LOCAL DIAGNOSTIC REFERENCE LEVELS (LDRLs) FOR ROUTINE CHEST X-RAY EXAMINATIONS AT A GOVERNMENT HOSPITAL IN THE NORTHERN CAPE

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N Dip Radiography (Diagnostic)

B Tech Radiography (Diagnostic)

A dissertation submitted in fulfilment of the requirement for the degree

MASTER OF RADIOGRAPHY

(DIAGNOSTIC)

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20.04.2021

DEDICATION

I dedicate this dissertation to my late parents, Mr Jacob Junda and Mrs Mary Junda.
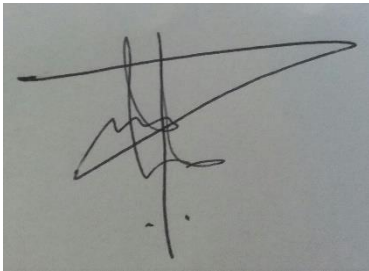
ACKNOWLEDGEMENTS

I would like to thank everybody who supported me throughout this project.

- My wife, for her support and encouragement.
- My supervisors, Prof. H.S. Friedrich-Nel and Mrs. H. Muller, for affording me the opportunity to study and guiding me during this project.
- The staff of Robert Sobukwe Hospital for their willingness to participate in this study.
- Dr J. Du Plessis, for her patience and guidance during the infant stage of this project.
- Dr. S. Acho, for her willingness to provide constructive ideas to make this research successful.

DECLARATION

I, Maurice Junda, hereby declare that LOCAL DIAGNOSTIC REFERENCE LEVELS (LDRLs) FOR ROUTINE CHEST X-RAY EXAMINATIONS AT A GOVERNMENT HOSPITAL IN THE NORTHERN CAPE is my own independent work. I further declare that this dissertation has not been submitted to any university for the purpose of obtaining a degree. All the sources that I have used have been acknowledged by means of complete references.

14.04.2021

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Maurice Junda   Date

ABSTRACT

LOCAL DIAGNOSTIC REFERENCE LEVELS (LDRLs) FOR ROUTINE CHEST X-RAY EXAMINATIONS AT A GOVERNMENT HOSPITAL IN THE NORTHERN CAPE

Keywords: entrance surface air kerma, as low as reasonably achievable, high kVp and digital radiography

BACKGROUND

The use of ionising radiation in the medical field accounts for the largest contribution of radiation exposure to the human population. The extent of radiation received by patients undergoing X-ray examinations needs to be quantified to estimate the possibility of harm.

The focal point of the research is chest X-ray examinations since these examinations are the most commonly performed worldwide. The chest contains two radiosensitive organs, namely the thyroid and breast tissue. This research study is deemed critical because it demonstrates how dose optimisation can be achieved. Dose optimisation is achieved when the local diagnostic reference levels (LDRLs) of chest X-ray examinations of the research site are less than the international values.

The Directorate of Radiation Control (DRC) has not yet established LDRLs for radiological examinations. The data generated by this research could assist the organisation to baseline diagnostic reference levels (DRLs) for adult chest X-ray examinations in the Northern Cape.

RESEARCH QUESTION

The research question is:

What are the LDRLs for routine chest X-ray examinations at a government hospital in the Northern Cape?

OVERALL GOAL OF THE STUDY

The overall goal of this study was to determine LDRLs values for adult chest X-ray examinations.

AIM OF THE STUDY

The aim of the study was to determine LDRLs for routine chest X-ray examinations in a diagnostic radiology department at a government hospital in the Northern Cape, in the absence of published values about this important concept in Republic South Africa.

OBJECTIVES OF THE STUDY

The objectives of this study were:

To calculate the entrance surface air kerma (ESAK) for routine chest X-ray examinations' postero-anterior (PA) and lateral (LAT) images.

To establish LDRLs for routine chest X-ray examinations (PA and LAT images) at the research site.

To compare LDRLs and the typical dose of chest X-ray examinations with relevant international organisations and values cited in the literature.

To propose changes to the specific research site to optimise and justify patient dose if there are significant differences in LDRLs compared to the values from cited literature.

METHOD

This research study was a cross-sectional study, which is used to examine data at a point in time, that is, the data at/on one occasion only with different participants. It was also a quantitative research study. Quantitative data are numerically measurable, for example, how many, how much or how often. This method determined how much radiation dose a patient receives for each projection. An indirect method was utilised to determine patients' dose.

The research site was a radiology department in the Northern Cape. Three general radiographic rooms were used, namely, two x-ray rooms equipped with computed radiography (CR) and the third room utilised digital radiography (flat panel detector) [(DR (FPD)].

The methodology was divided into three phases, namely quality control, imaging procedure and ESAK calculation. The quality control was performed by a medical

physicist. Radiographers executed the imaging procedure at the research site. The radiographers adhere to the Declaration of Helsinki with regard to ethical standards and behaviour. The radiographers had to obey the International Declaration of Helsinki to select patients, obtain chest X-ray radiographs and data for the research. The data recorded by the radiographers were kilo-voltage peak (kVp), focus film distance (FFD), patients' weight and patients' thickness at the centring point. These data were used to determine the ESAK of each projection of the participating patients. The indirect method recommended by International Atomic Energy Agency (IAEA) was used to determine the ESAK. A statistician used a statistical application (SAS version 9.2) to determine the LDRLs for chest X-ray examinations of the three X-ray rooms, radiographic systems and the research site.

The first sixty patients referred for chest X-ray examinations who met the inclusion criteria participated in this study. The patients selected were 18 years and above, accepted to sign the consent form, were referred for chest X-ray examinations, weighed 60 kilograms (kg) to 80 kg and the exposure index of chest X-ray images were within the prescribed manufacturer range.

The ESAK were measured using the indirect method recommended by the IAEA. A statistical application (SAS Version 9.2) was used to determine the LDRLs for chest X-ray examinations of three X-ray rooms, radiographic systems, and the research site.

The instruments that were used for this research were valid because weighing scale measures the weight of a patient in kilograms and a calliper measures the thickness of the patient at the centring point in centimetres (cm). The formula and procedure that were used to estimate dose to patients are recommended by IAEA and other researches have successfully used this formula and procedure to estimate patient dose.

This research study utilised instruments that were reliable. A known weight of 70 kg was placed on the weighing scale. The reading on the weighing scale and the value of the known weight correlated; the weighing scale was deemed reliable. The calliper measurement was compared to a measuring meter. The measurements were the same; the calliper was deemed reliable. Quality assurance (QA) and quality control (QC) were performed on the X-ray machines at regular intervals as per the QA guidelines to ensure the exposure parameters were reliable. The specific tests were:

accuracy and reproducibility of kVp, accuracy and reproducibility of exposure time and linearity of the output with milli-ampere (mA) and time.

RESULTS AND DISCUSSION

The following LDRLs for chest X-ray examinations were established; Room 1, postero-anterior projection (PA) (0.3 milli-Gray (mGy) and lateral projection (LAT) (0.8 mGy), Room 2, PA (0.3 mGy) and LAT (0.7 mGy), Room 3, PA (0.2 mGy) and LAT (0.8 mGy), computed radiography (CR), PA (0.3 mGy) and LAT (0.8 mGy), digital radiography (DR), PA (0.2 mGy) and LAT (0.8 mGy) and research site, PA (0.3 mGy) and LAT (0.8 mGy).

The results showed that there were wide ranges for exposure parameters and ESAK for chest examinations at the research site. These wide ranges could be attributed to patients' weight range and thickness, radiographer skill, knowledge and training and the use of automatic and manual exposure settings.

Comparison of the LDRLs of this study to other international DRLs.

PROJECTION	This study	IAEA 2004	RSA 2009	UK 2010 review	EU 2018 Most common value	Iran 2018	Turkey 2018
Chest PA	0.3	0.3	0.1	0.15	0.3	0.63	0.35
Chest LAT	0.8	1.5	0.2	0.54	1.5	1.11	0.78

PA= postero-anterior; LAT= Lateral; LDRLs= Local diagnostic reference levels; UK= United Kingdom; EU= European Union; RSA= Republic of South Africa; IAEA= International atomic energy agency; LDRL SI unit is mGy

CONCLUSION

The LDRLs for chest X-ray examinations were established at this research site. The LDRLs for chest X-ray examinations were lower than the published international diagnostic reference levels. The recommendation is LDRLs for routine chest X-ray examinations should be repeated after three years according to ICRP. The latest results should then be compared with the results of this research study.

This study did not demonstrate the LDRLs for routine chest X-ray examinations of patients whose weights are less than 60 kg or more than 80 kg. As a result, many patients had to be excluded from this research study because their weight was not

within the required weight range of this research study. This is the significant limitation of the research study.

TABLE OF CONTENTS

LIST OF ACRONYMS

Al	Aluminium
ALARA	As low as reasonably achievable
AP	Antero-posterior
BSC	Backscatter coefficient
cm	Centimetre
CT	Computed tomography
CR	Computed radiography
Cu	Copper
DAP	Dose area product
DNA	Deoxyribonucleic acid
DR	Digital radiography
DRC	Directorate Radiation Control
DR (FPD)	Digital radiography (Flat panel detector)
DRLs	Diagnostic reference levels
EC	European Commission
EI	Exposure index
ESAK	Entrance surface air kerma
EU	European Union
FDD	Focus detector distance
FFD	Focus film distance
FSD	Focus skin distance
$Gy.cm^2$	Gray centimetre squared

HPCSA	Health Professional Council of South Africa
k_i	Incident air kerma
K(d)	Air kerma
LAT	Lateral
LDRLs	Local diagnostic reference levels
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
kV	Kilovolt
kVp	Kilo voltage peak
kg	Kilogram
mA	Milliampere
max	Maximum
mAs	Milliampere-second
mGy	Milligray
min	Minimum
MRI	Magnetic resonance imaging
mm	millimetre
n	number
RSA	Republic of South Africa
TLD	Thermoluminiscent dosimeter
T7th	7th thoracic vertebra
UFS	University of the Free State
UK	United Kingdom

PA	Postero-anterior
PACS	Picture archiving and communication system
QA	Quality assurance
QC	Quality control
Y (d)	X-ray output
WHO	World Health Organisation
3rd	Third
75th	75 percentile
-	Data not available

LIST OF TABLES

LIST OF APPENDICES

CHAPTER 1

ORIENTATION TO THE STUDY

1.1 INTRODUCTION

The use of ionising radiation in the medical field is currently known as the largest contributing factor to human exposure to ionising radiation (Wambani, Onditi, Korir & Korir, 2015:1). Ionising radiation has the potential to break apart the biological essential molecules such as deoxyribonucleic acid (DNA) in exposed cells and cause harm. As a result, the amount of radiation received by patients undergoing X-ray examinations needs to be quantified in order to estimate the possibility of harm (Shahbazi-Gahrouei, 2006:1). Given these circumstances, the practice of justification, optimisation of the radiation dose and diagnostic reference levels (DRLs) assist with optimal radiation protection.

Dose optimisation is one of the radiation protection principles recommended by the International Commission on Radiological Protection (ICRP). Dose optimisation ensures adherence to the "as low as reasonably achievable" (ALARA) principle. In addition, the ICRP recommends the practise of DRLs to optimise and monitor radiation dose. Determining DRLs and comparing these values with published data will ensure that the ALARA principle is achieved in radiology departments (ICRP, 2007:128). If the determined DRLs are higher than the published data, there are steps to be taken to investigate these DRLs values (see section 2.3.5). A lower determined DRL is an indication that the optimal amount of radiation was used to produce radiographs that are of acceptable image quality.

1.2 LITERATURE BACKGROUND

In South Africa, the Directorate of Radiation Control (DRC) at the Department of Health defines DRLs and gives the objectives of DRLs in the code of practice for users of medical X-ray equipment (DRC, 2015:14). The DRC has developed procedures to obtain DRLs, yet there is only one South African publication to date that addresses this topic. This study was conducted at the Charlotte Maxeke Hospital by Nyathi, Nethwadzi, Mabhengu, Pule and Van der Merwe in 2009. As such, the limited information published in the Republic of South Africa (RSA) identifies the gap in the literature and the requisite for this study.

1

This research study demonstrates how to measure patients' dose and determine the local diagnostic reference levels (LDRLs) of a radiographic projection at a research site for adult chest X-ray projections. LDRLs are recommended for radiation protection of patients. The other technique that radiology departments can execute in order to optimise dose to the patients is the justification of practice and optimisation of radiation protection. Justification of practice is a judgement of whether the radiological procedure will provide the necessary diagnostic information about the exposed individual (ICRP, 2007:127) while optimising radiation protection is about respecting the principle of ALARA. Using the minimum exposure parameter to obtain an adequate image with the image quality of a diagnostic standard (ICRP, 2007:91).

Digital radiography (DR) systems have a greater dynamic range than screen-film combinations. The dynamic range is the range of X-ray exposure over which a meaningful image can be acquired. Radiographers used high exposure parameters with these systems because, as exposure parameters increase, the detector function also improves. This is referred to as dose creep. The setting of an LDRL is the recommended method to avoid this phenomenon (Korner, Weber, Wirth, Pfeifer, Reiser & Treitl, 2007:682).

1.3   PROBLEM STATEMENT

A wide range of exposure factors is used in diagnostic radiology (Martin, 2006:1). It is surprising though, that, even for the same average patient size, exposures may vary substantially between facilities and radiographers. A wide range of exposure factors leads to a wide variation in patient dose. This proves that there is room to optimise the radiation exposure to the patient.

Rapid advances in imaging modalities occurred over the past decade, such as the change from film/screen technology to DR. These technological changes are also evident in the imaging departments of the Northern Cape. These changes necessitate patient dose assessment for diagnostic procedures and are ultimately the motivation for conducting this research.

Chest X-ray examinations are the most common X-ray examinations performed in RSA. However, there are very few publications on the dosages received by patients during this procedure and the same applies to DRLs for chest X-ray examinations.

1.4 RESEARCH QUESTION

Resulting from the aforementioned inadequacy that was identified specifically in the South African context, the research study poses the following question:

What are the LDRLs for routine chest X-ray examinations at a government hospital in the Northern Cape?

1.5 OVERALL GOAL OF THE STUDY

The overall goal of this study is to determine optimal LDRLs values for adult chest X-ray examinations.

1.6 AIM OF THE STUDY

The study aims to determine LDRLs for routine chest X-ray examinations in a diagnostic radiology department at a government hospital in the Northern Cape, given the absence of published values regarding this important concept in RSA.

1.7 OBJECTIVES OF THE STUDY

The objectives of this study are set out as follow:

i) To calculate the entrance surface air kerma (ESAK) for routine chest X-ray examinations' postero-anterior (PA) and lateral (LAT) images.

ii) To establish LDRLs for routine chest X-ray examinations (PA and LAT images) at the research site.

iii) To compare LDRLs and the typical dose of chest X-ray examinations with relevant international organisations and values cited in the literature.

iv) To propose changes to the specific research site to optimise and justify patient dose if there are significant differences in LDRLs compared to the values from cited literature.

1.8   SUMMARY OF THE RESEARCH METHODOLOGY

The data collection was done using a cross-sectional approach. The first sixty patients referred for chest X-ray examinations who met the inclusion criteria (see section 3.7) were included in this study. The data collection was divided into three phases. Phase one dealt with quality control (QC). A medical physicist performed all the QC tests as required by the DRC on all the X-ray machines at the research site. During phase two, the chest imaging procedures were performed. Radiographers at the research site assisted with the process of collecting data from the participating patients. Phase three illustrated how the ESAK was calculated using the indirect method proposed by the International Atomic Energy Agency (IAEA) (see section 3.8.3).

The data were employed to determine the LDRLs for the research site, the LDRLs for the X-ray rooms and DR, flat panel detector (FPD) and computed radiography (CR) systems (see Tables 4.13, 4.14 and 4.15). The data also revealed the exposure parameters used at the research site (see section 4.3).

1.9   ARRANGEMENT OF THE DISSERTATION

The dissertation is comprised of five chapters and is arranged as follow:

Chapter 1: Introduction, literature background and methodology

This chapter provides the introduction, summary of the literature background and methodology of the research study. It also describes the background to the research problem, problem statement, research question, and the overall goal of the research study.

Chapter 2: Literature perspectives

The concept of diagnostic reference levels, as well as DRLs for chest examinations, are described. This chapter also provides a theoretical framework for the study.

Chapter 3: Methodology

In this chapter, the research design, study location, research tool, study population, sample and sampling method, as well as the inclusion and exclusion criteria are focused on. The data collection method, data analysis, pilot study, ethical approval, informed consent, and validity and reliability of the research study are also reported.

Chapter 4: Results and discussion

In this chapter, the data collected during the three phases of the research study are presented and discussed. The LDRLs of chest X-ray projections are displayed, discussed and compared to international values.

Chapter 5: Conclusions, recommendations and limitations

This chapter contains the conclusions, recommendations and limitations of the research study. In addition, it alludes to the possible contribution of the study.

CHAPTER 2

LITERATURE PERSPECTIVES

2.1 INTRODUCTION

In chapter 1, a brief orientation to the research study is presented. In chapter 2, more information to inform the research study, such as DRLs and how a DRL is used for radiation protection, is provided. In this chapter, information on the literature and chest radiograph is relayed; the concept 'DRL' is explored and the background of the research problem and theoretical framework for the study is provided.

2.2 THE LITERATURE RELEVANCE

Radiographic system (digital radiography systems), the weight range of patients and the method used to calculate radiation dose to patients are the most relevant elements that influence the amount of radiation dose a patient receives at the radiology department of the research site. In addition, these elements are crucial for the results of this study to meet the standard required by the ICRP.

