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IMAGE INTERPRETATION SYSTEM FOR DIAGNOSTIC RADIOGRAPHY: A COLLABORATIVE APPROACH

by

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Thesis submitted in fulfilment of the requirements for the degree

Doctor of Radiography

in the Faculty of Health and Wellness Sciences

at the Cape Peninsula University of Technology

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Bellville/Cape Town

Date submitted: 19 September 2023

DECLARATION

I, Abel Karera, declare that the contents of this thesis represent my unaided work and that the thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

19 September 2023

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ABSTRACT

In healthcare, medical imaging is essential to patient management, but rising demand and dependence on imaging services have led to radiologists focusing primarily on high-end modalities, resulting in a gap in image interpretation of routine radiographic imaging procedures. As a result, image interpretation of radiographs may be delayed or absent, potentially compromising patient management and healthcare quality. This is the case in many countries in Africa, where the number of radiologists is consistently low and insufficient. Radiographers are qualified health professionals whose responsibilities have expanded, in countries across the world, to include image interpretation in response to the radiologist shortage. Radiographers can provide image interpretation services via three recognised pathways: the red-dot system, preliminary clinical evaluation (PCE), and clinical reporting.

The primary function of a radiology department is to provide medical images with accurate and efficient image interpretation reports for patient diagnosis and management. The radiographic service in Namibia's state hospitals provides for the production of medical images upon request. However, the image interpretation system in Namibia seems to be underperforming, resulting in a significant number of plain images being left unreported. Additionally, the roles of radiographers in Namibia related to image interpretation are not well defined, and their preparedness for such roles has not been investigated. An evaluation of the image interpretation system was therefore proposed to assess the system's capacity and effectiveness and to explore ways to improve performance, including determining possible roles for radiographers to enhance the quality of image interpretation services. The purpose of this study was to examine the radiology image interpretation system and explore possibilities for improvement by actively involving radiographers in a collaborative approach, using one example of an under-resourced environment as a case study.

A multiphase mixed method design was used to collect data from radiographers, radiologists, referring doctors from three hospitals and lecturers at one higher education institution in Namibia. Purposive sampling was used, aiming for maximum variation and data saturation in the qualitative strands and maximum recruitment in the quantitative strands. Data were collected using a combination of instruments, including questionnaires, checklists, and semi-structured, one-on-one interviews, and analysed using quantitative and qualitative methods as appropriate. Ethical approval for the study was sought and granted by all relevant bodies. The research process consistently upheld principles of respect for persons, beneficence, and justice, with participants providing informed and voluntary consent to participate in the study.

The findings of the study provided evidence of a severe shortage of radiologists, with no reporting of plain images and a significant backlog on CT reporting. All the surveyed departments followed a doctor-driven structure with no specified roles for radiographers in image interpretation. The referring medical doctors indicated that image interpretation services were poor and characterised by delays that compromise patient diagnosis and treatment. They also indicated that comments from the radiographers would assist them in image interpretation in the absence of a radiologist's report. The participating radiographers demonstrated an adequate level of knowledge regarding plain image abnormalities. However, in practical assessments, the radiographers showed a high level of accuracy and sensitivity in detecting abnormalities in the images. The participating lecturers and graduates from the higher education institution indicated that the teaching and learning processes were not optimised to develop the necessary competencies for radiographers in image interpretation. This was compounded by a theory-to-practice paradox that hindered the acquisition of skills.

Based on the study results and existing literature, a modified image interpretation system was developed using systems theory. The system included the practice of a Radiographer Abnormality Detection System (RADS) and Preliminary Clinical Evaluation (PCE) by radiographers as a means to tackle the shortage of radiologists. System modifications were introduced across four primary stakeholder groups to enhance the involvement of radiographers. These groups include radiographers and radiologists, medical doctors, the higher education institution, and the Allied Health Professions Council of Namibia. Implementation of the modified system would ensure that most plain radiography images receive an interpretation to inform referring healthcare professionals and enhance patient management.

Furthermore, an implementation plan was developed based on the diffusion of innovation theory to guide the adoption and implementation of the modified system. The implementation plan consisted of four successive phases, based on the four stakeholder groups identified during the system modification process, and to facilitate system adjustments through feed-forward and feedback mechanisms. The study has contributed valuable information, regarding image interpretation in under-resourced settings. These findings will also have relevance to well-resourced environments through the proposed approach for modifying and implementing systems to incorporate radiographers in image interpretation. The study also emphasises the importance of aligning training and regulatory provisions with industry demands through periodic evaluations. Additional research on image interpretation is recommended to gather more empirical evidence to support and enhance the incorporation of radiographers into the image interpretation system.

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to my supervisors, Prof. P. Engel-Hills, and Dr F. Davidson, for their invaluable guidance, support, and inspiration throughout this research project. Their extensive knowledge, expertise and mentorship have been critical in shaping the direction of the research and ensuring its successful completion. The researcher is truly grateful for their exceptional contributions and for their unwavering dedication to the project.

I would like to express my gratitude to Stanley Lekata, the Postgraduate Development Support Coordinator, for providing valuable statistical support which shaped the data analysis for this study. I would also like to thank Michelle Snyders, the faculty librarian, for her support and guidance during the literature search and referencing process. Furthermore, I extend my appreciation to the staff from MITS at CPUT for their advice and assistance during the project, as well as for their warm welcome during my contact visits.

I would like to acknowledge the contribution of the following research assistants who provided valuable assistance during the data collection phase of the project: Martha Sitareni, Ebba Kangandjo, Magdalena Daniel, and Cesilia Aipanda. Their hard work and dedication significantly contributed to the quality of this research. Furthermore, I am also thankful to the radiographers, radiologists, medical doctors, and lecturers who generously gave their time and shared their experiences and perspectives. Without their contribution, this research would not have been possible. Their expertise and insights have greatly informed the findings of this thesis, and their efforts are sincerely appreciated. I would also like to thank my workmates at UNAM for their support and understanding, especially during the times when I had to balance work responsibilities with research work. Their support, encouragement, and understanding have been invaluable to the success of this research.

Finally, I would like to express my deepest appreciation and gratitude to my family, who have been my pillars of strength and support throughout this journey. Their unwavering love, encouragement, and understanding have been a constant source of motivation and inspiration, without which I could not have achieved this feat. Their sacrifices, patience, and belief in me have been immeasurable, and I am forever grateful for their unwavering support and love.

The financial assistance of the CPUT Postgraduate Bursary 2021-2022, towards this research is acknowledged. Opinions expressed in this thesis and the conclusions arrived at, are those of the author, and are not necessarily to be attributed to the funding agency.

DEDICATION

I dedicate this thesis to all radiographers, past, present, and future, who have dedicated their lives to the advancement of the radiography profession. May we continue to work together to harness our strength and develop the profession to those unimaginable levels. I also dedicate this work to my family, friends, and colleagues for their unwavering support, encouragement, and understanding throughout my academic journey.

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ABBREVIATIONS AND ACRONYMS

AHPCNA	Allied Health Professions Council of Namibia
AI	Artificial intelligence
ANOVA	Analysis of Variance
ASMIRT	Australian Society of Medical Imaging and Radiation Therapy
BMJ	British Medical Journal
CT	Computed Tomography
COVID-19	Coronavirus disease of 2019
CPUT	Cape Peninsula University of Technology
CR	Computed Radiography
DR	Digital Radiography
GP	General Practitioner
GMC	General Medical Council
HCPC-UK	Health and Care Professions Council United Kingdom
HEI	Higher Education Institution
HIS	Hospital Information System
HOD	Head of Department
HPCNA	Health Professions Councils of Namibia
HPCSA	Health Professions Council of South Africa
IV	Intravenous
ISRRT	International Society of Radiographers and Radiological Technologists
KR-20	Kuder–Richardson Formula 20
MOHSS	Ministry of Health and Social Services
MRI	Magnetic Resonance Imaging
NHS	National Health Service
PACS	Picture Archiving and Communication Systems

PCE	Preliminary Clinical Evaluation
PET	Positron Emission Tomography
PET-CT	Positron Emission Tomography and Computed Tomography
PET-MRI	Positron Emission Tomography and Magnetic Resonance Imaging
PNG	Portable Network Graphics (for free download)
RANZR	Royal Australian and New Zealand College of Radiologists
REC	Research Ethics Committee
RCR	Royal College of Radiologists
RADS	Radiographer Abnormality Detection System
RII	Radiographic Image Interpretation
RIIS	Radiographic Image Interpretation System
RIS	Radiology Information Systems
RTAT	Radiology Turnaround Time
SAT	Study Ascribable Time
SCoR	Society and College of Radiographers
SOP	Standard Operational Procedure
SoR	Society of Radiographers
SPSS	Statistical Package for Social Scientists
SSA	Sub-Saharan Africa
TL	Traffic light
UK	United Kingdom
UN	United Nations
UNAM	University of Namibia
USA	United States of America
WHO	World Health Organisation

GLOSSARY OF KEY TERMS

Clinician	A medical professional who refers patients for imaging and reviews their results.
Image evaluation:	Refers to a normal radiographic process of assessing the technical quality of a radiograph and making decisions regarding the imaging processes (Bontrager & Lampignano, 2014).
Image Interpretation System (IIS)	Refers to a system that utilises healthcare professionals with knowledge of the imaging modality, anatomy, physiology and pathology to interpret and determine abnormalities on radiographic images as a way to support patient diagnosis and management (Brown & McNitt-Gray, 2000).
Red dot system:	Refers to a system where a radiographer places a red sticker or other visual cue or indicator on the radiograph to signal a potential abnormality (Hargreaves & Mackay, 2003; Coelho & Rodrigues, 2011). It is also known as a Radiographer Abnormality Detection System (RADS)
Preliminary clinical evaluation:	Refers to a practice where radiographers assess and interpret images for abnormalities, and communicate these clearly in written forms to referrers (SOR, 2013).
Radiographer	A diagnostic radiographer working in an imaging department.
Radiograph	An image of the internal anatomy of the body produced by a radiographer after exposing the patient to radiation.
Radiographer image reporting:	Refers to the production of a definitive image report by radiographers who have completed education and training in image reporting for defined fields of practice (SOR, 2013).
Radiologist report:	This is a definitive report of abnormalities on a radiograph produced by a radiologist (Murphy et al., 2019).

Healthcare system: Refers to how people, resources, and institutions are organised and linked to enable the provision of healthcare services or to meet health needs (Arteaga, 2014).

Healthcare procedure: Refers to step-by-step instructions on how to perform certain healthcare tasks (Keane, 2003).

CHAPTER 1 : STUDY SYNOPSIS

1.1 Introduction

Role extension, role development, skill transfer and skill mix are phrases that have become common in healthcare discussions that are intended to address the chronic problem of skill shortages. Generally, these terms are synonymous with the acquisition and clinical practice of professional roles that are not commonly associated with the particular profession (Wuni et al., 2021; Nelson et al., 2018). This is usually driven by the ever-increasing demand for healthcare services, the continued expansion of healthcare specialities, the shortage of healthcare workers in some categories, and the ageing population (Dubois & Singh, 2009; Buchan & Calman, 2005). Resources permitting, the implementation of such human resource developments has been positively associated with improvements in service delivery (Gilburt, 2016). One area where practice shifts have been observed is in the interpretation of radiology images, where diagnostic radiographers (referred to as radiographers hereinafter) in some countries have extended their roles into areas of practice that were traditionally reserved for radiologists. In these countries, this has been actively supported by empirical evidence emanating from years of contextual research and randomised control trials making it easier to convince the regulatory bodies of the need and the benefits of such practice as well as the suitability of radiographers to perform such roles (Culpan et al., 2019; Henderson et al., 2017; Hardy et al., 2008).

While the drivers of role extension for radiographers into radiology image interpretation may have been similar or even stronger in under-resourced as compared to well-resourced environments, active efforts to develop context-specific solutions have not received equal attention. Under-resourced environments, characterised by limited healthcare funding, continue to face a genuine need to extend the role of radiographers, despite the lack of contextual evidence to support or guide its implementation. Evidence from well-resourced contexts (Woznitza et al., 2020; Rowe et al., 2019; Lancaster & Hardy, 2012), is in many aspects impractical to transfer into these settings due to notable differences in health system structures, operations, funding, and other factors. The current study therefore aimed to address this knowledge gap and it was intended to generate evidence based on one under-resourced healthcare environment where the radiographer's scope of practice did not include image interpretation.

This chapter will establish the foundation of the study, including the empirically based problem and the research question to be addressed. The specific objectives, that informed the literature review, research methodology and data analysis, will be discussed and justified in the subsequent chapters. Finally, the philosophical foundations underlying the study and the conceptual framework will be described to provide an understanding of how the study progressed.

1.2 Background

Image interpretation and reporting have always been part of the medical imaging process and were primarily undertaken by radiologists. The effectiveness of this service mainly depends on timely and accurate image interpretation reports as these can impact patient management (Wuni et al., 2021). Technological advancements have shaped the medical imaging field, resulting in the introduction of advanced equipment in radiology. This has caused radiologists to focus on high-end modalities, which in turn has led to a service gap in routine procedures like reporting on plain radiographic imaging, trauma, and emergencies (Freeman, 2006). This service gap has continued to grow and worsen over time and has been compounded by the rising demand for imaging services and an increasing reliance on imaging by clinicians (Reid & Edwards, 2011). As a result of this, in addition to the worldwide shortage of radiologists, many radiographs are not reported or there is a significant delay before a definitive image report is provided, potentially negatively impacting patient management and the quality of healthcare services (Ofori-Manteaw & Dzidzornu, 2019; Page et al., 2014). This impact is particularly significant in the African context, where the number of radiologists has consistently been low and insufficient. In 2012, there was a report of 14 countries in Africa having no radiologists working in public hospitals (Coulborn, Panunzi, Spijker, William E. Brant, et al., 2012). In the same year, Benin had 12, Rwanda had seven and Zambia had two (Kawooya, 2012). In 2020, Wuni et al. (2020) reported that Kenya, with a population of 43 million, was served by 202 radiologists while Ghana with a population of 25 million had 35 radiologists. This contrasts sharply with well-resourced countries such as Australia which had a population of 24.50 million and 4,081 radiologists in 2017, the United Kingdom (UK) with a population of 67 million and 4,127 radiologists in 2021, and the United States of America (USA) with a population of 333 million and 29,250 radiologists in 2022 (United States Department of Labor, 2022; Australia Government- Department of Health, 2017; The Royal College of Radiologists, 2016). In addition to the shortage of radiologists in Africa, the expansion of imaging services and the growing volume of imaging requests have further impacted image interpretation services, thereby compromising the quality of healthcare (Ofori-Manteaw & Dzidzornu, 2019).

The traditional operational structure in medical imaging is that radiographs are produced by radiographers and reported on by radiologists. A radiographer, also known as a radiation technologist, is an appropriately trained health professional who uses his/her expertise and knowledge in human sciences, physical sciences, and imaging sciences among others, to assess patients and select an appropriate imaging protocol as well as to evaluate the technical quality of the resultant images (ASMIRT, 2019). The roles of radiographers are stipulated and regulated by national health professions organisations such as the Health and Care Professions Council UK (HCPC-UK), Health Professions Council of South Africa (HPCSA) and Health Professions Councils of Namibia (HPCNA). These regulatory bodies prescribe the scope of practice for health professionals, including radiographers, and through this determine what they are permitted to do in line with their training. They can also recommend further training to enable professionals to respond to service demands and changes in the healthcare system. This was evidenced in radiography where, due to a shortage of radiologists and failing image interpretation systems, the scope of practice for radiographers has expanded to include new roles such as image reporting and clinical governance (HPCSA, 2020; ISRRT, 2019; SCoR, 2015).

Image reporting is one of the three recognised pathways for radiographers to offer image interpretation, with the other two being the red-dot system and preliminary clinical evaluation (PCE). The red-dot system, also known as a radiographer abnormality detection system (RADS), was the initial system used by radiographers to offer image interpretation. In this system, a potential abnormality would be marked by placing a red dot on the image to assist the referring doctor in identifying critical areas that require attention (Neep et al., 2014a). However, RADS had its disadvantages, with the primary one being the absence of an option to specify the location and severity of the detected abnormality (Hardy & Culpan, 2007; Younger & Smith, 2002). This resulted in the introduction of a system that goes beyond the non-specific identification of an abnormality to a description of such abnormality, known as the initial image commenting system (Kelly, 2009; Younger & Smith, 2002), or preliminary clinical evaluation (Beardmore, 2013). PCE is intended to increase the specificity of the red-dot system by providing a written comment regarding image interpretation and improving the efficiency of the image interpretation system (Stevens & Thompson, 2018). According to the Society and College of Radiographers UK (SCoR), PCE and clinical reporting are an integral part of the radiography profession and the growth of these roles aids in meeting patients' and referrers' needs for accessing timely results. However, PCE is not intended to replace a definitive radiologist image report which signifies the final step of the imaging process (Snaith et al., 2015). Furthermore, the effectiveness of PCE in practice relies on a comprehensive foundational education at the undergraduate level, supplemented by clinical guidance during preceptorship or the probationary period, as well as post-qualification studies that lead to accurate image interpretation (Stevens & Thompson, 2018).

Significant improvements in quality of care have since been reported when radiographers partake in image interpretation. These benefits include a reduction in interpretive errors (Hardy, Snaith, et al., 2013), a reduction in service costs (Hardy, Hutton, et al., 2013), assisting the multidisciplinary team (Neep et al., 2014b) and enhanced patient diagnostic outcomes (Howard, 2013). Stevens reported that image interpretation by radiographers had a positive impact on patient management by emergency nurse practitioners as it improved abnormality localisation accuracy and reduced false-negative diagnoses (Stevens & Thompson, 2020).

The majority of these studies have been conducted in well-resourced settings, with limited research carried out in Africa regarding image interpretation by radiographers. A recent systematic review by van de Venter and Ten Ham-Baloyi (2019) identified six studies that focused on image interpretation accuracy by radiographers in South Africa between 2007 and 2017. The study concluded that image interpretation by radiographers can significantly contribute to patient management in clinical practice. However, to enhance practice and increase its effectiveness, there is a need for contextualised policy and practice guidance that standardises the image interpretation practice by radiographers (Wuni et al., 2021; Woznitza et al., 2020). These guidelines should be grounded in contextual evidence, aiming to enhance consistency in practice as well as the quality of service (Woznitza et al., 2020). Therefore, the current study is focused on generating the essential contextual evidence that can be utilised to advocate for potential policy changes in the future.

1.3 Study rationale

The provision of a total quality radiographic service is crucial for timely patient diagnosis and effective patient management. Without image interpretation, the imaging service cycle remains incomplete, leaving the referrer without any diagnostic information. Although radiographers have been employed to bridge this gap in certain situations, there is limited guidance on how radiographers can effectively offer image interpretation services in under-resourced environments such as Namibia. This study has contributed knowledge and insights into the role of radiographers in the image interpretation process within under-resourced settings, where radiologist support is typically limited. The study underscored the significance of training and preparation for radiographers in such settings to enable their participation in these evolving roles. This acquired knowledge will be valuable across different contexts in understanding image interpretation by radiographers. It serves as a valuable addition to the existing body of knowledge derived from well-resourced settings. The modified system in this study aimed to provide new knowledge that will enable and facilitate the practice of image interpretation by all radiographers especially in under-resourced settings such as Namibia. Furthermore, the study generated knowledge that will provide the benchmark and foundation for future studies focusing on image interpretation in various resource contexts. The clinical application of this new knowledge will contribute to an improved healthcare service through the effective utilisation of radiographers' skills in image interpretation.

1.4 The study context

Namibia is a country located in the southwest part of Africa (latitude -22.95764 and longitude 18.49041), with a land size of 824,292 km² (Geodatos, 2022; Green, 2021). It shares its border with four countries: South Africa in the south and southeast, Botswana in the East, Zambia in the northeast and Angola in the North, while the Atlantic Ocean covers the western border as shown in Figure 1.1. Its population was estimated to be 2.58 million as of 2021 (The World Bank, 2022).

Figure 1.1Map of Namibia *(Green, 2021)(freeware)*

Namibia's health and radiology infrastructure

The medical infrastructure in Namibia is continuously expanding with the country having a total of 599 hospitals, health centres, and clinics, encompassing both state-owned and private facilities, as of 2018 (MoHSS, 2018). Out of these, only 43 were hospitals operating at different levels and providing a range of services. Among these, just three hospitals functioned as the nation's state referral hospitals, with two located in Windhoek (Khomas region) and the third situated in Oshakati (Oshana region), as indicated by circles on the map. A total of 24 health facilities were identified as having a radiology department, of which 18 were under state ownership (MoHSS, 2018). The majority of state-owned radiology departments provided basic X-ray services, with only a limited number offering a comprehensive range of imaging modalities. The three referral hospitals boasted fully equipped radiology departments and employed a significant portion of the radiographers (approximately 45%) within state hospitals, thus they were chosen as the research sites for this study.

Radiology human resources in Namibia's state hospitals

Namibia, like many African countries, has been affected by a chronic shortage of radiologists with no immediate solution in sight. This has been compounded by the lack of training of radiologists at the University of Namibia (UNAM) due to a lack of capacity and resources. With a population of approximately 2.7 million (United Nations, 2020), the country is served by fewer than 18 radiologists (Brigitte Weidlich, 2010), giving a patient ratio greater than 1:150000. State hospitals are mostly affected, as over 80% of the radiologists are estimated to be currently working in the private sector. The radiology departments within the state health facilities are severely understaffed, with only three radiologists serving the three referral hospitals in the country. One radiologist serves the two referral hospitals in Windhoek, with assistance from two medical officers, while the other two radiologists are based in Oshakati. This has negatively affected the image interpretation system, as most of the plain images go unreported, creating space for misdiagnosis and mismanagement of patients by inexperienced doctors (Brigitte Weidlich, 2010). This is similar to reports from other contexts, where medical interns and junior doctors, with experience of fewer than five years, were shown to possess inadequate image interpretation skills and were at great risk of misdiagnosing patients (Miranda et al., 2019; Cheung et al., 2018; Christiansen et al., 2014). In addition to the radiologist shortage, the number of radiographers in Namibia is notably low, with a total count of 240, out of which 42 are allocated to the three referral hospitals (MoHSS Official). A total of 26 radiographers service the two referral hospitals in Windhoek on a rotational basis, while the other 16 are based in Oshakati. These three hospitals are equipped with computed and digital radiography (CR and DR), Computed Tomography (CT), ultrasound, fluoroscopy, and mammography machines that are integrated using Radiology Information Systems (RIS) and Picture Archive and Communication System (PACS). However, there was no operational Hospital Information System (HIS) connected to these departments. Moreover, the three primary referral hospitals are accredited for radiography student training. As part of their duties, radiographers at these facilities are obligated to offer supervision and guidance to the students. The efficiency and effectiveness of the image interpretation system in supporting patient management within the state hospitals in Namibia remain uncertain.

The scope of practice for Namibian radiographers was primarily derived from and closely resembled the scope of practice of radiographers from the Health Professions Council of South Africa (HPCSA), with some guidance also taken from the practice guidelines of the Society and College of Radiographers (SCoR) in the UK. In its draft revised scope of practice document published in May 2020 for public feedback, the HPCSA outlined various tasks that radiographers can undertake, including plain image interpretation among other responsibilities (Government of South Africa, 2020). The SCoR on the other hand indicated that it is a core responsibility for radiographers to offer image interpretation as part of their service which includes preliminary clinical evaluation and/or clinical reporting (Beardmore, 2013). These roles have been well incorporated into clinical practice in the UK with support and regulation from the SCoR and the Health and Care Professions Council (HCPC). The Health Professions Council of Namibia (HPCNA) regulates radiographic practice in Namibia using the Allied Health Professions Act, of 2004 (Allied Health Professions Council, 2004). The current legislation and scope of practice for radiographers in Namibia have not completely incorporated recent professional advancements and shifts in radiography practice to address the shortcomings in image interpretation. The current literature does not provide substantial evidence to endorse the integration of image interpretation into radiographic practice, primarily due to the absence of clinical competency assessments in this area.

1.5 The research problem

The primary function of a radiology department is to provide medical images with accurate and efficient image interpretation reports that contribute towards patient diagnosis and management. This goal is achievable when an effective and efficient system is in place with well-defined roles and responsibilities for all health professionals within the radiology department. This approach ensures the efficient utilisation of available resources, both human and material. The image interpretation system in Namibia’s state hospitals seems to be failing to achieve the primary goal of the radiology department as evidenced by a large number of unreported radiographs. Unpublished departmental statistics from the two referral hospitals in Windhoek show that up to 90% of the plain images are unreported with only a few plain chest images for international visa applications being reported. Furthermore, requests for plain image interpretation especially from the accident and emergency department often go unaddressed due to reporting pressure from complex imaging modalities such as CT. Even for the CT examinations, where the image interpretation, by the radiologists, seems to be focused, preliminary assessment in the two departments indicated that it could take between 4 to 6 weeks for a report to be ready. There was a lack of evidence regarding the evaluation of the image interpretation system to quantify its performance, identify challenges faced, and determine how it was influencing patient management within these departments. A system evaluation was therefore necessary to quantify the capacity and effectiveness of the image interpretation system as a basis upon which to explore methods for enhancing its performance. Furthermore, the roles of radiographers in the image interpretation system are not stipulated (HPCSA, 2020; Allied Health Professions Council, 2004) and it is apparent that radiographers rarely (if at all) formally participate in image interpretation as a way of improving the quality of health care to patients. Anecdotal evidence has indicated that some medical interns and junior doctors do informally consult with radiographers for their opinions on image appearances, but this has not been researched. Furthermore, the extent to which the radiography training curriculum prepares graduates for possible roles in image interpretation has also not been explored or analysed. This is important as it can provide empirical evidence needed to determine or support possible new roles for radiographers. This study was therefore designed to assess the current image interpretation system, evaluate the knowledge and competencies of radiographers in the pathology of the chest and appendicular skeleton, and determine the potential roles that radiographers could play in enhancing the quality of image interpretation services.

1.6 The research question

What are the current and possible future roles of radiographers in a collaborative radiology image interpretation system, relevant to a scope of practice for an under-resourced environment?

1.7 The study purpose

The purpose of this study was to examine the radiology image interpretation system and explore possibilities for improvement by actively involving radiographers in a collaborative approach, using one example of an under-resourced environment as a case study.

1.8 Study phases and objectives

In order to understand the current image interpretation system and the knowledge and competencies of radiographers, as well as explore the nature and extent of training in image interpretation, it was necessary to structure the study into three phases. The phases were structured in chronological order with each phase building on the findings of the previous phase. Each phase had its own aim and specific objectives as indicated below.

1.8.1 Phase One: Image interpretation system capacity and effectiveness within Namibia's state hospitals

This phase aimed to investigate the current radiology image interpretation system design, capacity, and effectiveness, in Namibia's state hospitals. In this phase, the researcher aimed to gain a detailed understanding of how image interpretation is designed within the radiology departments, its capacity, the roles of the different health professionals as well as the effectiveness of the process. To enable this, a full system evaluation was done that included all relevant stakeholders. This phase consisted of four specific objectives within Namibia's state healthcare namely to:

1. Determine and observe the current radiology image interpretation system capacity and performance.
2. Explore and describe the setup of the radiology image interpretation system within the radiology departments.
3. Determine the effectiveness of the image interpretation system in the management of patients.
4. Explore and describe the experience of referring doctors in state hospitals regarding the utilisation of the image interpretation system.

1.8.2 Phase two: Preparedness of Namibian radiographers to extend their roles into image interpretation

This phase aimed to determine the preparedness of radiographers to take up new roles in image interpretation. In this phase, the researcher assessed the current level of knowledge and clinical competencies of radiographers regarding image interpretation of chest and appendicular plain images. Furthermore, the study also examined the nature of training and assessed its perceived adequacy through interviews with lecturers and recent graduates from a selected higher education institution (HEI). The phase provided evidence of the current preparedness of radiographers for roles in image interpretation, outlining both areas of strength and areas that require improvement. The specific objectives in this phase were to:

5. Determine and analyse the knowledge of qualified radiographers in Namibia regarding image presentation of common chest and appendicular plain image abnormalities.
6. Evaluate the clinical competencies of qualified radiographers in Namibia regarding image interpretation of plain images of the chest and appendicular skeleton.
7. Explore and describe the perceptions and experiences of radiography educators regarding the preparedness of graduates to take up image interpretation roles.

8. Explore and describe the perceptions and experiences of recent graduates regarding their preparedness to take up image interpretation roles.

1.8.3 Phase three: Development of an improved image interpretation system for state hospitals in Namibia

This phase aimed to develop an improved image interpretation system that defines possible roles for radiographers and its implementation plan. This phase was guided by evidence generated from phases one and two of this study. The objective was to identify mechanisms to improve the image interpretation system, which included utilising radiographers. Furthermore, the implementation plan for the improved image interpretation system was developed during this phase. The specific objectives were to:

9. Develop a modified image interpretation system with clearly defined roles for radiographers in the process of image interpretation.
10. Develop an implementation plan for integrating the modified image interpretation system within the state hospitals.

1.9 The philosophical foundation of the study

The philosophical foundation provides the base on which the study was founded. It generates the basis for understanding the problem and the methodology applied to solve the problem. This study was based on the critical realism meta-theory developed by Roy Bhaskar (Bhaskar, 1975). Critical realism is a recent philosophy of science that is gaining popularity and application in social sciences. It is considered a meta-theory as it concerns several aspects of science philosophy that have implications for scientific research (Hoddy, 2019).

Traditionally, positivism and social constructionism were the main meta-theoretical philosophies driving the conduct of research. Critical realism was developed to offer an alternative worldview that deviates from prescriptive existing theories (Bhaskar, 2016; Gorski, 2013; Bhaskar, 1975). Critical realism thus introduced a new approach to methodologies that gave researchers the flexibility to empirically assess social phenomena with the intent to develop and understand the underlying causal mechanism that accounts for them (Hoddy, 2019; Angus & Clark, 2012). In order to achieve this, the meta-theory combines two separate philosophies into one: transcendental realism, which is a philosophy of science, and critical naturalism, which is a philosophy of the social sciences (Mcevoy & Richards, 2006). Transcendental realism presents the world as stratified and distinct whilst questioning what the ideal status of the world needs to be for certain human activities to be possible (Bhaskar, 2016). Critical naturalism is a via media between naturalists who believe that social phenomena can be studied in a similar way as natural sciences and anti-naturalists who believe that the study of the social phenomenon requires a different approach (Bhaskar, 2016).

