?       |        |              |
| 8. Did the radiographer explain the examination to you?   |        |              |
| 9. Did the radiographer tell you exactly what to do?  |        |              |
| 10. Did the radiographer provide you with support if you were unable to hold a certain position for the x-ray?                            |        |              |
| <b>FEMALE PATIENTS OF REPRODUCTIVE AGE ONLY</b>   |        |              |
| 11. Did the radiographer ask you if you could be pregnant?  |        |              |
| 12. If you were uncertain about your pregnancy status, did the radiographer ask you when the first day of your last menstrual period was? |        |              |
| 13. Did the radiographer explain the risks involved with an x-ray being taken while you might be pregnant?                                |        |              |

Thank you for your participation in this research study!

|  |  |
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|  |  |
|--|--|

**APPENDIX H2**

**DIE KONTROLELYS**

- Wees asseblief so vriendelik om al die areas van die kontrolelys te voltooi.
- Daar is egter 'n addisionele afdeling vir slegs vroulike deelnemers, dus kan manlike deelnemers van vraag 11 af uitlos.
- Die kontrolelys sal ongeveer 15 minute neem om te voltooi.

**Instruksies:**

- Merk die toepaslike blokkie met 'n X.
- Sien voorbeeld vir die korrekte metode:

| Vraag                   | Ja | Nee |
|-------------------------|----|-----|
| Die lug is blou vandag. | X  |     |

| Geslag van die deelnemer.   | Vroulik | Manlik          |
|---|---------|-----------------|
| Vir watter x-straalondersoek is jy hier vandag?   | Borskas | Lumbale werwels |
| Vrae  |         | Ja    Nee       |
| <b>MANLIKE EN VROULIKE PASIËNTE</b>   |         |                 |
| 1. Het die radiografis jou gevra om jou naam te verifieer?  |         |                 |
| 2. Het die radiografis jou gevra om jou van te verifieer?   |         |                 |
| 3. Het die radiografis jou gevra om jou geboortedatum te verifieer?   |         |                 |
| 4. Het die radiografis jou gevra hoekom jy hier is vir die ondersoek?   |         |                 |
| 5. Het die radiografis jou gevra of jy onlangs dieselfde x-straal ondersoek gehad het?  |         |                 |
| 6. Het die radiografis jou gevra om in 'n aantrekhoek te ontklee en 'n hospitaaljas aan te trek vir die ondersoek?                          |         |                 |
| 7. Het die radiografis jou gevra om alle juwele, enige ander metaalvoorwerpe en/of vreemde voorwerpe uit die toepaslike area te verwyder?   |         |                 |
| 8. Het die radiografis die ondersoek vir jou verduidelik?   |         |                 |
| 9. Het die radiografis vir jou verduidelik presies wat om te doen?  |         |                 |
| 10. Het die radiografis jou van ondersteuning voorsien indien jy nie in staat was om 'n sekere posisie te hou vir die x-straal nie?         |         |                 |
| <b>SLEGS VROULIKE PASIËNTE VAN REPRODUKTIEWE OUDERDOM</b>   |         |                 |
| 11. Het die radiografis jou gevra of jy swanger kan wees?   |         |                 |
| 12. As jy onseker was oor die status van jou swangerskap, het die radiografis jou gevra wanneer jy jou laaste menstruele periode gehad het? |         |                 |
| 13. Het die radiografis aan jou verduidelik watter risiko's betrokke is by 'n x-straal wat geneem word terwyl 'n pasiënt swanger kan wees?  |         |                 |

Dankie vir jou deelname aan hierdie navorsing!

|  |  |
|--|--|
|  |  |
|--|--|

**APPENDIX H3**

**ISIQINISEKISO**

- Uyacelwaukuba ubhale kuzo zonke iindawo ezifanelekileyo kwesi siqinisekiso.
- Kukho icandeloelongoziweyo ukulungiselela amabhinqa akwiminyaka yokuba angakhulelwa, amadoda angalishiya icandelo 11 ukuya ku 13.
- Esisiqinisekiso sizokuthatha imizuzuelishumi elinesihlanu.

