# The utilisation of digital radiography by diagnostic Radiographers in South Africa.

# THE UTILISATION OF DIGITAL RADIOGRAPHY BY DIAGNOSTIC RADIOGRAPHERS IN SOUTH AFRICA

by

**DANIEL LAMOLA**

Submitted in partial fulfilment of the requirements for the degree

**MAGISTER TECHNOLOGIAE: RADIOGRAPHY**

In the

Department of Biomedical Sciences

FACULTY OF SCIENCE

**TSHWANE UNIVERSITY OF TECHNOLOGY**

Supervisor: Prof WA Hoffmann

Co-supervisor: Dr MA Van der Watt

2018

# DECLARATION BY CANDIDATE

I hereby declare that this dissertation, submitted for the degree M Tech: Radiography to Tshwane University of Technology, is my own original work and has not previously been submitted to any other institution of higher education. I further declare that all sources cited or quoted are indicated and acknowledged by means of a comprehensive list of references.

_____

D LAMOLA

## THANK YOU, LORD JESUS CHRIST

Thank you, Jesus Christ, for the gift of the Holy Spirit and thank you for the love of God the Father. Thank you for the strength and courage to go through this project. Thank you for a wife who supported me and for two daughters whose smiles illuminated my world. Thank you for GTFAN, a church that gave me spiritual strength during the process of my study. Thank you for blessing me with responsible parents, who laid an educational foundation for my life; the role they played in my life is the reason I say thank you. Thank you for blessing me with three brothers and five sisters. Thank you for this Master's degree, to the glory of Jesus Christ.

**AMEN**

# ACKNOWLEDGEMENTS

I would like to express my sincere gratitude and appreciation to:

The Faculty of Science, Tshwane University of Technology. Thank you for granting me sabbatical leave to complete my studies. Thank you for allowing me to use the resources of the university for my study.

Prof D du Toit (now retired) and Dr C Boshoff (acting), Head: Department of Biomedical Sciences, Tshwane University of Technology. Thank you for paving a path and granting me the opportunity to grow in my academic career.

Prof JJ Pieterse (now retired), Section Head: Department of Biomedical Sciences, Tshwane University of Technology. Thank you for sharing your wisdom with me. Your support, encouragement and motivation played a major role in my studies.

The “R” Team of academic colleagues, namely Ms B Johnson, Ms SR Smit and the “captain”, Dr MA van der Watt. Thank you for your continual support, encouragement, guidance and understanding. You are a gift and a blessing from God.

Prof WA Hoffmann (supervisor), Department of Biomedical Sciences, Tshwane University of Technology. Your positive critique, as well as your comprehensive and timely feedback, is highly appreciated. Your expertise motivated me, while your patience encouraged me to keep pushing. You have a way of inspiring a student to go the extra mile. Thank you, Prof.

Dr MA van der Watt (co-supervisor), Department of Biomedical Sciences, Tshwane University of Technology. Thank you for sharing your knowledge and experience. You have a way of stretching my thinking in the right direction. Thank you for offering your shoulder to cry on when I needed relief from academic programme duties.

To all participants in this study, I appreciate your willingness to participate and I am convinced that without your participation this study would not have been possible. Thank you.

# ABSTRACT

**Background:** Digital radiography is broadly divided into two sub-imaging systems, namely computed radiography and flat-panel detectors. Flat Panel Detectors are further divided into two sub-imaging systems, namely direct and indirect conversions. Computed radiography is also known as cassette-based digital radiography. Digital radiography offers numerous features that diagnostic radiographers can utilise on a day to day basis. However, some of these features seem to be hardly or ever used by diagnostic radiographers in South Africa.

**Aims:** The first aim of this study was to gain deeper understanding of the utilisation of digital radiography features by diagnostic radiographers in South Africa. The second aim was to develop a curriculum framework to guide institutions of higher learning in South Africa in the development and implementation of curricula that adequately address the current digital radiography developments and training needs in the field of diagnostic radiography.

**Study design:** A mixed methods approach involving three phases was followed in this study to address the study objectives. Phase 1 focused on a document analysis of the current diagnostic radiography study guides being used at institutions of higher learning in South Africa. Phase 2 focused on an online survey of current practising diagnostic radiographers in South Africa. Phase 3 involved focus group interviews with diagnostic radiographers working in different imaging facilities in both the private and public sectors in South Africa.

**Results:** The Phase 1 results highlight three main categories of digital radiography feature curricular coverage, namely digital radiography features *inadequately* covered by the analysed study guides for undergraduate diagnostic radiography, digital radiography features *adequately* covered and digital radiography features *not* covered. The Phase 2 results reflect a quantitative analysis of the application and utilisation of the various digital radiography features. Lastly, the Phase 3 results highlight four main categories in the clinical application and utilisation of the various digital radiography features, namely features *hardly used or never* used, features *commonly* used, features radiographers are *not interested* in using; and features about which radiographers have *no knowledge*.

**Conclusion:** Digital radiography features are in general not adequately covered in the undergraduate curricula of institutions of higher learning offering courses in diagnostic radiography in South Africa. Practising diagnostic radiographers utilise the various available features of digital radiography only sub-optimally; to a certain extent, some radiographers even lacked basic knowledge of digital radiography jargon. Lastly, the diagnostic radiography profession in South Africa is facing various challenges, such as an outdated formal scope of practice, as well as role ambiguity between diagnostic radiographers and information technology specialists.

# ABBREVIATIONS

| | |
|---|---|
| ADC | Analogue-to-digital converter |
| AEC | Automated exposure control |
| AIS | Administrative information system |
| ALARA | As low as reasonably achievable |
| AP | Antero-posterior |
| a-Se | Amorphous selenium |
| a-Si | Amorphous silicon |
| AXIM | Africa x-ray industrial medical |
| CAD | Computer-aided diagnosis |
| CCD | Charge-coupled device |
| CD | Compact disc |
| CIS | Clinical information system |
| CR | Computed radiography |
| CRT | Cathode ray tube |
| CsI | Cesium iodide |
| CT | Computed tomography |
| CPD | Continuous professional development |

| | |
|---|---|
| D | Diagnostic |
| DDR | Direct digital radiography |
| DFPD | Direct flat panel detector |
| DI | Deviation index |
| DICOM | Digital imaging and communication in medicine |
| DoH | Department of Health |
| DQE | Detection quantum efficiency |
| DR | Digital radiography |
| DRC | Dynamic range control |
| EI | Exposure index |
| EMS | Electronic medical records |
| EVP | Enhanced visualisation processing |
| FCRE | Faculty of science committee for research ethics |
| FPD | Flat-panel detectors |
| $Gd_2O_2S$ | Gadolinium oxysulphide |
| HASA | Hospital Association of South Africa |
| HEIs | Higher education institutions |
| HIS | Hospital information system |
| HL7 | Health level 7 |

| | |
|---|---|
| HPCSA | Health Professions Council of South Africa |
| IFPD | Indirect flat panel detector |
| IP | Imaging plate |
| IR | Image receptor |
| IT | Information technology |
| LAN | Local area network |
| LCD | Liquid crystal display |
| lgM | Log median |
| lp/mm | line-pairs per millimeter |
| MAN | Metropolitan area network |
| MFP | Multi-objective frequency processing |
| mm | Millimetre |
| MRI | Magnetic resonance imaging |
| MTF | Modulation transfer function |
| MTF | Multi-scale image contrast amplification |
| NHRD | National Health Research Database |
| PA | Posterior-anterior |
| PACS | Picture Archiving and Communication System |
| PSP | Photostimulable storage phosphor |

| | |
|---|---|
| QA | Quality assurance |
| QC | Quality control |
| RFA | Reject film analysis |
| RIS | Radiology Information system |
| SA | South Africa |
| SAQA | South African Qualifications Authority |
| SF | Screen film |
| SMU | Sefako Makgatho Health Sciences University |
| SNR | Signal-to-noise ratio |
| SORSA | Society of Radiographers of South Africa |
| TFT | Thin film transistor |
| TRC | Tshwane research committee |
| TUT | Tshwane University of Technology |
| UP | University of Pretoria |
| UPS | Uninterruptable power supply |
| WAN | Wide area network |
| Z | Atomic number |
| ZAR | South African Rand |

# GLOSSARY

| | |
|---|---|
| Analysis rubric | A scoring instrument (guide) consisting of specific pre-established level descriptor criteria for the purpose of evaluating a product, activity or document. |
| Application specialist | A person, usually a qualified radiographer, who is working for an x-ray equipment manufacturer; his/her primary function is to train clinical practising radiographers on how to use newly procured x-ray equipment. |
| Diagnostic radiographer | In this study the term refers specifically to a duly trained and professionally registered person who uses x-radiation and magnetic resonance imaging to produce images of a patient's condition, in so doing assisting medical practitioners and radiologists to make a medical diagnosis of the patient's condition. |
| Imaging facility | In this study the term "imaging facility" refers specifically to an x-ray department. |

| | |
|---|---|
| Information technology specialist | A person who is usually a non-medically trained professional responsible for maintaining and managing the technical aspects of digital radiography technology; he/she supports diagnostic radiographers to fulfil their medical imaging duties. |
| Radiologists | A professionally registered medical doctor who is a duly trained specialist in radiology. His/her responsibilities include writing diagnostic reports using radiographs. |
| Scope of practice | A formal description of healthcare practitioners' professional-ethical responsibilities. |
| Study guide | An academic resource that contains themes and topics for a particular study field to guide students' teaching and learning activities. |

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# CHAPTER 1

# INTRODUCTION

## 1.1 BACKGROUND

The discovery of diagnostic radiography is attributed to Wilhelm Conrad Roentgen, a professor of physics at the German University of Wurzburg, in 1895 (Carrol, 2007; Farmelo, 1995:86; Fauber, 2017:2; Nyathi, Chirwa & Van der Merwe, 2010:1; Reed, 2011:3S; Thomas & Banerjee, 2013:4). On 22 December 1895, the first analogue radiograph of the hand of Professor Roentgen's wife, Bertha, hand was produced (Thomas & Banerjee, 2013:5). Since then, radiography has evolved over the years from analogue [screen-film (SF)] to digital radiography (DR), which has become the standard technology in most imaging departments (Lehnert *et al*, 2011:1368; Nyathi, Chirwa & Van der Merwe, 2010). Medical imaging has not only grown in image production, but also in image processing, image display, image recording and image transmission (Doi, 2006:R6). DR began with computed tomography (CT) and magnetic resonance imaging (MRI) in the early 1980s (Bushong, 2008:413; Carlton & Adler, 2006:356).

According to Seeram (2011:254), DR refers to "a radiographic imaging modality that produces digital images which are displayed for interpretation and diagnosis, stored and archived for medical and legal purposes, and retrospective analysis. Also, these images can be transmitted to remote locations for use by surgeons, emergency physicians and others". DR in a broad sense is divided into two sub-imaging systems,

namely computed radiography (CR) and flat-panel detectors (FPD) (Carlton & Adler, 2006:356; Doi, 2006:R15; Fauber, 2017:68). FPDs are divided into two sub-imaging systems, namely direct and indirect conversions (Carlton & Adler, 2006:356; Doi, 2006:R15; Fauber, 2017:68). CR is also known as cassette-based DR (Carlton & Adler, 2006:356). The cassette-based system utilises a photostimulable storage phosphor (PSP) imaging plate (IP) (Carlton & Adler, 2006:356). This cassette can be used in a bucky (built-in cassette holder) or for portable examinations, similar to a traditional SF cassette. Once the IP is exposed, the radiographer takes it to a unit reader for processing and creates the image electronically. It is considered indirect digital imaging because the radiographer must literally move the detector (PSP) between image acquisition and the actual image display (Carlton & Adler, 2006:356; Nyathi, Chirwa & Van der Merwe, 2010).

In contrast to CR's cassette-based system, FPD is a cassette-less system. The detector and reader form a permanent part of a table or wall unit; as such, there is no need for a cassette (Nyathi, Chirwa & Van der Merwe, 2010; Carlton & Adler, 2006:356). A number of detector configurations are used in an FPD system that employs either direct acquisition (without phosphor material; it uses a photoconductor) or indirect acquisition (phosphor material, coupled to a photodiode). Indirect acquisition systems use a two-part process involving a scintillator (which converts incoming x-ray photons to light) and a photodiode (which converts light into an electronic signal) (Carlton & Adler, 2006:356; Nyathi, Chirwa & Van der Merwe, 2010:2). Direct acquisition systems directly convert incoming x-ray photons to an electronic signal (Carlton & Adler, 2006:356; Nyathi, Chirwa & Van der Merwe, 2010:2).

DR has a number of advantages over the analogue system, namely: offers a wide dynamic range; linear response to radiation; availability of post-processing tools; easy archiving of digital format images; higher patient through-put; separate image capture, processing, storage and display processes that can be optimised individually; dose reduction; ease of use; cost savings; revenue generation and time saving (May, Deer & Dackiewics, 2000:76; Frost & Sullivan, 2008; Lehnert *et al*., 2011:1370; Nyathi, Chirwa & Van der Merwe, 2010).

According to Sonoda *et al.* (1983:833) and Drost, Reese and Hornof (2008:138), the first successful DR imaging system was industrialised by Fuji Photo Film Co. and was called CR. The first-generation FCR 101™ included an IP made of a storage phosphor such as europium-activated barium fluorohalide and a laser readout system (Sonoda *et al.*, 1983:833). FPDs were introduced as early as 1995 for use in radiographic imaging (Seeram, 2011:104). The flat-panel DR active matrix array is a technology that was developed for laptop computer display (Rowlands & Yorkston, 2000:230). FPDs were firstly introduced for clinical use in 1995 (Doi, 2006:R15). It is worth noting that other detectors used in radiography were developed between 1983 and 1995 (Korner *et al*., 2007:676). According to Korner *et al.* (2007:676), the first DR system outside CR to be used in a clinical context was a charge-coupled device (CCD chip) slot-scan digital detector, which was introduced in 1990. The selenium drum DR system was introduced in 1994, followed by the first flat-panel detector DR systems based on amorphous silicon and amorphous selenium in 1995 (Korner *et al*., 2007:676). Currently there are two types of indirect digital FPD detectors, namely the CCD digital detector and the flat-panel thin film transistor (TFT) digital converter (Fauber, 2017:82; Seeram, 2011:106).

## 1.2 RESEARCH PROBLEM

An extensive literature review over a period of six months in 2014 revealed that no empirical study had till that time focused on the utilisation of DR in clinical practice in South Africa. Google Scholar was primarily used to search literature meeting the following keywords and phrases: “digital radiography”; “utilisation of digital radiography features”; “computed radiography”; “utilisation of computed radiography features”; “flat-panel detectors”; and “utilisation of flat-panel detectors”. In addition, an informal discussion with application specialist, Africa X-ray Industrial Medical (AXIM) on 07 June 2014 highlighted that a large proportion of diagnostic radiographers seemingly did not utilise the possibilities offered by DR optimally. A further discussion with an application specialist, (SIEMENS) on 07 June 2014 confirmed that clinical diagnostic radiographers do not utilise DR applications optimally.

The most important under-utilised features seem to be the following: edge enhancement, dynamic range control, body part orientation, exposure factors, lead markers postero-anterior/ antero-posterior and quality assurance (QA). This notion is supported by Nyathi, Chirwa and Van der Merwe (2010:6) who state that “… there is a need for formal education, continuing education and manufacturer training with respect to quality control as institutions make the transition from conventional screen film to digital radiology.”

The researcher’s personal experience as a lecturer responsible for undergraduate radiography subjects in image recording (1st, 2nd and 3rd year) since 2012 corresponds with application specialists’ concerns, as well as with the recommendations of Nyathi, Chirwa and Van der Merwe (2010:6), specifically regarding the need to cover DR

utilisation to a larger extent in the curriculum than what is currently the case. This strongly aligns with the findings of Winberg *et al*. (2013) who stated that the purpose of professional education is to educate students to become competent practitioners with a deep sense of civic and social responsibility. However, as a matter of potential concern, the diagnostic radiography curriculum for undergraduate tertiary students at the initiation of this study seemed to be covering less than ideal DR content, taking into account what the world of work (clinical practice) demands from the graduates. In the South African context, the traditional universities and universities of technology that offer diagnostic radiography training should focus on building a theoretical basis for students to be effective in clinical practice (Winberg *et al*., 2013). However, the above-mentioned discussions with the application specialists from AXIM and SIEMENS suggested significant shortcomings in undergraduate training programmes, specifically with regard to DR content. Thus, the main problem identified for investigation in this study was the sub-optimal utilisation of DR features by practising clinical diagnostic radiographers in South Africa.

## 1.3 AIMS AND OBJECTIVES

The primary aim of this study was to gain deeper understanding of the utilisation of DR features by diagnostic radiographers in South Africa. The secondary aim was to develop a curriculum framework to guide institutions of higher learning in South Africa in the development and implementation of curricula that adequately address the current DR developments and training needs in the field of diagnostic radiography.

The specific objectives of the study were:

- to analyse the incorporation of formal DR content and concepts in the current undergraduate diagnostic radiography curricula being offered at institutions of higher learning in South Africa;
- to investigate the application and utilisation range of the various DR features by diagnostic radiographers in clinical practice in South Africa; and
- to investigate practising diagnostic radiographers' perceptions of the utilisation of DR features in South Africa.

## 1.4 BASIC RESEARCH APPROACH

A mixed methods approach involving three phases was followed in this study to address the study objectives (see Chapter 3). Phase 1 focused on a document analysis of current diagnostic radiography study guides being used at institutions of higher learning in South Africa. Phase 2 focused on an online survey of current practising diagnostic radiographers in South Africa. Phase 3 involved focus group interviews with diagnostic radiographers working in different imaging facilities in both the private and public sectors. See Chapter 3 for an in-depth description of the research methods followed in the study.

## 1.5 RESEARCH ETHICS

The proposal for this study was presented to and approved by the Departmental Committee for Postgraduate Studies, Department of Biomedical Sciences, Tshwane University of Technology (TUT). The project further served at the TUT Faculty of Science Committee for Postgraduate Studies and the TUT Faculty of Science Committee for Research Ethics; due approval was granted by both committees (FCRE

Reference Number 2014/08/001) (see Annexure A). Additional phase-specific ethical clearances were required from the relevant gatekeepers and affected parties (see Sections 3.3.7, 3.4.7 and 3.5.6 for more detail).

## 1.6 OUTLINE OF THE STUDY

The dissertation addresses the various aspects of the research process in seven chapters:

- Chapter 1 addresses the background, justification and research problem, as well as the study aims and objectives.
- Chapter 2 covers an in-depth literature review of DR. The historical background of DR, as well as the different DR features, are described and reviewed in this chapter.
- Chapter 3 outlines the research methodology followed for the three study phases.
- Chapter 4 presents the results of the respective study phases.
- Chapter 5 discusses the results of the rubric analysis (Phase 1), quantitative survey (Phase 2) and the focus group interviews (Phase 3).
- Chapter 6 presents a proposed DR curriculum framework for institutions of higher learning in South Africa.
- Chapter 7 concludes the study with a summary of the main research findings. This chapter also makes some recommendations based on these findings. Lastly, the strengths and limitations of this study are indicated.

# CHAPTER 2

# LITERATURE REVIEW

This chapter reviews the current literature regarding the different aspects of DR. The main purpose of a literature review is to review what has been written and documented about the utilisation of the features of DR and to review literature on the advantages and disadvantages of DR. In this chapter the history and background of DR, as well as the history of formal undergraduate training, are reviewed. Furthermore, the different DR imaging systems are discussed in depth. Lastly, the scope of practice for DR is reviewed, followed by a discussion of the literature regarding the undergraduate curriculum for DR.

Scientific articles sourced from different search engines (eg. Google scholar) as well as latest text (2010 to 2018) books were used to review literature. The following phrases were used: Digital radiography, computed radiography, screen film radiography. Once articles were gathered, the researcher classified articles according to subjects (themes) of interest.

## 2.1 HISTORY AND BACKGROUND OF DIAGNOSTIC RADIOGRAPHY

The origin of diagnostic radiography in 1895 is attributed to Wilhelm Conrad Roentgen, who was a professor of physics at the University of Wurzburg, Germany (Carrol, 2007; Farmelo, 1995:86; Nyathi, Chirwa & van der Merwe, 2010:1; Reed, 2011:3S; Thomas & Banerjee, 2013:4). On 22 December 1895, the first analogue radiograph of the hand of Professor Roentgen's wife, Bertha, was produced (Thomas & Banerjee, 2013:5).

Radiographs came into use in the United State of America and Europe a mere month later, after the discovery of x-rays, whereas only six months later x-rays were used by military personnel to check for bullets in the bodies of injured soldiers (Reed, 2011:3S).

X-rays were not used in a clinical context before 1913, as exposure to produce adequate images required high kilovoltage; such exposure could literally destroy an x-ray tube (Reed, 2011:3S). The high vacuum x-ray tube inventions of 1913 by Coolidge, as well as the invention of a 1-million volt x-ray generator in 1931 by General Electric Company, made it possible for x-rays to be accepted and readily used in the world of medicine (Reed, 2011:3S). X-ray technology arrived for the first time in South Africa just six months after the discovery of x-rays when A Walsh, who was a photographer, brought it to Port Elizabeth (Bensusan, 1967:778). The first radiograph to be taken in South Africa was of the hand of Mr A Walsh in August 1897 (Bensusan, 1967:778).

Medical imaging has not only developed in image production, but also in image processing, image display, image recording and image transmission (Doi, 2006:R6). A remarkable breakthrough was witnessed in the early 1960s when an automated film processor was introduced, which reduced film processing to 90 seconds, ultimately improving the imaging facility efficiency while reducing patient waiting time (Doi, 2006:R12). Haus and Cullinan (1989:1203) reported a further reduction in automated processor time from 90 to 30 seconds in the early 1980s. SF had used intensifying screens (calcium tungstate) since its inception, which was ultimately replaced by the introduction of rare earth intensifying screens in the 1960s; this development of technology reduced patient dose by a factor of 2 while enhancing image quality (Doi, 2006:R13).

### 2.1.1 Radiography Training in South Africa

Radiography training started in Britain around 1910 (Engel-Hills, 2005:24). The training of radiographers in South Africa can be traced back as early as 1930 in Johannesburg. May Tomkins is recorded as the first person in South Africa to qualify as a radiographer; in 1930 she completed a radiography course in London (Engel-Hills, 2005:24). Collaboration between the British Society of Radiographers and the South African Radiography Society was proposed by two Johannesburg-based engineers, Messrs F Gillham and V Gillwald. The South African Radiography Society was to operate as a branch of the British Society of Radiographers. After an agreement had been reached, the first British radiography examination was written in Johannesburg in 1933 (Hochschild, 1983 as quoted by Venter, 2008:1). The first South African radiography examination was written in Johannesburg in 1953 (Hochschild, 1983 as quoted by Venter, 2008:1). Engel-Hills (2005:24) indicates that the first formal diagnostic radiography training started at Groote Schuur Hospital in South Africa's Western Cape Province in 1953.

### 2.1.2 Computed Radiography

DR began with CT and MRI in the early 1980s (Bushong, 2008:413; Carlton & Adler, 2006:356). According to Seeram (2011:254), "DR refers to a radiographic modality that produces digital images which are displayed for interpretation and diagnosis, stored and archived for medical and legal purposes, as well as for retrospective analysis. In addition, these images can be transmitted to remote locations for use by surgeons, emergency physicians and other health care practitioners."

DR is divided into two sections, namely CR and FPD (Carlton & Adler, 2006:356; Doi, 2006:R15). CR employs the same principle as SF, except that the IP has to be scanned by a CR cassette reader (Drost, Reese & Hornof, 2008:138); CR is also known as cassette-based DR (Carlton & Adler, 2006:356). The cassette-based system uses a PSP IP (Carlton & Adler, 2006:356). This cassette can be used in a bucky (built-in cassette holder) or for portable examinations, similar to analogue radiography. Once the PSP has been exposed, it is taken to a reader to process the plate and to create the image. It is considered indirect digital imaging because the radiographer must physically move the detector between image acquisition and the actual display (Carlton & Adler, 2006:356 ;Nyathi, Chirwa & van der Merwe, 2010). A latent image may effectively be stored for eight hours, then later, if not processed, it will begin to fade away (Drost,Reese & Hornof, 2008:138-139).

According to Dobbins *et al*. (1995:1581) and Seeram (2011:103), the main challenge of the first-generation CR technology was that it had lower detection quantum efficiency (DQE) and lower spatial resolution compared to the SF system, which suggests that image quality would be poor, as opposed to SF image quality.

Furthermore, Dobbins *et al*. (1995:1581) and Seeram (2011:103) add that CR IPs can easily be damaged (the radiographer can drop the cassette) as they must be moved to a separate image processor for image data extraction. Cao and Huang (2000:80) also highlight that CR IPs have a high signal-to-noise ratio (SNR), which is not ideal for some specialised radiographic procedures such as scaphoid views and small nodules on chest imaging. The challenges of the first-generation CR presented

themselves in three areas: the IP, the unit-reader and the display monitors for viewing images.

### 2.1.3 Flat-Panel Detectors Digital Radiography

Flat-panel DR detectors were introduced as early as 1995 for use in radiographic imaging (Doi, 2006:R15; Seeram,2011:104).The flat-panel DR active matrix array is a technology that was developed for laptop computer display (Rowlands & Yorkston, 2000:230). It is worth noting that other radiography detectors were used before 1995, i.e. between 1983 and 1995. According to Korner *et al.* (2007:676), the first DR system apart from CR to be used in a clinical context was a CCD chip slot-scan digital detector, which was introduced in 1990. The selenium drum DR system was introduced in 1994. Thereafter the first flat-panel detector DR systems based on amorphous silicon and amorphous selenium were introduced in 1995. The selenium drum was specifically designed for imaging the chest (Seeram, 2011:104).

Generally, all FPDs should have the following components: pre-amplifiers, switching control, central logic circuit, analogue-to-digital converters and internal memory (Seeram, 2011:104). With FPDs as opposed to CR, x-ray detection and digitisation of the x-ray signal takes place within the unit itself, which circumvents the need to take an FPD to a separate unit for signal readout, as happens in CR (Seeram, 2011:104).

#### 2.1.3.1 Indirect Conversion Detectors

Indirect conversion detectors use a scintillator (phosphor material). Phosphor materials may be structured (needle-packed) or unstructured (powder-packed).

Typical examples of phosphor materials used in FPDs include cesium iodide (Csl) or gadolinium oxysulphide ($Gd_2O_2S$: which was introduced in 1997 and has been used for FPDs since 2001 (Korner *et al.*, 2007:676)) to convert the exit radiation into visible light (Fauber, 2017:82). There are two types of indirect digital detectors, namely CCD digital detectors and flat-panel TFT digital converters (Fauber, 2017:82; Seeram, 2011:106). The main differences between the two types of indirect conversion detectors are linked to the technical component used to convert light into an electrical signal (Seeram, 2011:106). The CCD digital detector is based on an indirect conversion process and uses a CCD chip to convert light into an electrical signal (Seeram, 2011:107). The TFT digital detector is based on an indirect conversion, which includes an X-ray scintillator coupled to an amorphous silicon (a-Si) photodiode flat panel with a TFT array for readout of the electrical charges by the photo diode array (Seeram, 2011:108).

#### 2.1.3.2 Direct Conversion Detectors

Digital conversion detectors use an amourphous selenium-coated (a-Se) detector to convert exit radiation directly to an electrical charge (Fauber, 2017:83). To compensate for the low atomic number of selenium (Z = 34), the thickness of the amorphous selenium is relatively high (approximately 1 mm) (Fauber, 2017:83). A high voltage is applied, which limits the lateral diffusion of electrons as they migrate towards the TFT (Fauber, 2017:73; Seeram, 2011:110).

## 2.2 ADVANTAGES AND DISADVANTAGES OF DIGITAL RADIOGRAPHY

SF radiography involves numerous challenges, which include working with hazardous chemicals that have the potential to cause respiratory, dermatological and cardiac effects (Nallon, Herity & Brennan, 2000:39). As such, the move to DR offers many advantages over SF radiography.

### 2.2.1 Advantages of Digital Radiography

The most important advantages offered by CR and FPDs are described in this section.

#### 2.2.1.1 Digital Radiography is Compatible with the Health Enterprise System

The health enterprise system comprises the hospital information system (HIS), radiology information system (RIS), the picture archiving and communication system (PACS), and electronic patient or medical records systems (EMS) (Cao & Huang, 2000:80). HIS handles patient records, billing, patient workflow and other administrative functions in a health facility. HIS significantly reduces the time it takes for patient details to be captured, which in turn results in reduced patient waiting time (Cao & Huang, 2000:80).

RIS is a fairly old technology in the imaging field. The first RIS system was developed in the 1960s and has significantly expanded over the last five decades (Nance *et al*., 2013:1064). RIS can function as a standalone system or it may be integrated with HIS to perform some of the following functions: “patient registrations; exam scheduling; patient tracking; film archiving; report generation; administration and billing;

documentation; inventory control; departmental statistics; and communication standards" (Seeram, 2011:185).

PACS is a computational technological system, which can be used among health institutions and in an institution to manage the acquisition, transmission, storage, distribution, display and interpretation of medical images. As such, the system is highly integrated with the imaging operation of the radiology department and with image-based clinical practice (Samei *et al*., 2004:314). PACS has been proved to improve work flow, throughput and productivity, as well as rapid, remote and simultaneous access to image data. In addition, it is integral to electronic archiving, the possibility of image manipulation (post-processing), and cost-effectiveness, all leading to overall better patient care (Samei *et al*., 2004:314).

In DR, images are immediately available in digital format. In this regard PACS and EMS eliminate the need for filing rooms, as all images and patient data can be stored electronically. PACS can also be of significant importance in an educational institution, as it can contribute to the following processes: it allows students to acquire images of phantoms using DR imaging modalities; stored images can be recalled for retrospective analysis; an instructor can access student images for the purpose of assessment; instructors can create teaching files (i.e. to make use of archived images to create lessons for teaching purposes) for their respective courses and images can be imported from affiliated hospitals, stored and archived in the institution's PACS for teaching and learning purposes (Seeram, 2011:191).

#### 2.2.1.2 Post-processing

Since digital images can be manipulated, it means that a dark image may be processed to become an acceptable image by using the post-processing tools of DR (Waaler & Hofmann, 2010:376). When used optimally, post-processing enhances the visualisation of pathology and allows the presentation of the full object irradiated range, while improving local contrast (Offiah *et al*., 2006:163).

#### 2.2.1.3 Dynamic Range

The dynamic range of a digital imaging system refers to the ability of a detector to capture the exact range of photon intensities that exit the patient (Fauber, 2017:83). A wider dynamic range means that a small degree of underexposure or overexposure would still result in acceptable image quality. The wider dynamic range of DR imaging modalities not only benefits the imaging field by yielding improved image quality due to the availability of post-processing tools, but also reduces the repeat or retake rate due to exposure errors from 40-60% in SF to 10-15% in DR (Waaler & Hofmann, 2010:376).

#### 2.2.1.4 Image Quality

Better options are available to use than post-processing tools, such as edge enhancement and image quality in the latest DR imaging systems when compared to the older DR systems and SF (Waaler & Hofmann, 2010:376). Nyathi, Chirwa & van der Merwe (2010:2) found that radiographers in clinical practices perceive DR as high

in image quality. This is supported by Zennaro *et al.,* (2013:6), who found that the move from SF to DR has improved image quality in diagnostic imaging.

#### 2.2.1.5 Dose Efficiency

DR imaging systems have a relatively high DQE, resulting in images being acquired with a lower dose to the patient (Busch & Faulkner, 2005:143). DR systems are built with an exposure indicator that gives a range of acceptable exposures. This may help the radiographer to notice when acceptable limits are exceeded (Willis, 2004: S198). Willis (2004:S198) further argues that a QA programme based on monitoring the exposure indicators can accomplish a reduction in doses. Willis (2004:S198) reports that "if exposure indicator targets were followed in paediatric bedside examinations, a 33% reduction in patient dose would have been achieved."

#### 2.2.1.6 Patient Throughput

Korner *et al*., (2007:676) regard higher patient output as an obvious advantage of DR. In addition, Drost, Reese and Hornof (2008:139) indicates that the workflow for flat-panel and CCD radiography is faster than for analogue radiography, resulting in an increased patient throughput in CR. Nyathi, Chirwa & van der Merwe (2010:4) further highlights that DR enables a higher patient throughput compared to SF, because with FPDs the image is immediately available.

#### 2.2.1.7 Consumable Costs

IPs can be used over and over again, unlike SF films. The same FPD can be used in or out of bucky for as long as it lasts, which ultimately saves costs. In addition, with DR there is no need to purchase processing chemicals and no need to have a darkroom operator (Patel, 2005:27).

### 2.2.2 Disadvantages of Digital Radiography

The most important disadvantages of using CR and FPDs are described in this section.

#### 2.2.2.1 Computed Radiography Exposure Creep

In CR, there is a documented tendency for radiographers to increase exposure factors. Exposure is increased by using higher technique factors than the technique chart exposures provided, as well as using plus density settings of automated exposure control (AEC) examinations. This tendency is termed “exposure factor creep” and it unnecessarily over-exposes the patient (Seeram, 2011:238). In simple terms, exposure creep is “the risk of increasing patient dose, possibly without being aware of it” (Seeram, 2013:331).

#### 2.2.2.2 Digital Radiography Cost

Initial costs are too high compared to the SF system (Nyathi, Chirwa & van der Merwe, 2010:4; Patel, 2005:29). According to Moodley and Moodley (2015:3), the capital costs for PACS include the following items: software, computers, digital X-ray equipment,

CT and MRI scanners compatible with digital Imaging and communications in medicine (DICOM), wide-screen monitors and 17-inch monitor screens for radiologists, CR cassettes, a compact disc (CD) printer, an uninterruptable power supply (UPS), a single-slot reader, operator consoles for radiographers and training costs. Moodley and Moodley (2015:3) estimated the initiation cost of DR and PACS at just below three million rand (ZAR). Rahoma and Chundi (2012:7) compared the costs incurred by imaging facilities from 2008 to 2012 when using SF versus CR for the same number of films used. The estimated costs for an IP SF system amounted to nearly US$ 4.6 million, while the estimated costs for CR amounted to United State (US) $ 82,600. The study by Rahoma and Chundi (2012:7) provides clear evidence that DR can save money for an imaging facility over a period when compared to an SF system.

#### 2.2.2.3 Lack of Familiarity with Technology among Radiologists and Radiographers

Nyathi, Chirwa & van der Merwe, (2010:4) indicate that most radiographers and radiologists are not familiar with digital imaging. This becomes a disadvantage, especially in relation to image quality and patient dose. A literature search found no recent studies published since the findings of Nyathi, Chirwa & van der Merwe, (2010:4), which suggests that familiarity with the technology among radiologists and radiographers has not improved.

## 2.3 FEATURES OF DIGITAL RADIOGRAPHY

An extensive online search did not yield any specific research-based literature results on the features of CR or DR, and the utilisation of the features of DR by radiographers. However, it must be noted that some authors discuss certain features of DR in relation to either image quality or dose. The following DR features are discussed in this section: exposure index (EI), look-up table, edge enhancement, IP and display monitors.

### 2.3.1 Exposure Index

Seeram (2011:254) defines EI as “a numeric value which appears on the image. It provides the radiographer with visual feedback regarding radiation exposure to the patient. As such, it is a QC tool to facilitate optimisation of radiation protection”. The exposure indicator provides a numeric value indicating the level of radiation exposure to the digital image receptor (IR) (Fauber, 2017:88).

The values of the exposure indicators are vendor-specific, i.e. Fuji and Konika use sensitivity numbers; the value is inversely related to the exposure to the IR. Carestream (Kodak) uses EI numbers; their values are directly related to the exposure to the IR and the changes are logarithmic expressions. Agfa uses log median (lgM) numbers; the value is directly related to the exposure to the IR and the changes are logarithmic in expression. Because of the challenge of variability among the manufacturer-specific exposure indicator values and relationships to the IE exposure, the industry has recommended a universal standard exposure indicator, namely the deviation index (DI). The DI is a value that reflects the difference between the desired or target exposure to the IR and the actual exposure to the IR (Fauber, 2017:89-90).

A DI of 0 indicates that there is no difference between the desired EI and the actual EI. A DI >0 indicates that there is increased exposure to the IR, while a DI <0 indicates a decrease in exposure to the IR (Fauber, 2017:89-90). Ultimately it is the primary responsibility of the radiographer to ensure that optimum exposure factors are selected.

### 2.3.2 Look-up Table

Fauber (2017:320) defines a look-up table as a way to provide a method of changing the image so that one ultimately changes the display of the digital image in a variety of ways. Since digital IRs have a linear response to exposure and a wider dynamic range than SF, the raw data prohibits low-contrast images. Such images must be altered to improve the visibility of anatomical structures. A look-up table provides a means to alter a digital image by using computer algorithms. Look-up tables are also used to reverse or invert image grey scale (Fauber, 2017:90). In simple terms, “look-up tables provide the means to alter the original pixel values to improve the brightness and contrast of the image” (Fauber, 2017:92).

### 2.3.3 Edge Enhancement

Seeram (2011:254) defines edge enhancement as a post-processing operation also known as spatial frequency processing. Digital images have lower spatial resolution than SF images (Offiah *et al.*, 2006:163). If digital images are to have acceptable image quality, techniques such as non-linear grey-scale enhancement, non-linear unsharp masking (edge enhancement) and single or dual exposure energy subtraction need to be in place (Offiah *et al.*, 2006:163). Offiah *et al.* (2006:163) further state that

“the proper use of edge enhancement can emphasise the edges and contrast of a lesion, thereby compensating for the lower spatial resolution of CR compared with SF systems”.

Seeram (2011:60) indicates that edge enhancement is “a commonly used post-processing algorithm that adjusts or controls the sharpness and/or detail of an image by adjusting the frequency components of the image. Edge enhancement, just like other features of DR, is vendor-specific. Fuji uses the term multi-objective frequency processing (MFP), while Agfa and Kodak use the terms multi-scale image contrast amplification (MUSICA) and enhanced visualisation processing (EVP)”. In musculoskeletal imaging, study results have been published both in support and against the use of edge enhancement (Offiah *et al.*, 2006:163). Those not in favour believe that edge enhancement in musculoskeletal imaging either enhances physiological trabecular irregularities or produces artefacts at the borders of cortical bone. In both instances the appearance may then be misdiagnosed as cortical defects or periosteal reaction (Offiah *et al.*, 2006:163).

### 2.3.4 Imaging Plate

According to Seeram (2011:53,257) an IP is “the detector used in CR imaging that consists of a PSP layered on a support base that can create and store a latent image when exposed to X-rays that are rendered visible by laser beam scanning and digital processing. The IP is reusable after erasure of the image by a high intensity light beam.” The IP has two protective layers, an electro-conductive layer and a light-shielding layer (Seeram, 2011:53). The front protective layer must be coated in such

a way that it can stand the mechanical pressure within a reader and will allow the IP to be reused (Seeram, 2011:53).

The IP containing storage phosphor is inserted in a cassette similar to an SF-system and then exposed to x-rays. The signal trapped by the IP is read by means of laser light beam scanning. A photomultiplier tube then enhances the signal coming from the light guide (Pongnapang, 2005:1). Image collimation is highly recommended when using an IP, as this reduces scatter radiation in the area of interest and reduces the noise that degrades the radiographic contrast (Pongnapang, 2005:2). This good practice is still valid for CR and most image processing software employed in CR relies on the fact that the image collimator edge is detected in order to optimise the contrast (Pongnapang, 2005:2). For this reason, it is not desirable to split a CR cassette into two or three to accommodate multiple views, as was common practice in SF radiography. This is not good practice when using the CR technique, since double or multiple exposures on a single PSP IP can lead to failure of the image processing software to detect the image boundary (Pongnapang, 2005:2). A CR IP may be operated at a different film speed; in so doing the exposure factors may be significantly reduced, ultimately reducing the dose to the patient. Existing CR has a speed similar to medium-speed SF systems, while spatial resolution is generally still inferior (Pongnapang, 2005:2).

### 2.3.5 Display Monitors

In DR, image quality is affected not only by the acquisition parameters and computer processing, but also by the type and performance of the display monitor (Fauber, 2017:95). Butt and Savage (2015:240) further highlight that display monitors always

degrade the information contained in an image, which makes it vital to ensure that measures are taken to limit this loss as much as possible. The degradation of image quality owing to the display monitor worsens as the monitor ages (Butt & Savage, 2015:240). The monitors used by radiologists for reporting are referred to as primary grade display and must be of higher quality than monitors used by radiographers in an x-ray room, which are secondary grade display (Fauber, 2017:95; Butt & Savage, 2015:240). However, the secondary grade display should be of sufficiently high quality to ensure that radiographers can discern adequate image quality prior to sending the image to the radiologists (Fauber, 2017:95; Butt & Savage, 2015:240).

There are two types of display monitors, namely cathode ray tubes (CRTs) and liquid crystal displays (LCDs). At present LCDs are gradually replacing CRTs, whereas the newer plasma-type monitors are rapidly developing and gaining ground in the imaging field (Fauber, 2017:94). In addition, the orientation of a display monitor (portrait or landscape), as well as the luminescence and contrast of the monitor, has a direct impact on the resultant digital image quality (Krupinski *et al*., 2007:390).

## 2.4 COMPUTERS, INFORMATION TECHNOLOGY AND DIGITAL IMAGING

Computers are an integral part of almost all activities in an imaging facility that has incorporated DR systems (Indrajit, 2013:17). Computers are used by different radiology modalities to acquire, process and post-process imaging data. They are also integral to the following functions in a DR imaging facility: patient scheduling, image creation, image processing and post-processing, viewing, analysing, computer aided diagnosis; multimedia integration, voice dictation, reporting, billing, transmitting, networking and electronic storage; as well as in PACS and RIS/HIS (Indrajit, 2013:17).

Indrajit (2013:17) states that mastering the skills of using computers will ultimately enhance workflow in an imaging facility.

## 2.5 SCOPE OF PRACTICE FOR DIAGNOSTIC RADIOGRAPHERS IN SOUTH AFRICA

Mungomba (2016:30) argues that the current undergraduate diagnostic radiography curriculum is not comprehensive, as it does not address the different professional needs outlined in the Health Professions Council of South Africa's (HPCSA) scope of practice for diagnostic radiographers. This scope of practice is fundamentally based on the Health Professions Act 56 of 1974 and Government Notice R2326 in *Government Gazette* 5349 of 3 December 1976 as amended on 20 April 1979, 25 October 1991 and 1 August 1997 (www.HPCSA.co.za). It is important to note that FPDs only became available for clinical use in 1995 (Doi, 2006:R15), with the implication that no direct reference to DR is made in the most recent scope of practice for diagnostic radiographers, i.e. as last updated in 1997. However, note that the HPCSA is currently (February 2018) conducting a review of the scope of practice for diagnostic radiographers; it will formulate a new and comprehensive scope of practice, which addresses matters relating to ethics, medical law and developments in IT and related technologies.

## 2.6 UNDERGRADUATE DIGITAL RADIOGRAPHY TRAINING

An extensive literature search could not locate any specific scholarly literature on diagnostic radiography undergraduate training and education in DR. However, it should be noted that a thesis by Mungomba (2016:1-2) investigated the need for a

review of undergraduate diagnostic radiography. This study focused on the extra skills and competencies required by rural radiographers in KwaZulu-Natal to enable them to be more productive in a rural setting. Another study related to diagnostic radiography undergraduate training was conducted at the Cape Peninsula University of Technology by Venter (2008), who investigated the relationship between radiography students' spatial abilities. She also studied interventions linked to the development of spatial skills in relation to the interpretation of specialised and modified radiographic images. Lastly, Louw (2018) from the University of Johannesburg wrote a chapter on simulation-based training in undergraduate diagnostic radiography training. All these studies address some aspects of undergraduate diagnostic radiography training, but none of the authors specifically investigated the features of DR or the utilisation and application of DR in clinical practice. This is not totally surprising, given that Mubuuke *et al.* (2008:2) have indicated a dearth of literature on radiography training and education, which is opposite to the situation related to medical training and education.

The training expectations of the HPCSA as highlighted by the Radiography and Clinical Technology Board are that the diagnostic radiography qualification should enable the learner to apply an integration of theory, principles, proven techniques, practical experience and appropriate skills competently to find solutions to well-defined and abstract problems in the selected field of diagnostic radiography (SAQA, 2012).

## 2.7 PRIVATE AND PUBLIC HOSPITALS IN SOUTH AFRICA

Undergraduate radiography students complete a significant component of their training in HPCSA-accredited private or public hospitals' imaging facilities. As such, it

is important to note that the South African health system consists of two major divisions, namely the public health system and the private health system (Pillay, 2008:1). There are currently 80 000 beds available in all the public hospitals in South Africa (Cullinan, 2006:10; Slabbert, 2018) and about 36 000 beds in private hospitals (Boshoff & Gray, 2004:27; Slabbert, 2018). According to Makanjee, Bergh and Hoffmann (2014:153), the public health sector is further divided into three levels: 1) primary (level 1, district hospital); 2) secondary (level 2, regional hospital); and 3) tertiary (level 3, central hospital). Care in the public health system is divided into four sections: 1) primary health care (clinics and community health centres); 2) district hospitals; 3) regional hospitals; and 4) tertiary hospitals. All these levels of care do offer x-ray imaging systems, which include DR in many cases (Makanjee, Bergh & Hoffmann, 2014:154). The public sector serves the indigent population constituting more than 80% of the total population and is funded predominantly by the government from general tax revenue (Pillay, 2008:1). Pillay (2008:2) notes that the public sector is regarded by many as inefficient, providing poor service and leaving patients dissatisfied (Pillay, 2008:1).

Pillay (2008:1) further highlights that the private sector, which is technologically highly developed, serves less than 20% of the population, in particular those who have private healthcare insurance (i.e. medical aid scheme membership) or are high-income earners. The private sector is regarded as efficient and generally renders good service to its clients. The private healthcare sector in South Africa is divided into a large, corporate private-for-profit hospital sector and a smaller and diversified private-not-for-profit sector (Makanjee, Bergh & Hoffmann, 2014:154).