Critical realism ontological assumptions propose that reality is multi-layered, containing structures and mechanisms that influence the observable and what can be experienced (Bhaskar et al., 2018). It provides a distinction between three ontological domains that define reality as the **empirical**, the **actual** and the **real** (Bhaskar, 1975). This is similarly emphasised by Acher's analysis which highlights the interplay between structures, culture, and agency in influencing behaviour (Brock et al., 2017; Emirbayer & Goodwin, 1994). These domains are distinct and separate but interact with each other to produce new mechanisms and experiences for an individual (Eastwood et al., 2014). The empirical domain according to Bhaskar, is characterised by events that are observable, measurable or that can be experienced by individuals (Bhaskar, 2016; Bhaskar, 1975). Similarly, culture and individual agency are thought to play a crucial role in shaping what is observed and experienced (Brock et al., 2017). The focus of critical realism, from both Bhaskar and Archer, is not only on what the empirical domain presents but on the underlying causes of such events. There is a belief that the explanations for what is observed and experienced are not necessarily found within the empirical events themselves but in deeper underlying structures and mechanisms (Angus & Clark, 2012). The actual is a reality domain that lies beneath the empirical domain. This domain houses all the events, activities or experiences that are occurring which may or may not be experienced in the empirical domain (Oltmann & Boughey, 2012; Bhaskar, 1975). In essence, this domain has a direct influence on what we experience but some of the events may occur beyond our awareness or experience. It is this actual domain that also reflects the interplay between cultural influences and individual agency in observations (Brock et al., 2017). The real is the deepest domain of reality and it is composed of structures and mechanisms that have a dual influence on both the actual and empirical domains (Bhaskar, 1975). Thus, the structures and mechanisms may cause events (a generative mechanism) in the actual domain which may be observed or experienced in the empirical domain (Oltmann & Boughey, 2012). They have a causal role and ability to affect the aspect of reality that is perceived (Brock et al., 2017). From this meta-theory, it is believed that scientific inquiry should be directed towards solving social phenomena through an understanding of the observable events (empirical) and analysing their underlying causal events (actual) or mechanisms (real). This ontological domain relationship is depicted in Figure 1.2.

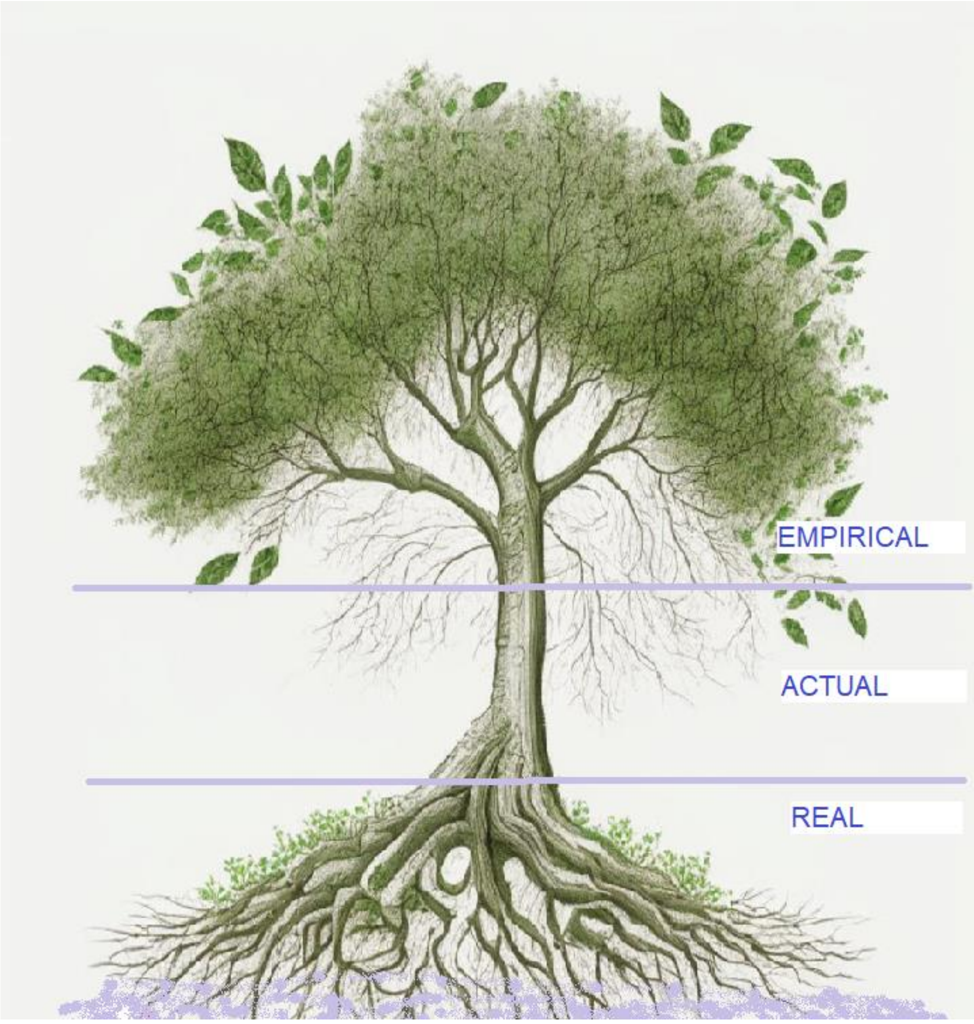

Figure 1.2: Relationship between ontological domains of critical realism *(Drawn with Adobe Illustrator - Adobe Inc., 2019)*

1.9.1 Contextual application of critical realism

This relates to how this meta-theory applied to the phenomenon in this study. As previously discussed, critical realism perceives reality as composed of three ontological domains, the empirical, the actual and the real. The **empirical** assumptions relate to those events or activities that can be experienced or observed directly or indirectly (Eastwood et al., 2014; Oltmann & Boughey, 2012). In this study, this domain relates to the status of the image interpretation system in terms of its capacity, design, and effectiveness. This can be directly observed, described, and quantified as reflected in phase 1 of the study. The **actual** assumptions are aspects of reality that occur or are in existence but may or may not be experienced or observed. The actual, though not observed at times, has an effect on the empirical or what is observed and experienced (Oltmann & Boughey, 2012). In this study, this domain relates to the knowledge and clinical competencies of radiographers regarding radiology image interpretation and identification of common pathologies. This may have a direct effect on what role they can or cannot take in the image interpretation system. The **real** assumptions are aspects of reality that relate to the structures and mechanisms in place that affect what is observed or experienced (Eastwood et al., 2014; Mcevoy & Richards, 2006). The real affects the actual and empirical reality. The real in this study relates to the legal and regulatory frameworks, the scope of profession and practice, the nature and quality of education, as well as the perceptions and experiences of the lecturers and graduates regarding image interpretation. These will indirectly affect the ability of radiographers to partake in image interpretation services. The relationship between these three ontological domains in this study is depicted in Figure 1.3.

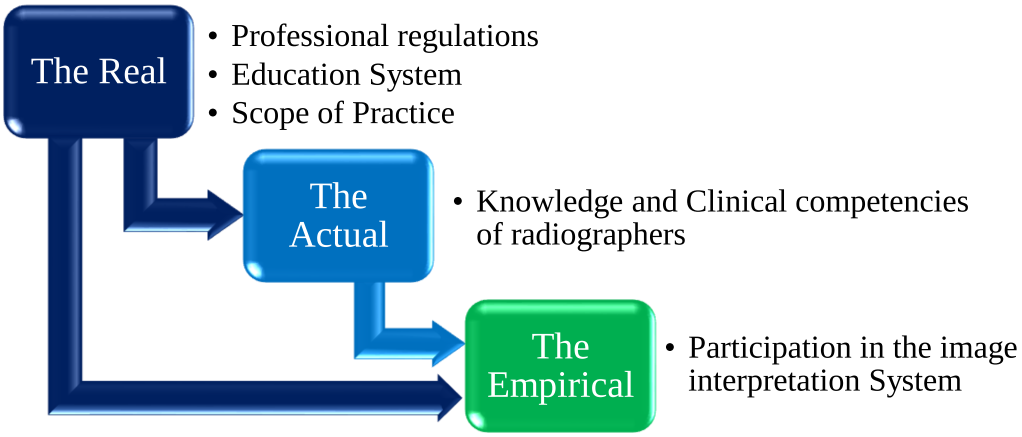

Figure 1.3: Application of Critical Realism in this study

1.9.2 Methodological application of Critical Realism

Critical realism asserts that the world operates within a multi-dimensional open system, necessitating research designs and methods that facilitate a holistic approach to addressing its complex issues (Khazem, 2018; Bhaskar, 2016). To provide this holistic assessment, critical realism recommends a combination of extensive (aka quantitative) and intensive (aka qualitative) approaches through mixed or multi-phase designs which give the research flexibility to choose a suitable design for each question (Mcevoy & Richards, 2006; Danermark et al., 2002). This approach is termed critical methodological pluralism and is aimed at neutralising the dichotomy associated with each approach separately (Danermark et al., 2002). In this study, the problem and objectives were multifaceted but complementary and aligned to one central question. Thus, a suitable approach and design were used for each objective to get a clear indication of how the particular aspect contributes to the problem, its causality, and its solution. This resulted in a multiphase mixed-method study consisting of a combination of quantitative (extensive) and qualitative (intensive) research designs in each phase as determined by the objectives.

Another important element and concept of critical realism that had methodological application in this study is retroduction. This concept refers to a mode of study where observable events are analysed concerning what might or could have caused them. This is premised on the concept of retroductive reasoning where the prominent question is to assess why current events are happening the way they are (Mcevoy & Richards, 2006). Therefore the researcher strives to understand and identify the mechanism that produces the observable events utilising their knowledge and experience as well as skills of abstraction (Danermark et al., 2002; Bergin et al., 2008). This concept applied to this study as the researcher sought to understand the current status of the image interpretation system, the reason for the current status as well as the role that radiographers can take to improve it. Therefore, an in-depth analysis of the underlying mechanism was necessary to understand the current status and reality.

1.10 Conceptual framework of the study

This conceptual framework was designed to give a pictorial overview of how the study was organised and the links and connections between the study phases and objectives. According to Miles, Huberman and Saldaña (2019), the conceptual framework explains graphically or narratively the key variables and factors in a study and their interrelationships. It provides the reader with a unique insight into the researcher's map of the area under study and how data was utilised to answer the main research questions. This study serves as a case study of the medical imaging service within Namibia's state hospitals, focusing on the image interpretation system. As an under-resourced setting characterised by radiologist shortage and resource constraints, the study sought to determine the potential roles of radiographers in the image interpretation process. In this study, the conceptual framework was used to first demonstrate the variables clearly in each phase with their inter-relationships as well as the central questions they were answering. Secondly, the phase-to-phase relationship was demonstrated especially how the central output for each phase flowed into or informed the subsequent phase until the final outcome was achieved. The study was conducted in three phases where the first phase was a situational analysis aiming at determining the current deficiencies in the radiographic image interpretation system through input from radiologists, heads of departments, radiographers, and doctors. The second phase aimed at determining the possible roles that radiographers can take up from the established deficiencies in Phase 1 and areas that require additional training. The last phase was focused on developing a radiographic image interpretation system that incorporates roles for radiographers as a way to improve service delivery to the patient and referrers. Figure 1.4. presents the pictorial representation of the conceptual framework for this study.

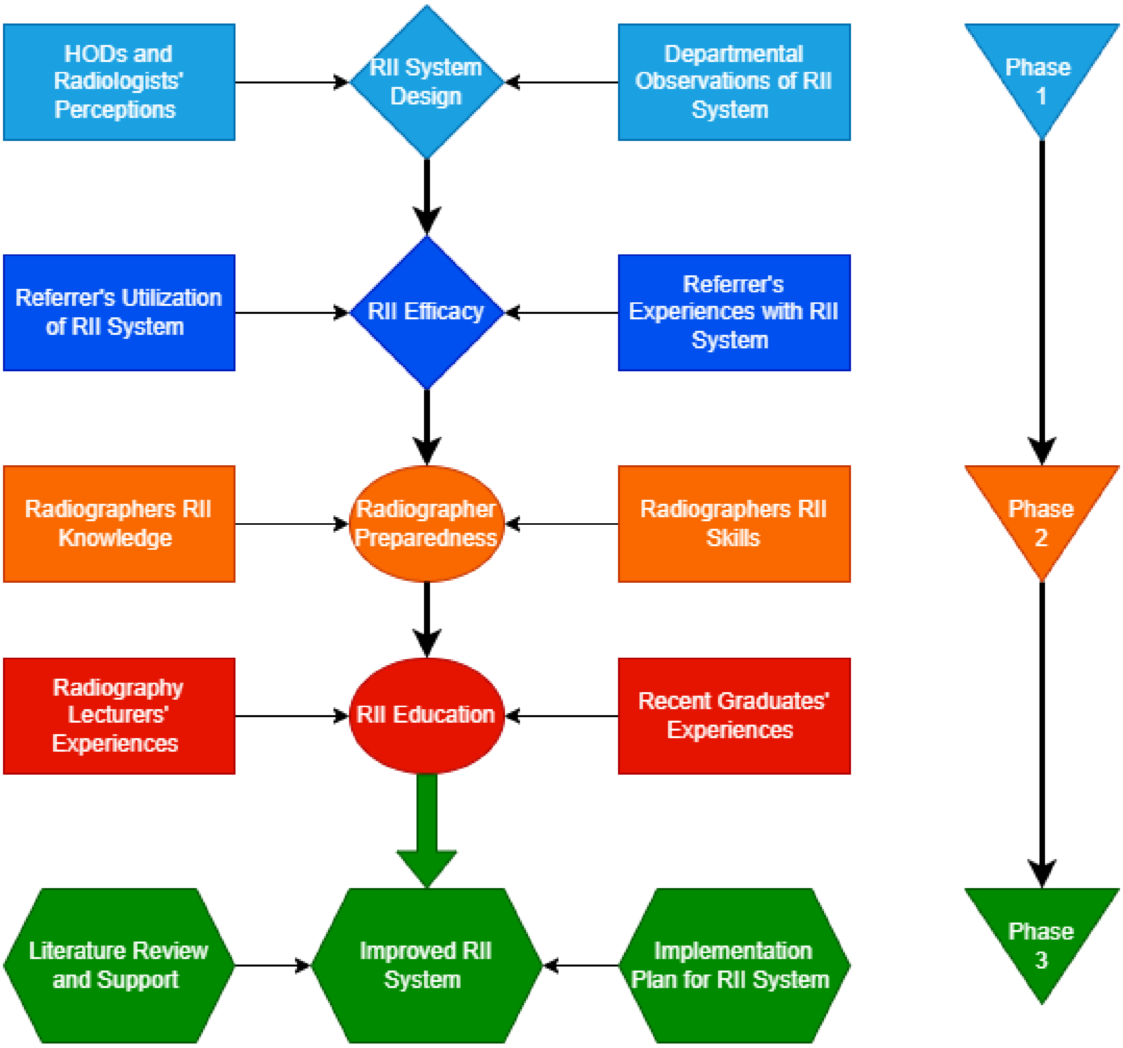

Figure 1.4: Conceptual framework of the study

RIIS=Radiographic Image Interpretation System; RII= Radiographic Image Interpretation

1.11 Overview of the Thesis

To enable an easier understanding of the thesis, the structure was divided into chapters that concentrated on different aspects of the research project. The thesis was divided into nine chapters and Figure 1.5. below displays how the chapters relate and provide the focus of each chapter.

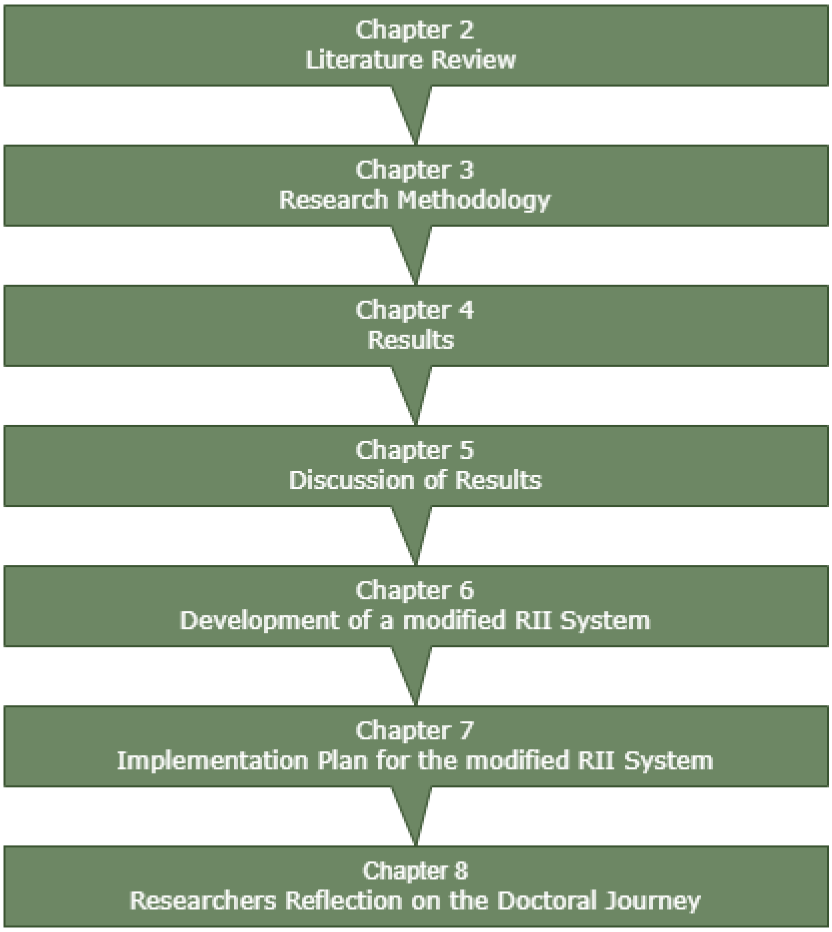

Figure 1.5: Outline of chapters in the report

RII=Radiographic Image Interpretation

Chapter two presents evidence of what is known about image interpretation in the literature from conception to the status, as well as the role of radiographers, both current and future. Chapter three provides details of the step-by-step methodology that was followed in executing this study, including ethical considerations. Chapter four contains the results, including the inadequacies of the current image interpretation process as reflected upon by radiologists, radiographers, and doctors, the adequate knowledge and competencies of radiographers in interpreting chest and appendicular images, as well as the experiences of graduates and lecturers regarding radiographer preparation for image interpretation. These results and findings were discussed in chapter five in the context of existing knowledge. A modified system was then developed and detailed in chapter six, focusing on enhancing the image interpretation process via radiographer utilisation. The implementation plan for this system was also developed and documented in chapter seven for the various stakeholders identified. Chapter eight concludes the thesis by providing a summary of the doctoral journey as experienced by the researcher.

1.12 Conclusion

This chapter has served the purpose of introducing the study and focus of the research. The background of what is established in this field was discussed followed by an integration of this into the current contextual research problem. From here, the research question, purpose, and objectives (divided into phases) were formulated and stated, thus serving as the guiding principles of the subsequent sections of the thesis. Furthermore, the underpinning meta-theory was discussed together with the contextual and methodological applications. Lastly, a brief outline of the arrangement of chapters in the thesis was provided to guide and create an appetite for the reader.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

In this chapter, the researcher set a foundation of what is known or established in this field of study and uncovered some of what remains unanswered (Kumar, 2011). This provides the point of departure for this study from which further knowledge could be developed (Nieswiadomy & Bailey, 2018). The literature review process was continuous, commencing from the study's inception and concluding only upon the finalisation of the thesis. Hence, there was a consistent development and updating of sources as new information became accessible. To streamline the search for information and the presentation of findings, the review was divided into three segments that concentrate on distinct yet interconnected sections of the study. The initial segment centred on the history and current status of radiography and radiology concerning image interpretation. The second segment concentrated on the evolving roles of radiographers in image interpretation, while the third segment centred on the global implementation of radiographer image interpretation across various regions.

2.2 Overview of the literature review approach

All three sections of the literature review were presented in a narrative format and followed the same strategy, even though they addressed different aspects of the study. The narrative framework provided the researcher with the freedom and flexibility to search and select literature from a wide array of sources including qualitative and quantitative studies as well as published and unpublished literature related to the study (Efron & David, 2019). The pluralistic nature of the narrative review served as the primary advantage, enabling the researcher to offer a comprehensive, cohesive, and coherent background of the area under investigation. This was particularly essential for highlighting the gaps in knowledge that the study aims to address. (Hempel, 2020; Efron & David, 2019).

The narrative review process was structured according to the strategy proposed by Greetham (2021). This strategy comprised seven steps that guided the process from formulating the literature review questions to the writing phase, as outlined below:

1. Generating your own ideas
2. Finding a research question
3. Searching the literature
4. Processing the ideas
5. Planning your review

6. Writing the first draft
7. Editing (Greetham, 2021)

2.2.1 Literature search strategy

Though the full description of the literature search strategy is not mandatory for narrative reviews, the researcher will briefly provide the criteria used for searching and reviewing the literature as guided by Greetham (2021) and summarised in Figure 2.1 (Efron & David, 2019).

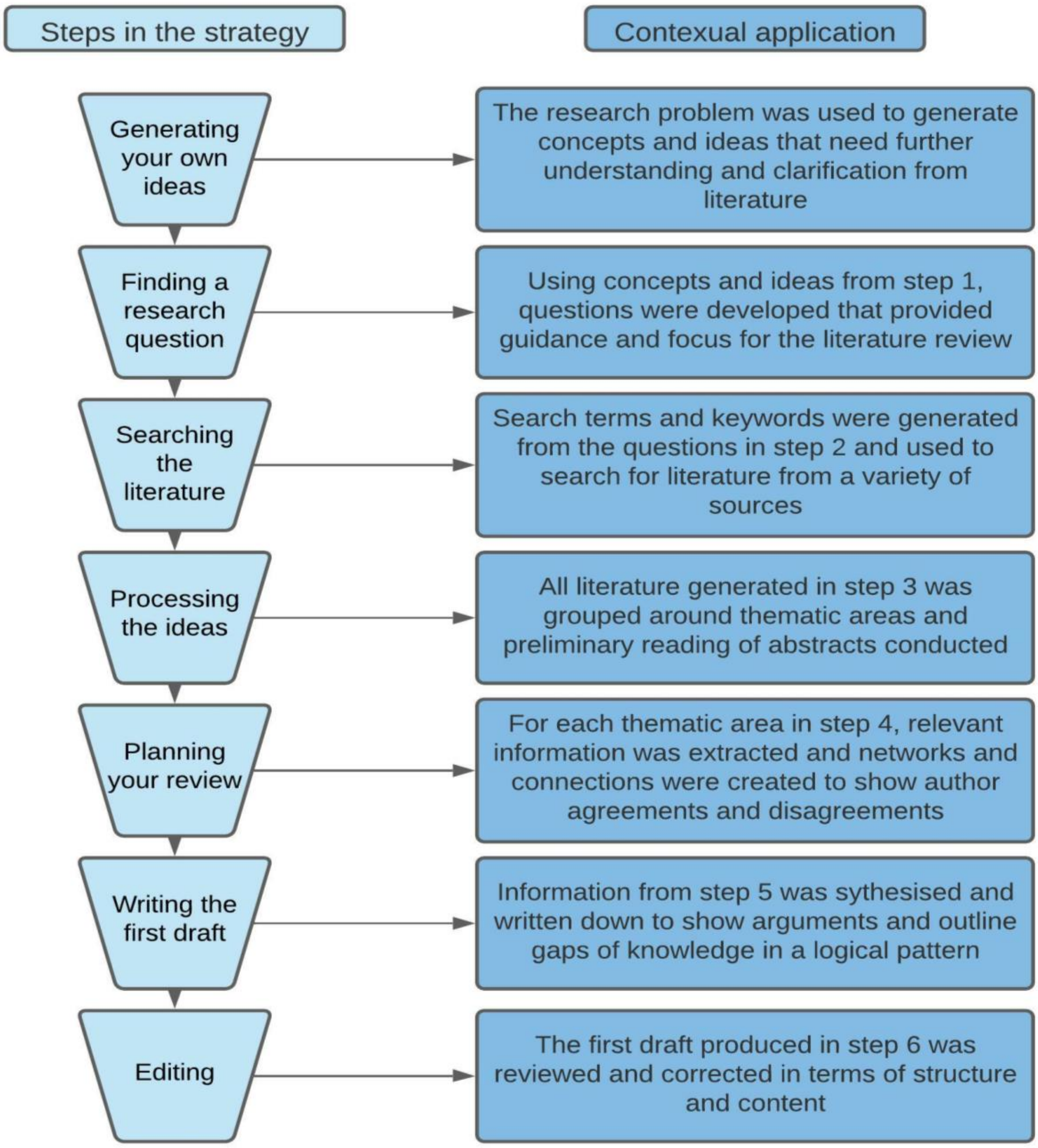

Figure 2.1: The literature review strategy - *modified from Greetham (2021)*

In line with the narrative review framework, primary, secondary and grey literature were included to ensure a comprehensive overview of the study's background area (Efron & David, 2019; Nieswiadomy & Bailey, 2018). Grey literature held particular significance, given that the field of image interpretation is still evolving. Certain data, in the form of theses and dissertations, might not be published in scientific journals. Additionally, other formats such as regulatory frameworks and scopes of practice offered crucial information to understand this area (Paez, 2017). A majority of the journal articles, conference papers, and unpublished materials were acquired through online sources, utilising search engines like Google Scholar, and databases including Science Direct Cochrane Library, PubMed, and Scopus. This approach was chosen to enhance the breadth of information sources and evidence within this area of radiography. Both single and multiple keyword combinations were utilised, in conjunction with Boolean operators (AND, OR, NOT, or AND NOT) to refine and enhance the quality of the search results (Nieswiadomy & Bailey, 2018; Kumar, 2011).

The keywords and phrases used in the literature search and their derivatives included x-rays (discovery, early medical use), radiography (conception, development OR growth, regulation, utilisation), radiology (conception, development, regulation), image interpretation OR reporting (onset, regulation, development, processes OR procedures, efficiency), radiologists' shortage, radiographer (training, scope of practice AND role extension, image interpretation).

2.3 Part 1: Image interpretation systems – The history and the present status.

2.3.1 The purpose of this review

The purpose of the literature reviewed in this section was to highlight the history of image interpretation through the lens of radiography and radiology and the current operational status. In essence, this section focuses on providing answers to questions such as how image interpretation started and developed over the years, where we are now, what is working and not working currently, as well as performance challenges being faced among other questions. Historical information as well as current information from textbooks, journal articles and grey literature was used during the information gathering and organised into thematic areas presented as subheadings in the following body of text.

2.3.2 History of radiography and radiology

The discovery of a strange form of energy by Professor Wilhelm Konrad Roentgen in 1895 while working with a Crookes tube marked the beginning of medical imaging (Bensusan, 1967). This energy was termed 'x' ray as an indication of its unknown quantity and form but was later renamed Roentgen after its discoverer. The evidence of this discovery was an image of his wife's hand which became the first radiograph of the internal human anatomy as shown in Figure 2.2 (Murphy, 1990). In the following years, the hand radiograph was replicated in various locations around the world as the discovery began to be utilised in medicine (McConnell, 2021; de Villiers, 2000; Murphy, 1990). The subsequent analysis and interpretation of the anatomy and abnormalities demonstrated by these images inadvertently marked the beginning of radiographic image interpretation (Murphy, 1990). Therefore, the X-ray discovery marked the beginning of internal human imaging (later to be known as radiography) and its image interpretation (later to be known as radiology). These two fields were not as distinct in the early years of X-ray utilisation, in fact, the terms radiologist and radiographer were used interchangeably as they essentially involved a single function of imaging and image interpretation (Tatsuhito, 2019). Additionally, in the early days of the discovery, the use of X-rays for medical imaging was not controlled and involved a wide array of professionals including doctors, physicists, engineers, pharmacists and hospital porters (Burrows, 1986).

Figure 2.2: Professor Wilhelm Konrad Roentgen and the first x-ray of the hand (Britannica Academic, 2022)

As the utilisation of X-rays and their clinical significance expanded in the years following their discovery, a debate emerged between medical and non-medical practitioners regarding the ownership of this emerging profession (Tatsuhito, 2019). A substantial concern revolved around the image interpretation aspect of the process, with medical practitioners arguing that it should solely be undertaken by professionals with medical training (Price, 2001). Between

1920 and 1925, significant debates, complaints and representations were made that resulted in the clarification of roles and functions in medical imaging (McConnell, 2015). The formation of the Society of Radiographers (SoR) in the UK was the primary step in the regularisation of the medical imaging and radiography profession. After a series of meetings and debates, this society, in 1923, published a notice that clearly distinguished the roles of radiologists and radiographers as evidenced by the following quote:

> *'The term 'radiologist' shall be applied to members of the medical profession who undertake radiographic diagnosis and treatment by means of X-rays and radium, while the term radiographer be applied to their trained non-medical assistants.'* (Lancet 1923 cited in Price (, 2001: 108)).

This announcement marked the separation of the two professions of radiography and radiology. The medical practitioners began to disassociate themselves from the task of producing images, leaving it as a domain for radiographers. However, the above announcement was not deemed explicit enough to prevent the radiographer from partaking in image interpretation or to prohibit medical practitioners from seeking the opinions of radiographers instead of radiologists. To ensure this, the Society of Radiographers further exerted control over what the radiographer could do through the following notice in 1924:

> *'That no member (i.e. who is without the qualifications entitling him to practise in Great Britain and Ireland as a physician or surgeon) shall accept patients for radiographic, radioscopic, or therapeutic work except under the direction and supervision of a qualified medical practitioner, neither shall such member make any report or diagnosis on any radiograph or screen examination, and any breach of this regulation shall be deemed conduct unfitting the member guilty thereof to remain a member of the Society...'* (SoR 1924 cited in Price (, 2001: 109)).