Kwindawo efanelekileyo faka uX. Jonga umzekelo ukuzeubone indlela eyiyo:

| Umbuzo                | Ewe | Hayi |
|-----------------------|-----|------|
| Isibhakablakasilhlaza | X   |      |

| Isini   | Umfazi  | Indoda |      |
|---|---------|--------|------|
| Igesiozele yona   | Isifuba | Umqolo |      |
| Umbuzo  |         | Ewe    | Hayi |
| <b>ZONKE IZIGULANE</b>  |         |        |      |
| 1. Iradiographerindicelile ukubandiqinisekise igama lam.  |         |        |      |
| 2. Iradiographerindicelile ukubandiqinisekise ifani yam.  |         |        |      |
| 3. Iradiographerindicelile ukubandiqinisekise umhla wokuzalwa kwam.   |         |        |      |
| 4. Iradiographeriwubuzile unobangelawozokuhlolwa.   |         |        |      |
| 5. Iradiographerindibuzile ukubabendikhe ndalenza oluhlobolwegesi.  |         |        |      |
| 6. Iradiographerindicelile ukubandikhulule kwigumbi elifihlakeleyo ndinxibe igawuni yasesibhedlele.                             |         |        |      |
| 7. Iradiographerindicelile ukubandikhulule bonke ubucwebe endibunxibileyo.  |         |        |      |
| 8. Iradiographerindicacisele kakuhle malunga nohlolo.   |         |        |      |
| 9. Iradiographerindicacisele into mandiyenze.   |         |        |      |
| 10. Iradiographerikuncedisile ukuba ubungakwaziukuhlala ngendlela ethile kwigesi.   |         |        |      |
| <b>IZIGULANE EZINGABAFAZI EZIKWIMINYAKA YOKUBAZINGAKHULELWA</b>   |         |        |      |
| 11. Iradiographerindibuzile ukubaingaba ndikhulelwe na.   |         |        |      |
| 12. Bendingaqinisekanga ukuba ndikhulelwe na,iradiographyandibuza ukuba ukugqibela kwam ukuya exesheni usukulokuqala lwalunini. |         |        |      |
| 13. Iradiographerindicacisele ubungozi obudibenokuthatha igesi ukubakunokwenzeka ukuba ndikhulelwe.                             |         |        |      |

Enkosi ngokuthabatha inxaxheba koluphando!

Checklist number:

|  |  |
|--|--|
|  |  |
|--|--|

## APPENDIX I

### THE RADIOGRAPHIC IMAGE CHECKLIST

|  |   |   |   |
|--|---|---|---|
| <b><u>Examination:</u></b>               |   |   |   |
| <b><u>EI value:</u></b>                  |   |   |   |
| <b><u>Reviewer:</u></b>                  | A | B | C |
| <b><u>Radiographic Image number:</u></b> |   |   |   |

|  | Yes | No |
|--|-----|----|
| 1. The original lead anatomical marker is present on the radiographic image. |     |    |
| 2. A post processing marker is present on the radiographic image.            |     |    |
| 3. The correct anatomical marker is used.                                    |     |    |
| 4. Collimated during the examination.  |     |    |
| 5. Collimated after the examination.   |     |    |
| 6. Correct centering of anatomy of interest on IP.                           |     |    |
| 1. Correct positioning of the anatomical part.                               |     |    |
| 2. The EI value same as target EI.   |     |    |
| 3. The EI value is not the target value but falls within EI min and EI max.  |     |    |
| 4. From EI- image is overexposed/ outside range.                             |     |    |
| 5. Adequate spatial resolution visible in centre of image.                   |     |    |
| 6. Grainy / quantum mottle appearance of image.                              |     |    |
| 7. Good contrast of image.   |     |    |
| 8. Enhancement / windowing of image required.                                |     |    |
| 9. Motion / blurring of image evident.                                       |     |    |
| 10. Artefacts present on image.  |     |    |
| 11. Optimal image density.   |     |    |
| 12. The EI value was influenced by:  |     |    |
| 12.1 Collimation.  |     |    |
| 12.1.1 Collimation too big   |     |    |
| 12.1.2 Collimation too small   |     |    |
| 12.2 Differences in density of anatomy.                                      |     |    |
| 12.3 Wrong anatomical processing algorithm.                                  |     |    |
| 12.4 Other.  |     |    |
| <b><u>Comment:</u></b>   |     |    |