## 2.8 CONCLUSION

In general, there is a scarcity of research on the utilisation of DR features by radiographers. However, the review of literature in this chapter identified some studies focusing on radiographers' familiarity with DR technology and DR undergraduate training. The literature that was reviewed provides clear justification for a detailed investigation into the utilisation of DR features, as this field of study has not been duly explored before. Much work has been done in understanding the physics, physical and operational aspects of IRs, while little has been done on the knowledge level of the users of the IRs and the entirety of the DR technology.

The following chapter describes the methodology used in this study.

# CHAPTER 3

# MATERIALS AND METHODS

In this chapter the methodology [phase 1 (content analysis), phase 2 (on-line survey) & phase 3 (focus groups interviews)] and settings of the study will be discussed.

## 3.1 BACKGROUND OF THE RESEARCHER

The researcher, Mr D Lamola, is a lecturer at TUT. He is involved in presenting radiographic imaging subjects from the first to the third year of undergraduate study. On a yearly basis, the researcher is involved with the University of Pretoria (UP) and the Sefako Makgatho Health Sciences University (SMU) in South Africa as a moderator for radiographic imaging subjects. Prior to joining the higher education sector, he practised as a diagnostic radiographer in both public and private healthcare facilities for a period of six years. During the period he worked with both SF radiography and DR. In addition, he has lectured on subject content dealing with SF and DR for five years at undergraduate level. Lastly, the researcher previously worked for UP as a clinical tutor responsible for closing the gap between theory and clinical practice; the facilities used were fully DR.

## 3.2 INTRODUCTION TO STUDY APPROACH

This study followed a mixed methods approach (Creswell & Plano Clark, 2011:2; Edmonds & Kennedy, 2013:146; Maree *et al.,* 2012:269); in other words, a

combination of quantitative and qualitative research methods and phases. Creswell, as quoted by Johnson, Onwuegbuzie and Turner (2007:119), defines mixed methods research as a research design (methodology) in which the researcher collects, analyses and mixes (integrates or connects) both quantitative and qualitative data in a single study or a multiphase programme of inquiry. This study consisted of three phases, namely: 1) Phase 1 (content analysis); 2) Phase 2 (online survey); and 3) Phase 3 (focus group interviews). Figure 3.1 below depicts the mixed methods relationship among the three phases of the study.

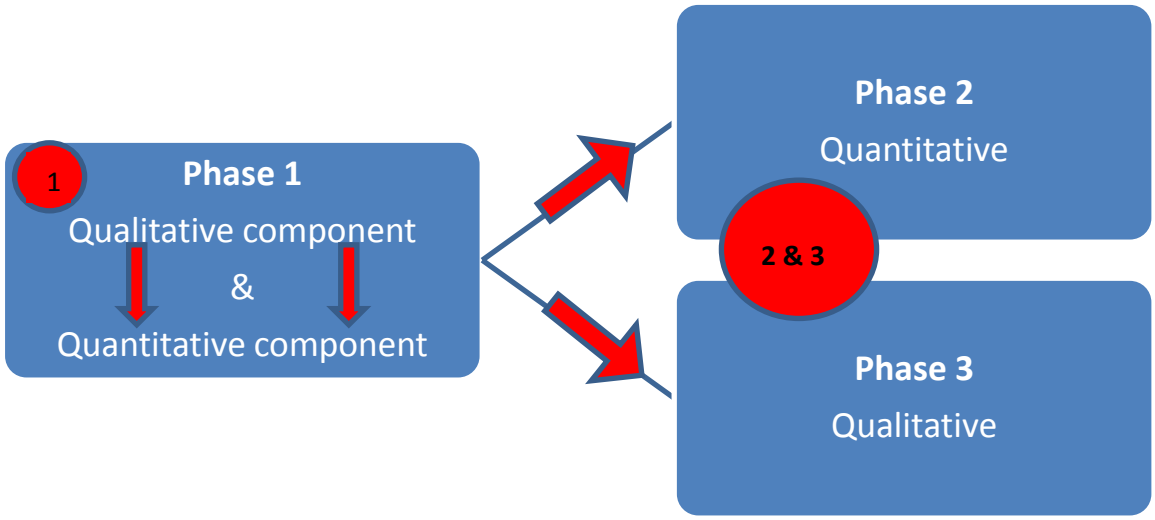



Figure 3.1: Mixed methods relationship among the three phases of the study

Phase 1 began with a qualitative component whereby data was sourced from application specialists by means of telephonic discussions. The data was then transcribed and used to formulate thematic codes. The qualitative data of Phase 1 was sequentially used to formulate a rubric (quantitative tool). In addition, the results of Phase 1 of the study were essential in the development of the Phase 2 data collection instrument (survey questionnaire) and the Phase 3 interview guide. The data collection

activities of Phase 2 and Phase 3 could not commence until the completion of Phase 1. In this study Phase 2 and Phase 3 were conducted simultaneously, independent of each other but both dependent on the Phase 1 results. The research methodology followed in this study involves more than triangulation, namely a combination of sequential explanatory (Phase 3) and sequential exploratory (Phase 1 and Phase 2) mixed methods designs (Creswell, 2008).

## 3.3 PHASE 1 – CURRICULUM ANALYSIS

The first phase of the study aimed to analyse the current incorporation of DR concepts and skills into the diagnostic radiography undergraduate programmes in South Africa. It focused on a detailed and systematic analysis of documents, namely the learner/study guides and prospectuses of higher education institutions in South Africa that offer undergraduate diagnostic radiography programmes, as well as the South African Qualification Authority (SAQA) documents for the different institutions offering undergraduate diagnostic radiography. Content analysis was performed to identify the relevant patterns or themes regarding DR and to determine the current undergraduate curricular status of diagnostic radiography. In order to collect the data for the content analysis, an analysis rubric instrument was developed prior to the actual document analysis activities. Literature searches using various search engines (e.g. Google Scholar) in the period 2015 to 2017 did not yield any appropriate literature regarding the DR rubric analysis instrument; the researcher therefore had to develop a DR rubric (see annexure B) as well as the rubric memorandum (see annexure C).

### 3.3.1 Research Design

The Phase 1 study followed a mixed methods approach. Phase 1 of the study specifically used a sequential exploratory design; this is to say the design began with a qualitative research component (i.e. development of analysis rubric instrument), followed by a quantitative research component (i.e. study guide analysis) (Creswell, 2008).

### 3.3.2 Development of Analysis Rubric Instrument

The primary literature sources discussed below formed the basis for the development of a draft rubric (Fauber, 2017; Cao & Huang, 2000; Seeram, 2011; Seeram & Seeram, 2008; Seeram *et al.*, 2013). The first draft of the rubric was developed with the aid of this literature, as well as the researcher's professional DR knowledge. In this way a number of DR concepts and topics were identified, formulated and included in the draft rubric. Besides the use of the primary literature sources, the researcher also sought the assistance of application specialists, to provide inputs to develop the rubric further.

A formal invitation and an information leaflet (see annexure D) were distributed by E-mail to all the potential application specialists. Telephone calls were made to manufacturing companies for the recruitment of application specialists. They were requested to indicate their willingness to participate within one week of receiving the E-mail. In such cases, they were requested to either fax or E-mail a scanned copy of the signed informed consent section back to the researcher. In addition, the researcher verbally reconfirmed with each participant, his/her consent at the start of the telephonic interview. The researcher sent follow-up E-mails to all industry participants who did

not respond to the first wave of invitation E-mails. Industry representatives who did not respond to the two waves of invitation E-mails were regarded as unwilling or not available to participate in the study and no further contact was sought with those people; their choice not to participate was fully respected.

Telephonic interviews were then conducted with the application specialists who consented to being interviewed to source their views on the utilisation and application of DR and CR features by diagnostic radiographers in clinical practices. In addition, the perceptions, views and opinions of the application specialists were sought regarding industry's expectations of the coverage of DR and CR in undergraduate diagnostic radiography curricula. The content of the interview guide was developed on the basis of literature, as well as the researcher's professional experience in the DR field. Annexure E contains the interview guide used during the interviews. Ultimately telephonic interviews were conducted with application specialists from three prominent DR industry companies in South Africa. The interviews were audio-recorded and later transcribed by the researcher. The transcribed information was then used to inform the content and focus of the rubric instrument further.

The following radiographic concepts related to DR emerged as the essential areas to be included in the rubric instrument: Introduction to basics of computer, basic information technology (IT), digital imaging modalities, digital image processing, image display, DR exposure technique chart, digital imaging artefact, health information systems, digital image characteristics, operating settings, and menu and accessories in digital imaging.

To enhance the validity of the data collection instrument further, the analysis rubric was then evaluated by the participating application specialists, as well as selected academics and diagnostic radiographers in clinical practice. These individuals were requested to critique the draft rubric, as well as to suggest any concept that should be added or removed. The suggestions and comments of these individuals were then incorporated in order to develop a more inclusive rubric. Once the updated rubric had been completed, the researcher sent it to these individuals for final fine-tuning and inputs. The researcher finalised the development of the rubric only after receiving the second round of comments.

A benchmark memorandum was developed for the rubric to allow assessment of the measure to which study guides covered each of the indicated concepts/themes in the rubric. Each of the rubric items was linked to a four-point Likert scale; 0 referred to “no incorporation at all”, 1 referred to “less than 50% incorporation”, 2 referred to “between 50% and 75% incorporation” and 3 referred to “75% or more incorporation” (see annexure B).

### 3.3.3 Study Guide Content Analysis

The second part of Phase 1 followed a document content analysis approach (Mouton, 2011:165). Bowen (2009:27); Leedy and Ormrod (2015:385) define content analysis as a qualitative research design in which a body of material is systematically examined in order to detect general patterns, themes or biases; the material typically involves some form of human communication. This approach was decided on to analyse the study guides from the different institutions of higher learning (Maree *et al*. 2012:101).

The study guide content was systematically reviewed to identify patterns and common themes (Leedy & Ormrod, 2013:148).

### 3.3.4 Document Sampling

A letter (see annexure F) was sent to all the identified institutions of higher learning that offered undergraduate diagnostic radiography training. The researcher used the official SAQA website to identify institutions of higher learning offering undergraduate diagnostic radiography. The letter requested copies of all the learner/study guides as well, to ascertain when DR content was first included in their formal programme offering. The learner/study guides for image recording subjects on first- to third-year level from three institutions of higher learning (hereafter referred to as Institutions A, B and C) were obtained. In addition, the online curriculum documents of SAQA (www.saqa.org.za) were sourced. The SAQA documents were sourced in addition to study guides as they provided specific information, which in most cases is not fully covered in study guides. Such information may include credits, the purpose and rationale of the programme and expiry dates of the qualification.

### 3.3.5 Data Analysis

Data analysis is “an ongoing and non-linear process, implying that data collection, processing, analysis and reporting are intertwined, and not merely a number of successive steps” (Maree *et al.,* 2012:100).

Content analysis of the curricula and the study guides was conducted by means of the analysis rubric to identify and investigate the presence and coverage of concepts

related to DR in different institutions of higher learning (Mouton, 2011:165). The study guides were analysed with the focus on determining which of the DR content listed in the rubric had been covered from the first year of study until third-year level. Note that some institutions cover CR and FPDs throughout all three years of undergraduate study, while other institutions only cover CR and FPDs in the second and/or third years of study. The findings were contextualised to current literature on the required DR knowledge and skills for qualified diagnostic radiographers.

### 3.3.6 Validity and Reliability

Only official documents of the different institutions of higher learning and the information from the official website of SAQA were used to ensure the highest level of document validity. In addition, peer review was used to ensure the credibility of the analysis, specifically in the form of regular discussions with the study leaders to check the progress and validity of the content analysis process (Krefting, 1991:214). Only study guides for image recording modules were requested from the various academic institutions, and similar themes were analysed. This enhanced the content and criterion validity (Leedy & Ormrod, 2013:90).

### 3.3.7 Ethics

Following the TUT approval process (see annexure A), the researcher sought research ethics clearance from each of the targeted institutions of higher learning. In addition, the study received ethical clearance (GP2016p48344) from the National Health Research Database (NHRD); this was necessary for recruiting diagnostic radiographers working in the public sector.

The names of the institutions of higher learning that participated in Phase 1 were anonymised during the content analysis process. In addition, these institutions are only referred to as Institution A, B and C respectively in all research outputs. Moreover, the results for the various academic institutions are reported in a way that does not compare and/or rank the institutions.

Lastly, all the study guides were stored by the researcher in a way that maintains their confidentiality. Ethical clearance was granted by the industry where interviews were conducted (see annexure G). In all cases, the researcher only collected data when specific permission was granted.

## 3.4 PHASE 2 – SURVEY OF THE APPLICATION AND UTILISATION OF DIGITAL RADIOGRAPHY FEATURES

Phase 2 of the study investigated the range of the application and use of the various DR features by diagnostic radiographers in clinical practice in South Africa. It was necessary to collect this data to give the researcher underpinning knowledge of which features are either commonly used or never used and furthermore to relate such features with the results of Phase 1 of the study. An online survey was used where a link was created and E-mailed to all diagnostic radiographers registered with the HPCSA.

### 3.4.1 Research Design

Phase 2 followed a cross-sectional survey approach to describe the range of application and use of the various DR features by diagnostic radiographers in clinical

practice in South Africa. A cross-sectional survey was an appropriate design to assist the researcher in answering the second objective of the study. It allowed the researcher to investigate diagnostic radiographers of different age groups and experiences at the same time on a once-off basis (Leedy & Ormrod, 2015:157-158).

### 3.4.2 Survey Questionnaire Development

An extensive literature search could not locate an applicable questionnaires that could be used in the current DR study. A survey questionnaire therefore had to be developed. All the questionnaire items were newly formulated. The results of Phase 1 were of primary significance and informed the development of the online survey questionnaire. The survey items included open-ended and close-ended items. Various question designs were used, for example drop-down menus, multiple choice questions, rating scales and comment boxes. Literature and the inputs from various stakeholders (application specialists, clinical diagnostic radiographers and academics) were also considered in the draft questionnaire development. The draft survey questionnaire was circulated to relevant stakeholders who commented on it and made suggestion to add, edit and review certain questionnaire items. The stakeholders' remarks were incorporated into the final version of the survey questionnaire.

To enhance the internal validity of the data collection instrument, the questionnaire was piloted with academic staff members of institutions of higher learning not associated with the researcher, practising diagnostic radiographers and application specialists. These individuals were requested to check issues such as concept clarification, readability of items, grammar and the time it takes to complete the

questionnaire. All the stakeholder comments were duly considered and incorporated into the final version of the survey questionnaire.

### 3.4.3 Survey Study Population

The survey study population included all 5 038 qualified diagnostic radiographers who were in good standing with the HPCSA in 2015 and 2016. Student radiographers were excluded from the survey, as they were deemed not to have enough clinical experience to respond truthfully to most of the survey items.

### 3.4.4 Data Collection

The self-administered questionnaire (see annexure H) was used as the survey data collection instrument (Leedy & Ormrod, 2005:185). A cover letter was E-mailed, together with the link created by the online survey platform. The E-mail provided details about the researcher (credentials), information relating to the study, what was required from the participant, exclusions, possible risks, benefits, rights of the participants, confidentiality and anonymity. In the context of Phase 2 of the study, implied consent was deemed appropriate, i.e. whoever responded to the survey would be considered as having consented to the study. The questionnaire was administered as a once-off online survey on the Survey Monkey™ (www.surveymonkey.com) platform. Survey Monkey is a commercial online survey, which charges a once-off annual fee. It provides templates that facilitate basic questionnaire design. In addition, it provides a variety of item types (e.g., multiple-choice items, rating scales) (Leedy & Ormrod, 2015:175). The link created by Survey Monkey for this study's questionnaire was E-mailed on 08 December 2016 to all diagnostic radiographers who met the

inclusion criteria (see Section 3.4.3). The E-mail addresses were formally obtained from the HPCSA.

Kaplowitz, Hadlock and Levine (2004:94) indicate that the return rate for an E-mailed questionnaire is lower than for a mailed questionnaire. This may be due to lack of internet access of targeted participants when using an online survey. Leedy and Ormrod (2015:175) found that when the desired sample size was quite large, an online survey was far more cost-effective than a mailed questionnaire. The response rate for this study (n = 116) was relatively low, but still within the 5% margin of error. More than 300 E-mails could not be delivered, possibly because of changes in E-mail address, whereas others could have landed in the spam folders. The various potential reasons for the low response rate were identified: radiographers who changed E-mail addresses without informing the HPCSA, radiographers who might have migrated overseas, work overload of radiographers and general scepticism about responding to unsolicited E-mail requests for research participation. The last-mentioned reason is closely linked to South African health professionals' intense awareness of confidentiality in terms of the Protection of Personal Information Act (Act 4 of 2013). A second wave of E-mail was not possible because of the researcher's agreement with the Society of Radiographers of South Africa (SORSA) in response to a formal complaint (see Section 3.4.7). In addition, at the time of distributing the E-mail, there was a nation-wide South African Post Office strike, which was the primary reason for not using the postal services as an additional survey questionnaire distribution-and-return strategy. The relatively low response rate means that the result from this phase should be interpreted with caution and that it has limited generalisability to the study

population. In this regard, Leedy and Ormrod (2015:187) indicate that response rates for questionnaire surveys are usually below 50%.

### 3.4.5 Data Analysis

A gold bundle was purchased in order to gain access to additional Survey Monkey functionalities. The Survey Monkey platform consequently collected the data and performed some descriptive statistical analyses; the analysed data was made available to the researcher in the form of histograms and tables.

### 3.4.6 Validity and Reliability

The Phase 1 results, together with the inputs from various stakeholders, as well as the relevant themes identified in recent peer-reviewed literature (see Chapter 2), formed the basis of the survey questionnaire, increasing its internal validity. Furthermore, the questionnaire was piloted with clinical radiographers, academics and application specialists, as well as peer reviewers, to evaluate the clarity of the survey items and the time required to complete the questionnaire (see annexure I). The various comments and suggestions from the reviewers were duly considered and incorporated in the final questionnaire.

### 3.4.7 Ethics

Ethical clearance for distribution of the questionnaire was granted by the TUT Faculty of Science Committee for Research Ethics (FCRE Reference Number 2014/08/001) (see annexure J). In addition, ethical approval was granted by the NHRD to include

public hospital radiographers in the study (GP2016P48344). The online survey had a cover page that served as an information leaflet; it summarised the nature of the study (see annexure K). Participation in this study was voluntary and on an anonymous basis. Voluntary return of the completed questionnaire was regarded as implied consent; consequently no form of written consent was required from the survey participants. Furthermore, to ensure optimum confidentiality, the raw data was downloaded from Survey Monkey™ and stored on an external hard drive, which will be kept in the researcher's office for five years after completion of the study. All the data was stored in a password-controlled environment in the researcher's office to ensure that only the study leaders and the researcher have access to it.

The Phase 2 survey approach encountered an ethical challenge when some members of SORSA raised concern about the researcher's access to and use of private E-mail addresses for research purposes, specifically in terms of the Protection of Personal Information Act (Act 4 of 2013). On 10 January 2017 SORSA sent the researcher a formal letter/E-mail of concern, seeking clarification on this matter. The researcher's formal clarification response and his apology to aggrieved SORSA members were formulated as follows (E-mail sent on 25 January 2017):

> The provisions of the *Protection of Personal Information Act* (Act 4 of 2013) state the following: The Act (Section 1) defines "direct marketing" as follows: ''… to approach a data subject, either in person or by mail or electronic communication, for the direct or indirect purpose of (a) promoting or offering to supply, in the ordinary course of business, any goods or services to the data subject; or (b) requesting the data subject to make a donation of any kind for any

reason". Chapter 8 (Section 69) of the Act specifically prohibits the use of unsolicited electronic communications (e.g. E-mails), as it specifically pertains to "direct marketing"; nowhere in the Act is the use of unsolicited electronic communications for research purposes prohibited; in actual fact the Act does allow such use under certain conditions (see below).

In line with the processing limitations of the Act the use/procurement of personal E-mail addresses in the research project was lawful and in a reasonable manner (Section 9), based on the principle of minimality (i.e. relevant and not excessive) (Section 10), as well as necessary for pursuing a legitimate research interest [Section 11(1)(f)]. The use of an online anonymous survey is compatible with the purpose to collect voluntarily submitted, research-based data [Section 15(1), Section 15(2)e and Section 15(3)(a) of the Act].

Given SORSA's objection to the use of its members' E-mail addresses in the research project, the Act does under certain conditions allow objections to the processing of personal information [Section 11(3)(a)]. As such, the researcher will honour this objection by complying with Section 11(4) of the Act, which states that "*If a data subject has objected to the processing of personal information in terms of subsection (3), the responsible party may no longer process the personal information.*" The implication is that the researcher will not make any further use of the relevant E-mail addresses to subsequently invite SORSA members to complete an online anonymous survey or take part in similar research-based action. However, note that any voluntary submission of a

completed online anonymous survey by radiographers will be confidentially retained in accordance with Section 14(2) of the Act.

The project strictly adheres to the requirement that *"… the information is used for … research purposes and the responsible party ensures that the further processing is carried out solely for such purposes and will not be published in an identifiable form*" [Section 15(3)(e)]. The implication is that the researcher will not publish identifiable information (e.g. E-mail addresses) or identifiable survey data in any research outputs emanating from the study.

The Act does not require the researcher to comply with the requirement to inform the participants of the source of the E-mail addresses [Section 18(1)(a)], since the information has been obtained in a lawful manner and strictly for research purposes [Section 18(4)(f)], and it is used in strict adherence to the conditions set by the provider.

As a matter of professional respect towards SORSA members the researcher wishes to apologise for the personal discontent experienced by some members, as the researcher's intention never was to make all the E-mail addresses "visible" to all the message recipients; the researcher had actually intended to use the E-mail system's "blind copy" (BCc) function but this unfortunately did not happen due to human error.

## 3.5 PHASE 3 – RADIOGRAPHERS' PERCEPTIONS OF THE UTILISATION OF DIGITAL RADIOGRAPHY FEATURES

Phase 3 of the study focused on the perceptions diagnostic radiographers hold regarding the utilisation of DR features in South Africa.

### 3.5.1 Research Design

Phases 2 and 3 were conducted simultaneously. Phase 3 followed a qualitative research approach, specifically in the form of focus groups, to investigate diagnostic radiographers' perceptions of their familiarity and utilisation of DR features in clinical practice (Leedy & Ormrod, 2005:146). This design was chosen because it allowed the researcher to probe the focus group participants to express their perceptions in relation to the topic of interest (Leedy & Ormrod, 2015:282).

### 3.5.2 Participant Sampling

A purposive sampling approach (Maree *et al*., 2012:79) was used to recruit qualified diagnostic radiographers who were working in public and private radiography facilities in Gauteng (Pretoria and Johannesburg); they had to be actively working with DR for a period of at least three years. For public institutions in the Tshwane region, permission for data collection was sought from the Tshwane Research Committee (TRC). The TRC indicated that prior to their office granting access for the researcher to conduct the study, the study also needed to be registered with the national research database. Once this had been done the TRC granted the requested permission. The researcher made appointments with each of the prospective hospital and imaging facilities to discuss the possibility of collecting data in their respective contexts. The

managers at the various imaging facilities then suggested suitable times for the researcher to collect data, based on the business of the imaging facility and the availability of staff.

Focus groups were conducted at four public health institutions and one private hospital; all of these facilities were using DR imaging systems. The focus group participants in each hospital were nominated by the head radiographer; in all instances almost all members of staff who were on duty on the day of the focus group interview participated. Imaging services to patients were not affected by the study, as the managers were willing to stand in during the focus group time; interviews were also scheduled in time slots when the imaging facilities were least busy. The work flow and patient services were important factors considered prior to granting permission for the study. To ensure voluntary participation, the researcher explained to the participants that they had the right to participate or withdraw their participation at any stage without stating reasons for withdrawal. An area in each of the imaging facilities with minimal noise interference was allocated to the researcher by the facility manager. The target radiographers were provided with information leaflets and requested only to sign consent once they had fully agreed to participate in the study.

Student radiographers were excluded from the focus groups because they were deemed not to have sufficient clinical experience to contribute significantly to the focus of this study phase. Radiographers who were not on duty and those who were designated specialised services on the day of the interviews were also excluded from the study.

### 3.5.3 Data Gathering

Information gathered from current literature, the Phase 1 results and the DR knowledge of the researcher were all used to inform the content of the draft interview guide for the focus group interviews. The draft interview guide was then sent to a number of application specialists, practising diagnostic radiographers and academics for input and comments. Once reviewed, their comments and suggestions were incorporated in the interview guide. Prior to using the interview guide, a pilot study was conducted among the application specialists, practising radiographers and academics to ensure its validity and applicability. These final inputs and feedback were incorporated in the final interview guide. The final interview guide (see annexure L) only included open-ended questions (Leedy & Ormrod, 2005:146).

Leedy and Ormrod (2015:146) suggest that a focus group should not consist of more than 10 or 12 participants to ensure adequate rapport between the participants and the researcher. In this study, each focus group had a minimum of four participants and a maximum of eight participants. The length of the focus group interviews ranged from 45 minutes to 1 hour and 10 minutes.

A quiet room with minimal noise interference in each participating imaging department was secured for the respective focus groups. The researcher provided bottled still water for all participants, with no cost attached. All participants were coded as participant 1, 2, 3 etc. before the onset of the focus group interview to ensure that during transcription words said by one person could not be mismatched to another participant. A technical assistant was used to operate a video camera to record the interviews. A confidentiality agreement was in place between the researcher and the

technical assistant (see annexure M). The researcher took written field notes during the interviews to capture qualitative aspects of the discussions, for example the general mood of the focus group and non-verbal behaviour. The researcher took enough time to explain the focus group procedure, as well as the aim and importance of the study. Moreover, the researcher urged the participating radiographers to express their opinions honestly, as there were no right or wrong answers. They were also assured that their answers would not be used for any employment-related promotional or performance reviews. The researcher used these strategies to improve the credibility of the data and to increase rapport during the interview sessions (Krefting, 1991:217-218).

### 3.5.4 Data Analysis

This research project followed Tesch's method (Cresswell, 2013:155). This involved the following analysis steps:

- Firstly, the researcher transcribed the video-recorded data. Once all the interviews had been transcribed, the researcher familiarised himself with the data by reading through each transcribed script, while replaying the video to ensure that what had been transcribed was in harmony with what was recorded.
- Once the researcher had read through all the transcriptions, he coded each participating institution with an alphabetic letter (for example Daniel Lamola Hospital was coded with the letter "A").
- Next, the researcher started the reading process from the first transcription to identify the relevant meaning units. A relevant code was allocated to each meaning unit. The meaning units that shared the same code were then linked in the text to identify patterns and similar themes.

- Once all the meaning units of all the focus group interviews had been coded, the researcher identified the higher-order categories, themes and patterns in the data. The higher-order categories were revised and reorganised in an iterative process to ensure category clarity and conceptual cohesion.

The recorded data was transcribed by the researcher. This is highly recommended in the literature as opposed to the use of transcription software or independent transcribers (Maree *et al.* 2012:104). Transcriptions were done for all the focus group interviews. Each focus group was coded with an alphabetic letter to ensure the respective participants' and the facilities' anonymity. Once data transcription had been completed, the researcher had to read the transcribed data line by line in pursuit of meaningful analytical units. Once the meaning units had been identified, they were coded. Maree *et al*., (2012) define coding as "marking segments of data with symbols, descriptive words or unique identifying words". For this study the researcher used descriptive words for coding. The qualitative narrative data was then categorised in themes and sub-themes until a state of saturation was reached, i.e. no new concepts or themes emerged from the data. Finally, higher order analysis was done where codes of common themes were identified and grouped together.

The following reference guideline (see footnote and an example of a quotation below) was adopted for the description and referencing of Phase 3 results (see Chapter 4 for the application of this coding system):

… *image stitching we never use* (B/4/24)[1].

### 3.5.5 Trustworthiness

The semi-structured questions developed from the findings of Phase 1 support and enhance its content validity. To increase the validity of the information received from the application specialists, all telephonic calls were recorded on a cell phone, then stored on a computer (this was done with the permission of the application specialists). The same set of open-ended questions (i.e. interview guide) was used for all the focus group sessions, which guided the respective focus groups to discuss similar themes. All interview sessions were video-recorded to ensure that the non-verbal cues were duly captured. These records were used during the data analysis to contextualise and interpret the nuanced meanings in some of the participants' responses (Maree *et al*., 2012:92).

The use and availability of video recordings enhanced the consistency of the data (Krefting, 1991:215) owing to its availability for cross-checking of the raw and analysed data by the researcher and study leaders. To ensure a high level of applicability (transferability) of the results (Krefting, 1991:2116), the researcher provided a detailed description of the method used for data collection (see Section 3.5.3), as well as the instrument used to record and analyse data (see Section 3.5.3).

[1] B (Alphabetical letter) = Name of institution; 4 = the first number is a page number; 24 = the last number is a line number

### 3.5.6 Ethics

Letters requesting permission to conduct research were sent to prospective hospitals (imaging facilities) (see annexure N). The study only commenced after ethical clearance had been granted. All potential focus group participants received an information leaflet (see annexure O), which described the nature of the study to be conducted. All participants were required to sign informed consent documents (Leedy & Ormrod, 2005:101) (see annexure O). Participation in the focus groups occurred on a voluntary and anonymous *(Participants were coded: participant A, B, C etc.; presentation of the results used participants 'codes and not their real names, further more participants were not asked to disclose their real names or any form of identity)* basis; the participants had the right to withdraw from the study at any stage without explaining their reasons. The video-recorded data was electronically stored on the researcher's laptop as well as on an external memory device only accessible to the researcher. This was done to ensure that confidentiality was maintained; the raw data was only accessible to the researcher and study leaders. Stored data will be kept safe for a period of five years after completion of the study; thereafter it will be destroyed.

Ethics clearance was obtained from the relevant research ethics committee (Reference number FCRE 2014/08/001, see annexure J) for the final interview guide, information leaflet and informed consent forms. The study received ethical clearance from the National Health Reseach Database (NHRD) (GP2016P48344) for data collection in public hospitals and was further ethically cleared by the TRC (clearance number: 34/2016). In addition, the relevant ethics clearances were obtained from the

relevant research ethics committees of each participating hospital[2]. Lastly, a confidentiality agreement was entered into between the researcher and the technical assistant who made the video -recordings (see annexure M).

## 3.6 CONCLUSION

A combination of mixed methods research strategies was followed in this study, implying that both quantitative and qualitative data was collected and integrated at various stages. The data collection instruments used in all three phases of the study were designed, developed and tested by the researcher. Lastly, the data was analysed using a variety of descriptive statistical measures (quantitative data) and Tesch's method (qualitative data).

Chapter 4 presents the results of the three phases.

[2] Signed ethical clearances and permissions for all hospitals and imaging facilities that participated in this study are kept in a confidential archive in the researcher's office. Note that because of anonymity considerations and assurances, these documents have not been included in the annexures section.

# CHAPTER 4

# RESULTS

In this chapter the results of the data obtained during the study (Phase 1-3), namely the analysis of the rubric data (phase I), analysis of the quantitative survey data (phase 2) and analysis of the focus group interviews (phase 2).are presented.

## 4.1 ANALYSIS OF THE RUBRIC DATA (PHASE I)

The analysis of the rubric data for the identified South African institutions of higher learning offering diagnostic radiography undergraduate programmes is presented in this chapter. The data was collected using a self-developed rubric (see annexure B), while content analysis was used to analyse the learner guides. The results of the content analysis are graphically presented in subsequent sections; important differences and comparisons are also highlighted in this chapter. The following main result themes have been identified:

- Introduction to basics of computer;
- Basic information technology;
- Digital imaging systems;
- Point-processing operations;
- Display monitors;
- Exposure technique charts;
- Digital imaging artefacts;
- Health information systems;
- Digital image characteristics;
- Operating settings and menu;

- Accessories in digital imaging;
- Prescribed and recommended literature;
- DR credits; and
- Admission requirements.

### 4.1.1 Introduction to Basics of Computer

Institution A more than adequately incorporates the basics of *computer hardware* and *software* in the curriculum, while Institution B is achieving the same for computer hardware and adequately addresses computer software in the curriculum (see Table 5.1, page 170). However, both institutions incorporate *Microsoft Word* and *Microsoft Excel* in the curriculum inadequately. In contrast, Institution C does not include any aspect of the basics of computers as part of the DR curriculum, although it is possible that Institution C includes these computer aspects in other courses/subjects offered by the programme.

It is highly recommended that basic computer knowledge and skills should be part of the formal DR curriculum, especially since most clinical facilities have migrated to DR, which primarily uses computers (Nyathi, Chirwa & Van der Merwe, 2010). Institution A includes all the expected components relating to computer software, which is of primary importance for students to understand the applications of DR. Institution B only includes between 50% and 75% of the expected knowledge base regarding computer software, whereas Institution C does not include any aspect of computer software in the DR curriculum. According to Indrajit (2013:17), computers are an integral part of many activities in an imaging facility. As such, it is an advantageous

skill for a practising radiographer to have a working knowledge of computers, which duly applied, enhances workflow.

Both Institutions A and B include less than 50% of basic applications such as Microsoft Word, Excel and PowerPoint, whereas Institution C does not incorporate the basic applications in their DR curriculum at all. Institutions A, B and C are perceived to prepare students inadequately to work competently with the basic computer aspects in DR. Floyd *et al*. (2015:321) identify general computer skills as one of the factors influencing the perceptions of diagnostic radiographers of PACS. These findings are in alignment with the interviews with radiographers from different clinical practices, during which it was noted that radiographers experienced significant problems with basic computer terminology (see Section 4.3.1.3a). A good working knowledge of Microsoft Office tools is essential to ensure that students are able to perform basic radiographic functions such as patient registration, annotations, search, archiving and storage, as well as reject film analysis (RFA).

### 4.1.2 Basic Information Technology

Institutions A and C address PACS in the DR curriculum inadequately, while Institution B includes more than 50% of the expected PACS content. According to Siegel and Reiner (2002:1573), PACS offers the potential to improve departmental productivity and overall image quality. Addressing less than 50% of the expected PACS content in a DR curriculum may ultimately be detrimental to patient health because of potentially poor image quality. Cao and Huang (2000) indicate that PACS digital technology plays a vital role in the success of medical imaging. PACS manages radiological examinations, collects digital images from DR imaging modalities, archives the

collected images strategically and selectively distributes such images for review (Cao & Huang, 2000:80).

The implication of sub-optimal incorporation of PACS in undergraduate DR curricula of diagnostic radiography programmes is the risk of producing radiographers who are merely technicians ("button pushers"), who lack a basic knowledge framework of the technology they use on a daily basis. Another negative implication is poor image quality (Floyd *et al*., 2015:316). Current DR curricula must incorporate PACS content, as PACS is becoming increasingly popular and widespread in imaging facilities (Jorwekar, Dandekar & Baviskar, 2016:774). An immediate challenge is that radiographers with good IT skills will become more popular and more employable rather than radiographers who lack such knowledge. Floyd *et al*. (2015:316) argue that gaps in PACS education might lead to the inappropriate use of PACS equipment. In contrast, a DR curriculum that addresses PACS might lead to the enhancement of patient safety and radiologic examination quality, as it has a direct impact on the radiographer's skills (Floyd *et al*., 2015:316).

The DR learner guides curricula of all three institutions indicate that *computer networking* is not included in the analysed institutional documents (see Table 5.1). Failure to incorporate computer networking in DR curricula further delays the notion of role extension and becomes an impediment to radiographers' career development, especially given that IT is now an integral part of DR.

The coverage of *image transmission* ranges from inadequate to more than adequate among the three institutions (see Table 5.1). In Institutions A and C the quality of

training on image transmission is compromised, with low or no coverage in the DR curriculum, whereas institution B adequately covered image transmission. Image transmission has a direct impact on image quality. It involves a possible risk of over-dosing the patient, as a particular image might have to be repeated because of errors resulting from the radiographer's lack of knowledge and skills in relation to image transmission.

In relation to *information communication standards in radiology*, Institution A had no coverage, while Institution C had less than 50% coverage and Institution B 50-75% coverage (see Table 5.1). These findings are in line with the survey findings (Phase 2, see Section 4.2.11; Table 4.11 and Figure 4.11A) that radiographers generally struggle with basic DR concepts and definitions. Any compromise on these core concepts of DR imaging in the DR curriculum denies future radiographers a basic right to know and understand the increasingly dominant world of digital imaging (Farhadi & Ahmadi, 2013:1040; Gunn, 2009:16; Indrajit, 2007:5; Indrajit, 2013:18;).

### 4.1.3 Digital Imaging Systems

All institutions' DR curricula included 50% to 75% of the content measured against the benchmark rubric (see Annexure C). Busch and Faulkner (2005:143), Korner *et al*. (2007:684) and Walsh *et al*. (2008:271) highlight that the immediate future of radiography will be dominated by DR. The study by Korner *et al*. (2007) also highlights that CR technology is to remain for a while, as indicated by new CR developments.

The curriculum coverage for CR by the institutions under study indicate that radiography in South Africa is lagging behind with regard to technological advances.

Common features omitted in the curriculum include image processing in CR, different types of readers and exposure control in CR. According to Korner *et al*. (2007), image processing is one the key feature of DR, as it significantly influences the way the image appears to the radiologist.

In relation to flat-panel DR, Institutions A and B include 50% to 75% of the content measured against the benchmark rubric (see annexure C), whereas Institution C includes less than 50% of the content (see Table 5.1). Specifically, indirect conversion systems are not covered in depth in any of the institutions studied.

FPDs offer the best image quality and low contrast performance of all the current digital detectors and are superior to conventional SF radiography (Korner *et al*., 2007:680). Lack of sufficient theoretical coverage of FPDs by institutions of higher learning in SA compromises the quality of imaging, consequently exposing patients to higher risks of increased radiation dose exposure.

### 4.1.4 Point Processing Operations

Institution C's learner guide does not include any of the components of point processing operations, whereas the learner guides of Institutions A and B include the basics of look-up tables(see Table 5.1). Moreover, Institutions A and B include less than 50% of what is expected according to the benchmark rubric. These results are in harmony with the findings from the interview sessions with clinical practising radiographers (see Section 4.3.1.3 a); most of the radiographers had no knowledge of concepts such as image histograms and look-up-tables.

The void in the curriculum coverage of imaging in the study guides of Institutions A, B and C is in contrast to the indications of Seeram and Seeram (2008:24), who highlight that digital image processing in radiology has become one of the routine skills of radiographers and radiologists alike. Seeram and Seeram (2008:24) further indicate that it is important for radiographers to understand the nature and scope of digital images and digital image processing to become effective and efficient users of the new technologies that have made a significant impact on the care and management of patients. A number of authors share the common view that digital image processing has a direct impact on image quality and they further add that radiographers must be familiarised with post-processing steps (Krupinski *et al*., 2007:392; Korner *et al*., 2007:680; Uffmann & Schaefer-Prokop, 2009:203; Seeram & Seeram, 2008:26). The main goal of digital image post-processing is to alter an image to enhance diagnostic interpretation (Seeram & Seeram 2008:24).

### 4.1.5 Display Monitors

The image recording learner guides of Institutions A and B do not address display monitors, monitor orientation, monitor and image quality, types of monitors or the quality control of display monitors (see Table 5.1). There is a possibility that these concepts may be included in other courses, such as basic or advanced computer courses. Insufficient coverage of this theme in the curriculum has a potentially direct negative impact on patient diagnosis, as well as on patient dose (Butt & Savage, 2015:241; Uffmann & Schaefer-Prokop, 2009:203), as images may be repeated because of poor image quality displayed on the monitor (Ludewig *et al*., 2011:1).

The image recording learner guide of Institution C does address the theme of image display. However, the content coverage is inadequate, as it includes less than 50% of what is expected according to the rubric memorandum. Institution C provides better coverage when compared to Institutions A and B (see Table 5.1). This suggests that students trained at Institution C might have better understanding of display monitors than students from Institutions A and B respectively.

The findings for Institutions A and B are important when understood in the context of the findings of Krupinski *et al*. (2007:389) and Ludewig *et al*. (2011:1), who emphasise that the manner in which images are displayed affects the image quality. Various core display factors are involved in digital image quality, namely equipment specifications and existing standards, image display technology, matrix size and display size, luminance and contrast, bit-depth, optics and viewing environment (Krupinski *et al*., 2007:390-394; Ludewig *et al*., 2011:5; Puchalski, 2008:S11; Samei *et al*., 2004:324). These factors require some technical understanding and insight that should be addressed by institutions of higher learning at undergraduate level.

None of the learner guides from the three institutions (A, B and C) included in this study made any direct reference to PACS monitors (see Table 5.1). However, it is possible that this theme may be included in other related courses. The implication of insufficient curricular coverage of PACS monitors may disadvantage students in terms of understanding PACS image display, its impact on patient radiation dose, as well as image quality. According to Hirschorn, Krupinski and Flynn (2014:1270), poor quality displays could result in misdiagnosis, as well as radiographer's eyestrain and fatigue.

Learners must therefore be adequately trained in the use and application of PACS monitors.

As far as laser printers are concerned, Institution B's learner guide does not include this theme, while Institutions A and C's curricular coverage is less than 50% of the expected coverage (see Table 5.1). These levels of coverage are insufficient measured against the rubric memorandum.

### 4.1.6 Exposure Technique Charts

Exposure factors as the subject of exposure technique charts received inadequate curricular coverage at Institutions A and C, with each institution scoring less than 50% of coverage. Institution B's curriculum coverage on exposure factors in digital imaging scores between 50% and 75%, which is better than that of the other two institutions under study (see Table 5.1). Institution C's curriculum analysis for image recording learner guides found 0% coverage on EI.

The clinical implication of such inadequate coverage or no coverage is that patients might unintentionally be exposed to high levels of radiation dose. Consequently, image quality may be rendered sub-optimal owing to high levels of noise associated with increased levels of exposure factors (Seeram *et al*., 2013:332). Seeram *et al*. (2013:332) are of the opinion that during the transition from SF to DR, radiographers incorrectly assumed that the exposure technique factors used for SF could still be used for DR. Williams *et al*., (2007:373) support this opinion by stating that there are core differences between SF and DR, which require separate exposure charts for SF and DR.

### 4.1.7 Digital Imaging Artefacts

A pattern of no coverage was found for all three institutions in this study regarding the DR curricular incorporation of digital artefacts in their learner guides. However, there is a possibility that digital artefacts are incorporated in general SF radiography artefacts. Drost, Reese and Hornof (2008:S48) indicate that a new set of artefacts came with the introduction of DR. The implication of no or low knowledge of digital imaging artefacts among qualified radiographers pose a direct risk in terms of increased levels of patient exposure due to repeat radiographs as a result of digital artefacts.

### 4.1.8 Health Information Systems

Institution A's DR curricular coverage of HIS, particularly the clinical information system (CIS), was found to be inadequate. The analysis found less than 50% coverage of the expected content according to the rubric memorandum. However, there is a possibility that HIS may be included in other radiographic modules offered by the programme. In contrast, 100% DR curricular coverage relating to CIS was found for Institutions B and C (see Table 5.1). The RIS has been an integral part of DR imaging since the inception of technology in radiology and it definitely has a footing in the future of ever evolving technology (Nance, Meenan & Nagy, 2013:1065).

No DR curricular coverage regarding the Administrative Information System (AIS) was found for Institution C, whereas Institution A scored less than 50% and Institution B scored between 50% and 75% (see Table 5.1). Note that Institution C may include AIS in other radiographic modules. The omission of AIS in the DR curriculum may

ultimately have a negative impact on the general waiting time of patients and it may affect departmental efficiency in radiology departments (Chaudhry *et al*., 2006:748). Lack of AIS knowledge by radiographers may result in radiographers taking longer to search for a patient on HIS or RIS, ultimately prolonging procedure time for the patient and patient waiting time. In private practice, business is the core of service rendered. A delay in procedure time affects the economy of the department negatively (Makanjee, Bergh & Hoffmann, 2014:154)

### 4.1.9 Digital Image Characteristics

The various digital image characteristics were covered as follows in Institution A's curriculum (see Table 5.1):

- less than 50% coverage on spatial frequency and spatial resolution;
- 100% coverage of dynamic range; and
- less than 50% coverage of SNR.

The various digital image characteristics were covered as follows in Institution B's curriculum (see Table 5.1):

- 100% coverage of spatial frequency, spatial resolution and modulation transfer function (MTF);
- 50-75% coverage of dynamic range; and
- less than 50% coverage of SNR.

The various digital image characteristics were covered as follow in Institution C's curriculum (see Table 5.1):

- less than 50% on spatial frequency and spatial resolution;
- less than 50% coverage regarding MTF;
- 50-75% coverage of dynamic range; and
- 50-75% coverage of SNR.

Similar to SF, a number of factors affect the quality of the DR image in DR. Such factors may include the following: noise, contrast detail, spatial resolution, the MTF and dynamic range of an imaging system (Krupinski *et al*., 2007:389; Williams *et al*., 2007:5). The findings of Krupinski *et al*., (2007:389) and Williams *et al*., (2007:5) are in harmony with the analysis for Institution B on spatial frequency and spatial resolution, as 100% of the factors affecting image quality are covered; however, this finding is in direct contradiction with the analysis of Institutions A and C, as they include less than 50% of the content as reflected in the rubric memorandum.

### 4.1.10 Operating Settings and Menu

**Changing time settings**. The analysis of Institutions A, B and C's DR curricula found 0% coverage of changing the time setting on the control panel (see Table 5.1). Note that there is a possibility that this theme may be offered as a learning unit in a different module in the radiography programme. However, the implication of no coverage is a potential failure to record the time on a radiograph accurately, which might hold serious medico-legal consequences when the radiographs are presented as evidence in a court of law.

**Adding a new protocol**. The analysis of Institutions A, B and C's DR curricula found 0% coverage of adding a new study protocol on the control panel (see Table 5.1). Note

that there is a possibility that this theme may be offered as a learning unit in a different module in the radiography programme. However, the lack of DR curricula coverage may be offset by clinical practice skills and experience.