To further ensure that radiologists became the only medical professionals interpreting images the following publication was made by the General Medical Council (GMC) in the British Medical Journal in 1925:

> *"Medical practitioners are prohibited from associating with unqualified persons who may assume medical functions... It is therefore incumbent on medical practitioners, in the interests of their patients as well as for their own professional security, to see that the line between radiographers and radiologists is honourably observed."* (BMJ 1925 cited in Price (, 2001: 110).

The aforementioned announcements were intended to establish regulations that designated medical image interpretation or film reporting as a domain exclusively reserved for radiologists. The role of radiographers was restricted to the technical aspects of image production and image quality. This deskilling of radiographers persisted for nearly 50 years until the participation of radiographers in image interpretation was reinstated, driven by the intervention of radiologists due to overwhelming workloads (Price, 2001).

2.3.3 Traditional image reporting system and outcomes

Medical images or radiographs of internal human anatomy are not self-explanatory but require special skills and knowledge to decode the data, in the form of shadows, into a meaningful image report that can inform diagnosis and patient management (Manning, 2019). Image interpretation and reporting have always been part of the medical imaging process and were primarily undertaken by radiologists. The effectiveness of this service mainly depends on timely and accurate image interpretation that can impact patient management (Wuni et al., 2021).

Since the proclamation by the General Medical Council in 1925, the operational model within the radiology department has remained largely unchanged, particularly in relation to image interpretation (Sistrom & Langlotz, 2005). In the majority of settings, whether public or private, the medical imaging system continues to adhere to a medical-oriented model that was prescribed in 1925 (Society of Radiographers, 1925). This model centres on the radiologist, as the physician, being in charge and directing all operations and functions within the imaging departments as a way of consolidating their power base and reinforcing their status and prestige as medical specialists (Mcconnell & Smith, 2008). Within this model, the medical imaging process is divided into various sequential steps that support each other culminating in the production of the image interpretation report by the radiologists. Generally, these steps can be grouped into three broad categories which are (1) the ordering of the examination through the request form, (2) the performance and completion of the requested examination by the radiographer and (3) the image interpretation and reporting of findings by the radiologist (Lundvall et al., 2021; Towbin et al., 2017). For the majority of examinations, this model often keeps the radiologists out of the patient's or referring physician's view, particularly in light of the current increased workloads (Gunn et al., 2015). The referring physician is responsible for delivering the findings of the image interpretation report to the patient thereby eliminating the radiologist-patient interaction. Certain departments have witnessed some modifications to this system, introducing a shift in the imaging interpretation process towards a more patient-centred approach. This change entails radiologists engaging in increased daily interactions with patients during and after imaging procedures, aiming to facilitate the communication and clarification of imaging results (Gunn et al., 2015; Mangano et al., 2014). However, changes of this nature need to be contextualised and are reliant upon local needs and circumstances.

The overall goal of the various models of imaging systems is to communicate findings from an imaging examination or procedure to the referring physician in a clear, unambiguous, accurate and timely manner (Kahn et al., 2009). Thus since the inception of image interpretation, the communication of image findings has occupied a central role in the evolution of image interpretation practices (Friedman, 1983). The image interpretation report has traditionally held and continues to hold the primary role as the communication medium for conveying findings between the radiologist and the referring physicians. This report serves as a dual-purpose document, serving both as a medical record and a legal official record of the care administered to the patient (Mityul et al., 2018; Mangano et al., 2014; Kahn et al., 2009; Sistrom & Langlotz, 2005). In most primary care settings, this report serves as the only channel of communication and its quality depicts the contribution of the radiologist to patient care (Mityul et al., 2018; Grieve et al., 2010). Regardless of technological and medical advancements, there remain several challenges that threaten the effectiveness of communication between radiologists and referrers including the quality of the reports, the language used, the report format, the length of the report, and the turnaround time among others. These have contributed to the dissatisfaction of referrers with radiologists' reports, especially the inconsistencies regarding the report structure and nomenclature (Mityul et al., 2018). Some opportunities can be explored to improve the contribution of medical imaging in patient care and management through the effective utilisation of human resources available in the imaging departments, such as radiographers, in the image interpretation process. This may lessen the burden on the radiologists allowing them more time to focus on the complex and advanced procedures.

2.3.4 Increased utilisation of imaging in medicine

Since the discovery of X-rays and the subsequent conception of the medical imaging field, there have been tremendous and continuous changes due to technological and medical advancements that have increased the variety of imaging modalities. These newer modalities offer opportunities for improved detection, diagnosis and treatment of previously difficult pathologies and disease conditions (Hendee et al., 2010). Modalities such as CT, and Magnetic Resonance Imaging (MRI), including recently their dual hybrids with Positron Emission Tomography (PET), offer thin-slice axial images that increase sensitivity and specificity in pathology detection thereby introducing a new range of possible disease diagnoses in clinical practice (Albertyn, 1991). The realisation of these obvious advantages and clinical utility of these modalities by referrers increased their clinical application creating a surge in the number of requests received in the imaging departments. In the UK alone, the number of CT and MRI procedures has been reported to be increasing at a rate of 10-12% annually (Bell et al., 2018). Similarly, an annual increase in combined imaging service demand of up to 4% and 4,3% have been reported for adult patients and 0.8% and 2,4% for paediatrics in the USA and Ontario respectively (Smith-Bindman et al., 2019). In most African countries, the adoption of these newer technologies has been at a slower pace due to limited health financing and human capacity (Makuta & O'Hare, 2015). However, significant progress has been made in the last decade, especially regarding the number of CT scanners and this has also seen an increase in the number of requests received by imaging departments (Adejoh et al., 2018). While the increased utilisation of these high-end modalities may be deemed to be positive in terms of quality of service to the patient, the potential gains can easily get eroded if it is not matched with the imaging department's capacity, especially for image interpretation. Unlike conventional 2-dimensional imaging, these high-tech modalities produce multiple image slices that will ultimately require extended time of analysis during image interpretation significantly contributing to radiologist workload (Ghali et al., 2010).

While the increase in the utilisation of newer and high-tech imaging modalities may appear as a positive development for the quality of patient care, some previous studies have reported the contrary. Overutilisation has been reported as one of the negative consequences of these new modalities and it is defined as the application of an imaging procedure in circumstances where it will not affect the patient management plan (Hendee et al., 2010). Overutilisation is regarded as an unnecessary procedure and has been reported to account for between 20% and 50% of high-tech imaging requests (Rao & Levin, 2012; Brenner & Hall, 2007; Picano, 2004). Numerous factors contribute to the overutilisation of imaging services but chief among these is the limited knowledge of the referrers regarding the best modality for a clinical question and the inability of the radiologists to actively justify imaging requests before the procedure is done (Alchallah et al., 2020; Hendee et al., 2010). Furthermore, self-referrals by radiologists for further imaging studies also account for overutilisation through a typical conflict of interest where the current payment schedules (especially in private practices), are based on; the more the procedures done, the higher the income for the radiologist and the institution (Smith-Bindman et al., 2019; Hendee et al., 2010). In addition to overutilisation, defensive medicine has been on the rise as more and more physicians have become cautious of potential litigations due to missed diagnoses. Defensive medicine occurs when the prescription of a procedure is primarily for safeguarding against possible malpractice claims rather than for the benefit of the patient (Hendee et al., 2010). Though it may be difficult to quantify separately, the practice is quite prevalent with previous studies reporting between

25% and 32% of imaging requests being due to defensive medicine (Kainberger & Kainberger, 2016; Osti & Steyrer, 2015; Hendee et al., 2010). The consequence of the above is an increase in the workload of the imaging departments and radiologists in particular, due to image interpretation demands. This results in radiologists failing to cope with the high demand for reporting these complex high-tech procedures, further isolating them, and limiting their availability for a physician or patient consultation. In addition, the turnaround times for image interpretation are negatively affected and the relevance of the image interpretation report in clinical decision-making may be compromised.

2.3.5 The global shortage of radiologists

The continuous introduction of high technology and advanced equipment, along with the ever-increasing application and demand for radiological services, have resulted in radiologists focusing more on high-end modalities such as CT, MRI, and interventional imaging. As a consequence, there is a deficit in service delivery for reporting on plain radiographic imaging procedures and other more routine procedures, including trauma and emergency (Freeman, 2006). This is compounded by a global shortage of radiologists, which expanded training programmes are failing to satisfy, as the workload continues to increase (Page et al., 2014; Piper, 1999). A recent report by the Royal College of Radiologists (RCR) in the UK highlighted severe radiologist shortages as all imaging departments surveyed were failing to meet their reporting requirements thereby raising questions about the sustainability of the service in the future, especially with the imminent retirement of a large portion of the radiologist workforce (Halliday & Maskell, 2020; The Royal College of Radiologists, 2016). This shortage has been compounded by the increasing demand for imaging services across the globe without concomitant adjustments in staffing levels due to a lack of capacity and inability to recruit (Reid & Edwards, 2011). In Scotland for example, CT and MRI procedures increased by 55% but the number of radiologists only improved by 3% between 2010 and 2015 thereby creating serious operational deficiencies (The Royal College of Radiologists, 2016). This is similar to Japan where there are more CT and MRI scanners available compared to any other country in the world but suffers from a shortage of radiologists, especially in rural locations resulting in an increased workload (Matsumoto et al., 2015). Canada, Australia and the USA have reported similar trends where radiologist shortages are prevalent and resulting in burnout which impacts negatively the quality of care (Ganeshan et al., 2020; Zha et al., 2019; Harolds et al., 2016; Smith & Reeves, 2009).

In Africa, the staffing situation is undocumented in most countries but seemingly worse than in well-resourced settings due to general under-funding of the healthcare sector as well as lack of training capacity (Rosman et al., 2019). Previous statistics have reported that the number of radiologists in well-resourced settings, such as Europe, usually ranges from 47 to 110 per million population, while in Africa this number is as low as 0-3.6 per million population with Sub-Sahara Africa averaging 0.9 radiologists per million (Rosman et al., 2019; Fowler, 2013; Monu et al., 2012). In some African countries, no single radiologist is serving in public health facilities (Coulborn, Panunzi, Spijker, William E Brant, et al., 2012). Several studies from different African countries have indicated a general shortage of radiologists to interpret radiographs thereby affecting the provision and quality of imaging services (Bwanga, 2020; van de Venter & ten Ham-Baloyi, 2019; Semakula-Katende et al., 2016).

The shortage of radiologists leads to either the absence of or substantial delays in, obtaining a definitive image report. This situation can potentially have a detrimental impact on patient management and the overall quality of healthcare service. (Ofori-Manteaw & Dzidzornu, 2019). This effect is significant in the African context where the shortage of radiologists is further compounded by shortages of medical officers who can fill the gap in image interpretation, especially for trauma images, as witnessed in well-resourced countries (Brady, 2011; Pitman & Jones, 2006). This lack of image interpretation reports has been identified as one of the causes of misdiagnosis contributing to high morbidity and mortality rates in Africa (Griggs et al., 2014). Immediate action thus is needed to address this shortage and improve the quality of imaging services possibly through the utilisation of radiographers in the image interpretation process as initiated already in well-resourced settings (du Plessis & Pitcher, 2015).

2.3.6 Current reporting efficiency

The increased utilisation of medical imaging has resulted in increased demand for image interpretation and pressure to reduce turnaround times (Griffith et al., 2019). As medical imaging has claimed a central role in patient management, delays in image interpretation may have a negative effect on diagnosis, management and patient hospital stay, especially in emergency departments (Jalal et al., 2021). Thus, the radiology turnaround time (RTAT) may be considered one of the indicators of quality of care and workflow efficiency. RTAT has been defined differently by several authors. However, in its basic sense, it is the amount of time between the completion of image acquisition (printing of films or on RIS) and the availability of an image interpretation report (printed hardcopy or online on HIS) (Lamb et al., 2015; Mehta et al., 2000). As the image interpretation report is considered the overall outcome of medical imaging, any delays in its availability affect the efficiency of the medical imaging process. A previous survey of 120 emergency departments in the USA reported dissatisfaction with the RTAT by departmental chairs, as they expect the turnaround time to be below 30 minutes (Rathnayake et al., 2017). Similarly, another study in South Africa reported that the RTAT for trauma CT procedures were worse than reported in other international studies (Tiemesmann et al., 2016). More assessments, especially in under-resourced settings, are essential to accurately quantify RTAT and its impact on patient management.

Various factors have been reported to affect RTAT including but not limited to, the departmental reporting workload, the complexity of cases and modalities, radiologist's speed, time spent teaching, use of structured or unstructured reporting, PACS system stability, design of workflow, non-image interpretation roles, sub-specialisation among others (Zabel et al., 2020; Rathnayake et al., 2017; Mehta et al., 2000; Twair et al., 2000). Currently, various efforts are directed at eliminating the effect of these factors on the image interpretation system to improve RTAT. Recent reports have shown, for example, that where more radiologists are available in the department, sub-specialisation or being modality-specific can significantly reduce RTAT (Zabel et al., 2020; Stern et al., 2018). Furthermore, significant reductions in RTAT were also reported due to the efficient use of modern technologies such as PACS and RIS as well as the incorporation of Artificial intelligence (AI) simulations (Almutairi et al., 2021; Baltruschat et al., 2021; Twair et al., 2000). The efficient use of the radiographers in image interpretation through role extension and skills mix has also been reported to be a cost-saving and safer alternative to managing reporting backlogs and reducing RTAT (Stevens et al., 2021; Culpan et al., 2019; Milner et al., 2016a). Despite the effect of the aforementioned and other contextual factors, The Royal Australian and New Zealand College of Radiologists (RANZR) proposed turnaround times for different radiological procedures in the form of study ascribable time (SAT) as indicated in Table 2.1 (Pitman et al., 2018). SAT includes, in addition to the actual film reporting time, all the other times the radiologist was involved in the imaging procedure such as contrast injection or locating and downloading the images from the PACS (Pitman et al., 2018).

Table 2.1: Study Ascribable Time (SAT) for common procedures

Modality	**Examination sub-type**	**SAT**
General x-ray	All single examinations	2-3 min
	Skeletal survey	7 min
	Mammography	6 min
	Fluoroscopy sterile (non-sterile)	20 min (35 min)
Computed Tomography	Head	6 min
	All other single regions	8 – 13 min
	Two regions (3 regions)	15 min (20-27 min)
	IVU	20 min

	Coronary Angio	35 min
	Biopsy	60 min
Magnetic Resonance Imaging	Extremities	16 min
	Spine	15 min
	Head and its variations	18 min
	Heart, neck, brachial plexus	20 min
	Breasts	35 min

(Pitman et al., 2018)

Increased RTAT results in several unreported procedures each day which can accumulate over time to create a significant backlog of unreported procedures or examinations (Yates et al., 2018). Backlog is defined as imaging procedures and examinations with no image interpretation report at least ten (10) days after the completion of the procedures or examination (NHS Benchmarking Network, 2017). The current image interpretation systems are associated with reporting backlogs which present a significant clog in the efficiency of the system (Hobson & Parris, 2017). In the UK, almost all departments are affected by reporting backlogs albeit varying in extent and severity. A backlog of 200 000 unreported images was reported in 2016, which was reduced slightly in 2017, across several departments in the UK (Kim & MacKinnon, 2018). The Radiology Benchmarking 2017 National report estimated an average of 2854 unreported examinations in each department in the UK in 2017 with the bulk of these being plain radiographs (Kim & MacKinnon, 2018; NHS Benchmarking Network, 2017). In many imaging departments, particularly in under-resourced environments, backlogs often go unrecorded due to a lack of research, yet they stand as a considerable barrier to delivering quality care, necessitating immediate attention. In most of these departments, given financial constraints and technological limitations, the most viable, feasible and sustainable action plan will be to explore the inclusion and use of radiographers in the image interpretation system which is the focus of this study.

2.3.7 The role of medical doctors in image interpretation

The medical and technological advancements over the last decade have strengthened the pivotal role of medical imaging in the diagnosis and management of patients as evidenced by increased utilisation of the vast modalities (Bell et al., 2019; Nanapragasam, 2014). Medical specialists have become extremely dependent on medical imaging resulting in a major increase in requisitions that the imaging departments struggle to cope with, especially the image interpretation aspect. Consequently, this has led to an increased Radiology Turnaround Time (RTAT) and the subsequent accumulation of backlogs that are difficult to manage. This has a detrimental impact, resulting in delays in patient diagnosis and compromising patient management. To mitigate this impact, medical officers often assume the responsibility of image interpretation (when definitive reports are absent) to guide diagnosis and patient management. This trend has been observed in various countries, including Australia (Glenn-Cox et al., 2019), Malaysia (Daud et al., 2018), and South Africa (Sethole et al., 2020), particularly concerning conventional imaging. In the UK emergency departments, medical officers are mandated to take immediate decisions on patient management, admission-discharge, triaging decisions as well as further testing required (Samara et al., 2021; Mehdipoor et al., 2017). The medical officer is ordinarily responsible for ordering the examination, understanding the image interpretation report, and utilising the findings in the management of the patient. The ability of medical officers to interpret these images accurately depends on their training, knowledge, and clinical experiences.

Undergraduate radiology training is usually the main source of image interpretation knowledge for medical officers. Regardless of this, there has been a limited focus on the content and nature of training resulting in wider variations across UK universities (Bell et al., 2019). In most of these UK universities, there is minimal emphasis on radiology or image interpretation during undergraduate medical training. Teaching at this level is often noted to be predominantly informal, infrequent, and lacking in both adequacy and structure (Glenn-Cox et al., 2019; Bell et al., 2019; Jacob et al., 2016; Satia et al., 2013). Furthermore, in some universities in the UK and Ireland, students only get image interpretation exposure through one-week rotations which is inadequate to build the skills and competencies expected upon graduation (Nanapragasam, 2014). The Royal College of Radiologists in the UK introduced an undergraduate curriculum to standardise undergraduate training in image interpretation (Bell et al., 2019; Glenn-Cox et al., 2019). The extent of incorporation of this in the various training programmes is yet to be fully assessed. In other contexts such as Australia, there is no agreement on undergraduate training content and it remains the responsibility of the training institution (Glenn-Cox et al., 2019). In Europe, the European Society of Radiology identified undergraduate training as a priority area that requires immediate attention while in New Zealand, the majority of graduates indicated that radiology training was inadequate (Bhogal et al., 2012; Subramaniam et al., 2005). Several surveys across the globe generally indicate a lack of preparedness among medical students in image interpretation and a need for more radiology input in the undergraduate medical training curriculum (Chew et al., 2020). In Africa, the field of radiology is poorly developed evidenced by a critical shortage of radiologists and the lack of training capacity (Iyawe et al., 2021; Rosman et al., 2019; Rehani et al., 2017). This hinders the comprehensive inclusion of image interpretation in undergraduate medical training programmes as the available radiologists are overwhelmed with clinical responsibilities.

Nonetheless, the same requirement for radiology knowledge to be instilled during undergraduate medical training remains the established norm (Sethole et al., 2020). Consequently, the burden of image interpretation falls upon inadequately trained medical officers, posing a risk of misdiagnosis and improper patient management.

Medical officers have to shoulder the responsibility of image interpretation, especially for conventional imaging and in emergency departments regardless of the shortcomings evident in their undergraduate training. Several studies in the literature have assessed and compared the accuracy of image interpretation between medical officers, general practitioners, and medical students, contrasted with radiologist reports with the findings mainly indicating incongruences (Ovington & Metters, 2021; Mehdipoor et al., 2017; Satia et al., 2013). The bulk of these studies were conducted in well-resourced settings like the UK and Australia, with a specific focus on the interpretation of plain chest radiographs. This emphasis is because plain chest radiographs are commonly requested from emergency departments and are regarded as among the most challenging to interpret due to the diverse array of potential pathologies (Samara et al., 2021; Satia et al., 2013; Harvey et al., 2005). A recent survey of medical practitioners in Iran reported poor image interpretation skills including a failure to recognise life-threatening pathologies in emergency departments (Mehdipoor et al., 2017). Furthermore, participants in the same study had serious challenges identifying normal chest radiographs as normal. Similarly, a high incidence of under and over-reporting of COVID-19 signs on chest radiographs was reported among junior clinicians when compared with radiologists' findings in a recent study in the UK. This study reported up to 23% of misdiagnoses by clinicians compared with radiologists' findings (Ovington & Metters, 2021). Similar findings were reiterated in an Australian study, which revealed low image interpretation accuracy for both students (56.1%) and junior doctors (57.6%) using 10 chest radiographs (Cheung et al., 2018). Of crucial significance to this study was the absence of substantial improvement in accuracy between students and junior doctors, even when experience was considered. This observation further solidifies the notion that the knowledge of medical officers is primarily rooted in their undergraduate medical training. Another study in Denmark, in agreement with these findings, concluded that the doctors in their investigation lacked the essential image interpretation skills required for chest radiograph interpretation (Christiansen et al., 2014).

A South African study highlighted inadequate and unsystematic image assessment among general practitioners during image interpretation, posing a substantial risk of misdiagnosis and errors. The study recommended comprehensive in-house training for general practitioners in systematic analysis and pattern recognition of chest radiographs (Sethole et al., 2020). This trend, though undocumented, is similar at most hospitals in Africa, including Namibia, as they follow the same training protocols and are affected by the severe shortage of radiologists. However, there are studies in Malaysia and Jordan that have reported good image interpretation skills among medical officers after going through a comprehensive training programme that included radiology during undergraduate training (Samara et al., 2021; Daud et al., 2018).

2.3.8 Artificial Intelligence in image interpretation

There has been a significant leap in technological developments over the past decade, marked by increased computing power and substantial advancements in Artificial Intelligence (AI). Motivated by the necessity to enhance healthcare services, AI is now being integrated into various core functions of healthcare, including image interpretation in radiology, primarily in response to the radiologist shortage (Mello-Thoms & Mello, 2023). Due to the increased workload and demand for imaging services, radiologists have become more susceptible to interpretation errors due to fatigue. In such cases, AI can help alleviate the workload and enhance productivity without causing burnout (Weisberg et al., 2021; Nishikawa & Bae, 2018). Hence, its utilisation can play a crucial role in assisting diagnosis and reducing backlogs in imaging departments. A recent study demonstrated that an AI model significantly aided in diagnosing coronavirus, differentiating it from pneumonia on chest CT scans (Weisberg et al., 2021). Similarly, AI models have been shown to perform at the same level as general and non-specialized radiologists in the diagnosis of various brain pathologies on MRI scans (Rauschecker et al., 2020). However, there are also studies in the literature that have reported no positive changes in work efficiency or practice from the introduction of AI in image interpretation (Allen et al., 2021; European Society of Radiology, 2022). The application of AI in image interpretation ranges from breast imaging, thoracic radiology, and neuroradiology, to musculoskeletal imaging (Mello-Thoms & Mello, 2023). In these domains, AI is applied for general abnormality detection or specific disease characterization. Additionally, AI has also been applied to non-interpretative functions within radiology departments, such as workflow enhancement, reducing patient dose, shortening scan times, and scheduling, among other tasks (Mello-Thoms & Mello, 2023). In radiography, AI has been associated with the automation of booking and scheduling, procedure planning, image acquisition, and digital image processing. Additionally, as the role of radiographers expands into image interpretation, AI has also shown potential to enhance this role as a supportive system (Hardy & Harvey, 2020). Research is ongoing to determine the optimal integration of AI in medical imaging, with a focus on improving the accuracy of AI models.

2.3.9 The emerging issues

A brief review of radiography history has highlighted that radiographers have been involved in image interpretation for approximately 25 years after the discovery of X-rays in 1895. The limitation to practice image interpretation was fronted by doctors with limited defence by radiographers who at that time, were not yet accorded a professional status. Compounding this was the lack of proper training with most being in-house programmes. Over time, due to technological advancements, standardisation of training and recognition of radiography as an independent profession, the return to image reporting became strongly justified. Training programmes continue to be reviewed and modified to create the necessary competencies in line with the scope of practice.

The advancement in technology has also brought in new imaging modalities and increased utilisation of imaging in medicine resulting in an overwhelming increase in imaging and requests for image interpretation. Consequently, radiologists are now failing to cope with this excessive workload and image interpretation reports are not always on time resulting in backlogs that are difficult to manage. Compounding this is the chronic global shortage of radiologists and limited training capacity, especially in under-resourced environments. Medical officers have tried to mitigate this by providing image interpretation for plain radiographs within emergency departments, but this has not always produced the desired effect. Their training in image interpretation is poor and results in low accuracy rates and high error rates. This can have a significant impact on missed and misdiagnoses leading to poor patient management. It is therefore imperative that the best-fit and contextual solution is explored to alleviate the effect of poor image interpretation capacity, especially in under-resourced environments including Namibia. One of the possible solutions is through the effective utilisation of radiographers in image interpretation which has been explored in other contexts and is the subject of this thesis.

2.4 Part 2: Radiographer’s role in mage interpretation – the past-future crossover

2.4.1 The purpose of this review

In this section, the primary objective was to review the evidence concerning the established roles of radiographers within the image interpretation system. The researcher examined literature related to the training of radiographers and how it has evolved over time to enhance their readiness for image interpretation. Additionally, the researcher analysed and discussed the connection between the nature of training and the prescribed scope of practice. Based on various sources of literature, a discussion of how image interpretation fits into the framework of role extension was provided including the justification of the practice. Most importantly, this section reviewed the established pathways of image interpretation, including their advantages and disadvantages. The performance of radiographers in the various image interpretation pathways also was reviewed through studies that compared their performance with radiologists and other healthcare professionals.

2.4.2 The training of a radiographer

Diagnostic radiography is a profession that is recognised internationally where practitioners use radiation and complex imaging systems to produce anatomical and physiological images of internal body structures (SCoR, 2019). A diagnostic radiographer, also known as a radiation technologist, is an appropriately trained health professional who uses his/her expertise and knowledge in human sciences, physical sciences, and imaging sciences among others, to assess patients and select an appropriate imaging protocol as well as to evaluate the resultant images (ASMIRT, 2019). During the training of radiographers at the undergraduate level, students cover theoretical and clinical modules including practical evaluation of radiographic images for diagnostic quality and the presence of abnormalities. However, variations exist between countries and even institutions within a country on the actual content of the diagnostic radiography curriculum, the arrangements of the content, the mode of delivery and assessment as well as the duration of training (McNulty et al., 2021). In the early years, 1920-1960s, radiography training was more focused on the technical aspects of imaging with little or no emphasis on radiographic pathology or pattern recognition (Hackle, 2004). While a few programmes have developed further from this, the majority of radiography training still follows this technically oriented approach however with contextual differences due to the heterogeneous uptake of technological advancements (Alaamer, 2012). Thus, training content and programme structure remain limited by country-specific demands and the availability of imaging modalities for training (Couto et al., 2018; McNulty et al., 2017). This has produced wide variations in graduates' competencies and primary focus areas between institutions, a difference which becomes more apparent across countries and continents (Sá dos Reis et al., 2018; England et al., 2017). This difference is significantly marked in Sub-Sahara Africa, primarily because of limited investments in radiography that have hindered both growth and training. In many programmes, the focus remains solely on cultivating competencies for conventional imaging. In some countries such as Namibia, a single training programme exists while in others such as South Africa, multiple training programmes are available albeit all offering non-uniform content and structure. Most of these programmes, however, aim to provide students with the basics of medical and radiation sciences that include content on anatomy, physiology, and pathology as well as imaging sciences.

The training of radiographers also displays significant variations in terms of duration and primary focus areas. The transition of training and assessment responsibilities from the Society of Radiographers to Higher Education institutions in the UK in 1987 led to a reshaping of training to align with the university-level training framework (Pratt & Adams, 2003). This gave training institutions the freedom to decide on the content and duration of their training programmes (Price, 2007). Thus, some institutions developed programmes that have different combinations of diagnostic radiography, radiotherapy, nuclear medicine, and ultrasonography. Other institutions, however, developed these as single dedicated programme pathways (McNulty et al., 2017). This diversity in programme focus and content is among the reasons cited for the variance in programme duration among different training institutions (Sá dos Reis et al., 2018). Previous surveys of radiography programmes in the UK have shown that most programmes are at the bachelor's level and vary in duration from three years to four years (Couto et al., 2018; McNulty et al., 2017). A recent survey on international qualifications in radiography also reported the three-year Bachelor’s degree as the most common training programme across the world for entry into radiography with other qualifications ranging from certificates (1-2 years) to Bachelor with Honours (4 years) (McNulty et al., 2021). In South Africa, the HPCSA prescribes that radiography training must be done through an accredited training programme and the majority of institutions follow a four-year degree programme awarding a Bachelor of Technology or Bachelor of Science honours (HPCSA, 2020). In Namibia, the HPCNA prescribes a three-year diploma or four-year degree as the requirement for registration as a radiographer with the only training institution offering a four-year Bachelor's Honours degree in diagnostic radiography (Allied Health Professions Council, 2004). The duration of a programme is a critical factor in the development of radiography competencies during work-integrated learning. Consequently, to attain the requisite minimum competencies, it is imperative to allocate sufficient time for work-integrated learning, ensuring a harmonious balance with the theoretical content.

2.4.3 Radiographer Scope of Practice

Since the discovery of X-rays in 1895, imaging technology has continued to evolve with new modalities and procedures being introduced (Bercovich & Javitt, 2018). Modalities in radiography have moved from conventional imaging to CT, MRI, and interventional studies as well as dual imaging such as PET-CT and PET-MRI of late. The development, acquisition, and utilisation of these newer modalities are occurring at various speeds throughout the world and usually dictate developments within the radiography profession as well. The scope of practice for radiographers, which sets the boundaries and limits of practice, has also followed trends and developments in the profession but is strongly guided by the knowledge base of radiographers and the availability of training programmes (ASRT, 2017). The variations highlighted before on content focus and duration of training programmes across the globe have also affected the definition of the scope of practice for radiographers in different countries.