A study conducted in Iran determined a national diagnostic reference level in routine digital radiography examinations (Mohsenzadeh, Deevband & Pouriran, 2018:6183-6192). In addition, results from studies done in Turkey (Bas Mor, Altinsoy & Söyler, 2018:377-385) as well as the United Kingdom (Hart, Hiller & Wall 2012:1-81) to determine the estimation of adult patient doses for chest X-ray examinations and comparison with diagnostic reference levels (DRLs) were utilised to compare, corroborate and support the findings of this research. The same approach of comparison to said studies and reviews was followed to determine the dose to patients from radiographic and fluoroscopic X-ray procedures.

The only study conducted in South Africa (Nyathi *et al.*, 2009:9-13) in order to determine a patient dose audit for patients undergoing six common radiography examinations potential dose reference levels was also utilised for the same purpose.

The ICRP recommends the use of ESAK, thermoluminescence dosimeter (TLD) and dose area product (DAP) methods to measure radiation dose (ICRP, 2017:52 & 54). ESAK was used to determine radiation dosage in this study, as this is the method recommended and utilised as per available literature and, as a result, enabling the

6

comparison of ESAK values of this study with other studies. The IAEA method was used to calculate radiation dose.

In lieu of the aforementioned, albeit not the only relevant literature mined for the purpose of this study, it is important to highlight the relevance of specifically the literature obtained from the Turkish, United Kingdom and South African studies and/reviews. This is due to the fact that it is employed throughout this study as a tool for comparison between the findings of those studies and reviews and the findings of this specific research study.

2.3   CHEST RADIOGRAPHY

Chest radiography is an X-ray projection of the chest, utilised to diagnose conditions affecting the chest and surrounding structures. This aspect makes chest radiographs the most commonly performed X-ray examination worldwide. The reasons for this include the ease with which a chest radiograph can be executed, lower radiation exposure to the patient and lower cost when compared with computed tomography (CT) scans (Raoof, Feigni, Sung, Irugulpati & Rosenow, 2012:545). A multitude of conditions can be diagnosed by means of chest radiography, such as those involving the chest wall, bones of the thorax and structures within the thorax, including the lung, heart and great vessels. Chest radiographs are also utilised to diagnose infectious diseases of the thorax and are used to screen for job-related lung diseases in industries such as mining, where workers are exposed to dust (Ibrahim, Daniel, Ayaninola, Ibrahim, Hamza & Umar, 2014:14).

It is important to establish LDRLs for the chest X-ray examination because the chest contains two radio-sensitive organs, namely the thyroid and breast tissue. Optimisation efforts will reduce the potential risk of stochastic effects on the patients (ICRP, 2017:63).

2.4   EXPLORING THE CONCEPT DIAGNOSTIC REFERENCE LEVELS

Diagnostic reference levels (DRLs) is a method used to aid in optimising the radiation protection of patients for diagnostic and interventional procedures. Chapter 1 eluded to the fact that the ICRP recommends the use of DRLs to optimise the radiation dose. DRLs are particularly useful for more common X-ray examinations, which may involve high doses or are frequently performed, such as chest, dental, lumbar spine,

7

mammography and barium enema (EC, 1999:12). Optimisation efforts should be prioritised based on the potential risk of stochastic effects on patients and priority given to those that result in substantial doses to radiosensitive organs (ICRP, 2017:63).

A DRL value is a selected level of a radiation dose quantity for broadly defined types of equipment for typical examinations for groups of patients within an agreed weight range or, in certain specific circumstances, a standard phantom (ICRP, 2017:40). These levels are expected not to be exceeded for standard procedures when acceptable practice regarding diagnostic and technical performance is applied (EC, 1999:6). In the radiology department, the DRLs of different radiological examinations are methods for optimising radiation dose in patients while maintaining diagnostic image quality. DRLs can be used to detect unusually high doses that do not contribute significantly to the clinical outcome of a medical examination (ICRP, 2017:140).

The ICRP indicate the aims of DRLs as follows:

- To improve a regional, national or local distribution of observed results for a general medical imaging task by identifying and reducing the number of unjustified high or low values in the distribution.
- To promote good practice for a specific imaging task, and
- To promote optimum values for a specific medical imaging protocol (ICRP, 2017:140).

It is important to differentiate between the terms DRL and LDRL since, in this study, LDRLs for chest x-ray examinations were determined. The abbreviation DRL is used to describe the DRL of a nation, a continent and international organisations' DRL values. On the other hand, LDRL illustrates the LDRL of a province, a district, surrounding group of hospitals and individual hospitals. The calculation and use of DRL and LDRL values are the same (ICRP, 2017:45).

2.4.1 Diagnostic reference levels for digital radiography

Digital radiography (DR) is a form of X-ray imaging, where digital X-ray sensors are used instead of radiating traditional radiographic film. The different types of DR are CR, charge-coupled devices and flat-panel detectors (FPD).

The advantages of digital detectors are that they permit the implementation of a fully digital picture archiving and communication system (PACS), with images stored digitally and available at any given time. Other advantages of DR are higher patient throughput and a greater dynamic range of digital detectors with the possible reduction of X-ray exposure to the patient (Korner *et al.,* 2007:676).

One of the advantages of digital radiography is the dynamic range. Dynamic range is the range of X-ray exposure over which a meaningful image can be acquired. Digital detectors have a wider dynamic range, which in clinical practice eliminates the risk of a failed exposure. The detector function improves as radiation exposure increases without saturation seen in film-screen imaging. However, care must be taken not to overexpose the patient by applying more radiation than is needed for a diagnostically sufficient image (Korner *et al.,* 2007:682).

The absence of deterioration of image quality at high doses means quality assurance (QA) and audit programmes are needed to ensure the patient dose is optimised to the task and that dose "creep" does not occur (ICRP, 2017:79). Dose "creep" is the unintentional overexposure of a patient to ionising radiation. Dose creep is a circumstance whereby radiation dosage has crept upwards due to a radiographer sometimes opting to use higher exposure factors, which results in a higher signal to noise ratio, producing a higher image quality with less noise. The radiographer is able to post-process the digital image to produce an image with better quality (Mc Fadden, Roding, de Vries, Benwell, Bijwaard & Scheurleer, 2018:137).

In collecting patient data on DRL quantities for DR, it is important to be aware of the detector type used so that the data may be analysed by detector type, as the values of the DRL quantities for specific examinations vary by detector, due to sensitivity differences. It may be worthwhile to consider the establishment of different DRL values for flat-panel detectors and CR detectors for the same procedure (ICRP, 2017:44).

In this study and the Iran 2018 study (Mohsenzadeh *et al.*, 2018: 6183-6191), DR systems were used, while in the South African 2009 study (Nyathi *et al.*, 2009:9-13) a film-screen system to obtain radiographs were used. In the other studies utilised for comparison, a mixed system was used. A mixed system is when DR systems and film-system are utilised to obtain radiographs and the dose results are used to determine DRL.

2.4.2 Diagnostic reference level quantities and values

For any diagnostic reference level (DRL) to be determined, there are certain quantities that need to be defined. The defined quantities ensure that the established DRLs meet the required standard of the ICRP. These quantities are the weight range, number of patients, image quality, ESAK calculation and radiographic system. These concepts are elucidated in the section that follows. The radiographic system was discussed in the aforementioned (see Section 2.4.1).

2.4.2.1 Weight range

The patient's weight is one of the criteria used to select patients to participate in this study. The weight of a patient is directly proportional to the radiation dose the patient will receive for a specific radiographic examination; it is important to have standardisation of the patient size. Standardisation of the patient size is achieved through weight restriction. Based on the ICRP (2017:49) recommendations, the weight range of this study is 60 kilogrammes to 80 kilogrammes. The studies that were conducted by the IAEA (IAEA, 2004:22) and Iran (Mohsenzadeh et *al.*, 2018:6184) utilised a similar weight range as ICRP. The weight range of the United Kingdom review (Hart, *et al.*, 2012:4) is 65 kilogrammes to 75 kilogrammes, while the weight range of the Turkey study is 64 kilogrammes to 96 kilogrammes (Bas Mor *et al.,* 2018:379). The Turkey study divided the weight range into subgroups of different weight ranges. In the South African study, the weight range was 41 kilogrammes to 127 kilogrammes (Nyathi *et al.*, 2009:11), while a study conducted in Europe by the International Code of Practice and the European Commission (EC) to determine clinical diagnostic reference levels did not indicate a weight range in its publication (Damilakis, Frija, Hierath, Jaschke, Mayerhofer-Sebera, Paulo, Repussard, Schegerer, Tsapaki & Verius, 2018:online).

2.4.2.2 Number of patients

According to the ICRP (2017:50), the minimum number of patients required to determine the DRL of any examination for a radiology department is twenty (20) patients. In lieu of this, the data of twenty patients that met the inclusion criteria for each X-ray room was captured during this research study.

2.4.2.3   Image quality

The highest priority for any diagnostic examination is achieving image quality sufficient for the clinical purpose in order for the image from the whole procedure to provide all the diagnostic information required (ICRP, 2017:60). However, DRL quantities are not descriptors of image quality. The DRL quantities at the radiology department that are above and, or below a particular value do not indicate that images are adequate or inadequate for a particular clinical purpose. A focus on DRL quantities alone, without image quality criteria, could drive the value of the DRL ever downward so that at some stage, image quality could be compromised. Image quality must be maintained at an appropriate level as the amount of radiation is decreased (ICRP, 2017:60). In DR, exposure index (EI) is the method used to determine whether the adequate image quality is achieved.

The EI is an indicator, which reflects the radiation exposure that is incident on a detector after an exposure event and that reflects the noise levels present in the image data. The purpose of EI is to facilitate the production of consistent and high quality digital radiographic images at an acceptable patient dose. This is not based on image optical density or brightness but on the feedback regarding the detector exposure provided and actively monitored by the imaging system. EI is also not a measure of patient dose (Shepard, Flynn, Gingold, Krugh, Leong, Mah, Ogden, Peck, Samei, Wang & Willis, 2009:2898).

An underexposed image has high noise content and therefore, can be readily recognised. However, an overexposed image has low noise and appears to be very acceptable, but without some indication of incident exposure level to the detector, this overexposure can go unrecognised with the corresponding unnecessary extra radiation dose to the patient (Seibert & Morin, 2011:581).

The EI value of each chest image has to be within the range of the EI as prescribed by the manufacturer of the X-ray machine for the anatomical area. The EI ranges of this study in Room 1 and Room 2 are 172 to 344. The EI for Room 3 is 300 to 500.

All the chest radiographs of the patients in this study who met the inclusion criteria had to be adequate and had to meet the acceptable image quality for diagnosis based on the image criteria prescribed by the EC guidelines. The prescribed image criteria for

an acceptable chest radiograph are attached as Appendix I. These criteria described are the prerequisites in term of the image standard for patient data to be included in this research study.

2.4.2.4 ESAK calculation

The radiation metric used for DRLs should be appropriate to the imaging modality being evaluated. It should assess the amount of ionising radiation applied to perform a medical task and be easily measured and determined (ICRP, 2017:13). Both DAP and ESAK can be used to determine the patient's radiation dose. ESAK was used for this research to determine the patient dose of chest X-ray examinations (see section 3.8.3). ESAK is the air kerma on the central X-ray beam axis at the point where the beam enters the patient (ICRP, 2017:21).

There are a number of different methods applied to measure the radiation dose in diagnostic radiography. These methods can be classified as direct or indirect methods. The direct methods are TLD and DAP, while the indirect method is described by IAEA (IAEA, 2007:130).

2.4.2.4.1 *Thermoluminescence dosimeter (TLD)*

TLDs are available in various types and made of various materials. Dosimeters most commonly used in medical applications are based on lithium fluoride doped with magnesium and titanium (IAEA, 2007:45).

The TLDs' chips are calibrated before use. The calibrated chips are annealed in an oven. The TLD chip is placed in the primary beam of X-rays, where the beam intercepts the irradiated part of the patient during exposure. The powder traps the radiation energy and when heated, this stored energy is released as emitted light. The measurement of the light is directly proportional to the radiation dose absorbed by the patient (Ball & Moore, 1994:213-226).

2.4.2.4.2 *Dose area product (DAP)*

DAP is defined as the absorbed dose in the air averaged over the area of the X-ray beam in a plane perpendicular to the beam axis, multiplied by the area of the beam in the same plane. The DAP is expressed in grey-centimetre squared ($Gy.cm^2$). In this quantity, radiation backscattered from the patient is excluded. It is mounted on the

12

diaphragm housing where it does not interfere with the examination (Institute of Physical Science in Medicine, National Radiological Protection Board & College of Radiographers, 1992:6).

The DAP meter has an ionisation chamber. This ionisation chamber is a vessel filled with air and positively as well as negatively charged electrodes. These electrodes are connected to a suitable electrometer. The response in terms of the charge collected by the electrodes is proportional both to the area of the chamber that is exposed to the primary X-ray beam and the dose (Institute of Physical Science in Medicine, National Radiological Protection Board & College of Radiographers, 1992:7).

2.4.2.4.3   ESAK calculation using IAEA method

The IAEA prescribed the ESAK method for the calculation of radiation dose in radiography. This method is expounded in Section 3.8.3. All the research studies utilised for comparison in this study employed this method to calculate the radiation dose.

2.4.3 Local diagnostic reference levels (LDRLs)

An LDRL value has often been defined as the 75th percentile of the median value of the ESAK values of the radiology department for a specific procedure. The 75th percentile is the same as the 3rd quartile, which are the ESAK values of the distribution arranged in ascending order and divided into four equal populated subgroups. The 75th percentile was chosen as an initial separator between acceptable and excessive values, but it is arbitrary and has no real scientific basis. However, the 75th percentile usually lies well below the high dose 'tail' of the distribution and serves as a useful marker for the identification of facilities whose results lie towards the upper end of the distribution (ICRP, 2017:57).

2.4.4 Using LDRLs for optimisation of protection

An LDRL quantity for medical imaging procedures for a specific X-ray room or a radiology department is compared with published DRL values to identify whether the data for the location is substantially higher or lower than local and national or organisations DRL values (ICRP, 2017:16).

An LDRL is exceeded when the LDRL quantity for a sample of a standard-sized patient at a facility is greater than the local or national value. If the LDRL value for any procedure is exceeded, an investigation might be undertaken without undue delay to determine possible reasons, and a corrective action plan should be implemented and documented (ICRP, 2017:16).

2.4.5 Corrective action

If a DRL value is exceeded, this must be investigated without undue delay. The outcome of the investigation should identify why the DRL value has been exceeded. If needed, remedial measures should be identified and instituted before commencing the next audit cycle (ICRP, 2017:103). The factors that are most likely to require remediation are survey methodology, equipment performance, procedure protocol, radiographer skill knowledge training and case-mix. These factors are described in the following five sections.

2.4.5.1   Survey methodology

The first aspect to be considered if a DRL value is exceeded is whether a survey was carried out following the correct steps consistent with how the DRL value was set in the first place. According to the ICRP (2017:105) the type of questions that should be asked to obtain this information are:

- Was the measurement device or system that was used calibrated correctly?
- Were all calculations performed using appropriate correction and calibration factors and based on the output measurement?
- Were the data for any patients who did not qualify for the group inadvertently included?

2.4.5.2   Equipment performance

The imaging equipment might be the reason for the LDRL being exceeded. Possible reasons for this might be relating to different types of equipment, such as the following outlined by the ICRP (2017:104),

- Use of a lower tube potential than what is required.
- Use of a shorter focus-to-image receptor distance.

- Use of a patient couch not designed for X-ray imaging.
- Use of a combination of CR/DR (FPD) and film techniques in the same facility.
- The difference in grid ratios usage.

2.4.5.3 Procedure protocols

When a radiograph meets the evaluation criteria of the projection, it is a result of the technical factors used at the facility. In general, a high kilo-voltage peak (kVp) and low milli-amperage per second (mAs) technique is used to produce chest radiographs. The kVp should be high enough to result in sufficient contrast to demonstrate the many shades of grey. This requires high kVp settings of 110 to 125 (Bontrager, 2014:79).

2.4.5.4 Radiographer skill, knowledge and training

The use of appropriate protocols for examinations depends on the radiographer's knowledge, skill and training. Practices of individual operators may vary due to a lack of knowledge on using the different radiographic systems in the department. Radiographer skill also extends to awareness and management of dose-saving features of the equipment. Variations in radiographer's skill can result in a large variation in the value of DRL quantities for the same procedure. When the median value for individual radiographers are found to be higher than for other radiographers, and especially when they exceed the DRL value, training on specific equipment may be necessary, particularly concerning dose saving features (ICRP, 2017:112).

2.4.5.5 Case-mix

Case-mix indicates that it may not be appropriate to compare DRL quantities for procedures performed in certain patient populations with DRL values determined from a survey of the general population. Chest X-rays performed in a specialist clinic may require higher image quality of the image for specific diagnoses (ICRP, 2017:113). For example, if a patient is referred for a chest X-ray with a clinical history of pneumonia, the radiographer needs to increase the exposure factors to produce a radiograph of high quality.

15

2.5 RADIATION PROTECTION

Radiation protection principles for DRL are based on the justification of the practice and optimisation of radiation protection.

2.5.1 Justification of the practice

The justification for medical exposure of patients vests with medical professionals. The main aim of medical exposures is to do more good than harm to the patient. Justification of a defined radiological procedure is a specific procedure with a specific objective that is defined and justified. The aim of this level of justification is to judge whether the radiological procedure will improve the diagnosis or treatment or will provide necessary diagnostic information about the exposed individual (ICRP, 2007:127).

Justification of a procedure for an individual patient's exposure should include checking that the required information is not already available and that the proposed examination is the most suitable method of providing the clinical information. This includes the details of the proposed procedure and alternative procedures, the characteristics of the individual patient and the expected dose that the patient will receive (ICRP, 2007:127).