The above analysis results suggest a pattern of non-incorporation of themes relating to settings and menu functions in the studied DR curricula. The implication of such a pattern is that radiographers may never master settings skills if not formally instructed in clinical contexts. These findings are also in alignment with the results of Phase 2 interview sessions, where most of the radiographers indicated that the work of settings and menu should not be performed by radiographers, but should rather be performed by the IT department or quality control (QC) radiographer (see Section 4.2.8).

**Switching collimator shutters on and off**. The analysis of Institutions A, B and C's DR curricula found 0% coverage of switching on and off collimator shutters on the control panel. This finding aligns with the results of the interviews with radiographers, where most of them indicated that they had no knowledge of accessing the shutters in order to switch the collimator shutters on and off (see Section 4.2.9).

**Reject film analysis**. Institution A's DR curriculum analysis found 0% coverage regarding RFA on a digital imaging system, while Institutions B and C both scored less than 50% respectively (see Table 5.1). In addition, the results of the interviews with radiographers highlighted the fact that many of the radiographers are not involved in QC, the reasons being access (computers require passwords; only QC radiographers have the password) or job responsibility limitations (see Section 4.2.9). These findings raise serious concerns about radiographers' QC activities and call for urgent

interventions by the relevant stakeholders. It is reasonable to recognise that any new technology brings with it new challenges in terms of its control and quality assurance (Walsh *et al*., 2008:271), but it does not negate radiographers' QC responsibilities. In this regard, Minnigh and Gallet (2009:84) state the following: "Repeats are indicators for the quality-imaging manager to schedule additional training and to be used as a basis for dialogue with the reading radiologists to improve the service and quality to patients and referring physicians."

**Image post-processing tools**. Institution B's DR curricular analysis found a score of less than 50%, whereas Institutions A and C scored between 50% and 75% for image post-processing tools (see Table 5.1). All three institutions scored 0% in relation to console settings in the DR curriculum. These findings are in alignment with the results of the Phase 3 interviews with the radiographers, where it was indicated that most radiographers are not familiar with some of the tools used for post-processing in DR (see Section 4.2.7).

### 4.1.11 Accessories in Digital Imaging

The analysis of Institutions A, B and C's DR curricula found 0% coverage of the compact disc robot, with a similar score for Institutions B and C regarding digitisers and simulated computerised programmes (see Table 5:1). Institution A scored below 50% for digitisers and between 50% and 75% for simulated computerised programmes. Lack of or insufficient incorporation of DR accessories may have a negative impact on radiographers, as they may reasonably be expected to use tools such as digitisers in imaging facilities that use both the SF and the DR systems.

### 4.1.12 Prescribed Literature and Recommended Literature

The analysis of Institution A's learner guide for DR reveals a score of 0% for both prescribed literature and recommended literature. This implies that the prescribed and recommended DR literature and textbooks are outdated (textbooks written before 2005). In contrast, Institutions B and C scored 100% for both aspects, which means that the prescribed and recommended literature and textbooks are current and include the latest developments in CR and DR.

### 4.1.13 Digital Radiography Credits

Institutions A, B and C reflect a score of zero. There is a possibility that DR credits are indicated in the lecturer's notes or other platforms available to the institutions.

### 4.1.14 Admission Requirements

Institutions A, B and C reflect a score of 100%. The admission requirements for all three institutions are the same.

## 4.2 ANALYSIS OF THE QUANTITATIVE SURVEY DATA (PHASE 2)

This section presents quantitative results of Phase 2 of the study. The results are presented in graphs and tables. The following main result themes have been identified:

- Radiographer's years of clinical experience
- Radiographers working for private or public hospitals
- Imaging systems used in clinical practices
- Length of period that clinical practice has used digital radiography
- Formal computer training
- Patient administration and registration
- Radiographic image post-processing tool
- Console setting
- Quality control
- Digital radiography artefacts
- Computer and information technology
- The extent through which manufacturer based training prepare radiographers to utilise the features of digital radiography
- Digital radiography courses attended
- The duration of time the digital radiography training course was presented

- Tertiary institutions'training of radiographers on digital radiography

### 4.2.1 Radiographers' Years of Clinical Experience

Table 4.1 and Figure 4.1 present the quantitative results for diagnostic radiographers according to their years of clinical experience.

TABLE 4.1: Quantitative results for radiographers' clinical experience

| Years of Clinical Experience | Responses (n = 116) | % of Responses |
|---|---|---|
| 0 – 5 | 40 | 34.48% |
| 6 – 10 | 21 | 18.10% |
| 11 – 15 | 9 | 7.76% |
| 15 + | 46 | 39.66% |

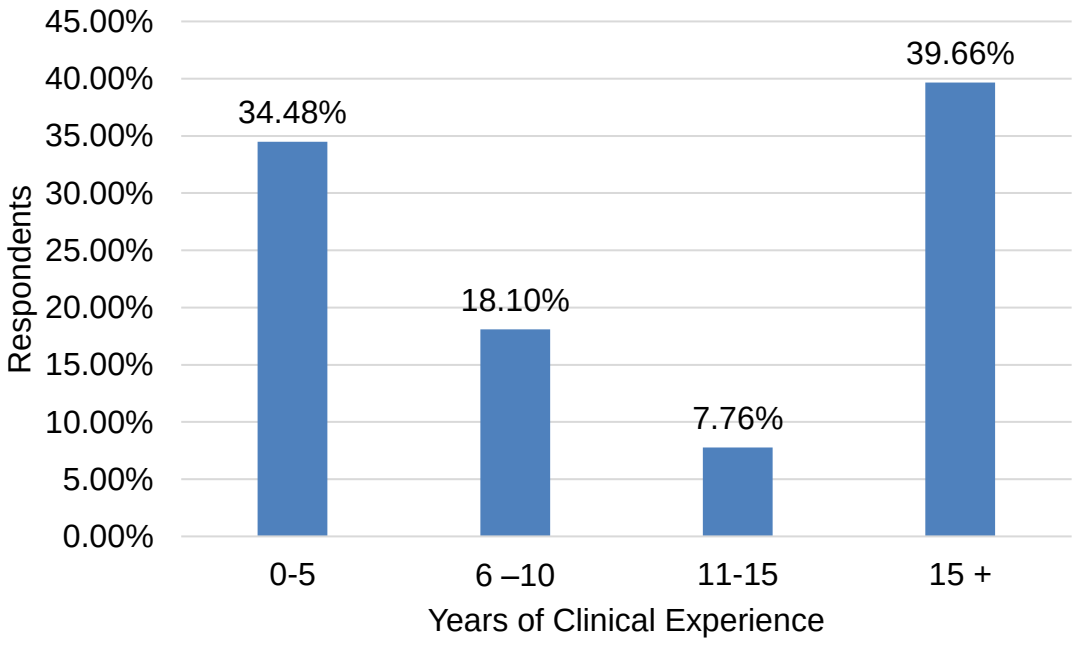



FIGURE 4.1: Histogram depicting the radiographers' clinical experience

The results of Phase 2 of the study indicate that the largest group (39.66%) of respondents have clinical experience of 15 years and above. According to the results of Phase 3 of the study (see Section 4.3.1.3; 4.3.1.4 and Table 5.1), radiographers who did not cover certain DR theory concepts seemed either not to know the relevant DR concepts or were not interested in such concepts. These results may indicate that radiographers who qualified in the early 2000s or before that did not receive theoretical training in DR, as it was not part of the curriculum (see Section 4.1.10 and Table 5.1).

The second highest group is made up of respondents (34.48%) with zero to five years' of clinical experience. They represent a cohort that qualified from 2012 onwards and who had been exposed to DR imaging systems as envisioned by Nyathi, Chirwa and Van der Merwe (2010:2). According to the results of Phase 3 of the study (see Section 4.3.1.2), this group is more familiar with DR jargon compared to radiographers with 15 or more years of clinical experience.

Radiographers with clinical experience of between six and ten years represented 18.10% of respondents, whereas the group with 11 to 15 years of clinical experience only make up 7.76% of the respondents. The results reflect a balanced distribution between highly experienced and less experienced radiographers.

### 4.2.2 Radiographers Working for Private or Public Hospitals

Table 4.2. and Figure 4.2 present the quantitative results for the proportion of diagnostic radiographers who work in private and those who work in public hospitals.

TABLE 4.2: Quantitative results for the proportion of radiographers who work in private and public hospitals

| Types of Hospital | Responses (n = 116) | % of Responses |
|---|---|---|
| Private | 61 | 52.59 |
| Public | 55 | 47.41 |

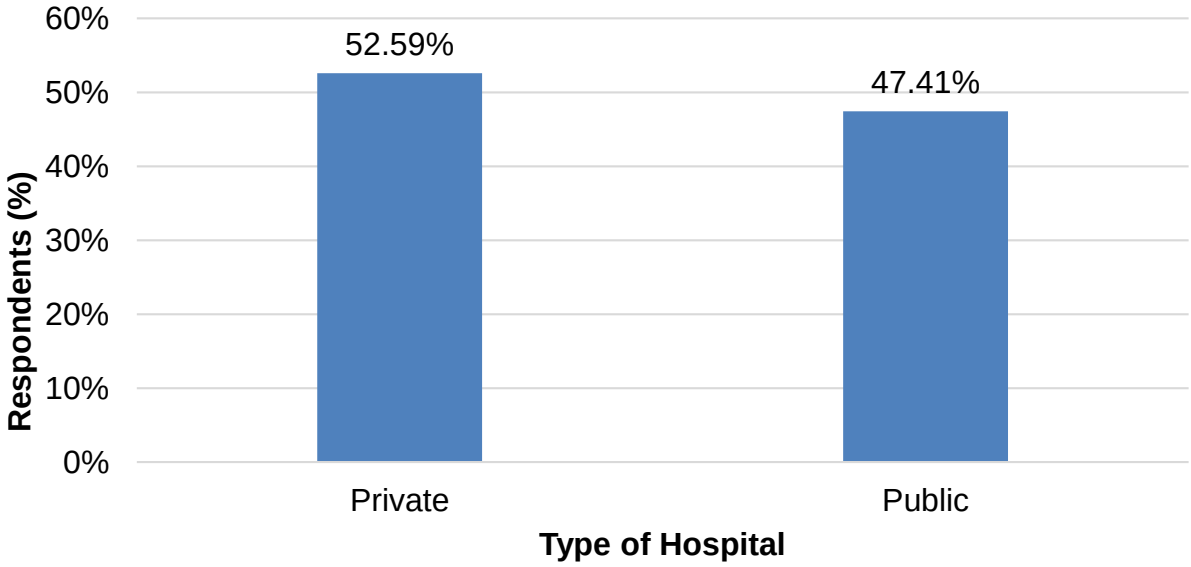



FIGURE 4.2.: Histogram depicting the proportion of radiographers who work in private and public hospitals

Just more than half (52.59%) of the respondents in this study are diagnostic radiographers who work in private hospitals, whereas 47.41% represent those who work in public hospitals.

### 4.2.3 Imaging Systems Used in Clinical Practice

Table 4.3 and Figure 4.3 present the quantitative results for different imaging systems used in clinical facilities.

TABLE 4.3: Quantitative results for the imaging systems used in clinical practice

| Imaging Systems | Responses (n=116) | % of Responses |
|---|---|---|
| Analogue/screen film radiography | 11 | 9.48% |
| Computed radiography | 79 | 68.10% |
| Direct/Indirect flat-panel digital radiography | 72 | 62.07% |

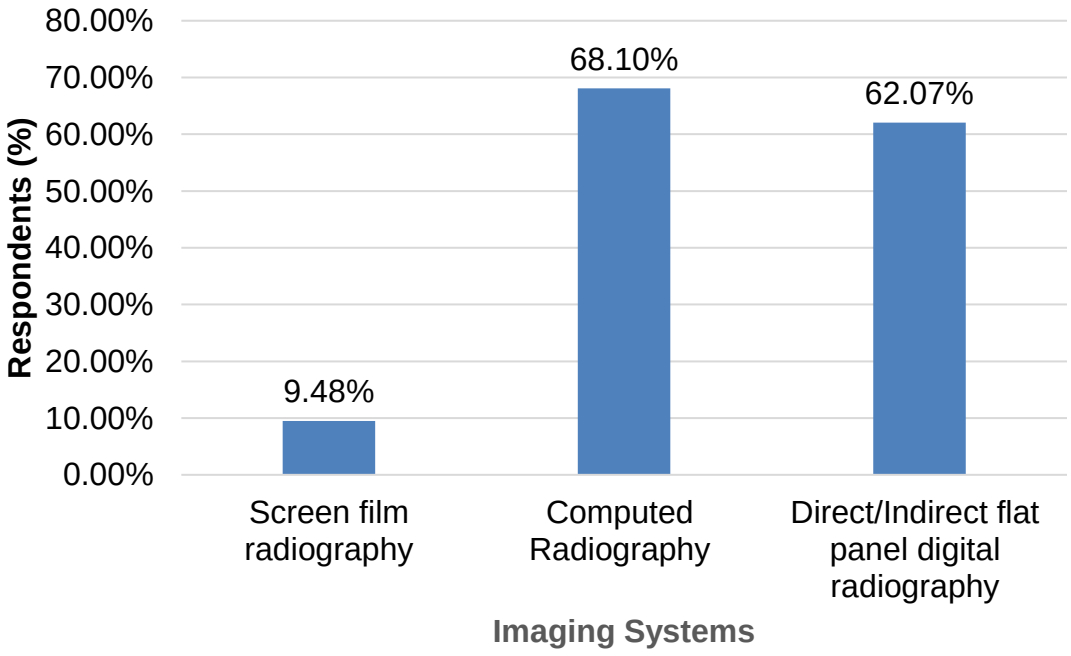



FIGURE 4.3: Histogram depicting the imaging systems used in clinical practices

Table 4.3 and Figure 4.3 indicate that radiography practices where the respondents work have significantly migrated from SF to DR radiography, with only 9.48% still operating with SF. It is, however, possible for one clinical practice to be operating with more than one system, i.e. using SF, CR, indirect flat panel detector (IFPD) and/or

direct flat panel detector (DFPD) simultaneously. Almost two thirds (62.08%) of the respondents indicated that indirect digital radiography/direct digital radiography imaging systems are gaining momentum compared to CR (68.10%), which is currently the most widely used. The results suggest that CR might soon be overtaken by indirect digital radiography/direct-digital radiography as the modalities of choice in South Africa.

### 4.2.4 Length of Period that Clinical Practice has Used Digital Radiography

Table 4.4 and Figure 4.4 present the quantitative results for the length of the period that the different clinical practices in the study have already used DR.

TABLE 4.4: Quantitative results for length of the period that the clinical practices have used DR

| Years of Using DR System | Responses (n=115) | % of Responses |
|---|---|---|
| Not using DR | 1 | 0.87 |
| Not sure | 1 | 0.87 |
| 0 – 3 | 28 | 24.38 |
| 4 – 6 | 53 | 46.09 |
| 7 – 9 | 21 | 18.26 |
| 10 – 12 | 9 | 7.82 |
| 13 + | 2 | 1.73 |

The results indicated that 1.74% of the clinical practices where the respondents worked did not use DR or respondents were not sure how long it had been in use. On the one hand, only 1.73% of the respondents indicated that their practices had used

DR for more than 13 years, while 27.81% had been using it for seven years or more. On the other hand, almost half (46.09%) of the practices had been using it for four to six years and 24.38% of practices for up to three years. This indicates that DR is a fairly new concept in South African radiography, with around 70% of the practices having used DR for six years or less.

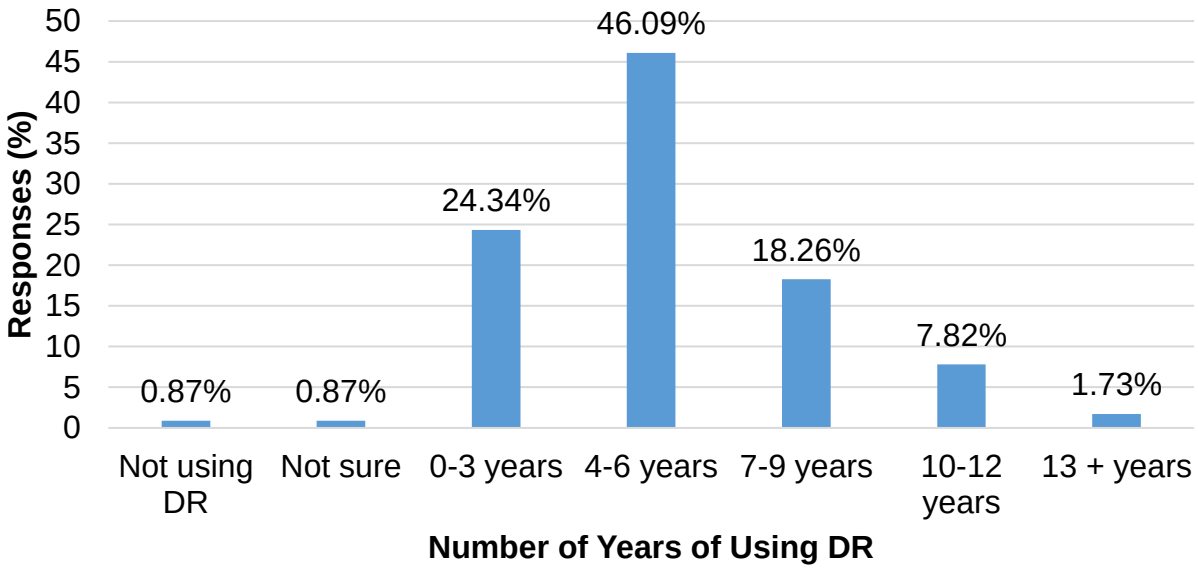



FIGURE 4.4: Histogram depicting the length of time that clinical practices have been using DR

### 4.2.5 Formal Computer Training

Table 4.5 and Figure 4.5 present the quantitative results for radiographers who have obtained formal computer training.

TABLE 4.5: Qualitative results for radiographers who have obtained formal computer training.

| Have Formal Computer Qualification | Number of Respondents (n = 115) | % Respondents |
|---|---|---|
| No | 39 | 33.91% |
| Yes | 76 | 66.08% |

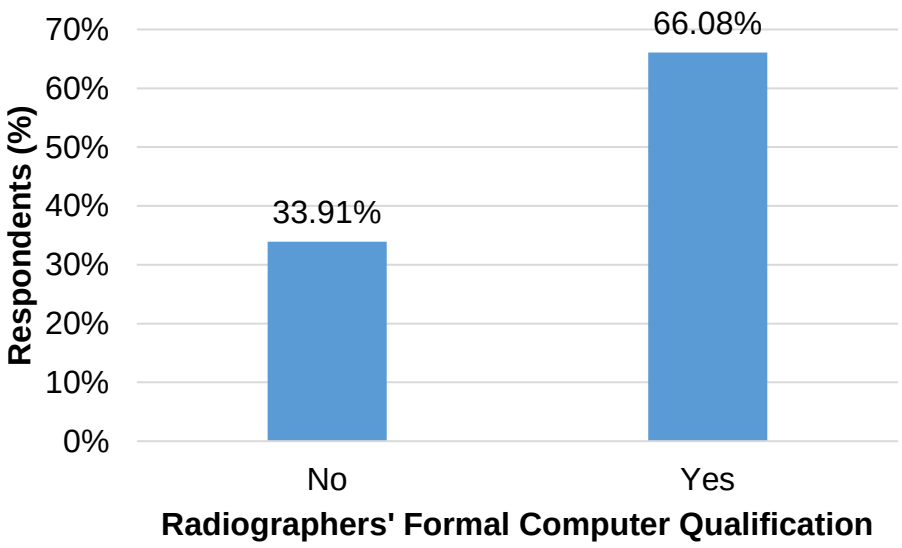



FIGURE 4.5: Histogram depicting radiographers who have obtained formal computer training.

The results indicate that two thirds (66.08%) of the respondents had obtained formal computer training as part of their professional capacity development. Only 33.91% of the respondents had never obtained formal computer training. Computer training with the emphasis on DR technology is necessary for optimal utilisation of DR by radiographers.

### 4.2.6 Patient Administration and Registration (Computer and Console)

Table 4.6 and Figure 4.6 present the quantitative results for radiographers' ability to use the patient administration and registration function of the x-ray equipment's console or computer. The results indicate that almost all (96.55%) of the respondents fully agreed that they could register patient information on the system manually, with only 2.59% indicating that they were not fully convinced of their ability to use the computer optimally for patient administration and registration purposes. Only one respondent disagreed to some extent about her/his ability in this regard. Similar findings were recorded for radiographers' ability to search the archived electronic patient records on the system; 94.83% of the respondents indicated full ability, with only 4.31% indicating some ability, although not full ability, to search archived electronic patient information. Only one respondent indicated absolutely no ability in this regard.

The largest majority (91.30%) of respondents fully agreed that they could check studies that are sent to PACS or are sent for printing. Only 6.09% of the respondents agreed to some extent that they could perform this function, while 2.61% of the respondents were not sure whether they could perform this function.

The largest majority (82.76%) of the respondents fully agreed that they could check images obtained for all patients using from a specific imaging modality (i.e. per imaging equipment), whereas 6.90% of the respondents agreed to some extent that they were able to perform this function. One in ten (9.48%) of the respondents was unsure if he/she could check for images obtained on a specific imaging modality. Only one respondent indicated absolutely no ability in this regard.

The results indicate that two thirds (65.52%) of the respondents fully agreed that they could check patients examined on a specific day, with another 6.03% indicating that they could perform this function to some extent. However, just over 28% of the respondents indicated either some disagreement (6.90%) or full disagreement (21.55%) about their ability to check patients examined on a particular day.

Almost two thirds (63.48%) of the respondents reported full agreement that they could write patients' comments on the imaging system, with another 11.30% agreeing to some extent on their ability to use this feature. Around 15% of the respondents were not sure if could can use this feature. However, just over 10% of the respondents indicated some disagreement (1.74%) or full disagreement (8.70%) about their ability to write patient comments on the system. Similar findings were recorded for radiographers' ability to capture patient information (e.g. patient history, height, weight, in/outpatient) on the system; 58.26% of the respondents indicated full ability, with 13.04% who agreed to some extent on their ability to use this feature. Another 11.30% of the respondents were not sure if they could capture patient information on the system, whereas 6.96% disagreed to some extent and 10.43% fully disagreed that they could use this feature.

The results indicate that only a quarter of the respondents reported full agreement (14.78%) or some agreement (10.43%) that they could capture the patient's blood type and write comments on the system. Another quarter (24.35%) of the respondents were not sure whether they could use this feature, while half of the participants reported some disagreement (13.91%) or full disagreement (36.52%) about their ability to capture patients' blood type and write comments on the system.

In terms of the last patient registration feature, namely capturing comments on the image regarding the patient's condition, almost half (46.55%) of the respondents fully agreed that they were able to use this feature, while 12.93% of the respondents agreed to some extent and 8.62% were not sure whether they could use this feature. However, almost one third of the respondents indicated that they disagreed (10.34%) to some extent or fully disagreed (21.55%) that they could capture comments on the image regarding the patient's condition.

TABLE 4.6: Quantitative results for radiographers' ability to use the patient administration and registration features

| Feature Statement | Fully Agree | Agree to some extent | Not Sure | Disagree to some extent | Fully Disagree | Total |
|---|---|---|---|---|---|---|
| I can register patient information on the system (manually) | 112 (96.55%) | 3 (2.59%) | 0 (0.00%) | 1 (0.86%) | 0 (0.00%) | 116 |
| I can search for the patient on the system | 110 (94.83%) | 5 (4.31%) | 0 (0.00%) | 0 (0.00%) | 1 (0.86%) | 116 |
| I can check for the studies that are delivered (sent through for PACS/printing) | 105 (91.30%) | 7 (6.09%) | 3 (2.61%) | 0 (0.00%) | 0 (0.00%) | 115 |
| I can check for all patients examined from a specific imaging modality | 96 (82.76%) | 8 (6.90%) | 11 (9.48%) | 0 (0.00%) | 1 (0.86%) | 116 |
| I can check for patients examined today only | 76 (65.52%) | 7 (6.03%) | 0 (0.00%) | 8 (6.90%) | 25 (21.55%) | 116 |
| I can write patient comments | 73 (63.48%) | 13 (11.30%) | 17 (14.78%) | 2 (1.74%) | 10 (8.70%) | 115 |
| I can capture patient information (e.g. patient's history, height, weight, in/outpatient) | 67 (58.26%) | 15 (13.04%) | 13 (11.30%) | 8 (6.96%) | 12 (10.43%) | 115 |
| I can capture patient blood type and make comments | 17 (14.78%) | 12 (10.43%) | 28 (24.35%) | 16 (13.91%) | 42 (36.52%) | 115 |
| I can capture comments on the image about the patient's condition | 54 (46.55%) | 15 (12.93%) | 10 (8.62%) | 12 (10.34%) | 25 (21.55%) | 116 |

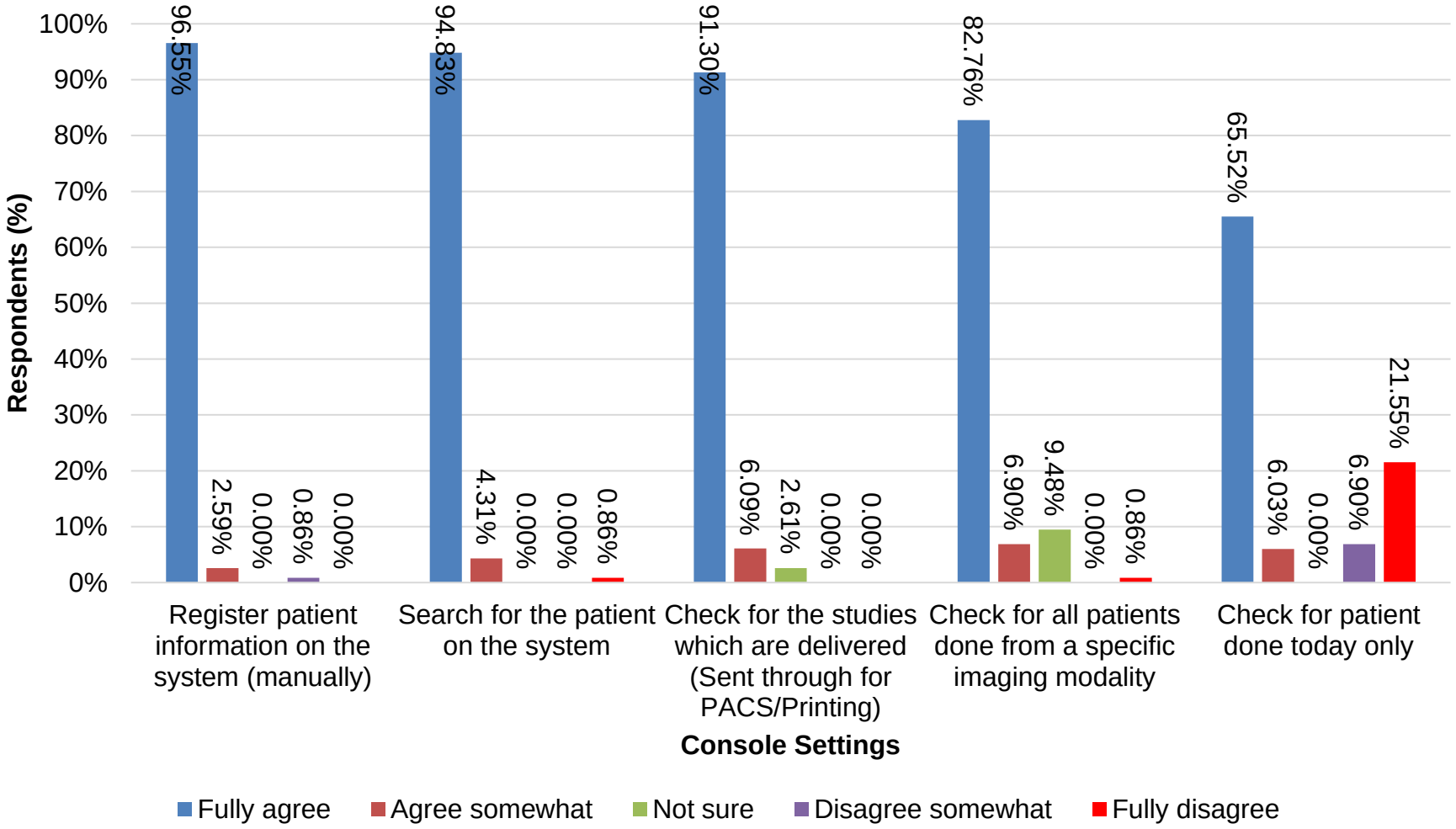



FIGURE 4.6A: Quantitative results for radiographers' ability to use the patient administration and registration features

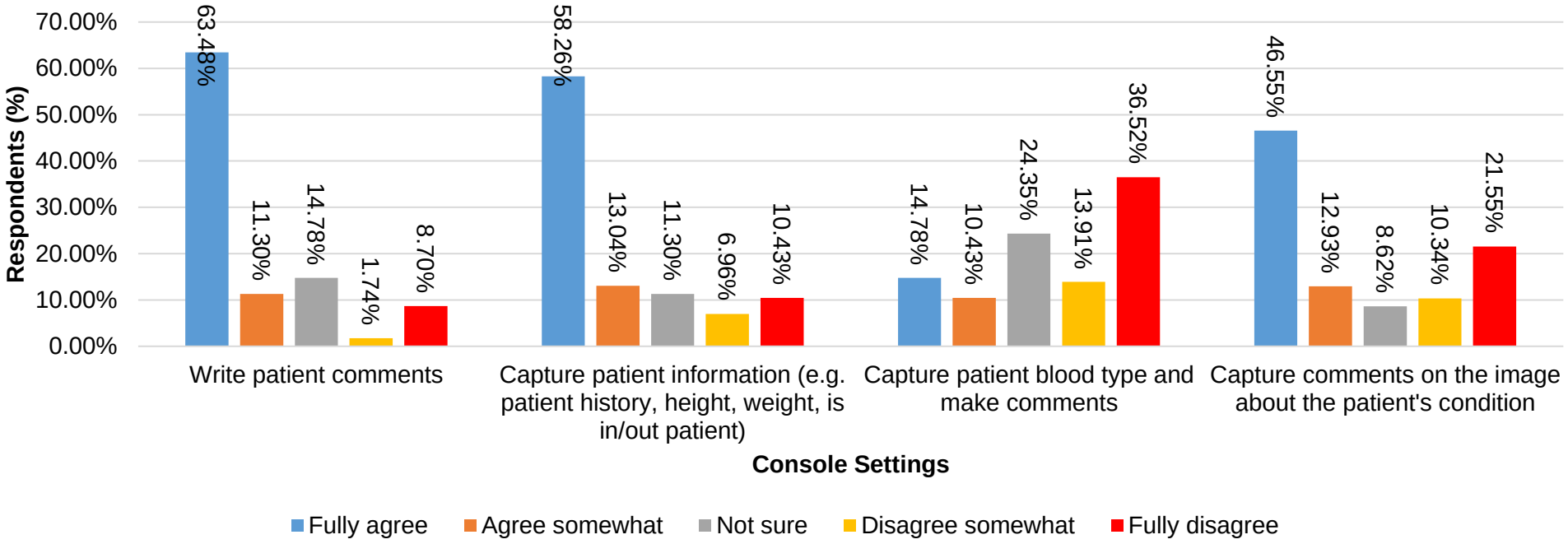



FIGURE 4.6B: Quantitative results for radiographers' ability to use the patient administration and registration features

### 4.2.7 Radiographic Image Post-processing Tool

Table 4.7 and Figure 4.7 present the quantitative results for radiographers' ability to use the radiographic image post-processing tool of the x-ray equipment's console or computer.

The following are the results of Table 4.7 and Figure 4.7A below. Only 98.28% of the respondents fully agreed that they could adjust brightness and contrast on a digital image. Respondents who may agreeing to some extent with the statement represented 0.86%, whereas no respondents indicated that they did not feel sure at all of their ability to adjust brightness and contrast on a digital image. With 98.28% fully agreeing on the utilisation of this feature, the results give the assurance that fewer images may be repeated because of photographic reasoning. A reduction in the repeat rate due to photographic properties equals a reduction in patient dose.

Fewer than 50% of the respondents fully agreed that they could change the EI. This group represented 48.28% of the respondents. Only 13.79% of the respondents agreed to some extent that they could change the EI of any given digital image, whereas 18.97% were not sure if they could change it. The last group is worrisome, since EI is primarily associated with radiation dose to the patient. The percentage that disagreed to some extent was 5.17%, whereas 13.79% of respondents fully disagreed that they could use this feature optimally.

The results of Table 4.7 and Figure 4.7A further highlight that 50.43% of the respondents fully agreed that they could interpret an EI of any given digital image.

According to the researcher, this finding is worrisome, since an EI indicates the extent of exposure received by the IR. Only 31.30% of the respondents agreed to some extent that they could interpret an EI of any given digital image, whereas 12.17% were not sure if they could interpret the EI of a digital image. Only 3.48% of the respondents disagreed to some extent that they might not be competent in interpreting an EI on a given DR image. Finally, 2.61% of the respondents fully disagreed that they were unable to interpret an EI of a DR image. The findings of this section may suggest high radiation risks to end-users of radiation, which are the patients.

The results of Table 4.7 and Figure 4.7A further indicate that 43.97% of the respondents fully agreed that they could check the exposure latitude on the monitor. This percentage is too low: below 50% of the total number of respondents. Only 21.55% of the respondents agreed to some extent that they could check an exposure latitude on a monitor, whereas 25.86% of the respondents were not sure if they could do this. The respondents who indicated that they disagreed to some extent were 5.17%, whereas those who fully disagreed represented 3.45%

Table 4.7 and Figure 4.7B highlight that 71.55% of the respondents fully agreed that they could use the post-processing tools to enhance image quality, especially edge enhancement, with 13.79% agreeing to some extent that they could use an edge enhancement tool. Furthermore, the results indicate that 11.21% of the respondents were not sure whether they could use an edge enhancement tool to enhance digital image quality. This significantly compromises imaging quality and exposure to patients, since it may result in repeat exposure. Only 1.72% of the respondents disagreed to some extent that they could use an edge enhancement tool to improve

digital image quality, whereas only 1.72% fully disagreed that they could use this post-processing tool.

The results of Table 4.7 and Figure 4.7B further elucidate that 98.28% of the respondents fully agreed that they could rotate a digital image on the monitor, with no uncertainty, and that 0.86% of the respondents indicated that they were not sure whether they could rotate the image or not. No one indicated a measure of disagreement, whereas 0.86% of the respondents indicated that they fully disagreed that they could use this DR tool.

The results further indicate that 98.28% of the respondents fully agreed that they were able to use the post-processing collimation tool, with zero comma eighty six in the category of agreeing to some extent. Only 0.86% of the respondents indicated that they were not sure whether they could use this tool. No respondents fell in the categories of disagreeing to some extent and fully disagreeing. These findings agree with the results of Phase 3 of the study, as this feature is classed as one of the commonly used features (see Section 4.3.1.2 c).

The results of Table 4.7 and Figure 4.7B further indicate that 79.13% of the respondents fully agreed that they added additional patient identification after image processing, with 12.17% agreeing to some extent on the ability to use this function, whereas 4.35% were not sure if they could add additional patient identification after image processing. Only 1.74 % of the respondents indicated they disagreed to some extent that they could use this DR tool, whereas those who fully disagreed represented

2.61% of the respondents. These findings do not put patients at risk, as they serve to give the radiologist additional information about the procedure used or about the patient.

According to the results of Table 4.7 and Figure 4.7B, 75% of the respondents fully agreed that they could switch the collimator shutters on and off. This is a significant advantage to clinical facilities involved in student training. Out of the total number of respondents, only 9.48% indicated that they agreed to some extent they could switch the collimator shutters on or off, whereas 9.48% of the respondents were not sure whether they could do this. Only 1.72% of the respondents indicated that they disagreed to some extent that they could switch the collimator shutters on or off, whereas 4.31% of the respondents indicated that they fully disagreed that they could do this.

Table 4.7 and Figure 4.7C highlight that 93.10% of the respondents fully agreed that they could use the magnification tool to enhance diagnosis, whereas only 5.17% of the respondents agreed to some extent that they could use this tool. In the category of ‘not sure’ the score was zero. Only 1.72% of the respondents indicated that they disagreed to some degree that they could use the magnification tool, whereas none disagreed fully. Only 33.04% of the respondents indicated that they fully agreed that they could use a look-up table to create a better image impression. This is in agreement with the findings of Phase 3 of the study (see Section 4.3.1.1 g). Only 19.13% of the respondents agreed to some extent that they could utilise this feature of DR, whereas 40% indicated that they were not sure if they could use a look-up table to create a better image impression. Only 0.87% of the respondents disagreed to some

extent that they could use this feature to create a better image impression and 6.96% of the respondents indicated that they fully disagreed: they could not utilise this feature of DR.

Table 4.7 and figure 4.7C further indicate that of the total number of respondents, only 30.97% fully agreed that they could access the image histogram. Only 13.27% of the respondents indicated that they agreed to some extent that they were able to access the image histogram and 46.90% indicated that they were not sure if they were able to access the image histogram. The high percentage of respondents who were not sure is significant, as the image histogram relates to the spread of exposures on the IR. Only 3.54% of the respondents disagreed to some extent that they knew how to access the image histogram, whereas 5.31% indicated that they fully disagreed that they could use this feature. Table 4.7 and Figure 4.7C further indicate that 21.24% of the participants fully agreed that they were able to interpret the image histogram, with 18.58% agreeing to some extent that they were able to interpret an image histogram.

The percentage of respondents indicating that they were not sure if they could interpret an image histogram was 46.90%. Only 5.31% of the respondents indicated that they disagreed to some extent and 7.96% of the respondents fully disagreed that they could interpret an image histogram of a digital image.

TABLE 4.7: Quantitative results for radiographers' ability to use the post-processing tools

| | Fully agree | Agree to some extent | Not sure | Disagree to some extent | Fully disagree | Total |
|---|---|---|---|---|---|---|
| Able to adjust brightness and contrast on an image (digital image) | 114 (98.28%) | 1 (0.86%) | 0 (0.00%) | 1 (0.86%) | 0 (0.00%) | 116 |
| Change the exposure index (S value/EI/IgM/REX) | 56 (48.28%) | 16 (13.79%) | 22 (18.97%) | 6 (5.17%) | 16 (13.79%) | 116 |
| Interpret an exposure index of any given digital image | 58 (50.43%) | 36 (31.30%) | 14 (12.17%) | 4 (3.48%) | 3 (2.61%) | 115 |
| Check the exposure latitude on the monitor | 51 (43.97%) | 25 (21.55%) | 30 (25.86%) | 6 (5.17%) | 4 (3.45%) | 116 |
| Enhance image quality by using edge enhancement | 83 (71.55%) | 16 (13.79%) | 13 (11.21%) | 2 (1.72%) | 2 (1.72%) | 116 |
| Rotate the digital image on the monitor | 114 (98.28%) | 0 (0.00%) | 1 (0.86%) | 0 (0.00%) | 1 (0.86%) | 116 |
| Crop the image (post-processing collimation) | 114 (98.28%) | 1 (0.86%) | 1 (0.86%) | 0 (0.00%) | 0 (0.00%) | 116 |
| Add patient identification after image processing | 91 (79.13%) | 14 (12.17%) | 5 (4.35%) | 2 (1.74%) | 3 (2.61%) | 115 |
| Switch the collimator shutters on or off | 87 (75.00%) | 11 (9.48%) | 11 (9.48%) | 2 (1.72%) | 5 (4.31%) | 116 |
| Magnify the image to enhance diagnosis (magnification tool and zoom technique) | 108 (93.10%) | 6 (5.17%) | 0 (0.00%) | 2 (1.72%) | 0 (0.00%) | 116 |
| Use look-up table to create a better image impression | 38 (33.04%) | 22 (19.13%) | 46 (40.00%) | 1 (0.87%) | 8 (6.96%) | 115 |
| Access the image histogram | 35 (30.97%) | 15 (13.27%) | 53 (46.90%) | 4 (3.54%) | 6 (5.31%) | 113 |
| Interpret the image histogram | 24 (21.24%) | 21 (18.58%) | 53 (46.90%) | 6 (5.31%) | 9 (7.96%) | 113 |

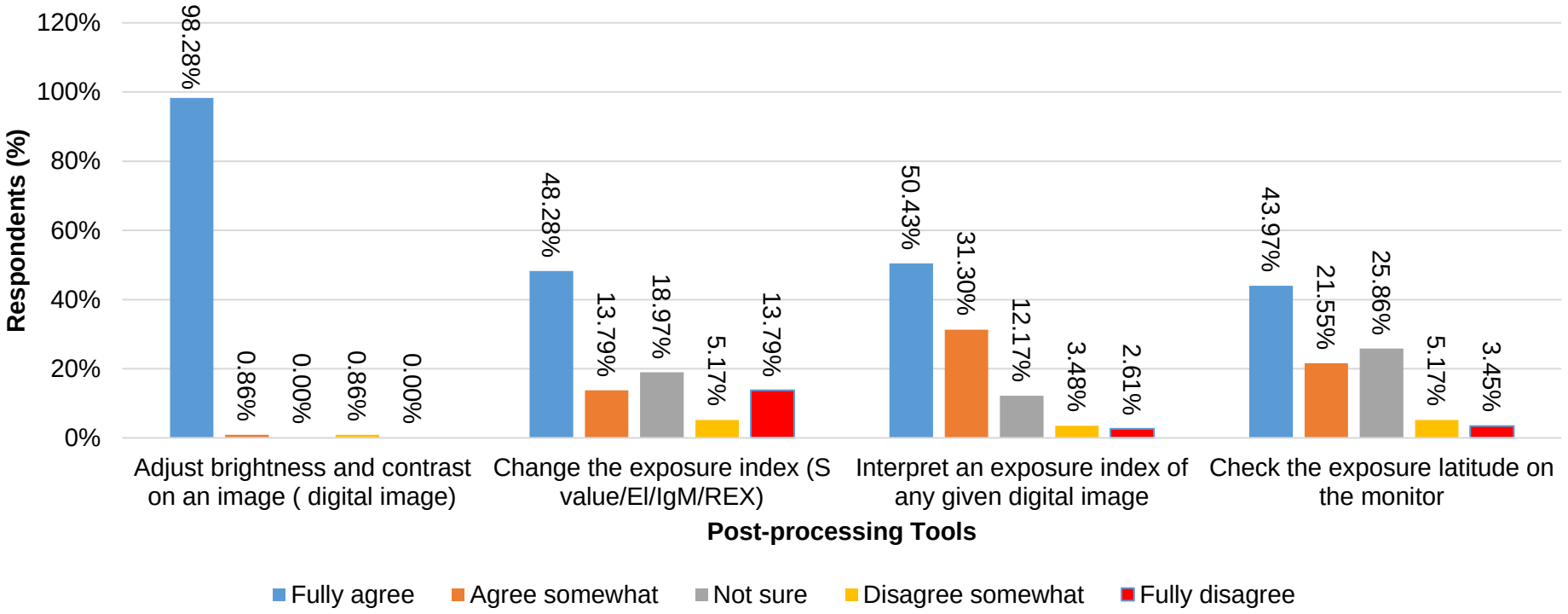



FIGURE 4.7A: Quantitative results for radiographers' ability to use the post-processing tools

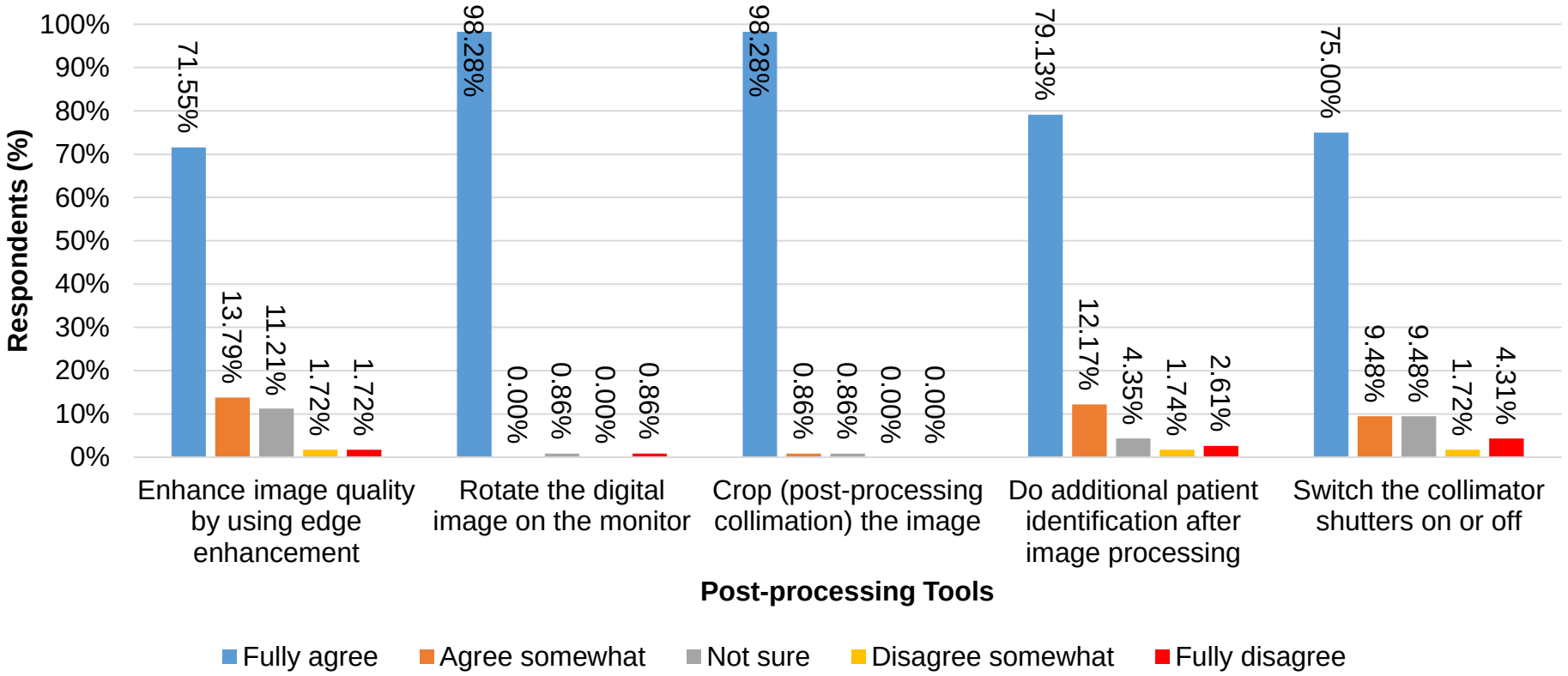



FIGURE 4.7B: Quantitative results for radiographers' ability to use the post-processing tools

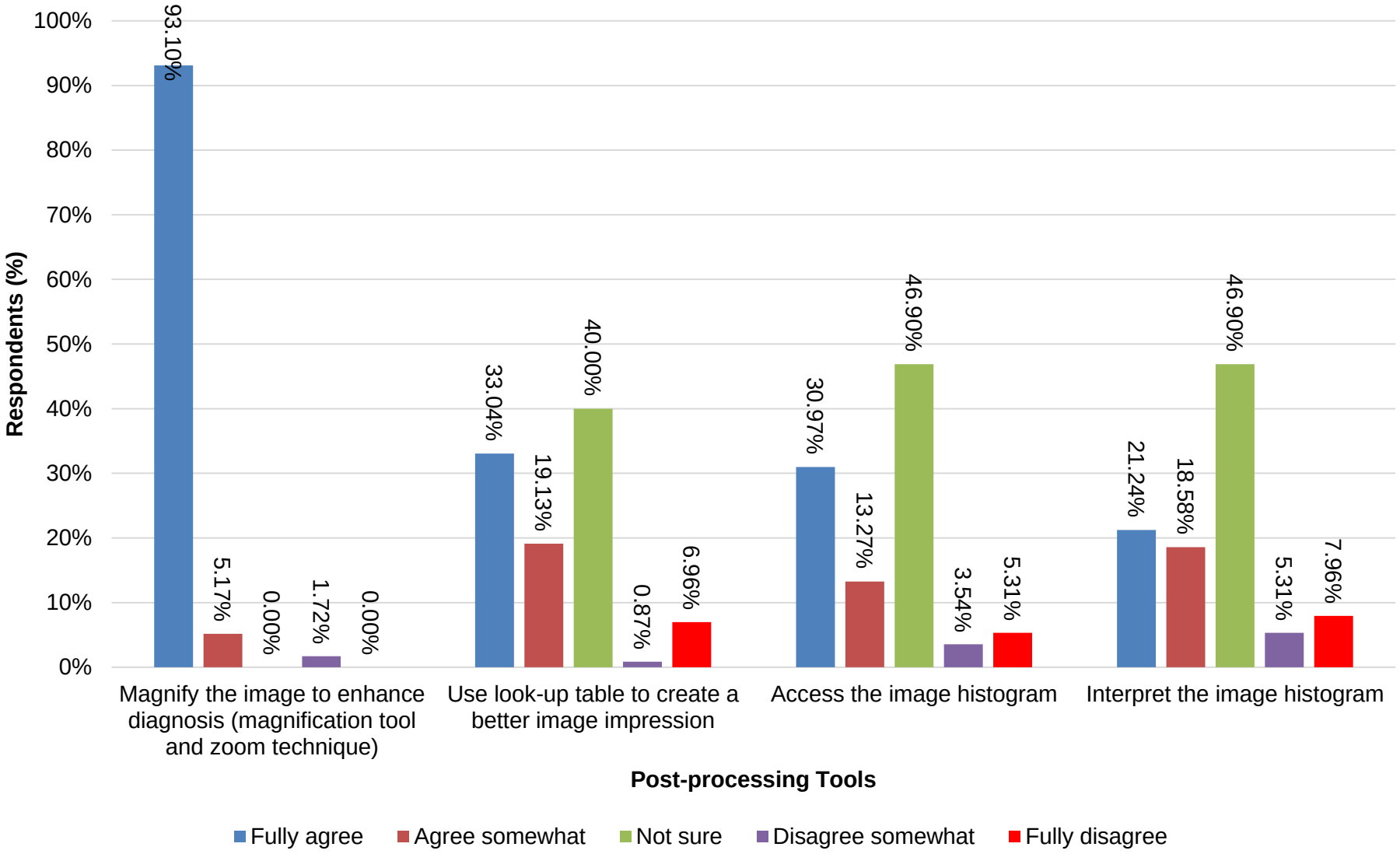



FIGURE 4.7C: Quantitative results for radiographers' ability to use the post-processing tools

### 4.2.8 Console Setting

Table 4.8, Figure 4.8A and Figure 4.8B (page 95 – 96) present the quantitative results for radiographers' ability to operate the console setting.