Most countries refer to their local training programme as a guideline to define the limits of practice for any profession. In some countries, the scope of practice is clearly spelt out consisting of four critical areas; the ability to properly care for the patient, the ability to perform diagnostic radiography procedures, the ability to assess the radiographs for diagnostic quality and the ability to protect self, the patient and public from unnecessary radiation exposure albeit at varying length and depth (Government of South Africa, 2020; IIRRT, 2019; ASRT, 2017). All these elements are benchmarked on the training programmes with limited recognition of on-the-job training and acquisition of competencies. Similarly, in Namibia, the scope of practice of radiographers is very prescriptive and mainly based on the training curriculum of the programme in that country (HPCNA, 2020). In contrast, in countries like the UK, the scope of practice has been expanded to encompass on-the-job training, acknowledging and empowering practitioners to define their own boundaries of responsibility (HCPC, 2018; SCoR, 2015). This has allowed the development and inclusion of newer roles such as image reporting for radiographers which started as on-the-job training before training programmes could be designed. However, for most scopes of practices of radiographers, the focus has remained mainly on technical skills with limited inclusion of image interpretation.

2.4.4 Role extension in radiography and its drivers

Role extension is a concept that is widely accepted and implemented within the health profession. Most health professions (including radiography) are licenced by regulatory bodies and subjected to practice limits as defined by their scope of practice. When members of a profession acquire additional skills and take up roles and responsibilities that are not traditionally prescribed in the scope of practice for their profession, it is considered role extension (Williams, 2006; Price, 2007). Numerous factors have been cited as the drivers of role extension including staff shortages, increasing service demands, technological advances, cost containment, reform within the health sector, demands and expectations from staff and patients, and changes in population dynamics among others (Williams, 2006; Smith & Reeves, 2009; Price, 2007; Decker & Iphofen, 2005). In radiography, these factors have had an effect on role extension but chief among them is the shortage of radiologists (Culpan et al., 2019; Field & Snaith, 2013). As a result, the roles and responsibilities of radiographers continue to develop, expanding into new directions, driven by the need to serve patients and improve the quality of the healthcare service (SCoR, 2019). Radiology departments had to adopt role extension practices aimed at mitigating the local impact of radiologists' shortage whilst addressing local service needs. Thus role extension activities have not been uniform in nature, focus or practice between departments or across countries as they are driven by contextual factors (Koch et al., 2017). Different practices have been reported as part of role extension for radiographers in the UK, the USA, Ireland, and Africa.

Numerous roles have been adopted by radiographers as part of role extension or skills mix in different departments and countries. In the UK, the extension of roles for radiographers to independently practice intravenous (IV) injections, barium meal and enema, conventional imaging and mammography reporting, as well as ultrasound reporting, have been well established (Culpan et al., 2019; Price, 2007; Price & Le Masurier, 2007). In the USA, radiographers can report on radiographs as radiology assistants while some can administer IV injections (American College of Radiology, 2014). Similarly, administering IV injections is permitted in Ireland after undergoing the necessary training (The Irish Institute of Radiography and Radiation Therapy, 2007). In South Africa, previous reports indicated the adoption of roles such as IV injections or pattern recognition though these were not formally recognised and deemed to be an illegal practice according to the scope of practice (Koch et al., 2017; Williams, 2006). However, the updated scope of practice for radiographers2, which is under ministerial review, has made substantial progress towards the formalisation of these roles and practices (Government of South Africa, 2020). Similarly, anecdotal reports in Namibia indicate the limited practice of IV injections by radiographers in private practice but no pattern recognition or film reporting has been reported. A recent review of radiographers' scope of practice in Namibia has specified IV injections as a new role for radiographers with oversight from radiologists but remained silent on image interpretation (HPCNA, 2020). Though there is a critical shortage of radiologists in Namibia, especially in state hospitals, role extension by radiographers into image interpretation has received little attention both clinically and in research. There is therefore a need to develop evidence to support this role and guide its implementation in practice to improve the quality of service rendered to patients.

2.4.5 Image interpretation pathways for radiographers

Image interpretation has emerged as an area of career advancement and role expansion for radiographers, particularly in well-resourced settings. This trend is primarily attributed to the shortage of radiologists, the increasing backlog of reporting, and the rising demand for imaging services. These factors have contributed to the underperformance of image interpretation systems, prompting a review of the scope of practice for diagnostic radiographers. This review has led to the incorporation of new roles, such as image interpretation and clinical governance, to address the shortcomings (ISRRT, 2019; SCoR, 2015). Image interpretation for radiographers has developed into three recognised pathways that have been implemented separately or in varying combinations in different contexts. The three pathways are the red dot system or radiographer abnormality detection system (RADS), preliminary clinical evaluation (PCE) and definitive modality-based clinical reporting.

2.4.5.1 Radiographer Abnormality Detection System

RADS, also known as the red-dot system or scheme, was the first method used by radiographers to extend their role in image interpretation following recommendations and early research by Swinburne and Burman (Woznitza, 2014). This method was introduced in the UK over 30 years ago and has been in operation in various forms ever since (Hargreaves & Mackay, 2003; Berman et al., 1985). In its original form, the method entailed radiographers expressing their opinion of a possible pathology or abnormality on a plain radiograph by highlighting it with a red dot or sticker as shown in Figure 2.3 (Murphy & Neep, 2018; Yates et al., 2018; Neep et al., 2014a). This would draw the attention of the medical practitioner or referrer to the possible pathology when the radiologist's report was not immediately available (Brown & Leschke, 2012; Okeji et al., 2012). It, therefore, provided a safety net for emergency practitioners and less experienced medical staff regarding image interpretation. Some operated a slight variation of the red-dot system known as Traffic Light (TL) where instead of appending a red dot, the dot marker would be either green, orange or red depending on whether pathology is absent, suspected or present, respectively (Akimoto, 2019). The system continued to be in use even with the advent of digital radiography as the dot/sticker could be affixed digitally during post-processing functions. RADS in all its forms, relies on the knowledge and ability of radiographers to distinguish normal from abnormal radiographic appearance which was and still is a clinical expectation as part of their job (van de Venter & Friedrich-nel, 2021).

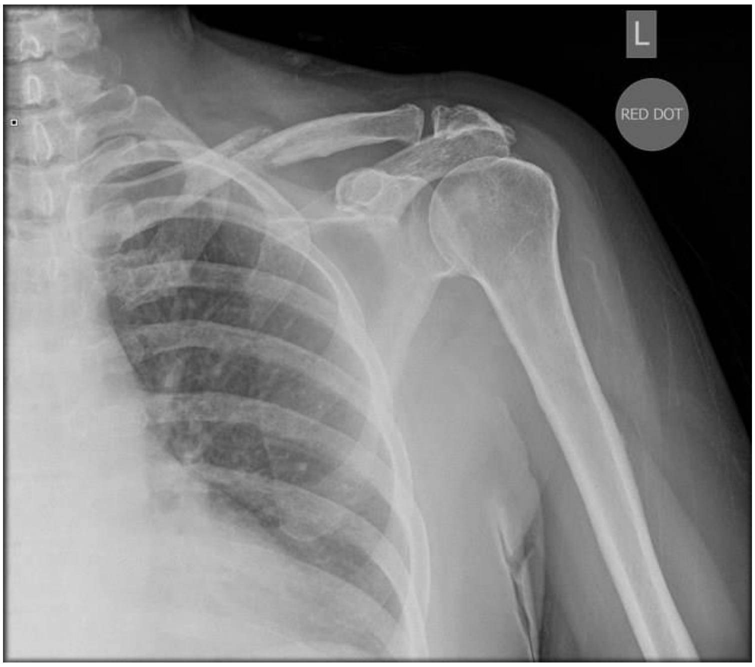

Figure 2.3: A red dot indicating abnormality on the image (Bickle, 2018)

The introduction of RADS was welcomed by many healthcare providers in the UK and its clinical relevance became apparent in emergency departments. Various previous surveys showed a high prevalence of clinical application of RADS across emergency departments in the UK. In 2004, a survey on the extended roles of radiographers reported that 81% of emergency departments were using a form of RADS in their daily operations (Snaith & Hardy, 2008). This increased to 92% in another survey in 2008 but later slightly decreased to 88.6% in 2011 (Murphy & Neep, 2018). Utilisation was even more significant in smaller departments and hospitals where collaboration was more acceptable and radiologists were scarce (Snaith & Hardy, 2008). Furthermore, this clinical application of RADS, as a way of role extension, was supported by professional bodies such as the SoR UK. Though the advantages of this system were clear, and its use was widespread, radiographer participation remained mainly voluntary and based on individual self-assessed competencies. However, the marked widespread adoption of the practice showed a positive acceptance of this form of role extension among diagnostic radiographers (Snaith & Hardy, 2008). It also demonstrated the application of the beneficence and non-maleficence ethical principles in practice as this form of radiographer communication to the referrer was intended to benefit the patient primarily (Squibb, 2013).

Several studies were conducted to determine the accuracy of radiographers in identifying abnormalities using RADS. These studies focused on generated evidence to support this area of role extension and defend its continual application. A systematic review of early studies done in the 90s in the UK showed that radiographers could identify abnormalities in all areas of the body with a pooled sensitivity and specificity of 88% and 91% respectively (Brealey et al., 2006). However, the effect of the different forms of radiographer training and clinical support was apparent in their ability to confidently detect any abnormalities on the plain radiographs. Thus, the effect of on-the-job training in image interpretation on sensitivity and specificity to detect abnormalities was explored as a way to improve the practice of RADS. Hargreaves and Mackay reported a marked improvement in sensitivity, 76.2% to 81.3%, and specificity, 89.9% to 93% after seven UK radiographers received a four-month training course in image interpretation of skeletal radiographs (Hargreaves & Mackay, 2003). Similarly, another UK study showed an increase in sensitivity from 71% to 96% and specificity from 81% to 95% after radiographers received training (Brealey et al., 2006). In South Africa, a previous study reported a fracture-detection sensitivity of 82% with a specificity of 93.7% among radiographers with no additional training in image interpretation (Hlongwane & Pitcher, 2013). They concluded that additional training would be required to enable radiographers to take up formal reporting roles in clinical practice. Though performance generally increased with training, these studies were not standardised in terms of the body regions which were assessed as some only focused on the appendicular skeleton while others focused on both appendicular and chest regions and reported combined estimates. Furthermore, the extent of training was different in duration and content as it was on-the-job training that was internally structured and may have had a different effect from one study to the other.

RADS acted as a safety net for referrers, particularly in high-stress accident and emergency departments, by providing some indications of potential abnormalities. It positively contributed to the reduction in image interpretation errors through support for junior and less experienced doctors (Murphy & Neep, 2018; Woznitza, 2014). It, therefore, presented an opportunity for radiographers to participate meaningfully in patient management decisions whilst transferring knowledge to less experienced medical practitioners thereby reducing the chances of malpractice litigations (Murphy & Neep, 2018; Radovanovic & Armfield, 2005). This led to an improvement in job satisfaction levels for radiographers who were participating actively in RADS (Brealey et al., 2006). Furthermore, RADS was reported to reduce patient waiting times and contributed towards a reduction in the radiologist’s workload. However, the voluntary nature and the scheme of operation of RADS resulted in several flaws that led to its abandonment. The most significant was its vagueness in communicating the presence or absence of an abnormality (Woznitza, 2014). The absence of a red dot resulted in confusion regarding the presence or absence of an abnormality among referrers. Thus misdiagnosis may occur when this absence is construed to mean no abnormality (van de Venter & Friedrich-nel, 2021). Additionally, the inability to describe or localise the detected abnormality still left the referrer with the responsibility to search for and identify the abnormality thereby reducing the impact of the support (Neep et al., 2014b). Lastly, where multiple abnormalities existed on the same radiograph, RADS provided limited support as there was no option to describe these in detail for the referrer (Murphy & Neep, 2018). To cater for these flaws, a much more objective system of communicating abnormalities was advocated for and recommended to replace the RADS where it was in use (SOR, 2013).

2.4.5.2 Preliminary Clinical Evaluation

The weaknesses identified with the RADS resulted in the introduction of a new system that goes beyond the non-specific identification of an abnormality on a radiograph to a detailed description of such abnormality. This new system was termed Preliminary Clinical Evaluation (PCE) by the College of Radiographers in 2006 but is also known by other names such as radiographer commenting, initial image commenting, initial evaluation, and preliminary image evaluation among others (Neep et al., 2019; SCoR, 2016). PCE is intended to improve the specificity of the red-dot system by providing a written comment regarding image interpretation thereby improving the efficiency of the image interpretation system (Stevens & Thompson, 2018). The SCoR defined PCE as 'the practice of radiographers whereby they assess imaging appearances, make informed clinical judgements and decisions and communicate these in unambiguous written forms to referrer' (SOR, 2013). Thus in its application, PCE requires radiographers to provide an informal clear written description of the abnormality and its localisation to better guide the referrers in image interpretation (Alexander-Bates et al., 2021; Stevens, 2020; Cosson & Dash, 2015). This marked a significant milestone in the extension of radiographers' roles in image interpretation, essentially positioning them as assistant radiologists. This new role was supported by the SCoR as a core function within the radiographers' scope of practice emphasising that it should be founded on both education and clinical competency (Lockwood & Pittock, 2019; SOR, 2013).

For the PCE to achieve its intended goal of being objective, the description provided by the radiographer must be standardised, specific and brief. Several models were suggested in literature with two gaining prominence and widespread recognition. The What, Where and How concept of structuring the PCE description was proposed in 2014 and gained popularity in clinical use and teaching over the years (Harcus & Wright, 2014). In this concept, the radiographer is guided on what details to describe as they compose their description in line with what information the referrers need the most. The 'What' aspect is a description of what the abnormality is (fracture, dislocation, mass, fluid etc.) and the 'Where' describes the location of the abnormality (the bone involved, the part of the bone, the organ etc.) while the 'How' aspect refers to the presentation of the pathology (what is the severity, any displacement, direction of deformity etc.) (Harcus & Wright, 2014). The concept was originally applied to the appendicular skeleton but has found application across all conventional imaging procedures. It also has been used to assess the structure and complexity of PCE reports by radiographers (Stevens, 2020).

Similarly, around the same period, a digital-based PCE structuring system was proposed to assist radiographers in standardising their PCE reports (Cosson & Dash, 2015). This system was based on combining options across three domains in the system, with predefined text, which will then be used to construct a PCE report. The three domains were: Diagnosis – whether an abnormality was present or not, Where – a description of the nature of the abnormality and its location, What – more specific detail on the pathology and its characteristics based on the experience of the radiographer (Cosson & Dash, 2015). Although distinct, these two methods of structuring a PCE report share common approaches in effectively and simply communicating findings to referrers. This improves the objectivity of communication and helps to make the communication short and brief as preferred by most referrers (Stevens, 2021). However, the authors also recommend adapting this structure to align with the specific requirements of local referrers, enhancing the overall effectiveness of the service.

The accuracy of radiographers to identify and describe the abnormalities on radiographs was assessed by different authors in well-resourced settings, for different anatomical regions of the body producing high levels of sensitivity and specificity. A review of previous studies in Australia showed the accuracy of PCE reports ranging from 79% to 98% with higher accuracy for appendicular skeleton and low accuracy for chest radiographs (Radovanovic & Armfield, 2005). Another longitudinal study to determine the accuracy of PCE reports by Australian radiographers at Logan Hospital, Queensland, reported a 92% accuracy when a PCE service was offered after a 10-week image interpretation training on the axial and appendicular skeleton (Brown et al., 2019). The authors, though acknowledging that this is below the accuracy benchmark for radiologists, (94%-97%), argued that the comparison to radiologists was unfair as they have a higher level of training and review images in a more suitable environment than radiographers. In recent studies done in Australia and the UK, the overall accuracy of PCE reports was reported as high at 88.7% and 92% respectively, when radiographers were only evaluating appendicular and axial radiographs (Verrier et al., 2022; Alexander-Bates et al., 2021). However, the accuracy was very high (97.9%) for chest evaluations of nasogastric tube position after intense focused training was offered among a group of UK radiographers (Keyte et al., 2021). It is important to note that PCE service is not a replacement for the radiologist's report but a service to support the referrers and its accuracy is expected to be higher when measured in combination with the referrer's interpretation (Thakkalpalli, 2019; Snaith et al., 2015). This is supported by a study where emergency department (ED) practitioners were reported to improve their abnormality detection accuracy when a PCE service was offered compared to no service (Stevens & Thompson, 2020). It is thus important to evaluate the value and accuracy of a PCE service on its contribution to the overall image interpretation objective rather than as an isolated service. Furthermore, the success of PCE in practice is based upon an adequate foundational education at the undergraduate level as well as clinical guidance during preceptorship or the probation period and post-qualification studies that result in an accurate image interpretation (Stevens & Thompson, 2018).

The main advantage of radiographer PCE is the removal of ambiguity and uncertainties presented by the red dot system through a more objective and detailed description of the suspected abnormality (Harcus & Stevens, 2021; Woznitza, 2014). It thus clarifies and directs interpretation, especially where multiple abnormalities are present on the radiograph. PCE is considered an effective way of rapidly communicating findings to referrers where an immediate reporting service is absent which may contribute to a reduction in time to diagnosis which in turn will reduce hospital stay (Stevens & Thompson, 2018). PCE service has been reported to positively contribute to a reduction in error rates, misinterpretation and mismanagement of patients by ED practitioners (Harcus & Stevens, 2021; Thakkalpalli, 2019; SOR, 2013). Thus when accurately provided, it can significantly improve patient management and patient experiences in the emergency departments (Alison & Wright, 2015). It is, however, important to note that when the PCE service is not adequately supported by education and training, the quality of service and support can be significantly reduced and its contribution rendered meaningless (Stevens & Thompson, 2018).

The numerous advantages of PCE service create an appetite for its implementation where there is a shortage of radiologists, but implementation has been impeded by various contextual barriers. Though some previous studies have reported that radiographers don't need additional training to partake in PCE, universities in the UK remain concerned about the adequacy of resources required to build the competencies graduates require before graduating (Stevens, 2020; Cosson & Dash, 2015; Hardy & Snaith, 2009; Hardy & Culpan, 2007). This limits the implementation of PCE as some universities are not yet well-resourced resourced to ensure the full development of image interpretation skills among their graduates. Additionally, the lack of dedicated training and continuous support for qualified radiographers in image interpretation prevents radiographers from participating in PCE or limits their contribution when they do offer it (Stevens et al., 2021; Thakkalpalli, 2019). It also leads to low confidence in their analysis and abnormality detection ability as they perceive their image interpretation knowledge to be limited, according to two reports from Australia (Alexander-Bates et al., 2021; Denham, 2019). The current workload of UK radiographers also limits the implementation of this service as managers and radiographers are concerned that there are no resources or extra time available to evaluate radiographs and produce a PCE report (Stevens et al., 2021; Neep et al., 2014b). Some radiographers in the UK and Australia feel that it is not their clinical responsibility to interpret radiographs while some radiologists in the same settings also feel that radiographers practising PCE are encroaching into their domain of practice and are thus resistant to this change (Alexander-Bates et al., 2021; Neep et al., 2014b). The aforementioned underscores the significance of conducting a contextual analysis to identify the optimal approach for implementing the PCE service. Collaboration with relevant stakeholders is crucial in minimising resistance to its implementation and ensuring its effectiveness.

2.4.5.3 Radiographer clinical reporting

Radiographers can also practice image interpretation at a more advanced level where they produce a definitive report that matches the radiologist's report and guide the diagnosis and management of patients. This is termed clinical reporting which is a level of advanced practice that has been well established in the UK and supported by both the SCoR and the Health and Care Professions Council (HCPC). The SOR defined clinical reporting as ‘The practice of radiographers who have completed postgraduate education and training approved by the College of Radiographers to enable them to produce diagnostic reports in defined fields of practice’(SOR, 2013). Thus, the minimum requirement for radiographers to participate in clinical reporting is postgraduate training in image interpretation and clinical reporting in a specific area of practice such as conventional imaging, mammography, CT, MRI, and nuclear medicine. This allows them to function as autonomous practitioners making clinical decisions and exhibiting leadership expected and defined at the level of advanced practice level (Cuthbertson, 2020). As the reporting radiographers produce a definite report, their performance in their defined area of practice is expected to be at the same level as the radiologist or any other medical or non-medical reporting practitioner (SOR, 2013), Thus in the UK, postgraduate training programmes have been established at Masters level and continue to develop to offer the necessary educational background that goes beyond PCE to enable clinical reporting by radiographers (Culpan et al., 2019). Other countries such as Canada, Australia, Norway and Denmark are also developing practice models that will enable radiographers to offer a definitive report as part of advanced practice (Woznitza, 2014). However, the uptake of this service in under-resourced contexts has been restricted primarily due to insufficient educational opportunities and other obstacles, including limited research and evidence to underpin its practice.

Radiographers undertaking clinical reporting in the UK are required to achieve a high level of performance, with an expected accuracy rate of 95%, comparable to that of radiologists (Wright & Reeves, 2016). Initially, UK radiologists had concerns regarding the ability of radiographers to attain this level of accuracy and produce quality clinical reports but these were dispelled over time through research evidence (Milner et al., 2016b). Previous studies in the UK, have also shown that with appropriate training, radiographers can produce reports comparable to consultant radiologists in defined areas of practice (Cain et al., 2022; Culpan et al., 2019; Woznitza, 2014). Up to 99.1% accuracy was reported in a previous multi-centre study conducted in the UK, with 97.6% sensitivity and 99.3% specificity when radiographers were performing clinical reporting (Woznitza, 2014). Overall, radiographer reporting has been shown to be a safe and accurate practice that creates opportunities for optimised patient pathways in the UK (Woznitza et al., 2020). Furthermore, continuous improvements in education and support have made this service successful in the area where it is provided.

Similar to other healthcare services, the implementation of clinical reporting by radiographers brings along an array of advantages. The major advantage and benefit is the filling of the service gap, which increases the reporting capacity of a department and ensures the image cycle is complete through the issuance of a definite report (Culpan et al., 2019). UK reporting radiographers have been shown to positively contribute to a reduction in reporting backlogs and reduced reporting turn-around times leading to an improvement in the quality of service (Culpan et al., 2019). As this service provides a definite report, it has been reported that it contributes significantly to a reduction in interpretive errors and misdiagnoses where a radiologist’s report was absent (Snaith & Hardy, 2014). Additionally, the implementation of radiographer reporting in the UK health service resulted in improved workflow and efficiency as well as cost-effectiveness in emergency departments, especially when provided after hours due to immediate support for diagnosis and elimination of other unnecessary diagnostic tests (Culpan et al., 2019; Hardy, Hutton, et al., 2013). Among UK radiographers, participation in clinical reporting has been reported to enhance job satisfaction, motivation, confidence and overall value within the medical team (Cuthbertson, 2020; Culpan et al., 2019). Despite these benefits, the implementation of this service in Scotland has been hampered by shortages of radiographers and radiologists, a lack of protected reporting times for radiographers and a negative perception of the service (McConnell, 2021). Hence, the design and mapping of the radiographer reporting service should be tailored to the specific local context to ensure its effectiveness.

2.5 Part 3: Radiographer image interpretation – The road less travelled

2.5.1 Regulatory prescriptions – a barrier and an enabler

The practice of radiography has been regulated since the control exerted by the General Medical Council early during the conception phase of the profession in the UK (BMJ 1925 cited in Price (, 2001: 110). Literature has shown how regulatory prescriptions have existed for more than half a century imposing limitations on what a radiographer can do (Price, 2001). Though there have been positive strides in melting away these rigid regulations in a few countries and contexts, the majority still practice radiography under these tight regulations. In these cases, the regulations become a serious impediment to the development of the profession thus acting as barriers to the implementation of image interpretation for radiographers. In most cases, there is limited ground for the existence of these regulations in their old state except for the lack of evidence for their updating or lack of active drive for their repulsion. This is particularly true in contexts where there are no active societies and trade union organisations advocating for and presenting a unified front for radiographers. However, where active persuasion has borne fruit, these regulations were successfully repealed or adjusted to allow for role extension and growth of the profession (HCPC, 2018; SCoR, 2015). In this manner, the regulatory framework acts as an enabler driving change and development for the profession.

2.5.2 Perceptions of key stakeholders

Literature has also shown us that the key stakeholders for the professional development of radiography have varied opinions regarding the need for radiographers to extend their roles into image interpretation. Radiographers themselves are not globally united in terms of their skills, confidence, and desire to venture into image interpretation (Bwanga, Chanda, et al., 2021; Neep et al., 2014a). Some explicitly consider this area outside their scope of practice and are not interested in extending their role in this regard (Neep et al., 2014a). Other radiographers consider themselves to have limited knowledge of pathology or radiographic patterns and are not open to further training. Additionally, some are just comfortable being radiographers as defined by the old regulations. Similarly, some other medical professionals have also held different opinions regarding radiographers interpreting radiographs. While some radiologists have supported the role extension and see it as a way of supporting them considering the ever-increasing workload, some have resisted this development as they see it as a threat to the scope of practice (Kekana et al., 2015; Williams, 2009). Some doctors expressed positive perceptions towards this development, and they consider radiographers' image interpretation as valuable and beneficial (Kelly et al., 2012). There has been a lot of active research undertaken to generate empirical data to dispel these perceptions and justify the need for this role extension among radiographers (Cain et al., 2022; Culpan et al., 2019; Woznitza et al., 2014). Most of these, however, have been confined to high-income settings where a different healthcare system is in operation compared to low-income settings.

2.5.3 Where is Africa - The emerging gap in the literature

Evidence to support role extension for radiographers into image interpretation has been garnered at a very slow pace in Sub-Sahara Africa compared to Western countries. Most radiographers still practice under restrictive regulations that are based on the traditional scope of practice for radiographers. Though in some countries, such as Ghana and Nigeria, postgraduate studies in image interpretation have been introduced, little has changed in the guiding policies and scope of practice for radiographers (Ohagwu et al., 2021; Bwanga et al., 2020). In South Africa, where there have been the highest number of publications in this area, a recent systematic review looking at the knowledge and accuracy of image interpretation among radiographers only analysed seven publications of which some were older than ten years (van de Venter & ten Ham-Baloyi, 2019). Their findings showed that the performance of South African radiographers was at the same level as reported in other European literature. Another recent literature review on image interpretation by radiographers across Africa managed to review 13 studies, including those reviewed in the South African study (Bwanga, Sichone, et al., 2021). Similarly, the findings from Bwanga's literature review support those of van de Venter regarding the similarity in performance between African and International radiographers (Bwanga, Sichone, et al., 2021; van de Venter & ten Ham-Baloyi, 2019). Other studies from Nigeria and Ghana equally echo the same sentiments as European literature in terms of the accuracy of radiographers in interpreting radiographs (Ohagwu et al., 2021; Ofori-Manteaw & Dzidzornu, 2019). Thus, it may be hypothesised that the level of training in African universities seems to impart internationally comparable skills to radiographers regarding image interpretation. Equally so these studies also recommend and believe additional training will significantly improve the performance of radiographers as witnessed in other international studies. Most of these studies also indicate that the legislative framework, policies and guidelines governing the profession need to be revised and reformulated to capture current professional developments as they currently restrict the practice of image interpretation by radiographers (Bwanga, Sichone, et al., 2021; Wuni et al., 2020; van de Venter & ten Ham-Baloyi, 2019; van de Venter et al., 2017). Additionally, the need to be guided by contextual factors and address contextual challenges was also emphasised during the revision and reformulation of these policies and guidelines (Wuni et al., 2021). Therefore, individual countries are encouraged to generate contextual evidence to support programmes that are tailor-made to address the local needs and demands to ensure their success.

Most African countries are characterised by severe underfunding of the public health sector which affects technological and human capital developments as well as service delivery (Cowan et al., 2021; Owumi & Eboh, 2021; Masaba et al., 2020; Masiye et al., 2020). Both training and retention of appropriately trained health professionals such as radiographers and radiologists are major problems that affect service delivery. In Namibia, like most African countries, the healthcare sector is divided into state-funded and private-funded institutions which exhibit marked differences in terms of service provision, human capital, accessibility, and affordability. The majority of the population, 70 to 80%, are not covered by medical insurance which creates disparities in access to healthcare facilities where service is guaranteed (Allcock et al., 2019). Despite these chronic challenges, no Namibian published studies could be found in the utilised research databases regarding the knowledge, capacity, or skills of radiographers in image interpretation which is a crucial service affected by the shortage of radiologists in state-funded hospitals. This study aims to generate knowledge and contribute to filling the gap in the literature by using Namibia as a case study.

2.6 Conclusion

The literature discussed has highlighted how the radiography profession was conceived over 100 years ago. It's clear that image interpretation dates to this period and has been a contentious issue ever since. The advent of role extension and changes in training programmes have all influenced the scope of practice for radiographers. However, these remain varied across the globe due to different regulatory frameworks and training programmes. Image interpretation is a developing area of role extension for radiographers, that is on a continuum from red dotting and going all the way to clinical reporting in selected areas. Though well accepted and implemented in some well-resourced countries, there is still limited evidence for its adoption and implementation in under-resourced settings such as Namibia. There is therefore a need to generate knowledge that can inform the implementation of this crucial service where there is a critical inadequacy such as in Sub-Sahara Africa. The next chapter will discuss the methodology employed in this study to address research objectives and contribute towards bridging the gaps identified in the existing literature.

CHAPTER 3 : RESEARCH METHODOLOGY

3.1 Introduction

The research focus and scope were presented in Chapter 1, followed by a reiteration of what has been established in the literature and the potential gaps that still exist. The main content of this chapter outlines the specific research plan that was followed to conduct this study. Research methodology is a framework that prescribes and guides the research process in the context in which the research is carried out (Grierson & Brearley, 2009). It is essentially the blueprint of how the research was carried out and provides the foundation for the evaluation of the research outcome. Thus, this chapter discusses the design followed, the methods selected for data collection and analysis, as well as the ethical principles applied in this study (Mason, 2002). Moreover, the chapter will explain the strategies for sampling and sample size calculations, as well as the measures taken to ensure data quality (validity, reliability, and trustworthiness). This chapter comprehensively covers how the research was conducted, including its key aspects. (Howell, 2013).