2.5.2 Optimisation of radiation protection

The process of optimisation in radiation protection is intended for application to those situations that have been deemed to be justified. The principle of optimisation is defined by the ICRP as the source-related process to keep the likelihood of incurring exposures, the number of people exposed, and the magnitude of individual doses ALARA, taking economic and societal factors into account. The process of optimisation over the past decades has resulted in substantial reductions in occupational and public exposure (ICRP, 2007:91).

Optimisation is a frame of mind, always questioning whether the best has been done in the prevailing circumstance and whether all that is reasonable has been done to reduce the dose. It also requires commitment at all levels and adequate procedures and resources (ICRP, 2007:92).

2.6 DETERMINISTIC AND STOCHASTIC EFFECTS

Biological damage from radiation exposure is classified as either deterministic effects on tissue or stochastic effects on cells.

Deterministic effects occur after the absorbed dose exceeds a dose threshold that leads to an observable biological change, which usually is a result of an inflammatory response by the organ or a reaction to cellular death. The severity of the tissue reaction increases with the magnitude of the radiation dose. Larger doses will result in temporary organ impairment or death (Choudhary, 2018:1).

Stochastic effects neither occur after a dose threshold nor do the severity of the stochastic effect increase with radiation dose. It is believed that the radiation dose will increase the probability of a stochastic effect occurrence; that is, the long-term potential of cancer or hereditary effects will increase with radiation dose (Choudhary 2018:2).

At low exposure levels, statistical limitations make it difficult to evaluate cancer risk in humans. This has led to the use of the "as low as reasonably achievable" (ALARA) principle for radiation protection. The full extent of biological changes caused by radiation exposure is not yet known; therefore as little radiation as possible should be administered when obtaining diagnostic quality images. The main task of radiation protection is not only to minimise the stochastic risks but also to avoid deterministic injuries (Edmonds, 2009:32).

2.7 DIFFERENCES IN PATIENT DOSES

A survey conducted in the United Kingdom (UK) during the early 1980s showed that mean doses from similar radiographic examinations varied by a factor of seven between hospitals and a factor of a hundred was present between doses of individual patients. It was apparent that in many hospitals, the dose levels were much higher than required to provide a sufficiently high-quality image for the radiologist to make a diagnosis (Martin, 2006:1). Some of the factors that influence the differences in patient doses are tube potential, filtration, grid and beam collimation.

2.7.1 Tube potential

The tube potential applied to the X-ray tube determines both the maximum photon energy and the proportion of high energy photons. The ESAK will be reduced by approximately 50% if the tube potential is increased by ten kilo-volts (kV). Standard kV ranges have been recommended for a selection of common radiographic examinations. Patient doses will be significantly greater if lower tube potentials are used than those recommended. As the thickness of the part of the patient's body that needs to be imaged or the weight of the patient increases, the exposure will need to be increased. If the potential remains the same, the ESAK is approximately doubled for each additional 50 millimetres (mm) of tissue in the range of 80 kVp to 100 kVp and will increase by 2.5 to 3 times at 60 kVp. Therefore, the tube potential will normally be increased for larger patients to keep the dose at a reasonable level (Martin, 2006:9).

2.7.2. Filtration

A thin sheet of metal, such as aluminium (Al) or copper (Cu), is incorporated into diagnostic X-ray tubes to reduce the proportion of low energy photons transmitted through the patient. A filter of at least 2.5 mm of Al is a standard requirement for all medical X-ray tubes. Copper will absorb a higher proportion of lower energy photons than aluminium, contributing significantly to patient ESAK (Martin, 2006:9).

2.7.3 Grid

Radiation scattered from tissue within the body increases the level of random background noise on the film and this degrades the visibility of low contrast details. The amount of scattered radiation can be reduced using the anti-scatter grid (Martin, 2006:10).

X-ray photons do not change direction as they are transmitted through the patient pass between the lead strips with little attenuation, whereas scattered photons are more likely to be attenuated by the lead strips. The grid attenuates the transmitted primary beam and removes scattered radiation, which requires a higher intensity X-ray beam resulting in a higher radiation dose to the patient (Martin, 2006:10).

A higher tube potential (110-130kV) with a grid is used to obtain chest radiographs, as these improve detailed visibility in the higher attenuation mediastinal area and

produces better image quality over the whole image. When tube potentials of 100 kVp or above are employed for chest radiography, a high scatter fraction is produced and a high sensitivity grid (12:1 to 18:1) should be used (Martin, 2006:10).

2.7.4 Beam collimation

The amount of scattered radiation will increase if a larger volume of tissue is irradiated. Therefore, optimum collimation will minimise the dose to the patient as well as improve the image quality. Collimation in most cases depends on the technique of the radiographer. Regular quality assurance is required by checking that the X-ray beam and the field from the light beam diaphragm are accurately aligned (Martin, 2006:12).

2.8 CONCLUSION

In this chapter, a theoretical framework to support the research study was provided. This chapter also outlined the reasons why chest X-ray examinations were utilised in this study. In the chapter that follows, the methodology utilised as well as the ethical consideration adopted in this study are described.

CHAPTER 3

METHODOLOGY

3.1   INTRODUCTION

In this chapter, the steps that were taken to collect data for this research are explained. In addition, the research design, study location, research tools, sampling method and inclusion and exclusion criteria are defined. The measures that were taken to ensure that the research results are valid and reliable are also outlined.

3.2   RESEARCH DESIGN

This research is a cross-sectional study whereby patient dose was determined in terms of the ESAK at a specific point in time. Brink, van Der Walt, and van Rensburg (2016:115) define cross-sectional studies as studies that are utilised to examine data at a point in time, that is, the data at/on one occasion only with different participants. The data were collected from patients who visited the radiology department for chest X-ray examinations. This research study did not require participants to return for follow-up chest X-ray examinations.

It is also a quantitative research study. Quantitative research studies are concerned with collecting and analysing data that is structured and can be represented numerically. One of the central goals is to build accurate and reliable measurements that allow for statistical analysis. Quantitative research focuses on data that can be measured-; it is very effective at answering the "what" or "how" of a given situation. Questions are direct, quantifiable, and often contain phrases such as: What percentage? What proportion? How many? and How much? (Goertzen, 2017:12-18). By using this method, it was determined how much radiation dose a patient receives for each projection. An indirect method was utilised to determine patients' dosage (IAEA, 2004:130).

3.3   THE STUDY LOCATION

This research was conducted at the diagnostic radiology department of a government hospital in the Northern Cape. This is a tertiary hospital with multi-disciplinary departments, including a radiology department. According to the Department of Health (2012:5), a tertiary hospital provides specialist level services, sub-specialities of

specialities referred and intensive care services under a specialist's supervision. A tertiary hospital may provide healthcare services training and receive referrals from regional hospitals not limited to provincial boundaries. A tertiary hospital has between 400 and 800 beds.

The research site has the following sections: fluoroscopy, general radiography, magnetic resonance imaging (MRI), computed tomography (CT), dental imaging and mammography. The general radiography section has three stationary X-ray machines. One DR (FPD) and two CR units comprise the stationary X-ray machines. All three X-ray machines were used to obtain chest radiographs and subsequently calculate LDRLs for this study.

3.4   RESEARCH TOOLS

The tools that were used for this study were a weighing scale, calliper, exposure parameters and a data sheet.

A weighing scale was used to measure the weight of patients referred for chest X-ray examinations at the radiological department of a government hospital in the Northern Cape. A calliper was employed to measure the thickness of the patient's chest at the centring point, which is at the level of the 7th thoracic vertebra (T7) in the midsagittal plane (PA projection) and midaxillary line (LAT projection) (Bontrager, 2014:83). The two projections (PA and LAT) measurements were on level T7 at 90-degree angles to each other. The selected exposure parameters mAs and kVp were displayed on the control panel when the patient was exposed. The radiographers documented these values on the datasheet (Appendix G).

3.5   STUDY POPULATION

Welman, Kruger and Mitchell (2005:52) define the population as the study object and consists of individuals, groups, organisations, human products and events or condition to which they are exposed. The target population consists of 18 years and older patients, referred for chest X-ray examinations and weighs from 60 kg to 80 kg at the radiology department of a government hospital in the Northern Cape Province.

3.6   SAMPLE AND SAMPLING METHOD

Non-probability sampling was used for this study. Non-probability sampling is usually more convenient and economical than random sampling. It allows the study of the populations when the researcher is unable to locate the entire population (Brink *et al.,* 2016:139).

A purposive sample is part of a non-probability sampling method. The purposive sampling method was the sampling method used for this study. This technique is based on the judgement of the researcher regarding participants or objects that are typical or representative of the study phenomenon (Brink *et al.,* 2016:141). The advantage of purposive sampling is that it justifies researchers to make generalisations from the sample that is being studied (Sharma, 2017:751).

The characteristics of the participants of this research study are based on the recommendations of the ICRP and informed consent (see Section 3.7). As suggested by the ICRP (2017:49), standard size patients were selected for this study. Standard size patients are patients whose weight are approximately 10 kilogrammes of the mean population being considered. According to the most recent publication by the Department of Health (Shisana, Labadarios, Rehle, Simbayi, Zuma, Dhansay, Reddy, Parker, Hoosain, Naidoo, Hongoro, Mchiza, Steyn, Dwane, Makoae, Maluleke, Ramlagan, Zungu, Evans, Jacobs and Faber, 2014), the mean weight of the South African population is 70 kilogrammes. Thus, patients who weigh from 60 kilogrammes to 80 kilogrammes were included to participate in this study. The patient had to be referred for a routine chest X-ray examination, be 18 years and older and agree to sign the informed consent form. The first 60 patients who met these criteria were selected to participate in this study.

3.7 INCLUSION AND EXCLUSION CRITERIA

The inclusion and exclusion criteria applied to select participants for the study are presented in Table 3.1.

Table 3.1   Inclusion and exclusion criteria of participants

Inclusion criteria	Exclusion criteria
Patients aged equal to and older than 18 years (HPCSA, 2016:10).	Patients who are not able to stand on the scale.
Patients referred for chest X-ray examinations.	Mobile chest X-ray examinations.
Patients weighing from 60 kg to 80 kg.	Patients weighing below 60 kg and above 80 kg.
Exposure index (EI) of chest X-ray examination within the manufacturer range (see Section 3.8.2.1).	Pregnant women.
Casualty patients	Casualty patients were excluded from the study because the majority of the patients are injured and cannot stand for chest X-ray examination.

3.8 DATA COLLECTION

Data collection is the process of collecting and measuring information on variables of interest in an established systematic fashion that enables one to answer stated research questions, test hypothesis and evaluate outcomes (Kabir, 2016:202). In this study, data collection was done in three phases, namely quality control (QC), chest imaging procedure and ESAK calculation.

3.8.1 Phase 1: Quality control (QC)

An appropriately trained professional registered with the HPCSA as a medical physicist ensured that all three monthly/yearly QC tests on all the stationary X-ray machines used for chest examinations at this hospital were performed and that the results met the requirements of the DRC (2015:14). The medical physicist carried out the following tests before the data collection process: accuracy and reproducibility of kVp, accuracy and reproducibility of exposure time, the linearity of output with milli-ampere (mA) and time, light/radiation beam alignment, X-ray tube warm-up, indicators, mechanical and other safety checks, general test: gonad shields, lead rubber aprons and gloves, collimation, detector dose indicator, image uniformity, condition of image plates, phosphor plate dark noise, automatic exposure control sensitivity and the state of the reporting monitor.

3.8.2 Phase 2: Chest imaging procedure

The researcher did a formal presentation at the radiology department. The presentation entailed a detailed explanation of the purpose of DRLs and how data will be captured for this study.

A total of seven radiographers assisted with the data collection process. All the radiographers who assisted with this research study's data collection had to complete and sign a letter of non-disclosure of patients' information (Appendix K) and a radiographer's consent form for research data collection (Appendix L).

The radiographer explained the study to the patients that were referred to the research site for chest X-ray examination (PA and LAT images). The patients received an information booklet (Appendices C, D, E & F). The information booklet was written in English and later translated into three local languages, namely, Afrikaans, Sesotho and Setswana. The patients signed the informed consent form to participate in the study.

All the willing patients referred for chest X-rays signed the informed consent form at the research site before they were weighed. Those patients with a body weight of 60 kilogrammes to 80 kilogrammes and adhered to the inclusion criteria were included in the study. A calliper was used to measure the patient thickness at the 7th thoracic vertebra for PA and LAT projections of the chest. The patient was imaged by a

qualified radiographer using the radiographer's own choice of exposure factors. The radiographer used either manual or automatic exposure settings. The weight, patient measurement (thickness), exposure parameters, focus film distance (FFD), room number, grid ratio and total filtration value were recorded on a data sheet (Appendix G). All the different categories of radiographers (community service and qualified radiographers) were registered with the HPCSA and assisted in documenting the exposure settings as well as other details as per Appendix G of this research study. Radiographers had to follow the standard procedure of the department to do chest X-ray examinations. The only additional action was that the patients were weighed and measurements were taken (thickness). Radiographers participating in data collection needed to follow the specific procedure of patient management, as attached in Appendix H.

Radiographers made use of the EI and the prescribed image criteria for an acceptable chest radiograph (Appendix I) to determine if a radiograph meets the criteria to be included in this study (refer to Section 2.4.2.3).

No retrospective data were investigated or captured in this research study. This means that no data of chest X-ray examinations from the PACS were utilised in this research.

3.8.3 Phase 3: ESAK calculation

In general radiography, the patient dose can be estimated with the DAP or ESAK. Not all X-ray machines have a DAP meter; hence ESAK was used to estimate patient dose.

ESAK can be measured directly or estimated indirectly. A direct measure of the dose is done with TLD. TLDs were not used to determine patient dose in this study because of the fading process. Fading is the action wherein trapped charges, which result from X-ray exposure, are slowly released at room temperature. The fading effect must be corrected for when evaluating TLDs long after irradiation. TLDs do not provide real-time information about the patient dose (IAEA, 2007:47). TLDs are also expensive and require a specific readout specification or environment.

Although TLDs are the gold standard to assess ESAK in radiological examinations, the indirect method is still widely used for dose assessment. This method is the most straightforward approach to adopt since it involves less additional equipment, but it

does require one to take a measurement of X-ray unit output. An indirect method of measuring patient dose is through the evaluation of ESAK from measured kVp, mAs, focus to skin distance (FSD) and X-ray tube output using an empirical formula (Essien, Inyang & Egbe , 2016:7).

The air kerma [K(d)] values at different kVp settings were first to be determined by using a calibrated detector (RaySafe: X2R/F). The detector was placed at one-meter focus detector distance (FDD) on top of the X-ray machine table in the central beam axis. The k(d) was measured at different kVp settings from 40 kVp to 125 kVp in 10 kVp steps and the mAs was kept constant at 20 mAs (Taha, Al-Ghorabie, Kutbi & Saib, 2015:101). The mAs, kVp and K(d) were recorded by the medical physicist. This process was repeated three times for the same setting, after which the mean K(d) was determined.

The X-ray tube output [Y(d)] was determined by dividing the air kerma value by mAs (IAEA, 2007:129).

$$Y(d) = K(d)/mAs \qquad \text{equation (1)}$$

A graph was plotted with the X-ray tube output on the y-axis and the kVp settings on the x-axis. An equation was created from this graph. This equation was used to determine the X-ray tube output at different kVp settings.

The incident air kerma patient exposure was directly calculated by using the tube efficiency and the inverse square law as

$$K_i = Y(d) \times mAs \times (d/(d_{FTD} - p_t))^2 \qquad \text{equation (2)}$$

Where k_i is the incident air kerma, d is the distance between the detector and the Tube focal spot, d_{FTD} is the distance between the tube focal spot and the table and p_t is the patient thickness at the irradiation site (Rasuli, Mahmoud-Pashazaden, Ghorbani, Juybari & Naserpour , 2016:377).

ESAK was calculated by the product of the calculated values of incident air kerma (dose free in air) and backscatter coefficient (BSC). The BSC is the conversion that relates the incident air kerma to the ESAK. A BSC is defined as the quotient between the absorbed dose on the surface of the patient (skin) to the absorbed dose at the same point in space in the absence of the patient. This parameter provides the factor

26

by which the radiation dose at a determined point in air is increased by radiation scattered to the same point from the patient (Rasuli *et al.,* 2016:377). The BSC varies between approximately 1.3 and 1.4 for general radiography, except for mammography; thus, a single average value of 1.35 can be employed in most situations without appreciable error (EC, 1996:28).

A pilot study was performed, with the data of the first ten patients who accepted to participate in the research. The first ten patients compromised of the first three patients data of each X-ray room and were utilised for the pilot study (refer to Section 3.10).

3.9   DATA VERIFICATION AND ANALYSIS

The researcher verified all the patient data to ensure that the data met the inclusion criteria. The researcher entered the data into the database and then a second person (radiographer) performed the data validation independently. To verify if the Microsoft Excel spreadsheet was programmed correctly, the Excel results were compared with manual calculations. This action also assisted in identifying errors in the design of the datasheet. Data were grouped according to X-ray rooms.

The ESAK values for each X-ray room were arranged in ascending order. The mean of each X-ray room was determined by adding all the ESAK values for each of the projections and dividing the total by the number of patient procedures carried out in that X-ray room. The radiology department LDRL is the 75th percentile of the median value of the distribution of ESAK values of the survey of each projection. The LDRLs for DR (FPD) and CR were also to be determined separately. A comparison was made between the DR (FPD) and CR systems. This comparison was made in order to evaluate the differences in ESAK and LDRLs of both systems. The LDRL for each X-ray room was calculated. The research site's LDRLs (PA and LAT chest X-ray examinations) were compared with DRLs of both national and international organisations cited in the literature.