Table 4.8 and Figure 4.8A indicate that 62.93% of the respondents can set/adjust the time on the x-ray equipment console, with 9.48% of the respondents agreeing to some extent that they can set the time on a console. Only 16.38% of the respondents indicated that they were not sure if they could set or adjust the time setting on the console. Another 3.45% of the respondents indicated that they disagreed to some extent and only 7.76% fully disagreed that they could use the feature. According to the researcher, this feature is a medico-legal aspect of radiography and radiographers must therefore be familiar with its utilisation.

Table 4.8 and Figure 4.8A (page 87 – 90) further highlight that 28.45% of the respondents fully agreed that they could adjust the volume and tone of sound on the console, with only 13.79% indicating that they agreed to some extent. The category of "not sure" yielded the highest result on this theme, representing at least 39.66% of the respondents, whereas 3.45% indicated that they disagreed to some extent. The remaining 14.66% indicated that they fully disagreed that they could adjust the volume and tone of sound on the console of an x-ray equipment.

Only 20% of the respondents indicated that they fully agreed they could synchronise different messages with different light colours on the console, with only 13.91%

indicating they agreed to some extent on the utilisation of this feature of DR (Table 4.8 and Figure 4.8A). Just above 40% of the respondents indicated that they were not sure whether they could use this feature. Only 6.09% of the respondents indicated that they disagreed to some extent that they could use this feature, whereas the remaining 19.13% of the respondents fully disagreed that they could use this feature

Table 4.28 and Figure 4.8B indicate that 60.34% of the respondents fully agreed that they could programme specific exposure factors to demonstrate applicable radiographic anatomy, whereas 13.79% indicated they agreed to some extent that they could use the feature. Only 13.79 % of the respondents indicated they were not sure if they could programme specific exposure factors to demonstrate applicable radiographic anatomy, with 4.31% indicating they disagreed to some extent. The group that indicated that they fully disagreed on their ability to use this feature of DR represented 7.76% of the total.

Table 4.8 and Figure 4.8B further indicate that 51.72% of the respondents fully agreed that they could edit the pre-programmed procedure(s) on the console of a DR imaging system. Only 13.79% of the respondents indicated they agreed to some extent about their abilities to use this feature of DR. In the category of “not sure”, only 14.66% of the respondents indicated they were not sure if they could edit the pre-programmed procedure(s). Moreover, 8.62% indicated they disagreed to some extent that they could use this feature of DR and finally, 11.21% of the respondents indicated that they fully disagreed that they could use this feature.

The results presented in Table 4.8 and Figure 4.8B further indicate that 51.33% of the respondents fully agreed that they could add a new procedure on the system and

10.62% of the respondents agreed to some extent that they could use this feature. Only 16.81% indicated that they were not sure if they could use this feature, whereas 8.85% indicated they disagreed to some extent that they could use this feature. Moreover, 12.39% of the respondents indicated that they fully disagreed that they were able to use this feature.

### 4.2.9 Quality Control

Table 4.9 and Figure 4.9 present the quantitative results for radiographers' ability to utilise the QC utility.

Table 4.9 and Figure 4.9 indicate that 56.90% of the respondents indicated that they fully agreed that they could access the reject image/film analysis (RFA) menu on the system, whereas only 13.79% of the respondents indicated they agreed to some extent that they could use this feature. Only 12.07% of the respondents indicated that they were not sure whether they could access the RFA menu on the system. Only 3.45% indicated they disagreed to some extent that they could use this DR feature, whereas 13.79% indicated that they fully disagreed that they could access the RFA menu on the system. Table 4.9 and Figure 4.9 further indicate that 43.10% of the respondents fully agreed that they could set radiographers' names against each repeated image, with only 11.21% agreeing to some extent that they could use this DR feature. Only 25% of the respondents indicated they were not sure if they could set a radiographer's name against the rejected image. The response of 4,31% of the respondents was that they disagreed to some extent that they could use this tool and 16.38% indicated that they fully disagreed that they could use this feature.

TABLE 4.8: Quantitative results for radiographers' ability to operate the console setting

| | Fully agree | Agree to some extent | Not sure | Disagree to some extent | Fully disagree | Total |
|---|---|---|---|---|---|---|
| Set/adjust time on the console | 73 (62.93%) | 11 (9.48%) | 19 (16.38%) | 4 (3.45%) | 9 (7.76%) | 116 |
| Adjust the volume and tone of sound on the console | 33 (28.45%) | 16 (13.79%) | 46 (39.66%) | 4 (3.45%) | 17 (14.66%) | 116 |
| Synchronise different messages with different light colours (e.g. error message with a flashing red light) | 23 (20.00%) | 16 (13.91%) | 47 (40.87%) | 7 (6.09%) | 12 (19.13%) | 115 |
| Programme specific exposure factors for demonstrating applicable radiographic anatomy | 70 (60.34%) | 16 (13.79%) | 16 (13.79%) | 5 (4.31%) | 9 (7.76%) | 116 |
| Edit the pre-programmed procedure (s) | 60 (51.72%) | 16 (13.79%) | 17 (14.66%) | 10 (8.62%) | 13 (11.21%) | 116 |
| Add a new procedure on the system | 58 (51.33%) | 12 (10.62%) | 19 (16.81%) | 10 (8.85%) | 14 (12.39%) | 113 |

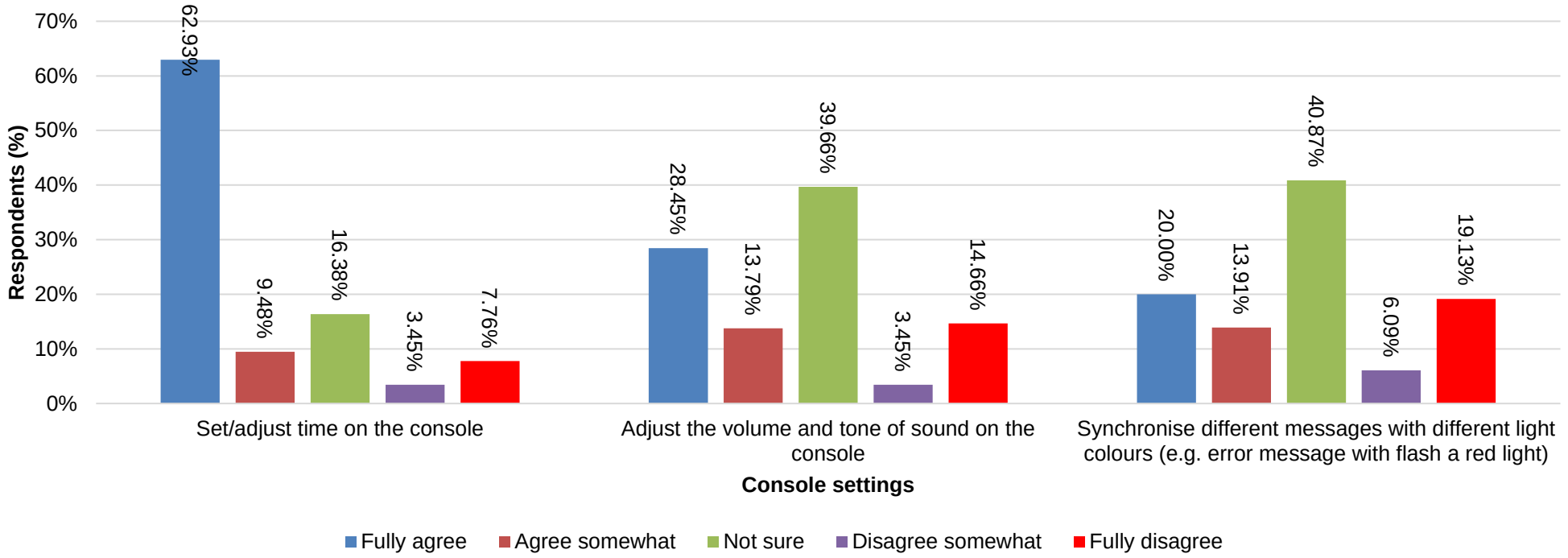



FIGURE 4.8A: Quantitative results for radiographers' ability to operate the console setting

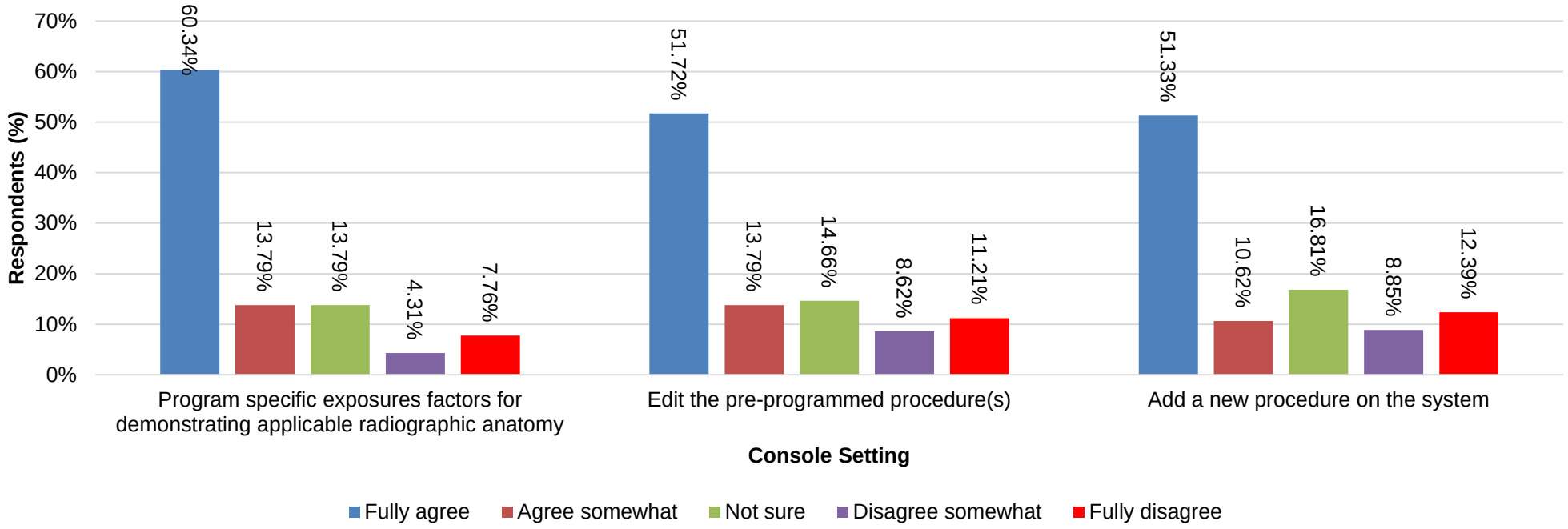



FIGURE 4.8B: Quantitative results for radiographers' ability to operate the console setting

Table 4.9 and Figure 4.9 further indicate that 19.30% of the respondents fully agreed that they could set the RFA threshold on the system, whereas only 13.16% agreed to some extent that they could do it. The response of 43,86% of the respondents indicated that they were not sure if they could set the RFA threshold on the system. Only 6.14% of the respondents indicated that they disagreed to some extent on their ability to use this feature, whereas 17.54% of the respondents fully disagreed that they could utilise this feature.

Table 4.9 and Figure 4.9 indicate that 17.39% of the respondents fully agreed that they could set destinations and passwords for rejected images. Only 18.26% of the respondents indicated they agreed to some extent that they could set destinations and passwords for rejected images. These percentages are insufficient, taking into consideration that radiography (D) uses radiation to produce images. QC parameter scores this low this may suggest that patients are being subjected to excessive unnecessary radiation.

Only 33.91% of the respondents indicated that they were not sure if they could set destinations and passwords for rejected images, with only 6.96% indicating they disagreed to some extent about their ability to set destinations and passwords for rejected images. Only 23.48% of the respondents indicated that they fully disagreed that they could set the destination and passwords for rejected images.

Table 4.9 and Figure 4.9 further indicate that 30.70% of the respondents fully agreed that they could calculate RFA over a specified period of time and only 15.79% indicated that they agreed to some extent that they could use this feature of DR. Only

29.82% of the respondents indicated that they were not sure if they could calculate RFA over a specified period.

Only 3.51% of the respondents indicated that they disagreed to some extent that they could calculate RFA over a specified period, whereas 20.18% of the respondents indicated that they fully disagreed that they could use this feature of DR.

### 4.2.10 Digital Radiography Artefacts

Table 4.10 and Figure 4.10 below present the quantitative results for radiographers' knowledge of DR artefacts.

Table 4.10 and Figure 4.10 indicate that 82.61% of the respondents fully agreed that they could identify artefacts on a digital image, whereas 11.30% agreed to some extent that they could identify artefacts on a digital image. Only 3.48% were not sure if they could identify artefacts on a digital image, whereas 1.74% disagreed to some extent that they could identify digital image artefacts. Those who fully disagreed represented 0.87% of the respondents.

The results further indicate that 58.77% fully agreed that they could classify digital artefacts into the three broad categories of digital artefacts, with only 22.81% agreeing to some extent that they could do this. Only 10.53% indicated that they were not sure if they could classify the digital image artefacts into different categories. Those who disagreed to some extent that they could classify digital image artefacts represented

1,75% of the participants, whereas only 6.14% indicated they fully disagreed that they could classify digital artefacts.

TABLE 4.9: Quantitative results for radiographers' ability to utilise QC utility

| | Fully agree | Agree to some extent | Not sure | Disagree to some extent | Fully disagree | Total |
|---|---|---|---|---|---|---|
| I can access the RFA menu on the system | 66 (56.90%) | 16 (13.79%) | 14 (12.07%) | 4 (3.45%) | 16 (13.79%) | 116 |
| I can set radiographers' names against each rejected image | 50 (43.10%) | 13 (11.21%) | 29 (25.00%) | 5 (4.31%) | 19 (16.38%) | 116 |
| I can set the RFA threshold on the system | 22 (19.30%) | 15 (13.16%) | 50 (43.86%) | 7 (6.14%) | 20 (17.54%) | 114 |
| I can set destinations and passwords for rejected images | 20 (17.39%) | 21 (18.26%) | 39 (33.91%) | 8 (6.96%) | 27 (23.48%) | 115 |
| I can calculate RFA over a specified period of time | 35 (30.70%) | 18 (15.79%) | 34 (29.82%) | 4 (3.51%) | 23 (20.18%) | 114 |

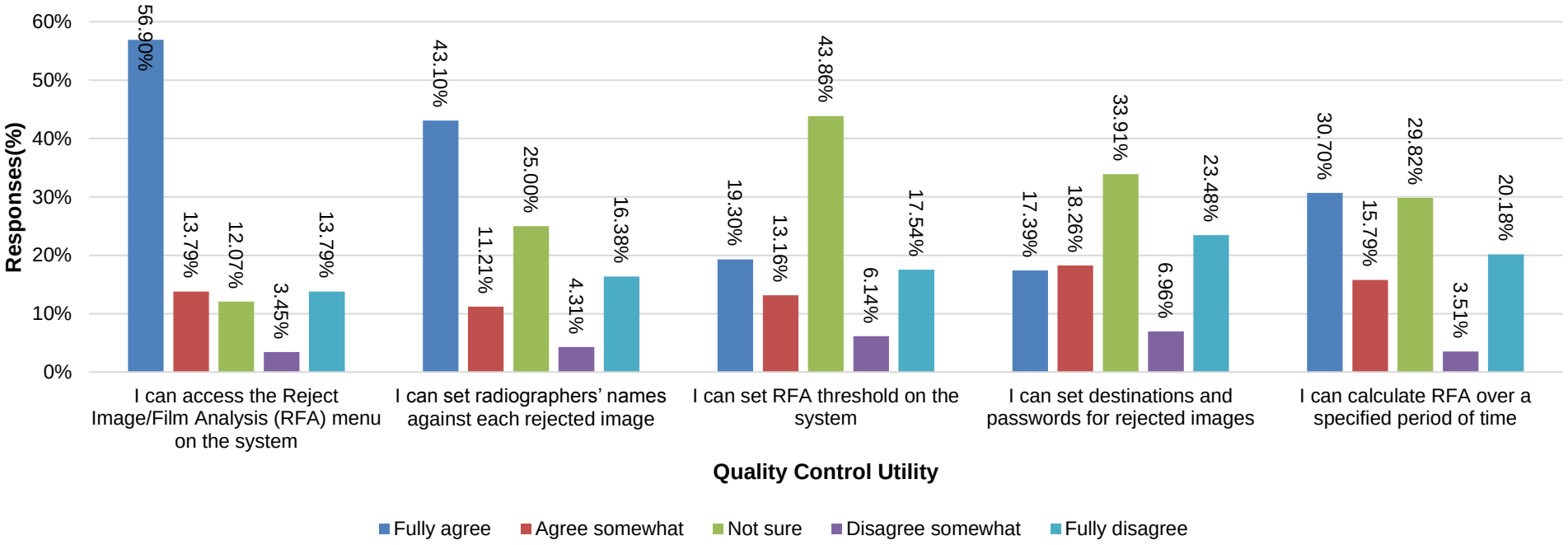



FIGURE 4.9: Quantitative results for radiographers' ability to use QC utility

Table 4.10 and Figure 4.10 further highlight that 43.86% of the respondents indicated that they fully agreed that they could identify the cause(s) of digital image artefacts, whereas 33.33% of the respondents indicated that they agreed to some extent that they could identify the cause(s) of digital artefacts. Only 14.04% indicated that they were not sure if they could identify the causes of digital artefacts. Moreover, 3.51% of the respondents disagreed to some extent that they could identify the causes(s) of the digital artefacts, whereas 5.26% of the respondents indicated that they fully disagreed that they could identify the cause(s) of digital artefacts.

### 4.2.11 Computer and Information Technology

Table 4.11, Figure 4.11A and Figure 4.11B present the quantitative results for radiographers' knowledge and utilisation of computers and IT.

Table 4.11 and Figure 4.11A indicate that 61.21% of the respondents fully agreed that they could operate the hardware of the computer, whereas 18.97% indicated that they could operate the hardware of the computer to some extent. Only 8.62% of the respondents were not sure if they could operate the hardware of the computer, whereas 4.31% indicated that they disagreed to some extent that they could operate the hardware of a computer. Another 6.90% indicated that they fully disagreed that they could operate the hardware of the computer.

TABLE 4.10: Quantitative results for radiographers' knowledge of DR artefacts

| | Fully agree | Agree to some extent | Not sure | Disagree to some extent | Fully disagree | Total |
|---|---|---|---|---|---|---|
| Identify if a digital image has an artefact | 95 (82.61%) | 13 (11.30%) | 4 (3.48%) | 2 (1.74%) | 1 (0.87%) | 115 |
| Classify digital artefacts into the following categories (Software artefacts, IR artefacts and object artefacts) | 67 (58.77%) | 26 (22.81%) | 12 (10.53%) | 2 (1.75%) | 7 (6.14%) | 114 |
| Identify the cause(s) of the artefacts | 50 (43.86%) | 38 (33.33%) | 16 (14.04%) | 4 (3.51%) | 6 (5.26%) | 114 |

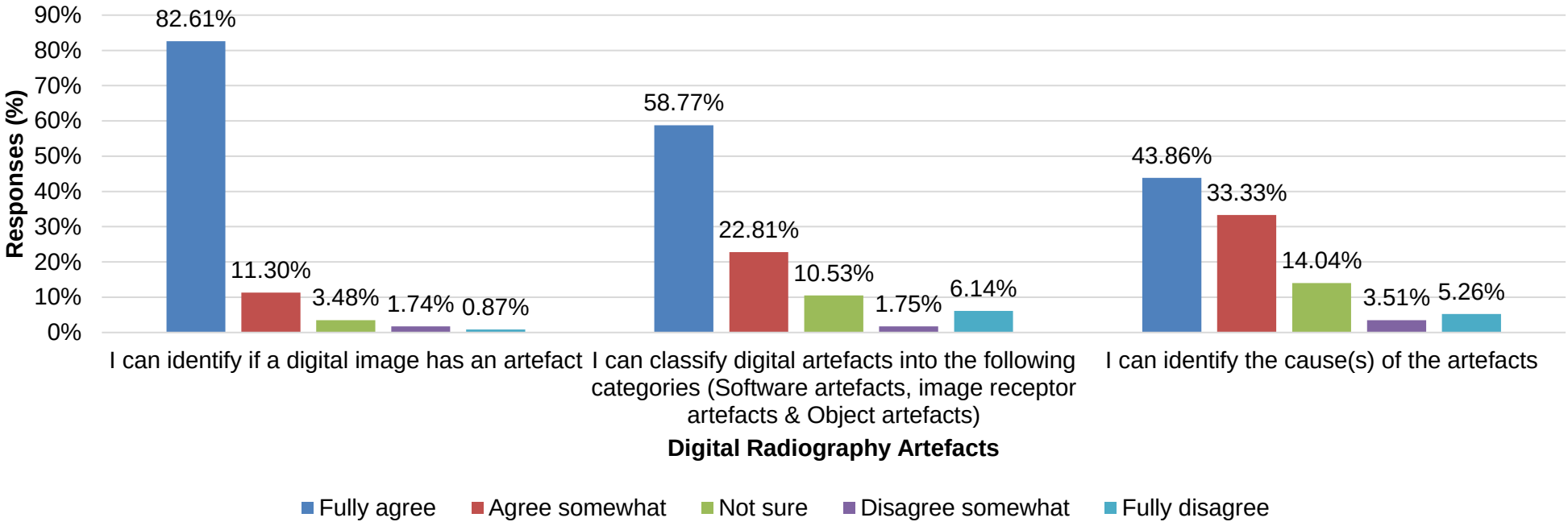



FIGURE 4.10: Quantitative results for radiographers' knowledge of DR artefacts

Table 4.11 and Figure 4.11 A indicate that 55.65% of the respondents fully agreed that they could operate the software of the computer, whereas 32.17% of the respondents indicated that they agreed to some extent that they could operate the software of the computer. Only 7.83% of the respondents indicated that they were not sure if they could operate the software of the computer, whereas 0.87% indicated that they disagreed to some extent that they could operate the software of the computer. Another 3.48% indicated that they fully disagreed that they could use the software of the computer.

The results highlight that 46.09% of the respondents fully agreed that they could identify the type of network used in various radiographic practices, whereas 26.09% indicated that they agreed to some extent that they could identify the type of network used in a clinical facility. Only 14.78% of the respondents indicated that they were not sure if they could identify the type of network used in any radiographic practice, whereas 2.61% indicated that they disagreed to some extent that they could identify the type of network used in any given clinical practice. Only 10.43% of the respondents indicated that they fully disagreed that they could identify the type of network used in the clinical practice.

The results in Table 4.11 and Figure 4.11A highlight that 57.76% of the respondents fully agreed that they could identify the communication protocol used in their practices, whereas 19.83% indicated they agreed to some extent that they could identify the communication protocol used in their clinical practices. Only 10.34% of the respondents indicated that they were not sure if they could identify the communication protocol in their clinical practices, whereas 3.45% indicated that they disagreed to some extent that they could identify the communication protocol used in their clinical practice. Only 8.62%

indicated that they fully disagreed that they could identify the communication protocol used in their clinical practice.

Figure 4.11A further indicates that 65.52% of the respondents fully agreed that they could register the patient on PACS, whereas only 10.34% indicated that they agreed to some extent that they were able to use this feature of DR. Only 13.79% of the respondents indicated that they were not sure if they could register the patient on PACS. Those who indicated that they disagreed to some extent that they could register the patient on PCAS made up 59% of the respondents, whereas 7.76% indicated they fully disagreed that they could register the patient on PACS.

Table 4.11 and Figure 4.11B indicate that 46.55% of the respondents fully agreed that they could access and identify codes/tags of digital images, whereas 11.21% indicated that they agreed to some extent that they could use this feature. Another 24.14% of the respondents indicated that they were not sure if they could access and identify codes/tags for digital images in PACS. Only 3.45% of the respondents indicated that they disagreed to some extent that they could access PACS to identify codes/tags on digital images, whereas 14.66% indicated they fully disagreed.

The results indicate that 59.13% of the respondents fully agreed that they could post-process digital images on PACS, whereas 15.65% indicated they agreed to some extent that they could post-process images on PACS. Only 10.43% of respondents indicated they were not sure if they could post-process images on PACS. Another 0.87% agreed to some extent that they could post-process images on PACS, whereas 13.91% indicated that they full disagreed that they could do this.

Table 4.11 and Figure 4.11B indicate that 72.17% of the respondents fully agreed that they could archive images on PACS, whereas 11.30% indicated that they agreed to some extent that they could archive images on PACS. Only 8.70% of the respondents indicated they were not sure if they could archive images on PACS. Another 0.87% of the respondents indicated that they disagreed to some extent that they could archive images on PACS, whereas 6.96% indicated that they fully disagreed that they could archive images on PACS.

The results indicate that 74.78% of the respondents fully agreed that they could store images on PACS, whereas 9.57% disagreed to some extent that they could store images on PACS. Only 6.96% indicated they were not sure if they could store images on PACS, whereas 0.87% disagreed to some extent that they could do this. Another 7.83% indicated that they fully disagreed that they could store images on PACS.

Table 4.11 and Figure 4.11B indicate that 57.76% of the respondents fully agreed that they could distribute images to linked users, whereas 12.93% agreed to some extent that they could do this. Only 18.97% of the respondents indicated they were not sure if they could distribute images to linked users. Another 0.86% of the respondents indicated they disagreed to some extent that they could distribute images to linked users, whereas 9.48% indicated they fully disagreed that they could do this.

TABLE 4.11: Quantitative results for radiographers' knowledge and utilisation of computers and IT

| | Fully agree | Agree to some extent | Not sure | Disagree to some extent | Fully disagree | Total |
|---|---|---|---|---|---|---|
| I can operate the hardware of the computer | 71 (61.21%) | 22 (18.97%) | 10 (8.62%) | 5 (4.31%) | 8 (6.90%) | 116 |
| I can operate the software of the computer | 64 (55.65%) | 37 (32.17%) | 9 (7.83%) | 1 (0.87%) | 4 (3.48%) | 115 |
| I can identify the type of network used in my radiographic practice (LAN/MAN/WAN) | 53 (46.09%) | 30 (26.09%) | 17 (14.78%) | 3 (2.61%) | 12 (10.43%) | 115 |
| I can identify the communication protocol used in my radiographic practice (HL7/DICOM) | 67 (57.76%) | 23 (19.83%) | 12 (10.34%) | 4 (3.45%) | 10 (8.62%) | 116 |
| I can register the patient on PACS | 76 (65.52%) | 12 (10.34%) | 16 (13.79%) | 3 (2.59%) | 9 (7.76%) | 116 |
| I can access and identify codes/tags for each image | 54 (46.55%) | 13 (11.21%) | 28 (24.14%) | 4 (3.45%) | 17 (14.66%) | 116 |
| I can post-process the image on the PACS monitor | 68 (59.13%) | 18 (15.65%) | 12 (10.43%) | 1 (0.87%) | 16 (13.91%) | 115 |
| I can archive images on PACS | 83 (72.17%) | 13 (11.30%) | 10 (8.70%) | 1 (0.87%) | 8 (6.96%) | 115 |
| I can store images on PACS | 86 (74.78%) | 11 (9.57%) | 8 (6.96%) | 1 (0.87%) | 9 (7.83%) | 115 |
| I can distribute images to linked users | 67 (57.76%) | 15 (12.93%) | 22 (18.97%) | 1 (0.86%) | 11 (9.48%) | 116 |

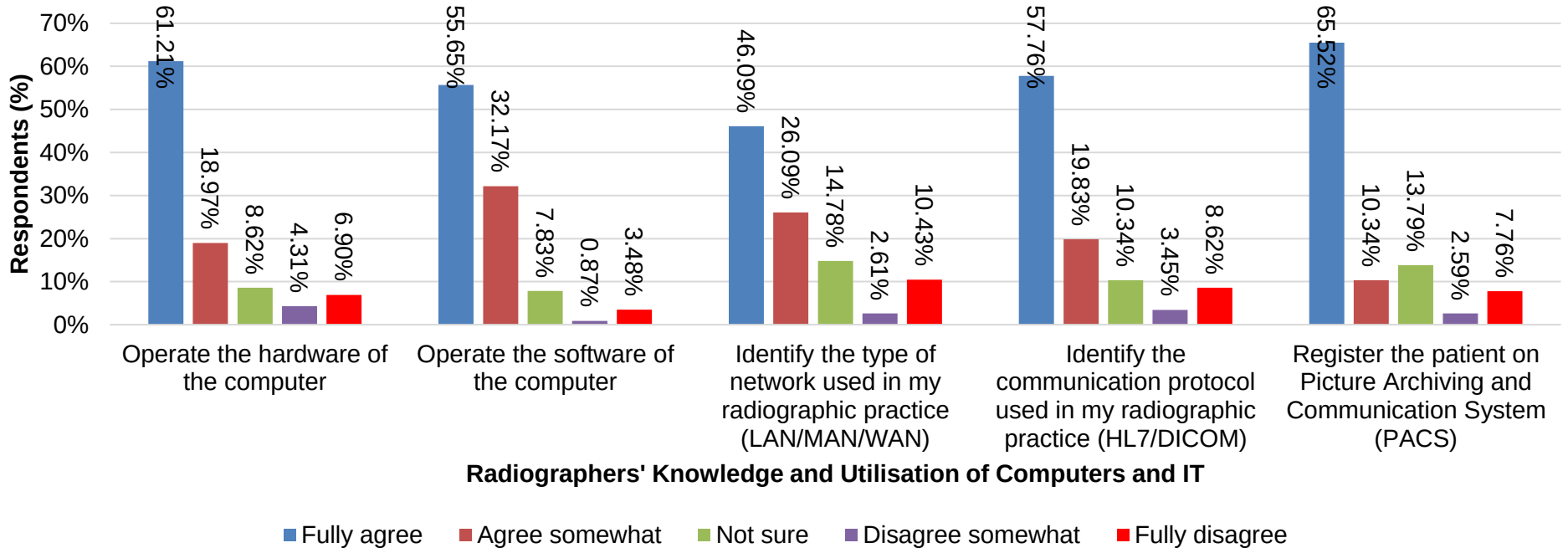



FIGURE 4.11 A: Quantitative results for radiographers' knowledge and utilisation of computers and IT

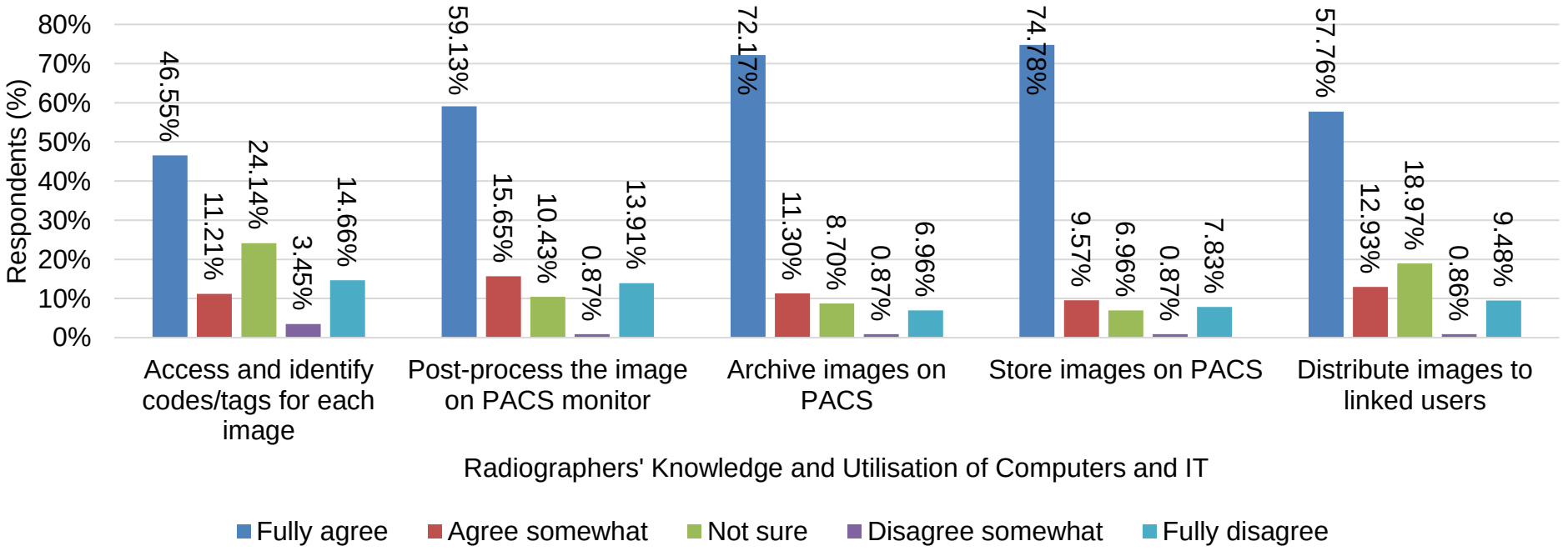



FIGURE 4.11B: Quantitative results for radiographers' knowledge and utilisation of computers and IT

### 4.2.12 Most Recent Digital Radiography Training

Table 4.12 and Figure 4.12 present the quantitative results for the most recent DR training attended by radiographers

TABLE 4.12: Quantitative results for the most recent DR training attended by radiographers

| How Long Ago Did You Attend DR Training | Responses (n=97) | % of Responses |
|---|---|---|
| Never | 37 | 38.14% |
| 1 year ago | 19 | 19.59% |
| 2-3 years ago | 9 | 9.28% |
| More than 3 years ago | 32 | 32.99% |

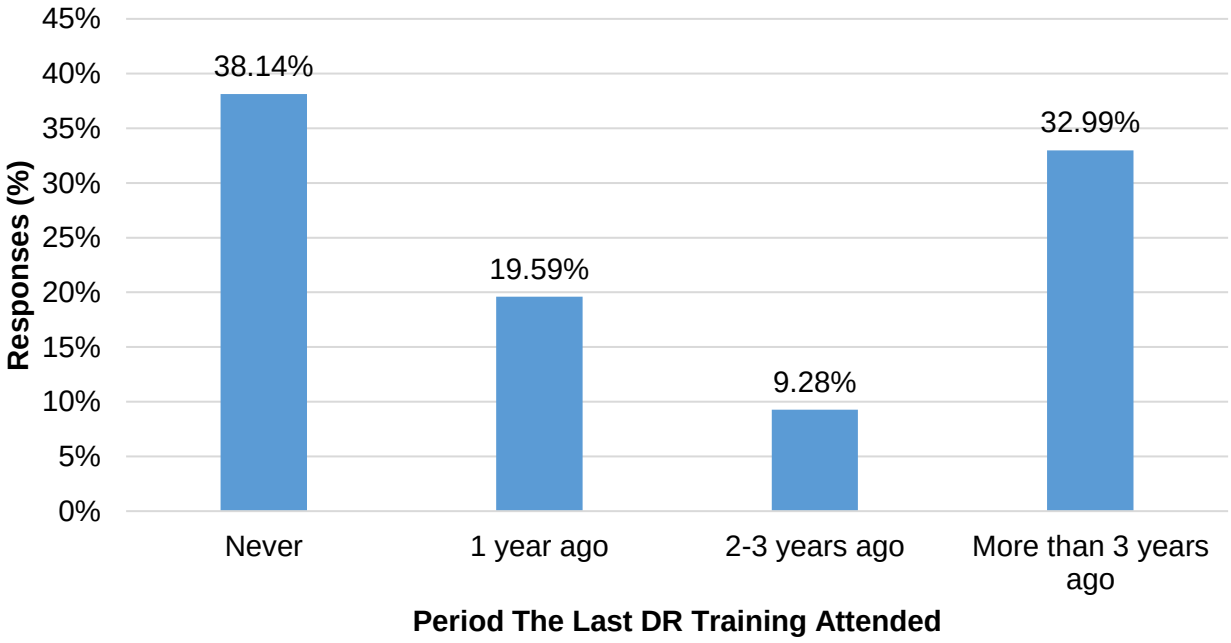



FIGURE 4.12: Quantitative results for most recent DR training attended by radiographers

Table 4.12 and Figure 4.12 above indicate that 38.14% of the respondents never attended DR training, whereas 19.59% of respondents indicated that they last attended a DR training session a year previously. Only 9.28% of the respondents indicated that they last attended a DR training in the past two to three years, whereas 32.99% of the respondents indicated that they last attended DR training more than three years previously. It is worth noting that the highest percentage indicated in this section was for those who had never attended a DR training session at all.

### 4.2.13 Extent to which Manufacturer-based Training Prepares Radiographers to Utilise the Features of Digital Radiography

Table 4.13 and Figure 4.13 present the quantitative results for the extent to which manufacturer-based training prepares radiographers to utilise the features of DR.

TABLE 4.13: Quantitative results for the extent to which manufacturer-based training prepares radiographers to utilise the features of DR

| Extent to which Manufacturer-based Training in DR Prepares Radiographers | Responses (n=71) | % of Responses |
|---|---|---|
| Fully prepare | 10 | 14.08% |
| Moderate | 56 | 78.87% |
| Does not prepare | 5 | 7.04% |

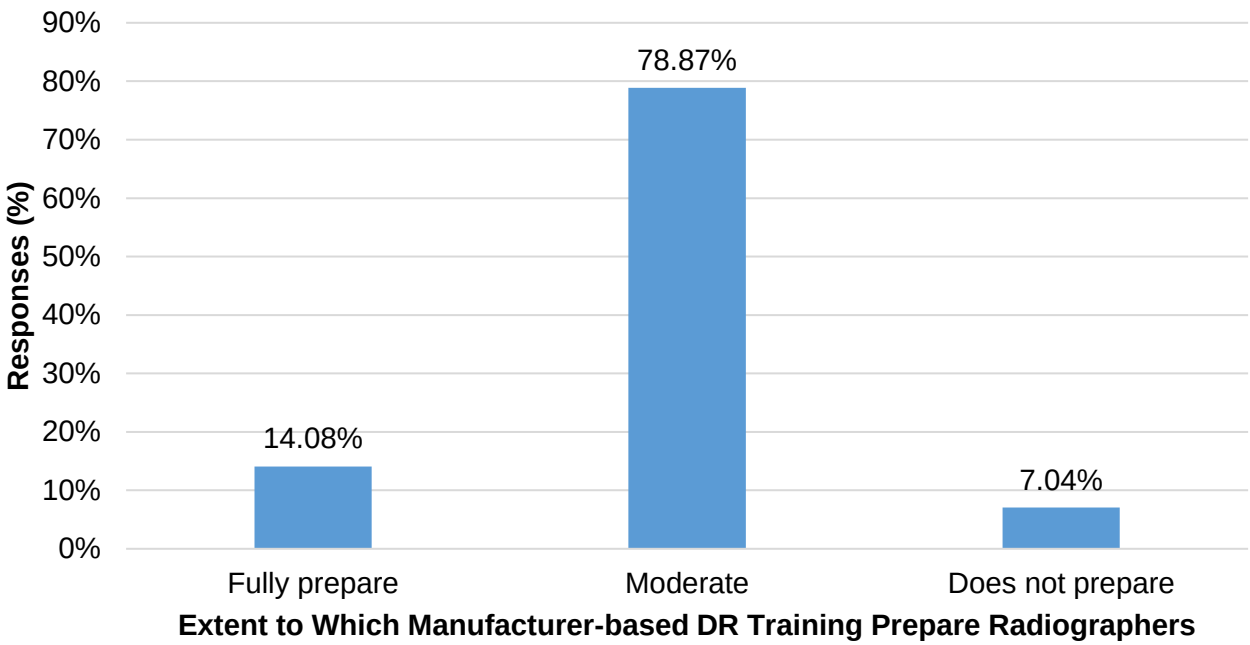



FIGURE 4.13: Quantitative results for the extent to which manufacturer-based training prepares radiographers to utilise the features of DR

Table 4.13 and Figure 4.13 above indicate that 78.87% of radiographers who participated in this study think that manufacturer-based training moderately prepares radiographers to utilise the features of DR. It is further indicated in Table 4.13 that 14.08% of the respondents think that manufacturer-based training fully prepares radiographers to utilise the features of DR, whereas 7.04% indicate that manufacturer-based training does not prepare the radiographers to utilise the features of DR optimally.

### 4.2.14 Digital Radiography Courses Attended

Table 4.14 and Figure 4.14 present the quantitative results for the number of DR courses attended by radiographers.