The research question that was addressed in this study was “What are the current and possible future roles of radiographers in a collaborative radiology image interpretation system, relevant to a scope of practice for an under-resourced environment?”. The purpose of this study was to examine the radiology image interpretation system and explore possibilities for improvement by actively involving radiographers in a collaborative approach, using one example of an under-resourced environment as a case study. To achieve this, the study was divided into three phases with the following aims:

Phase one – to investigate the current radiology image interpretation system design, capacity, and effectiveness in Namibia’s state hospitals.

Phase two – to determine the preparedness of radiographers to take up new roles in image interpretation.

Phase three –to develop an improved image interpretation system that defines possible role/s for radiographers and its implementation plan.

3.2 Research sites

The study was conducted in Namibia, with four research sites chosen in alignment with the objectives outlined in Chapter One. Three sites (Hospitals 1, 2 and 3) were the main referral hospitals in Namibia. Hospital One was a tertiary referral hospital with a bed capacity of 855 patients, Hospital Two was a general referral hospital with a bed capacity of 840 patients while Hospital Three was a regional referral hospital with a bed capacity of 885 patients (MOHSS, 2018). All the hospital sites housed a radiology department offering general X-ray, CT, mammography, fluoroscopy, and sonography services. The departments had limited PACS mainly used for image storage, while all image reporting was paper-based. At research sites 1-3, various research data were collected to meet the following objectives:

1. Determine and observe the current radiology image interpretation system capacity and performance.
2. Explore and describe the setup of the radiology image interpretation system within the radiology departments.
3. Determine the effectiveness of the image interpretation system in the management of patients.
4. Explore and describe the experience of referring doctors in state hospitals regarding the utilisation of the image interpretation system.
5. Determine and analyse the knowledge of qualified radiographers in Namibia regarding image presentation of common chest and appendicular plain image abnormalities.
6. Evaluate the clinical competencies of qualified radiographers in Namibia regarding image interpretation of plain images of the chest and appendicular skeleton.

Research site four was a Higher Education Institution (HEI) that offered a four-year Bachelor of Radiography (Diagnostic) Honours degree programme. This programme was initially offered as a diploma in 1992 and transitioned to a degree programme in 2009, with an annual intake of 15 students. The four-year training curriculum has remained consistent since 2009 and includes core modules such as anatomy, physiology, radiation technique, radiation protection, and ethics, among others. Throughout their training, students undergo a series of clinical placements to accumulate a minimum of 2500 hours, during which they develop and are clinically assessed for their competencies. At research site 4, data was collected to meet the following objectives:

7. Explore and describe the perceptions and experiences of radiography educators regarding the preparedness of graduates to take up image interpretation roles.
8. Explore and describe the perceptions and experiences of recent graduates regarding their preparedness to take up image interpretation roles.

3.3 The design of the study

The selection of the appropriate research design for this study took into consideration the intended outcomes, the type and quality of data to be collected, and the analysis to be conducted (Nieswiadomy & Bailey, 2018; Creswell, 2013). A multiphase mixed-methods design was employed in this study, as it provided the researcher with the flexibility to choose suitable approaches for each phase and objective (Mcevoy & Richards, 2006; Danermark et al., 2002). The research objectives in this study aimed to assess the problem from multiple dimensions in order to gather data that could inform system improvements. The research design was flexible enough to accommodate suitable strategies for addressing each objective while remaining aligned with the overarching research question. This design was also in line with the critical realism philosophy that guided the study, emphasising the importance of choosing a research design that is suitable for each objective and phase of the study (Khazem, 2018; Bhaskar, 2016).

3.3.1 Multiphase design

The multiphase design is a relatively recent approach that is characterised by its complexity, incorporating various methods across multiple phases of a research project (Almeida, 2018). In this study, the multiphase design incorporated a combination of quantitative and qualitative approaches, employing a convergent mixed methods approach where applicable across the various phases (Almeida, 2018; Creswell & Plano Clark, 2011). The researcher opted for this design due to its ability to enhance the research outcomes by employing a comprehensive approach to data collection and analysis (Creswell & Plano Clark, 2011). Additionally, this design is well-suited for studies focused on programme development, modification, and evaluation, which aligns with the objectives of this study (Davidov et al., 2019). The application of the mixed method is detailed in the following section.

3.3.2 Mixed methods

Mixed method research is the type of research where researchers utilise both quantitative and qualitative approaches in the collection and analysis of data before integrating the findings to answer a research question in a single or multiphase study (Nieswiadomy & Bailey, 2018; Creswell, 2013). In this study, this design facilitated an understanding of the real-life situation by utilising multiple lenses and perspectives before developing an image interpretation system that incorporates radiographers. This approach enhanced the study by harnessing and complementing the strengths of both quantitative and qualitative approaches (Shneerson & Gale, 2015; Creswell, 2013; Tariq & Woodman, 2010). The specific mixed method utilised in this study was the convergent parallel mixed method design.

3.3.3 The convergent parallel strategy

This is one strategy of mixed methods where the quantitative and qualitative approaches are implemented simultaneously without interference (Kimmons & Johnstun, 2022; Creswell, 2013). In this study, data collection and data analysis were initiated simultaneously for different objectives in the various phases of the study, allowing the researcher to tap into the full strength of each approach. After data analysis, the results from each approach were merged and interpreted together (Creswell & Plano Clark, 2011). The strategy enabled the efficient use of time, as the data collection processes were not dependent on the completion of the analysis of another data strand. Therefore, data collection and analysis for each objective were independent of other objectives, although all contributed to answering the same overarching question. The processes were generally divided into two categories: quantitative data collection and analysis, and qualitative data collection and analysis. Figure 3.1 below illustrates in general, how this strategy was applied in this study:

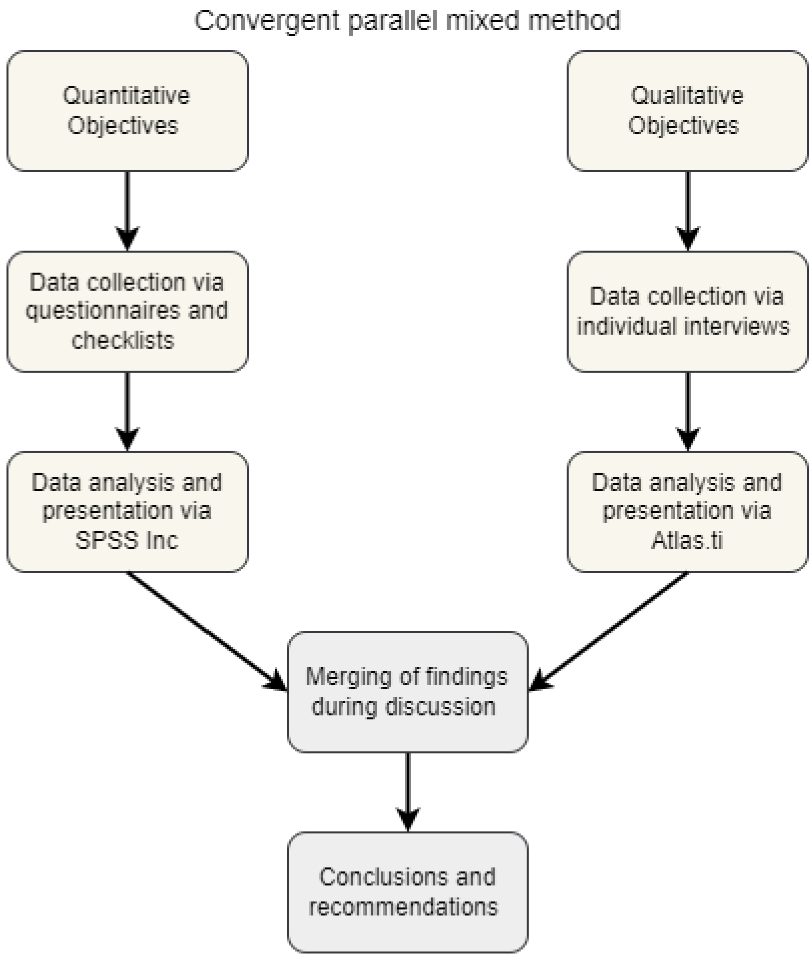

Figure 3.1: The convergent parallel design

3.3.4 Quantitative approach and designs

The quantitative approach is an inquiry into a social or human problem, based on the testing of variables measured with numbers and analysed with statistical procedures (Creswell & Plano Clark, 2011). This approach is suitable when there are preconceived ideas and variables to be tested numerically and analysed using statistical processes (LoBiondo-Wood & Haber, 2014). In this study, several objectives involved predefined variables that needed to be tested or assessed for their statistical significance within the population under study. Moreover, for these objectives, the researcher aimed to ascertain and comprehend the distribution of variable responses and the generalisability of outcomes, as these were crucial inputs for the development of the image interpretation system. Objectives one and three (Phase One), as well as five and six (Phase Two), applied a quantitative approach with a descriptive correlational design.

3.3.5 Descriptive correlational design

Descriptive research is research focused on defining and describing characteristics of a population group through numerical quantification of sample parameters (Asenahabi, 2019; Marczyk et al., 2005). In this study, the researcher wanted to measure, quantify, and describe the different variables for the different objectives without any manipulation and report on their natural status, making descriptive research an appropriate choice (Kothari, 2011). Furthermore, the researcher wanted to explore the different variable associations and relationships emphasising the strength of these relationships (Marczyk et al., 2005). This design therefore allowed the researcher to describe the characteristics of the sample, explore trends and variations in the data and conduct comparisons in a relatively short time (Kothari, 2011; Marczyk et al., 2005). The application of this design is detailed in Table 3.1.

Table 3.1: Application of quantitative designs

Objective	**Application of research design**
Objective 1 Determine the current radiology image interpretation system capacity and performance.	A quantitative descriptive correlational design was used to observe the radiology image interpretation system in operation. This was the appropriate approach and design as it enabled the creation of variables in advance and the use of statistics to describe its performance. Furthermore, the design also enabled comparisons to be made between the three imaging departments.
Objective 3 Determine the effectiveness of the image interpretation system in the management of patients.	A quantitative descriptive correlational design was employed which enabled the accurate measurement of variables that determine the effectiveness of the image interpretation system. The design enabled the application of descriptive and inferential statistics to determine possible associations between reported system effectiveness across imaging procedures and demographic and training characteristics.
Objective 5: To determine and analyse the knowledge of qualified radiographers in Namibia concerning image presentation of common radiographic pathologies. Objective 6: To evaluate the clinical competencies of qualified radiographers in Namibia regarding image interpretation of plain radiographs of the chest and appendicular skeleton.	A quantitative descriptive correlational design was employed as the variables to quantify the knowledge and clinical competencies of radiographers could be determined beforehand. Furthermore, the objective assessment of knowledge and clinical competencies is numerical and requires statistical procedures for accurate quantification. The design enabled the application of inferential statistics to determine the possible relationship between demographic characteristics and the knowledge and clinical competencies of the radiographers.

3.3.6 Qualitative approach and design

Qualitative research is primarily concerned with stories and accounts of events; including subjective understandings, feelings, opinions, and experiences (Grove & Gray, 2018; LoBiondo-Wood & Haber, 2014). This is research that typically takes place in the natural setting focusing on a few participants but aiming to generate quality in-depth data regarding an individual's interpretation of life events (Nieswiadomy & Bailey, 2018; LoBiondo-Wood & Haber, 2014). In this study, the qualitative approach was applied to generate subjective opinions of the participants regarding the phenomenon under study. This approach allowed the researcher and the participant some degree of flexibility and freedom in asking and answering questions in order to gain an in-depth understanding of human experiences (Nieswiadomy & Bailey, 2018). As is the nature of the qualitative enquiry, the approach enabled the researcher to gain an emic understanding of each phenomenon in a naturalistic context (Tracy, 2013; Finlay & Ballinger, 2006). The naturalistic context enabled the researcher to minimise the external influence on the participants as the study was conducted in the field where participants were ordinarily located (Tracy, 2013; Merriam, 2009). All qualitative objectives in this study applied an exploratory-descriptive contextual design. These objectives relied on the participant's subjective perceptions and experiences of the different phenomena that were being measured and how the participants navigated through it in the past. This was the appropriate design as it enables clarification of an unknown area and a better understanding of the phenomena being studied from each subject's viewpoint (Nieswiadomy & Bailey, 2018).

3.3.7 Exploratory-descriptive design in the qualitative approach

Exploratory studies are usually qualitative in approach and are directed at understanding a phenomenon where little information is available or known (Nieswiadomy & Bailey, 2018). To generate sufficient information about a phenomenon, the design enables researchers to be flexible and use techniques such as interviews that allow for in-depth data gathering. The lack of structure and flexibility of both the instrument and the data collection process gives the exploratory design its strength and ability to generate rich data (Kumar, 2011). The researcher selected the design because of the low cost, flexible and interactive nature of this design (Kothari, 2011). The characteristics that were explored needed to be described in the context of their occurrence in a naturalistic environment. Thus the phenomenon and its characteristics are described as part of the research process (Kumar, 2011). This was ideal for this study as the researcher was aiming to provide rich and luminous data descriptions of the phenomenon through the input of the participants. Rich and luminous data best shows how a phenomenon unfolds and is shaped whilst highlighting why it unfolds in this way for the particular population group in the context of the study (Tracy, 2013). The design is different from its application in the quantitative approach as there are no preconceived ideas on the characteristics of the phenomenon enabling an emic description instead (Nieswiadomy & Bailey, 2018; Singh, 2006; Kothari, 2004).

3.3.8 Contextual research

Contextual research is focused on generating data on a phenomenon with particular reference to the context in which the study was done (Mason, 2002). The context in this aspect is defined by the environment where the study was occurring. Contextual research, therefore, takes the study to the participants by visiting them in their everyday environment and observing them in their day-to-day activities. A clear understanding of the environment and its potential effects on the study outcome is very important in determining the use of the research outcomes. Applicability and replication of the study may be difficult if the context is poorly understood (Howarth et al., 2016). In line with the qualitative approach, the context in this study was the natural environment where the participants are usually housed and perform their daily duties (Duda et al., 2020). In this way, the researcher aimed to minimise distortion of thought or response due to a change in environment by the participants. The context was different for each of the qualitative research objectives but included the various hospital and university departments where each participant works.

3.4 Study Population

The study population is the individuals or groups of people or objects that possess the desirable characteristics that are important in answering a research question (Nieswiadomy & Bailey, 2018). In the current study, the population was defined per each objective and included all health professionals involved in the image interpretation process such as lecturers, recent graduate radiographers, radiographers, radiologists, and referring doctors as specified in Table 3.2.

Table 3.2: Study population and applicable objectives

Objective	Population
Objective 1 To determine the current radiology image interpretation system capacity and performance.	Records of conventional imaging and CT procedures that were done in 2021 within the filing rooms at three imaging departments at the three main referral hospitals in Namibia.
Objective 2 To explore and describe the setup of the radiology image interpretation system within the radiology department.	All Heads of Departments of the three imaging departments, radiologists and radiographers working at the three main referral hospitals as they set up and design the image interpretation processes within their departments.

Objectives 3 To determine the effectiveness of the image interpretation system in the management of patients. Objective 4: To explore and describe the experience of referring doctors in state hospitals regarding the utilisation of the image interpretation system.	All doctors (interns and medical officers) working at three main referral hospitals in Namibia as they are the only medical practitioners authorised to request x-ray procedures and utilise their findings during patient management (MOHSS, 2011).
Objectives 5 To determine and analyse the knowledge of qualified radiographers in Namibia concerning image presentation of common radiographic pathologies. Objective 6: To evaluate the clinical competencies of qualified radiographers in Namibia regarding image interpretation of plain radiographs of the chest and appendicular skeleton.	All qualified radiographers working at the three main referral hospitals, as they are grounded in conventional imaging and are exposed to radiographs daily.
Objective 7: To explore and describe the perceptions and experiences of radiography educators regarding the preparedness of graduates to take up image interpretation roles.	All lecturers and clinical instructors teaching in the radiography programme at the participating HEI who are well informed of the radiography learning process
Objective 8 To explore and describe the perceptions and experiences of recent graduates regarding their preparedness to take up image interpretation roles.	All recent radiography graduates from the participating HEI who still have a clear reflection of the whole training process and how it prepares them for image interpretation roles

3.5 Sampling Strategy

A sample, a smaller representation of the population, is crucial in research to collect data that mirrors the population's characteristics (Nieswiadomy & Bailey, 2018; Singh, 2006). This study employed purposive sampling, utilising its various sub-types tailored to different objectives and phases.

3.5.1 Purposive sampling

Purposive sampling involves selecting samples based on the researcher's prior knowledge of critical characteristics to be retained (Nieswiadomy & Bailey, 2018). This method was chosen due to the researcher's substantial knowledge of the population and its characteristics, providing better control over essential variables in the study (Nieswiadomy & Bailey, 2018; Palinkas et al., 2015). While both qualitative and quantitative approaches aim to save time and money through sample selection, the guiding principles differ (Singh, 2006; Marczyk et al., 2005).

Application in the qualitative approach

In the qualitative approach, the sampling principle aimed to identify participants with contextual knowledge, who will be able to provide detailed experiences of the phenomenon under study (Kumar, 2011). A purposive approach, specifically homogenous sampling, was employed to select different samples for all qualitative objectives. Selection criteria for each objective guided this process (Kumar, 2011).

Application in the quantitative approach

In the quantitative approach, prioritising an adequate sample size, the researcher adopted total population sampling, a form of purposive sampling encompassing the entire population (Lavrakas, 2008). This method was suitable as the population size was manageable (less than 100), allowing the researcher to minimize sampling bias by including all elements (Palinkas et al., 2015; Lavrakas, 2008). Moreover, it provided each population member with an opportunity to participate based on their availability during data collection and meeting inclusion criteria as indicated in Table 3.3.

Table 3.3: Inclusion and exclusion criteria per objectives

Objective	Inclusion criteria	Exclusion criteria
Objective 1: To determine the current radiology image interpretation system capacity and performance.	Records of conventional imaging and CT procedures that were done between August and September 2021. Only records done within the specific department will be included.	All records that were done outside the specific timeframe. Records from other hospitals Records of other procedures
Objective 2: To explore and describe the setup of the radiology image interpretation system within the radiology department.	At the three main referral hospitals in Namibia: Be a HOD/Acting HOD Be a full-time/ part-time radiologist. Be a qualified senior radiographer working full-time at the three main referral hospitals in Namibia	Locum/part-time radiologists and radiographers
Objectives 3: To determine the effectiveness of the image interpretation system in the management of patients. Objective 4: To explore and describe the experience of referring doctors in state hospitals regarding the utilisation of the image interpretation system.	Qualified medical doctor (intern or Medical Officer) working full-time at the three main referral hospitals in Namibia.	Locum/part-time medical doctors Consultants or Specialists
Objectives 5: To determine and analyse the knowledge of qualified radiographers in Namibia concerning image presentation of common radiographic pathologies. Objective 6: To evaluate the clinical competencies of qualified radiographers in Namibia regarding image interpretation of plain radiographs of the chest and appendicular skeleton.	Qualified radiographer with more than 1 year of working full-time at the three main referral hospitals in Namibia	Locum/part-time radiographers
Objective 7: To explore and describe the perceptions and experiences of radiography educators regarding the preparedness of graduates to take up image interpretation roles.	Be a full-time employee of the participating HEI. Have one year of experience teaching in the radiography programme	Part-time lecturers
Objective 8:	Be a radiography graduate of the participating HEI.	Graduates with more than 2 years

To explore and describe the perceptions and experiences of recent graduates regarding their preparedness to take up image interpretation roles.	Have a maximum of 1 year of post-graduate experience	Graduates with postgraduate qualifications

3.5.2 Sample size

Sample size indicates the appropriate number of participants that need to be included in the study to draw valid conclusions. The approach to determining this number differs between quantitative and qualitative studies due to the variations in their primary objectives.

Application in the qualitative approach

For all qualitative objectives, the sample size for each objective was determined by data saturation during the data collection process. Data saturation was the point during data collection where no new information was emerging and the responses became repetitive of the codes already established (Grove & Gray, 2018; LoBiondo-Wood & Haber, 2010). The study data at this point was considered enough to provide the rich and thick descriptions typical of a qualitative study (Brink et al., 2018). Data saturation was determined for each specific qualitative objective.

Application in the quantitative approach

For all quantitative objectives, all elements of the population were included in the sample for that particular objective to increase the accuracy of data collected as the population sizes were relatively small (Lavrakas, 2008). This reduced bias and increased the strength and precision of the study, especially for post-stratification analysis (Little, 1993).

3.6 Research instruments

The types of research instruments used in this study were determined by the type of data that was to be collected and the research approach that was adopted for each objective (Nieswiadomy & Bailey, 2018).

3.6.1 Research instruments for quantitative methods

Research instruments for quantitative methods are focused on standardising the data collection processes and maximising the generalisability of the research outcomes. To ensure this, questions and variables are developed in advance with close reference to the particular objectives to be covered (Kumar, 2011). Four quantitative data collection instruments were utilised in this study. One questionnaire was designed for radiographers to measure their knowledge of common radiographic pathology. The second was an image interpretation checklist that measured radiographers' ability to describe radiographic appearances on plain images of the chest and appendicular skeleton. The third instrument was a questionnaire designed for referring doctors who refer patients for imaging procedures to determine the effectiveness of the image interpretation system from their perspective. The instruments were selected for these aspects of the data collection as they afforded the researcher a standardised approach to asking the questions enabling objective interpretation of the outcomes as well as subjective comparisons (Brace, 2008). To increase the objectivity of the questionnaires, a combination of interrogative, imperative and declarative forms of questions were utilised (Saris & Gallhofer, 2014). The fourth instrument was a departmental data extraction checklist which enabled the extraction of similar data across the three research sites for easier comparison of findings. A full description of each quantitative research instrument is given in Table 3.4.

Table 3.4: Research instruments for quantitative objectives

Objective	**Research instruments**
Objective 1 To determine the current radiology image interpretation system capacity and performance.	A structured, document review was carried out using a departmental data extraction checklist (**see Appendix A**) to guide and aid in collecting data. The checklist had predetermined variables that indicated the departmental performance in image interpretation for the various X-ray procedures.
Objective 3 To determine the effectiveness of the image interpretation system in the management of patients.	A structured self-administered questionnaire assessing the effectiveness of the image interpretation process at each hospital was used (**see Appendix E**). This instrument was based on and modified from an evaluative framework for assessing the effects of image interpretation by Brealey (, 2001). It consisted of sections A on demographic characteristics of the doctors as well as sections B and C on diagnostic performance and diagnostic outcome rating of the different x-ray procedures.
Objective 5 To determine and analyse the knowledge of qualified radiographers in Namibia concerning image presentation of common radiographic pathologies.	A structured self-administered questionnaire assessing the educational background and theoretical knowledge of radiographers on radiographic patterns of common radiographic pathologies was used (**see Appendix C**). The questionnaire development was guided by two common radiographic pathology referral books used for teaching radiographic pathology (Kowalczyk, 2018; Eisenberg & Johnson, 2020). Questions had both positive and negative wording to minimise acquiescent bias and were phrased on a matching and dichotomous scale.
Objective 6 To evaluate the clinical competencies of qualified radiographers in Namibia regarding image interpretation of plain radiographs of the chest and appendicular skeleton	The clinical competencies of radiographers were evaluated using Ten chest and ten appendicular skeleton radiographs with varying pathologies together with an image interpretation checklist (**see Appendix D**). A similar method was applied before to assess the accuracy and confidence of junior doctors and medical interns in medical image interpretation (Christiansen et al., 2014; Cheung et al., 2018)A local radiologist provided a reference report that was used to assess participants' responses (Miranda et al., 2019). For each radiograph, participants were asked to identify any pathology on the radiograph and to describe it in terms of location and appearance, the What, Where, and How model (Harcus & Stevens, 2021). They also rated their confidence for each of the three aspects of a four-point Likert scale (0=no confidence; 1=slight confidence; 2= moderate confidence; 3=high confidence) (Cheung et al., 2018).

3.6.2 Research instruments for qualitative methods

Data collection in qualitative studies was focused on affording the participants as much freedom in their response to questions as possible to generate their subjective opinions. The research instruments were therefore designed with less prescriptive questions or response guidelines but provided an opportunity for discussion around central thematic areas of concern (Kumar, 2011). The semi-structured interview was selected as the data collection method of choice with the interview guide as the instrument. The semi-structured interview guide provided broad guidance on the areas that the interview was expected to cover leaving enough room for probing questions and subjective responses (Nieswiadomy & Bailey, 2018; Kumar, 2011). The interview questions were all non-directive, open-ended questions that allowed the participants the freedom to express and explain their viewpoints creating opportunities for mutual discovery and understanding (Kvale & Brinkmann, 2009). As the researcher had the opportunity to generate the questions, their format and wording as well as the order they were asked, the researcher became an instrument of data collection themselves (Kumar, 2011). To remain objective, the researcher had to apply the bracketing principle. Bracketing is a process where the researcher self-reflects and becomes aware of their own experiences and perceptions of a phenomenon under study before setting these temporarily aside to minimise their influence on the data collection and interpretation in qualitative research (Brink et al., 2018; Nieswiadomy & Bailey, 2018; Merriam, 2009). Furthermore, the researcher tried to reduce bias by applying a principle of Horizontalization which is part of the phenomenological reduction process. Horizontalization is a process of applying equal weight to all statements in the dataset at the beginning of data analysis thereby ensuring that no information is lost or overshadowed (Merriam, 2009). All qualitative data were collected using one-on-one semi-structured interviews (face-to-face, and telephonic). All the interviews were recorded using a voice recorder. Different interview guides were developed and utilised for each of the qualitative objectives. The specific details of the interview guides are discussed in Table 3.5.

Table 3.5: Research instruments for qualitative objectives

Objective	Research instruments
Objective 2 To explore and describe the setup of the radiology image interpretation system within the radiology department.	A Semi-structured interview guide with one main question and four sub-questions was used (**see Appendix B**). The main question was: *Can you describe to me the image interpretation process in this department and hospital?* Sub-questions focused on: *what is/ is not reported and why? challenges encountered during the process, the current role of the radiographer and suggestions for system improvements*.
Objective 4 To explore and describe the experience of referring doctors in state hospitals regarding the utilisation of	A semi-structured interview guide with one main question and four sub-questions were used (**see Appendix F**). The main question was: *What are your experiences regarding the utilisation of the image interpretation system?*

the image interpretation system.	Sub-questions focused on; *interpretation competencies across modalities, the challenges faced during interpretation, areas requiring support and the perception of preliminary clinical evaluation*
Objective 7 To explore and describe the perceptions and experiences of radiography educators regarding the preparedness of graduates to take up image interpretation roles.	A semi-structured interview guide with one main question and four sub-questions were used (**see Appendix G**). The main question was: *What are your experiences regarding image interpretation skills training of graduate radiographers from your institution?* Sub-questions focused on: *module content, the inclusion of preliminary clinical evaluation, alignment of content with international trends and industry needs and demands*
Objective 8 To explore and describe the perceptions and experiences of recent graduates regarding their preparedness to take up image interpretation roles.	A Semi-structured interview guide with one main question and four sub-questions was used (**see Appendix H**). The main question was: *What are your perceptions regarding image interpretation skills training*? Sub-questions focused on: *the content covered, the inclusion of preliminary clinical evaluation, assessments that were done for competency*

3.6.3. Pilot study

A pilot study was conducted to assess the research questionnaires for medical doctors and radiographers, involving final-year medical and radiography students from the participating HEI. A total of five final-year medical students and five radiography students were recruited for the pilot study and asked to complete the questionnaires. Participants in the pilot study were also invited to provide feedback on the clarity and complexity of the research instruments, as well as any areas where modifications might be needed. No recommendations for modifications or alterations were made for either questionnaire following the pilot study, and both instruments were maintained in their original form.

Additionally, one interview was conducted using each interview guide as part of the pilot study to test the instrument and the data collection procedure prior to the final data collection. All participants who were involved in the pilot study interviews were excluded from the final study.

3.7 Data collection procedures

Data collection commenced after ethics approval and institutional access permissions were granted. The actual procedure varied according to the objective and procedures involved. Initially, the relevant departments were contacted through the HODs and radiologists of these departments at the three hospitals as well as the training department at the participating HEI. Meetings were held where an in-depth discussion of the study aims and objectives, as well as procedures, were provided. The HODs provided a list of staff members in their departments as well as their contact details. The HODs and radiologists were recruited into the study during these initial contact meetings while radiographers, doctors and lecturers were recruited through individual contact.

3.7.1 Retrospective departmental records review

Data collection commenced with retrospective departmental assessments that were done using various department records. Chest and appendicular X-rays as well as CT results in the form of radiographs and radiologist reports were retrieved from the filling rooms and data on reporting status and dates were extracted using a departmental data extraction checklist (Appendix A). The patients' register, reported films sign-out register and the radiologist's reporting register were used to collect data on the relevant and corresponding dates of reporting for the various CT images for procedures done and completed between August and October 2021. To aid this process, the researcher recruited and trained two research assistants who assisted with the records retrieval, data extraction and repackaging of patient records from the filling rooms. No specific patient identifying details were collected apart from the study data. Furthermore, departmental statistics for the August to October 2021 period were obtained to give a reflection of the workload and case variety. Data were collected in November 2021 for Windhoek-based hospitals and in March 2022 for the Oshakati-based hospital.

3.7.2 Data collection from HODs, Senior Radiographers and Radiologists

All the interviews with the HODs, senior radiographers and radiologists were conducted face-to-face as part of objective 2 of the study. All the interviews were scheduled early in the morning so as to minimise the disruption of the normal work routines for the department. These interviews were conducted in the respective offices of participants where privacy and confidentiality could be assured. The office doors were always closed with a 'Do Not Disturb – Interview in progress' sign hung on the door to ensure no disturbance during the interview. The set-up of the interviews consisted of a table with two chairs (interviewer and interviewee) facing and opposite each other. The interview guide (Appendix B) provided the reference questions with probing questions added depending on the responses from each participant. All proceedings during the interview were recorded using a voice recorder. Additionally, notes were also taken for important cues to support the voice recordings during analysis. All interviews lasted between 15 to 20 minutes. Once completed, the interview recordings were password-protected and uploaded onto Google Drive for secure storage until transcription and data analysis were performed.