| <b><u>Evaluation criteria</u></b>  |  |  |
|--|--|--|
| <b>THE CHEST</b>   |  |  |
| <b>20. PA chest view</b>   |  |  |
| • 20.1 Entire lung fields from apices to costo-phrenic angles clearly demonstrated.  |  |  |
| • 20.2 No rotation.  |  |  |
| • 20.3 Trachea is visible in midline.  |  |  |
| • 20.4 Scapula projected outside lung fields.  |  |  |
| • 20.5 Ten posterior ribs visible above diaphragm.   |  |  |
| • 20.6 Sharp outline of the heart and diaphragm.   |  |  |
| • 20.7 Faint shadow of ribs and superior thoracic vertebrae visible through the heart shadow.  |  |  |
| • 20.8 Lung markings visible from hilum to periphery of lung.  |  |  |
| <b>21. Lateral chest view</b>  |  |  |
| • 21.1 Entire lung fields from apices to costo-phrenic angles clearly visible.   |  |  |
| • 21.2 Arms not superimposed over portions of lung fields.   |  |  |
| • 21.3 Sharp radiographic outline -- outline of diaphragm and lung markings.   |  |  |
| • 21.4 No rotation. <ul style="list-style-type: none"> <li>• 21.4.1 Ribs superimposed posterior to vertebral column without any separation of right and left posterior ribs and both costo-phrenic angles.</li> <li>• 21.4.2 Lateral aspect of sternum forms anterior border.</li> <li>• 21.4.3 No ribs projecting in front of sternum.</li> </ul> |  |  |
| • 21.5 No tilt - Thoracic intervertebral spaces and intervertebral foramina open.  |  |  |
| • 21.6 Hilum in center of radiographic image.  |  |  |
| <b>THE LUMBAR SPINE</b>  |  |  |
| <b>22. AP view of lumbar spine</b>   |  |  |
| • 22.1 Lumbar vertebral bodies, disk spaces, spinous and transverse processes, lateral margin of psoas muscle, SI joints, and sacrum clearly visible.  |  |  |
| • 22.2 T12 to S1 included.   |  |  |
| • 22.3 No rotation. <ul style="list-style-type: none"> <li>▪ 22.3.1 Spinous processes in midline of vertebral bodies.</li> <li>▪ 22.3.2 Right and left transverse processes equal in length.</li> <li>▪ 22.3.3 Symmetric vertebrae.</li> <li>▪ 22.3.4 SI joints equal distance from spine.</li> </ul>  |  |  |
| • 22.4 Optimal exposure. <ul style="list-style-type: none"> <li>• 22.4.1 Demonstrate soft tissues, margins of psoas muscle and bony vertebrae.</li> </ul>  |  |  |

|   |  |  |
|---|--|--|
| <b>23. Lateral view of lumbar spine</b>   |  |  |
| <ul style="list-style-type: none"> <li>• 23.1 Lumbar vertebral bodies, intervertebral foramina, disk spaces, spinous and transverse processes, SI joints, and sacrum clearly visible.</li> </ul>  |  |  |
| <ul style="list-style-type: none"> <li>• 23.2 T12 to S1 included.</li> </ul>  |  |  |
| <ul style="list-style-type: none"> <li>• 23.3 No rotation. <ul style="list-style-type: none"> <li>▪ 22.3.1 Nearly superimposed iliac crests when x-ray beam is not angled.</li> <li>▪ 22.3.2 Superimposed posterior margins of each vertebral body.</li> <li>▪ 22.3.3 Open intervertebral disc spaces.</li> <li>▪ 22.3.4 Vertebrae aligned down in middle of radiographic image.</li> </ul> </li> </ul> |  |  |
| <ul style="list-style-type: none"> <li>• 23.4 Optimal exposure. <ul style="list-style-type: none"> <li>▪ 23.4.1 Demonstrate soft tissues, joint spaces and bony vertebrae.</li> </ul> </li> </ul>   |  |  |
| <b>24. L5-S1 lumbosacral junction lateral view</b>  |  |  |
| <ul style="list-style-type: none"> <li>• 24.1 Demonstrate lower one or two lumbar vertebrae and upper sacrum.</li> </ul>  |  |  |
| <ul style="list-style-type: none"> <li>• 24.2 Lumbosacral joint in center of radiographic image.</li> </ul>   |  |  |

## APPENDIX J

### CONSENT FROM STATISTICIAN



Maryn Viljoen  
Statistics Consulting Services

maryn.viljoen@vodamail.co.za  
082 823 5731

Protocol and research methodology consultation • Ethical consultation • Database construction and capturing of data  
Analyzing data using statistical software packages (SAS Version 9.1.31) • Statistics consultation services to analyze and interpret data  
Conveys results with statistical tables and figures where needed.