TABLE 4.14: Quantitative results for number of DR courses attended by radiographers.

| Number of DR Courses Attended | Responses (n=67) | % of Responses |
|---|---|---|
| Only 1 | 49 | 73.13% |
| 2 | 10 | 14.93% |
| 3 and more | 8 | 11.94% |

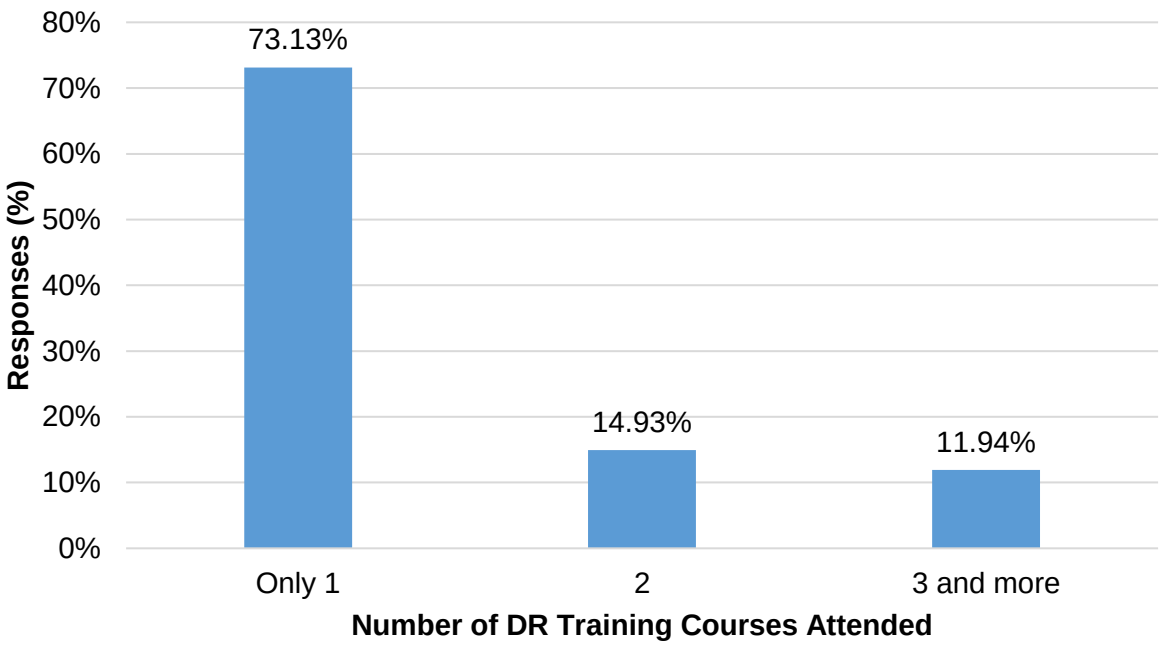



FIGURE 4.14: Quantitative results for number of DR courses attended by radiographers.

Table 4.14 and Figure 4.14 above indicate that 73.13% of the respondents attended only one course on DR training, whereas 14.93% of the respondents indicated that they had attended at least two DR training courses. Only 11.94% of the respondents indicated that they had attended three or more DR training courses.

### 4.2.15 Assessment Method Used after DR Training

Table 4.15 and Figure 4.15 present the quantitative results for the assessment method used to check radiographers' level of competency after completing the DR training course.

TABLE 4.15: Quantitative results for the assessment method used to check radiographers' level of competency

| Assessment Method Used | Responses (n=69) | % of Responses |
|---|---|---|
| None | 39 | 56.56% |
| Practical | 29 | 42.03% |
| Written test | 1 | 1.45% |

Table 4.15 and Figure 4.15 above indicate that 56.56% of the respondents did not undergo any form of assessment after training, whereas 42.03% of the respondents indicated that assessment in the form of a practical test was done. Only 1.45% of the respondents indicated that they completed a written test after the training.

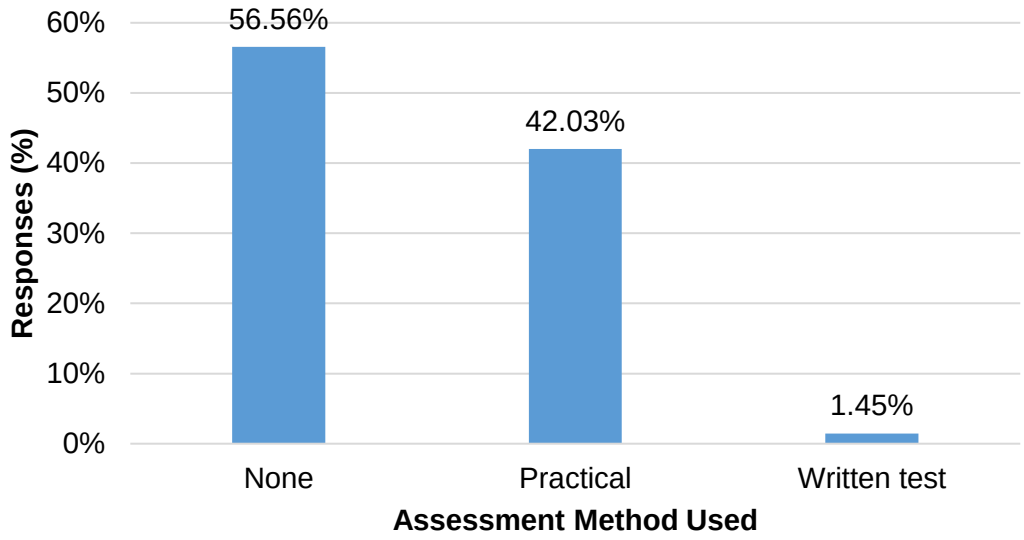



FIGURE 4.15: Quantitative results for the assessment method used to check radiographers' level of competency

### 4.2.16 Duration of Digital Radiography Training Course

Table 4.16 and Figure 4.16 present the quantitative results for the duration of the DR training course.

TABLE 4.16: Quantitative results for the duration of the DR training course.

| Duration of DR Course | Responses (n=69) | % of Responses |
|---|---|---|
| Less than 8 hours | 32 | 46.38% |
| 1 full day | 18 | 26.09% |
| 2 full days | 11 | 15.94% |
| 3 days and more | 8 | 11.59% |

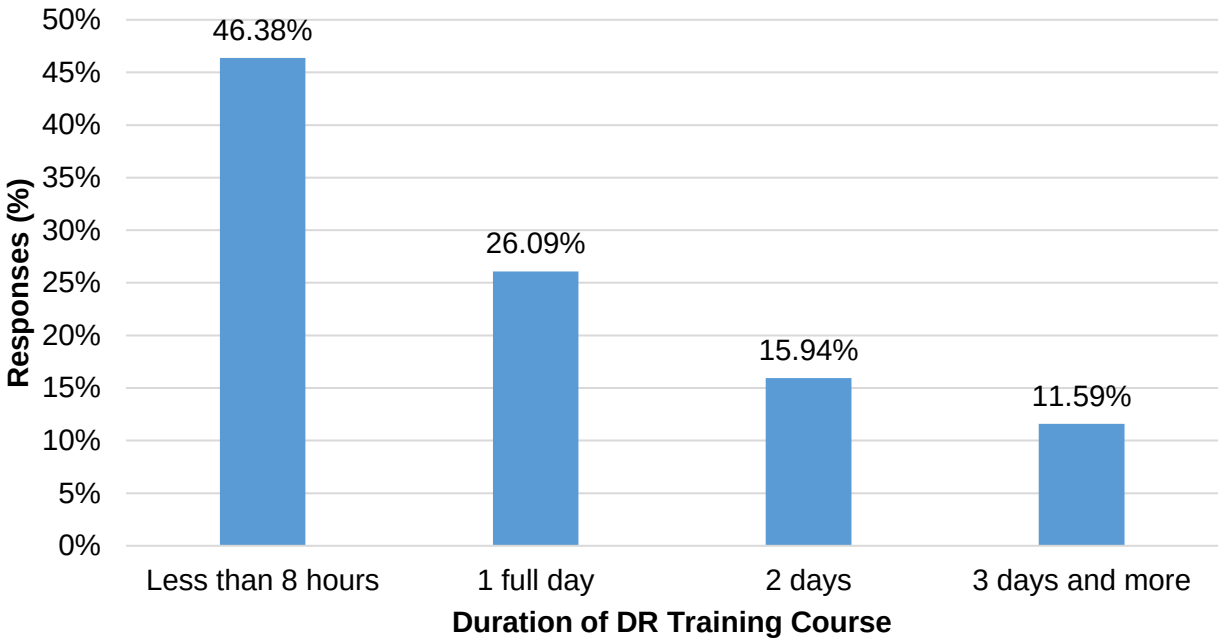



FIGURE 4.16: Quantitative results for duration of DR training course.

Table 4.16 and Figure 4.16 above indicate that 46.38% of the respondents attended a DR course that was presented in less than eight hours, whereas 26.09% of the respondents attended a DR course that took one full day. Only 15.94% of the respondents attended a DR course that took two days, whereas 11.59% of the respondents attended a DR course that took three days and more.

### 4.2.17 Tertiary Institutions' Training of Radiographers on Digital Radiography

Table 4.17 and Figure 4.17 present the quantitative results for perceptions of radiographers of the DR training offered by tertiary institutions.

TABLE 4.17: Quantitative results for perceptions of radiographers of the DR training offered by tertiary institutions

| Tertiary Institutions Offer Adequate DR Training to Radiographers (D) | Responses (n=116) | % of Responses |
|---|---|---|
| Fully agree | 15 | 12.39% |
| Agree to some extent | 39 | 33.62% |
| Not sure | 24 | 20.69% |
| Disagree to some extent | 21 | 18.10% |
| Fully disagree | 27 | 14.66% |

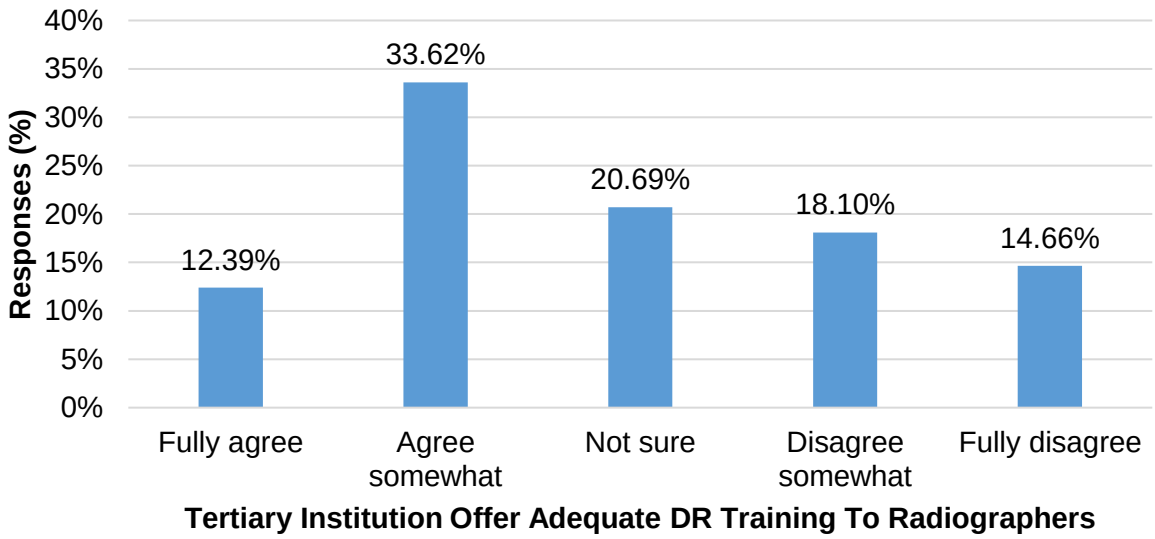



FIGURE 4.17: Quantitative results for perceptions of radiographers of the DR training offered by tertiary institutions

Table 4.17 and Figure 4.17 above indicate that 33.62% of the respondents agreed to some extent that tertiary institutions offered adequate DR training to radiographers, whereas only 12.39% of the respondents fully agreed that tertiary institutions offered adequate DR training to radiographers. Only 20.69% of the respondents indicated that they were not sure if tertiary institutions offered adequate DR training to radiographers. Whereas 18.10% of the respondents disagreed to some extent that tertiary institutions offered adequate DR training, 14.66% of the respondents fully disagreed that tertiary institutions offered adequate DR training to radiographers.

## 4.3 ANALYSIS OF FOCUS GROUP INTERVIEWS (PHASE 3)

This section presents qualitative results of Phase 3 of the study. The results are presented in different themes. The following main result themes have been identified:

- Application of the features of digital radiography
- Digital radiography as a preferred modality as compared to screen film radiography
- Professional challenges
- Radiography education and training

THEME AND SUB-THEMES

Table 4.18: Summary of the themes and subthemes of Phase 3

| Theme | Sub-themes |
|---|---|
| 4.3.1 Application of the features of digital radiography | 4.3.1.1 Features hardly ever or never used<br>4.3.1.2 Features commonly used<br>4.3.1.3 Features of which radiographers have no knowledge<br>4.3.1.4 Features in which radiographers do not show interest |
| 4.3.2 Digital radiography is a preferred modality compared to SF radiography | 4.3.2.1 Risks to the patient<br>4.3.2.2 Risks to the radiographer<br>4.3.2.3 Implication(s) of radiology report<br>4.3.2.4 Work flow efficiency |
| 4.3.3 Professional challenges | 4.3.3.1 Job responsibilities and priorities<br>4.3.3.2 Professional scope of practice<br>4.3.3.3 Physician request(s)<br>4.3.3.4 Knowledge limitations<br>4.3.3.5 Supporting professions<br>4.3.3.6 Years of clinical experience |
| 4.3.4 Radiography education and training | 4.3.4.1 Academic institutions<br>4.3.4.2 Clinical facilities<br>4.3.4.3 Industry-based training |

### 4.3.1 Application of the Features of Digital Radiography

The application of the features of DR will be discussed under the following subthemes: 1) Features hardly ever or never used; 2) Features commonly used; 3) Features of which radiographers have no knowledge; and 4) Features radiographers are not interested in using (see Table 4.18).

#### 4.3.1.1 Features Hardly Ever or Never Used

Features hardly or never used are the features that radiographers know about, but never use in a day-to-day work context. It includes the following: image stitching, calibration, edge enhancement, measurements, image histogram analysis, collimator shutters, look-up table, console light adjustments, console time setting, image tag on PACS and add a new protocol on the menu (also see Table 5.2)

a) Image Stitching

Image stitching (mosaicing with blending) can be described as a feature used to produce a single, edgeless image by putting together a set of overlapping images (Rankov *et al*., 2005:190). This feature is of significant importance in breast imaging, as well as in long bone study. The results in Phase 1 of the study (see Section 4.1) found that none of the analysed study guides included the concept of image stitching. This should be interpreted with caution, however, as it cannot be regarded as conclusive evidence and representative of whether institutions of higher learning in South Africa that offer radiography training cover the concept(s) in other modules (for example radiographic technique) or even in the clinical subjects. Notwithstanding this, the results of this study

indicate that practising radiographers are familiar with this feature, but for some reason/s never actually use it:

> I*mage stitching we never use* (B/4/24)[3].

The use of image stitching may have a positive impact on the diagnosis of the patient, as the radiologist will be offered an opportunity to view the entirety and extent of pathology on one consolidated image, making it easier to report. Furthermore, image stitching is of significant importance in scoliosis imaging, as it makes it easier for the radiologist to study the entire vertebral column on one image. This is necessary, as it guides the surgeons in operative decision-making and also helps the radiologists in writing a comprehensive and accurate radiological report (Malfair *et al.*, 2010:S8). According to Malfair *et al. (*2010:S8*)*, radiography remains the mainstay of diagnosis and evaluation of scoliosis. The failure or even merely sub-optimal utilisation of this feature by radiographers can affect surgical interventions for scoliotic patients negatively, as the radiologists will not be in an optimal position to obtain accurate measurements of the spine. Furthermore, failure by radiographers to utilise this feature optimally is potentially to the disadvantage of patients, as reporting physicians may misdiagnose small lesions, which might develop into significant health problems.

b) Calibration

Calibration is a feature of great benefit in DR imaging, especially in pre-operative planning for hip replacement (Franken, Grimm & Heyligers, 2010:136). In the clinical context, especially in some of the public hospitals with no resident radiologists, radiographers are

[3] B (Alphabetical letter) = Code of institution; 4 = the first number refers to the transcript page number; 24 = the last number refers to the transcript line number

the first line of consultation by physicians for a second opinion in radiographic image interpretation or pattern recognition (Cowan *et al.,* 2007:528). As such, patients in public hospitals without resident radiologists can benefit when radiographers utilise features like calibration, especially those patients scheduled for hip replacement. The radiographers in this study seemed to be familiar with the concept “calibration”; however, they indicated that it was hardly ever or never used in clinical practice:

> *Like I think the only thing which we are not using is calibration* (A/3/20).

The reasons for sub-optimal usage of the feature may be that physicians never request it or that radiographers have learned about it during their undergraduate training but never got a fair chance to practise in the clinical context.

c) Measurements

Measurement is one of the features added to digital imaging to assist physicians to perform measurements of different organs and pathology. The radiographers in this study were aware of this concept but they hardly ever or never used it:

> *Image stitching we never use; measurements as well; I have never seen any physician requesting it or asking radiographers to measure anything. It is influenced by the hospital you working for. I know in private they will say “do long bones with measurements” or something of that nature* (B/4/24-27)

The reasons for the sub-optimal use of the measurements feature may be that physicians never request x-rays with measurements, and/or the lack of clinical training for radiographers to know how to use this feature on a DR imaging system.

The optimal utilisation of this feature may aid physicians or radiologists in writing a comprehensive report, especially in scoliotic imaging. The sub-optimal utilisation of this feature is of significant disadvantage to the radiologist as well as the scoliotic patients, as radiography remains the imaging system of choice for scoliotic measurements (Malfair *et al.,* 2010:S8). However, a comprehensive report can still be written without this feature being utilised. The sub-optimal utilisation of this feature exposes the patient to a significant risk.

d) Edge Enhancement

Edge enhancement is a post-processing algorithm that emphasises the edges and contrast of a lesion, ultimately compensating for the low spatial resolution of CR compared to SF radiography (Korner *et al.,* 2007:680; Offiah *et al*., 2006:163). The DR imaging system, especially in the case of CR, has a limiting spatial resolution of 4 lp/mm, compared to SF, which has a limiting spatial resolution of 8 lp/mm (Bushong, 2008:455-456).

In the researcher's personal experience, edge enhancement is a tool that is supposed to be used on a day-to-day basis because DR imaging systems lack spatial resolution when compared to SF radiography. The use of this feature overcomes the limitation of the DR imaging modality, ultimately enhancing diagnosis and possibly avoiding undue repetition of x-rays due to poor geometry of the image.

The radiographers in this study reported wide utilisation of edge enhancement. Some were familiar with the concept and indicated daily use of it, while others were not even aware of it:

> *You know when you do QA test there is a film that comes in the machine for QA purposes; it has this edge enhancement. I do not know what it is. The problem with us is like we are, I do not want to use the word "spoiled", but if there is something assigned to that person, we just do not care; it's just none of our business* (C/10/91-92).

Some radiographers in this study indicated that they used the edge enhancement feature but that they were not familiar with the technical name of the concept. This anomaly may be linked to the overall limited coverage of DR in the undergraduate curriculum, as highlighted in Phase 1 of the study (see Section 4.1). Generally, processing algorithms such as edge enhancement must be optimally utilised to improve the quality of the CR and DR images. Failure to use this feature may result in an increased repetition rate due to poor image quality, which will affect the patient negatively in terms of unjustifiable exposure to radiation. Moreover, failure to use it may result in the reporting radiologist missing small lesions due to poor geometry of the DR system.

e) Image Histogram Analysis

Fauber (2017:88) highlights the importance of histogram analysis: "… as a result of histogram analysis, valuable information is provided to the radiographer regarding the exposure to the image receptor …" The image histogram should be checked frequently to monitor whether the exposure received by an IR is ideal; such a practice may assist in

reducing repeat exposure due to histogram analysis errors (Fauber, 2017:88). However, the radiographers in this study indicated that histogram analysis is a specialised feature and educational concept, as they regarded it as an unnecessary procedure for their professional role:

> *To be honest with you nobody does that. Personally I think I am here to take the image and if it looks ok and of diagnostic quality, then I send it through. We do not really go that deep, but still no one checks the image histogram* (B/6/39-40).

The practical reality is that radiographers are often under-staffed and they work under severe pressure (Gam, 2015:82; Makanjee, 2004:145-146). The histogram analysis feature might be regarded as a "waste of time" or unnecessary by most radiographers, as radiographers are frequently expected by their seniors to process as many patients as possible within a reasonable time. In private practice, healthcare is often not primarily regarded as an act of kindness but rather an act of business. The business focus of radiology practice forces radiographers to focus primarily on the production of radiographs that are of diagnostic value; other quality assurance and control procedures, including histogram analysis, are left for specific radiographers who are regarded as QC radiographers.

f) Collimator Shutters

In DR unjustifiably large collimation can easily be masked by electronic shutters (Uffman & Chaefer-Prokop, 2009:204). A large collimation field has a negative effect on patient radiation exposure as well as on student training (Azpiri-Lopez *et al.* 2013:112). Some radiographers are not familiar with this concept. Inadequate knowledge of features may

be due to the fact that some radiographers qualified before DR was incorporated in the curriculum for institutions of higher learning offering radiography training.

> *That one, I think we were supposed to do it in the morning when we do quality control (check list) but I do not think we use it but we are supposed to be using it every morning* (C/13/108).

Radiographers should be able to switch a collimator/electronic shutters on or off. Students and qualified radiographers who do not collimate should be identified and be recommended for a refresher course. Post-processing collimation should not be encouraged or even substitute pre-processing collimation. If this feature is not used, patients will receive unnecessary exposure to radiation, as well as poor image quality due to excessive scatter, which will ultimately affect the radiographic contrast (Willis, 2004:196).

g) Look-up Table

Look-up tables provide a method of altering the image to change the display of the digital image (Fauber, 2017:90). Some repeat exposures are unnecessary when radiographers know how to utilise the features of DR optimally. Currently some radiographers are not aware of the concept “look-up table”. The reason could be that some of the radiographers qualified before DR was included in the undergraduate training curriculum. It was found in Phase 1 of the study (see Section 4.1.4) that some of the study guides analysed included the concept of a look-up table. This may be the reason why some radiographers are familiar with the concept but for some reason/s they are not using this feature.

*(They all shook their heads and then asked a question): Is it a table which goes over the bucky, the one you move?* (D/8/75-76).

In the experience of the researcher, radiographers do utilise this feature, but they are not aware of its technical name, especially when working with CR. In the view of the researcher, it is impossible to work in an imaging facility with DR systems and never use the look-up table algorithm. When radiographers do not use this feature there will consequently be a high rate of repeat exposures due to algorithm processing errors, resulting in unnecessary radiation exposure to the patient.

h) Console Light Adjustments

According to the research participants:

*You will do positioning and all that, and you will be assessed on that but you will never be assessed on operating the machine. It's theory only, with theory you can cram that this one will be asked* (B/9/64).

The research participants indicated that they hardly ever or never used this feature. The reason could be that neither the theoretical nor the clinical training ever exposes students to the possibilities of using features such as changing and assigning different colours to light on the console panel. It was found in Phase 1 of the study (see Section 4.1) that none of the study guides analysed included the concept of "console light adjustment". However, this should be interpreted with caution, as it cannot be regarded as conclusive evidence and representative of whether institutions of higher learning in South Africa that

offer radiography training cover the concept(s) in other modules (for example radiographic technique) or even in the clinical subjects.

If this feature is not used, neither the image quality nor radiation dose is affected. Often radiographers classify this kind of feature as a time-wasting exercise or exclusively the responsibility of IT specialists or application specialists. However, if this feature is used optimally, it may aid the radiographer to know whether the unit is out of order or if there is an error on the machine. In the clinical context, when the x-ray console has an error, the radiographer may set the light to red; whenever the machine indicates a red light, it is not in working order. The radiographer will then know in advance not to use the dysfunctional machine, which is to the advantage of the patient as he/she will not wait longer because of a dysfunctional machine.

i) Console Time Settings

According to the research participants:

> *You know, as I am listening to this questions which you are asking I then realise that these things we do not do them. Those technicians where we bought the machines, they do it for us. Like setting the time, these things of exposure index, they come and do them. If there is something, they just call them and they will come* (B/9/55).

The time on the imaging system console reflects the time that appears on the image. In the case of electricity interruptions, it is likely that an incorrect time will be displayed on the console panel. Radiographs form part of legal documents (i.e. visual evidence) in a

court of law and an incorrect time on the radiograph might interfere with the correctness and acceptance of such radiograph as a reliable piece of evidence (Feigenson, 2010:149). Radiographers often shift the responsibility of changing time setting to the QC radiographer or at times to an application specialist.

It is the researcher's view that the issue of correct time is a medico-legal matter. As such, every qualified radiographer must take full responsibility for ensuring that the equipment is regularly checked and corrected when found to reflect an incorrect time. However the workload of radiographers is often very high. Long queues of patients in the waiting area of imaging facilities and a shortage of staff may be among the reasons why radiographers never use this feature. Furthermore, the results in Phase 1 of the study (see Section 4.1.10) indicated that none of the study guides analysed included the console time setting adjustment.

j) Image Tag on PACS

According to the research participants:

> *I do not know about that; we can ask our IT guys about that* (D/12/09).

Some radiographers are not familiar with the concept of image tags on PACS. These radiographers sometimes blame the inadequacy of their knowledge on the IT specialists, radiologists and/or application specialists. Image tags, just like time setting, form part of the medico-legal evidence that may be required in a court of law. The image tag does not affect the patient radiation dose or even the diagnosis process. However, it is one of those features that radiographers may want to familiarise themselves with in their spare time, especially in clinical facilities responsible for student training. Insufficient utilisation

of image tags may be due to the finding in Phase 1 of the study (see Section 4.1.2) that none of the study guides analysed included the concept of image tags on PACS.

k) Adding a new protocol to the menu

According to the research participants:

> *Sometimes you find that there is a new doctor who comes with a different name for a view that is not routinely done. No, we never add a new procedure, we rather just do it on an anterior-posterior (AP) or lateral of a view related to it. The radiographer just choose[s] a particular protocol and the machine just moves into that position and everything is ready.*

Radiographers hardly ever or never use this feature, which is available on all DR imaging systems. Once a new procedure is added, it forms part of the exposure technique chart, ultimately benefiting all radiographers using the system. It indirectly benefits the patient, as no repeat exposures will occur owing to exposure factors. Directly, this feature does not affect image quality or even the radiation dose to the patient.

Tools such as “adding a new procedure on the menu” are features that are more managerial in nature and the researcher is of the opinion that possessing knowledge of such features might give be added advantage when aspiring to be a manager. Taking into consideration factors such as radiographers’ workload, patient waiting time and the business side of a radiographic practice, it is justifiable and reasonable that some of the radiographers do not know this feature or never use it.

l) Summary of Features Hardly Ever/Never Used

The following features were not covered by the undergraduate learner guides analysed in Phase 1 of the study: image stitching, calibration, measurements, image histogram analysis, collimator shutters, console light adjustment, console time setting, image tag on PACS and adding a new protocol on the menu are features hardly or never used by radiographers in clinical practice (phase 3 Focus groups). An extensive literature search could not find any information on the clinical practice utilisation of the following features: console light adjustment, adding the new protocol on the menu, image tag on PACS, console time setting and console light adjustment. This may be one of the reasons such features are hardly ever or never used in a clinical setup. Of all features listed as hardly ever or never used, it is only the look-up table that reflects coverage by the learner guides of the participating institutions of higher learning offering radiography that were analysed (see Table 5.1, p.170).

#### 4.3.1.2 Digital Radiography Features Commonly Used

Features commonly used are the features that radiographers use on a frequent basis, as the need arises. It includes the following: contrast and density manipulation, annotations, image cropping, exposure index, auto-positioning of the x-ray machine, patient administration parameters and the summary of features commonly used

a) Contrast and Density Manipulation

The photographic properties of radiographic imaging controls the visibility of the image; however, in DR image processing influences image quality (Fauber, 2009:60-61; Schaefer-Prokop *et al.,* 2008:1826). In DR an underexposed image appears with an increased level of noise, whereas an overexposed image appears to have high image quality (Schaefer-Prokop *et al.* 2008:1826). The wide dynamic range and the availability of image post-processing tools pose a significant challenge to the patient as far as radiation exposure is concerned, as the radiographer may manipulate the density and contrast of an overexposed image to make the image quality optimal. The manipulation of density and contrast benefits not only the radiologist and patients, but also the running costs of the clinical facility, as the repeat rate is usually reduced and tube life prolonged.

Density and contrast post-processing features are commonly used by radiographers; *"… the rest of other features we always use: density and contrast" (*A/3/21). This is to the advantage of the patient. The learner materials of the participating institutions of higher learning that were analysed indicate that this concept is optimally covered in the learner guide (see Section 4.1.9). Failure on the part of radiographers to use these features on a regular basis may result in patients being overexposed. Also, radiologists may miss pathologies that will have a negative impact on the health state of the patient, ultimately adding to the running costs of the hospital (e.g. x-ray tube life deteriorating in response to high repeat rate).

b) Annotations

Channin *et al.,* (2009:590) define radiographic annotation as the explanatory or descriptive information on the meaning of an image that is generated by a human observer. Such information is of significant importance to the radiologist. According to Channin *et al.* (2009:590), radiographic annotations, such as measurements, indications of patient positions, arrows, circles etc., are of significant importance in assisting the radiologist with report writing. For example, in situations where the hospital does not have radiologists, the radiographer may use arrows to indicate areas of pathology or fracture so as to assist the physicians not to miss such an abnormality, which will have a negative implication for the patient's diagnosis and state of health. Hargreaves and Mackay (2003:284) highlighted that in the majority of hospitals the casualty physicians tend to be the most junior among the medical staff. They generally have very little experience in interpreting radiographs, which led to the red dot system, namely a system in which the radiographer marks a radiograph that he or she believes shows an acute abnormality (Hargreaves & Mackay; 2003:283). Radiographers use the *"annotation"* feature on a frequent basis. They are also familiar with the technical name of the feature.

According to the researcher, this feature must be commonly used, as failure to use it optimally may have a negative impact on making a diagnosis, especially in trauma units where inexperienced physicians depend on radiographers for guidance on image interpretation:

> *But the rest of other features: density, contrast, annotations of supine and contrast, you can even tell this one is not big enough, you can change the size* (A/3/21)

This finding is in line with the results of Phase 1 of the study (see Section 4.1.1), where more than 50% of the study guides analysed highlighted coverage of this feature in the undergraduate curricula.

c) Image Cropping

According to one participant:

> *I commonly use the post-processing feature image cropping* (E/4/36-37).

Radiographers are familiar with the technical name of this feature and they frequently use it. According to the researcher, the frequent use of this feature is an indication of malpractice, as this feature is used in cases where pre-processing collimation was not done. In DR unnecessary large collimation can easily be masked by electronic shutters (Uffman & Schaefer-Prokop, 2009:204). A large collimation field has a negative effect on patient radiation exposure, as well as student training. It is interesting to note that some focus group participants regard this feature as hardly used (see Section 4.3.1.1f), whereas others regard it as a commonly used feature (see Section 4.3.1.2 b). The results of Phase 1 of this study (see Section 4.1.10) indicate no coverage of this concept in study guides. Radiographers could have learned this feature from the application specialists and or from other radiographers in clinical practice.

d) Exposure Index

According to the results of Phase 1 (see Section 4.1.6), EI is covered by two of the three institutions included in the study, with only one institution not covering this feature. This

may be one of the reasons why some radiographers regard this concept as a hardly used feature, whereas others classify it as a commonly used feature:

> *I use it very often … if it's not busy (in an imaging facility) I change my exposures but if it's not busy then I will check so I can adjust for the next patient* (D/9/85).

According to the researcher this feature should be used frequently, as it gives an indication of whether the patient has been overexposed or underexposed. This is a necessary feature, as DR makes it difficult to indicate whether the image is overexposed because of the wide dynamic range of the imaging system (Schaefer-Prokop *et al.,* 2008:1826). Failure on the part of radiographers to use this feature on a frequent basis should be regarded as unethical radiation practice towards the patient, as more exposure may be received.

e) Reject Film Analysis Menu

According to the results of Phase 1 of the study, two of the three participating institutions cover the RFA feature in the undergraduate programme (see Section 4.1.10). According to Minnigh and Gallet (2009:84), RFA has a direct bearing on service delivery as well as the quality of service received by patients. This is one of the features where the radiographers reported a range of utilisation; some indicated they hardly used it while others indicated that they commonly used it:

> *I do it monthly, I even try to show this one (referring to a colleague) but he is not interested. The responsibility is not only on a QA radiographer, like we have a checklist and they do not do it, there is only few people, it's like there are lot of things but they do not do them* (E/12/103–104).

Radiographers who use this feature seem to be those who are in managerial positions or those delegated as QA radiographers. The radiographers who are not in such positions seem not to be interested in exploring this feature. According to the researcher, all qualified diagnostic radiographers should be able to operate the RFA feature, as high rejection rates have a negative impact on the reputation of the practice and the radiographers' professional skills, as well as negative implications for the patient's health due to exposure to radiation. These views are in line with the views of Waller and Hofmann (2010:375), who indicate that the introduction of DR did not eliminate the usefulness of RFA. Instead, the rejection rates in DR still range around 5% to 6%. Although RFA in DR is associated with various challenges and limitations, it is still the responsibility of the radiographer to perform proper QC of radiation-emitting equipment to ensure that acceptable exposure of the patient is achieved (Waller & Hofmann, 2010:375).

f) Auto-Positioning of the X-ray Machine

According to one participant:

> *In our department I would say we use 6 out of 10 of the features, we use features such as auto-positioning of the machine* (B/4/22-23).

The results of Phase 1 of the study indicate no coverage whatsoever of this feature in the learner guides of the participating institutions (see Table 5.1 and 5.2). However, it is not surprising that this feature is commonly used among diagnostic radiographers. This is a nice-to-have type of feature, as it does not affect image quality or even patient exposure.

However, the utilisation of this feature may assist with improved work efficiency, as optimal positioning of the equipment will be done in the minimum time.

g) Patient Administration Parameters

According to one participant:

> *Are we only talking here and not in general? In our department I would say we use 6 out of 10 of the features. Features commonly used include: patient administration* (B / 4 / 22-23).

This is one of the most commonly used features. Although the results of Phase 1 (see Section 4.1) do not indicate inclusion of this feature in the curriculum, it makes clinical sense that all radiographers must know how to register and record patient administration on the system. According to the researcher, computer administration skills are acquired during clinical training of students. In cases where this feature is not optimally utilised, patients may be affected negatively in terms of longer waiting times (i.e. it may take longer to capture patient information on the system). Although most clinical facilities have administrative officers, it remains the responsibility of every radiographer to capture the information on their patients and/or to retrieve existing patient information from the radiology database.

h) Summary of Features Commonly Used

It is evident from the results of Phase 1 of the study that features commonly used in clinical practice are those covered in the undergraduate programme, however there are some exceptions where features commonly used may have no curricular coverage of the

analysed study guides (see Table 5.1 and 5.2). Another finding worth noting is that features such as patient parameters (administration) and image cropping revealed zero percentage coverage in the study guides analysed. However, they appear on the list of commonly used features. This may suggest that learner guides are not the only tools to check if inclusion or exclusion of concepts in the learner guide suggests radiographers will be unable to utilise DR features optimally.

#### 4.3.1.3 Features of which Radiographers Have No Knowledge

The features of which radiographers have no knowledge refer to features of whose existence radiographers are not aware in a DR imaging system.

a) Look-up table

According to one participant:

> *Is it a table which goes over the bucky … the one you move?* (D/8/76).

Radiographers are not familiar with this concept; however, it is of significant importance to note that this feature has also been classified under features hardly used (see Section 4.3.1.1. g). According to one participant (D/8/76), radiographers are not familiar with the technical names of some of the features, and they hardly ever or never use some with which are they familiar. According to Fauber (2017:90), a look-up table is one of the features that has the capacity to alter the image on a display monitor. The implication is that when radiographers never use this feature or hardly use it, radiographs may be repeated, which will result in double exposure of the patient.

According to the researcher's observations and experience, radiographers do use this feature, particularly those who qualified before the introduction of DR to the curriculum, but are just not familiar with its technical name. It is also worth noting that the results of Phase 1 of the study (see Section 4.3.1.1g) indicate that this concept is covered in the undergraduate curricula of the institutions that participated in this study.

b) Types of DR imaging systems

According to one participant:

> *I think … direct, we send images to everyone. I think indirect is when you print the images* (D/1/1-3).

Radiographers are daily using DR imaging systems but they seem not to be familiar with the different types of DR systems, especially the direct and indirect DR systems. The reasons for this may be that because of the nature of their work, the business focus of their work (especially private practice radiographers) and the constant pressure they work under, it is difficult in practice for radiographers to keep abreast of new concepts regarding the imaging system they use to service patients (Gam, 2015:82).

A study conducted by Gijbels *et al.* (2004:151) highlights the differences in IR sensitivity to radiation and in radiation exposure when different imaging systems (direct or indirect) are used. Gijbels *et al.* (2004:151) indicate that different exposure factors are used when a different imaging system is used. The implication of sub-optimal or no knowledge of this feature is that radiographers may be limited in constructing exposure technique charts

for different imaging systems, which ultimately affects the amount of dose received by the patient.

c) Exposure Index

Seeram *et al.,* (2013:337) indicate that strong correlation exists between higher exposure indices and higher patient dose. This suggests that EI can be used by radiographers to estimate whether an image is under- or overexposed. Furthermore, an EI can be a good indicator of the amount of radiation exposure received by the patient (Seeram *et al.,* 2013:337):

> *Like for example when we do spine, we prefer to give higher mAs and lower kVp, such things you see* (E/8/70).

Some radiographers do not know the technical name of this concept, but it is clear that they use this feature, as it also appears with the commonly used features (see Section 4.3.1.2 d).

d) Change Time Settings on a Console

According to one participant:

> *We do not learn things like changing time settings and things like that (from the university), to be straight up, we do not learn things like that, like if I recall from an institution where I trained* (B/8/70).

On a practical level, some radiographers do not even know where to change the time on the console panel. This poses a serious medico-legal challenge, as radiographs can be

used as evidence in a court of law. This feature also appears among the features that are hardly used (see Section 4.3.1.1.i), which indicates that radiographers do not just have sub-optimal knowledge of this feature, but they also never or hardly ever use it. Failure to use this feature is of significant disadvantage to the patient, as clinically significant radiographs may fail as evidence in court because of incorrect and/or inaccurate information.

e) Collimator Shutters

According to Uffman and Schaefer-Prokop (2009:204), large collimation fields contribute to higher radiation exposure to the patient and poor image quality, while also setting a wrong precedent to student radiographers. Radiographers' knowledge of switching collimator shutters on or off may contribute to combating unnecessary radiation exposure to the patient, as most radiographers may begin to use collimation:

> *We do not know where that can be done, will you show us on this machine? We as long time radiographers we just know that we must cone (collimate)* (C/13/114).

Collimator shutters also appear alongside those features that are hardly ever or never used (see Section 4.3.1.1 f). It seems that radiographers do not have any knowledge of this feature, neither do they use it in clinical practice. The implication of such a knowledge gap is that patients may unknowingly be overexposed by students and then the image is cropped prior to approval by qualified radiographers.

f) Communication Protocols in Digital Radiography

According to one participant:

> *… maybe because things are changing we must be taught how to do this IT thing so that we can know how to change the programmes and how to set the programmes* (C/13/114).

According to Indrajit (2013:17), computer programs (communication protocols) as part of the imaging facilities enhance work flow. The radiographers in this study reported no knowledge of these features which they may actually be using on a routine basis. Ultimately the features of DR are incorporated to enhance work flow in order to reduce patient waiting time, which in turn can improve patient satisfaction.

In the researcher's experience radiographers do use digital systems that utilise various communication protocols, but they are just not aware of the technical names of the protocols. The researcher also believes that radiographers should not be blamed for not knowing this feature, as the work design often only allow access to DR systems by application specialist and IT technicians.

g) Summary of section 4.3.1.3

It is of significant importance to note that the following features were either sub-optimally covered or not covered at all in the learner guides analysed (Phase 1, see Section 4.3.1.1): look-up table, types of DR imaging systems, EI, changing time settings on a console and collimator shutters. There seems to be correlation between what is absent

from the undergraduate learner guides and the features of which radiographers have no knowledge or that they hardly use.

#### 4.3.1.4 Features Radiographers Are Not Interested in Using

This section addresses the DR features that radiographers may or may not know about, but crucially are not interested in understanding and/or attempting to use. These include the following features: time settings on a console, collimator shutters and image histogram analysis.

a) Time Settings on a Console

According to one participant:

> *[Note: The researcher had to provide some clarification regarding the feature first, as the participants were initially not familiar with the concept.] Time setting we use it when we have a very big patient … it's all automatic, we just switch on the machine and it sort[s] itself automatically. We do it when we do mobile but sometimes we do not do it as our time shows on the film. I do not think anybody will ever look into that* (D/11/99).

The radiographers in the study seemed not to be familiar with this feature, as they thought it was equivalent to the exposure time used as part of the exposure factors. The opinion expressed in the above quotation that nobody will ever use this feature reveals a dismissive and/or negative attitude to the utilisation and/or practical value of this feature. This is further highlighted by the findings of Phase 1 of the study that this feature was not covered in the learner guides analysed (see Section 4.1.10). In addition, an extensive

literature search could not locate any studies on the use of this feature. Lastly, it is worth noting that this feature is classified under the DR features that are hardly ever or never used (see Section 4.3.1.1.i). Despite this seeming lack of focus on time setting, the researcher of the current study is of the opinion that it is not a by-the-way kind of feature. Time setting is a significant feature that can potentially form part of medico-legal evidence in a court of law.

b) Collimator Shutters

According to the participant:

*Why would you do that (i.e. referring to "collimator shutters"?* (D/13/115).

The radiographers in this study seemed not to be interested in understanding and/or using this feature. This can be interpreted in the context of one or more of the following observations: 1) The results of Phase 1 of the study found no coverage of this feature in the learner guides analysed (see Section 4.1.10); 2) An extensive literature search could not locate any studies regarding the utilisation of this feature; and 3) This feature is classified under the DR features that are hardly ever or never used in clinical practice (see Section 4.3.1.1.f).

The sub-utilisation or non-utilisation of this feature may pose a significant disadvantage to patients, as radiographers may give large collimation and then compensate for it by means of cropping. This kind of practice can be regulated by switching on the shutters so that the supervisors can identify the radiographers who do not collimate.

c) Image histogram analysis

According to one participant:

> *(This) is just one of those things which you just do for academics* (C/9/84).

The results of this study indicate that radiographers feel image histogram analysis is just one of those features that are of less practical significance. However, the researcher of the current study is of the opinion that image histogram analysis is as important as sensitometry in analogue imaging. This idea is supported by Fauber (2017:88), who highlights that the analysis of image histograms is of significant importance, as it indicates the amount of radiation the IR captures.

Despite the fact that this feature is covered to some extent in literature, the findings of Phase 1 in the current study reflect no coverage in the learner guides analysed. Moreover, this feature also appears in the list of features hardly ever or never used (see Section 4.3.1.1.e). A significant implication of the above findings is that patients are potentially exposed to unnecessary radiation, which is in direct conflict with the ALARA principle (as low as reasonably achievable).

d) Summary of Features Radiographers are Not Interested in Using

It is noteworthy that none of the features the radiographers in this study are not interested in understanding and/or using is covered in the learner guides analysed (Phase 1). In addition, the features in this section are either poorly addressed or not addressed at all

in the literature. Lastly, all the features in this category form part of the hardly or never used features.

### 4.3.2 Digital Radiography is Preferred Imaging Modality Compared to Film Screen Radiography

According to one participant:

> *The fact is that, because of hospitals getting more doctors, there is more work. Then digital has a better throughput; we do not have to wait for films. You can send it to the doctors; better image quality. Also, less radiation dose to the patient because the image just appear on the screen and you cannot say I forgot the marker. The radiation dose is not supposed to be too high but students they will say 'You see, I am just a little bit out, I am going to do it again'* (D/2/18)

The diagnostic radiographers in this study prefer DR to SF. DR is generally preferred for various reasons: better patient throughput, lower radiation dose to the patient, lower repeat rate due to incorrect exposure factors, post-processing, high luminescence and high resolution monitors and increased dynamic range (Nyathi, Chirwa & Van der Merwe, 2010:2). The current study found the following reasons for the preference for DR: lower risks to the patient, lower risks to the radiographer, implications for the diagnostic report and workflow efficiency.

#### 4.3.2.1 Lower Risks to the Patient

Although the radiographers in this study prefer DR to SF, it is worth noting that DR still poses an amount of radiation risk to the patient. CR and DFPD, as well as DFPD,

accommodate a wide variation in acceptable radiation exposure, which may subject the patient to unnecessary radiation exposure (Willies *et al.,* 2004:196). According to Willies *et al*., (2004:196), radiographers and radiologists generally prefer overexposed digital images to underexposed digital images, resulting in unnecessary radiation exposure to patients. According to Korner *et al.,* (2007:677), DR offers lower radiation exposure to patients when all variables are optimum. The main challenge is that DR IRs have a wider dynamic range than SF radiography, which makes it more likely to overexpose the patient with DR. According to one of the participants:

> *Otherwise, as she said about image manipulation, it reduces repeat rate. Nevertheless, the issue of radiation dose depends more on a radiographer than on the machine … if you select the correct thing, then it is going to give less exposure. Therefore, we cannot say digital gives more radiation* (B/2/5-7).

In general, radiographers are of the opinion that DR exposes the patient to less radiation than SF. The researcher agrees with this view, but it is worth noting that factors such as wide dynamic ranges and exposure creeps pose patient exposure challenges to DR imaging. However, DR may give reduced exposure radiation because of the availability of features such as post-processing (Uffmann & Schaefer-Prokop, 2009:202).

#### 4.3.2.2 Risks to the Radiographer

According to Nallon, Herity and Brennan (2000: 39), a number of hazardous agents are present in the developing and fixing solutions of modern-day x-ray film processors, most notably glutaraldehyde, diethylene glycol and sulphur dioxide. The same authors emphasise that inappropriate or careless handling of the chemicals involved in film

processing can potentially produce a range of severe effects in exposed individuals, the so-called “darkroom disease”. Common medical problems experienced by radiographers and darkroom technicians include among others respiratory, dermatological and cardiac disorders (Nallon, Herity & Brennan, 2000:39). According to one participant:

> *Film screen radiography is time-consuming due to the processing of films. Safety from exposure to chemicals, from everybody* (E/2/17-19).