The range is the difference between the smallest and the largest value in a distribution. The range is useful for displaying the spread within a distribution and for comparing the spread between similar distributions. The range of the mAs, kVp and ESAK of the research site was determined. Tables were drawn to indicate the different grid ratios, type of filters and thickness of the filter for each X-ray machine. The total number of

patients who participated in the study and the mean patient weight of each X-ray room was demonstrated by means of tables (refer to Chapter 4).

To summarise, the researcher captured all data electronically onto a Microsoft Excel spreadsheet. Statistical analysis was done by a statistician using SAS (Version 9.2). Means and standard deviations or medians and percentiles were calculated for numerical data. Analytical statistics, namely the Shapiro-Wilk test, was performed to test for the normality of the distributions (Hanusz & Tarasińska, 2014:35). A p-value of distribution less than 0.05 indicated that the distribution and the data are skewed. The report was done on the median. If the p-value of the distribution was greater or equal to 0.05, the distribution and the data are not skewed. The report was done on the mean and standard deviation.

According to Chan and Walmsley (1997:1755), the Kruskal-Wallis test is used to decide whether three or more independent groups are the same or different on some variable of interest when an ordinary level of data or an interval or ratio level of data is available. The Kruskal-Wallis test was utilised to compare the variable of the three X-ray rooms. A p-value of less than 0.05 indicated that there was a significant difference in the median values of the three X-ray rooms. A p-value greater or equal to 0.05 revealed that there was no significant difference in the median values of the three X-ray rooms. Mann-Whitney U-test is a non-parametric statistical technique. It is utilised to analyse differences between the medians of two sets of data. In order for the Mann-Whitney U-test to be applied, values need to be measurable on an ordinary scale and comparable in size (Milenovic, 2011:73). The Mann-Whitney U-test was used to compare the variables of two X-ray rooms or the DR (FPD) and CR systems. The interpretations of the Mann-Whitney U-test are similar to the Kruskal-Wallis test. A significance level of 0.05 was used.

3.10   PILOT STUDY

A pilot study is a small scale study conducted prior to the main study on a limited number of participants from the study population. Its purpose is to investigate the feasibility of the research study and detect possible flaws in the methodology (Brink *et al.,* 2016:175).

During the pilot study, the information from the datasheet, the programmed Microsoft Excel spreadsheet, was used to calculate ESAK. The radiographers followed the prescribed procedure for collecting data, verifying the data, and avoiding pitfalls. The first ten patients' data were used for the pilot study and were included in the research, as there were no changes between the pilot study (data collection) and the research study.

The electronic spreadsheet was utilised to calculate the ESAK for each pilot study patient. A manual calculation was also done for each pilot study patient. The results of the manual calculation and the electronic spreadsheet calculation were compared. The electronic spreadsheet and manual calculation of the ESAK for each pilot study patient were the same; thus, the datasheet and programmed electronic spreadsheet were deemed reliable and valid.

The pilot study allowed the researcher to practically teach the radiographers how to measure the participants' weight and thickness correctly. It also enabled the researcher to answer questions from the radiographers.

3.11   ETHICAL APPROVAL

Research ethics are the moral principles that govern how researchers carry out their work. These principles are used to shape research regulations agreed by groups such as University governing bodies, communities or government. The three fundamental ethical principles are; the principle of respect for a person, the principle of beneficence and the principle of justice (Brink *et al.,* 2016:43).

The benefits of ethics are:

- To guard/protect human participants rights, dignity and welfare.
- To make sure that research is directed in a manner that assists welfares of persons, groups and/or civilisation as a whole.
- To inspect particular research events and schemes for their ethical reliability, considering issues such as the controlling risk, protection of privacy and the progression of informed consent (Adhikari, 2020:online).

Approval to conduct the study was obtained from the Health Science Research Ethics Committee of the Faculty of Health Sciences (HSREC: UFS-HSD2018/1610/2603)

(Appendix M), University of the Free State (UFS) and the deputy manager of the radiological department of a government hospital in the Northern Cape Province as well as the Northern Cape Department of Health. The research was conducted according to the ethical guidelines and principles of the International Declaration of Helsinki (World Health Organisation (WHO), 2001:373-374).

3.12   INFORMED CONSENT

According to Adhikari (2020:online) informed consent means that a person knowingly, voluntarily and intelligently gives consent to participate in research. All participants of this study did so on a voluntary basis. The objectives of this study were explained to all participants in their home language in order to facilitate full comprehension. No patients participating in this research received additional radiation. Patients who did not want to participate were not discriminated against.

All patients participating in this research signed an informed consent form (Appendices C, D, E & F), which explained the details of the study. A radiographer verbally explained and informed the patient about the procedure before signing the informed consent form. Patients received their routine X-ray examinations of the chest as requested and thus did not receive any additional projections; therefore, approval of the Radiation Control Committee was not required. Information, which could be used to identify the patient was not captured (refer to Appendices C, D, E & F for details required for the study). The accession number of the patient was merely recorded. Other patient identification- details were not captured and patient confidentiality and anonymity were maintained.

3.13   VALIDITY

Instrument validity strives to ascertain whether an instrument accurately measures what it is supposed to measure, given the context in which it is applied (Brink *et al.,* 2016:165). The instruments that were used for this research are deemed valid because a weighing scale measures the weight of a patient in kilograms and a calliper measures the thickness of the patient at the centring point in centimetres (cm). The formula and procedure that were used to estimate dose to patients are recommended by the IAEA and other researchers have successfully used this formula and procedure to estimate patient dose. A pilot study was used to achieve validity.

3.14   RELIABILITY

Reliability refers to the degree to which the instrument can be depended upon to produce consistent results if utilised repeatedly over time on the same person (Brink *et al.,* 2016:169). A known weight of 70kg was placed on the weighing scale. The reading on the weighing scale and the value of the known weight correlated; the weighing scale was deemed reliable. The calliper measurement was compared to a measuring meter. The measurements were the same; therefore, the calliper was deemed reliable. QA and QC were performed on the X-ray machines at regular intervals as per the QA guidelines to ensure the exposure parameters were reliable. The specific tests were: accuracy and reproducibility of kVp, accuracy and reproducibility of exposure time and linearity of the output with mA and time.

3.15   CONCLUSION

This chapter outlined the procedure that was followed to obtain patients' data and the calculation method of ESAK is outlined. Ethical considerations taken by the researcher ensured that the principles of the international Declaration of Helsinki were respected and adhered to during this study.

In Chapter 4 that follows, the results are presented and illustrated by using tables. A detailed discussion of the results is also provided. In this chapter, the ESAK of CR and DR (FPD) systems are also compared. The determined LDRLs of chest X-ray examinations of the research site are also discussed in this chapter.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

The results and discussion of this study are presented in this chapter. The demographics of patients, radiographic parameters, ESAK and LDRLs, are presented in table format, followed by a discussion. A comparison between the X-ray rooms and CR and DR (FPD) systems are also examined. The LDRLs of the research site is compared to international organisations' DRLs.

The results and discussion are presented in three sections, namely, quality control, chest imaging and the ESAK calculation.

4.2 QUALITY CONTROL

The specifications of the three X-ray machines at the research site that were used for chest X-ray examinations are presented in Table 4.1. See the list of QC tests performed at this research site in section 3.8.1.

Table 4.1   Specifications of the X-ray machines at the research site

SPECIFICATIONS	ROOM 1	ROOM 2	ROOM 3
Make	SHIMADZU	SIEMENS	PHILIPS
Model	UD 150V-40	POLYDOROS IT	DIGITAL DIAGNOST TH
Date of installation	25-July-12	24-June-04	18-April-11
Max/Min mAs	0.5 – 800 mAs	0.5 – 800 mAs	0.5 – 850 mAs
Max /Min kVp	40 kV - 150 kV	40 kV – 150 kV	40 kV – 150 kV
Total filtration	2.5 mm Al at 70kV	2.5 mm Al at 70kV	2.5 mm Al at 70 kV
Screen size in cm	35x43	35x43	35x43
Exposure setting	Manual	Manual/Automatic	Manual/Automatic
Grid ratio	-	17:1	12:1
Prescribed EI range	172 - 344	172 - 344	300 - 500

mAs= mill-amperage per second; kVp= kilo-voltage; min= minimum; max= maximum; kV= kilo-voltage; cm= centimetre; mm= millimetre; EI=exposure index; - = no data available.

Table 4.1 illustrates the specifications of the X-ray machines used for general radiography at the research site. Room 1 and 2 are CR units, while Room 3 is a digital radiography unit. The total filtration and Max/Min kVp were the same for all the X-ray rooms. The total filtration of these machines is less than the requirement of the EC, which is greater and equal to 3 mm Al (EC, 1999:20). According to Martin (2006:9), the 2.5 mm Al filtration meets the minimal requirement for an X-ray machine. The grid ratios of the X-ray machines were greater than the required standard of the EC, which is 10:1 (EC, 1999:20).

4.3   CHEST IMAGING

This section shows how different kVp, mAs and FFD settings were used to produce chest radiographs of patients with varying weights and chest thicknesses for the three X-ray rooms (Tables 4.2, 4.3 and 4.4).

4.3.1 Number of patients performed with CR and DR (FPD) system in each room

The first sixty patients who met the inclusion criteria were included in the study. The data of twenty patients were collected from each X-ray room used in the study. The chest X-ray examinations were performed in the three general X-ray rooms at the research site. Room 1 and Room 2 made use of a CR system. A total of forty patients were radiographed with the CR system. Room 3 utilised a DR (FPD) system and a total of twenty patients were radiographed using the DR (FPD) system. All sixty patients were radiographed for both PA and LAT chest X-ray examinations.

According to the ICRP (2017:50), the minimum number of patients required to determine the DRL of any general radiography examination for a radiology department are twenty patients. This is the reason twenty patients' data who met the inclusion criteria were captured for each X-ray room. This special number of patients (n=20), allowed for the LDRLs for chest X-ray examinations of each X-ray room on both DR (FPD) and CR systems to be calculated.

Table 4.2   Patients' weight and thickness for PA and LAT chest projections

Variable	n	PA CHEST PROJECTIONS					LAT CHEST PROJECTIONS				
		Mean	Median	Min	Max	Range	Mean	Median	Min	Max	Range
Weight in kg	60	69.6	70.5	60	80	20	69.6	70.5	60	80	20
Thickness in cm	60	23.5	23	18	31	13	29.2	30	18	37	19

n= number of patients; min= minimum; max= maximum; PA= postero-anterior; LAT= lateral; kg= kilograms, cm= centimetre.

The weight, falling into the specified weight range of standard size patients, was one of the inclusion criteria for patients to participate in this study. The weight range for standard size patients for this research study was from 60 kg to 80 kg (refer to Section 3.6). The mean weight for patients included in this research study was 69.6 kg (Table 4.2). The mean weight for patients included in this study compares well with the mean weight (70 kg) of the RSA population (Shisana et al. 2014). The mean weight for patients included in this study indicates that this study met the criterion of weight range as prescribed by the ICRP (ICRP, 2017:49). The mean thickness measurements of the participants of the research study were 23.5 cm and 29.2 cm (Table 4.2) for PA and LAT chest projections respectively.

Table 4.3   Patients' weight and thickness measurements for PA and LAT chest projections of each individual X-ray room

Room	Variable	n	PA CHEST PROJECTION				LAT CHEST PROJECTION			
			Mean	Median	Min	Max	Mean	Median	Min	Max
1	Weight in kg	20	69.3	68.5	60.0	80.0	69.3	68.5	60.0	80.0
	Thickness in cm	20	22.3	22.0	18.0	30.0	27.9	28.0	18.0	34.0
2	Weight in kg	20	70.0	68.8	60.0	80.0	70.0	68.8	60.0	80.0
	Thickness in cm	20	24.4	24.0	19.0	31.0	29.1	30.0	21.0	34.0
3	Weight in kg	20	69.5	72.6	60.0	79.9	69.5	72.6	60.0	79.9
	Thickness in cm	20	24.0	23.5	20.0	31.0	30.6	30.0	25.0	37.0

n= number of patients; min= minimum; max= maximum; PA= postero-anterior; LAT= Lateral; kg= kilograms, cm= centimetre.

As revealed in Table 4.3, the maximum thickness of the LAT chest projection of each X-ray room was higher than the PA chest projection for all three X-ray rooms. Room 3 has the highest mean thickness of 30.6 cm for the LAT chest projections, while Room 2 has the highest mean thickness of 24.4 cm for the PA chest projections. The least mean thickness was recorded in Room 1 with 22.3 cm for the PA chest projection and 27.9 cm for the LAT chest projection.

The mean weight of the patients from the three X-ray rooms was similar for both chest projections. This is because each participating patient was radiographed for both PA and LAT chest projections. Room 2 has the highest mean weight value of 70 kg, while Room 1 has the lowest mean weight value of 69.3 kg for both chest projections.

Table 4.4   Radiographic parameters for PA and LAT chest projections per X-ray room

Room	Variable	n	PA CHEST PROJECTION				LAT CHEST PROJECTION			
			Mean	Median	Min	Max	Mean	Median	Min	Max
1	mAs	20	4.2	4.0	3.2	5.6	11.2	12.5	6.5	14.0
	kVp	20	110.0	110.0	102.0	119.0	113.9	113.0	103.0	122.0
	FFD	20	180.0	180.0	180.0	180.0	180.0	180.0	180.0	180.0
2	mAs	20	4.2	4.0	3.2	5.0	8.9	8.5	6.3	12.5
	kVp	20	111.9	109.0	107.0	117.0	118.4	117.0	109.0	125.0
	FFD	20	178.5	180.0	150.0	180.0	178.5	180.0	150.0	180.0
3	mAs	20	2.4	2.2	1.0	4.0	9.0	7.9	3.4	19.8
	kVp	20	119.1	121.0	102.0	125.0	118.6	117.0	109.0	125.0
	FFD	20	177.0	180.0	150.0	180.0	177.0	180.0	150.0	180.0

n= number of patients; min= minimum; max= maximum; PA= postero-anterior; LAT= lateral; mAs= milli-ampere per second; kVp= kilo-voltage peak; FFD= focus film distance.

To obtain a chest radiograph, the radiographer has to select exposure parameters. These parameters are kVp, mAs, and FFD. The kVp and mAs are selected based on the thickness of the patient's chest. The FFD is most often at 150 cm or 180 cm. To achieve an optimal chest radiograph, a high kVp and low mAs technique are used.

Table 4.4 illustrates that the mAs of the PA chest projection for Room 1 and Room 2 have the same median mAs of 4.0 mAs. The median values for Room 1 and Room 2 (4.0 mAs per room) are double that of Room 3 (2.2 mAs). According to Table 4.4, Room 1 has the highest median mAs (12.5 mAs) for the LAT chest projection. The p-values of the Kruskal-Wallis test were greater than 0.0001 mAs and 0.0059 mAs for PA and LAT chest projections, respectively. The Kruskal–Wallis test indicated that there is a significant difference in the median values of the mAs of the three rooms for both projections. The p-values were less than 0.05.

The Mann-Whitney U test of the PA chest projection (mAs) for Room 1 and 2 was 0.9890. This indicates that there were no significant differences in the median values of the rooms. The Mann-Whitney U test p-value of Room 1 and 3 and Room 2 and 3 was 0.0001. This indicated that there was a significant difference in the median values of these rooms. The p-values of the Mann-Whitney U test for the LAT chest projection (mAs) were Room 1 and 2 (0.0021), Room 1 and 3 (0.0306) and Room 2 and 3 (0.5357). These p-values showed that there was a significant difference in median values of Room 1 and 3 and Room 2 and 3.

For the PA chest projection, Room 3 had the highest median kVp (121.0 kVp) of all three x-ray rooms. The median value kVp (109.0 kVp) for Room 2 and (110.0 kVp) for Room 1. The LAT chest projection, median kVp value for Room 2 and Room 3 was 117.0 kVp. Room 2 and 3 median kVp was higher than Room 1, which was 113.0 kVp. The p-values of the Kruskal-Wallis test were 0.0002 kVp and 0.0285 kVp for PA and LAT chest projections, respectively. The Kruskal–Wallis test indicated that there is a significant difference in the median values of the kVp of the three rooms for both projections. The p-values were less than 0.05.

The results of the Mann-Whitney U test (kVp) for the PA chest projection were Room 1 and 2 (p-value 0.3985), Room 1 and 3 (p-value 0.0008), and Room 2 and 3 (p-value 0.0017). Room 1 and 2 p-value indicated there was no significant difference in the median values of the rooms, while the p-values of Room 1 and 3 and Room 2 and 3 revealed the opposite of Room 1 and 2. The p-values of the Mann-Whitney U test for the LAT chest projection were Room 1 and 2 (0.0226), Room 1 and 3 (0.0370) and Room 2 and 3 (0.8204). There were significant differences in the median values of Room 1 and 2 and Room 2 and 3.

The Shapiro-Wilk test was performed for the values of mAs and kVp for both PA and LAT chest projections. The p-values of the mAs for the Shapiro-Wilk test were 0.0002 mAs and 0.0572 mAs for PA and LAT chest projections, respectively. The p-values of the kVp for the Shapiro-Wilk test was 0.0002 kVp for both PA and LAT chest projections. The Shapiro–Wilk test demonstrated that the distribution of mAs and kVp values for both projections were skewed. A skewed Shapiro-Wilk test indicates that the p-values were less than 0.05. This means that the median values of the mAs and

kVp were to be used to compare mAs and kVp values for the X-ray rooms and CR and DR (FPD) systems.