**Attention: Ethics Committee Chairperson**

Block D, Room 115  
Francois Retief Building  
Faculty of Health Sciences  
University of the Free State

19 August 2015

**Title:** "RADIATION PROTECTION PRACTICE IN DIGITAL RADIOGRAPHY IN  
EASTERN CAPE GOVERNMENT HOSPITALS."

**Researcher:** Ms. K. Fourie (212035266)  
M.Tech Radiography (Diagnostic)  
Department of Clinical Sciences (Programme Radiography)  
Faculty of Health and Environmental Sciences  
Central University of Technology (Free State)

I have seen and read through this protocol. I gave input and recommendations  
and will be the biostatistician responsible for the analysis of the data.

Maryn Viljoen  
M.Sc. Risk Analysis (UFS)  
[maryn.viljoen@vodamail.co.za](mailto:maryn.viljoen@vodamail.co.za)  
082 82 35 731

## **APPENDIX K**

### **MEMORANDUM FOR THE RADIOGRAPHER SURVEY**

1. Yes (1)
  - 1.1 It is a medico-legal requirement hence all images must show anatomical markers since it is very easy to accidentally flip/rotate an image during post- processing. Unless the original markers are visible, there is no way of truly knowing which side is which; therefore it could result in misdiagnosis and serious legal implications, if the original lead anatomical markers are not present.
  
2. MAs
  
3. As low as reasonably achievable.
  
4. Verbally request patient to verify at least 3 personal details i.e. full name; surname; date of birth (DOB); address; ID number; examination they are there for.
  
5. Sometimes (3)
  - 5.1 The patients' acquaintances or family members should not and must not stay in the x-ray room during an x-ray examination, however if the radiographer has a difficult patient i.e. a very ill or injured patient; a child or baby; a patient where there is a communication barrier and translation is required or a confused patient etc and there is no other way, but to allow an acquaintance or family member to come into the x-ray room, in order to help and assist – (whether to translate or help the patient hold a position or hold down a baby or unco-operative patient for an image), then the acquaintance or family member must be given a full lead apron or any other radiation protecting apparel to provide the best possible radiation protection measures to the acquaintance / family member.

6. No (2)
- 6.1 Even though the patient may not directly be in the primary beam, the patient must still be protected from scatter radiation and prevent radiation reaching and effecting the patients' radiosensitive organs i.e. gonads; breasts; thyroid. Thus the patient must be seated parallel to the x-ray table and wear either a full lead apron or half lead apron and tight collimation must be applied in order to provide sufficient means of radiation protection for the patient.
7. EI = Exposure Index
8. The purpose of EI in digital radiography is to determine whether adequate exposure has reached the image receptor (Herrmann, *et al*, 2012: online), and to evaluate EI values, together with image quality to determine whether the digital image adheres to departmental standards; identify that because the EI has limitations and other variables may affect the value, one must comprehensively evaluate whether a repeat examination is required, hence EI values are used to determine how the exposure factors must be adjusted to produce a better quality image which falls within the EI min and EI max values.
9. Digital radiography has affected / adapted exposure factors negatively as exposure factors are no longer as crucial as they used to be due to wider exposure latitude and post-processing algorithms which can mask the evidence of underexposure and overexposure. Underexposure produces noisy, grainy images which can impede diagnosis and overexposure results in a greater radiation dose to the patient.
10. If the EI value is too high, it means the exposure given was too high, thus one must lower the exposure given and if the EI value is too low, it means the exposure given was too low, hence one must increase the exposure given.

11. AGFA's suggested EI Range for optimum image quality for an extremity is:  
Target EI = 100; EI min = 690 & EI max = 1378.

12. The influential factors affecting the EI in digital radiography include:

- kVp;
- Collimation;
- Distance (FFD & SID);
- Time after exposure processing.

Additional factors affecting EI include:

- Positioning and centring i.e. radiographic technique, the histogram analysis and scatter.

13. The radiographer must look at and assess the patient, taking into account:

- the size of the patient;
- the patients build;
- the density of the anatomical part under examination;
- artefacts that may be present (metallic objects i.e. screws, plates);
- the requested examination i.e.in or out of bucky;
- the suspected pathology.

From the above factors, the radiographer must adjust the average exposure factors accordingly to provide enough radiation to produce high quality images.

14. The best practice in digital imaging to reduce the radiation exposure to the patient is to use the highest kVp within the optimal range for the position and part coupled with the lowest amount of mAs needed to provide an adequate exposure to the image receptor.