The opinions of the radiographers in this study are in agreement with the findings of Nallon, Herity and Brennan (2000:39) in that SF chemical processing is a potential health hazard to all persons working in darkrooms. Hence, DR is the preferred imaging modality compared to SF.

#### 4.3.2.3 Implication(s) for Diagnostic Report

According to Offiah *et al.* (2006:163), DR systems have lower spatial resolution than SF radiography. This gives SF an added advantage in terms of image quality. However, because of the post-processing tools of DR, DR still offers better image quality than SF. DR features enhance the visualisation of pathology, ultimately making it convenient for the radiologist to report.

#### 4.3.2.4 Workflow Efficiency

Generally, CR workflow is better than SF workflow. However, the workflow for flat-panel and CCD radiography is even faster (Drost, Reese & Hornof, 2008:139). Image processing in IDR and DDR appears almost immediately after exposure, making the

patient turnaround time much shorter. In the case of SF, the cassette needs to be processed in a darkroom, which is time-consuming and poses a health hazard. In a CR imaging system, the image is formed on an IP that still needs to be processed by a reader, which is time-consuming. However, the latest technology in CR allows the CR system to operate like a flat-panel system (Yorkston, 2007:975). The latest development in DR is systems that are automated and can be controlled remotely, making it convenient for radiographers to operate them.

### 4.3.3 Professional Challenges

The rapid pace of technological advancements in the world of radiography brings with it new professional challenges. The following challenges emerged from the data in this study: job responsibilities and priorities, professional scope of practice, medical practitioner request limitations, knowledge limitations, radiography support professions, and years of clinical experience.

#### 4.3.3.1 Job Responsibilities and Priorities

According to one participant:

> *I think that is the responsibility of the manager, we never use that one (RFA)* (B/11/71)

The above quotation illustrates the finding that diagnostic radiographers perceive specific job functions as the responsibility of other persons in the healthcare team. In other words, they clearly distinguish between their specific job responsibilities and those of other, but

related, healthcare professionals. Such responsibilities may include among others areas such as QC, RFA and histogram analysis. Diagnostic radiographers often link these responsibilities to managers, supervisors, application specialists or IT personnel.

According to one of the participants:

> *You have a pile of patients piling up so there is no time for that. Just when you get out of the room, someone is already in the room and you must let the patient go. You see, there are people responsible for different aspects of things in the department. If something is wrong, she will call an application specialist to come and assist with that* (D/10/89-92).

From a clinical point of view, and taking into consideration the nature of the radiography profession, radiographers prioritise patient throughput and they direct other responsibilities to the relevant specialised individuals. In other words, diagnostic radiographers are of the opinion that as many patients as possible must be examined in any given space of time, while any other responsibility (e.g. QC, RFA and histogram analysis) must be delegated to those in the relevant senior management positions.

#### 4.3.3.2 Professional Scope of Practice

The formal scope of practice for radiographers in South Africa was first published under Government Notice R2326 in *Government Gazette* 5349 of 3 December 1976; it was subsequently reviewed on 25 October 1991 and 1 August 1997 (www. HPCSA. co.za). The first clinical use of CR occurred in 1980, followed by the first DR charge-coupled device in 1990. Indirect FPDs were only introduced in the late 1990s (Korner *et al*.,

2007:676). As such, the current scope of practice has lagged behind the tremendous technological advancements over the last 20 years, which in turn has resulted in numerous professional challenges related to the overlap between diagnostic radiographers' current job demands and the advances in technology. Similarly, it was found in Phase 1 of the current study that the relevant learner guides and curricula of the participating higher education institutions largely failed to incorporate the relevant and essential concepts relating to DR (see Sections 4.1.1 to 4.1.11). Not surprisingly then, the radiographers in the current study reported DR situations in which they felt a level of professional incompetence outside their core professional role:

*"We do not work with that or we call our IT guys to come and do that"* (D/101/11).

#### 4.3.3.3 Medical Practitioner Request Limitations

According to one of the participants:

> *I have never seen any doctor requesting it or asking radiographers to measure anything* (B/4/26).

In clinical practice, radiographers are primarily informed by the images and projections that have been requested by the medical practitioners. If the requesting practitioner therefore does not request a procedure that requires the utilisation of certain DR features, the radiographers are more likely not to use such features. The formal HPCSA policy that guides requests for medical x-ray examinations states that any healthcare professional as defined in the National Health Act (Act 61 of 2003) may request an x-ray examination. However, this poses a significant challenge to radiographers, as other healthcare professionals (e.g. nurses, physiotherapists, etc.) may have limited knowledge of radiation and the clinical justification for requesting x-ray examinations. In this regard,

Rassin *et al.* (2005:25) recommends that formal training courses be developed for medical practitioners and nurses regarding the health hazards of radiation to the patient.

#### 4.3.3.4 Radiography Support Professions

According to Poon *et al.,* (2006:2), IT has significant potential to improve patient safety, organisational efficiency and patient satisfaction in healthcare in general. This statement is equally true for the specific fields of radiography and radiology. The implication is that the specialist inputs of IT experts (e.g. application specialists) have become a common occurrence in DR radiography clinical practice. According to one of the participants: *"You see there are people responsible for different aspects of things in the department and if something is wrong she will call an application specialist to come and assist with that"* (D/10/91-92). However, a potentially negative implication of this multidisciplinary DR team is that diagnostic radiographers might become more prone to shift blame and responsibilities to application specialists or IT specialists in cases where they should have taken responsibility for learning and/or using the clinical applications of DR features.

#### 4.3.3.5 Years of Clinical Experience

The rapid growth and use of DR in the field of radiography over the past 20 years poses a significant professional challenge to diagnostic radiographers who qualified in an era when SF radiography was dominant and DR unknown. According to one of the participants: *"I am 50 years now and I just wrote an immigration test but I did not know a thing on the technical aspect of DR"* (D/7/67). The implication is that older generation radiographers struggle to understand, use and stay abreast of many DR concepts,

whereas those in the younger generation who have received some formal training in DR are much more comfortable and familiar with basic DR features.

### 4.3.4 Radiography Training and Education

In South Africa undergraduate radiography students receive theoretical training from higher education institutions and clinical training from HPCSA-accredited clinical facilities. Qualified radiographers receive onsite-based training from the industry, through application specialists, as well as through HPCSA-accredited continuous professional development programmes.

#### 4.3.4.1 Higher Education Institutions

The radiographers in this study were of the opinion that the higher education institutions did contribute to their undergraduate academic knowledge of DR: *"They tried, they even went as far as teaching us the binary system, like on how a computer works in physics"* (C/6/60). However, it should be noted that the Phase 1 results indicated that relatively little time and curriculum content are devoted to DR features in the undergraduate curriculum. This was further underlined by the findings of Phase 2, where it was found that some radiographers had no or very little knowledge and understanding of certain DR features, while other radiographers were apparently simply not interested in using some of the DR features.

#### 4.3.4.2 Clinical Facilities

Lambert and Glacken, (2005:670) highlight the importance of clinical training in collaboration with theoretical training for nurses. This collaboration is equally important for radiographers. According to one of the participants: *"… so you can go and study and read and pass but you do not have a system you could practice on*" (C/7/67). This indicates that radiographers acknowledge the significance of clinical education as a way of enhancing clinical skills.

#### 4.3.4.3 Industry-based Training

Radiographers recognise the importance of industry-based training to stay abreast of the latest developments and skills. In addition, when they experience problems with the DR equipment, the first line of help to be called is often the industry-based application specialist: *"If something is wrong she will call an application specialist to come and assist with that"* (D/10/92). However, the results of Phase 2 (see Table 4.14 and Figure 4.14) of the study indicated that most radiographers did not attend additional industry-based training beside the compulsory equipment induction training offered by the industry. The implication is that radiographers will not be up to date with the latest developments in technology. This may result in radiographers utilising x-ray equipment and accessories sub-optimally, which may have a negative impact in terms of dose to the patient and image quality

## 4.4 CONCLUSION

The data and results of the various study phases that were analysed were duly presented in this chapter by means of tables, figures and narratives. In addition, the specific results were contextualised with reference to current knowledge as reported in the available peer-reviewed literature.

The following chapter provides an in-depth discussion and integration of the study results.

# CHAPTER 5

# DISCUSSION OF RESULTS

## 5.1 INTRODUCTION

The findings of Phase 1 (Section 4.1) of the study served as the framework for the discussions of Phases 2 and 3. The results of Phase 1 (see Sections 4.1.1 to 4.1.11) of the study highlighted three main categories in relation to the coverage of DR features in undergraduate curricula of institutions of higher learning offering diagnostic radiography:

- DR features adequately covered in study guides;
- DR features inadequately covered in study guides; and
- DR features not covered in study guides.

In addition, the results of Phases 2 and 3 (see Sections 4.2 and 4.3) of the study highlight the following broad categories regarding the utilisation of DR features in clinical practice:

- DR features hardly ever or never used;
- DR features commonly used;
- DR features about which radiographers have no knowledge; and
- DR features in which radiographers do not show interest.

The results of different phases are interpreted in this chapter in relation to each other to strengthen the mixed methods approach followed in the study. All these results support the study's original idea that DR features do not seem to be used optimally by clinical radiographers practising in South Africa (see Section 5.4 in this chapter for a detailed discussion of the results).

The Phase 1 results further indicate that some DR concepts and features are inadequately covered in the radiography curricula offered by institutions of higher learning in South Africa, while others are adequately covered. In general, the results of Phase 2 should be interpreted with caution in view of a relatively poor survey response rate. This is also applicable to the results of Phase 1, which were based on the study guides of three institutions of higher learning in South Africa (see Section 5.2 in this chapter for a detailed discussion of the results). Finally, Section 5.4 in this chapter provides a detailed discussion of practising diagnostic radiographers' attitudes to the utilisation of DR features in the context of medical imaging.

## 5.2 FEATURES OF DIGITAL RADIOGRAPHY IN THE UNDERGRADUATE CURRICULUM

This section discusses the curricular incorporation of DR features as well as the features that are not incorporated in the study guides. Both the quantitative results (Phase 2) and the qualitative results (Phase 3) are used to deepen the discussion of the Phase 1 results, as well as to justify the level of incorporation and/or omission where possible.

### 5.2.1 Digital Radiography Features Adequately Covered in Study Guides

This section presents the DR features and concepts that are adequately covered in the study guides of institutions of higher learning offering undergraduate diagnostic radiography. These include the following features: introduction to basic computer, digital imaging systems (CR and FPDs) and health information systems. The features adequately covered in the study guides are summarised in Table 5.1 in this section. Note

that the meaning of the terms *adequately covered*, *inadequately covered* as well as *more than adequately covered* is described in annexure B and *omission* indicates that the subject matter is not covered in the study guide analysed.

DR has many features, some of which diagnostic radiographers learn from institutions of higher learning. Other features are learned from application specialists (industry-based training) (see Section 4.2.14), whereas some other features are learned through knowledge exchange among radiographers working in the same imaging facility.

*Introduction to basic computer* is adequately covered in the study guides of the participating institutions of higher learning (see Section 4.1.1). This finding is supported by the Phase 2 findings, which indicate that 66.08% (see Section 4.2.5) of the respondents confirmed that they had formal basic computer training. Although results indicate that a high percentage of radiographers had received formal computer training, only 61.2% of the respondents fully agreed that they could operate computer hardware, while 8.6% of the respondents were not sure that they could operate the computer (see Section 4.2.11). Indrajit (2013:17) highlights that mastering the skills of using computers will ultimately enhance workflow in an imaging facility. DR features that require the use of computer software, such as annotations, image cropping and RFA, are all classified under the commonly used DR features (see Sections 4.3.1.2.b – 4.3.1.2.e). These findings indicate good alignment between the computer skills covered by institutions of higher learning and what radiographers commonly use in clinical practice. However, the results of Phase 2 (Section 4.2.11) also indicate that only 55.65% of the respondents fully agreed that they could operate computer software. This is a worrying finding, as DR systems and features rely mostly on the use of software programmes rather than

hardware, which may be a reason why radiographers are not aware of basic DR terminology (see Table 5.2.).

*Digital imaging systems (CR and FPDs)* are adequately covered in the study guides of the participating institutions of higher learning (see Section 4.1.3). The Phase 2 results (see Section 4.2.3.) indicate that only 9.48% of the respondents use SF, while 68.10% use CR and 62.07% use FPDs. In addition, the Phase 3 focus group results indicate that radiographers prefer working with DR rather than SF (see Section 4.3.2, quotation D/2/18). The reasons for such a preference could be traced to the wide variety of benefits and advantages offered by DR imaging when compared to SF, such as the following:

- compatibility to the health enterprise system;
- post-processing;
- wider dynamic range;
- improved image quality;
- increased dose efficiency;
- higher patient throughput; and
- reduced expenses for consumables.

*Health information systems*, specifically RIS, have been adequately covered in the study guides of the participating institutions of higher learning (see Section 4.1.8). RIS is a necessary technology in DR imaging facilities and clinical radiographers are expected to use this feature almost on a day-to-day basis; as such, knowledge about this feature is a prerequisite to the effective utilisation of DR features. Similarly, Institution A, B and C's curricular coverage of *dynamic range* was deemed adequate (see Section 4.1.9). According to Krupinski *et al*. (2007:389), dynamic range is one of the key factors affecting

image quality in DR. DR has a wider dynamic range than the SF system and it becomes highly important for radiographers to have a good fundamental theoretical knowledge base of dynamic range, as a wider dynamic range may pose a challenge regarding image quality and dose to the patient. Institution B was the only institution among the three that had adequate study guide coverage for *spatial frequency* and *resolution* (see Section 4.1.9). Institutions that do not cover this feature adequately could potentially compromise the quality of radiographic training, as these two features are central to digital image quality. In a worst case scenario, such curricular omissions may render radiographers unemployable.

### 5.2.2 Digital Radiography Features Inadequately Covered in Study Guides

This section presents features that are inadequately covered in study guides of institutions of higher learning offering undergraduate diagnostic radiography. These include the following features: introduction to basic computer, information technology (picture archive and communication systems), point-processing operations, look-up tables and display monitors. The features inadequately covered in the study guides are summarised in Table 5.1.

The study guide coverage of software applications (Microsoft Word™, Excel™ and PowerPoint™) in *Introduction to Basic Computer* for Institutions A and B is inadequate (see Section 4.1.1). DR features such as RFA, annotations and capturing patient details require basic knowledge of MS Word and MS Excel. However, the Phase 3 results indicate that DR features that commonly use these applications are classified as “features commonly used” (see Section 4.3.1.2). This suggests that the inadequate undergraduate

coverage of these software applications do not affect them negatively in clinical practice, probably because most undergraduate students and qualified radiographers are well acquainted with the specific software applications through personal experience or acquiring it from fellow qualified radiographers and/or the application specialists (industry-based training). The Phase 2 results further indicate that 97% of radiographers fully agreed that they could use these specific software applications (see Section 4.2.6). This indicates that shortcomings in what is covered in the study guides might in some cases still have other causes.

As far as IT is concerned, PACS is inadequately covered in the study guides of Institutions A and C. Cao and Huang (2000:80) indicate the primary functions of PACS in an imaging facility as follows: the ability to manage radiological examinations, collect digital images from DR imaging modalities, archive the collected images strategically and selectively distribute such images for review. According to Siegel and Reiner (2002:1573), PACS can offer the potential to improve departmental productivity and overall image quality. Inadequate coverage of this topic has a potentially negative outcome on radiographers' understanding and insight into the importance of this DR feature. However, the Phase 2 results (see Section 4.2.11) indicate that a significant number of diagnostic radiographers indicated full agreement regarding their ability to perform specific PACS procedures: register patients on PACS (66%), identify image tags (47%), post-process images (59%), store images (75%) and distribute images to linked users (58%).

The percentages of utilisation of PACS (see Table 4.6) are low compared to its importance, this means that clinically PACS is highly important in the day-to-day running of an imaging facility. The results of Phase 3 (see Section 4.3.1.1.j) indicate that PACS

(particularly image tags on PACS) is regarded as a hardly used feature by radiographers. However, it is important to note that radiographers may have acquired knowledge of PACS from other sources, such as colleagues, conferences or industry training, or to a certain extent PACS may have been covered in other modules (such as radiographic technique) offered in undergraduate diagnostic radiography programmes.

Institutions A and B's study guide coverage of *point processing operations* is inadequate; less than 50% of the *look-up table* is covered (see Section 4.1.4). According to Seeram and Seeram (2008:24), digital image processing in radiology has become one of radiographers' and radiologists' routine skills. The Phase 3 results (see Section 4.3.1.1.g) indicate that radiographers regard look-up tables as a feature of DR that is hardly used. These findings are supported by the Phase 2 results where 40% of the radiographers indicated they were not sure or disagreed, 1% disagreed to some extent and 7% disagreed that they could use the look-up-table feature to create a better image impression (see Section 4.2.7). To a certain extent, this situation may be due to the fact that the look-up table feature was inadequately covered during their undergraduate training. The Phase 3 results (see Section 4.3.1.3.a) further indicate that the look-up-table feature is classified as one of the features of which radiographers have no knowledge. The results of Phase 1(see Section 4.1.4) indicate that this feature is inadequately covered by the study guides, and to a certain extent this may be a reason why some radiographers have no knowledge of features such as the look-up-table.

Institution C's curricular coverage of *display monitors* is inadequate (see Section 4.1.5). Krupinski *et al.* (2007:389) and Ludewig *et al.* (2011:1) highlight that the manner in which images are displayed affect image quality. Radiographers' knowledge of image display

may have been acquired from other sources, such as industry-based training, conferences and colleagues (fellow clinical radiographers). Institutions A and B completely omitted display monitors in their DR curricula. This has potential negative consequences, as display monitors may directly affect image quality. Radiographers without adequate knowledge of display monitors may be disadvantaged to serve as DR quality control radiographers.

### 5.2.3 Digital Radiography Features Not Covered in Study Guides

This section presents features that are not covered in the study guides of institutions of higher learning offering undergraduate diagnostic radiography. It includes the following features: information communication standards, communication protocol and display monitors (primary and secondary display). The features not covered in the study guide are summarised in Table 5.1.

Institution C's study guide does not reflect any coverage of *information communication standards* in diagnostic radiography; Institution A had adequate curricular coverage whereas Institution B had inadequate coverage (see Section 4.1.2). This finding is in agreement with the results of Phase 3 (see Section 4.3.1.3.f), when one of the participants was quoted as saying this concept was outside the defined scope of diagnostic radiography and that it was purely an IT field (C/13/114; Section 4.1.1.3.f). Furthermore, the Phase 3 results (Section 4.3.1.3.f) indicate that this concept is one of the DR features about which radiographers do not have knowledge.

The Phase 2 results (see Section 4.2.11) indicate that only 57.76% of the respondents fully agreed that they could identify the *communication protocol* used in an imaging

facility. Radiographers who have knowledge of communication protocols in DR will increasingly be more employable and in demand, as their expertise may help the imaging facility in purchasing relevant equipment for the facility. Ultimately, the absence of this concept in the curricula of institutions of higher learning may have a negative effect on the DR knowledge base of diagnostic radiographers.

Institutions A and B's curricular coverage (see Section 4.1.5) does not include *display monitors* (primary and secondary display). However, it is conceivable that this feature may be covered in other radiography-related modules. Although more than one third of radiographers (38.14%) indicated that they had never attended manufacturer-based training, whereas 19.59% of participants indicated that they had attended manufacturer-based training in the previous year (see Section 4.2.12). There is therefore a real possibility that some radiographers may have been exposed to the theory of display monitors in those training sessions or in interacting and learning from experienced colleagues.

Table 5.1 provides a summary of the curricular coverage results for institutions of higher learning. The alphabetical letters in the table represent the different institutions of higher learning that took part in Phase 1. It is worth noting that all the features not covered in the curriculum of the study guides analysed (Phase 1) also fall under the following Phase 3 categories: features hardly ever or never used, features in which radiographers have no interest and features of which radiographers have no knowledge (Table 5.2; see Section 5.2.3).

TABLE 5.1. Curriculum analysis of DR topic coverage for institutions of higher learning offering undergraduate diagnostic radiography. Note that the red blocks indicate the DR features that were not covered by all/most of the institutions of higher learning participating in the study, while the yellow blocks indicate the DR features inadequately covered by most of the institutions and the green blocks indicate the DR features adequately covered by most of the institutions.

| Features Adequately Covered | Features Inadequately Covered | Features Not Covered |
|---|---|---|
| Computer hardware (A & B) | PACS (A & C) | Computer hardware (C) |
| Computer software (A & B) | Image transmission (A & C) | Computer software (C) |
| PACS (B) | Information communication standard (C) | Computer networking (A, B & C) |
| Image transmission (B) | Flat-panel detectors (C) | Information communication standard (A) |
| Information communication standard (B) | Look-up-table (A & B) | Look-up-table (C) |
| Flat-panel detectors (A & B) | Display monitors (C) | Display monitors (A & B) |
| Exposure technique charts (B) | Laser printers (A & C) | PACS monitors (A, B & C) |
| Clinical information system (B & C) | Exposure technique charts (A & C) | Laser printers (B) |
| Administrative information system (B) | Clinical information system (A) | Digital artefacts (A, B & C) |
| Spatial frequency and t (B) | Administrative information system (A) | Administrative information system (C) |
| Dynamic range (A & B) | Spatial frequency and spatial resolution (A & C) | Changing time settings (A, B & C) |
| Signal-to-noise ratio (C) | Dynamic range (C) | Adding a new protocol (A, B & C) |
| Image post-processing tools (A & C) | Signal-to-noise ratio (A & B) | Switch on and off collimator shutters (A, B & C) |
| | Reject image analysis (B & C) | Reject image analysis (A) |
| | Image post-processing tools (B) | Accessories in digital imaging (A, B & C) |
| | | CR image processing, different types of unit readers and exposure control in CR (A, B & C) |

TABLE 5.2. DR features that radiographers never use, have no knowledge about and/or are not interested in using.

| Features Hardly or Never Used | Features Radiographers Have no Knowledge About | Features Radiographers are not Interested in Using |
|---|---|---|
| Image stitching | Look-up-table | Time settings on a console |
| Calibration | Types of digital radiography imaging systems | Collimator shutters |
| Measurements | Exposure index | Image histogram analysis |
| Edge enhancement | Change time settings on console | |
| Image histogram analysis | Collimator shutters | |
| Collimator shutters | Communication protocols in digital radiography | |
| Look-up-table | | |
| Console light adjustments | | |
| Console time setting | | |
| PACS image tag | | |
| Add a new protocol | | |

The Phase 2 and 3 results show that none of the DR features that radiographers never use or hardly use (see Section 4.3.1.1) was covered in the study guides analysed (see Section 4.1). The same applies to all the features about which radiographers have no knowledge (see Section 4.3.1.3), as well as those in which radiographers are not interested (see Section 4.3.1.4). The only exception to this pattern is the “look-up-table” and “different imaging modalities” features, which were inadequately covered in the study guides analysed (see Section 4.1.4). It is important to emphasise that all the

features indicated in Table 5.2 are of significant importance in digital radiographic imaging and as such they should ideally be commonly used in radiographic practice.

The Phase 3 results indicate that diagnostic radiographers regard a number of DR features as common to their day-to-day practice (see Section 4.3.1.2):

- contrast and density manipulation;
- annotations;
- image cropping;
- EI;
- repeat image analysis menu;
- auto-positioning of the x-ray machine; and
- patient administration parameters.

It is worth noting that all these commonly used DR features were covered either inadequately or not at all in the study guides of the institutions of higher learning that were analysed (see Table 5.1). However, despite these shortcomings in the undergraduate curricula, the practising radiographers are still aware of these features and use them daily. A possible explanation for this apparent anomaly is that practising radiographers may have gained the relevant awareness and knowledge from other, possibly more experienced, radiographers or through the available manufacturer-based training (see Section 4.2.14).

## 5.3 COMMENTS ON DIGITAL RADIOGRAPHY FEATURES' CURRICULAR COVERAGE

Some of the DR features that were found not to be covered by the study guides analysed (see Table 5.1) are of significant importance in diagnostic radiography. Some of the features, such as *digital artefacts*, are important for diagnostic purposes and must ideally be given preference in any undergraduate DR training programme. This notion is further supported by the Phase 2 findings (see Section 4.2.10) that 82.61% of the participants fully agreed they were able to identify whether a digital image had an artefact, with a further 11.30% agreeing to some extent that they were able to identify this.

Various DR features are important for patient diagnosis, departmental efficiency, medico-legal aspects, quality control and image quality. As such, it is worrisome that the Phase 1 findings (see red blocks in Table 5.1) indicate that none of the participant institutions' study guides analysed included the following clinically important DR features:

- PACS monitors;
- switching on and off collimator shutters;
- computer networking;
- changing time settings;
- adding a new protocol;
- accessories in digital imaging; and
- CR image processing, types of unit readers and exposure factors.

It is also worth noting that none of the adequately covered DR features (Table 5.1) was included in the study guides of all the participating institutions; each of these features was covered by only one or at most two institutions. A similar finding applies to the DR features not adequately covered. However, some of these features may have a direct impact on imaging facility efficiency, patient waiting time, patient diagnosis, patient dose and image quality. As such, the following DR features in the inadequately covered category are regarded as essential DR features that should ideally be adequately covered in undergraduate training programmes:

- PACS;
- flat-panel detectors;
- look-up-table;
- display monitors;
- exposure technique charts;
- clinical and administrative information systems;
- reject image analysis; and
- image post-processing tools.

## 5.4 CLINICAL APPLICATION AND UTILISATION OF DIGITAL RADIOGRAPHY FEATURES

This section discusses the application and utilisation of the various DR features in terms of the radiographers' imaging modality preferences (Section 5.4.1), professional challenges (Section 5.4.2), as well as radiography training and education (Section 5.4.3).

### 5.4.1 Imaging Modality Preferences

The Phase 2 results (see Section 4.2.3) indicate a clear migration pattern from SF to DR, with only 9.48% of the respondents indicating that they still had an SF system in their imaging facilities. CR is used in more than two thirds (68.10%) of the cases, while FPDs are used in 62.07% of the cases. The benefits of DR are well recognised, namely better patient throughput, not using hazardous chemicals for image processing, compatibility to PACS connectivity, better image quality, lower patient dose and increased dynamic range (see Section 4.3.2, quote D/2/18; Nyathi, Chirwa & Van der Merwe; 2010:2). Literature indicates that radiographers prefer DR over SF (Nallon, Herity & Brennan, 2000:39). However, no literature could be found regarding radiographers' preferences between CR and FPDs. Radiographers' main concern seems to be the presence of hazardous agents in the SF developing process (Nallon, Herity & Brennan, 2000:39).

### 5.4.2 Professional Challenges

The Phase 3 results indicate that some radiographers are not familiar with, i.e. have no knowledge about, the basic jargon of DR (see Section 4.3.1.3.e; C/13/114). Various challenges may play a role in radiographers not knowing about or not being interested in quite a number of DR features (Table 5.2). According to one participant (see Section 4.3.3.1, quotation B/11/71) many job responsibilities and priorities are among the factors that contribute to radiographers not being well-versed in matters relating to *repeat image analysis*. The organisational structure of imaging facilities may mean that often only a specific person, usually an experienced senior radiographer, is tasked to be in charge of specialised functional fields, such as quality control. Inevitably, this

type of job allocation structure excludes junior radiographers from being exposed to such specialised fields.

Similarly, the Phase 2 results (see Section 4.2.9) indicate that just more than half (56.90%) of the participants fully agreed that they could access the reject image analysis menu, while 12% of the participants were not sure whether they could access the RFA menu on a DR imaging system. Less than one third (30.70%) of the participants fully agreed that they could calculate the RFA on a DR system for a defined period of time. In addition, the Phase 1 results (Table 5.1) indicate that features such as *quality control* and *RFA* are not covered in some of the study guides from institutions offering undergraduate diagnostic radiography.

One professional challenge that may contribute to the sub-optimal use of DR features by diagnostic radiographers is the HPCSA's professional scope of practice of radiographers, which was last updated in 1997 (see Section 4.3.3.2). The scope of practice prescribes the limits of what may and may not be done in an imaging facility. Another challenge for radiographers is the seemingly limited DR knowledge of medical practitioners; this limits their x-ray request scope, which in turn restricts radiographers in applying the wide range of DR imaging functionalities effectively (see Section 4.3.3.2). Yet another challenge for radiographers is that the DR field is shared with IT professionals and industry-based application specialists who are involved in on-site DR training to radiographers (see Section 4.2.13). The implication is that radiographers may tend to accept or expect that DR-related technical aspects will be dealt with by IT technicians (see Section 4.3.3.4, quotation D/10/91-92). Again, this is linked to the absence of a defined scope of practice, which clearly distinguishes

between the professional responsibilities of IT technicians and diagnostic radiographers.

### 5.4.3 Radiography Training and Education

The Phase 3 results indicate that diagnostic radiographers acknowledged the role that institutions of higher education play in training and equipping undergraduate students with DR knowledge (see Section 4.3.4.1, quotation C/6/60). In addition, the practising radiographers in some cases demonstrated some knowledge of DR features that were not covered in the undergraduate curriculum of institutions of higher learning. The Phase 2 results (see Section 4.2.17) indicate that only 12.39% of the respondents fully agreed that the institutions of higher learning offered adequate DR training to diagnostic radiographers, while 33.62% agreed to some extent, 20.69% were not sure, and almost one third (32.76%) either disagreed to some extent or fully disagreed that institutions of higher learning were doing enough to train radiographers in DR. However, on the positive side, the Phase 2 results indicate that almost three quarters (73.13%) of the respondents attended at least one DR training session offered by the relevant manufacturer (see Section 4.2.14). It is also reasonably conceivable that practising radiographers are regularly learning more about DR features from their colleagues in the imaging facility who are more experienced in using various DR features.

### 5.4.4 COMMENTS ON THE CLINICAL APPLICATION AND UTILISATION OF DIGITAL RADIOGRAPHY FEATURES

The diagnostic radiographers in this study indicated a clear preference and acceptance of the transition from the SF to the imaging system. CR is currently the most popular imaging system (68.10%) in use in imaging facilities, closely followed by FPDs (62.07%), with SF far down in third position (9.48%) (see Section 4.2.3). It is anticipated that in the foreseeable future SF will be phased out almost completely, while FPDs may overtake CR in popularity. As previously indicated (see Section 4.3.2), there are many reasons and advantages why FPDs and CR should be preferred over SF by practising diagnostic radiographers. For one, SF is often disliked because of the hazardous nature of the processing chemicals and the lack of post-processing tools, which may ultimately result in unnecessary radiation exposure to the patient.

Even though diagnostic radiographers mostly prefer DR over SF, there are various challenges confronting them and the radiography profession at large. Radiographers in general seem to use few of the many clinically useful features DR provides. Some of the most salient challenges are that they are not familiar with DR jargon, they do not use features that give indications of exposure received by IR (e.g. EI), and are not interested in learning certain DR features (see Table 5.1 and Table 5.2). Other challenges include the current somewhat outdated HPCSA scope of practice for diagnostic radiographers. The scope was last reviewed in 1997, while DR technology has grown rapidly over the last 20 years. Medical practitioners' limited knowledge of useful DR features pose a further challenge and appear to be a contributing factor to some radiographers not using or having knowledge of certain DR features.

DR is closely linked to the world of IT. As such, there is at times an undefined and invisible demarcation between the profession of diagnostic radiography and IT when it comes to DR. It seems that radiographers often forward or transfer any IT-related issue experienced when using DR features to IT practitioners or application specialists. However, these undefined role limitations may result in undue or unnecessary role demarcation between diagnostic radiographers, application specialists and IT practitioners in imaging facilities. This is the case especially when radiographers hold the opinion that their primary work is to x-ray the patient and any other responsibilities must be handled by the QC radiographers, IT specialists and, where applicable, the application specialists.

Lastly, industry training and educational programmes, as well as peer-based education, can play a significant role in closing the DR-content gap created by institutions of higher learning in their undergraduate programmes. While institutions of higher learning already play an important role in teaching DR content at undergraduate level, much is still required to bridge the gap to practice-based needs.

## 5.5 CONCLUSION

Many DR features are not adequately covered by the undergraduate curriculum of institutions of higher learning offering diagnostic radiography. Also, Diagnostic radiographers use various features of DR sub-optimally, and to a certain extent, they lack basic knowledge of DR jargon. Various challenges facing the profession have been discussed in this chapter, such as the outdated scope of practice.

The following chapter presents a proposed DR curriculum framework.

# CHAPTER 6

# PROPOSED DIGITAL RADIOGRAPHY CURRICULUM FRAMEWORK

## 6.1 INTRODUCTION

This chapter describes a proposed DR curriculum framework that is based on the literature review (Chapter 2), the results of Phases 1 to 3 (Chapter 4) and the discussion of the results (Chapter 5). The framework indicates the DR features which, according to the aforementioned chapters, as well as the experience of the researcher, are regarded as the essential curriculum content that should form the baseline for institutions of higher learning involved in undergraduate DR training (see Section 6.2). Furthermore, Section 6.3 addresses the DR features that are regarded as non-essential; these are features of which diagnostic radiographers must be aware but which they should not necessarily understand in depth. The primary determinants ("pillars") of the appropriate DR curriculum content are the following: 1) the patient; 2) radiation dose; 3) imaging facility efficiency; and 4) radiographic image quality.

## 6.2 ESSENTIAL DIGITAL RADIOGRAPHY FEATURES

*Essential DR features* refer to those features that affect at least three of the main "pillars" (see Section 6.1), whereas *non-essential DR features* refer to those features that affect at most two of the main "pillars". Table 5.1 and Table 5.2 provide a comprehensive list of the DR features considered in this study.

### 6.2.1 Essential Digital Radiography Features to be Covered in Depth

A number of DR features are regarded as essential in any DR curriculum framework, as they form the baseline knowledge requirement for diagnostic radiographers to operate optimally and benefit from DR imaging systems. As such, the following features should be discussed in depth: DR imaging systems, picture archiving and communication system, DR quality control, image processing (post-processing tools), EI and DR exposure technique charts.

#### 6.2.1.1 Digital Radiography Imaging Systems

DR began with CT and MRI in the early 1980s (Bushong, 2008:413; Carlton & Adler, 2006:356). DR is divided into two sections, namely CR and FPD (Carlton & Adler, 2006:356; Doi, 2006:R15). Gijbels *et al.* (2004:82) indicate in their study that different IRs differ in terms of image sensitivity. As such, the radiation dose to the patient differs when using CR or FPDs. The CR component of DR should discuss in depth the data acquisition stages, image processing, exposure factor, IP, image plate readers and image display; this applies to FPD systems. In the case of FPDs indirect conversions and direct conversions should also be discussed in depth.

#### 6.2.1.2 Picture Archiving and Communication System

PACS is one of the DR features that is already adequately covered in the study guides of some institutions, while either inadequately covered or not covered at all in others (see Table 5.1). Seeram & Seeram (2008:25) describe PACS as one of the major and essential components of a digital imaging system. Floyd *et al.,* (2015:315) emphasise

that the introduction of PACS in an imaging facility increases productivity. Samei *et al.* (2004:313) highlight the key PACS components that must be discussed in depth for the benefit of undergraduate students, namely that it is "… an inter- and intra-institutional computational system that manages the acquisition, transmission, storage, distribution, display, and interpretation of medical images."

#### 6.2.1.3 Digital Radiography Quality Control

Chapter 4 indicates that radiographers find it challenging to use the repeat image analysis menu to calculate the repeat rate over a specified period of time (see Section 4.2.9). Only 30.70% of the respondents fully agreed that they could perform such a function, while 29% were not sure and 20.18% fully disagreed that they could use it. In addition, this feature was not covered in the study guide of Institution A, whereas it was inadequately covered in the study guides of Institutions B and C (see Section 4.1.10).

Waaler & Hofmann (2010:375) highlight an interesting finding about the reject repeat rate in DR when they indicate that several "research papers report a reject/retake rate in some digital departments as high as 5%, and even higher in others." A high repeat rate in DR may negatively affect the patient in terms of dose, may reduce the tube life of an x-ray unit and ultimately affect the imaging facility efficiency, as patients may have to wait for longer periods because of increased procedure times.

#### 6.2.1.4 Image Processing (Post-processing Tools)

Seeram & Seeram (2008:25) regard the following stages as the most essential in digital imaging: image acquisition, image processing (pre-processing and post-processing) and image display, as well as the PACS. Digital image processing is divided into two parts, namely pre-processing and post processing. “Pre-processing corrects errors from the raw data whereas post-processing changes the image contrast, reduces image noise and enhances the sharpness of the image displayed in an effort to enhance diagnostic interpretation” (Seeram & Seeram, 2008:25). Post-processing affects the imaging facility efficiency and image quality and it may also indirectly result in reducing the dose to the patient that might otherwise have occurred owing to repetition in cases of photographic errors.

Seeram & Seeram (2008:26) identified five classes of image processing, namely: “1) image restoration; 2) image analysis; 3) image synthesis; 4) image enhancement; and 5) image compression.” Two of these classes are specifically applicable to DR, namely image enhancement and image compression.

**Image enhancement**. Image enhancement processing alters the signal of a digital image to ensure it meets the needs of the observer. “The operations include contrast enhancement, edge enhancement, spatial and frequency filtering, image combining, and noise reduction” (Seeram & Seeram, 2008:26). Point processing operations (algorithms) are commonly used in DR. A point on an input image is used to change the signal strength of the same point on an output image until the entire image’s contrast is modified to suit the observer. A commonly used point processing operation is called windowing. In order for radiographers to understand the post-processing

algorithm adequately, the following two concepts must be understood: 1) histogram; and 2) look-up table. A histogram can be used to change image contrast and image brightness significantly. A look-up table alters the contrast of the image by changing the input value of a given image pixel to a higher or lower number on the corresponding output pixel value of the same image (Seeram & Seeram, 2008:26).

**Image compression**. "The purpose of digital image compression is to reduce the size of the image in order to decrease transmission time and to reduce storage space" (Seeram & Seeram, 2008:26). Offiah *et al.,* (2006:163) indicate "that post-processing improves the visualisation of pathology and allows the display of the full object irradiated range while improving local contrast."

Although literature highlights the importance of image processing (post-processing tools), the Phase 1 results of this study indicate that the study guides of Institutions A and B covered the look-up table inadequately, while Institution C did not cover this feature (see Section 4.1.4). Post-processing tools may reduce the repeat rate by altering the photographic properties of a digital image (i.e. density and contrast); this will ultimately reduce unnecessary exposure to the patient. Furthermore, the Phase 3 results indicate this feature as one that radiographers are not interested in using, have no knowledge about and hardly use or never use (see Table 5.1 and Table 5.2). Almost 40% of surveyed radiographers were not sure whether they could use a look-up table to create a better image impression (see Section 4.2.7). During the Phase 3 focus group interviews one of the participants made the following comment when asked about post-processing (look-up table): *"Is it a table which goes over the bucky, the one*

*you move?*" (D/8/76). The quotation clearly illustrates the extent of some radiographers' ignorance of the components of image post-processing.

#### 6.2.1.5 Exposure Index

Seeram (2011:254) defined EI as "a numeric value which appears on the image and provides the radiographer with visual feedback regarding radiation exposure to the patient." It is therefore a QC tool to facilitate optimisation of radiation protection (see Section 2.3.1. for an in-depth discussion of this feature). EI is one of the features not adequately covered in the study guides analysed (Phase 1). It is also one of the features about which radiographers have no knowledge (Table 5.1 and Table 5.2). Since the values of exposure indicators are vendor-specific, it is important in the undergraduate DR curriculum to include an in-depth discussion of the main DR equipment vendors. The main vendors supplying DR equipment are Fuji and Konika, Carestream, AXIM and SIEMENS.

#### 6.2.1.6 Digital Radiography Exposure Technique Charts

Williams *et al*., (2007:373) and Seeram *et al.* (2013:332) highlight the differences between SF (analogue) and DR exposure technique charts. The exposure factors and exposure techniques differ between the SF system, CR system and FPDs. Exposure factors and exposure techniques directly affect image quality and patient dose and may indirectly increase repeat images, which may ultimately increase the procedure time. As such, there is a need for this feature to be discussed in depth in undergraduate DR curricula. Currently the subject exposure technique charts and DR exposure

factors are adequately covered in the study guides of some institutions, whereas other institutions cover this feature inadequately (see Section 4.1.6).

### 6.2.2 Essential Digital Radiography Features to be Moderately Covered

The DR features discussed in this section are regarded as moderately essential in the sense that they directly or indirectly affect two or one of the primary determinants ("pillars") of the appropriate DR curriculum content (see Section 6.1). The following two features should therefore be moderately covered: DR artefacts and dynamic range.

#### 6.2.2.1 Digital Radiography Artefacts

The development of DR introduced a new set of radiographic artefacts (Drost, Reese & Hornof, 2008:S48). Artefacts refer to "portions of the image that may mimic a clinical feature, impair image quality or obscure abnormalities" (Drost, Reese & Hornof, 2008:S48). DR artefacts are of significant importance in DR imaging, as they impair diagnosis. They may also obscure pathology and in some instances may result in repeat exposure. Bushong (2008:487) identified three main categories of DR imaging artefacts, namely IR artefacts, software artefacts and object artefacts. Image artefacts may cause an image to be repeated and/or impair image quality. The results of this study indicate that DR artefacts were not covered in the study guides analysed (see Section 4.1.7). However, more than 80% of the radiographers in Phase 2 fully agreed that they could identify whether a digital image had an artefact; just less than 60% fully agreed they could classify artefacts into the three main categories, while only around

43.86% fully agreed that they could identify the cause(s) of the artefacts (see Section 4.2.10).

#### 6.2.2.2 Dynamic Range

The dynamic range of a digital imaging system refers to the ability of “a detector to accurately capture the range of photon intensities that exit the patient” (Fauber, 2017:83). This feature is essential, as it is the bedrock of post-processing in DR imaging. DR systems have a wider dynamic range than SF systems. It should be noted that these features have been adequately covered in the analysed image recording study guides of institutions of higher learning offering undergraduate diagnostic radiography (see Section 4.1.9).

### 6.2.3 Essential Digital Radiography Features to be Covered on an Elementary Level

The DR features discussed in this section are regarded as essential baseline knowledge for diagnostic radiographers to benefit optimally from a DR imaging system. However, the following two features should only be discussed at an elementary level in the undergraduate programme, as they do not necessarily affect the technique and imaging principles: display monitors and computers (hardware and software). It is also important to note that these features are of importance at managerial level to aid in the process of procurement.

#### 6.2.3.1 Display Monitors

The Phase 1 results indicate that display monitors are at most inadequately covered in the study guides of some institutions, while they are not covered at all in the study guides of other institutions (see Section 4.1.5). Image quality in DR is affected not only by the acquisition parameters and computer processing, but also by the type and performance of display monitors (Fauber, 2017:95). Butt and Savage (2015:240) further indicate that “display monitors inevitably degrade the information contained in an image.” This makes it vital to ensure that certain measures are taken to limit this loss as much as possible. Primary grade display monitors (i.e. radiologist reporting monitors) and secondary grade display monitors (i.e. radiographer work station monitors) are generally the two types of monitors in use in an imaging facility. Primary grade monitors are used for reporting and should therefore be of high quality to allow optimal visualisation of small nodules (pathology). However, secondary grade display monitors are of lower quality. These are used by radiographers to accept or reject images before these are sent to the radiologists for reporting; they are therefore not required to be of the same high quality as the reporting monitors. According to Hirschorn, Krupinski and Flynn (2014:1270), poor quality monitor displays could result in misdiagnoses, as well as radiographer eyestrain and fatigue. Ideally, the undergraduate DR curriculum should at least address baseline (elementary) information on display monitors, monitor orientation, monitor and image quality, types of monitors and the quality control of display monitors.

#### 6.2.3.2 Computers (Hardware and Software)

Indrajit (2013:17) highlights that computers are an integral part of many activities in an imaging facility. According to Floyd *et al.,* (2015:321), radiographers' perception of using PACS is dependent on their general competency to use computers. The Phase 2 results indicate that two thirds (66.08%) of the survey respondents have had some form of formal computer training (see Section 4.2.5). In addition, the Phase 1 results (see Table 5.1) indicate that computer hardware and software are adequately covered in the study guides of some institutions, but not covered in the study guides of other institutions. Since computer hardware and software form the foundation of DR technology, it should be incorporated in the DR curriculum. However, it is worth mentioning that basic computer skills and knowledge may be covered in general computer skills subjects, whereas DR-specific knowledge about computers should be covered by DR-specific subjects.

## 6.3 NON-ESSENTIAL DIGITAL RADIOGRAPHY FEATURES

The DR features discussed in this section are regarded as non-essential in terms of inclusion in the undergraduate DR curriculum. However, awareness of these features can optimise diagnostic radiographers' utilisation of DR imaging systems. As such, these features should preferably only be discussed on a basic level, as they are mostly technical in nature. Note that the non-essential features do not necessarily affect patient dose or image quality, but may improve departmental efficiency and may play a role in managerial decisions, especially when procuring new equipment. Given this context, the following features are regarded as non-essential in this study: accessories

in digital imaging, information communication standard, information systems (clinical and administrative) and console features.

### 6.3.1 Accessories in Digital Imaging

The accessories of DR may include the following: compact disc robot, digitiser and simulated computerised programmes. The Phase 1 results of the study highlights that these features are hardly ever or never incorporated in the study guides analysed (see Section 4.1.11). These features must be incorporated in a DR curriculum and the mode of delivery must be on a basic level. These features become important, for example, when patient data should be stored on a compact disc or when an SF image has to be digitised.