Table 4.5   Radiographic parameters used for PA and LAT chest projections for CR and DR (FPD) systems

Type of radiography	n	Variable	PA CHEST PROJECTION				LAT CHEST PROJECTION			
			Mean	Median	Min	Max	Mean	Median	Min	Max
CR	40	mAs	4.2	4.0	3.2	5.6	10.0	10.0	6.3	14.0
		kVp	111.0	110.0	102.0	119.0	116.1	117.0	103.0	125.0
		FFD	179.3	180.0	150.0	180.0	179.3	180.0	150.0	180.0
DR (FPD)	20	mAs	2.4	2.2	1.0	4.0	9.0	7.9	3.4	19.8
		kVp	119.1	121.0	102.0	125.0	118.6	117.0	109.0	125.0
		FFD	177.0	180.0	150.0	180.0	177.0	180.0	150.0	180.0

n= number of patients; min= minimum; max= maximum; PA= postero-anterior; LAT= lateral; mAs= milli-ampere per second; kVp= kilo-voltage peak; FFD= focus film distance; DR (FPD) = digital radiography (flat panel detector); CR= computed radiography.

Table 4.5 illustrates that the median values for the PA chest projection were 4.0 mAs (CR) and 2.2 mAs [(DR (FPD)]. The median values of the kVp were 110.0 kVp (CR) and 121.0 kVp [(DR (FPD)]. The p-values of the Mann-Whitney U-test were 0.0001 (mAs) and 0.0002 (kVp). The p-values were less than 0.05; hence this demonstrates that there is a significant difference in the median values of the CR and DR (FPD) systems.

As can be seen in Table 4.5, the median values of the LAT chest projections were 10.0 mAs (CR) and 7.9 mAs [(DR (FPD)]. The median values of the kVp were 117.0 kVp (CR) and 117.0 kVp [(DR (FPD)]. The p-values of the Mann-Whitney U-test were 0.1010 mAs and 0.1677 kVp. The p-values were higher than 0.05, there is no significant difference in the median values of the CR and DR (FPD) systems.

Table 4.6   Radiographic parameters for PA and LAT chest projections for Turkey 2018 (Bas Mor *et al.,* 2018:382-383).

Type of radiography	Variable	PA CHEST PROJECTION			LAT CHEST PROJECTION		
		Mean	Min	Max	Mean	Min	Max
DR1	mAs	5.7	4.0	8.0	13.7	10.0	25.0
	kVp	67.1	63.0	78.0	76.5	70.0	85.0
DR2	mAs	20.0	-	-	16.0	-	-
	kVp	80.0	-	-	100.0	-	-
CR	mAs	25.5	20.0	32.0	13.7	10.0	25.0
	kVp	62.5	59.0	66.0	82.6	69.0	90.0

mAs= milli-ampere per second; kVp= kilo-voltage peak; DR1 & 2= digital radiography; CR= computed radiography; PA= postero-anterior; LAT= lateral; - = no data available.

A comparison is made between the radiographic parameters of the CR and DR (FPD) systems and the results from Turkey (2018). The mean mAs of this study was 4.2 mAs for the CR system (Table 4.5), while the mean mAs of Turkey (2018) was 25.2 mAs (Table 4.6) for the PA chest projection. The mean of Turkey (2018) for the DR system was DR1 (5.7 mAs) and DR2 (20 mAs) (Table 4.6), while the mean mAs of this study was 2.4 mAs for the PA chest projection (Table 4.5). The mean mAs of Turkey (2018) for the PA projection, CR system was higher than the mean mAs of this study for the same projection.

Table 4.5 illustrates that during this study, a higher mean kVp for both the CR (111.0 kVp) and DR (FPD) (119.1 kVp) were used as compared to Turkey (2018) where DR1 (67.1 kVp), DR2 (80 kVp) and CR (62.5 kVp) for the PA chest projection (Table 4.6) were used.

For the LAT chest projection, the mean mAs for Turkey (2018) was DR1 (13.7 mAs), DR2 (16 mAs) and CR (13.7 mAs) (Table 4.6). The mean mAs for Turkey (2018) was higher than the mean mAs of this study, which was DR (FPD) (9.0 mAs) and CR (10.0 mAs) (Table 4.5). The mean kVp of this study was higher than in Turkey (2018).

A comparison of the CR radiographic parameters of this study with Turkey (2018), indicated that radiographers in this study used higher kVp values for chest X-ray examinations, while Turkey (2018) used medium kVp values. This could be due to the fact that radiographers in Turkey prefer to use a medium kVp for chest X-ray

39

examination with the CR system because the CR plates have a low spectra sensitivity (İnal & Ataç, 2014:102).

Table 4.7   Radiographic parameters for PA and LAT chest projections of the research site

Variable	n	PA CHEST PROJECTIONS					LAT CHEST PROJECTIONS				
		Mean	Median	Min	Max	Range	Mean	Median	Min	Max	Range
mAs	60	3.6	4	1	5.6	4.6	9.7	9.7	3.4	19.8	16.4
kVp	60	113.7	112.5	102	125	23	117	117	103	125	22
FFD	60	178.5	180	150	180	30	178.5	180	150	180	30

n= number of patients; min= minimum; max= maximum; PA= postero-anterior; LAT= lateral; mAs= milli-ampere per second; kVp= kilo-voltage peak; FFD= focus film distance.

The ideal range for mAs and kVp is zero for a radiology department. A range of zero means all the radiographers at the radiology department used similar exposure factors for patients with the same weight and thickness to obtain radiographs. This will never happen at a radiology department because radiographers use varying exposure factors due to varying patient sizes. As the range increases, so does the number of the distribution vary (refer to Section 3.9).

A wide range of kVp and mAs were used in this study. The kVp ranges were 23 kVp for the PA chest projection and 22 kVp for the LAT chest projection (refer to Table 4.7). The mAs ranges were 4.6 mAs and 16.4 mAs for the PA and LAT chest projections, respectively, as indicated by Table 4.7. The wide ranges of kVp and mAs were a result of the variation in patient's weight and thickness. The weight range was from 60 kg to 80 kg and the thickness ranges were 19 cm for LAT chest projection and 13 cm for PA chest projection (refer to Table 4.2). As the weight and thickness of a patient increased, the exposure parameters also increased and vice versa. The wide range of the radiographic parameters can also be attributed to the radiographer's skill, knowledge and training (see Section 2.4.5.4) and the fact that both manual and automatic exposures were used in this research study.

A high kVp and low mAs were used by the radiographers at the research site to produce the chest radiographs. This technique produces high-quality chest images. The chest images had a long scale of contrast and adequate density. A high kVp helps to penetrate all the different tissues of the chest, produce a long gradient contrast and reduce radiation dose to the patients (see Section 2.3.7).

A total of 120 images were included in this research study. Out of the 120 images, 6 images were taken at an FFD of 150 cm. The other images were taken at an FFD of 180 cm. These FFDs are within the range 180 (140-200) cm recommended by the EC for chest X-ray examination (EC, 1996:12).

Table 4.8   Radiographic parameters for PA and LAT chest projections of IRAN 2018 (Mohsenzadeh *et al.,* 2018:6186) **and UK 2010 review** (Hart *et al.,* 2012:12)

	PA CHEST PROJECTION						LAT CHEST PROJECTION					
	IRAN 2018			UK 2010 REVIEW			IRAN 2018			UK 2010 REVIEW		
Variable	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
mAs	12.3	3.2	25	5	-	-	17.5	6.4	28	13	-	-
kVp	80.2	61	135	88	65	125	87.3	70	135	89	70	125

PA= postero-anterior; LAT= lateral; mAs= milli-ampere per second; kVp= kilo-voltage peak; UK= United Kingdom; - = No data available.

When this study was compared to the Turkey 2018 research and the UK 2010 review (Table 4.8), it illustrated that the radiographers of this study adhered to the high kVp and low mAs technique to produce chest radiographs. The compared studies used medium kVp and high mAs to produce chest X-ray radiographs. The mean mAs and mean kVp of this research study were 3.6 mAs and 113.7 kVp for PA projection and 9.7 mAs and 117kVp for the LAT projection (Table 4.7).

4.3.2 Image quality

DRL and ESAK values are not a description of the image quality of a chest radiograph. A focus on lower DRL and ESAK values only may reduce these values to the extent that the image quality does not meet the diagnostic standard. To prevent this from occurring, EI and radiographic criteria of chest radiographs were also used to ensure that the radiographs of patients used to calculate ESAK and DRL were of adequate image quality (see Section 2.4.2.3).

The EI value of each chest image was within the range of EI as prescribed by the manufacturer of the X-ray machine for the anatomical area. The EI range for Room 1 and Room 2 is 172 to 344. The EI for Room 3 is 300 to 500.

All the chest radiographs of the patients who met the inclusion criteria were adequate and had acceptable image quality for diagnosis that met the image criteria required by the EC guidelines. The prescribed image criteria for an acceptable chest radiograph

41

are attached as Appendix I. These criteria described were the prerequisites in terms of the image standard for patient data to be included in this research study.

4.4   ESAK CALCULATION

The ESAK was determined by using the indirect method prescribed by the IAEA (2004:130). A statistical application (SAS Version 9.2) was used to determine the LDRL of chest X-ray examinations for each X-ray room, radiographic systems and the research site (refer to Sections 3.8.3 and 3.9).

Table 4.9   ESAK for PA and LAT chest projections per X-ray rooms

Room Number	Variable	n	PA CHEST PROJECTION				LAT CHEST PROJECTION			
			Mean	Median	Min	Max	Mean	Median	Min	Max
1	ESAK	20	0.2	0.2	0.2	0.3	0.7	0.7	0.4	0.9
2	ESAK	20	0.2	0.2	0.2	0.4	0.6	0.6	0.4	0.8
3	ESAK	20	0.1	0.1	0.1	0.3	0.6	0.5	0.2	1.4

n= number of patients; min= minimum; max= maximum; PA= postero-anterior; LAT= lateral; ESAK= entrance skin air kerma; EASK SI unit is mGy.

Table 4.9 demonstrates the mean ESAK values for PA chest projections for Room 1 (0.2 mGy), Room 2 (0.2 mGy) and Room 3 (0.1 mGy). The Kruskal-Wallis test (p-value 0.0001) indicated that there is a significant difference in the median values of the three rooms for the PA chest projection. The Mann-Whitney U-test was performed to compare the median value differences between the X-ray rooms. The Mann-Whitney U-test (0.1682) illustrated that there was no significant difference in the median values between Room 1 and Room 2, whereas there were significant differences in the median values between Room 1 and Room 3 and Room 2 and Room 3. The p-values were 0.0007 and 0.0001 for Room 1 and 2 and Room 2 and 3, respectively.

The mean ESAK value for the PA chest projection for Room 3 was half the value of Rooms 1 and 2. This can be correlated with the highest kVp and lowest mAs demonstrated in Table 4.4. The high kVp, low mAs and grid ratio contributed to Room 3 having the lowest mean ESAK value of all the rooms.

As can be seen from Table 4.9, the mean ESAK values for the LAT chest projection were; Room 1 (0.7 mGy), Room 2 (0.6 mGy) and Room 3 (0.6 mGy). The Kruskal-

Wallis test (p-value 0.2709) demonstrated that there is no statistically significant difference in the median values of the three rooms for the LAT chest projection. Furthermore, the Mann-Whitney U-test was done to compare the median values between the three rooms. The results indicated that there is no significant difference in the mean EASK values between the rooms for the LAT projection. The Mann-Whitney U-test p-value for Room 1 and 2 was 0.2569, Room 1 and 3 was 0.1595 and Room 2 and 3 was 0.4943.

The p-values of the Shapiro-Wilk test (PA 0.1511 and LAT 0.0503) for the ESAK were greater than 0.05. This indicates that the ESAK followed a normal distribution; hence the mean values of the ESAK were used for the results.

Table 4.10   ESAK values for PA and LAT chest projections of CR and DR (FPD) systems

Type of radiography	n	Variable	PA CHEST PROJECTION				LAT CHEST PROJECTION			
			Mean	Median	Min	Max	Mean	Median	Min	Max
CR	40	ESAK	0.2	0.2	0.2	0.4	0.6	0.6	0.4	0.9
DR (FPD)	20	ESAK	0.1	0.1	0.1	0.3	0.6	0.5	0.2	1.4

n= number of patients; min= minimum; max= maximum; PA= postero-anterior; LAT= lateral; ESAK= entrance skin air kerma; DR (FPD) = digital radiography (flat panel detector); CR= computed radiography; EASK SI unit is mGy.

As illustrated in Table 4.10, the mean ESAK values of 0.2 mGy for CR and 0.1 mGy for DR (FPD) were recorded for PA chest projections. The Mann-Whitney U-test illustrated that there is a statistically significant difference in the median values of the two systems for the PA projection. The Mann-Whitney U-test was 0.0001.

The mean ESAK value of the PA chest projections of the DR (FPD) system is half the value of the CR system. This is due to dose efficiency. The dose efficiency of the DR (FPD) system is two to three times more efficient at converting dose to signal than the CR system. This increased dose utilisation means that the DR (FPD) system can produce the same image quality as the CR system at a lower dose (Colbeth, 2016:1).

The DR (FPD) and CR mean ESAK values of 0.6 mGy and 0.6 mGy are the recorded DR (FPD) and CR, respectively, for the LAT chest projections as illustrated in Table 4.10. The mean ESAK of the DR (FPD) system for the LAT chest projection was similar

to the CR system. There was no difference in the ESAK values to demonstrate dose efficiency as illustrated by the PA chest projection. The Mann-Whitney U-test (p-value 0.2201) also demonstrated that there is no significant difference in the median values of the CR system and DR (FPD) system for the LAT chest projection.

Table 4.11   ESAK values for PA and LAT chest projections of Turkey 2018 (Bas Mor *et al*., 2018:382-383) **and UK review 2010** (Hart *et al*., 2012:49)

Type of radiography		PA CHEST PROJECTION		LAT CHEST PROJECTION
		Turkey 2018	UK review 2010	Turkey
	Variable	Mean	Mean	Mean
CR	ESAK	0.328	0.13	1.161
DR1	ESAK	0.162	0.11	0.5
DR2	ESAK	0.75	-	1.009

PA= postero-anterior; LAT= lateral; ESAK= entrance skin air kerma; DR1 & 2= digital radiography; CR= computed radiography; UK= United Kingdom; - = No data available; EASK SI unit is mGy.

The mean ESAK values of this study of the PA projection were higher than that of the UK 2010 review. DR1 of Turkey 2018 (Table 4.11), the mean ESAK values are almost similar to the mean ESAK values of the DR (FPD) system of this research study for both projections. On the other hand, DR2 of Turkey 2018 (Table 4.11), the mean ESAK values were higher than the DR (FPD) system mean ESAK values of this research study for PA and LAT projections.

Table 4.12   Comparison of the ESAK values of this study to other international ESAK values. Turkey 2018 (Bas Mor *et al.,* 2018:384), **Iran 2018** (Mohsenzadeh *et al.,* 2018:6188), **UK 2010 review** (Hart *et al.,* 2012:11)

PROJECTION	This study				UK 2010 review				Iran 2018				Turkey 2018	
	Mean	Min	Max	Range	Mean	Min	Max	Range	Mean	Min	Max	Range	Mean	Range
Chest PA	0.2	0.1	0.4	0.3	0.12	0.02	1.1	1.08	0.6	0.13	1.12	0.99	0.33	-
Chest LAT	0.6	0.2	1.4	1.2	0.48	0.22	1.26	1.04	0.85	0.25	1.98	1.73	0.73	-

PA= postero-anterior; LAT= lateral; UK= United Kingdom; EASK SI unit is mGy; - = no data available.

Table 4.12 illustrates that the mean ESAK values of this research study were less than the international compared values, except for the UK 2010 review, where the mean ESAK values were less than the ESAK of this study. The calculation of the ESAK is very important in assessing the dose to patients and which would help in making decisions on how the optimisation of the radiation dose can be achieved in the radiology department.

The ESAK ranges were wide for both chest X-ray projections. The ESAK range values were 0.3 mGy and 1.2 mGy for PA and LAT chest X-ray projections, respectively. These wide ranges of ESAK for this study can be linked to the wide ranges of the mAs, kVp, weight range, patients' thickness and radiographer skill, knowledge and training (refer to Table 4.2 and 4.7). The UK 2010 review and Iran 2018 have higher ESAK range values than this study, except for the ESAK range of the UK 2010 review's LAT chest projection.

Table 4.13   LDRLs for PA and LAT chest projections per X-ray room

Room Number	n	Variable	PA CHEST PROJECTION			LAT CHEST PROJECTION		
			Median	Lower Quartile	Upper Quartile	Median	Lower Quartile	Upper Quartile
1	20	LDRL	0.2	0.2	0.3	0.7	0.5	0.8
2	20	LDRL	0.2	0.2	0.3	0.6	0.5	0.7
3	20	LDRL	0.1	0.1	0.2	0.5	0.4	0.8

n= number of patients; PA= postero-anterior; LAT= lateral; LDRL= local diagnostic reference level; LDRL SI unit is mGy.

The LDRL is the same as the 3rd quartile, 75th percentile and upper quartile of the mean dose distribution. Table 4.13 indicates the LDRLs of the LAT chest projection for all three rooms, which are Room 1 (0.8 mGy), Room 2 (0.7 mGy) and Room 3 (0.8 mGy). As for the PA chest projection, Room 3 had the lowest LDRL (0.2 mGy), while Room 1 and Room 2 LDRL values were similar at 0.3 mGy.

Table 4.14   LDRLs for PA and LAT chest projections for CR and DR (FPD) systems

Type of radiography	n	PA CHEST PROJECTION			LAT CHEST PROJECTION		
		Median	Lower Quartile	Upper Quartile	Median	Lower Quartile	Upper Quartile
CR	40	0.2	0.2	0.3	0.6	0.5	0.8
DR (FPD)	20	0.1	0.1	0.2	0.5	0.4	0.8

n= number of patients; PA= postero-anterior; LAT= lateral; LDRLs= local diagnostic reference levels; CR= computed radiography; DR (FPD) = digital radiography (flat panel detector); LDRL SI unit is mGy.