15. Negative Influence (2)
  - 15.1 Broad exposure latitude has had a negative influence of digital imaging regarding the selection of exposure factors. A patient could be overexposed due to a broad exposure latitude, which allows for the single detector to be sensitive to a wide range of exposures. kVp still influences subject contrast, but radiographic contrast is primarily controlled by an image processing look-up table & mAs setting has more control over image noise, whereas density is controlled by image-processing algorithms.
  
16. The 15% kVp rule states that: if you change the KVP by 15% then you will have the same effect on density as doubling the mAs. More interactions occur at the target as kVp increases, so more photons are created. Affect is more so than mAs. Thus doubling kVp will increase quantity (intensity) by 4. - So the 15% rule comes into play so the density will not increase and blacken the film. We want to keep the density the same and just increase contrast. So if increasing kVp by 15%, you'll need to decrease mAs by 1/2 to maintain density.
  
17. Worsen the quality (2)
  - 17.1 Scatter radiation worsens the image quality in DR as scatter radiation is another source of image degradation in radiography, and it acts in the same manner as other noise sources. Scatter reduces the available dynamic range of x-ray intensities at the exit side of the patient. The primary effect of scatter is the reduction of subject contrast. In addition to reducing subject contrast, scatter decreases the SNR because it contains no signal but does contain quantum noise, thus worsening and reducing the image quality.

- 18 Collimation is a lot more critical and of extreme importance in DR therefore it is essential that radiographers carefully use collimation to the appropriate anatomy of interest when performing digital examinations to minimize patient exposure and prevent errors in processing of the digital image data. By limiting the anatomy that receives radiation, a smaller area of the patient's tissue is exposed, thereby reducing patient dose and minimizing scatter radiation to the image receptor. Collimation is very important in digital radiography because digital image receptors are more sensitive to low levels of radiation, and the resulting digital image might demonstrate reduced image contrast because of excess scatter radiation striking the receptor.
- 19 DR allows one to produce an image of adequate diagnostic quality, but yet may be overexposed or underexposed as digital radiography separates acquisition, processing and display, which enables a radiographer to produce an image that has acceptable diagnostic quality, but could be underexposed or overexposed. Adjustments to compensate for exposure technique errors can be made at the time of display, although doing so is not a best practice. The best practice is to select the appropriate exposure technique factors for the patient's size and condition, based on a planned exposure system designed to determine adequate image quality for diagnosis.
- 20 When the signal is obtained, averaging of the signal occurs to shorten processing time and storage. The more pixels involved in the averaging, the smoother the image appears. Signal strength of one pixel is averaged with the strength of adjacent pixels or neighborhood pixels. Edge enhancement occurs when fewer pixels in the neighborhood are included in the signal average. The smaller the neighborhood, the greater the enhancement. When frequencies of areas of interest are known, they can be amplified and other frequencies can be suppressed. Amplification, also known as high-pass filtering, results in an increase of contrast and edge enhancement. Suppression of frequencies, also known as masking, can result in loss of small details.

Too much edge enhancement is therefore not favourable during post-processing of a digital image since too much edge enhancement can degrade the diagnostic quality of the image and therefore potentially affect the final image interpretation and diagnosis.

21 Image / Quantum mottle is the only image noise that affects image quality and can be controlled by the radiographer. Quantum mottle is a result of and or produced on a digital image due to the inefficient number of photons reaching the imaging plate due to an error in the preset exposure factors (mAs and kVp). This can produce a grainy image that can be easily corrected by adjusting the mAs or kVp.

22.1 Not measuring the anatomical part to be examined:

- Experience;
- Time consuming;
- No equipment;
- Laziness.

22.2 Not using exposure charts:

- With experience – learn exposures and remember them;
- Not always correct;
- There no exposure charts available to use;
- Laziness.

22.3 Not using collimation or other forms of beam limiting devices:

- Bad habits;
- Laziness;
- Does not want to repeat;
- No time - Under high pressure to finish high workload;
- No devices / equipment available to use;
- Negligence.

22.4 Not using anatomical lead markers:

- Laziness;
- Bad habits;
- Does not have own anatomical lead markers to use;
- Negligence;
- Time consuming.

22.5 Use EI values as reference during normal practice:

- Does not know or understand how EI works;
- Time consuming;
- Laziness;
- Negligence.

22.6 Not protecting the patient with lead shielding:

- Negligence;
- No time - Under high pressure to finish high workload;
- Laziness;
- Bad habits;
- No lead shielding / lead aprons available.