3.7.3 Data collection from radiographers

For radiographers, each staff member was approached in person through a face-to-face contact meeting or over the phone. In both cases, the researcher explained the purpose and objectives of the study as well as the procedures and commitment expected of the radiographer during the different aspects of the study. Those who agreed to participate in the study were asked to sign a consent form including for being recorded during interviews. These forms were provided physically to the radiographers during face-to-face contact and via email to those who were recruited over the phone. After consenting, the questionnaire (Appendix C), which assessed knowledge of common radiographic pathologies (objective 5) was administered immediately for the participants to complete while appointments for interviews were made for a later more convenient date. To ensure that the questionnaire objectively assessed returned knowledge, all questionnaires were administered in person as a hard copy that could only be completed during working hours. Thus, all radiographers were instructed to complete the questionnaire and return it on the same day. Due to the small population size and the need for effective monitoring, the administration and collection of the questionnaires were handled by the researcher. A temporary log file was created to track who had received and returned the questionnaire daily and this log file was destroyed at the end of each day. All completed questionnaires were filed in a secure office until utilised during data analysis.

The second data set collected from the radiographers was the completed image interpretation checklist (Appendix D) that required access to a set of chest and extremity plain images. A set of ten chest and ten extremity images were selected and copied from the PACS at one of the participating hospitals. Consultation with the radiologist was conducted to identify and describe the abnormality on each image using the 'What, Where and How' method, similar to what the radiographers were expected to utilise (Harcus & Stevens, 2021). The images were then further processed to remove any identifying details of the patient and hospital before being saved in a Portable Network Graphic (PNG) format, which ensures retention of the highest image quality. Two separate folders for the two image sets were created on Google Drive for the two image sets and a password-protected sharing link was created. The participating radiographers were then given the image interpretation checklist (hard copy) and the access link to open the images online on their laptops or mobile devices. To ensure an objective assessment, participants were also required to complete the checklist immediately after receiving it during working hours. Again, to ensure effective monitoring, the researcher managed this data collection process. The radiographs and image interpretation checklist (objective 6) were only administered only at least one month after all the radiographers had completed the questionnaires to minimise acquaintance bias as some of the pathologies and associated radiographic patterns were described in the questionnaire.

3.7.4 Data collection from referring doctors

The recruitment strategy for referring doctors needed to be adjusted to align with the new working routines imposed by COVID-19 protocols. Within most hospital departments, potential key informants were identified through personal inquiries and recommendations from radiographers. Subsequently, these identified key informants were enlisted into the study via telephone conversations, wherein a comprehensive overview of the study and its objectives was provided. Following these explanations, all recruited referring doctors who participated as key informants expressed their agreement to take part by completing the questionnaire (Appendix E) and the interview (Appendix F). Subsequently, the identified key informants were requested to serve as research assistants and assist in recruiting additional referring doctors within their respective departments who fulfilled the inclusion criteria. To facilitate this, the questionnaire for referring doctors was converted into an online instrument using Google Forms and the key informants assisted by distributing the link. All the responses from the participants were automatically captured online on the researcher's Google Drive account and later downloaded as a Microsoft Excel file. Furthermore, recruitment also occurred in the imaging departments as many of the referrers frequent the department to follow up on their patient's results. For interviews with the referring doctors (objective 4), telephonic communication was employed. Due to the busy schedules, most of the interviews were often scheduled in the late afternoon when the doctors were typically more available. In preparation for the interviews, the referring doctors were asked to be in a noise-free, secure environment that also ensured their privacy and ability to speak freely. The researcher conducted these interviews from his office and ensured the door was always locked to prevent disruptions during the process. The set-up consisted of a mobile phone which was used for making the call and a voice recorder utilised to capture and record the conversation. After the interviews were concluded, the recordings were encrypted and securely uploaded to the researcher's Google Drive storage, and subsequently removed from the mobile phone's memory.

3.7.5. Data collection from the participating HEI lecturers

Initial contact and subsequent individual interviews with the lecturers were conducted in person. All interviews related to objective 7 took place within the lecturers' respective offices. Comprehensive details of the study were shared with each lecturer, and they were provided the opportunity to review and sign the consent form. Interview appointments were scheduled at times when lecturers were not engaged in teaching or student consultations. During the interviews, both the researcher and the interviewee were seated facing each other across an office desk. To ensure privacy, the office door remained closed, and a 'Do Not Disturb – Interview in Progress' sign was displayed on the door. The interview guide (Appendix G) was used, encompassing reference questions and additional probing questions based on participants' responses. The entirety of the interview was recorded using a voice recorder. Upon completion, the interview recording was safeguarded with a password and uploaded to Google Drive for secure storage until the data analysis phase was initiated.

3.7.6 Data collection from the participating HEI recent graduates

For the study, recent graduates were exclusively selected from the 2020 cohort of the participating HEI. The researcher obtained a list of 2020 radiography graduates from the HEI, which included contact details. Using this list, initial contact was established through email, where the study information sheet and consent forms were shared. Subsequently, a telephonic follow-up was conducted to recruit participants. For the interview (objective 8), appointments were scheduled with those who expressed willingness and provided informed consent to take part in the study, at a mutually convenient date and time. All interviews were conducted via telephone and recorded with permission, using the call recorder application on a mobile phone. To ensure a conducive environment for interviews, participants were advised to be in a noise-free and secure setting that guaranteed privacy and unrestricted expression. The interview guide (Appendix H) provided a set of reference questions, supplemented by probing questions based on participants' responses. The interviews were facilitated by the researcher, and data collection continued until the simultaneous analysis showed that no new data was evident, and saturation was achieved. Following completion, interview recordings were password-protected and stored securely on Google Drive until the data analysis phase.

3.8 Validity, reliability, and trustworthiness

The quality of a research study and its outcomes are essential in determining the usability of the findings. The instruments used play a crucial role in determining the quality of a study, including how they are utilised. In quantitative research, the quality of a study is assessed through validity and reliability tests, while in qualitative research, quality is assessed by applying various elements of trustworthiness (Farrelly, 2013; Roberts & Priest, 2006).

3.8.1 Validity and reliability of quantitative methods

Face validity was evaluated by analysing the feedback received from the participants of the pilot study, ensuring that all questions were clear and comprehensible. Content validity was established through an extensive literature review and expert guidance during the development of the instruments, ensuring that the questions or indicators accurately measured the intended concept.

Questionnaire reliability was assessed after the pilot study using Cronbach's alpha (for Likert scale questions) (Ritter, 2010) and Kuder–Richardson Formula 20 (KR-20) (for dichotomous questions) (Kuder & Richardson, 1937) to gauge the level of internal consistency. All Cronbach's alpha coefficients and KR20 scores exceeded 0.7 (0.79 and 0.81 respectively), signifying strong internal consistency and reliability (Ritter, 2010; Kuder & Richardson, 1937).

3.8.32 Trustworthiness of qualitative methods

Trustworthiness is a measure of the quality and rigour of qualitative research including the data, data collection methods as well as the interpretation and conclusions from the data (Nieswiadomy & Bailey, 2018). Its assessment consists of four elements that need to be considered: credibility, dependability, transferability, and confirmability. Credibility is a measure of confidence in the true value of the data and its interpretation in the study. Dependability is a measure of the stability of the collected data over time which is very similar to reliability in quantitative research. Transferability refers to the extent to which the findings of the study can be transferred to other contexts. Confirmability is a measure of the objectivity and accuracy of the data and its representation of the actual truth (Nieswiadomy & Bailey, 2018). The researcher used various strategies to ensure the trustworthiness of the qualitative methods as detailed in Table 3.6.

Table 3.6: Application of trustworthiness to qualitative methods

Concept	Enhanced by:
Credibility	Prolonged engagement in the field was utilised to build trust and encourage truthfulness from the participants to enhance credibility. Member checking to confirm interview responses and the interpretation thereof was also applied during the data collection process. Persistent observation was applied to enable the collection of the most appropriate data to respond to the research questions. Lastly, space triangulation was also used to enhance credibility using multiple sites for data collection.
Dependability	Dependability was ascertained through the creation of audit trails and documents of the whole research process from conception to conclusion. This will enable an assessment of the reliability of the data and the processes utilised.
Transferability	Dense description of the study to enable assessment of applicability in different contexts. All characteristics of populations used in the qualitative studies are well described to enable readers to effectively judge the applicability of results in their contexts. The application of purposive sampling to select the appropriate participants for the appropriate objective supported by detailed inclusion and exclusion criteria provides support when the transferability of findings is being determined.
Confirmability	Confirmability was assured through the processes of bracketing to prevent and minimise the researcher's bias from affecting the evidence collected. In addition, there is a detailed documentation of the research process from conception, instrument design, data collection and data analysis procedures to effectively support an audit to ascertain the data’s accuracy and relevance.

3.9 Data analysis

Data analysis is an important and integral part of the scientific process, and its execution may affect the integrity of the whole study. It is therefore important that data analysis is well planned and executed in accordance with the set objectives of the study and the research instruments utilised thereby creating an audit of how results were arrived at (Barton & Peat, 2014). To enable a clear description of the data analysis carried out in this study, separate sections detailing statistical and narrative data analysis processes conducted are presented below.

3.9.1 Statistical data analysis

Data for objectives 1, 3, 5 and 6 were analysed by statistical methods. IBM SPSS Statistics for Windows, Version 26.0 was used to capture and analyse data. All data were checked for completeness before being entered into SPSS. Once entered, data was cleaned and checked for errors twice before data analysis was conducted. Univariate descriptive analysis was conducted for all variables generating reports on the frequency and percentage as appropriate. These statistical results are presented in tables as well as visual charts. Bivariate analyses were then conducted to check associations and correlations between variables and the data is presented in cross-tables with frequency and percentages. The specific analyses for the different objectives are shown in Table 3.7.

Table 3.7: Statistical data analysis

Objectives	**Statistical data analysis**
Objective 1 To determine the current radiology image interpretation system capacity and performance.	Percentages and proportions of image interpretation were calculated and averaged per day over the period of data collection. The proportion of reported vs unreported radiographs was computed in general and per each hospital before reporting status comparisons were made using the Chi-squared test. Time taken to report a radiograph was calculated in general and per each hospital and procedure before comparisons were made between hospitals using the Independent-Samples Kruskal-Wallis Test with secondary Dunn Bonferroni correction due to the non-normal distribution of the data. Reporting times in weeks were also calculated in general and per each hospital with comparisons using the Chi-squared test.
Objective 3 To determine the effectiveness of the image interpretation system in the management of patients.	The effectiveness of image reporting was generated across two dimensions, diagnostic performance, and diagnostic outcome. Firstly, frequencies and percentages of responses were generated for each statement and presented in frequency tables. Indicators questions under diagnostic performance and diagnostic outcome in the questionnaire were then scored and summed up separately to indicate the level of effectiveness of the image interpretation system for each of the procedures using the mean scores as the cut-off points. Scores below the mean per procedure and overall were considered indicators of low effectiveness while scores above the mean were considered indicators of high effectiveness regarding diagnostic performance and diagnostic outcome. Association between individual characteristics with image interpretation effectiveness were analysed and tested using Chi-squared and Fisher's Exact tests where appropriate at an alpha level of 0.05.
Objective 5 To determine and analyse the knowledge of qualified radiographers in Namibia concerning image presentation of common radiographic pathologies.	Firstly, frequencies and percentages of responses were generated for each statement and presented in tables. Individual items for knowledge were scored and summed up to determine the overall knowledge level of each participant. Knowledge statements were also summed up for each of the four sections: chest, appendicular skeleton, joint pathologies, and fracture types. Descriptive statistics, frequency, and percentages, as well as mean scores and standard deviation, were calculated in general and separately for the three

	aspects. The association of knowledge of participants and demographic variables such as age, gender, years of experience, hospital of employment, and training institution were analysed and tested using Chi-squared and t-test (at alpha =0.05) where appropriate. Data were presented in tables and graphs for easier interpretation.
Objective 6 To evaluate the clinical competencies of qualified radiographers in Namibia regarding image interpretation of plain radiographs of the chest and appendicular skeleton.	Firstly, frequencies and percentages of responses were generated for each statement and presented in tables. Individual participants' ability to identify and describe pathological findings on radiographs was scored and summed up overall and per each of the two regions: chest and extremities. The overall scores were used to determine the level of efficacy (accuracy and sensitivity) of each participant in image interpretation (Baratloo et al., 2015). The association of the level of efficacy with demographic variables were analysed and the differences shown were tested for significance using Chi-square/Fisher's exact test and Kruskal Wallis test where appropriate (at alpha=0.05) due to the non-normal distribution of the data.

3.9.2 Narrative data analysis

Data for objectives 2, 4, 7 and 8 were analysed using qualitative data analysis methods. The audio recordings from the interviews were transcribed using Microsoft 365 by research assistants and transcription accuracy was verified by the researcher. After transcriptions were authenticated, they were uploaded to the relevant folders on Atlas.ti. in preparation for data analysis. All the data analysis was then conducted using Atlas.ti 9.0 (Atlas.ti Scientific Software Development GmbH, 2020). The analysis of interview transcriptions aimed to address various research questions, necessitating the use of different methods. While these methods varied slightly, they all adhered to the four fundamental principles of qualitative data analysis: reading, coding, categorising, and theming. Each method and its application are elaborated upon in the following sections.

3.9.2.1. Approach to data analysis of objective 2 (Image Interpretation process)

The data analysis for this objective was based on creating an understanding of how the image interpretation process is structured, its challenges as well as potential solutions, and the possible roles of radiographers. To enable this, the directed content analysis approach was used to guide the analysis and derive meaning and conclusions from the data. Directed content analysis is a subcategory of content analysis that is grounded in deductive data analysis based on pre-existing theories, concepts, or frameworks (Hsieh & Shannon, 2005; Assarroudi et al., 2018). It allowed the researcher to use prior knowledge gained from observations conducted in departments before interviews (objective 1) as a framework for analysing interview transcriptions. The researcher applied the 4-step method to content analysis because it still yields accurate results without being too cumbersome (Luo, 2022). The application of these steps is detailed below.

Step 1: The interview recordings were listened to before being transcribed, and then the transcripts were read to gain a general understanding of what the data was indicating.
Step 2: Each transcription was analysed, and significant texts and phrases were highlighted and coded using terms that reflected their underlying meaning.
Step 3: The codes were then extracted and compared with each other to remove and collapse redundant codes and group similar codes under the same categories that represent the sub-themes in the study.
Step 4: Categories were again analysed and regrouped together using overarching terms and phrases that represent the themes.

3.9.2.2. Approach to data analysis for objective 4 (experiences of referring doctors)

The data analysis for this section was focused on understanding how referring doctors were utilising image interpretation services through their experience. To enable this, the researcher applied conventional content analysis to analyse the data and create themes and sub-themes (Hsieh & Shannon, 2005). This approach is considered the most inductive of the content analysis methods and ensures that the final themes and sub-themes are grounded in the actual data (Leung & Chung, 2019). The steps outlined in section 3.9.2.1 were applied to analyse the data.

3.9.2.3. Approach to data analysis for objective 7 (experiences of educators)

The data analysis for this objective was based on exploring the preparedness of radiography graduates for image interpretation roles from the educators' perspective. The directed content analysis approach, discussed in section 3.9.2.1., was used to guide the analysis and derive meaning and conclusions from the data. It was chosen as it allowed the researcher to use emerging information from recent graduates on how they perceive their preparedness for image interpretation roles as a framework for data analysis (objective 8). An open coding matrix was employed, enabling flexibility in data analysis and accommodating additional findings that surfaced beyond the boundaries of the initial coding matrix (Assarroudi et al., 2018). The four steps of content analysis discussed in section 3.9.2.1. were applied during data analysis (Luo, 2022).

3.9.2.4. Approach to data analysis for objective 8 (experiences of graduates)

The data analysis approach was based on descriptive phenomenology, as this aspect of the study aimed to explore and describe the experiences of recent graduates regarding the image interpretation training, they received during their degree programme. This approach is based on describing the findings from the study without any interference and maximising bracketing to limit the researcher's influence (Holloway & Wheeler, 2010). In this way, the researcher intended to establish common experiences that go beyond subjective contributions as promulgated by Holloway and Wheeler (2010). The researcher utilised Colaizzi's seven steps of data analysis (Colaizzi, 1978) which has been reported to be flexible, thorough, and exhaustive, thereby ensuring the credibility of the findings (Northall et al., 2020; Wirihana et al., 2018; Morrow et al., 2015; Colaizzi, 1978). The following steps were applied during data analysis:

Step 1: Familiarisation

Step 2: Extraction of significant statements

Step 3: Formulating meanings

Step 4: Creating clusters and categories

Step 5: Exhaustibly describe the phenomenon

Step 6: Describing the fundamental structure

Step 7: Returning to the Participants

3.10 Research ethics

Research ethics provides a guide that directs how research is to be conducted to produce valid scientific results while protecting and minimising harm to those from whom data is collected. It provides a prescription for the most appropriate conduct of research. To ensure that researchers adhere to the principles of research ethics, research projects cannot proceed without being reviewed by a research ethics committee (REC) in most countries and academic institutions. Most academic institutions have RECs that are tasked with reviewing, judging, and approving research projects according to their scientific validity and ethical standards. CPUT subscribes to this practice and requires all research projects to be approved by an ethics committee before implementation. Thus, this study was reviewed and approved by the Faculty of Health and Wellness Sciences Research Ethics Committee before data collection commenced (Appendix I). To gain access to the research sites, permission from the custodians of these sites was required. For this study, institutional access permission was sought from and granted by; The Executive Director at the Ministry of Health and Social Service Namibia (Appendix J), all three hospitals from which radiographers and doctors were recruited (Appendix K and Appendix L) and the HEI (Appendix M). All individual respondents and participants were informed of the study by use of an information sheet and gave written and verbal informed consent before the commencement of data collection (Appendix N). The following ethical principles were adhered to and applied in this study:

3.10.1 Respect for persons

Respect for persons is based on the principle of autonomy, which is the right of the person to self-determination. Individuals need to be well informed before they can decide on participation in a research study (Ghandour et al., 2013). Thus, an information sheet containing the study purpose and objectives, as well as the procedures and possible risks associated with the study was provided to all human participants in the study. The researcher was available to answer questions and clarify concerns where necessary before informed consent was given. All participants were informed that participation in the study was voluntary, and the decision not to participate was respected without any consequences. Furthermore, participants were informed that they could withdraw from the study at any time, even after consent was initially given, without any negative consequences.

3.10.2 Beneficence

This principle refers to researchers acting in a manner that promotes the safety and well-being of others. Essentially it refers to doing good and minimising harm to research participants (Johansen et al., 2008). There was no direct benefit to the participants of this study but indirect benefits in the future may be realised through the application of the research findings. Participants were not paid and did not incur any costs to participate in this study as the study was conducted in their work setting. The researcher ensured that questions in the research instruments were phrased in a way that did not induce emotional or psychological distress. Though it was unexpected, the researcher made provisions for psychological support in case of evidence of distress.

3.10.3 Confidentiality

Only the researcher and supervisors had access to the raw data and all hard copies were stored in a lockable cupboard in a secure office. All captured electronic data and interview recordings were encrypted and stored in a password-protected laptop and backed up on an encrypted external hard drive as well as online using Google Drive. Data from the participants was not reported at the individual level but as aggregated findings. Copies of consent forms were separated from the questionnaires to prevent accidental disclosure.

3.10.4 Anonymity

No personal names or any identifying data was collected from the participants or respondents during data collection. The participants and health institutions were assigned and identified using unique identifiers only.

3.10.5 Privacy

All data obtained in this study was treated as confidential and private. Procedures mentioned under autonomy and confidentiality were also accorded maximum privacy. Copies of the informed consent forms that contain some details of the participants and the actual data were separated to prevent accidental exposure. All interviews were conducted in secluded private spaces within each department. Interview data was thoroughly cleaned to prevent the risk of deductive disclosure in the final report.

3.11 Conclusion

This chapter served to outline the research methodology that guided this study. Emanating from the study objectives, the design sought to provide relevant support to ensure the research objectives could be met. The suitability of the design was discussed in this chapter, which set the tone for the selection of the appropriate samples and research instruments, all of which were thoroughly discussed. The nature of each research instrument prescribed how it was used to collect data as well as how the data was analysed. Thus, a comprehensive explanation of the procedures carried out during data collection and the subsequent data analyses was also provided. The application of research ethics which influences the integrity of the study and its findings was also discussed and justified in this chapter. The chapter has therefore created a framework that links the aims and objectives of the study presented in Chapter One to the results that are discussed in the following chapters.

CHAPTER 4 : RESULTS

4.1 Introduction

The study employed a convergent parallel mixed methods design, which involves separate processes of data collection and analysis. Convergence was applied during the discussion of the findings, as elaborated in Chapter 3 (see Figure 3.1 on page 52). Drawing from the conceptual framework introduced in Chapter 1 (refer to Figure 1.4 on page 31), the results will be divided into four sections, aligning with each layer (row) of the framework. Each section will, therefore, present results corresponding to two objectives that had a similar focus area as defined by the central core column of the conceptual framework. Table 4.1 depicts the four results sections and their conceptual framework-guided focus areas. The sample characteristics and applied data analysis strategies were discussed in the previous chapter and referenced per the objective concerned.

Table 4.1: Sections used to present results

Section	Results focus area	Objectives
Section 1:	Image interpretation system design, capacity, and efficiency	1 and 2
Section 2:	Impact of image interpretation on patient management – a referrer's perspective	3 and 4
Section 3:	Preparedness of radiographers to adopt new roles in image interpretation	5 and 6
Section 4:	Experiences of image interpretation education – a lecturer-student perception	7 and 8

4.2 Section 1: Image interpretation system design, capacity, and efficiency

In this section, results from objective one—"Determine and observe the current radiology image interpretation system capacity and performance"—and objective two—"Explore and describe the setup of the radiology image interpretation system within the radiology department"—will be presented separately. Objective one used a quantitative design, and the results are based on statistical analysis using SPSS version 26, while objective two was qualitative and used content analysis using Atlas.ti version 9.0. Section 4.2.1 is the presentation of results for Objective 1, and Section 4.2.2 is the results for Objective 2.

4.2.1 The current radiology image interpretation system capacity and performance

To create awareness of the departmental workflow and prepare for the interviews with the radiologists and heads of departments, a departmental observation was undertaken in two steps. First, the daily routine of the department was observed, and a summary will be provided for each hospital. Second, a three-month retrospective evaluation of image interpretation (film reporting) was carried out in the film storage rooms at the three research sites (Hospitals 1, 2, and 3). These results will be presented in frequency tables and graphs.

4.2.1.1. Departmental staff compliment

The table below indicates the staffing levels for each radiology department.

Table 4.2: Departmental staff compliment

Research Sites	Number of radiologists	Number of radiographers	Number of general X-ray units	Number of CT units
Hospital 1	0.5	12	3	1
Hospital 2	0.5	14	4	1
Hospital 3	3	14	2	1

One qualified radiologist oversaw both Hospital 1 and 2 imaging departments, as far as image reporting was concerned, with the assistance of two medical officers. At Hospital 3, three radiologists were employed in the department and worked on a rotational schedule for the different departmental sections.

4.2.1.2. The average number of daily and monthly imaging requests received

Table 4.3 summarises the average number of imaging requests received daily and per month during the period of data collection at the three research sites.

Table 4.3: The average number of daily and monthly imaging requests received

Research Sites	Number of Conventional radiography procedures				Number of Special imaging procedures
	Daily Average	August 2021	September 2021	October 2021	All contrast-enhanced studies' daily average
Hospital 1	50	1071	1201	1270	0
Hospital 2	130	3956	3793	4018	0
Hospital 3	106	3104	3210	3315	4
Total	286	8131	8204	8603	4

Hospitals 2 and 3 received more than twice the number of conventional imaging referrals per day compared to Hospital 1 across the three months of data collection.

4.2.1.3. The conventional procedures routinely reported

The procedures that were observed as routinely reported are indicated in Table 4.4.

Table 4.4: The conventional procedures routinely reported

Research Sites	Reported Conventional radiography procedures			Reported Special imaging procedures
	Chest	**Extremities**	**Other**	**Contrast studies**
Hospital 1	None	None	None	N/A
Hospital 2	None	None	None	N/A
Hospital 3	None	None	None	**100%**

Conventional imaging procedures were not reported on at all as part of the standard practice at the three research sites. None of the research sites had mammography services because the equipment was being replaced. Similarly, two of the research sites lacked special contrast studies because their fluoroscopy machines were also being replaced.

4.2.1.4. Results from a three-month retrospective review of CT records

A retrospective review of the records in the file storage area was performed (from August to October 2021) to quantify the reporting capacity and turnaround times of CT images, which were the only ones observed to be reported on daily across the three research sites. The following results show the findings from this review.

4.2.1.5. The number of CT procedures performed

The numbers of CT procedures performed over the three months of data collection were extracted from the departmental statistics and an annual estimate extrapolated as shown in Table 4.5

Table 4.5: The number of CT procedures performed

Research Sites	Month when the exam was done in 2021			3-month Total	Annual estimate
	August	**September**	**October**		
Hospital 1	354	388	399	1141	**4564**
Hospital 2	477	622	668	1767	**7068**
Hospital 3	427	440	538	1405	**5620**
Total	1234	1450	1604	4313	**17 252**

Hospital 2 had the highest number of CT procedures (1767) over the three months, with an estimated annual number of 7068 procedures. All the departments showed an increase in CT procedures over the short period.

4.2.1.6. The number of CT procedures reported

The number of reported CT procedures was assessed using the presence of a radiologist's report inside the filed results for the three months as shown in Table 4.6

Table 4.6: The number of CT procedures reported

<table>
<tr><th rowspan="2">Research Sites</th><th colspan="2">CT Image Reporting status (Aug-Oct 2021)</th><th rowspan="2">Total CT scans for 3-months</th><th rowspan="2">p-value</th></tr>
<tr><th>Total Number Not reported</th><th>Total Number Reported</th></tr>
<tr><td>Hospital 1</td><td>625 (54.8%)</td><td>516 (45.2%)</td><td>1141</td><td rowspan="4">0.001</td></tr>
<tr><td>Hospital 2</td><td>1187 (67.2%)</td><td>579 (32.8%)</td><td>1766</td></tr>
<tr><td>Hospital 3</td><td>1221 (86.9%)</td><td>184 (13.1%)</td><td>1405</td></tr>
<tr><td>Combined Total</td><td>3033 (70.3%)</td><td>1279 (29.7%)</td><td>4312</td></tr>
</table>

More than 50% of the CT procedures were not reported in each department, with the greatest number recorded at Hospital 3 at 86.9%. In total, 70.3% of the CT procedures were not reported across the three research sites. The chi-squared test was used to test for differences in reporting status between the hospitals and showed a significant difference across the three hospitals (p=0.001).

4.2.1.7. Time taken to report the CT procedures

The time taken to report the CT images was calculated from the day the procedure was performed to the day the report was available and is indicated in days in Figure 4.1.

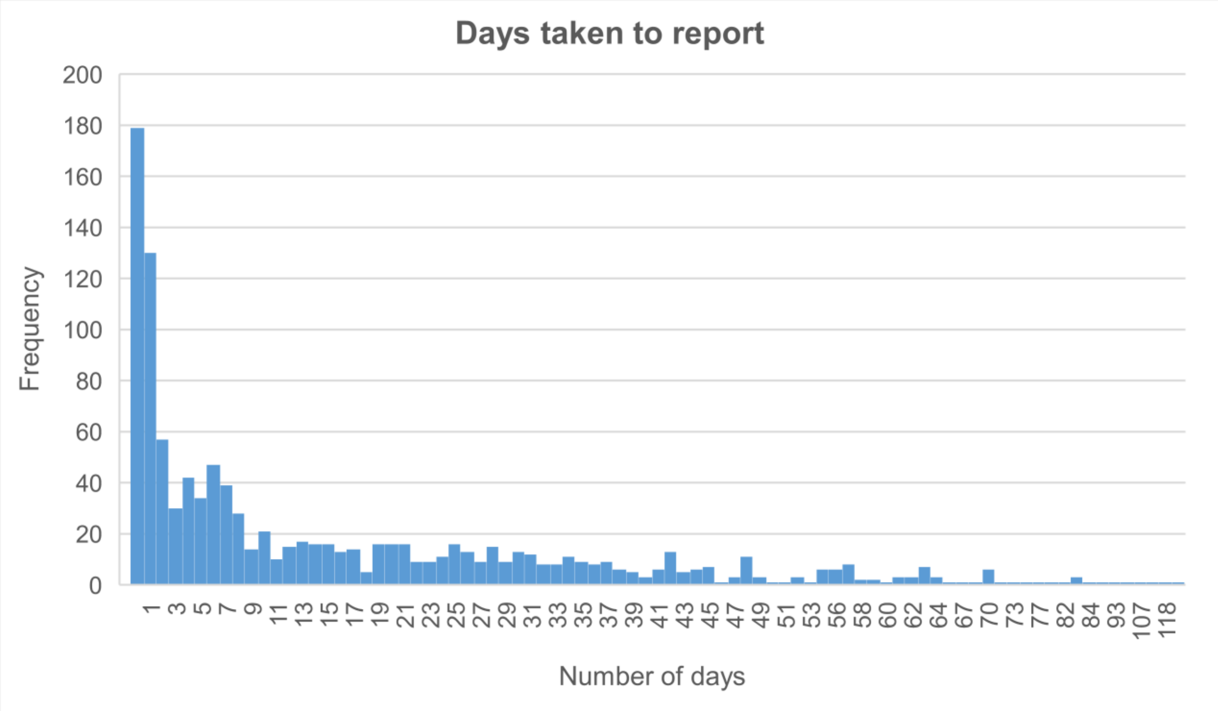

Figure 4.1: Days taken to report on the CT images

Reporting time ranged from immediate (0 days) to 125 days, with a median of 7 days and an interquartile range of 24 days. The time required to report CT procedures exhibited a non-normal distribution (Shapiro-Wilk Sig = 0.001) and demonstrated a significant difference among the hospitals, as determined by the Independent-Samples Kruskal-Wallis Test (p=0.001). Further analysis of hospital-hospital differences was done as detailed below.