### 6.3.2 Information Communication Standard

The Phase 1 results indicate that this feature is differentially covered from adequately to not at all in the study guides of the participating institutions (see Section 4.1.2). In addition, the Phase 2 results indicate that only around 60% of the respondents could identify the communication protocol in their radiographic practice, while almost 10% of the respondents fully disagreed that they could do so (see Section 4.2.11). According to Blazona & Koncar (2007:S425) the two primary communication protocol standards in an imaging facility are digital imaging and communication in medicine (DICOM) and Health Level 7 (HL7). They further indicate that DICOM specifies the network communication rules and the physical data format to enable communication between modalities and humans through software solutions developed, while the HL7 standard

represents the foundation of many healthcare information management systems (Blazona & Koncar 2007:S426). DICOM and HL7 should be discussed as part of the non-essential part of the DR curriculum. These features may be of assistance at managerial level when an imaging facility intends to purchase radiographic equipment or PACS. In addition, knowledge of these features may assist in student training.

### 6.3.3 Information Systems (Clinical and Administrative)

According to Seeram (2011:207), health information systems can be classified into two broad categories, namely: 1) CIS; and 2) AIS. CIS inter alia includes the RIS and monitoring systems, while AIS is used for patient registration and scheduling, financial payroll and quality assurance functions. The Phase 1 results indicate that this feature and its components are differentially covered from adequately to not at all in the study guides of the participating institutions (see Section 4.1.8). The information systems should form part of the DR non-essential curriculum in order to create awareness among radiographers of these features and their importance in clinical application. These features are of significant importance in patient administration, as well as in communicating images in an imaging facility.

### 6.3.4 Console Features

The features on the console menu may have medico-legal implications, for example the time setting adjustment feature on the console may be required to display the correct time on an image). The Phase 2 results (see Section 4.2.8) indicate that between 20% and 63% of the respondents fully agreed that they could operate the

various console features. However, the Phase 3 results (see Table 5.2) indicate that diagnostic radiographers were mostly not interested in using the console setting feature.

The following console panel settings features should ideally form part of the DR non-essential curriculum in order to create awareness among radiographers of matters relating to medico-legal aspects, identifying error messages on a console and adding new radiographic procedures on the system:

- set/adjust time;
- adjust the volume and tone of sound;
- synchronise different messages with different light colours (e.g. error message with red light flash);
- programme specific exposure factors to demonstrate applicable radiographic anatomy;
- edit pre-programmed procedures; and
- add a new procedure on the system.

## 6.4 SUMMARY OF DIGITAL RADIOGRAPHY CURRICULUM FRAMEWORK

The curriculum for undergraduate DR training should ideally cover a number of DR features regarded as essential (see Section 6.2) and others that are non-essential (see Section 6.3). The various essential DR features should be covered in depth (see Section 6.2.1), moderately (see Section 6.2.2) or on an elementary level (see Section 6.2.3), depending on their impact and link to the four radiography “pillars”, namely the patient, radiation dose, imaging facility efficiency and radiographic image quality. Even

though the non-essential DR features (see Section 6.3) are not compulsory, they should ideally be offered on an elementary and introductory basis in the DR curriculum to ensure that radiographers are aware of such features. Table 6.1 provides a summary of the undergraduate DR curriculum aspects of the DR features discussed in the previous sections.

## 6.5 CONCLUSION

A comprehensive DR curriculum framework should cover the essential features presented in depth and nonessential ones presented on moderate and elementary level, as well as non-essential DR features.

Table 6.1: Curriculum framework for undergraduate DR training programmes. Note that the various section numbers are indicated in brackets to facilitate cross-referencing to the content of this chapter.

| ESSENTIAL FEATURES (6.2) | | | NON-ESSENTIAL FEATURES (6.3) |
|---|---|---|---|
| **In-depth Coverage (6.2.1)** | **Moderate Level Coverage (6.2.2)** | **Elementary Level Coverage (6.2.3)** | |
| DR imaging systems (6.2.1.1) | DR artefacts (6.2.2.1) | Display monitors (6.3.3.1) | Accessories in digital imaging (6.3.1) |
| PACS (6.2.1.2) | Dynamic range (6.2.2.2) | Computers (hardware and software) (6.3.3.2) | Information communication standard (6.3.2) |
| DR quality control (6.2.1.3) | | | Information systems (6.3.3) |
| Image processing (6.2.1.4) | | | Console features (6.3.4) |
| Exposure index (6.2.1.5) | | | |
| DR exposure technique charts (6.2.1.5) | | | |

The following chapter presents a summary of conclusions for Phases 1, 2 and 3 of the study. It also makes recommendations based on the findings.

# CHAPTER 7

# CONCLUSIONS AND RECOMMENDATIONS

## 7.1 INTRODUCTION

This chapter summarises the main research findings that arose from this study (see Section 7.2). Furthermore, it makes some recommendations (see Section 7.3), highlights the strengths, limitations and challenges of the study (see Sections 7.4 to 7.6), and presents the main implications of the study (see Section 7.7).

## 7.2 SUMMARY OF THE MAIN RESEARCH FINDINGS

The first objective of this study (see Section 1.3) was to investigate the incorporation of formal DR image recording concepts and themes in the undergraduate diagnostic radiography curricula being offered at institutions of higher learning in South Africa. The following Phase 1 findings transpired during the study:

- The study guide content mostly focused on SF radiography, while DR content and concepts were incorporated to different degrees by the participating institutions of higher learning offering undergraduate diagnostic radiography.
- The following DR features are *adequately* covered in the undergraduate diagnostic radiography curricula offered at most of the participating institutions of higher learning in South Africa (see Table 5.1): computer hardware and software, FPDs, the CIS, administrative information system, dynamic range and SNR.

- The following DR features are *inadequately* covered in the undergraduate diagnostic radiography curricula offered at most of the participating institutions of higher learning in South Africa (see Table 5.1): PACS; image transmission, the look-up table, laser printers, exposure technique charts, spatial frequency, spatial resolution SNR, and RFA.
- The following DR features are *not covered* in the undergraduate diagnostic radiography curricula offered at most or all of the participating institutions of higher learning in South Africa (see Table 5.1): computer networking, display monitors, PACS monitors, digital artefacts, changing time settings, adding a new protocol, switching on and off collimator shutters, accessories in digital imaging, and CR image processing, different types of unit readers and exposure control in CR.

The second objective of this study (see Section 1.3) was to investigate the application and utilisation of the various DR features by diagnostic radiographers in clinical practice in South Africa. Generally, diagnostic radiographers in clinical practice utilise various DR features. However, the study also found that some radiographers have insufficient knowledge of specific DR features even though they might actually be using such features on a day-to-day basis. In this regard, it is important to note that diagnostic radiographers may gain knowledge of the application and utilisation of the various DR features from three main sources, namely undergraduate training at institutions of higher learning, colleagues in clinical practice and training and advice offered by application specialists (industry representatives). The following Phase 2 findings transpired during the study:

- Clinical facilities have migrated from SF to CR and FPDs, with only 9.48% of the respondents still utilising SF (see Table 4.3 and Figure 4.3.).
- Most clinical radiographers (66.08%) have attended formal computer training (see Section 4.2.5).
- The Phase 2 findings (see Table 4.6) indicate that radiographers frequently utilise the patient administration and registration features; it is utilised by more than 80% of the participating radiographers.
- The following are post-processing tools (see Table 4.7) which radiographers seem to be familiar with: adjust brightness and contrast, enhance image quality by using edge enhancement, rotate digital image, post-processing collimation, switch on and off collimator shutters, and image magnification. It is also worth noting that radiographers seemed to be less familiar with the application of the following features: access and interpretation of image histogram, the use of look-up table, checking the exposure latitude on the display monitor, as well as changing the exposure index (see Section 4.2.7).
- The application and utilisation of DR unit console features by radiographers range between 20% and 63% of those who fully agree that they can operate the respective DR console unit features, whereas between 7.8% and 19.1% of radiographers fully disagree that they can operate the respective DR console unit features (see Section 4.2.8).
- The utilisation and application of DR system QC features by radiographers range between 17.4% and 57% of the respective features (see Section 4.2.9). In particular, the RFA feature is not optimally utilised by practicing diagnostic radiographers.

- The radiographers indicated that they generally embrace and utilise computers and IT in their facilities to enhance their day to day job responsibilities (see Section 4.2.11).
- Only 38% of the participating radiographers indicated that they've never attended a DR training course, while almost 20% indicated they had attended a DR training course within the previous year. A further 9.3% have attended a DR training course within the previous 2-3 years and 33% have attended such a course more than 3 years ago (see Section 4.2.12).

The third objective of this study (see Section 1.3) was to investigate practising diagnostic radiographers' perceptions of the utilisation of DR features in South Africa. Generally, the diagnostic radiographers in clinical practice are in agreement that DR features are sub-optimally utilised. In this regard, this following challenges were highlighted:

- The DR features that are *hardly ever or never used* by diagnostic radiographers in clinical practice include the following (see Section 4.3.1.1): image stitching, calibration, measurements, edge enhancement, image histogram analysis, collimator shutters, look-up-tables, console light adjustments, console time setting, PACS image tag and add new protocol.
- The DR features of which diagnostic radiographers in clinical practice have *no knowledge* include the following (see Section 4.3.1.3): look-up-table, types of DR imaging systems, EI, change time settings on console and communication protocols.

- The DR features diagnostic radiographers in clinical practice are not interested in using include the following (see Section 4.3.1.4): console time settings, collimator shutters and image histogram analysis.
- The DR features on which diagnostic radiographers in clinical practice reported a *deeper level of understanding and frequent use* in their day-to-day operations include the following (see Section 4.3.1.2): contrast and density manipulation, annotations, image cropping, EI, RFA, auto-positioning of x-ray equipment and patient administration parameters.
- DR is the imaging modality of choice in comparison to SF. This is primarily due to various advantages of the DR system, namely a lower radiation dose to the patient, no wet chemistry processing and higher workflow efficiency.

- The organisational and job structure for diagnostic radiographers in terms of job responsibilities and priorities make it difficult for radiographers to utilise DR features optimally, specifically because of the differential allocation of radiographers to managerial, quality control and operational (clinical) duties.
- The seemingly inadequate DR knowledge of medical practitioners who request x-ray services further serves as a limiting factor for radiographers; in these cases the requesting medical practitioners do not request or do not know that they can request certain DR applications and features.
- The areas of professional overlap between application specialists, IT practitioners and diagnostic radiographers pose a challenge, as there is no clarity on the professional responsibilities of each in relation to the application of DR features in a clinical context.

- Diagnostic radiographers view delegated responsibilities as a barrier to the use of DR features, as only a few radiographers in an imaging facility may have access codes (i.e. passwords) to access the menu settings for functions such as RFA.

## 7.3 RECOMMENDATIONS

This section presents recommendations to the following stakeholders: institutions of higher education offering diagnostic radiography in undergraduate training; diagnostic radiography clinical practice, future researchers, industry (DR equipment manufacturers) and the HPCSA.

### 7.3.1 Institutions of Higher Learning Offering Undergraduate Diagnostic Radiography

The following recommendations for institutions of higher learning offering undergraduate diagnostic radiography programmes emerged from the study:

- A proposed curriculum framework (see Chapter 6, Table 6.1) may serve as a guideline to curriculum developers and institutions of higher education in the process of recurriculation for four-year undergraduate diagnostic radiography programmes.
- Institutions of higher learning may use the findings of this study (Chapters 4 and 5) to design an accredited induction/refresher course for diagnostic radiographers who have predominantly been trained in using the SF system.
- The proposed curriculum framework (see Chapter 6, Table 6.1) and the findings of this study (Chapters 4, 5 and 6) may provide guidance and insight to

institutions of higher learning that offer training programmes for medical students (undergraduate level), as well as radiologists (postgraduate level). This may ultimately result in more effective utilisation of DR features when patients are referred to imaging facilities for diagnostic imaging procedures.

- Institutions of higher learning offering undergraduate diagnostic radiography programmes should ideally reduce the SF-focused credits to below 30% of the total programme credits in the next few years, while increasing the DR-focused credits to 70% of the total programme credits.

### 7.3.2 Diagnostic Radiography Clinical Practice

The following recommendation on diagnostic radiography clinical practice emerged from the study:

- Diagnostic radiography clinical practice should review the organisational structures that delegate specific job responsibilities and priorities to radiographers, specifically to ensure that all practising diagnostic radiographers are duly exposed to all sections of an imaging facility. This may enhance radiographers' job satisfaction and increase their overall knowledge and experience in utilising all the relevant DR features. This also includes a recommendation that clinical facilities should consider allowing more diagnostic radiographers to have access (i.e. passwords) to DR functions traditionally only allocated to specific individuals, such as the QC radiographer. This may ensure that more diagnostic radiographers learn and are exposed to the different features offered by DR, which may ultimately improve the utilisation rate and patient benefit of such features.

### 7.3.3 Future Research

The following recommendations for future research emerged from the study:

- Future researchers may replicate the survey phase (Phase 2) of this study with a bigger sample and using a wider variety of recruitment strategies. The response rate in the current study was relatively low, which means that the results should be interpreted with caution.
- Future researchers should inter alia conduct a study on the incorporation of DR features in the undergraduate curriculum for medical practitioners. Another study that investigates the utilisation rate of DR features by medical practitioners in South African public hospitals should be conducted.

### 7.3.4 Industry (Digital Radiography Equipment Manufacturers)

The following recommendations for the industry (DR equipment manufacturers) emerged from the study:

- The findings of this study (especially as reported in Chapter 5) can be used to emphasise the clinical importance of the DR features that radiographers hardly ever or never use, the features about which radiographers have no knowledge, and the features that radiographers are not interested in using.
- Industry-based training courses should ideally incorporate at least some form of formal assessment (summative) at the end of training sessions to ensure some level of knowledge assimilation and integration. This form of assessment may be done in addition to the practical demonstrations currently offered.

### 7.3.5 Health Professions Council of South Africa

The following recommendations for the HPCSA emerged from the study:

- Since the inception of formal diagnostic radiography as a profession in 1953 (Engel-Hills, 2005:24), the scope of practice (gazetted in 1976, amended in 1979, reviewed in 1991 and 1997) has remained almost the same until in 2018. However, in response to the rapid change in imaging technology and its impact on the professional role of diagnostic radiographers in an imaging facility, the formal scope of practice should ideally be reviewed at five-year intervals.
- DR technology is a very dynamic and fast-developing area. For institutions of higher learning to stay abreast of the latest developments, requirements and challenges, it is recommended that the academic committee of the HPCSA's Radiography and Clinical Technology Board initiate a process of recurriculation/revision or programme audit for accreditation of diagnostic radiography curricula at five-year intervals to ensure alignment with current DR trends. This may ultimately result in graduates who are highly employable.

## 7.4 STRENGTHS OF THE STUDY

The overall quality and applicability of the study are characterised by the following significant strengths:

- A mixed methods approach involving three phases was followed in this study to address the study objectives. Qualitative as well as quantitative approaches of data gathering were uses to gather data. This enhanced the principle of triangulation.

- The researcher used a variety of widely accepted data collection strategies and data collection instruments to collect the data in Phases 1, 2 and 3 (see Chapter 3). The various data collection instruments were developed and designed with inputs from industry-based DR specialists, academics in higher education institutions, as well experienced diagnostic radiographers in clinical practice. Furthermore, the analysis of data for Phases 1 and 3 was done under the strict supervision of peer reviewers.

## 7.5 LIMITATIONS

The following study limitations were identified:

- Concerns about institutional anonymity and institutional reputation were notable limitations in Phase 1 of the study. A number of institutions of higher learning offering undergraduate diagnostic radiography declined to release their imaging study guides for content analysis. The results of Phase 1 are consequently only based on the documentation of three institutions, which limits the generalisability of the results and interpretations. In addition, the location of all the Phase 3 research sites in the Tshwane region may have introduced some regional bias. However, it should be noted that the research sites included imaging facilities in the private and public health sectors. This became the real limitation of this study, as other DR concepts such as PACS may have been covered in other modules not analysed by this study.
- Because of the time constraints on this project, radiologists' knowledge of DR features and the utilisation rate was not investigated. This may be considered

a limitation, as it could have added significant insights in the general DR knowledge of the end-users of DR imaging technology.

## 7.6 CHALLENGES

This project encountered an ethical challenge in the Phase 2 survey when members of SORSA lodged a complaint regarding the manner in which the researcher inadvertently used their members' E-mail addresses in a "To" instead of "Bcc" manner to distribute invitations to participate in the survey (see Section 3.4.7). The research matter was resolved when the researcher provided SORSA with a detailed explanation of the legitimate research process followed and offered a sincere formal apology to the affected parties.

## 7.7 IMPLICATIONS OF THE STUDY

This study investigated the DR curriculum coverage of institutions of higher learning offering undergraduate diagnostic radiography. The study further highlights the utilisation rate of DR features by diagnostic radiographers as well as the perceptions of diagnostic radiographers about the utilisation of DR features. As such, this study contributes new insights regarding the DR features in clinical practice that are commonly, hardly or never used, features in which radiographers are not interested and features of which radiographers have no knowledge. Furthermore, the study proposed a DR curriculum framework for institutions of higher learning that can be used during the process of recurriculation or for short learning programmes.

## 7.8 A FINAL WORD

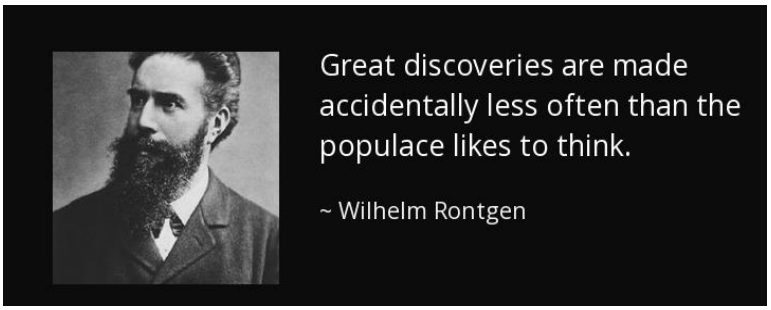



Image source: www.azquotes.com (Accessed: 1 March 2018) [5]

[5] Permission to use image granted by Jane Smith (per E-mail) on 1 March 2018

# REFERENCE LIST

AZPIRI-LÓPEZ, J.R., ASSAD-MORELL, J.L., GONZÁLEZ-GONZÁLEZ, J.G., ELIZONDO-RIOJAS, G., DÁVILA-BORTONI, A. GARCÍA-MARTÍNEZ, R. & TREVIÑO-FRUTOS, R. 2013. Effect of physician training on the X-ray dose delivered during coronary angioplasty. *Journal of Invasive Cardiology*, *25*(10), pp. 109-113.

BENSUSAN, A.D. 1967. Early history of radiography in South Africa 1896-1900. *South African Medical Journal*, *41*(31), pp.778-781.

BLAZONA, B. & KONCAR, M. 2007. HL7 and DICOM based integration of radiology departments with healthcare enterprise information systems. *International Journal of Medical Informatics*, *76*, pp.S425-S432.

BOSHOFF, C. & GRAY, B. 2004. The relationships between service quality, customer satisfaction and buying intentions in the private hospital industry. *South African journal of business management*, *35*(4), pp.27-37.

BOWEN, G.A. 2009. Document analysis as a qualitative research method. *Qualitative Research Journal*, *9*(2), pp.27-40.

BUSCH, H.P. & FAULKNER, K. 2005. Image quality and dose management in DR: a new paradigm for optimisation. *Radiation Protection Dosimetry*, *117*(1-3), pp.143-147.

BUSHONG, S.C. 2008. *Radiologic science for technologists: physics, biology and protection.* 9th ed. St. Louis: Mosby Elsevier.

BUTT, A. & SAVAGE, N.W. 2015. Digital display monitor performance in general dental practice. *Australian Dental Journal*, *60*(2), pp.240-246.

CAO, X. & HUANG, H.K. 2000. Current status and future advances of digital radiography and PACS. *IEEE engineering in medicine and biology magazine*, *19*(5), pp.80-88.

CARLTON, R.R. & ADLER A.M. 2006. *Principles of radiographic imaging: an art and a science.* 4th ed. New York: Delmar.

CARROL, B.Q. 2007. *Practical radiographic imaging.* 8th ed. Springfield: Thomas Publisher.

CHANNIN, D.S., MONGKOLWAT, P., KLEPER, V. & RUBIN, D.L. 2009. The annotation and image mark-up project. *Radiology,* 253:pp. 590-592.

CHAUDHRY, B., WANG, J., WU, S., MAGLIONE, M., MOJICA, W., ROTH, E., MORTON, S.C. & SHEKELLE, P.G. 2006. Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. *Annals of Internal Medicine*, *144*(10), pp.742-752.

COWAN, I., SMITH, T., NAKABEA, P., AJIBULU, O. & HENNESSY, O. 2007. Developing the image interpretation skills of South Pacific radiographers: a joint WHO/RANZCR/ISRRT project. *Journal of Medical Imaging and Radiation Oncology*, *51*(6), pp.527-531.

CRESWELL, J.W. (2008) 'Mixed Methods Research: Design and Procedures'. [PowerPoint presentation] Accessed: 15/02/2018

CRESWELL, J.W. (2013). *Research design, qualitative and quantitative approaches.* Thousand Oaks, CA: Sage.

CRESWELL, J. W. & PLANO CLARK, V. L. 2011. *Designing and conducting mixed methods research.* 2nd ed. Thousand Oaks, CA: SAGE.

CULLINAN, K. 2006. Health services in South Africa: a basic introduction. *Health-e News Service* [On line]. Available from: https://www.health-e.org.za/wp-content/uploads/2013/04/Health_services_briefing_doc.pdf
[Accessed: 18/04/2018]

DOBBINS, J.T., ERGUN, D.L., RUTZ, L., HINSHAW, D.A., BLUME, H. & CLARK, D.C. 1995. DQE (f) of four generations of computed radiography acquisition devices. *Medical Physics*, *22*(10), pp.1581-1593.

DOI, K. 2006. Diagnostic imaging over the last 50 years: research and development in medical imaging science and technology. *Physics in Medicine and Biology*, *51*(13), pp.R5-R27.

DROST, W.T., REESE, D.J. & HORNOF, W.J. 2008. Digital radiography artifacts. *Veterinary Radiology & Ultrasound*, *49*(s1), pp. S48-S56.

EDMONDS, W. A. & KENNEDY, T. D. 2013. *An applied reference guide to research designs: quantitative, qualitative and mixed methods.* Thousand Oaks, CA: SAGE.

ENGEL-HILLS, P.C. 2005. An integrated approach to curriculum. *The South African radiographer*, *43*(2), pp. 24-27.

FARHADI, A. & AHMADI, M. 2013. The information security needs in radiological information systems—an insight on state hospitals of Iran. *Journal of Digital Imaging*, 26(6), pp. 1040–1044.

FARMELO, G. 1995. The discovery of X-rays. *Scientific American*, *273*(5), pp.86-91.

FAUBER T.L. 2009.*Radiographic imaging and exposure.* 3rd ed. Missouri: Elsevier

FAUBER T.L. 2017.*Radiographic imaging and exposure.* 5th ed. Missouri: Elsevier

FEIGENSON, N. 2010. Visual evidence. *Psychonomic Bulletin & Review*, *17*(2), pp.149-154.

FLOYD, D.M., TREPP, E.R., IPAKI, M. & NG, C.K. 2015. Study of radiologic technologists' perceptions of picture archiving and communication system (PACS) competence and educational issues in Western Australia. *Journal of Digital Imaging*, *28*(3), pp.315-322.

FRANKEN, M., GRIMM, B. & HEYLIGERS, I. 2010. A comparison of four systems for calibration when templating for total hip replacement with digital radiography. *Bone & Joint Journal*, *92*(1), pp.136-141.

FROST & SULLIVAN. 2008. Rrealizing the full operational and cost benefits of direct digital radiography. A Frost & Sullivan white paper [On line]. Available from: http://www.swissray.com/downloads/casestudies/SwissrayWhitepaper_10_2008.pdf [Accessed:10/03/2014].

GAM, N.P. 2015. *Occupational stressors in diagnostic radiographers working in public health facilities in the eThekwini district of KwaZulu-Natal.* M. Tech. dissertation, Durban University of Technology

GIJBELS, F., SANDERINK, G., WYATT, J., VAN DAM, J., NOWAK, B. & JACOBS, R. 2004. Radiation doses of indirect and direct digital cephalometric radiography. *British Dental Journal*, *197*(3), pp.149-152.

GUNN, C. 2009. *Digital and radiographic imaging: a practical approach.* Churchhill Livingstone: Elsevier.

HARGREAVES, J. & MACKAY, S. 2003. The accuracy of the red dot system: can it improve with training? *Radiography*, *9*(4), pp.283-289.

HAUS, A.G. & CULLINAN, J.E. 1989. Screen film processing systems for medical radiography: a historical review. *Radiographics*, *9*(6), pp.1203-1224.

HIRSCHORN, D.S., KRUPINSKI, E.A. & FLYNN, M.J. 2014. PACS displays: how to select the right display technology. *Journal of the American College of Radiology*, *11*(12), pp.1270-1276.

INDRAJIT, I.K. 2007. Digital imaging and communications in medicine: A basic review. *Indian journal of radiology & imaging,* 17(1), pp. 5-7.

INDRAJIT, I.K. 2013. Computers in radiology: few recent advances. *Journal of international medical sciences academy*, *26*(1). pp. 17-20.

JOHNSON, R.B., ONWUEGBUZIE, A.J. & TURNER, L.A. 2007. Towards a definition of mixed methods research. *Journal of mixed methods research*, 2(1), pp. 112–133.

JORWEKAR, G.J., DANDEKAR, K.N. & BAVISKAR, P.K. 2015. Picture archiving and communication system (PACS): clinician's perspective about filmless imaging. *Indian Journal of Surgery*, *77*(3), pp.774-777.

KAPLOWITZ, M.D., HADLOCK, T.D. & LEVINE, R. 2004. A comparison of web and mail survey response rates. *Public Opinion Quarterly*, *68*(1), pp.94-101.

KORNER, M., WEBER, C.H., WIRTH, S., PFEIFER, K.J., REISER, M.F. & TREITL, M. 2007. Advances in digital radiography: physical principles and system overview. *Radiographics*, *27*(3), pp.675-686.

KREFTING, L. 1991. Rigor in qualitative research: the assessment of trustworthiness. *The American Journal of Occupational Therapy,* 45(3), pp.214-222.

KRUPINSKI, E.A., WILLIAMS, M.B., ANDRIOLE, K., STRAUSS, K.J., APPLEGATE, K., WYATT, M., BJORK, S. & SEIBERT, J.A. 2007. Digital radiography image quality: image processing and display. *Journal of the American College of Radiology*, *4*(6), pp.389-400.

LAMBERT, V. & GLACKEN, M. 2005. Clinical education facilitators: a literature review. *Journal of Clinical Nursing*, *14*(6), pp.664-673.

LEEDY, P.D. & ORMROD, J.E. 2005. *Practical research: planning and design*. 8th ed. New Jersey: Pearson Education.

LEEDY, P.D. & ORMROD, J.E. 2013. *Practical research: planning and design*. 10th ed. New Jersey: Pearson Education.

LEEDY, P.D. & ORMROD, J.E. 2015. *Practical research: planning and design*. 11th ed. New Jersey: Pearson Education.

LEHNERT, T. NAGUIB, N.N. ACKERMANN, H. SCHOMERUS, C. JACOBI, V. BALZER, J.O. & VOGL, TJ. 2011. Novel, portable, cassette-sized, and wireless flat-panel digital radiography system: initial workflow results versus computed radiography, *American journal of roentgenology,* 196, pp.1368-1371.

LOUW, A. 2018. High Fidelity Simulation – based Training in Radiography. University of Johannesburg. Available from: https://www.researchgate.net/publication/322339522_High_Fidelity_Simulation-Based_Training_in_Radiography [Accessed:16/04/2018].pp. 263 - 287

LUDEWIG, E., BOELTZIG, C., GAEBLER, K., WERRMANN, A. & OECHTERING, G. 2011. Display quality of different monitors in feline digital radiography. *Veterinary Radiology & Ultrasound*, *52*(1), pp.1-9.

MAKANJEE, C.R. 2004. The effect of occupational stress and organizational commitment on diagnostic imaging radiographers in rendering quality service. M. Rad. dissertation, University of Pretoria.

MAKANJEE, C.R., BERGH, A.M. & HOFFMANN, W.A. 2014. A model for understanding diagnostic imaging referrals and complex interaction processes within the bigger picture of a healthcare system. *Radiography*, *20*(2), pp.153-157.

MALFAIR, D., FLEMMING, A.K., DVORAK, M.F., MUNK, P.L., VERTINSKY, A.T., HERAN, M.K. & GRAEB, D.A. 2010. Radiographic evaluation of scoliosis. *American Journal of Roentgenology*, *194*(3_supplement), pp.S8-S22.

MAREE, K. CRESWELL, J. W. EBERSÖHN, L. ELOFF, I. FERREIRA, R. IVANKOVA, N. JANSEN, J. D. NIEUWENHUIS, J. PIETERSON, J. PLANO CLARK, V. L. & VAN DER WESTHUIZEN, C. 2012. *First steps in research.* 11th ed. Pretoria: Van Schaik.

MAY, G.A., DEER, D.D. & DACKIEWICS, D. 2000. Impact of digital radiography on clinical workflow. *Journal of digital imaging,* 13(2), pp. 76-78.

MINNIGH, T.R. & GALLET, J. 2009. Maintaining quality control using a radiological digital X-ray dashboard. *Journal of Digital Imaging*, *22*(1), pp.84-88.

MOODLEY, I. & MOODLEY, S. 2015. A comparative cost analysis of picture archiving and communications systems (PACS) versus conventional radiology in the private sector. *South African Journal of Radiology*, *19*(1), pp.1-7.

MOUTON, J. 2011. *How to succeed in your master's & doctoral studies: A South African guide and resource book*. 15th ed. Pretoria: Van Schaik.

MUBUUKE, A.G., KIGULI-MALWADDE, E., BYANYIMA, R. & BUSINGE, F. 2008. Evaluation of community based education and service courses for undergraduate radiography students at Makerere University, Uganda. *Rural and remote health*, *8*(4), pp. 976.

MUNGOMBA, B. 2016. *Core competencies of radiographers working in rural areas of South Africa* Doctoral Health Science dissertation, Pretoria, University of South Africa.

NALLON, A.M., HERITY, B. & BRENNAN, P.C. 2000. Do symptomatic radiographers provide evidence for 'darkroom disease'? *Occupational Medicine*, *50*(1), pp.39-42.

NANCE JR, J.W., MEENAN, C. & NAGY, P.G., 2013. The future of the radiology information system. *American Journal of Roentgenology*, *200*(5), pp.1064-1070.

NYATHI, T. CHIRWA, T.F. & VAN DER MERWE, D.G. 2010. A survey of digital radiography practice in four South African teaching hospitals: an illuminative study. *Biomedical imaging and intervention journal*, 6(1), pp.1-6.

OFFIAH, A.C., MOON, L., HALL, C.M. & TODD-POKROPEK, A. 2006. Diagnostic accuracy of fracture detection in suspected non-accidental injury: the effect of edge enhancement and digital display on observer performance. *Clinical Radiology*, 61(2), pp.163-173.

PATEL, R.J. 2005. Digital applications of radiography. Proceedings of 3rd Middle East Non-destructive Testing Conference & Exhibition.

PILLAY, R. 2008. Managerial competencies of hospital managers in South Africa: a survey of managers in the public and private sectors. *Human Resources for Health*, *6*(1), pp.1-7.

PONGNAPANG, N. 2005. Practical guidelines for radiographers to improve computed radiography image quality. *Biomedical Imaging and Intervention Journal*, *1*(2), pp. 1-5.

POON, E.G., JHA, A.K., CHRISTINO, M., HONOUR, M.M., FERNANDOPULLE, R., MIDDLETON, B., NEWHOUSE, J., LEAPE, L., BATES, D.W., BLUMENTHAL, D. & KAUSHAL, R. 2006. Assessing the level of healthcare information technology adoption in the United States: a snapshot. *BMC Medical Informatics and Decision Making*, *6*(1), pp.1-9.

PUCHALSKI, S.M., 2008. Image display. *Veterinary Radiology & Ultrasound*, *49* (1), pp. S9-S13

RANKOV, V., LOCKE, R.J., EDENS, R.J., BARBER, P.R. & VOJNOVIC, B. 2005, March. An algorithm for image stitching and blending. In *Proceedings of the International Society for Optics and Photonics* (Vol. 5701, pp. 190-199).

RAHOMA, U.A. & CHUNDI, P.K. 2012. Economic evaluation of conventional radiography with film and computed radiography: applied at BMC. *Advances in Computed Tomography*, *1*(03), p.23.

RASSIN, M., GRANAT, P., BERGER, M. & SILNER, D. 2005. Attitude and knowledge of physicians and nurses about ionizing radiation. *Journal of radiology nursing*, *24*(2), pp.26-30.

REED, A.B., 2011. The history of radiation use in medicine. *Journal of vascular surgery*, *53*(1), pp.3S-5S.

ROWLANDS, J.A. & YORKSTON, J., 2000. Flat panel detectors for digital radiography. *Handbook of Medical Imaging*, *1*, pp.223-328.

SAMEI, E., SEIBERT, J.A., ANDRIOLE, K., BADANO, A., CRAWFORD, J., REINER, B., FLYNN, M.J. & CHANG, P. 2004. AAPM/RSNA tutorial on equipment selection: PACS equipment overview: general guidelines for purchasing and acceptance testing of PACS equipment. *Radiographics*, *24*(1), pp. 313-334.

SCHAEFER-PROKOP, C., NEITZEL, U., VENEMA, H.W., UFFMANN, M. & PROKOP, M. 2008. Digital chest radiography: an update on modern technology, dose containment and control of image quality. *European Radiology*, 18(9), pp.1818-1830.

SEERAM, E. 2011. *Digital radiography: an introduction*. New York: Delmar Cengage Learning.

SEERAM, E., DAVIDSON, R., BUSHONG, S. & SWAN, H. 2013. Radiation dose optimization research: exposure technique approaches in CR imaging – a literature review. *Radiography*, *19*(4), pp.331-338.

SEERAM, E. & SEERAM, D. 2008. Image postprocessing in digital radiology — a primer for technologists. *Journal of Medical Imaging and Radiation Sciences*, *39*(1), pp.23-41.

SIEGEL, E. & REINER, B. 2002. Work flow redesign: the key to success when using PACS. *American Rournal of Roentgenology*, *178*(3), pp.563-566.

SLABBERT, S. 2018. [Telephone conversation on number of beds in private hospitals in South Africa] (personal communication, 14 March 2018).

SONODA, M., TAKANO, M., MIYAHARA, J. & KATO, H. 1983. Computed radiography utilizing scanning laser stimulated luminescence. *Radiology*, *148*(3), pp. 833-838.

SOUTH AFRICAN QUALIFICATIONS AUTHORITY. 2017. *Homepage*. [Online]. Available from: www.saqa.org.za [Accessed: 04/09/2017]

THOMAS, A.M. & BANERJEE, A.K. 2013. *The history of radiology*. OUP Oxford.

UFFMANN, M. & SCHAEFER-PROKOP, C. 2009. Digital radiography: the balance between image quality and required radiation dose. *European Journal of Radiology*, *72*(2), pp. 202-208.

VENTER, D. 2008. Three-dimensional thinking in radiography. M. Tech. Radiography dissertation, Cape Town, Cape Peninsula University of Technology.

WAALER, D. & HOFMANN, B. 2010. Image rejects/retakes — radiographic challenges. *Radiation Protection Dosimetry*, *139*(1-3), pp.375-379.

WALSH, C., GORMAN, D., BYRNE, P., LARKIN, A., DOWLING, A. & MALONE, J.F. 2008. Quality assurance of computed and digital radiography systems. *Radiation Protection Dosimetry,* 129(1-3), pp.271-275.

WILLIAMS, M.B., KRUPINSKI, E.A., STRAUSS, K.J., BREEDEN, W.K., RZESZOTARSKI, M.S., APPLEGATE, K., WYATT, M., BJORK, S. & SEIBERT, J.A. 2007. Digital radiography image quality: image acquisition. *Journal of the American College of Radiology*, *4*(6), pp. 371-388.

WILLIS, C.E., 2004. Strategies for dose reduction in ordinary radiographic examinations using CR and DR. *Pediatric Radiology*, *34*(3), pp.S196-S200.

WINBERG, C. ENGEL-HILLS, P. GARRAWAY, J. & JACOBS, C, 2013. Professional knowledge and the purpose of professional higher education. Kagisano (special issue on the purpose of higher education).

YORKSTON, J. 2007. Recent developments in digital radiography detectors. *Nuclear instruments and methods in physics research section A: accelerators, spectrometers, detectors and associated equipment*, *580*(2), pp. 974-985.

ZENNARO, F., GOMES, J.A.O., CASALINO, A., LONARDI, M., STARC, M., PAOLETTI, P., GOBBO, D., GIUSTO, C., NOT, T. & LAZZERINI, M. 2013. Digital radiology to improve the quality of care in countries with limited resources: a feasibility study from Angola. *PloS One*, *8*(9), p.e73939.

# ANNEXURE A: RESEARCH ETHICS COMMITTEE APPROVAL (PHASE 1), TSHWANE UNIVERSITY OF TECHNOLOGY

Tshwane University of Technology

## Faculty Committee for Research Ethics [FCRE-SCI]

The TUT Senate Committee for Research Ethics is a registered Institutional Review Board (IRB 00005968) with the US Office for Human Research Protections (IORG# 0004997) (Expires 19 Jan 2014), Also, it itas Federal Wide Assurance for the Protection of Human Subjects for International Institutions (FWA 00011501) (Expires 31 Jan 2014). In South Africa it is registered with the national Health Research Ethics Council (REC-ã6û509-21).Yie;- e-ubcommittee of the TUT Senate

21 November 2014

| | |
|---|---|
| | Ref FCRE 2014/08/001 (2) (SCI) |
| | Name: Lamola, D |
| Student | 215470644 |

Mr D Lamola
Department of Biomedical Sciences

Dear Mr Lamola

Title: The utilization of digital radiography by diagnostic radiographers in South Africa
Investigator: Mr D Lamola Programme:
M Tech: Radiography
Supervisor: Dr WA Hoffmann
Co-supervisor: Dr MA van der Watt

The amended M Tech proposal has been reviewed by the Faculty of Science Committee for Research Ethics.

It was acknowledged that the recommendations as set out in the fetter dated 1 September 2014 were corrected and explained to the satisfaction of the FCRE.

Phase 1 of the project is approved. A report must be handed in annually until the completion of the project.

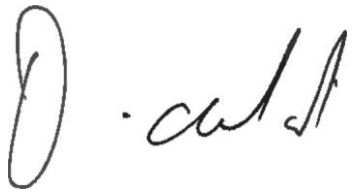
Annual review:

1. The formal ethics approval of all research projects need to be renewed on an annual basis.
2. The current approval expiry date for this project is 30 **September** 2015.
3. No research may continue after the ethics approval expiry date indicated on the formal Research Ethics Committee approval letter.
4. The Research Ethics Progress Report (electronic copy available at the following website:

http://www.tut.ac.za/Other/rnjnew/ResearchEthicsCommÎttees/Pages/default.aspx) constitutes an application for such ethics a roval renewal and must be submitted to the REC b 31 Au ust 2015.



Kind regards



Chair: Prof D du Toit
Faculty Research Ethiœ Committee
Ref: FCRE 2014/08/001 (2) (SCI)

Cc: Prof WA Hoffmann (Supervisor)
Dr MA van der Watt (Co-Supervisor)

# ANNEXURE B: RUBRIC FOR STUDY GUIDE ANALYSIS

## Institution XYZ

**Keys**

0 = Not covered at all

- The study guide does not address this theme at all. i.e nothing has been mentioned in the study guide concerning this theme

1 = inadequately covered

- The study guide does address the theme but the content covered is less than 50% of what the theme is about. This is based on information available in radiographic imaging text books as well as the journals (articles).

2 = adequately covered

- The study guide does address the theme and a content of over 50% of the information available is covered, but such coverage is less or equals to 75%.