Table 4.14 illustrates that the CR LDRL value for the PA chest projection is higher than the DR (FPD) LDRL value. The LDRLs of the PA chest projections were 0.3 mGy for the CR and 0.2 mGy for the DR (FPD). The LAT chest projection has similar values for both CR and DR (FPD) projections. The LAT chest projection LDRL was 0.8 mGy.

Table 4.15   Comparison of the LDRLs of this study to other international DRLs.

PROJECTION	This study	IAEA 2004	RSA 2009	UK 2010 review	EU 2018 Most common value	Iran 2018	Turkey 2018
Chest PA	0.3	0.3	0.1	0.15	0.3	0.63	0.35
Chest LAT	0.8	1.5	0.2	0.54	1.5	1.11	0.78

PA= postero-anterior; LAT= lateral; LDRLs= local diagnostic reference levels; UK= United Kingdom; EU= European Union; RSA= Republic of South Africa; IAEA= International Atomic Energy Agency; LDRL SI unit is mGy.

The purpose of the LDRL is to help optimise radiation dose to patients by identifying that extra dose that does not contribute to the clinical purpose of the medical imaging. This is achieved by comparing the LDRL values to international values. If this study's LDRL values are less than the international DRLs, then this research site achieved the purpose of the LDRL for chest X-ray examinations. If the study LDRL value is higher

than the international value, an investigation needs to be conducted to search for the reason (see Section 2.4.5).

The LDRLs for chest X-ray examinations were compared with international DRLs published in articles. The international organisations are the IAEA and EU. The LDRL of this study (0.3 mGy) was similar to IAEA 2004 and EU 2018 for the PA chest projection. The LDRL for the LAT chest X-ray projection for this study was 0.8 mGy, which is less than the DRLs (1.5 mGy) of the international organisations revealed by Table 4.15 (EC, 2018:30, IAEA, 2004:17).

Both the UK 2010 review and the Iran 2018 DRLs' results were obtained at a national level. Table 4.15 indicates that the LDRLs of this study were lower than that of the Iran 2018 study but higher than the UK 2010 review for both projections (Hart, *et al*., 2012:11 & Mohsenzadeh *et al.*, 2018:6189).

The DRL results of the RSA study were obtained from a single radiology practice in one hospital, while the results of the Turkey review in 2018 were from three hospitals. The LDRL of this study for the LAT chest X-ray projection was similar to that of the Turkey 2018 review. The PA chest projection's LDRL of this study (0.3 mGy) was less than that of the Turkey review in 2018 (0.35 mGy). The DRLs of the RSA study were less than the LDRLs of this research study, as can be seen in Table 4.15 (Nyathi *et al.,* 2009:12; Bas Mor *et al.,* 2018:384).

Since the implementation of DRLs by the ICRP, the methodology to calculate DRLs has changed numerous times over the years. Before comparing a study's DRL values to other results, the researcher has to investigate what weight range was used to select patients, what method was utilised to measure radiation dose to the patient and the type of radiographic system used to acquire these images. It will be fair to compare the LDRLs of this study with the Iran review of 2018. This is because Iran (2018) used a similar weight range to select patients and method to measure radiation dose to patients and radiographic system. The LDRL values of this study were lower than that of the Iran review of 2018 (Mohsenzadeh *et al.,* 2018:6189).

The LDRL values of this study were lower than international organisations and some of those published in other articles because the radiographers at the research site utilised the high kVp and low mAs technique to produce chest X-ray radiographs. This

47

technique also contributes to the reduction of the radiation dose to the patients. The patients who were selected to participate in this research weighed from 60 kg to 80 kgs. The weight range of the comparable DRL studies was from 50 kg to 105 kg. As the bodyweight increases, so too does the radiation dose to patients and vice versa. The DRL results above used a mixed detector systems (CR, DR (FPD) and film-screen system), except for that of Iran in 2018. This research study and the Iran study of 2018 made use of CR and DR (FPD) radiographic systems. This research site has a full-time employed HPCSA registered medical physicist who performs QC and QA as stipulated by the DRC and ensures that the X-ray machines are fixed and work appropriately.

4.5   CONCLUSION

A total of 60 patients participated in this research study. PA and LAT chest projections were performed for each participant. The mean weight of the patients in this research study was 69.8 kg. The research also provided the following data of the research site for chest X-ray examinations: radiographic parameters (mAs, kVp and FFD), ESAK and LDRLs of the X-ray rooms, radiographic systems and the research site. A high kVp and low mAs technique were used by the radiographers to produce the radiographs. The mean kVp of this study was 113.7 kVp for a PA chest projection and 117 kVp for the LAT chest projection. The mean mAs were 3.6 mAs and 9.7 mAs for the PA and LAT chest projections, respectively. The mean ESAK values were 0.2 mGy for the PA projection and 0.6 mGy for the LAT chest projection. The LDRLs of this study were 0.3 mGy and 0.8 mGy for PA and LAT chest projections, respectively. The ESAK and LDRLs were less than the compared international values.

According to the Kruskal-Wallis test and the Mann-Whitney U-test (Table 4.5, Table 4.9 and Table 4.10), there were significant differences in the mean and median values of the ESAK and radiographic parameters for the PA chest projections of the X-ray rooms and the radiographic systems. On the other hand, the LAT chest projections revealed that there were no significant differences in the X-ray rooms and radiographic systems. These differences between the PA chest projections and LAT chest projections of the research site were communicated to the medical physicist for further investigation.

The next chapter consists of the conclusion, recommendations and limitations of the study. In this chapter, the contribution of this research study is also explained.

CHAPTER 5

LIMITATIONS, RECOMMENDATIONS AND CONCLUSION

5.1 INTRODUCTION

The purpose of this chapter is to provide a brief overview of how the objectives of the study were addressed, followed by the conclusion and a discussion of the limitations of the study. The chapter concludes with the recommendations and the contribution of the research.

5.2 OVERVIEW OF THE RESEARCH STUDY

This research study was performed to determine the LDRLs of routine chest X-ray examinations at a government hospital in the Northern Cape. Chest radiographs were taken of the patients who met the inclusion criteria by radiographers at the research site. The radiographic parameters were recorded on a data sheet. The IAEA (IAEA, 2004:130) method was utilised to determine ESAK for each projection. A statistic software application was used to establish the LDRLs of the X-ray rooms, radiographic systems and research site.

5.2.1 Research question and objectives of this research study

The research question addressed in the study was: What are the LDRLs for routine chest X-ray examinations at a government hospital in the Northern Cape? The objectives addressed the research question employing the IAEA method to calculate the ESAK of each patient. The ESAK of the patients were captured into a statistical application to calculate the LDRLs of routine chest examinations.

The objectives of this study and how they were achieved are presented in the section that follows.

5.2.1.1 To calculate the ESAK for routine chest X-ray examinations' PA and LAT images

The objective to calculate the ESAK for routine chest X-ray examinations' PA and LAT was achieved and illustrated in Section 3.8.3 as well as Tables 4.10 and 4.11. Section 3.8.3 explained how to use the IAEA method to determine the radiation dose the

patients acquired during the process of obtaining chest radiographs and Table 4.14 displayed the ESAK results of the research site.

5.2.1.2 To establish LDRLs for routine chest X-ray examination (PA and LAT images) at the research site

The objective of establishing LDRLs for routine chest X-ray at the research site was achieved, as illustrated in Section 3.8.2. Furthermore, it demonstrated how the statistical application was used to organise the ESAK values in order to determine the LDRLs of chest X-ray examinations at the research site.

5.2.1.3 To compare LDRLs and typical dose of chest X-ray examinations with relevant international organisations and values cited in the literature

The objective of comparing the LDRLs of chest X-ray examinations with relevant international organisations and values cited in the literature were achieved in Section 3.8.2. Furthermore, Section 3.8.2 demonstrates how a statistical application organised the ESAK values to determine the LDRLs of chest X-ray examinations at the research site. The comparison of the LDRLs to international organisations' DRL values is illustrated in Table 4.8.

5.2.1.4 To propose changes to the specific research site to optimise and justify patient dose if there are significant differences in LDRLs compared to the values from cited literature

The LDRLs for chest X-ray examinations at the research site were lower than those of the international organisations and the articles used for comparison are revealed in Table 4.8. There is no proposed change or recommendation to the research site in terms of optimisation of radiation dose to patients at present.

The above information indicates that the research question, which was the determination of LDRLs for routine chest X-ray examinations at a government hospital in the Northern Cape, was answered by this research study. The radiographic parameters were used to determine the ESAK of the patients that met the inclusion criteria and consented to participate in this research study. The ESAK were captured into a statistical application. The application calculated the LDRLs for routine chest X-ray examinations for the research site.

5.3 LIMITATIONS OF THE RESEARCH STUDY

This study did not demonstrate the LDRLs for routine chest X-ray examinations of patients whose weight is less than 60 kilogrammes or more than 80 kilogrammes. As a result, many patients had to be excluded from this research study because their weight was not within the required weight range of this research study.

Not all radiographers were present at the research site during the research study. Some were working night duty while others were allocated to different departments of the hospital, which have X-ray machines. At the end of the research study, a total of seven radiographers participated in the data collection. However, this research site has forty radiographers. The seven radiographers included in the study do not necessarily represent the skills of all the radiographers at the research site.

The clinical condition of a patient has an influence on the exposure parameters. A clinical condition of a patient might require the radiographer to increase or decrease the exposure parameters. The clinical condition of the patient was not considered in this research study.

5.4 RECOMMENDATIONS

- The LDRLs for routine chest X-ray examinations should be repeated after three years, according to ICRP. The latest results should then be compared with the results of this research study.
- A comparative study of LDRLs for routine chest X-ray examinations using automatic exposures and manual exposures at the research site is recommended.
- A study of LDRLs for routine chest X-ray examinations for patients with a bodyweight of more than 80 kilogrammes or less than 60 kilogrammes is recommended.

5.5 CONTRIBUTION OF THE RESEARCH

There are currently no established or published DRL values prescribed by the DRC in South Africa, leaving a gap in the evaluation and optimisation of radiation dose to patients. The LDRLs established for routine chest X-ray examinations at this research site can serve as a guideline for the establishment of DRL values for other anatomical

regions at the research site and other radiology departments in the country. The gap in this research study will be further addressed by the publication of an article with a journal.

5.6   CONCLUSION

This study answered the research question by determining the ESAK for chest X-ray examinations for the participating patients, after which the LDRLs of chest X-ray examinations were established. The LDRLs of the examinations were compared to the DRL's of international organisations as well as those of relevant, applicable articles. The LDRLs of chest X-ray examinations were lower than those of international organisations and some published DRL values. The mean kVp, mAs, ESAK and LDRLs for chest X-ray examinations of this research site were 113.7 kVp for PA chest projection and 117 kVp for the LAT chest projection.

The mean mAs were 3.6 mAs and 9.7 mAs for the PA and LAT chest projections, respectively.

The mean ESAK values were 0.2 mGy for the PA chest projection and 0.6 mGy for the LAT chest projection.

The LDRLs of this study were 0.3 mGy and 0.8 mGy for PA and LAT chest projections, respectively.

The ESAK and LDRLs were less than that of the compared international values.

The LDRL values established in this specific study for PA and LAT chest radiographs compares well with international values. This finding is an indication that the radiographers at the research site utilised the ALARA principle to obtain chest radiographs for this research. However, compliance may not necessarily indicate that all the chest radiograph procedures were optimally performed with the least amount of radiation. Radiographers constantly need to critically look at methods to optimise radiation dose.

The Kruskal-Wallis test and Mann-Whitney U-test revealed that there are significant differences in the mean values of the ESAK for the PA chest projections of the X-ray rooms and the radiographic systems. These differences were not observed in the LAT chest projections.

The study is limited in terms of the clinical conditions of the patient that were not considered when setting exposure parameters that not all the radiographers at the research site participated in the research study. Finally, the patients with body weight less than 60 kilogrammes and more than 80 kilogrammes were excluded from the study. The most important recommendation is to repeat the study after three years and compare the results to this study.

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APPENDIX A

APPLICATION FOR A CLEARANCE CERTIFICATE FROM THE HEALTH SCIENCE RESEARCH ETHICS COMMITTEE OF THE FACULTY OF HEALTH SCIENCE, UNIVERSITY OF THE FREE STATE
TO THE CHAIRPERSON

HEALTH SCIENCE RESEARCH ETHICS COMMITTEE UFS

Dear sir/Madam

I hereby apply for a clearance certificate to conduct a research study. I am a master's degree student at the Department of Clinical Sciences, Central University of Technology, Free State, Bloemfontein. The title of the research study is: **Local Diagnostic Reference Levels (LDRLs) for routine chest X-ray examinations at a government hospital in the Northern Cape**.

I will be very grateful should I be granted a clearance certificate to conduct this research.

Yours faithfully

Maurice Junda

APPENDIX B

APPLICATION LETTER TO CONDUCT RESEARCH AT A GOVERNMENT HOSPITAL IN THE NORTHERN CAPE
(HSREC: UFS-HSD2018/1610/2603)

TO: The Head of the Radiology Department, Robert Sobukwe Hospital

Dear Sir/ Madam

I hereby apply for permission to conduct research, which is part of the requirements for obtaining a master in radiography degree at the Department of Clinical Science, Central University of Technology, Free State, Bloemfontein.

The title of the research study is: **Local Diagnostic Reference Levels (LDRLs) for routine chest X-ray examinations at a government hospital in Northern Cape**. This study aims to determine diagnostic reference level for chest X-ray examinations at the Robert Sobukwe Hospital.

Patients referred for routine chest X-ray examinations, who have signed the informed consent form and adhere to the inclusion criteria, will be included. The different categories of radiographers (qualified, community service, supplementary and student radiographers) are allowed to collect data for this research. The researcher will educate the radiographers on the data collection method and will assist with data collection. The data collection period will be approximately three months or as soon as the number of patients required for each X-ray room is attained.

The department will receive the results, which will assist the department in optimisation of patient dose for chest X-ray examinations.

I will be very grateful should I be granted permission to execute this research study at your beautiful department.

Yours faithfully

Name of researcher :   Mr. Maurice Junda

Supervisor: Prof. H. Friedrich-Nel & Co-supervisor: Mrs. H. Muller

APPENDIX C

INFORMATION LEAFLET AND PATIENT CONSENT FORM IN ENGLISH

LOCAL DIAGNOSTIC REFERENCE LEVELS (LDRLs) FOR ROUTINE CHEST X-RAY EXAMINATIONS AT A HOSPITAL IN THE NORTHERN CAPE

You are invited to participate in a research project. The radiographer will explain the details of your participation in this research. Please ask the radiographer any question about any part of this project that you do not fully understand. Also, your participation is entirely voluntary and you are free to decline to participate. If you say no, this will not affect you negatively in any way, whatsoever. You are free to withdraw from the study at any point, even if you did agree to take part.

This study has been submitted for approval by the Health Research Ethics Committee at the Free State University (HSREC: UFS2018/1610/2603**) and will be conducted according to South African Guidelines for Good Clinical Practice.**

This research will be executed at the radiology department, Robert Sobukwe Hospital. If you agree to participate in the study, you will be required to do the following:

- Stand on a weighing scale for your weight to be captured.
- Your chest thickness will be measured in two dimensions.
- You will be placed in front of the X-ray machine and two images of your chest will be taken.

There is no financial benefit to participate in this research. The researcher will not compensate you in the event that any injury results from participation in this research project.

This study will assist the researcher to establish/determine/calculate diagnostic reference levels of chest X-ray examinations and this may help optimise radiation dose to the population in the future.

If you do not agree to take part in this research, your rights to have your chest X-ray images done at the radiology department of the Robert Sobukwe Hospital will not be affected in any way.

In this study, your participation will remain confidential. No information about your identity will be collected. Technical information will be collected about the X-ray images and your weight and measurements will be captured. The information collected will be written on a data sheet. Only your unique hospital number and no other personal information will be written on the data sheet. Publication of the results of this research study will not contain your hospital number.

You can contact Mr Maurice Junda at tel.: 0784447634 if you have any further queries or encounter any problems.

You can contact the chairperson of the Health Research Ethics Committee, University of the Free State at 0514017794/5 if you have any concerns or complaints regarding the research study.

CONSENT TO PARTICIPATE IN RESEARCH

TITLE: LOCAL DIAGNOSTIC REFERENCE LEVELS (LDRLs) FOR ROUTINE CHEST X-RAY EXAMINATIONS AT A HOSPITAL IN THE NORTHERN CAPE

(HSREC: UFS2018/1610/2603)

You have been asked to participate in a research study.

You have been informed about the study by…………………………

You may contact Maurice Junda at 0784447634 at any time if you have questions about the research or encounter any problems as a result of the research.

You may contact the Secretariat of the Health Science Research Ethics Committee, University of the Free State at telephone number (051) 4017794/5 if you have questions about your rights as a research subject.

Your participation in this research is voluntary, and you will not be penalised or lose benefits if you refuse to participate or decide to terminate participation. No additional examination will be performed for the research study. **Your decision not to participate in the study will not negatively affect your chest X-ray examinations**. There is no additional cost involved in your participation. However, there is no financial benefit for you if you participate in the study.

If you agree to participate, you will be given **a signed copy of this document as well as the participant information sheet, which is a written summary of the research.**

I hereby confirm the following:

- I was informed about my participation in the research study,
- I understand that my participation is voluntary,
- That my personal information will be treated as confidential and
- I agree to be weighed and measured.