4.2.1.8. Pairwise comparison for days taken to report CT procedures

Reporting of CT procedures was further explored using pairwise comparison to assess the individual hospital associations, with the result corrected for Family Wise Error Rate (FWER) using Dunn Bonferroni [a] correction, as shown in Table 4.7.

Table 4.7: Pairwise comparison for days taken to report CT procedures

Sample 1-Sample 2	**Test Statistic**	**Sig.**	**Adj. Sig.**
Hospital 1- Hospital 2	62.896	0.002	**0.006**
Hospital 2- Hospital 3	-90.314	**0.003**	**0.009**
Hospital 1- Hospital 3	-27.418	0.361	1.000

The reporting time for CT procedures was found to be significantly different between Hospital 1 and Hospital 2 (p=0.006) as well as Hospital 2 and Hospital 3 (p=0.009) after FWER correction.

4.2.1.9. Reporting time in weeks

The reporting times for the three research sites were further classified into weeks for only those CT procedures with reports as shown in Table 4.8

Table 4.8: Reporting time in weeks for reported CT procedures

Time in weeks for reported images	Frequency	Per cent (%)
Within 1 week	558	51.4
1 - 2 weeks	121	11.1
2 - 3 weeks	96	8.8
3 - 4 weeks	82	7.6
4 - 5 weeks	70	6.4
5 - 6 weeks	50	4.6
Over 6 weeks	109	10.0
Total reported	1086	100.0

The majority (51.4%) of the CT procedures were reported within 1 week while 10% took over six weeks to be reported.

4.2.1.10. Reporting times per hospital in weeks

The time taken to report the CT procedures was further analysed per week and the research site for only images with reports and the results are shown in Table 4.9.

Table 4.9: Reporting times per hospital in weeks

Number of weeks taken to report	The research site			P value
	Hospital 1	Hospital 2	Hospital 3	
Within 1 week	251 (49.90%)	244 (54.80%)	63 (45.70%)	0.026
1 - 2 weeks	65 (12.90%)	38 (8.50%)	18 (13.00%)	
2 - 3 weeks	40 (8.00%)	47 (10.60%)	9 (6.50%)	
3 - 4 weeks	44 (8.70%)	27 (6.10%)	11 (8.00%)	
4 - 5 weeks	24 (4.80%)	33 (7.40%)	13 (9.40%)	

5 - 6 weeks	20 (4.00%)	19 (4.30%)	11 (8.00%)	
Over 6 weeks	59 (11.70%)	37 (8.30%)	13 (9.40%)	
Total	503 (100%)	445 (100%)	138 (100%)	

Most of the reported CT procedures were reported during the same week (7 days) that the images were acquired. A significant difference in the time taken to report the CT images was shown between the three research sites (p=0.026).

4.2.2. The setup of the radiology image interpretation system within the radiology department.

To further understand how the image interpretation systems were set up and operating within each department, interviews were conducted with the radiologists, heads of departments, and senior radiographers. The intention was to complement the numeric data obtained from the departmental observation as presented in the previous section.

4.2.2.1. Approach to data analysis

The data analysis for this objective was based on creating an understanding of how the image interpretation process is structured, its challenges as well as potential solutions, and the possible roles of radiographers. To enable this, the directed content analysis approach was used to guide the analysis and derive meaning and conclusions from the data. The application of this method is detailed in Chapter Three section 3.9.2.1. Conclusions were then drawn from the analysis and presented for each theme supported by the relevant direct quotations from participants coded using their hospital and participant number *(H0; P0)*.

4.2.2.3. Participants' demographic characteristics

For this study strand (objective 2), a total of ten individual face-to-face interviews were conducted at the three research sites. Of these participants, 40% were males and 60% were females. The majority (60%) were senior radiographers with more than five years of experience and knowledge of the operational systems of the department. There were two (20%) radiologists, one representing the two research sites (Hospitals 1 and 2) and the other the third site (Hospital 3). Both radiologists had worked for over 5 years in their respective departments. In addition, two (20%) HODs (Radiographers) were available during data collection. One had insight and operational knowledge of the two research sites (Hospitals 1 and 2), while the other was based at the third site. All HODs had more than ten years of experience managing their respective departments.

4.2.2.4. Themes and subthemes

Three themes and a total of 10 subthemes emerged from the data analysis. Using the coding matrix, a thematic map was developed as shown in Figure 4.2.

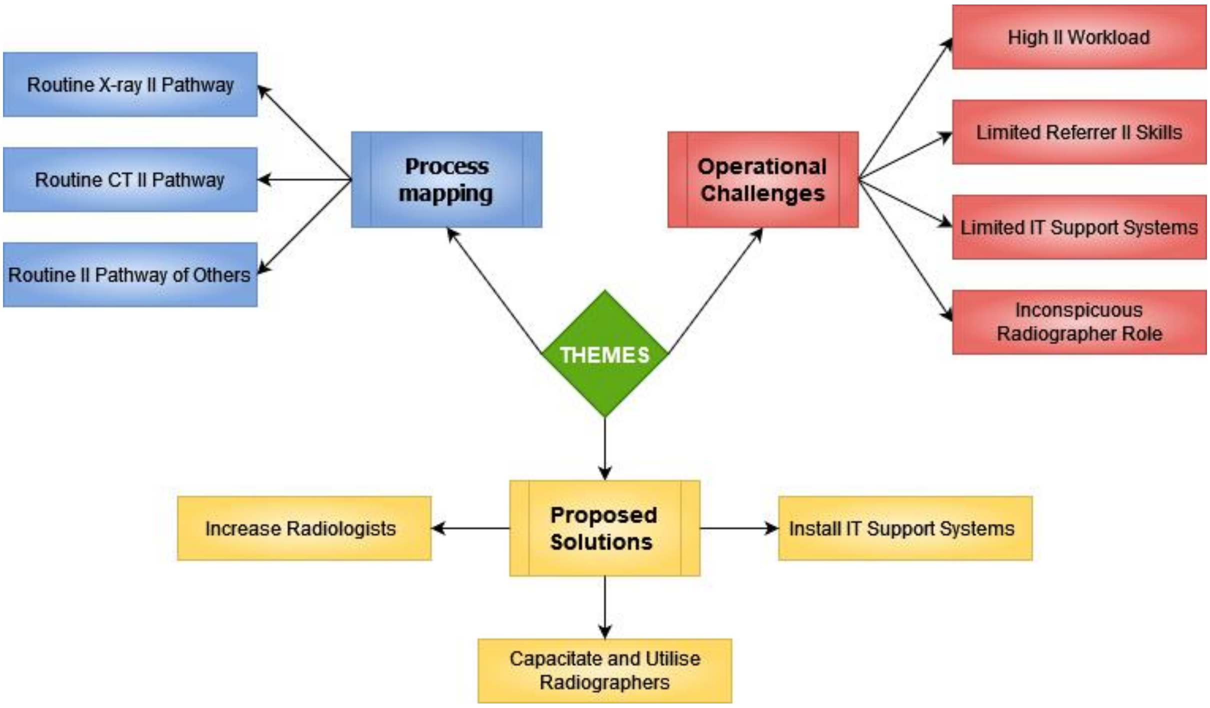

Figure 4.2: Thematic map 1 (II = Image interpretation).

4.2.2.5. Theme 1 – Image interpretation process mapping

This theme offers insight into the operation of the image interpretation process within the departments. It provides a fundamental basis for understanding the observed patterns of reporting and clarifying what aspects of the process are permanent or incidental. The theme was supported by three subthemes that created a more comprehensive picture of the image interpretation process, covering conventional imaging procedures, CT procedures, as well as any other imaging procedures within the departments.

4.2.2.6. Subtheme 1.1: Routine plain image interpretation pathway

This subtheme focuses on the conventional X-ray procedures, which make up the bulk of the workload for the three departments. All the participants in the three departments reiterated and supported the observed trend that none of the conventional imaging procedures was being reported unless a special request had been made by the referrers. This is what one of the participants said:

"For conventional imaging, as soon as the images are taken and the radiographer has fully assured that the images are of diagnostic quality, they send them to the referring doctors. So, interpretations are mainly done by doctors" (H3: P2)

"Most of the time, 90% or 95%, we give straight to the doctors when they need a report, they bring them back, give them to, the radiologist for reporting." (H2: P10)

The only exception, also across the three departments, was when a chest X-ray was done for a medical check-up (commonly for visa applications), and then the image was reported immediately if the radiologist was available.

"…a report is given for medical examinations of which most of the times these are chest x-rays for study visa purposes and work permit purposes." (H1: P5)

The responsibility of image interpretation for conventional imaging was therefore transferred to the referrer, regardless of whether that referrer is a consultant, medical officer, or medical intern. However, there was an acknowledgement that the image interpretation should ideally be the responsibility of the imaging department, and all images should be reported as indicated below.

"*Plain x-rays are not reported, but ideally, we know that they should be reported. Any image that leaves the imaging department should be reported, but they are not reported." (H1: P5)*

"*The plain x-rays, most of them are not reported because the number becomes so big for the number of reporting staff that we have" (H3: P9)*

4.2.2.7. Subtheme 1.2: Routine CT image interpretation pathway

This subtheme outlines the reporting pathway for routine CT procedures. The image interpretation pathways across the three research sites were similar, including what is or is not being prioritised for reporting. All three research sites indicated that CT procedures are prioritised for reporting as they are deemed to be complex to interpret for most non-consultant medical doctors. In most cases, the patients will leave their images behind and only collect a report one to three weeks later. Below is what some of the participants said.

"So, CT images are mainly reported by consultant radiologists just because it's an advanced imaging modality." (H1: P7)

"For CTs, most are left for reporting, so the patients are told to come back after three weeks or call after three weeks for them to get a report." (H2: P1)

"So, when the procedure is done, let's say CT scan brain, abdomen or chest, we normally inform a patient to come for their image report after a full working week, which is seven working days." (H3: P3)

However, within the routine pool of CT procedures, there are some procedures where the results are given back to the patient immediately after the scan without the CT report, regardless of who the referrer is. For these cases, image interpretation is left to the referrers, with support from the radiologists upon request and if available. Across the three imaging departments, trauma and stroke CT scans were not immediately scheduled for reporting but were sent out without image interpretation.

"…but for trauma patients, they don't really get a report because those procedures are done after hours so the referring doctors interpret their own images." (H2: P1)

"…some CT images, especially after hours, you just give them to the patients, especially for emergencies such as stroke and accidents, we sent straight to casualty or to the referring doctor." (H2: P10)

The time taken to report the CT radiographs for those procedures that require routine image interpretation is not similar across the three hospitals. While they all operate on a scheduling system or first come, first served ideology, the actual time it takes to get an interpretation report can be a few hours to a few months. Some of the comments they made were:

"He (the radiologist) prioritises to report CT images, it may not be on the same day, but yes, in the same week." (H1: P5)

"But sometimes it can even take up to two months or more for the patient to get their report." (H2: P1)

4.2.2.8. Subtheme 1.3: Routine image interpretation pathway for other procedures

Two of the three departments were only performing conventional imaging and CT as all their other imaging equipment was dysfunctional and due for replacement during the data collection phase. The third department had a working fluoroscopy machine, and in addition to CT and conventional imaging, they were also producing radiographs for special contrast procedures, which were also priorities for reporting. In addition, most of these procedures required the active presence of radiologists during the imaging procedure, and preliminary image interpretation was conducted during that process. Because of the low numbers of patients for these procedures, there was no backlog of reporting as it could be done immediately after imaging or at most a day after, as indicated below.

“For fluoroscopy, immediately after the procedure, the radiologist set up at the screening machine and do the reporting.” (H3: P6)

Furthermore, the three departments also had a special arrangement where CT procedures requested by a specialist in surgery, orthopaedics, cardiology, or ophthalmology are also not reported and the responsibility of image interpretation is placed on the referring consultant. This is because they consider they are capable of interpreting CT images in their area of specialisation, and it is a quicker process. However, if they require some guidance, they usually consult the radiologist directly to discuss the findings. Below are the sentiments of the participants.

“Other professional colleagues like the surgeons, the oncologist and doctors from the cardiac unit, they take their images, and they look at them themselves.” (H1: P5)

“Yeah, for the cardiologist, we usually select the images that they want and put them in the file, but they don't get reported.” (H2: P1)

“You know with some consultants the moment their patients are imaged; we print and send them the images without a radiologist report.” (H3: P2)

4.2.2.9. Theme 2– Image interpretation - operational challenges

This theme highlighted the operational challenges that were faced within the imaging departments regarding image interpretation. As the three imaging departments were all housed within public hospitals, the challenges that they alluded to were similar. These operational challenges included a high reporting workload, limited referrer image interpretation skills, limited IT support, and the inconspicuous role of the radiographer.

4.2.2.10. Subtheme 2.1: High image interpretation workload

The biggest challenge that was raised by all participants was the high image interpretation workload that has resulted in huge backlogs of unreported radiographs. Workload refers to the amount of work that is to be done or completed by a person (Oxford University Press, 2021), and in this case, the amount of image interpretation to be completed by the radiologists. Because of this, it has become impossible to satisfy the image interpretation demand and clear the existing backlog, as highlighted below:

“The radiologists and the medical officers we have are not enough for the amount of work that we do for them to look at it and interpret it.” (H1: P5)

“The images that are coming for reporting, be it general or CT images, is quite high. The number is quite too much.” (H3: P6)

“So that makes it very difficult for a very small group of professionals to keep up and report all of the images and give quality reports to clinicians” (H1: P7)

In addition to the low number of reporting radiologists, the workload was reported as increasing over the past years due to increased reliance on and requests for medical imaging across all modalities, as indicated below:

“So, I think we are moving into the realm of medicine with imaging and unfortunately the demand for imaging has increased exponentially over the past two or three years ever since I've been here.” (H1: P7)

This unfortunately cascades to the patient as they had to wait a long time to get their image interpretation reports, which further delayed their treatment and management, which might rely on these results as reported below:

“I think one of the major challenges is patients are waiting too long for their report.” (H2: P1)

“Reporting is taking too long and delaying patients’ treatment.” (H2: P10)

4.2.2.11. Subtheme 2.2: Limited referrers' image interpretation skills

The training of medical doctors, who are the sole referrers in this context, was reported to have insufficient development of image interpretation skills. Participants indicated that referrers appear to lack the skills and knowledge in image interpretation that are typically expected from their undergraduate training.

“We get patients that are sent back for what doctors think are artefacts, which are actually just normal anatomies. So that shows that the interpretation part of it is lacking.” (H2: P1)

“…like generally speaking, radiology does not feature or it's not a big part in undergraduate medical training” (H1: P7)

“They (doctors) are probably not really trained on how to interpret the images, so they tend to rely on the radiologist.” (H2: P8)

The radiologists have had to step in to try to improve the referrers' knowledge of basic image interpretation but because of the high turnover of interns, it was not sufficient.

“We started radiological sessions where we take maybe a complicated image for teaching purposes, especially when the medical students joined us, we'll take an x-ray and teach how to systematically report them.” (H3: P9)

4.2.2.12. Subtheme 2.3: Limited IT support systems

Medical imaging has been based on IT systems ever since the introduction of CT, and this has become an operational reliance due to the adoption of technologies such as RIS, HIS, PACS, and teleradiology. Participants in this study indicated that the absence or limited functionality of these systems in their departments negatively affects image interpretation and reporting efficiencies both internally and externally. Below are some of the shared sentiments.

> *"We don't have a HIS or RIS system. So those are other things that complement the radiology services and help to streamline things." (H1: P7)*

> *"…teleradiology would help a lot because you share one image, you don't need to share another, but we don't have that…" (H3: P9)*

4.2.2.13. Subtheme 2.4: Inconspicuous radiographer role

The participants also indicated that the role of radiographers in the image interpretation process is unclear and unnoticed in their local context because of several factors. Though the profession has developed and progressed through role extension and development, these have not been reflected or recognised locally. The radiographers felt that if they could contribute that could help alleviate the current image interpretation challenges if given the opportunity.

> *"For us (radiographers), we have that limitation of expressing yourself on what you are seeing on a certain image when somebody wants to hear." (H3: P6)*

> *"Most of the time they (referrers) say we don't really have much input on the image interpretation." (H3: P2)*

> *"It's like you also can tell what the problem is, but the image is just lying there because only one specific person is supposed to do reporting." (H2: P10)*

Regardless of the above, the radiographers highlighted that they do sometimes give their opinion to referrers when asked for advice, especially after hours when the radiologist is not available. In such cases, they indicated that their opinion was valued and meaningful for patient management.

> *"Most of the time they are interns, so you make sure that you point out that this area is suspicious so for them not to miss it out." (H3: P2)*

> *"… you would tell them this, I think this is this and this is that especially when you are dealing with a medical intern, and something is vivid." (H3: P3)*

Even in advanced modalities such as CT, the role of the radiographers, though not clearly recognised and outlined, was highlighted by one of the radiologists:

> *"Radiographers who perform CT are able to tell a clinician or an intern that there's a massive bleed on the scan or something abnormal because they've seen so many bleeds already." (H1: P7)*

4.2.2.14. Theme 3 – Proposed solutions

The theme highlights proposed solutions that the participants thought would result in an improvement of the image interpretation system within the three imaging departments. Since the operational processes and challenges are similar across the three imaging departments, the proposed solutions are also centred on the same thematic areas. These areas were focused on increasing the number of reporting radiologists, the installation of relevant IT support systems, and the capacitation and utilisation of radiographers.

4.2.2.15. Subtheme 3.1: Increase the number of reporting radiologists

The biggest challenge raised was the high image interpretation workload, which reflects an imbalance between demand and available capacity. In addition, the number of radiologists in each department was mentioned as being too low to be able to service the image interpretation need. Thus, the first recommended solution from the participant was to increase the number of reporting radiologists to meet and match the image interpretation demand within each department, as highlighted below.

> *"The ideal situation would be to hire more radiologists." (H2: P1)*

> "*Add more, the qualified staff I think, radiologists." (H1: P7)*

This solution assumed that with more radiologists, the more image interpretation requests they can attend to, thereby reducing report turnaround time and backlog while aiding patient management.

> *"Increase may be the number of radiologists probably so that reporting time can be shortened, and patients can receive their results in time." (H3: P3)*

> *"I think if we can have more staff for reporting so that we don't delay reporting for the patients." (H2: P8)*

4.2.2.16. Subtheme 3.2: Install IT support systems

As the process of medical imaging has evolved to be IT-based, especially with the full adoption of digital systems, the efficiency of image interpretation has also become dependent on the operational capacity of these systems. Thus, the participants in this study believed that a fully functional IT system would aid in the image interpretation process and may help streamline the process, thereby increasing its efficiency.

> *"So, we have mentioned the PACS and the proper HIS and RIS system that will definitely help to streamline things." (H1: P7)*

> *"I think once we have PACS that will definitely make a difference in terms of reporting and issuing reports in a timely fashion." (H1: P7)*

Furthermore, they also indicated that proper connectivity with colleagues can help optimise the process of peer consultation which can be done in real-time.

> *"Our connectedness with colleagues and maybe also with other radiologists, for example, teleradiology, would help a lot… (H3: P9)*

4.2.2.17. Subtheme 3.3: Capacitate and utilise radiographers

The participants in this study recognised the potential of radiographers to aid in improving the image interpretation process in their departments. There were indications that their experience and familiarity with different pathologies seen on the radiographs could make them a good source of knowledge to support the less experienced doctors.

> *"They are the ones taking the image and are the first to see it. So at least they should be allowed to have an opinion." (H3: P2)*

> *"I think radiographers are continuously being exposed to imaging and with the interaction with radiologists, they are in a position to provide some form of advice." (H1: P7)*

There was also a consensus on the need for further training of radiographers to enhance their capacity to perform some basic image interpretation. This would ensure standardised practice as well as increase the quality and accuracy of interpretation, as highlighted below.

> *"It's something that you do every day, it's something that you see every day so with a little bit of training, radiographers really can help out, especially when it comes to reporting." (H2: P4)*

“Some training, especially in pattern recognition and refresher courses and some workshops, need to be provided by the institution or the ministry where one is working in conjunction with the training institutions.” (H3: P6)

There was also an indication that for this to be fully realised and benefited from, the scope of practice of radiographers should be adjusted to include such new roles to enable their adoption.

“I think training would do, and probably, then changing and including that in the scope of practice somehow.” (H2: P1)

4.3 Section 2: Impact of image interpretation on patient management – a referrer’s perspective

The study strand targeted referrers and users of radiology services, which are primarily medical doctors. The section is focused on the results from objectives 3 (“Determine the effectiveness of the image interpretation system in the management of patients") and 4 (“Explore and describe the experience of referring doctors in state hospitals regarding the utilisation of the image interpretation system"). Objective 3 used a quantitative approach to collect data using a questionnaire, while Objective 4 used a qualitative approach using individual interviews to collect data. Data analysis was conducted using SPSS version 26 for objective 3 and will be presented in section 4.3.1, while Atlas.ti version 9 was used to analyse the interviews.

4.3.1. Effectiveness of the image interpretation system in the management of patients.

A questionnaire was used to collect data from consenting medical doctors. A total of 120 questionnaires were distributed online and physically within the hospital departments to recruit junior doctors, medical interns, and medical officers. After six months of data collection, a total sample of 79 doctors across the three research sites was achieved, giving a response rate of 66%, which was deemed sufficient for this survey to generate satisfactory results (Story & Tait, 2019; Fincham, 2008). The 79 questionnaires were analysed, and the results are presented as follows: univariate analysis, including demographic data then bivariate analysis, including inferential analysis for the significance of the association.

4.3.1.1 Demographic characteristics of doctors

Table 4.10 displays the demographic characteristics of the participating doctors in this study.

Table 4.10: Demographic characteristics of doctors

Demographic characteristics		***Frequency n (%)***	***Total***
Gender	Male	37 (46.8%)	
	Female	42 (53.2%)	79
Age	30 and below	51 (64.6%)	
	31 - 35 years	18 (22.8%)	
	36 and above	10 (12.7%)	79
Employment rank	Medical Intern	34 (43.0%)	
	Junior Medical Officer	37 (46.8%)	
	Senior Medical Officer	8 (10.1%)	79
Highest Qualification	MBChB or equivalent Degree	77 (97.5%)	
	MBChB or equivalent plus Postgraduate Diploma	2 (2.5%)	79
Years of experience	2 years and below	51 (64.6%)	
	3 to 4 years	14 (17.7%)	
	5 years and above	13 (16.5%)	
	Missing entry	1 (1.3%)	79
Image Interpretation Training	Yes	41 (51.9%)	
	No	38 (48.1%)	79
Area of training	No training	38 (48.1%)	
	General x-rays	35 (44.3%)	
	CT	5 (6.3%)	
	Obstetrics	1 (1.3%)	79
Hospital of appointment	Hospital 1	27 (34.2%)	
	Hospital 2	31 (39.2%)	
	Hospital 3	21 (26.6%)	79

From Table 4.10, it can be seen that a total of 52.3% were females; 64.6% were aged 30 years and below and 46.8% were junior medical officers; 97.5% were qualified with an MBChB or equivalent degree; 65.6% had two and below years of experience and 51.9% were trained in image interpretation.

4.3.1.2. Diagnostic performance – Procedures where the doctors would request a radiologist's report

The table below indicates the procedures where the doctors indicated that they would request a radiologist to report the images.

Table 4.11: Procedures where the doctor would request a radiologist's report

Imaging Procedure	Requestion of radiologist's report		
	No not at all	**Yes sometimes**	**Yes always**
a) Chest X-ray	43 (54.4%)	26 (32.9%)	10 (12.7%)
b) Shoulder X-ray	68 (86.1%)	11 (13.9%)	0 (0%)
c) Humerus/Elbow x-ray	73 (92.4%)	6 (7.6%)	0 (0%)
d) Forearm/hand X-ray	72 (91.1%)	7 (8.9%)	0 (0%)
e) Pelvis X-ray	63 (79.7%)	16 (20.3%)	0 (0%)
f) Femur/knee X-ray	69 (87.3%)	10 (12.7%)	0 (0%)
g) Leg/ankle/foot X-ray	70 (88.6%)	9 (11.4%)	0 (0%)
h) CT head	1 (1.3%)	33 (41.8%)	45 (57%)
i) CT chest	1 (1.3%)	14 (17.7%)	64 (81%)
j) CT abdomen	0 (0%)	14 (17.7%)	65 (82.3%)

Most of the doctors indicated that they don't request a radiologist's report for plain long bone radiographs such as the leg (88.6%), femur (87.3%), forearm (91.1%) and humerus/elbow (92.4%). However, for a plain chest radiograph, 32.9% indicated they would sometimes request a report and 12.7% would always request a radiologist's report. For CT scans, the majority would always request a radiologist report as shown in Table 4.11

4.3.1.3. Diagnostic performance – Opinion on procedures where the radiologist's report is provided without request

The table below indicates the procedures for which the doctors assumed they would receive a radiologist's report without requesting it.

Table 4.12: Doctors' opinion on radiologist reports received without request for various images

Imaging Procedure	Radiologist reports received without request		
	No not at all	**Yes sometimes**	**Yes always**
a) Chest X-ray	74 (93.7%)	5 (6.3%)	0 (0%)
b) Shoulder X-ray	79 (100%)	0 (0%)	0 (0%)
c) Humerus/Elbow X-ray	79 (100%)	0 (0%)	0 (0%)
d) Forearm/hand X-ray	79 (100%)	0 (0%)	0 (0%)
e) Pelvis X-ray	79 (100%)	0 (0%)	0 (0%)
f) Femur/knee X-ray	79 (100%)	0 (0%)	0 (0%)
g) Leg/ankle/foot X-ray	79 (100%)	0 (0%)	0 (0%)
h) CT head	26 (32.9%)	30 (38%)	23 (29.1%)
i) CT chest	18 (22.8%)	21 (26.6%)	40 (50.6%)
j) CT abdomen	17 (21.5%)	21 (26.6%)	41 (51.9%)

Most doctors indicated that no radiologist report is provided for the plain chest (93.7%) and all radiographs of the extremities (100%). However, only 50.6% and 51.9% indicated that a report is always provided for CT chest and CT abdomen respectively (Table 4.12.)

4.3.1.4. Diagnostic performance – Opinion on agreement of the doctors with the radiologist's report

The table below indicates the doctors' opinions on their agreement with the radiologist's report when a report is available.

Table 4.13: Agreement of the doctors with the radiologist's report

Imaging Procedure	No report is ever provided	Agreement between requesting doctor and imaging report on available reports		
		No not at all	Yes sometimes	Yes always
a) Chest X-ray	47 (59.5%)	5 (6.3%)	10 (12.7%)	17 (21.5%)
b) Shoulder X-ray	58 (73.4%)	6 (7.6%)	6 (7.6%)	9 (11.4%)
c) Humerus/Elbow X-ray	58 (73.4%)	6 (7.6%)	6 (7.6%)	9 (11.4%)
d) Forearm/hand X-ray	58 (73.4%)	6 (7.6%)	6 (7.6%)	9 (11.4%)
e) Pelvis X-ray	57 (72.2%)	5 (6.3%)	5 (6.3%)	12 (15.2%)
f) Femur/knee X-ray	59 (74.7%)	5 (6.3%)	6 (7.6%)	9 (11.4%)
g) Leg/ankle/foot X-ray	59 (74.7%)	5 (6.3%)	4 (5.1%)	11 (13.9%)
h) CT head	1 (1.3%)	0 (0%)	24 (30.4%)	54 (68.4%)
i) CT chest	1 (1.3%)	0 (0%)	23 (29.1%)	55 (69.6%)
j) CT abdomen	1 (1.3%)	0 (0%)	22 (27.8%)	56 (70.9%)

Most of the doctors indicated that no report is usually provided at all for plain images. For CT procedures, most indicated they would agree with the radiologist's report for CT head (68.4%), CT chest (69.6%) and CT abdomen (70.9%). The subset of these results is displayed in the figure below, indicating only cases where the report was available.

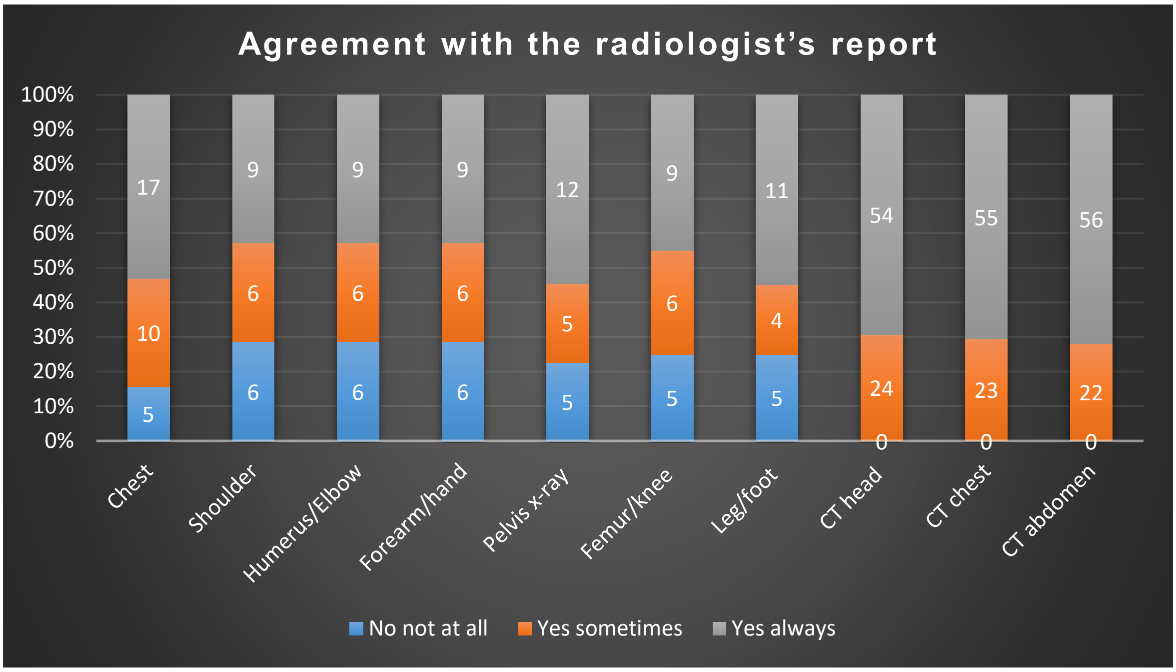

Figure 4.3: Agreement of the doctor with the radiologist's report

4.3.1.5. Timeliness of the imaging report

The doctors were asked to indicate their opinion on the timeliness of the image interpretation report in patient management and their responses are shown in Figure 4.4.