3 = More than adequately covered

- The study guide address more than 75% of the content per theme

| Themes / Topics | Scale of incorporation | | | |
|---|---|---|---|---|
| | 0 | 1 | 2 | 3 |
| **1. Introduction to basics of computer** | | | | |
| 1.1. Computer hardware | | | | |
| 1.2. Computer software | | | | |
| 1.3. Microsoft word | | | | |
| 1.4. Microsoft excel | | | | |
| **2. Basic Information Technology** | | | | |
| 2.1. Picture Archiving & Communication System | | | | |
| 2.2. Computer networking | | | | |
| 2.3. Image transmission | | | | |
| 2.4. Information communication standards in radiology | | | | |
| **3. Digital Imaging systems** | | | | |
| 3.1. Computed radiography (CR) | | | | |
| 3.2. Flat-panel Digital Radiography | | | | |
| **4. Digital Image Processing** | | | | |
| 4.1. A point processing operations | | | | |
| **5. Image Display** | | | | |
| 5.1. Display monitors | | | | |
| 5.2. PACS monitors | | | | |
| 5.3. Laser Printers | | | | |
| **6. Exposure technique chart for DR** | | | | |
| 6.1. Exposure factors in digital imaging | | | | |
| 6.2. Exposure index | | | | |
| **7. Digital imaging artefacts** | | | | |
| 7.1. Image Receptor artefacts | | | | |
| 7.2. Software artefacts | | | | |
| 7.3. Object artefacts | | | | |
| **8. Health Information systems** | | | | |
| 8.1. Clinical Information System (CIS) | | | | |
| 8.2. Administrative Information System (AIS) | | | | |
| **9. Digital Image Characteristics** | | | | |
| 9.1. Spatial frequency | | | | |
| 9.2. Spatial resolution | | | | |
| 9.3. Modulation Transfer Function | | | | |
| 9.4. Dynamic range | | | | |
| 9.5. Signal to Noise Ratio | | | | |
| **10. Operating settings and menu** | | | | |
| 10.1. Change time settings on the control panel | | | | |
| 10.2. Add a new procedure | | | | |
| 10.3. Switch on and off collimator shutters | | | | |
| 10.4. The Reject Film Analysis on a digital imaging system | | | | |
| 10.5. Image post processing tools | | | | |
| 10.6. Console settings | | | | |
| 10.7. Quality control | | | | |
| **11. Accessories in Digital imaging** | | | | |
| 11.1. Compact Disc Robot | | | | |

| | | | | |
|---|---|---|---|---|
| 11.2. Digitizer | | | | |
| 11.3. Simulated computerised programs | | | | |

**Qualitative analysis**

12. Prescribed Literature

13. Recommended literature

14. Assessments on DR

15. DR credits

16. Admission requirements

# ANNEXURE C: DIGITAL RADIOGRAPHY BENCHMARK MEMORANDUM

| Theme | Description |
|---|---|
| **1. Introduction to the basics of computer** | |
| a. Computer hardware | Is everything about the computer that is visible-the nuts, the bolts and chips of the system that forms the central processing unit (CPU) and the various input/output devices (Bushong, 2009:400)<br>- Keyboards<br>- Pointing devices<br>- Monitors<br>- Storage devices<br>- Memory<br>- Processing<br>- Output and<br>- Communications |
| b. Computer software | The software is invisible. It consists of the computer programs that tells the hardware what to do and how to store and manipulate data [Bushong, 2009:400]<br>- Binary number system<br>- Computer programs<br>- Systems software<br>- Application programs |
| c. Microsoft word | - Typing<br>- Search function<br>- Storage function<br>- Paintings and colour functions |
| d. Microsoft excel | - Design a graph<br>- Information storage<br>- Calculations |
| **2. Basic Information Technology:**<br>Uses computer technology and information technology to produce, manipulate, store, communicate, and disseminate information [Seeram, 2011:256] | |
| a. Picture Archiving & Communication System | A comprehensive computer system that is responsible for the electronic storage and distribution of medical images. The system is highly integrated with digital acquisition and display devices and is often related closely to other medical information systems, such as the Radiology Information System (RIS) or Hospital Information System (HIS) [Seeram, 2011:15] |

| | |
|---|---|
| | - The definition of the concept<br>- Major system components<br>- The utilisation and application of the features of PACS |
| b. Computer networking | Refers to the three types of networks, based on the size of the network<br>- Local area network (LAN)<br>- Metropolitan area network (MAN)<br>- The wide area network (WAN) as well as<br>- The wireless communication media |
| c. Image transmission | This refers to the state of communicating and sharing information with other users<br>- Teleradiology |
| d. Information communication standards in radiology (Indrajit, 2013:18; Indrajit; 2007:5; Farhadi & Ahmadi, 2013; Gunn, 2009:16) | Systems such as DICOM and HL-7 that enable communication between digital imaging and information systems<br><br>- Digital Imaging and Communication in Medicine (DICOM)<br>- Health Level Seven (HL-7)<br>- Intergrating the Health Entreprise (IHE) |
| **3. Digital Imaging modalities (Computed Radiography (CR) & Digital Radiography direct & indirect (inDR & DDR) )** | |
| a. Computed radiography (CR) | A cassette based indirect digital image acquisition system that uses existing X-ray technology to produce data that is then processed by a computer into visible digital images (CR) [Seeram, 2011:253]<br><br>- The CR imaging system<br>- CR Imaging Plate (IP)<br>- The CR reader (types)<br>- Exposure control in CR |

| | |
|---|---|
| b. Flat-Panel Digital Radiography | Radiography that uses a flat-panel device to both detect X-rays and to digitize the signal [Seeram, 2011:255]<br>- Indirect digital radiography (CCD)<br>- Indirect digital radiography (TFT)<br>- Direct digital radiography (DDR) |
| **4. Digital image processing**<br>Computer processing of digital data into a numerical representation of the patient that must then be converted to an analog image for human viewing [Seeram, 2011:255] | |
| a. A point processing operations | - Histogram<br>- Look-up-Table<br>- Windowing |
| **5. Image Display**<br>Monitors used in the x-ray room and workstations(secondary grade display)) by radiographers as well as monitors used by the radiologists (primary grade display (Butt & Savage, 2015:240) | |
| a. Display monitors | - portrait display<br>- landscape display<br>- the role of display monitors on image quality and diagnostic outcomes (Savage & Butt, 2015:241)<br>- Quality control of display monitors (Butt & Savage, 2015:241)<br>- Types of monitors (Fauber, 2017:94) |
| b. PACS monitors | - portrait display<br>- landscape display<br>- the role of display monitors on image quality and diagnostic outcomes (Butt & Savage, 2015:241)<br>- Quality control of display monitors (Butt & Savage, 2015:241; Hirschorn, Krupinski, & Flynn, 2014:1270) |
| c. Laser Printers | - The anatomy of a laser printer<br>- The impact of laser printer on image quality |

| | |
|---|---|
| **6. Exposure technique charts for DR**<br>Pre-established guidelines used by the radiographer to select standardised manual or AEC exposure factors for each type of radiographic examination (Fauber,2017:320) | |
| a. Exposure factors in digital imaging | - The use of kVp & mAs<br>- Dose creep |
| b. Exposure index | - A numeric value that is displayed on the processed image to indicate the level of x-ray exposure received on the digital image receptor (Fauber,2017:320)<br>- S value<br>- EI<br>- IgM |
| **7. Digital imaging artefacts**<br>Any false visual feature on a medical image that simulates tissue or obscure tissue (Bushong, 2009:487) | |
| a. Image Receptor artefacts | Artefacts caused as a result of the imaging plate<br>- Dust, dirt, scratches<br>- Pixel malfunction<br>- Ghost images |
| b. Software artefacts | Artefacts which results due to one of the following reasons:<br>- Histograms<br>- Range/scaling<br>- Image compression |
| c. Object artefacts | Artefacts which results due to the following<br>- Patient positioning<br>- Collimator/partitioning<br>- Backscatter |
| **8. Health information systems**<br>Clinical information system, including administration functions (Seeram, 2011:207) | |
| a. Clinical information system (CIS) | - Radiology information system (RIS)<br>- Order entry system<br>- Monitoring system |
| b. Administrative information system (AIS) | - Patient registration<br>- Patient scheduling<br>- Financial payroll<br>- Quality assurance |

| | |
|---|---|
| **9. Digital Image Characteristics**<br>The flexibility of altering the brightness and contrast of a digital image (Fauber, 2017:68) | |
| a. Spatial frequency | - variation in anatomic details imaged as white to black brightness levels that can be defined by the unit of line pairs per millimeter (lp/mm) |
| b. Spatial resolution | - the smallest detail that can be detected in an image; the term typically used in digital imaging |
| c. Modulation Transfer Function (MTF) | - A measure of the imaging systems ability to display contrast of anatomic objects varying in size |
| d. Dynamic range | - The rang of exposure intensities an image receptor can accurately detect |
| e. Signal to Noise Ratio | - A method of describing the strength of the radiation exposure compared with the amount of noise apparent in a digital image |
| **10. Operating settings and menu** | |
| a. Change time settings on the control panel | - Access time setting menu<br>- Adjust the time on a control panel |
| b. Add a new procedure | - Add a new procedure on the imaging system<br>- E.g (Oblique mandible) |
| c. Switch on and off collimator shutters | - Access the menu settings<br>- Switch on and off the collimator shutters |
| d. Quality control (QC) for DR | - The Reject Film Analysis (RFA) on a digital imaging system<br>- Access the menu setting<br>- Calculate the monthly RFA<br>- program the radiographer's name against each rejected name<br>- Access the menu setting on QC<br>- Perform QC for an x-ray equipment<br>- QC for the reader (CR)<br>- QC for the printers<br>- QC for display monitors |

| | |
|---|---|
| e. Image post processing tools | Operate the following tools<br>- Edge enhancement<br>- Change exposure index<br>- Change exposure latitude<br>- Rotate the image<br>- Annotate the image<br>- Crop the image<br>- Magnify the image<br>- Access image histogram |
| f. Console settings | Operate the following tools<br>- Adjust the volume and tone of sounds on the console<br>- Synchronise different messages with different light colours<br>- Program exposures for specific radiographic anatomy<br>- Edit programmed procedure |
| **11. Accessories in Digital imaging**<br>Radiographic equipment used to aid in an imaging department, but do not involve the patient and the x-ray machine | |
| a. Compact Disc Robot | - Operating the disc printer |
| b. Digitizer | - Operating the digitizer |
| c. Simulated computerised programs | - Operating the simulated computer program |
| **12. Prescribed literature**<br>The following books, authors are regarded as the most comprehensive books on the subject of DR and are therefore regarded as the benchmark. Any of the three authors may be prescribed as the main reading source for students | |
| - CARLTON, R. & ADLER, A. 2013. *Principles of Radiographic Imaging*. 5th ed. Albany: Delmar.<br>- SEERAM E. 2011. Digital radiography: an introduction. New York: Delmar Cengage Learning.<br>- FAUBER, T.A. 2012. Radiographic Imaging & Exposure. 4th edition. Elsevierhealth<br>- FAUBER, T.A. 2017. Radiographic Imaging & Exposure. 5th edition. Elsevierhealth | |

| **13. Recommended literature** |
| --- |
| The following books, authors are regarded as the most comprehensive books on the subject of DR and are therefore regarded as benchmark for recommended literature. |
| - BUSHONG, S.C. 2008. Radiologic science for technologists: physics, biology and protection. 9th ed. St. Louis: Mosby Elsevier.<br><br>- GUNN,C. 2009. Digital and radiographic imaging: a practical approach. Edinburgh: Churchill Livingstone. |
| **14. Assessments on DR** |
| DR should form part of the formative assessments (Assignments & tests) |
| **15. Credits** |
| The total credits spread over the three years should be 10 for DR |
| **16. Admission requirements** |
| The student must have the following subjects on the APS score of level 4 and above:<br>- Mathematics Level 4<br>- Physical Science Level 4<br>- Life science Level 4<br>- English Level 4 |

# ANNEXURE D: INFORMATION LEAFLET AND INFORMED CONSENT

Tshwane University of Technology

We empower people

**FACULTY OF SCIENCE**

DEPARTMENT OF BIOMEDICAL SCIENCES

## INFORMATION LEAFLET AND INFORMED CONSENT

## PROJECT TITLE: THE UTILISATION OF DIGITAL RADIOGRAPHY BY DIAGNOSTIC RADIOGRAPHERS IN SOUTH AFRICA

Primary investigator: MR D Lamola, M Tech (Radiography) (Candidate)

Study leader: Dr WA Hoffmann, D Ed (Psychology of Education), Department of Biomedical Sciences

Tshwane University of Technology, Pretoria

Co-study leader: Dr MA Van der Watt , D Ed, Department of Biomedical Sciences

Tshwane University of Technology, Pretoria

Dear Potential research participant,

You are invited to participate in a research study that forms part of my formal M Tech-studies. This information leaflet will help you to decide if you would like to participate. Before you agree to take part, you should fully understand what is involved. You should not agree to take part unless you are completely satisfied with all aspects of the study.

**WHAT IS THE STUDY ALL ABOUT?**

The study aims to investigate the utilisation of Digital Radiography (DR) by diagnostic radiographers in South Africa. Since the inception of DR in the early 80s, there has never been a study which focused on the utilisation of DR. The outcomes of this study can be of importance to the following context: 1) the re-curriculation process currently underway in institutions of higher learning, 2) the design of appropriate training programmes for qualified diagnostic radiographers by the Department of Health, and 3) optimising the DR skills of diagnostic radiographers working in units and departments that uses DR technology. The study shall be conducted in three phases linked to the following objectives:

- to analyse the incorporation of formal DR image recording in the current undergraduate Diagnostic Radiography curriculum being offered at institutions of higher learning in South Africa;
- to investigate the application and utilisation range of the various DR features by diagnostic radiographers in clinical practice in South Africa; and
- to investigate practicing diagnostic radiographers' perceptions regarding the utilisation of DR features in South Africa.

**WHAT WILL YOU BE REQUIRED TO DO IN THE STUDY?**

Phase 1 (Telephone interviews: industry)

An interview shall be conducted by the researcher with an application specialist from the industry. The interviews will be recorded. The interview is estimated to take a maximum of 15 minutes and it will be a once off activity. There is no prescribed location for the interview to take place. An application specialist can be interviewed on land line in the comfort of his/her office, alternatively cell phone can be used.. There is no prior learning or

preparations required as general questions regarding the utilization of DR system shall be asked .Participation in this study is absolutely free. All telephone expenses will be covered by the researcher.

**ARE THERE ANY CONDITIONS THAT MAY EXCLUDE YOU FROM THE STUDY?**

You will not be eligible to participate in this study if you are a student radiographer or not in good standing with the HPCSA.

**CAN ANY OF THE STUDY PROCEDURES RESULT IN PERSONAL RISK, DISCOMFORT OR INCONVENIENCE?**

**Telephone interviews**: In the interview/s you will only be required to share information regarding your work experience, the DR equipment's sold by your company, manufacturer-based training offered to the practices/hospitals and your perceptions regarding the utilisation of DR features.

Note that participation in the study only involves minimal risk, discomfort and/or inconvenience that are no more than the risks, discomforts and/or inconveniences one encounter in daily living.

**WHAT ARE THE POTENTIAL BENEFITS THAT MAY COME FROM THE STUDY?**

The benefits of participating in this study are:

- Even though you may not directly benefit from participating in this study, your inputs shall significantly contribute towards the advancement of the radiography profession, specifically in the emerging field of digital radiography.

- Your contribution shall assist institutions of higher learning to formulate cutting-edge curricula that effectively incorporate the latest technology in radiography.
- Through your participation, the Department of Health may design an appropriate training programme for qualified diagnostic radiographers.

**WILL YOU RECEIVE ANY FINANCIAL COMPENSATION OR INCENTIVE FOR PARTICIPATING IN THE STUDY?**

Please note that you **will not** be paid to participate in the study.

**WHAT ARE YOUR RIGHTS AS A PARTICIPANT IN THIS STUDY?**

Your participation in this study is entirely voluntary. You have the right to withdraw at any stage without any penalty or future disadvantage whatsoever. You don't even have to provide the reason/s for your decision. Your withdrawal will in no way influence your continued care and relationship with the researcher, university and/or employer. Note that you are not waiving any legal claims, rights or remedies because of your participation in this research study.

**HOW WILL CONFIDENTIALITY AND ANONYMITY BE ENSURED IN THE STUDY?**

All information obtained during the course of this study is strictly confidential. The study data will be coded so that it will not be linked to your name. Your identity and that of the company, institution of higher learning as well as the practice/ x-ray department will not be revealed while the study is being conducted or when the study is reported in scientific journals. All the data sheets that have been collected will be stored in a secure place. Any

information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. The information received during the project will only be used for research purposes and will not be released for any employment-related performance evaluation, promotion and/or disciplinary purposes.

**IS THE RESEARCHER QUALIFIED TO CARRY OUT THE STUDY?**

The researcher is a qualified diagnostic radiographer who has previously completed similar research studies. All parts of this project will be conducted under the direct supervision of the two study supervisors.

**HAS THE STUDY RECEIVED ETHICAL APPROVAL?**

Yes. TUT ethics number:_____ The Faculty Committee for Postgraduate Studies and the Senate Committee for Research Ethics of the Tshwane University of Technology have approved the formal study proposal. All parts of the study will be conducted according to internationally accepted ethical principles.

**WHO CAN YOU CONTACT FOR ADDITIONAL INFORMATION REGARDING THE STUDY?**

The primary investigator, Mr D Lamola, can be contacted during office hours at Tel (012) 382-6261, or on his cellular phone at 073 464 - 3520. The study leader, Dr WA Hoffmann, can be contacted during office hours at Tel (012) 382-6246. Should you have any questions

regarding the ethical aspects of the study, you can contact the chairperson of the TUT Faculty Committee for Research Ethics, Dr E Olivier, during office hours at tel (012) 382-6393, e-mail (OlivierEI@tut.ac.za). Alternatively, you can report any serious unethical behaviour at the University's Toll Free Hotline 0800 21 23 41.

**DECLARATION: CONFLICT OF INTEREST**

This research study was funded by the Tshwane University of Technology. No publication prohibitions, conditions or limitations were placed on the researcher.

**A FINAL WORD**

Your co-operation and participation in the study will be greatly appreciated. Please sign the informed consent below if you agree to participate in the study. In such a case, you will receive a copy of the signed informed consent from the researcher.

**CONSENT**

I hereby confirm that I have been adequately informed by the researcher about the nature, conduct, benefits and risks of the study. I have also received, read and understood the above written information. I am aware that the results of the study will be anonymously processed into a research report. I understand that my participation is voluntary and that I may, at any stage, without prejudice, withdraw my consent and participation in the study. I had sufficient opportunity to ask questions and of my own free will declare myself prepared to participate in the study.

Research participant's name: _____ (Please print)

Research participant's signature: _____Date: _____

Researcher's name: _____ (Please print)

Researcher's signature: _____

Date: _____

_____
Signature/Name

# ANNEXURE E: INTERVIEW GUIDE QUESTIONS TO APPLICATION SPECIALISTS

1. To what extent do you think radiographers utilise the applications of DR and CR?
2. Which features of DR and CR are not optimally utilised in your opinion?
3. Do you think that tertiary institutions provide adequate training to radiographers with regards to DR and CR specifically?
4. Which topics and/or aspects of DR and CR should form part of the core curriculum offered by tertiary institutions in their Radiography programmes?
5. Does your company offer manufacturer-specific training for clinical practices which purchase CR and DR?
6. Can you describe the approach, content, duration, frequency and/or assessment used in the on-site training session/s

## ANNEXURE F: LETTER TO INSTITUTIONS OF HIGHER LEARNING


Faculty of Science
Department of Biomedical sciences

30 October 2015

Office of the Executive Dean/ Research Ethics Committee

UNIVERSITY of A

Dear Sir/Madam

**REQUEST FOR ACCESS TO RADIOGRAPHY CURRICULUM DOCUMENTS FOR RESEARCH PURPOSES**

Study title: The utilisation of digital radiography by diagnostic radiographers in South Africa

Primary Researcher: Mr Dan Lamola

TUT student number: 215470644

Qualification: M Tech (Diagnostic Radiography)

Supervisors: Dr WA Hoffmann (TUT) & Dr M van der Watt (TUT)

**WHAT IS THE STUDY ALL ABOUT?**

The study aims to investigate the utilisation of Digital Radiography (DR) by diagnostic radiographers in South Africa. The outcomes of this study can be of importance to the following context: 1) the re-curriculation process currently underway in institutions of higher learning, 2) the design of appropriate training programmes for qualified diagnostic

radiographers by the Department of Health, and 3) optimising the DR skills of diagnostic radiographers working in units and departments that uses DR technology.

May you kindly assist me with the following information which shall be used purely for the purpose of this study (Phase 1) and not for comparative reasons?

1. Image Recording and/or Radiographic Science study guides for first, second and third years
2. Please advise as to when digital radiography became part of the formal curriculum in your institution?

Names of institutions and the contents of their documents shall remain anonymous and confidential at all stages and phases of the study. These documents are necessary for phase one of the project, namely a document analysis. The information from the document analysis will inform the development of a survey data collection instrument (Phase 2 and Phase 3 of the study). Find attached the TUT-approved project proposal for your perusal.

This project is conducted under the supervision of Dr WA Hoffmann, Dept Biomedical Sciences, TUT (Tel: 012 382-6246, E-mail: HoffmannWA@tut.ac.za) and Dr M Van der Watt, Dept Biomedical Sciences, TUT (Tel: 012 382-6340, E-mail: VanDerWattMA@tut.ac.za). Full approval has been granted for Phase 1 of the project by the TUT Faculty of Science Committee for Research Ethics (Reference #: FCRE 2014/08/001).

I will highly appreciate your assistance in this regard as we collectively strive to make radiography a better place of work in the health sciences field.

Kind regards

Dan Lamola

Dept of Biomedical Sciences

Tshwane University of Technology

Tel (W) : 012 382-6261

Fax : 012 382-6262

Cell : 073 464 3520

E-mail : lamolad@tut.ac.za

# ANNEXURE G: ETHICAL CLEARANCE FOR INDUSTRY

programmes for qualified diagnostic radiographers by the Department of Health, and 3) optimising the DR skills of diagnostic radiographers working in units and departments that uses DR technology.

I hereby request your formal permission to conduct an interview with one of the digital radiography application specialist in your company. Find attached to this letter the following documents for your perusal: 1) interview guide, 2) TUT ethics clearance letter, 3) interviewee information leaflet, and 4) the research proposal.

The request is Approved / declined (kindly underline/circle the relevant decision)

CEO/Director Name: (Please print)

Signature:

Date: 23/01/2015

Researcher name: / 15/01/2015

Researcher signature: re:

Date: 15/01/2015

Kind regards

Mr D Lamola

Tel (012) 382 6261
Fax: 012 382 6262
Cell: 073 464-3520
E-mail: lamolad@tutacza

**ANNEXURE H: ONLINE SURVEY QUESTIONNAIRE**

# THE UTILISATION OF DIGITAL RADIOGRAPHY BY DIAGNOSTIC RADIOGRAPHERS IN SOUTH AFRICA

## Questionnaire

Instruction: Tick the appropriate box with (**X**)

1. How long (years) have you worked as a qualified radiographer?

| 0-5 | | 6 –10 | | 11-15 | | More than 15 years | |
|---|---|---|---|---|---|---|---|



2. Are you currently working for a private or public hospital?

| Private | | Public | |
|---|---|---|---|

3. Which of the following radiographic systems does your practice use?

| Analogue | | Computed radiography (CR) | | Direct/indirect digital radiography (IDDR/ DDR) | |
|---|---|---|---|---|---|

4. For how many years has your imaging department been using digital radiography? (CR/IDDR/DDR)----------

5. Do you have formal computer training (MS Word, Ms Power point) qualification (computer course covered as a module in radiography training is also regarded as formal training) ----------

6. The following questions are applicable to Computed radiography (CR), indirect digital radiography (IDDR) and DDR (Direct Digital Radiography). Please mark an appropriate box

6.1. Questions on radiographic unit's console (Patient administration and registration)

| **Patient administration and registration** | **Fully agree** | **Agree to some extent** | **Not sure** | **Disagree to some extent** | **Fully disagree** |
|---|---|---|---|---|---|
| I can register patient information on the system (manually) | | | | | |
| I can search for the patient on the system | | | | | |
| I can check for the studies which are delivered (sent through for PACS/printing) | | | | | |
| I can check for all patients done by a specific imaging modality | | | | | |
| I can check for patients done today only | | | | | |
| I can write patient comments | | | | | |
| I can capture patient information (e.g. patient history, height, weight, is in/out patient | | | | | |
| I can capture patient blood type and make comments | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| I can capture comments on the image about the patient's condition | | | | | |

6.2. Radiographic image post processing

| **Post processing** | **Fully agree** | **Agree to some extent** | **Not sure** | **Disagree to some exten** | **Fully disagree** |
|---|---|---|---|---|---|
| K2I am able to adjust density and contrast | | | | | |
| I can change the exposure index (S value/EI/IgM/REX) | | | | | |
| I can check the exposure latitude on the monitor | | | | | |
| I can enhance image quality by using edge enhancement | | | | | |
| I can rotate the image | | | | | |
| I can annotate the image | | | | | |
| I can crop the image | | | | | |
| I can do additional patient identification after image processing | | | | | |
| I can switch the collimator shutters on or off | | | | | |
| I can magnify the image to enhance diagnosis | | | | | |
| I can use lookup table to create a better image impression | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| I can access the image histogram | | | | | |
| I can interpret the image histogram | | | | | |

6.3. Console setting

| **Console setting** | **Fully agree** | **Agree to some extent** | **Not sure** | **Disagree to some extent** | **Fully disagree** |
|---|---|---|---|---|---|
| I can set/adjust time on the console | | | | | |
| I can adjust the volume and tone of sounds on the console | | | | | |
| I can synchronise different messages with different light colours (eg. error message with flash red light) | | | | | |
| I can programme specific exposure factors for demonstrating applicable radiographic anatomy | | | | | |
| I can edit the pre-programmed procedure | | | | | |



6.4. Quality control

| **Quality control** | **Fully agree** | **Agree to some extent** | **Not sure** | **Disagree to some extent** | **Fully disagree** |
|---|---|---|---|---|---|
| I can access the Reject Image Analysis (RFA) menu on the system | | | | | |
| I can set radiographers' names against each rejected image | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| I can set RFA threshold on the system | | | | | |
| I can set destinations and passwords for rejected images | | | | | |
| I can calculate RFA over a specified period | | | | | |

6.5. Digital radiography artefacts

| **Digital radiography artefacts** | **Fully agree** | **Agree to some extent** | **Not sure** | **Disagree to some extent** | **Fully disagree** |
|---|---|---|---|---|---|
| I can identify if a digital image has an artefact | | | | | |
| I can classify digital artefacts into the following categories: | | | | | |
| - Software artefacts | | | | | |
| - Image receptor artefacts | | | | | |
| - Objects artefacts | | | | | |
| I can identify the causes of the artefacts | | | | | |



6.6. Computer and information technology

| **Computer and information technology** | **Fully agree** | **Agree to some extent** | **Not sure** | **Disagree to some extent** | **Fully disagree** |
|---|---|---|---|---|---|
| I can operate the hard ware of the computer | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| I can operate the software of the computer | | | | | |
| I can identify the type of network used in the radiographic practice (e.g.LAN/MAN/WAN) | | | | | |
| I can identify the communication protocol used in my radiographic practice (HL7/DICOM) | | | | | |
| I can register the patient on Picture Archiving and Communication System (PACS) | | | | | |
| I can access patient tags (codes) on PACS | | | | | |
| I can post process the image on PACS monitor | | | | | |
| I can archive the images on PACS | | | | | |
| I can store images on PACS | | | | | |
| I can distribute images to linked users | | | | | |



7. How long ago did you attend the most recent training offered?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Never | | 1 year ago | | 2-3 years ago | | More than 3 years ago | |

Please proceed to Question 8 if you have never attended the training offered by the manufacturer of Digital x-ray equipment, but please answer the next questions if you have attend any such training.

7.1. To what extend do you think the manufacturer based training is enough to prepare you to fully utilise all the features of DR?

| Fully prepare | | Moderate | | Does not prepare | |
|---|---|---|---|---|---|

7.2. How many courses did you attend?

| Only 1 | | 2 | | 3 and more | |
|---|---|---|---|---|---|

7.3. What form of assessment was done to check your level of competency, after completing the training?

| None | | Practical | | Test | |
|---|---|---|---|---|---|

7.4. How long (days, hours) did the course run?

| Less than 8 hours | | 2 days | | 3 days and more | |
|---|---|---|---|---|---|

247 8. Do you think that tertiary institutions provide adequate training to radiographers with regards to CR and DR specifically?

| Yes | | No | |
|---|---|---|---|

**Thank you for taking part in this study.**

# ANNEXURE I: QUESTIONNAIRE REVIEW REQUEST LETTER


Faculty of Science
Department of Biomedical sciences

07 March 2016

Dear Prof/Dr/Colleague/Sir/Madam

**RE: A REQUEST TO REVIEW THE DATA COLLECTION INSTRUMENT**

Study tile: The utilisation of digital radiography by diagnostic radiographers in South Africa

Primary Researcher: Mr Dan Lamola

Qualification: M Tech (Diagnostic Radiography)

Supervisors: Dr WA Hoffmann & Dr M van der Watt

I am a Masters student in Diagnostic Radiography in the Faculty of Science, Tshwane University of Pretoria. You are invited to volunteer to evaluate my data collection instrument (questionnaire). This questionnaire aims to collect data from practicing diagnostic radiographers across South Africa. The purpose of the questionnaire is to gather data which will assist the researcher in quantifying the extent of utilisation of the features of digital radiography by diagnostic radiographers. You are chosen to assist with the review and piloting of the questionnaire because you are regarded by the researcher as an expert who can significantly contribute in advancing radiographic imaging in South Africa.

**WHAT IS THE STUDY ALL ABOUT?**

The study aims to investigate the utilisation of Digital Radiography (DR) by diagnostic radiographers in South Africa. The outcomes of this study can be of importance to the following context: 1) the re-curriculation process currently underway in institutions of higher learning, 2) the design of appropriate training programmes for qualified diagnostic radiographers by the Department of Health, and 3) optimising the DR skills of diagnostic radiographers working in units and departments that uses DR technology.

During this pilot phase you are requested to provide inputs on the content, language, relevance of themes/items to digital radiography as well as the time required to complete the questionnaire. Your input to the information leaflet and consent form to the potential participants in the study will also be highly appreciated.

The reviewed questionnaire can be mailed back to the primary researcher. All comments and suggestions will be kept in a safe space at Tshwane University of Technology, Biomedical Sciences department in a safe place to ensure confidentiality. This questionnaire will be submitted to the ethic committee of the Faculty of Science at TUT for approval; hence forth data can be collected using this tool.

The data obtained from this data collection tool may be reported in scientific journals. Anonymity in writing will be ensured at all levels of reporting, as to ensure that the information does not identify with you or your institution. If you have any questions, please do not hesitate to contact me at 0734643520/0123826261 or lamolad@tut.ac.za. Alternatively you may contact my supervisor, Dr W.A. Hoffmann at (012) 382 6246. Should

you have any questions regarding the ethical aspects of the study, you can contact the chairperson of the Faculty Research Ethics Committee (FREC), Dr Eugene Olivier, during office hours at Tel (012) 382-6393, E-mail OlivierEI@tut.ac.za. Alternatively, you can report any serious unethical behaviour at the University's Toll Free Hotline 0800 21 23 41.

Thank you for your assistance.

Mr D Lamola

Tel (W): (012) 382 6261

Fax: 012 382 6262

Cell: 073 464-3520

E-mail: lamolad@tut.ac.za

# ANNEXURE J: TUT ETHICS CLEARANCE FOR PHASE 2 & 3

Tshwane University of Technology

## Faculty Committee for Research Ethics [FCRE-SCI]

*The TUT Senate Committee for Research Ethics is a registered Institutional Review Board (IRB 00005968) with the US Office for Human Research Protections (IORG# 0004997) (Expires 19 Jan 2014). Also, it has Federal Wide Assurance for the Protection of Human Subjects for International Institutions (FWA 00011501) (Expires 31 Jan 2014). In South Africa it is registered with the National Health Research Ethics Council (REC-160509-21).The FCRE-SCI is a subcommittee of the TUT Senate Committee for Research Ethics*

20 April 2016

Ref #: FCRE 2014/08/001 (3) (SCI)
Name: Lamola, D
Student #: 215470644

Mr D Lamola
Department of Biomedical Sciences

Dear Mr Lamola

---

Title: The utilization of digital radiography by diagnostic radiographers in South Africa
Investigator: Mr D Lamola
Programme: M Tech: Radiography
Supervisor: Dr WA Hoffmann
Co-supervisor: Dr MA van der Watt

---

The proposal for phase two and three of the study has been reviewed by the Faculty of Science Committee for Research Ethics.

The following was recommended from the review:

1. Please write out the abbreviated words in your information leaflet

2. Please add the contact detail of the FCRE Chairperson in your information leaflet and informed consent forms (Dr EI Olivier, contact number 012 382 6393; OlivierEI@tut.ac.za) k2
3. Editorial comments on the proposal have been included and will be send to you for improvement of your proposal.

Phase 2 and 3 of the project is approved with comments.



Kind regards

Chairperson: Dr EI Olivier

Faculty Research Ethics Committee

Ref: FCRE 2014/08/001 (3) (SCI)

Cc: Prof WA Hoffmann (Supervisor)

Dr MA van der Watt (Co-Supervisor)

*We empower people*

Tel. 0861 102 422, Tel. (012) 382-5154, Fax (012) 382-4409, www.tut.ac.za • The Registrar, Private Bag X680, Pretoria 0001

## ANNEXURE K: INFORMED CONSENT FOR AN ONLINE SURVEY QUESTIONNAIRE

Tshwane University of Technology
We empower people

FACULTY OF SCIENCE

DEPARTMENT OF BIOMEDICAL SCIENCES

# INFORMATION LEAFLET AND INFORMED CONSENT

## PROJECT TITLE: THE UTILISATION OF DIGITAL RADIOGRAPHY BY DIAGNOSTIC RADIOGRAPHERS IN SOUTH AFRICA

Primary investigator: MR D Lamola, M Tech (Radiography) (Candidate)

Study leader: Dr WA Hoffmann, D Ed (Psychology of Education), Department of Biomedical Sciences

Tshwane University of Technology, Pretoria

Co-study leader: Dr MA Van der Watt , D Ed, Department of Biomedical Sciences

Tshwane University of Technology, Pretoria

Dear Potential research participant,

You are invited to participate in a research study that forms part of my formal M Tech-studies. This information leaflet will help you to decide if you would like to participate. Before you agree to take part, you should fully understand what is involved. You should not agree to take part unless you are completely satisfied with all aspects of the study.

**WHAT IS THE STUDY ALL ABOUT?**

The study aims to investigate the utilisation of Digital Radiography (DR) by diagnostic radiographers in South Africa. Since the inception of DR in the early 80s, there has never been a study which focused on the utilisation of DR. The outcomes of this study can be of importance to the following context: 1) the re-curriculation process currently underway in institutions of higher learning, 2) the design of appropriate training programmes for qualified diagnostic radiographers by the Department of Health, and 3) optimising the DR skills of diagnostic radiographers working in units and departments that uses DR technology. The study shall be conducted in three phases linked to the following objectives:

- to analyse the incorporation of formal DR image recording in the current undergraduate Diagnostic Radiography curriculum being offered at institutions of higher learning in South Africa;
- to investigate the application and utilisation range of the various DR features by diagnostic radiographers in clinical practice in South Africa; and
- to investigate practicing diagnostic radiographers' perceptions regarding the utilisation of DR features in South Africa.

**WHAT WILL YOU BE REQUIRED TO DO IN THE STUDY?**

Phase 2 (Questionnaire)

This is an online survey; you are requested to click on a link in the email to participate in this survey. It will take you 5-7 minutes to complete all questions.. There are no specific

requirements prior participation. Voluntary completion of the questionnaire shall serve as an implied consent.

**ARE THERE ANY CONDITIONS THAT MAY EXCLUDE YOU FROM THE STUDY?**

You will not be eligible to participate in this study if you are a student radiographer or not in good standing with the HPCSA.

**CAN ANY OF THE STUDY PROCEDURES RESULT IN PERSONAL RISK, DISCOMFORT OR INCONVENIENCE?**

**Questionnaires**: The study and procedures involve no foreseeable physical discomfort or inconvenience to you or your family. Due to the personal nature of the questions, you may experience some emotional discomfort.

Note that participation in the study only involves minimal risk, discomfort and/or inconvenience that are no more than the risks, discomforts and/or inconveniences one encounter in daily living.

**WHAT ARE THE POTENTIAL BENEFITS THAT MAY COME FROM THE STUDY?**

The benefits of participating in this study are:

- Even though you may not directly benefit from participating in this study, your inputs shall significantly contribute towards the advancement of the radiography profession, specifically in the emerging field of digital radiography.
- Your contribution shall assist institutions of higher learning to formulate cutting-edge

curricula that effectively incorporate the latest technology in radiography.

- Through your participation, the Department of Health may design an appropriate training programme for qualified diagnostic radiographers.

**WILL YOU RECEIVE ANY FINANCIAL COMPENSATION OR INCENTIVE FOR PARTICIPATING IN THE STUDY?**

Please note that you **will not** be paid to participate in the study.

**WHAT ARE YOUR RIGHTS AS A PARTICIPANT IN THIS STUDY?**

Your participation in this study is entirely voluntary. You have the right to withdraw at any stage without any penalty or future disadvantage whatsoever. You don't even have to provide the reason/s for your decision. Your withdrawal will in no way influence your continued care and relationship with the researcher, university and/or employer. Note that you are not waiving any legal claims, rights or remedies because of your participation in this research study.

**HOW WILL CONFIDENTIALITY AND ANONYMITY BE ENSURED IN THE STUDY?**

All information obtained during the course of this study is strictly confidential. The study data will be coded so that it will not be linked to your name. Your identity and that of the company, institution of higher learning as well as the practice/ x-ray department will not be revealed while the study is being conducted or when the study is reported in scientific journals. All the data sheets that have been collected will be stored in a secure place. Any

information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. The information received during the project will only be used for research purposes and will not be released for any employment-related performance evaluation, promotion and/or disciplinary purposes.

**IS THE RESEARCHER QUALIFIED TO CARRY OUT THE STUDY?**

The researcher is a qualified diagnostic radiographer who has previously completed similar research studies. All parts of this project will be conducted under the direct supervision of the two study supervisors.

**HAS THE STUDY RECEIVED ETHICAL APPROVAL?**

Yes. TUT ethics number: FCRE 2014/08/001 The Faculty Committee for Postgraduate Studies and the Senate Committee for Research Ethics of the Tshwane University of Technology have approved the formal study proposal. All parts of the study will be conducted according to internationally accepted ethical principles.

**WHO CAN YOU CONTACT FOR ADDITIONAL INFORMATION REGARDING THE STUDY?**

The primary investigator, Mr D Lamola, can be contacted during office hours at tel (012) 382-6261, or on his cellular phone at 073 464 - 3520. The study leader, Dr WA Hoffmann, can be contacted during office hours at tel (012) 382-6246. Should you have any questions regarding the ethical aspects of the study, you can contact the chairperson of the TUT Faculty Committee for Research Ethics, Dr E Olivier, during office hours at tel (012) 382-

6393, e-mail OlivierEI@tut.ac.za. Alternatively, you can report any serious unethical behaviour at the University's Toll Free Hotline 0800 21 23 41.

**DECLARATION: CONFLICT OF INTEREST**

This research study was funded by the Tshwane University of Technology. No publication prohibitions, conditions or limitations were placed on the researcher.

**A FINAL WORD**

Your co-operation and participation in the study will be greatly appreciated. Please sign the informed consent below if you agree to participate in the study. In such a case, you will receive a copy of the signed informed consent from the research

**ANNEXURE L: INTERVIEW QUESTIONS GUIDE (PHASE 3)**

# THE UTILISATION OF DIGITAL RADIOGRAPHY BY DIAGNOSTIC RADIOGRAPHERS IN SOUTH AFRICA

## Interview guide for phase 3

1. Which of the following radiographic systems do your practice use? Why do you think there was a need to move from FS to DDR

   - Film screen radiography (FS)
   - Computed radiography (CR)
   - Indirect digital radiography (IDR)
   - Direct digital radiography (DDR)

2. In your opinion, do you think the move from FS to DR was the best (Financial, turnaround time and diagnostics) move? Justify your answer

3. In your opinion, what do you think are the negative aspects of moving from FS to DR?

4. To what extent do you think radiographers optimally utilise the application of DR?

5. Which features of DR do you commonly use, and which features you hardly or never use? Elaborate on the reasons for your answer.

6. How often and in what circumstances do you use some of the following DR features:
   - Lookup table
   - Exposure index
   - Image histogram analysis
   - Edge enhancement
   - Change time setting on the control panel
   - Add a new procedure

- Check the tag of the image on PACS
- Switch on/off the collimator shutters
- Use RFA function on the system to calculate the repeat rate of the department

7. Which communication protocol does your institution use?

8. Which DR features would you like to receive more training in? What training approach (CPD event, university course, x-ray company) would you prefer? How often would you like to attend a refresher course?

9. To what extend do you think that tertiary institutions provide adequate and/or appropriate training to radiographers with regards to CR and DR. Justify

10. Lastly, in what ways would you like tertiary institutions to actively contribute to or participate in DR training on undergraduate level and to qualified diagnostic radiographers?

Thank you for taking part in this study.

## ANNEXURE M: CONFIDENTIALITY AGREEMENT CONTRACT WITH TECHNICAL ASSISTANT


FACULTY OF SCIENCE

Department of Biomedical Sciences

### FIELDWORKER AND/OR RESEARCH ASSISTANT CONFIDENTIALITY AGREEMENT

I, _____, hereby agree to:

1. Abide by the confidentiality requirements of this study, as approved by the Senate Committee for Research Ethics (SCRE) of Tshwane University of Technology, by ensuring that the identities and information of the participants are not revealed during and after the course of study;

2. Keep all the research information shared with me confidential by not discussing or sharing the research information in any form or format with anyone other than the Principal Investigator(s);

3. Keep all research information in any form or format securely stored while it is in my possession;

4. Return all research information in any form or format to the Principal Investigator(s) when I have completed the research tasks;

5. After consulting with the Principal Investigator(s), erase or destroy all research information in any form or format regarding this research project that is not returnable to the Principal Investigator(s) (e.g. information sorted on computer hard drive).

If you have any questions or concerns about this study, please contact:

Dr. W A Hoffmann

Phone: (012) 382 6246

E-mail: hoffmannWA@TUT.ac.za

This study has been reviewed and approved by the Senate Committee for Research Ethics at Tshwane University of Technology. For questions regarding your rights and/or the ethical conduct of research, contact the SCRE Chairperson, Dr. WA Hoffmann, at (012) 382 6246 (hoffmannwa@tut.ac.za).

Research Assistant or Fieldworker:

| _____ | _____ | _____ |
|---|---|---|
| Print name | Signature | Date |

Principal Investigator:

| _____ | _____ | _____ |
|---|---|---|
| Print name | Signature | Date |

# ANNEXURE N: REQUEST LETTER TO HOSPITALS/IMAGING FACILITIES

Tshwane University of Technology
We empower people

Faculty of Science
Department of Biomedical sciences

27 June 2016

The Chief Executive Officer / Director

Lamola Daniel Hospital

Dear Sir/Madam

**REQUEST TO INTERVIEW DIAGNOSTIC RADIOGRAPHERS IN YOUR INSTITUTION, FOR RESEARCH PURPOSE.**

Study title: The utilisation of digital radiography by diagnostic radiographers in South Africa

Primary Researcher: Mr Dan Lamola

Qualification: M Tech (Diagnostic Radiography)

Supervisors: Prof WA Hoffmann & Dr M van der Watt

**WHAT IS THE STUDY ALL ABOUT?**

The study aims to investigate the utilisation of Digital Radiography (DR) by diagnostic radiographers in South Africa. The outcomes of this study can be of importance to the following context: 1) the re-curriculation process currently underway in institutions of higher learning, 2) the design of appropriate training programmes for qualified diagnostic radiographers by the Department of Health, and 3) optimising the DR skills of diagnostic radiographers working in units and departments that uses DR technology.

I hereby request your formal permission to conduct focus group interviews with diagnostic radkiographers working in your institution. The interview will be conducted during staff meeting time or as it suits your department. Find attached to this letter the following documents for your perusal: 1) interview guide, 2) TUT ethics clearance letter, 3) interviewee information leaflet, and 4) the research proposal.

The request is approved / declined (kindly underline/circle the relevant decision)

CEO/Director Name: _____ (Please print)

Signature: _____

Date: _____

Researcher name: _____

Researcher signature: _____

Date: _____

Kind regards

Mr D Lamola

Tel (W): (012) 382 6261

Fax: 012 382 6262

Cell: 073 464-3520

E-mail: lamolad@tut.ac.za

## ANNEXURE O: INFORMATION LEAFTLET AND CONSENT FORM FOR PHASE 3

Tshwane University of Technology

We empower people

**FACULTY OF SCIENCE**

DEPARTMENT OF BIOMEDICAL SCIENCES

# INFORMATION LEAFLET AND INFORMED CONSENT

## PROJECT TITLE: THE UTILISATION OF DIGITAL RADIOGRAPHY BY DIAGNOSTIC RADIOGRAPHERS IN SOUTH AFRICA

Primary investigator: MR D Lamola, M Tech (Radiography) (Candidate)

Study leader: Dr WA Hoffmann, D Ed (Psychology of Education), Department of Biomedical Sciences

Tshwane University of Technology, Pretoria

Co-study leader: Dr MA Van der Watt , D Ed, Department of Biomedical Sciences

Tshwane University of Technology, Pretoria

Dear Potential research participant,

You are invited to participate in a research study that forms part of my formal M Tech-studies. This information leaflet will help you to decide if you would like to participate. Before you agree to take part, you should fully understand what is involved. You should not agree to take part unless you are completely satisfied with all aspects of the study.

**WHAT IS THE STUDY ALL ABOUT?**

The study aims to investigate the utilisation of Digital Radiography (DR) by diagnostic radiographers in South Africa. Since the inception of DR in the early 80s, there has never been a study which focused on the utilisation of DR. The outcomes of this study can be of importance to the following context: 1) the re-curriculation process currently underway in institutions of higher learning, 2) the design of appropriate training programmes for qualified diagnostic radiographers by the Department of Health, and 3) optimising the DR skills of diagnostic radiographers working in units and departments that uses DR technology. The study shall be conducted in three phases linked to the following objectives:

- to analyse the incorporation of formal DR image recording in the current undergraduate Diagnostic Radiography curriculum being offered at institutions of higher learning in South Africa;
- to investigate the application and utilisation range of the various DR features by diagnostic radiographers in clinical practice in South Africa; and
- to investigate practicing diagnostic radiographers' perceptions regarding the utilisation of DR features in South Africa.

**WHAT WILL YOU BE REQUIRED TO DO IN THE STUDY?**

Phase 3 (Focus group interviews)

A focus group interview consisting of 8-10 members will be established. Discussions with the focus group interviews shall be video-taped. The researcher shall facilitate the discussion and participants will be required to engage by answering questions. The discussion is estimated to take a maximum of an hour and it will be a once off activity. The interviews shall be conducted in the X-ray department's board/team room or as per recommendations of the management of the department. There is no prior learning or preparations required before one participates in this study, as all qualified radiographer on

duty on the day of the interviews will be requested to participate in the focus groups. Participation in this study is absolutely free of charge. The researcher will conduct the interviews in your department; as such there is no transportation fees incurred due to participation in this study. Refreshments shall be served to all participating.

**ARE THERE ANY CONDITIONS THAT MAY EXCLUDE YOU FROM THE STUDY?**

You will not be eligible to participate in this study if you are a student radiographer or not in good standing with the HPCSA.

**CAN ANY OF THE STUDY PROCEDURES RESULT IN PERSONAL RISK, DISCOMFORT OR INCONVENIENCE?**

**Focus group interviews**: In the interview/s you will only be required to share information regarding your work experience, the equipment used in the unit and your perceptions regarding the utilisation of DR features in your department.

Note that participation in the study only involves minimal risk, discomfort and/or inconvenience that are no more than the risks, discomforts and/or inconveniences one encounter in daily living.

**WHAT ARE THE POTENTIAL BENEFITS THAT MAY COME FROM THE STUDY?**

The benefits of participating in this study are:

- Even though you may not directly benefit from participating in this study, your inputs

shall significantly contribute towards the advancement of the radiography profession, specifically in the emerging field of digital radiography.

- Your contribution shall assist institutions of higher learning to formulate cutting-edge curricula that effectively incorporate the latest technology in radiography.
- Through your participation, the Department of Health may design an appropriate training programme for qualified diagnostic radiographers.

**WILL YOU RECEIVE ANY FINANCIAL COMPENSATION OR INCENTIVE FOR PARTICIPATING IN THE STUDY?**

Please note that you **will not** be paid to participate in the study.

**WHAT ARE YOUR RIGHTS AS A PARTICIPANT IN THIS STUDY?**

Your participation in this study is entirely voluntary. You have the right to withdraw at any stage without any penalty or future disadvantage whatsoever. You don't even have to provide the reason/s for your decision. Your withdrawal will in no way influence your continued care and relationship with the researcher, university and/or employer. Note that you are not waiving any legal claims, rights or remedies because of your participation in this research study.

**HOW WILL CONFIDENTIALITY AND ANONYMITY BE ENSURED IN THE STUDY?**

All information obtained during the course of this study is strictly confidential. The study data will be coded so that it will not be linked to your name. Your identity and that of the company, institution of higher learning as well as the practice/ x-ray department will not be

revealed while the study is being conducted or when the study is reported in scientific journals. All the data sheets that have been collected will be stored in a secure place. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. The information received during the project will only be used for research purposes and will not be released for any employment-related performance evaluation, promotion and/or disciplinary purposes.

**IS THE RESEARCHER QUALIFIED TO CARRY OUT THE STUDY?**

The researcher is a qualified diagnostic radiographer who has previously completed similar research studies. All parts of this project will be conducted under the direct supervision of the two study supervisors.

**HAS THE STUDY RECEIVED ETHICAL APPROVAL?**

Yes. TUT ethics number:_____ The Faculty Committee for Postgraduate Studies and the Senate Committee for Research Ethics of the Tshwane University of Technology have approved the formal study proposal. All parts of the study will be conducted according to internationally accepted ethical principles.

**WHO CAN YOU CONTACT FOR ADDITIONAL INFORMATION REGARDING THE STUDY?**

The primary investigator, Mr D Lamola, can be contacted during office hours at Tel (012) 382-6261, or on his cellular phone at 073 464 - 3520. The study leader, Dr WA Hoffmann, can be contacted during office hours at Tel (012) 382-6246. Should you have any questions regarding the ethical aspects of the study, you can contact the chairperson of the TUT Faculty Committee for Research Ethics, Dr E Olivier, during office hours at tel (012) 382-6393, e-mail OlivierEI@tut.ac.za. Alternatively, you can report any serious unethical behaviour at the University's Toll Free Hotline 0800 21 23 41.

**DECLARATION: CONFLICT OF INTEREST**

This research study was funded by the Tshwane University of Technology. No publication prohibitions, conditions or limitations were placed on the researcher.

**A FINAL WORD**

Your co-operation and participation in the study will be greatly appreciated. Please sign the informed consent below if you agree to participate in the study. In such a case, you will receive a copy of the signed informed consent from the researcher.

## CONSENT

I hereby confirm that I have been adequately informed by the researcher about the nature, conduct, benefits and risks of the study. I have also received, read and understood the above written information. I am aware that the results of the study will be anonymously processed into a research report. I understand that my participation is voluntary and that I may, at any stage, without prejudice, withdraw my consent and participation in the study. I had sufficient opportunity to ask questions and of my own free will declare myself prepared to participate in the study.

Research participant's name: _____ (Please print)

Research participant's signature: _____Date: _____

Researcher's name: _____ (Please print)

Researcher's signature: _____Date: _____

_____
Signature/Name