\--------------------------   \------------------------------

Signature of participant   Date

\--------------------------   \-------------------------------

Signature of witness   Date

\--------------------------   \-------------------------------

Signature of translator   Date

CUT HERE\---

\--------------------------   \-------------------------------

Signature of participant   Date

\--------------------------   \-------------------------------

Signature of witness   Date

\--------------------------   \-------------------------------

Signature of translator   Date

Name of radiographer\--

Unique hospital number of patient \--

APPENDIX D

FOROMO YA TSEBISO YA TUMELLO YA MOKUDI KA SESOTHO

HLAHLOBO E ENTSWENG SEBAKENG SE ITSENG KA MOKGWA O TLWAELEHILENG WA DIHLAHLOBO TSA DI-X-RAY YA SEFUBA SEPETLELENG SA KAPA LEBOYA

O memelwa ho nka karolo porojekeng ya dipatlisiso. Radiokerafa e tla fana ka tlhaloso e tletseng ya ho nka karolo dipatlisisong tsena. O ka botsa potso efe kapa efe ho Radiokerafa ka karolo e itseng eo o sa e utlwisiseng. Hape, ho nka karolo ha hao ho tswa ho wena, ebile o na le hona ho ka hana ho nka karolo. Ho sa dumeleng ha hao ho keke ha o ama hampe ka tsela efe. O kgona ho ka fetola maikutlo a hao nako e nngwe le nngwe le hoja o ne o dumetse ho ka nka karolo.

Dithuto tsena, di hlahisitswe ho Komiti ya Boitshwaro ya Lefapha la Dipatlisiso la Yunivesithi ya Freistata (UFS2018/1610/2603) mme e tla tsamaiswa ho ya ka melawana ya disebediswa ya Lekgotla la Afrika Borwa la Tshebediso le Dipatlisiso tsa kalafo *(MRC).*

Dipatlisiso tsena, di tla phethahatswa lefapheng la Radioloji *(X-rays)* sepetleleng sa Robert Sebokwe. Haeba o dumela ho nka karolo o tla tshwanela ho etsa tse latelang:

- Ho ema sekaleng hore boima ba mmele wa hao bo lekanywe.

- Botenya ba sefuba sa hao bo tla lekanywa ka mekgwa e mmedi.

- O tla ema ka pela motjhini wa X-ray mme ho nkwe ditshwantsho tse pedi tsa sefuba.

Ha ho moputso wa tjhelete ho nka karolo patlisisong ena. Mmatlisisi ha a na ho o lefa haeba o ka tswa kotsi, ha o nka karolo porojekeng ena ya dipatlisiso. Radiokerafa e tla o netefaletsa tshireletseho kgahlanong le mahlasedi a X-ray.

Thuto ena e tla thusa mofuputsi ho ithuta haholo ka boemo ba matshwao a diteko tsa mafu a sefuba ho mme e ka ba le thuso e kgolo taolong ya mahlasedi setjhabeng sa bokamoso.

Haeba o sa dumele ho ka nka karolo dipatlisisong tsena, hoo ho bolele hore tokelo ya hao ya ho ka nka ditshwantso tsa X-ray lefapheng la radioloji la Robert Sobukwe e tla senyeha ka mokgwa ofe kapa ofe.

Dithutong tsena, ho nka karolo ha hao e tla ba sephiri. Ha ho na tsebiso kapa pokello e ka etswang ka boitshupo ba hao.

Ho tla nkwa fela tsebahalo ya setekgeniki ya ditshwantsho tsa X-ray, boima ba hao le tekanyetso tseo di tla hlahiswang. Mme tsebiso ena e tla kenywa leqepheng la dipalopalo. Phatlalatso ya tlhahiso ena ya dithuto ha e na ho kenyeletsa nomoro ya hao ya sepetlele. Nomoro e kgethehileng ena e tla ba feela leqepheng la dipalopalo. Ke mofuputsi feela kapa baselebetsi ba dumeletsweng ba sepetlele ba ka kgonang ho fihlella nomoro ya hao ya sepetlele.

O ka kgona ho ikopanya le Monghadi Maurice Junda nomorong ya mohala ya 078 444 7634 haeba o na le ditletlebo kapa o lemoha bothata bo itseng.

O ka kgona ho ikopanya le Modulasetulo wa Komiti ya Diphuputso tsa Bophelo bo botle le Boitshwaro ya Yunivesithi ya Freistata mohaleng wa -051 401 7794/5 haeba o na le mabaka kapa ditletlebo mabapi le diphuputso tsena.

TUMELLO YA HO NKA KAROLO DIPHUPUTSONG

SEHLOHO: HLAHLOBO E ENTSWENG SEBAKENG SE ITSENG KA MOKGWA O TLWAELEHILENG WA DIHLAHLOBO X-RAYS YA SEFUBA SEPETLELENG SA KAPA LEBOYA

(HSREC: UFS-HSD2018/1610/2603)

O ile wa kotjwa ho nka karolo thutong ena ya dipatlisiso.

O ile wa tsebiswa ka thuto ena ke ………………………………………………

O ka ikopanya le Maurice Junda nomorong ya mohala ya 078 444 7634 nako efe kapa efe haeba o na le dipotso ka diphuputso kapa, o teana le mathata a itseng a bakwang ke diphuputso.

O ka ikopanya le Mongodi wa Komiti ya Bophelo bo botle ya Saense le Boitshwaro ya Yunivesithi ya Freistata mohaleng wa 051 401 7794/5 haeba o na le dipotso mabapi le ditokelo jwaloka sesebediswa sa diphuputso.

Ho nka karolo ha hao ke boithaopo, o ke ke wa qhelelwa thoko, kapa wa lahlehelwa ke meputso haeba o hana ho nka karolo, ha o nka qeto ya tlohela ho nka karolo. Ha hona hlahlobo e nngwe e tla etswa mabapi le thuto ya diphuputso. Ho hana ha hao ho ba le seabo thutong ena, ho ke ke ha silafatsa hlahlobo ya X-ray ya sefuba hao. Ha ho na ditshenyehelo tse ekeditsweng ho nkeng karolo ha hao. Fela ha hona moputso ha o nka karolo thutong ena.

Haeba o dumela ho nka karolo, o tla fuwa khopi ya tokomane esita le leqephe la dintlha tsa tsebiso ho monkakarolo, eo e leng kgutsufatso ya diphuputso tsena.

Ke nnetefatsa tse latelang:

- Ke ile ka tsebiswa ka ho nka karolo ha ka

- Ke utlwisisa hore ho nka karolo ha ka ke boithaopo

- Le hore tsebiso ya ka e tla sebediswa ka sephiri, le hore ke a dumela hore boima ba mmele bo nkwe le ho lekanywa.

--   -------------------------
Tshaeno ya Monkakarolo   Letsatsi

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 Tshaeno ya Mofetoleli   Letsatsi

--   ---------------------
 Tshaeno ya Paki   Letsatsi

KGAOLA MONA --------------------------------------

Tshaeno ya Monkakarolo   Letsatsi

--   -----------------------------
Tshaeno ya Paki   Letsatsi

------------------------------------   ---------------------
Tshaeno ya Mofetoleli   Letsatsi

Lebitso la Radiokerafa   --

Nomoro e kgethehileng ya sepetlele   --

UHN: Unique Hospital Number. **Boima ba mokudi ka kilogramo.** *Patient thickness (TK)* **ho boemo ba T7 ka disentimethara.** *Exposure index (EI)*

APPENDIX E

INLIGTINGSPAMFLET EN PASIËNT TOESTEMMINGSVORM IN AFRIKAANS

PLAASLIKE DIAGNOSTIESE VERWYSINGSWAARDES (LDRLs) VIR ROETINE BORSKAS-X-STRAAL ONDERSOEKE BY 'N HOSPITAAL IN DIE NOORDKAAP

U word uitgenooi om deel te neem aan 'n navorsingsprojek. Die radiograaf sal die besonderhede van u deelname aan die navorsing aan u verduidelik. Vra die radiograaf gerus enige vrae oor enige deel van die projek wat u nie volledig verstaan nie. Verder is u deelname heeltemal vrywillig en kan u met vrymoedigheid weier om deel te neem. Indien u sou weier, sal dit u op geen manier negatief beïnvloed nie. U is by magte om op enige stadium van die studie te onttrek, selfs indien u ingestem het om deel te neem.

Die studie is voorgelê by die Etiekkomittee vir Gesondheidsnavorsing van die Universiteit van die Vrystaat (nommer) en sal volgens die Suid-Afrikaanse riglyne vir 'goeie kliniese praktyk' uitgevoer word.

Die navorsing sal by die radiologie department van die, Robert Sobukwe Hospitaal gedoen word. Indien u toestemming sou gee om aan die studie deel te neem, sal die volgende van u verwag word:

- Staan op die weegskaal om u gewig te bepaal,
- Die deursnit van u borskas sal in twee rigtings gemeet word,
- U sal voor die x-straal masjien geplaas word en twee beelde van u borskas sal geneem word.

Daar is geen finansiële voordeel om deel te neem aan hierdie studie nie. Die navorser sal u nie vergoed indien u tydens deelname aan hierdie navorsingsprojek beseer word nie.

Hierdie studie sal die navorser help om diagnostiese verwysingswaardes (DRLS) van borskas x-straalondersoeke te bepaal/bereken en dit mag help om die stralingsdosis waaraan die populasie in die toekoms blootgestel word te verminder.

Indien u nie instem om aan die navorsing deel te neem nie, sal u regte om u borskas x-straalbeelde vanaf die radiologie-department van die Robert Sobukwe Hospitaal te verkry nie op enige manier geaffekteer word nie.

U deelname aan hierdie studie sal vertroulik bly. Geen inligting in verband met u identiteit sal ingesamel word nie. Slegs tegniese inligitng sal ingesamel word in verband met x-straalbeelde en u gewig en mates sal gedokumenteer word. Die inligitng wat ingesamel word sal op die datavorm neergeskryf word. Slegs u unieke hospitaalnommer en geen persoonlike inligting sal op die datavorm neergeskryf word nie. Publikasie van die navorsingstudie se bevindings sal nie u hospitaalnommer insluit nie.

U kan Mnr Maurice Junda by tel: 0784447634 kontak indien u verdere navrae het of enige probleme ondervind.

U kan die voorsitter van die Navorsingetiekkomitee vir Gesondheidsnavorsing van die Universiteit van die Vrystaat by 0514017794/5 kontak indien u enige kwelpunte of klagtes aangaande die navorsingstudie het.

TOESTEMMING VIR DEELNAME AAN DIE STUDIE IN AFRIKAANS

TITEL: LOCAL DIAGNOSTIC REFERENCE LEVELS (LDRLs) FOR ROUTINE CHEST X-RAY EXAMINATIONS AT A HOSPITAL IN THE NORTHEN CAPE

(HSREC: UFS-HSD2018/1610/2603)

U is versoek om deel te neem aan 'n navorsingstudie.

……………….. het u ingelig in verband met die studie.

U kan Mnr Maurice Junda by tel: 0784447634 kontak indien u verdere navrae het of enige probleme aangaande die navorsing ondervind.

U kan die voorsitter van die Etiekkomitee vir Gesondheidsnavorsing by die Universiteit van die Vrystaat by 0514017794/5 kontak, indien u navrae aangaande u regte as navorsingsdeelnemer het.

U deelname aan hierdie navorsing is vrywillig en u sal nie gepenaliseer word of voordele verloor indien u weier om deel te neem, of besluit om u deelname te staak nie. Geen addisionele borskas x-straalondersoeke sal uitgevoer word vir die navorsingstudie nie. **U besluit om nie aan die studies deel te neem nie sal nie u borskas x-staalondersoeke negatief beïnvloed nie**. Daar is geen addisionele koste betrokke in u deelname nie. Daar is verder geen finansiële voordeel vir u om deel te neem aan die studie nie.

Indien u instem om deel te neem, sal u 'n **getekende afskrif van hierdie dokument sowel as die deelname-inligtingstuk ontvang. Hierdie is 'n geskrewe opsomming van die navorsing.**

EK bevestig hiermee die volgende:

- Ek is ingelig in verband met my deelname aan die navorsing,
- Ek verstaan dat my deelname vrywillig is,
- Dat my persoonlike inligting vertroulik sal bly,
- Ek gee toestemming om geweeg en gemeet te word.

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Handtekening van deelnemer   Datum

---------------------------   --------------------------------

Handtekening van getuie   Datum

---------------------------   --------------------------------

Handtekening van tolk   Datum

SKEUR HIER--

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Handtekening van deelnemer   Datum

---------------------------   --------------------------------

Handtekening van getuie   Datum

---------------------------   --------------------------------

Handtekening van tolk   Datum

Handtekening van radiograaf---

Unieke hospitaalnommer van die pasiënt --

APPENDIX F

FOROMO YA KITSISO YA GO NEELA KA TETLELELO KE MOLWETSI KA SETSWANA

TLHATLHOBO E E TLWAELEGILENG YA MAFATLHA (LDRLs) MO BOOKELONG BA MMUSO BO MO KAPA BOKONE.

O lalediwa go nna le seabe mo porojekeng ya dipatlisiso. Radiokerafa e tla neelana ka tlhaloso ka botlalo ya go tsaya karolo mo ditlhomamisong tseno. O letlelesega go ka botsa potso efe kgotsa efe fa go na le fa o sa tlhaloganyeng. Gape, go tsaya karolo ga gago go tswa go wena, ebile o letlelesega go ka gana go tsaya karolo. Go gana ga gago ga go kitla go o ama ka mokgwa ope o o sa siamang. O kgona go ka fetola maikutlo a gago nako nngwe le nngwe le fa o ne o neelane ka tetla ya go tsaya karolo.

Dithuto tseno, di tlhagisitswe mo Komiting ya Maitshwaro ya Lefapha la Dipatlisiso la Yunibesiti ya Freisitata (nomoro) go atlenegisa mme e tla tsamaisiwa go ya ka melawana ya didiriswa ya Khansele ya Aforika Borwa ya tiriso le dipatlisiso tsa kalafi *(MRC)*

Dipatlisiso tse, di tla dirafadiwa mo lefapheng la radioloji (X-rays) tsa bookelo jwa Robert Sobukwe.

Fa o neelana ka tetla ya go nna le seabe o tla tshwanela ke go dira tse di latelang: -

- Go ema mo sekaleng gore boima ba mmele wa gago bo tseiwe.
- Bokima ba sehuba sa gago bo tla lekanngwa ka maphata a le mabedi.
- O tla emisiwa fa pele ga matshine wa X-ray mme go tsewe ditshwantsho di le pedi tsa sehuba.

Ga go na moputso ope wa madi go nna le seabe go seno. Mobatlisisi ga a kitla a go duela fa o ka tlhagelwa ke kgobalo ka ntlha ya go nna le seabe mo dipatlisisong tseno. Radiokerafa o tla go netefaletsa tshireletsego kgatlhanong le marang a X-ray.

Thuto eno, e tla nna le thuso go mobatlisisi go ithuta ka botlalo ka boemo ba matshwao a ditlhatlhobo tsa malwetsi a mafatlha mme e tla nna le thuso e kgolo mo go laoleng marang mo setshabeng sa ka moso.

Fa o sa dumelane le go ka nna le seabe mo diphuputsong tse, ga go tlhalose gore ditshwanelo tsa gago tsa go tsaya ditshwantsho tsa X-ray lefapheng la Radioloji la bookelo jwa Robert Mangaliso Sobukwe e tla senyega ka mokgwa mongwe.

Dithutong tseno, go nna le seabe ga gago e tla nna sephiri. Ga go kitla go nna le kitsiso kgotsa kgobokanyo e tla dirwang ka boemo ba gago.

Go tla tsewa fela kitsiso ya setegeniki ya ditshwantsho tsa X-ray, boima/bokete ba mmele wa gago le tekanyetso tse di tla tlhagisiwang. Mme kitsiso e, e tla tsengwa mo setlankaneng sa dipalopalo. Phatlalatso ya tlhagiso eno ya dithuto ga e na go tsenyeletsa nomono ya gago ya bookelo. Nomoro e kgethegileng e, e tla nna fela mo setlankaneng sa dipalopalo. Ke mobatlisisi ka esi fela kgotsa badiri ba ba setheo sa diX-ray tsa bookelo ba dumeletsweng go ka fitlhelela nomoro ya gago ya bookelo.

O ka kgona go kopana le Motlotlegi Maurice Junda nomorong ya selefounu ya 078 44447634 fa o na le dingongorego kgotsa o lemoga bothata bo bo rileng.

O ka kgona go ikopanya le Modulasetulo wa Komiti ya Dipatlisiso tsa Bophelo le Maitshwaro ya Yunibesiti ya Freisitata mo mogaleng wa 051 401 7794/5 fa o na le mabaka kgotsa dingongorego tse di sa rarabololwang ke Mobatlisisi.

TETLELELO YA GO NNA LE SEABE MO DIPATLISISONG.

SETLHOGO: BOSUPI BA MAEMO A TLHATLHOBO E TLWAELEGILENG YA MAFATLHA BOOKELONG JWA KAPA BOKONE.

(HSREC: UFS-HSD2018/1610/2603)

O ile wa kopiwa go nna le seabe thutong e ya dipatlisiso.

O itsesitswe ka ga thuto e ke …………………………………………………………

O ka ikgolaganya le Maurice Junda mo nomorong ya selefounu ya 078 4447634 nako nngwe le nngwe fa o na le dipotso mabapi le diphuputso kgotsa o itemogela bothata bo bo rileng bo bo tlholwang ke diphuputso.

O ka ikopanya le Mokwaledi wa Komiti ya Bophelo ya Saense le Boitshwaro Yunibesiting ya Freisitata mo mogaleng wa 051 401 7794/5 fa o na le dipotso mabapi le ditshwanelo jaaka o le sediriswa sa diphuputso.