## APPENDIX L

### ETHICS APPROVAL LETTER



IRB nr 00005240  
REC Reference nr 230408-011  
ICRG0005187  
FWA00012784

16 September 2015

MS K FOURIE  
DEPARTMENT OF CLINICAL SCIENCES,  
CENTRAL UNIVERSITY OF TECHNOLOGY

Dear Ms K Fourie

ECUFS NR 177/2015

MS K FOURIE  
CLINICAL SCIENCES, CUT

PROJECT TITLE: RADIATION PROTECTION PRACTICE IN DIGITAL RADIOGRAPHY IN EASTERN CAPE GOVERNMENT HOSPITALS

1. You are hereby kindly informed that the Ethics Committee reviewed the above research project. Research may not be conducted before the following condition(s) has/have been met and the Ethics Committee grants final approval for the project:

- The signed permission letter from the Eastern Cape Department of Health has to be submitted before the study may be conducted

**\*PLEASE NOTE:** This ethics letter must accompany your application for a approval to the Department of Health for their consideration, along with submitting the online application.

2. Upon receipt of the above feedback/document(s), the Ethics Committee will issue a final approval letter. Only thereafter may the study be conducted.
3. All relevant documents e.g. signed permission letters from the authorities/institutions; amendments to the protocol, questionnaires etc. have to be submitted to the Ethics Committee before the study may be conducted.
4. Kindly use the ECUFS NR as reference in correspondence to the Ethics Committee Secretariat.
5. Thus, this letter only serves as **conditional** approval.
6. The Ethics Committee functions in compliance with, but not limited to, the following documents and guidelines: The SA National Health Act, No. 61 of 2003; Ethics in Health Research: Principles, Structures and Processes (2015); SA GCP(2006); Declaration of Helsinki; The Belmont Report; The US Office of Human Research Protections 45 CFR 461 (for non-exempt research with human participants conducted or supported by the US Department of Health and Human Services- [HHS], 21 CFR 30, 21 CFR 56; CDMS; ICH-GCP-P6 Sections 3-4; The International Conference on Harmonization and Technical Requirements for Registration of Pharmaceuticals for Human Use (ICH Tripartite), Guidelines of the SA Medicines Control Council as well as Laws and Regulations with regard to the Control of Medicines, Constitution of the Ethics Committee of the Faculty of Health Sciences.

Yours faithfully



DR SM LE GRANGE  
CHAIR: ETHICS COMMITTEE

Cc: Dr R Botha  
Cc: Dr B van der Merwe

Ethics Committee  
Office of the Dean: Health Sciences  
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www.ufrs.ac.za



## APPENDIX M

### **CURRICULUM VITAE OF STUDENT**

**RESEARCH TITLE:** “Radiation protection practice in digital radiography in Eastern Cape government hospitals.”

**PROTOCOL NO:**

**PERSONAL DETAILS:**

**Title:** Mrs

**Full First Names:** Karin

**Initials:** K

**Surname:** Fourie

**Gender:** Female

**Student number:** 212035266

**Identification number:** 8902230017088

**HPCSA No:** DR 0118540

**Course:** Radiography (Diagnostic)

**Home language:** English

**Other languages:** Afrikaans

**Cell Phone number:** 083 641 5328

**E-mail address:** k.fourie@hotmail.com

**SITE / INSTITUTION DETAILS**

**Site / Institution Name:** Central University of Technology (CUT)

**Telephone No:** +27 (0) 51 507 3911

**Fax No:** +27 (0) 51 507 3199

**QUALIFICATIONS**

**Tertiary Qualifications**

Studies Completed: National Diploma Radiography: Diagnostic 2011.

Baccalaureus Technologiae Radiography: Diagnostic 2012-2013.

**Secondary Qualifications**

Highest Grade Passed: Grade 12 (Senior Certificate) (2007)

**WORK EXPERIENCE**

Student Radiographer (Diagnostic): St George's Hospital, Drs Erasmus, Vawda, Rabe and Partners: 2009-2011.

Community Service Radiographer (Diagnostic): East London Hospital Complex: Frere Hospital: 2012.

Independent Senior Radiographer (Diagnostic): St George's Hospital, Drs Erasmus, Vawda, Rabe and partners: January 2013 – May 2016.

Independent Senior Radiographer (Diagnostic): Wilgehuewel Hospital, Theatre: June 2016 - present.



12 / 12/ 2018

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**SIGNATURE**

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**DATE**