Go nna le seabe sa gago ke boithaupi, o ka se beelwe kwa thoko, kgotsa wa senyegelwa ke moputso fa o gana go nna le seabe, kgotsa fa o tsaya tshwetso ya go tlogela go nna le seabe. Ga go kitla go nna le tlhatlhobo nngwe e tla dirwang mabapi le thuto ya diphuputso. Go gana ga gago go nna le seabe thutong e, go ka se go senyetse tlhatlhobo ya X-ray ya mafatlha ya gago. Ga go na ditshenyegelo tse di okeditsweng go nneng le seabe sa gago. Fela ga gona moputso fa o nna le seabe thutong e.

Fa o dumela go tsaya karolo, o tla fiwa khopi e e saenilweng ya tokomane eno e, e le kamogelo ya tshedimosetso ya motsaakarolo, e le tshobokanyo ya dipatlisiso tseno.

Ke netefatsa tse di latelang:

- Ke ile ka itsesiwa ka go nna le seabe ga me
- Ke tlhalogantse gore go nna le seabe ga me ke boithaopi.
- Le gore kitsiso ya me e tla dirisiwa ka mokgwa wa sephiri,
- Le gore ke letlelela gore boima ba mmele bo tsewe le go lekangwa.

77

Sikinetjhara ya Motsaakarolo   **Letlha**

--   --

Sikinetjhara ya Moranoledi   **Letlha**

--   --

KGAOLA FA ---

Sikinetjhara ya Motsaakarolo   **Letlha**

--   ----------------------------------

Sikinetjhara ya Paki   **Letlha**

--   ----------------------------------

Sikinetjhara ya Moranoledi   **Letlha**

--   ------------------------------------

:

Leina la Radiokerafa   --

Nomoro e kgethegileng ya Bookelo ya Motsaakarolo   --------------------------------

UHN: Unique Hospital Number. **Bokima jwa molwetsi ka dikilogramo.** *Patient thickness (TK)* **mo go boemo jwa T7 ka disentimetara.** *Exposure index (EI)*

APPENDIX G

DATA SHEET

		ROBERT SOBUKWE HOSPITAL DATA SHEET										
	ROOM NO			GRID RATIO				TOTAL FILTRATION				
		PA CHEST					LAT CHEST					
UHN	WEIGHT	TK	EI	kVp	mAs	FFD	TK	EI	kVp	mAs	FFD

APPENDIX H

DATA COLLECTION PROCEDURE FOR RADIOGRAPHERS TO FOLLOW

- Radiographer to call and identify patient.
- Give patient information leaflet and consent form to patient.
- Explain purpose and procedure of the research to patient.
- Give patient the opportunity to ask questions.
- If patient agrees to sign consent form then the patient has to be weighed.
- If the patient weight is 60kg to 80kg, the patient thickness is measured at the level of T7 with a calliper.
- The measurement of the two projections will be at the level of T7for both PA and LAT (at 90 degrees to each other).
- The patient is provided with radiation protection material.
- The radiographer explains and rehearses the breathing technique.
- The patient is placed in front of the bucky of the X-ray unit.
- The radiographer records exposure parameters and patient thickness of both projections and the weight of the patient on the data sheet.

APPENDIX I

EVALUATION CRITERIA FOR OPTIUM QUALITY POSTERO-ANTERIOR AND LATERAL CHEST PROJECTIONS

Image criteria for PA chest

- Performed at full inspiration (assessed by the position of the ribs above the diaphragm either six anteriorly or ten posteriorly) and with suspended respiration.
- Symmetrical reproduction of the thorax as shown by the central position of the spinous process between the medial end of the clavicles.
- Medial border of the scapulae to be projected outside the lung fields.
- Visually sharp reproduction of a vascular pattern in the whole lung, particularly the peripheral vessels.
- Visually sharp reproduction of
    - The trachea and proximal bronchi,
    - The borders of the heart and aorta,
    - The diaphragm and lateral costo-phrenic angles.
- Visualisation of the retro cardiac lung and mediastinum.
- Visualisation of the spine through the heart shadow.
- From T1 to below the costo-phrenic angles and the lateral borders of the chest should be included in the collimated area.

Image criteria for LAT chest examination

- Performed at full inspiration and with suspended respiration.
- Arms should be raised clear of the thorax.
- Superimposition of the posterior lung borders.
- Reproduction of the trachea.
- Reproduction of the costophrenic angles.
- Visually sharp reproduction of the posterior border of the heart, the aorta, mediastinum, diaphragm, sternum and thoracic spine.
- Entire lungs from apices to costo-phrenic angles and from sternum anteriorly to posterior ribs should be included.

APPENDIX J

LETTER OF APPROVAL FROM THE STATISTICIAN

Maryn Viljoεn
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 9.1.3) • Statistics consultation services to analyze and interpret data
Conveys results with statistical tables and figures where needed

The Chairperson: Health Sciences Research Ethics Committee (HSREC)
For Attention: Mrs. M.G.E. Marais
Block D, Room 104
Francois Retief Building
Faculty of Health Sciences
University of the Free State

31 August 2018

Title: "DIAGNOSTIC REFERENCE LEVELS FOR ROUTINE CHEST X-RAY
           EXAMINATIONS AT A GOVERNMENT HOSPITAL IN BLOEMFONTEIN."

Researcher: Mr. M. Junda
               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
082 82 35 731

APPENDIX K

LETTER OF NON-DISCLOSURE OF PATIENT'S INFORMATION

I (Name of radiographer) --- agree that the patient's information that will be collected during this research will not be disclosed to the public. All the information will be written on the data sheet and the data sheet will be handed to the researcher.

Yours truly,

Signature -----------------------------------

Place --

Date ---

APPENDIX L

RADIOGRAPHER'S CONSENT FORM FOR RESEARCH DATA COLLECTION

I, Mr/Mrs/Miss _____ is a registered radiographer with the Health Profession Council of South Africa (HPCSA) and give consent to participate in this research. My responsibility in this research is to collect research data as prescribed in the research proposal. The researcher has explained the purpose of the research and the method to collect research data extensively.

Yours truly,

Signature _____

Date _____

APPENDIX M

EHTICS APPROVAL LETTER

UNIVERSITY OF THE
FREE STATE
UNIVERSITEIT VAN DIE
VRYSTAAT
YUNIVESITHI VA
FREISTATA

UFS·UV
HEALTH SCIENCES
GESONDHEIDSWETENSKAPPE

Health Sciences Research Ethics Committee

07-Jun-2019

Dear MR Maurice Junda

Ethics Number: UFS-HSD2018/1610/2603
Ethics Clearance: **Local Diagnostic Reference Levels (LDRLs) for routine chest x-ray examinations at a hospital in the Northern Cape**
Principal Investigator: **MR Maurice Junda**
Department: **Radiography – CUT**
SUBSEQUENT SUBMISSION APPROVED

With reference to your recent submission for ethical clearance from the Health Sciences Research Ethics Committee. I am pleased to inform you on behalf of the HSREC that you have been granted ethical clearance for your request as stipulated below:

Change in study location from Pelonomi hospital to Robert Sobukwe hospital at Kimberley.

Title change from "Local Diagnostic Reference Levels (LDRLs) for routine chest X-ray examinations at Pelonomi hospital in Bloemfontein" to "Local Diagnostic Reference Levels (LDRLs) for routine chest x-ray examinations at a hospital in the Northern Cape" .

Use all 3 stationary x-ray machines at the general radiography section for data collection.

The total number of patients require to participate in this research is now 60.
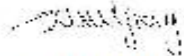
The information leaflet is translated to Setswana

The HSREC 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 50, 21 CFR 56; CIOMS; ICH-GCP-E6 Sections 1-4; 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 HSREC of the Faculty of Health Sciences.

For any questions or concerns, please feel free to contact HSREC Administration: 051-4017794/5 or email EthicsFHS@ufs.ac.za.

Thank you for submitting this request for ethical clearance and we wish you continued success with your research.

Yours Sincerely

Dr. SM Le Grange
Chair : Health Sciences Research Ethics Committee

Health Sciences Research Ethics Committee
Office of the Dean: Health Sciences
T: +27 (0)51 401 7795/7794 | E: ethicsfhs@ufs.ac.za
IRB 00006240; REC 230408-011; IORG0005187; FWA00012784
Block D, Dean's Division, Room D104 | P.O. Box/Posbus 339 (Internal Post Box G40) | Bloemfontein 9300 | South Africa
www.ufs.ac.za

APPENDIX N

APPROVAL LETTER FROM THE DEPARTMENT OF HEALTH NORTHERN CAPE AND ROBERT MANGALISO SOBUKWE HOSPITAL

DEPARTMENT OF HEALTH	**Robert Mangaliso**	
LEFAPHA LA BOPHELO BO BOTLE	**Sobukwe Hospital**	
DEPARTEMENT VAN GESONDHEID	Head Clinical Management: Medical	
ISEBE LENKONZO ZENTLALONTLE	Du Toitspan Road Tel: 053 802 2147	
	Private Bag X5021 Fax: 053 832 9435 /	
	Kimberley 086 617 4089	

Reference :
Tshupelo :
Verwysings :
Isalathiso :

Date
Leshupelo
Datum : **19th June 2019**   **Dr H Saeed**
Umhla

TO: Mrs M Junda

RE: Permission to do research

Permission is hereby granted to conduct a medical research project at Kimberley Hospital complex, title proposed: "LOCAL DIAGNOSTIC REFERENCE LEVELS (LDRLs) FOR ROUTINE CHEST X-RAY EXAMINATIONS AT A GOVERNMENT HOSPITAL IN THE NORTHERN CAPE"

Please submit proof of ethics clearance, before commencing with the research.
Kindly submit research protocol to the Northern Cape Provincial Health Research and Ethics Committee for approval.

Contact Details:
Dr E Worku
Email address: eworku@ncpg.gov.za
Tel: (053) 8302134

Dr H Saeed
MBBS,H.Dip.Int.Med.(CMSA),M.Fam.Med.(UFS),
Specialist Family Physician, Affiliate Lecturer – UFS
Acting Head Clinical Management: Medical

Date: 19/06/2019

APPENDIX O

ROOM 1 LATERAL CHEST PROJECTION DATA

TYPE OF EXAMINATION	kV$_p$	mAs	FFD(cm)	Patient Thickness(cm)	ESD (µGy)
Chest (LAT)	108	10	180	26	0.53
Chest (LAT)	113	11	180	22	0.60
Chest (LAT)	115	8	180	25	0.47
Chest (LAT)	111	6.5	180	27	0.37
Chest (LAT)	116	9	180	18	0.49
Chest (LAT)	103	12.5	180	26	0.61
Chest (LAT)	122	12.5	180	32	0.89
Chest (LAT)	122	12.5	180	34	0.91
Chest (LAT)	113	12.5	180	29	0.75
Chest (LAT)	110	9	180	27	0.50
Chest (LAT)	121	10	180	27	0.66
Chest (LAT)	121	10	180	30	0.68
Chest (LAT)	111	14	180	34	0.86
Chest (LAT)	109	14	180	31	0.80
Chest (LAT)	110	12.5	180	29	0.71
Chest (LAT)	110	12.5	180	34	0.76
Chest (LAT)	117	12.5	180	26	0.76
Chest (LAT)	114	12.5	180	32	0.79
Chest (LAT)	112	12.5	180	29	0.73
Chest (LAT)	119	9	180	20	0.52

APPENDIX P

ROOM 1 PA CHEST PROJECTION DATA

TYPE OF EXAMINATION	kV_p	mAs	FFD(cm)	Patient Thickness(cm)	ESD (µGy)
CHEST (PA)	108	3.6	180	22	0.18
CHEST (PA)	102	4	180	20	0.18
CHEST (PA)	109	3.6	180	20	0.18
CHEST (PA)	103	3.2	180	24	0.15
CHEST (PA)	116	4.5	180	30	0.28
CHEST (PA)	103	4	180	19	0.18
CHEST (PA)	106	3.2	180	24	0.16
CHEST (PA)	108	4.5	180	26	0.24
CHEST (PA)	113	4.5	180	19	0.24
CHEST (PA)	110	3.6	180	18	0.18
CHEST (PA)	110	4	180	23	0.21
CHEST (PA)	110	4	180	23	0.21
CHEST (PA)	111	5.6	180	20	0.29
CHEST (PA)	109	4	180	23	0.21
CHEST (PA)	110	5	180	20	0.25
CHEST (PA)	110	5	180	21	0.26
CHEST (PA)	117	3.2	180	23	0.19
CHEST (PA)	114	5	180	21	0.27
CHEST (PA)	112	5	180	22	0.27
CHEST (PA)	119	4.5	180	28	0.29

88

APPENDIX Q

ROOM 2 LATERAL CHEST PROJECTION DATA

TYPE OF EXAMINATION	kV_p	mAs	FFD(cm)	Patient Thickness(cm)	ESD (µGy)
Chest (LAT)	117	8	150	31	0.84
Chest (LAT)	109	12.5	180	27	0.70
Chest (LAT)	117	8	180	32	0.54
Chest (LAT)	117	9	180	27	0.57
Chest (LAT)	109	11	180	34	0.67
Chest (LAT)	113	7.1	180	21	0.39
Chest (LAT)	117	8	180	21	0.47
Chest (LAT)	109	12	180	27	0.67
Chest (LAT)	125	10	180	33	0.78
Chest (LAT)	125	10	180	30	0.75
Chest (LAT)	125	8	180	32	0.61
Chest (LAT)	121	7.1	180	33	0.52
Chest (LAT)	121	7.2	180	29	0.50
Chest (LAT)	125	10	180	31	0.76
Chest (LAT)	125	10	180	32	0.77
Chest (LAT)	117	8	180	30	0.53
Chest (LAT)	117	6.3	180	21	0.37
Chest (LAT)	125	8	180	32	0.61
Chest (LAT)	117	9	180	30	0.59
Chest (LAT)	117	9	180	29	0.59

APPENDIX R

ROOM 2 PA CHEST PROJECTION DATA

TYPE OF EXAMINATION	kV_p	mAs	FFD(cm)	Patient Thickness(cm)	ESD (µGy)
CHEST (PA)	109	4.5	150	26	0.38
CHEST (PA)	109	4	180	23	0.21
CHEST (PA)	113	4.5	180	30	0.28
CHEST (PA)	109	3.2	180	21	0.17
CHEST (PA)	109	4	180	22	0.21
CHEST (PA)	113	3.6	180	27	0.21
CHEST (PA)	117	4	180	29	0.26
CHEST (PA)	109	4	180	21	0.21
CHEST (PA)	109	4.5	180	31	0.26
CHEST (PA)	113	4.5	180	23	0.25
CHEST (PA)	109	4	180	24	0.21
CHEST (PA)	109	4	180	23	0.21
CHEST (PA)	107	3.6	180	26	0.19
CHEST (PA)	109	5	180	25	0.27
CHEST (PA)	109	4	180	26	0.22
CHEST (PA)	117	3.6	180	24	0.22
CHEST (PA)	117	5	180	19	0.29
CHEST (PA)	117	5	180	21	0.29
CHEST (PA)	117	4.5	180	25	0.28
CHEST (PA)	117	4	180	21	0.24

APPENDIX S

ROOM 3 LATERAL CHEST PROJECTION

TYPE OF EXAMINATION	kV$_p$	mAs	FFD(cm)	Patient Thickness(cm)	ESD (µGy)
Chest (LAT)	125	5.76	150	30	0.64
CHEST (LAT)	125	4.39	150	31	0.49
CHEST (LAT)	125	12.9	180	30	0.91
CHEST (LAT)	109	5	180	35	0.29
CHEST (LAT)	117	5	180	28	0.30
CHEST (LAT)	125	6.5	180	34	0.48
CHEST (LAT)	117	5	180	33	0.32
CHEST (LAT)	117	19.8	180	37	1.36
CHEST (LAT)	117	10.7	180	33	0.69
CHEST (LAT)	117	6.56	180	30	0.41
CHEST (LAT)	117	7.77	180	36	0.53
CHEST (LAT)	125	12.5	180	29	0.87
CHEST (LAT)	109	8	180	29	0.43
CHEST (LAT)	109	12.5	180	31	0.69
CHEST (LAT)	125	3.4	180	25	0.22
CHEST (LAT)	125	6.3	180	26	0.42
CHEST (LAT)	109	16	180	30	0.87
CHEST (LAT)	109	10	180	27	0.52
CHEST (LAT)	125	12.3	180	28	0.85
CHEST (LAT)	125	9.4	180	29	0.66

APPENDIX T

ROOM 3 PA CHEST PROJECTION

TYPE OF EXAMINATION	kV$_p$	mAs	FFD(cm)	Patient Thickness(cm)	ESD (µGy)
CHEST (PA)	125	1.13	150	21	0.11
CHEST (PA)	125	2.34	150	22	0.23
CHEST (PA)	125	1.6	180	27	0.11
CHEST (PA)	109	3	180	28	0.16
CHEST (PA)	117	3	180	23	0.17
CHEST (PA)	125	1.5	180	27	0.10
CHEST (PA)	117	3.2	180	26	0.19
CHEST (PA)	117	2.06	180	27	0.12
CHEST (PA)	117	2.78	180	25	0.16
CHEST (PA)	117	1.89	180	24	0.11
CHEST (PA)	117	3.41	180	31	0.22
CHEST (PA)	125	1.3	180	23	0.08
CHEST (PA)	109	4	180	20	0.19
CHEST (PA)	125	4	180	25	0.26
CHEST (PA)	125	1	180	21	0.06
CHEST (PA)	125	1.12	180	21	0.07
CHEST (PA)	109	4	180	24	0.20
CHEST (PA)	102	3.2	180	20	0.13
CHEST (PA)	125	1.38	180	22	0.09
CHEST (PA)	125	1.3	180	22	0.08

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