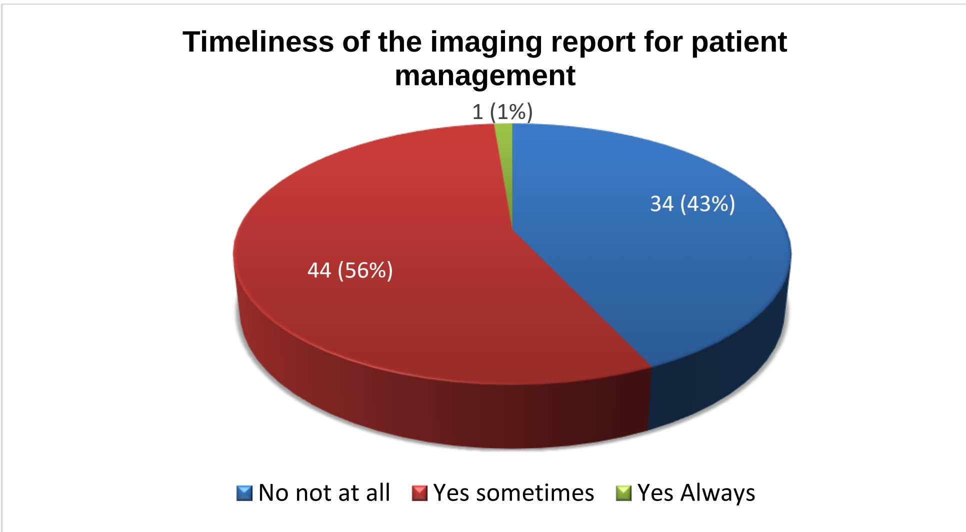

Figure 4.4: Timeliness of the imaging report for patient management

Only 1% of the doctors perceived the radiologist's report to be always on time for patient management whilst 43% felt it was not on time for that purpose.

4.3.1.6. Diagnostic outcome – Improvement in confidence and understanding when the imaging report is available

The doctors were asked to indicate their opinion on how a radiologist's report contributes to their confidence and understanding of the diagnosis from radiographs as shown in Figure 4.5.

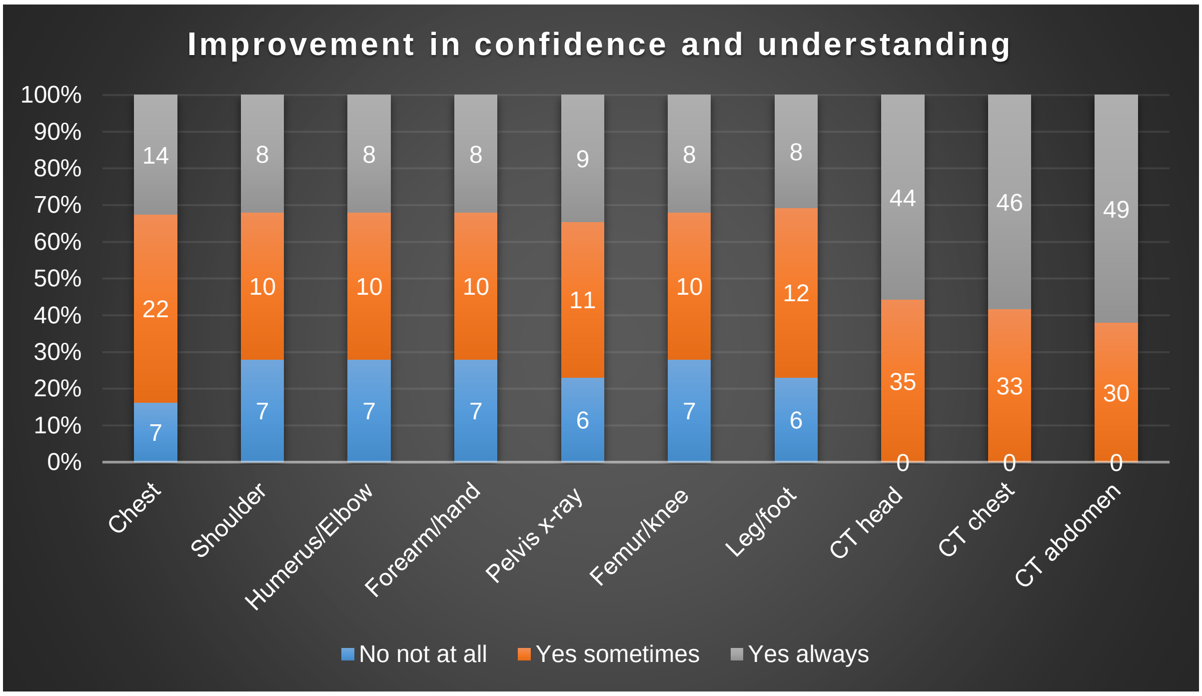

Figure 4.5: Improvement in confidence and understanding due to the imaging report

From Figure 4.5, CT reports for the head, chest and abdomen were indicated to increase the doctor's confidence and understanding of the diagnosis when compared to conventional plain images. For the conventional plain images, some of the doctors did not respond as they had not encountered these reports before.

4.3.1.7. Diagnostic outcome – Doctors' opinion on the imaging report's effect on the removal of further investigations

The doctors were asked to indicate their opinion on the procedure where a radiologist's report would remove the need for further investigations. Most doctors indicated that a report sometimes removes the need for further investigations for the CT head (54: 68.4%), CT chest (48: 60.8%) and CT abdomen (46: 58.2%). The other results are shown in the figure below, for cases where the report was available.

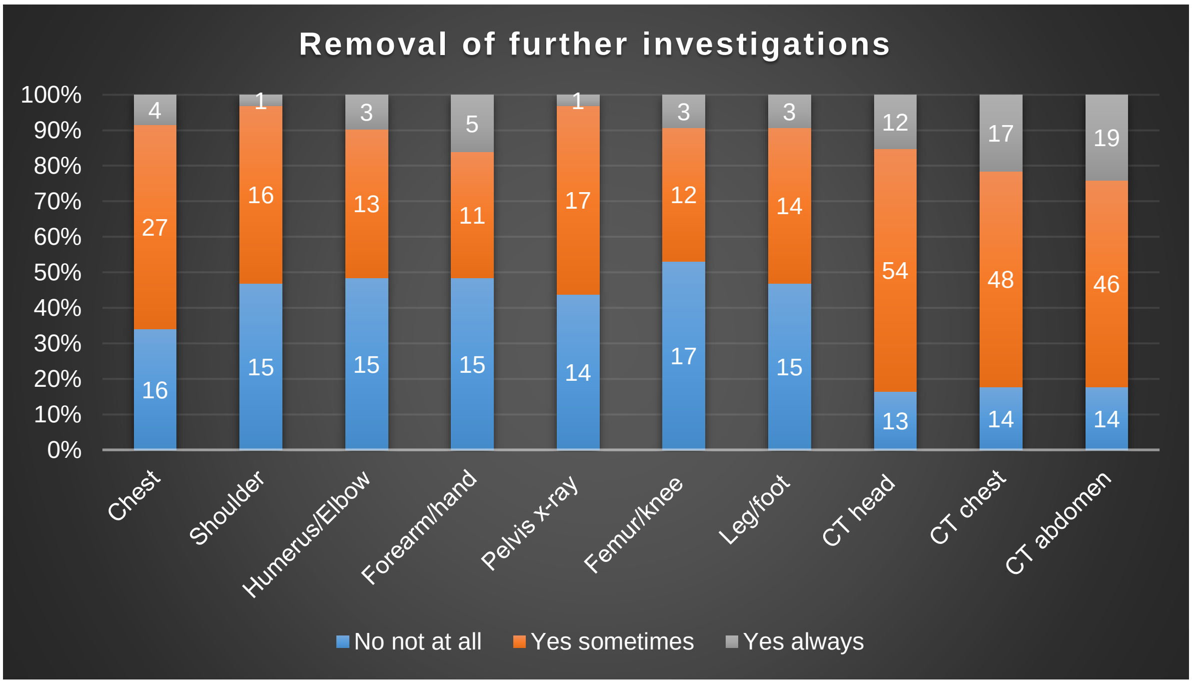

Figure 4.6: Removal of further investigations

4.3.1.8. Diagnostic outcome – Opinion on the effect of the imaging report in complementing other investigations

Table 4.14 indicates the doctors' opinions on procedures where the radiologist's report would complement other investigations.

Table 4.14: Effect of the report in complementing other investigations

Imaging Procedure	Effect of the imaging report in complementing other investigations when available		
	No not at all	Yes sometimes	Yes always
a) Chest X-ray	5 (6.3%)	29 (36.7%)	13 (16.5%)
b) Shoulder X-ray	6 (7.6%)	21 (36.6%)	3 (3.8%)
c) Humerus/Elbow X-ray	6 (7.6%)	21 (36.6%)	3 (3.8%)
d) Forearm/hand X-ray	6 (7.6%)	21 (36.6%)	3 (3.8%)
e) Pelvis X-ray	6 (7.6%)	20 (25.3%)	5 (6.3%)
f) Femur/knee X-ray	8 (10.1%)	19 (24.1%)	3 (3.8%)
g) Leg/ankle/foot X-ray	7 (8.9%)	22 (27.8%)	1 (1.3%)
h) CT head	0 (0%)	34 (43%)	45 (57%)
i) CT chest	0 (0%)	29 (36.7%)	50 (63.3%)
j) CT abdomen	0 (0%)	33 (41.8%)	46 (58.2%)

In the majority of cases, the doctors indicated that the imaging report always complements other investigations for CT head (57%), CT chest (63.3%) and CT abdomen (58.2%).

4.3.1.9. The overall effectiveness of the image interpretation process

The doctors were asked to rate the overall outcome of the reporting process in terms of its contribution to diagnosis, patient management and cost and the results are shown in Figure 4.7.

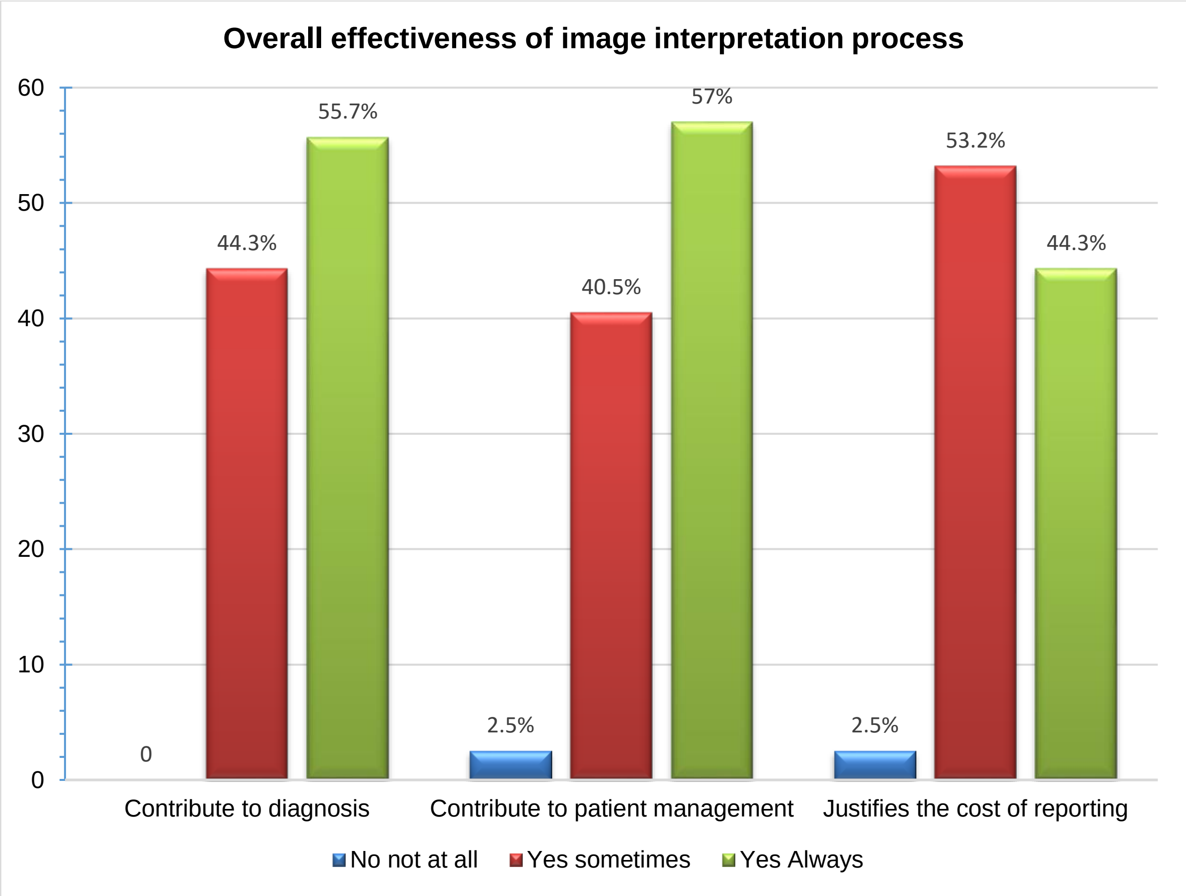

Figure 4.7: The overall effectiveness of the image interpretation process

A total of 55.7% and 57% of the doctors indicated that image interpretation contributes to diagnosis and patient management respectively. Regarding the cost of reporting, 44.3% indicated that the cost is always justified.

4.3.1.10. Association between the overall outcomes and demographic characteristics of the doctors.

Further analysis was performed to see whether there was an association between demographic characteristics with the overall effectiveness of image interpretation using Fisher's Exact test at an alpha level of 0.05. The results show no statistically significant association between the demographic characteristics and the contribution of imaging reports to diagnosis, patient management, and justification of the cost of image reporting.

4.3.2 The experience of referring doctors in state hospitals regarding the utilisation of the image interpretation system

This section of the study was intended to explore the experiences of medical doctors, specifically interns and medical officers, regarding image interpretation utilisation and support from the imaging departments of the three research sites. Medical doctors who routinely utilise imaging services across the different departments of the hospital were invited to participate in this study. A total of thirteen doctors were interviewed mostly face to face with a few telephonically.

4.3.2.1 Approach to data analysis

The data analysis for this section was based on creating an understanding of the experience of medical doctors when utilising image interpretation services. To enable this, the researcher applied conventional content analysis to analyse the data and create themes and sub-themes. The application of this method is described in Chapter Three section 3.9.2.2. The results are presented with direct quotations from participants coded as *DP* representing doctor participants.

4.3.2.2 The demographic characteristics of the medical doctors

The table below summarises the demographic characteristics of the medical doctors who participated in the study.

Table 4.15: Demographic characteristics of the medical doctors

Demographic Characteristic		**Number (%)**
Gender	Males	5 (38.5%)
	Females	8 (61.5%)
Rank	Medical Interns	10 (77%)
	Medical Officers	3 (23%)

There were more females than males who participated in the study (61.5%) and most of the respondents were medical interns (77%) as some of the Medical Officers (4) delegated participation to their interns.

4.3.2.3 Themes and subthemes from the medical doctors

A total of three (3) themes emerged from the data with a combined total of six (6) sub-themes as shown in Table 4.16 below and the thematic map in Figure 4.8.

Table 4.16: Themes and subthemes from the medical doctors

Themes	Subthemes
Theme 1: Poor Image Interpretation service	1.1 Long Turnaround Times
	1.2 Compromised Patient Management
Theme 2: Training and Support Deficiency	2.1 Inadequate Training
	2.2 Limited On-The-Job Support
Theme 3: Inconspicuous Radiographer's Role	3.1 Informal Radiographer Support
	3.2 Potential Image Interpretation Role

Thematic Map

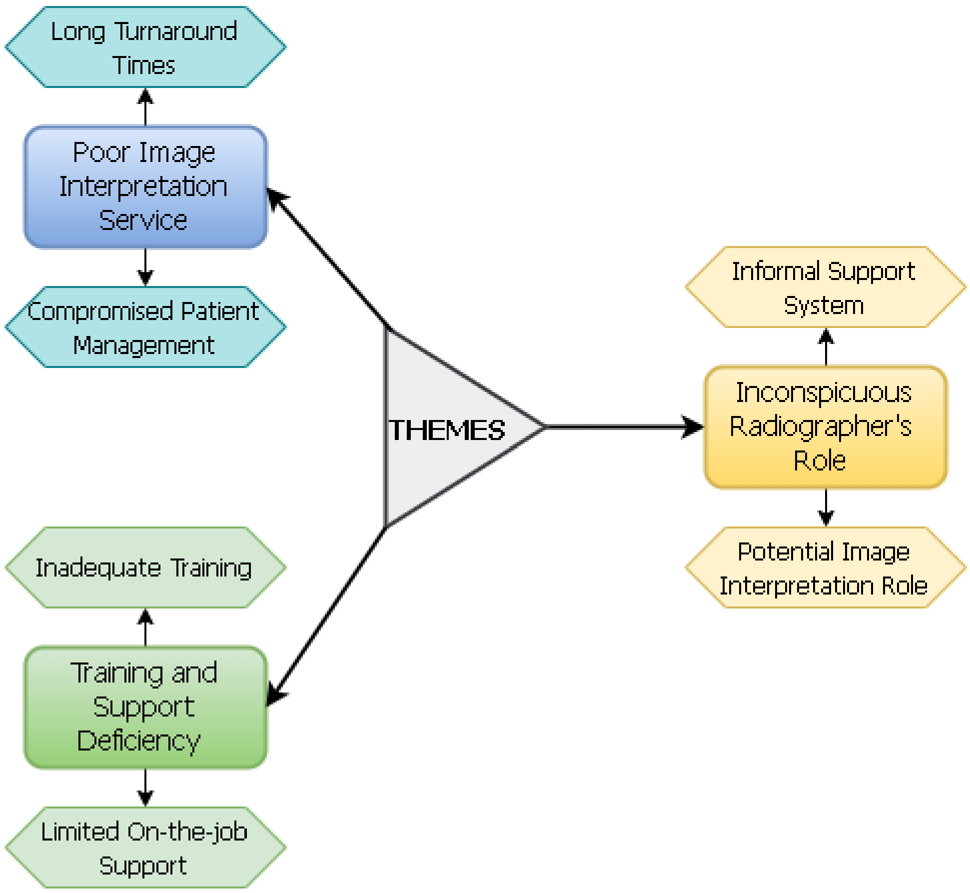

Figure 4.8: Thematic Mapping - Medical Doctors' Experiences

4.3.2.4 Theme1: Poor image interpretation service

The timeliness of the service in this study was a reference to the extent to which it informs and affects patient management. The participants in this study reported experiencing poor image interpretation services typified by long turnaround times and compromised patient management.

Sub-theme 1.1: Long turnaround times

The participants indicated that the turnaround time for image reporting was generally too long, spanning from a few weeks to several months at times. The following quotations reflect the typical experiences of the participants.

> *"The reporting process is really bad, because it takes a long time, like, a patient's CT scan will be taken like now in November, it will only be reported in February or so." (DP3)*

> *"That one can even take 3 months to get reported, I do not know maybe radiologists are few or so." (DP4)*

> *"However, the reporting takes time. I think we need to do something about the reporting because sometimes we need urgent reports." (DP10)*

The participants further highlighted that the reporting process is not standardised and organised as they have to go and beg in the radiology department for their patients' reports to be expedited as reflected below.

> *"Yes, and if you want the procedure to be reported early, like urgent or fast, you have to go beg and pull strings." (DP1)*

> *"I as a doctor have to constantly pressurise the radiologist to report this on time." (DP2)*

> *"It depends on how hard you push, to be honest. If you keep begging and begging, you might get it in a month or two." (DP3)*

There were also indications that, though the reporting process is long, the procedures from acute care and emergency departments were usually prioritised and reported much faster (within days) compared to other departments.

> *"We are in the ICU (Intensive Care Unit), so they prioritise us. They take days to report our procedures, not even a week." (DP7)*

> *"Urgent cases may take a week, emergency cases maybe hours, outpatients' settings can take up to four months on average. It is very terrible." (DP11)*

“We do not really have problems in acute care, because we are a critical care unit, and when we request for reporting they do it quite quickly.” (DP12)

Subtheme 1.2: Compromised Patient Management

An image interpretation report usually marks the conclusion of the imaging process and gives guidance to the referrer on a definite or potential pathology affecting the patient. It, therefore, is crucial in the decision regarding the management of a patient’s condition. The participants indicated that a poor reporting service impacts patient management which may have negative effects on the patient.

“This delay in reporting can lead to a delay in patient management, however.” (DP8)

“There is a delay in CT reporting affecting management of patient’s condition.” (DP9)

In some situations, the prognosis of a patient’s condition changes from manageable to terminal while waiting for the image interpretation report as highlighted by one of the participants in a quotation below.

“It took up to 6 months to get the report and it was actually a cancer patient. We could not even treat this patient surgically anymore, we had to send the patient straight to oncology for palliative care” (DP2)

Another participant highlighted that the prolonged reporting time leads to an extended hospital stay, which could potentially cause treatment delays, as detailed below.

“If they take long to interpret the scan, the more we keep the patients in the wards, the more the treatment is delayed.” (DP11)

Some participants, in trying to expedite patient management, would advise their patients to get imaging services from private healthcare facilities outside of the hospital which can be unaffordable or uncomfortable for most patients.

“Sometimes we ask the patients if they can afford or maybe know anyone who can help so they can get the x-rays done at private.” (DP3)

Theme 2: Training and Support Deficiency

Image interpretation training for doctors continues upon graduation in the form of clinical support and mentorship through supervision and monitoring of practice. Participants in the study indicated that both image interpretation training and support were inadequate.

Subtheme 2.1: Inadequate Training

The participants indicated that the training in image interpretation was inadequate in terms of the depth of content covered when compared to expectations in practice. They reported that the basic training did not cover image interpretation in any detail and that it is expected that this competence is developed in practice.

> *"At school, no we were not taught in-depth, they were not really specific. We just know when to request for what, but for interpretation, no." (DP1)*

> *"School is like a blueprint of all other things. They do not go into details; they just give you an overview of what you are going to do." (DP2)*

> *"We did not really go into details of image interpretation." (DP6)*

One of the participants indicated that what was covered was more of a basic image interpretation course during their training.

> *"We had medical imaging in our third year, where we were taught general X-rays, and some CT scans, and we had a basic course on how to read different X-rays. So, we are interpreting general x-rays, and some CT scans." (DP5)*

While the medical doctors are expected to interpret images from conventional imaging on their own as they are not reported, participants in this study expressed some challenges in interpreting some of the images as highlighted below.

> *"Those difficult conditions like for example abdominal syndromes, interpreting these x-rays is quite tricky, it is difficult to know. Also, orthopaedics and the spine images are a bit challenging." (DP5)*

> *"Image interpretation can be challenging, there are certain things that are obvious to someone who is just having an undergraduate medical knowledge but then there are certain things which are not specific, in which a radiologist or maybe a senior need to interpret." (DP6)*

> *"It is challenging, we can do a basic interpretation of x-rays for example, but there are some pathologies that we tend to struggle with like is it pulmonary oedema or is it just lung infiltrates. So, a lot of x-rays we need our consultant to come and interpret." (DP12)*

Due to the inadequate preparation noted during undergraduate training, most of the participants indicated that additional training is required for them to be able to fulfil the image interpretation role expected in practice as evidenced below.

“We need training on how to interpret. Maybe we can have seminars, or maybe on-the-job training to train the staff on how to interpret the images.” (DP2)

“I need a crash course on image interpretation. It can be offered by the radiologists on how to read a CT chest or abdomen. How to read when it is normal or how normal looks” (DP6)

“Yes, we need training, the more we do it, the more experience we get and the more we will be able to pick up pathologies and any abnormalities.” (DP10)

Subtheme 2.2: Limited On-the-Job Support

The healthcare sector is usually organised in such a way that optimum quality care is achieved only when various medical professionals and departments work together and support each other while putting the patient’s interest at the centre (Mosadeghrad, 2014). Thus, on-the-job support both internally from senior colleagues in the same speciality and externally from other healthcare professionals becomes important. The participants in this study indicated that they need support to properly perform their role in image interpretation as highlighted below.

“I need support from the radiology department for CT scan, I need support to interpret from the radiologist.” (DP7)

“I think we just need teamwork to interpret x-rays, like seniors and radiologists to help interpret the difficult cases.” (DP10)

“Chest x-rays, even if you ask other doctors here, we are really struggling with chest x-rays and need help to interpret.” (DP12)

The participants further highlighted the need for support due to their limited experience with image interpretation. They stressed the importance of experience in creating the image interpretation knowledge base required for clinical practice.

“It is also very easy to miss something if you are not experienced.” (DP1)

“I insist experience gives more knowledge and accuracy to interpret.” (DP5)

“Doctors depend on what they see, the previous exposure as well as how many images they have reviewed and interpreted in the past.” (DP12)

The ability to interpret the abnormalities in the images also depends on the quality of the images or the projections that the radiographers produce. The participants felt that sometimes they don’t get the necessary support from the radiographers as they release poor-quality images which are difficult to interpret as highlighted below.

“I think the way they print it, it is very small, sometimes it is clear but sometimes it is really challenging.” (DP1)

“Sometimes our x-rays are rotated, sometimes they are overexposed or underexposed making it difficult.” (DP7)

“Mostly the quality. Rotated x-rays because babies cannot lie still.” (DP9)

One of the participants elaborated on the need for collaboration and teamwork in image interpretation, especially for challenging cases.

“I think we just need teamwork, to interpret x-rays, like seniors and radiologists and interpret the difficult cases.” (DP10)

Theme 3: Inconspicuous Radiographer Role

The radiographers are mainly tasked with image production and ensuring that the image quality meets the diagnostic criteria for the specified anatomical region. They, however, can also play a role in image interpretation which according to the participants, was not as clear or visible but showed great potential to assist with the current image interpretation challenges as highlighted in the following subthemes.

Subtheme 3.1: Informal Radiographer Role

Some of the participants indicated that they had consulted the radiographer for their opinion on the abnormalities shown in the images in the past.

“I have consulted many times, especially where the diagnosis is a bit difficult.” (DP5)

"I think I did. When they did a CT scan, I asked when they were viewing the image after it was printed." (DP6)

“Yes, I did. It was very helpful; I use their opinions to make decisions on diagnosing pathologies.” (DP7)

Though this was an informal inquiry and consultation, without any documentation, the participants indicated that it was very helpful in the interpretation of the abnormalities on the image as indicated in the quotations below.

“We managed to diagnose what was wrong with the patient.” (DP9)

“It gave me a conclusion I was looking for. We ask them when we want to confirm something or have a preliminary diagnosis, and radiographers assist with that.” (DP11)

“It helped us in our diagnosis and patient management.” (DP12)

However, some participants indicated that there is no opportunity to ask for the radiographers’ opinion as they only communicate via the request form while one indicated that the radiographers are not very welcoming of consultation.

“Not, entirely, I have never asked. We do not really get to interact with them, you just request then you send the patient.” (DP1)

“But radiographers tend to be like a bit protective of their territory, they are not too welcoming at all.” (DP2)

Subtheme 3.2: Potential Image Interpretation Role

Though currently the radiographers are not actively participating in image interpretation, participants in this study felt that it would assist them in image interpretation if radiographers were to provide an indication of possible abnormality (red dotting) or a comment (PCE). Some of their comments are highlighted below.

“It will be helpful because we see a lot of patients every day, and maybe it is easy for us to miss something, so if you have an additional pair of eyes, or you pick up something that I didn’t notice, it will be helpful because it will also guide me during my diagnosis process.” (DP1)

“I might miss something that you saw, or you might just add something that will help.” (DP3)

“If an x-ray is already seen by one professional, it is really helpful, it is a big plus because we have already something we can build on from the department.” (DP5)

The participants believed that the assistance from the radiographers can help them formulate a diagnosis faster which may prevent delays in treatment and management.

“It will speed up the process because when the doctor comes, there is already a foundation built, they will just follow through.” (DP2)

“It will also help doctors in reducing the delay in diagnosing patients. It is something we can build on.” (DP6)

“Yes, it will be helpful, it will speed up the diagnosis process, I have a foundation that I can build on.” (DP8)

They also felt that this would improve the diagnostic process, especially with the current shortage of radiologists in the hospitals.

“Those countries utilising this, their diagnosis process is very efficient, so ours will also become faster.” (DP5)

“It will be helpful, there is a whole delay with the radiologists, so if we can get an opinion from someone else, it will help us a lot.” (DP6)

“On some images, yes it will help because radiologists are understaffed.” (DP8)

Furthermore, one of the participants regarded this as a good way to build knowledge and confidence for those who are less experienced. They indicated that it could be a way of training in image interpretation.

“I am speaking now from my level, I am a medical intern, and I am still in training, I think that will be helpful to me. Sometimes we are questioning our diagnosis, if they put up comments it will be helpful to us.” (DP10)

4.4 Section 3: Radiographer preparedness to adopt roles in image interpretation

In this section, the results regarding the level of preparedness of the radiographers to take on image interpretation roles will be presented. These are the results for Objective 5: “Determine and analyse the knowledge of qualified radiographers in Namibia concerning image presentation of common radiographic pathologies” and Objective 6: “Evaluate the clinical competencies of qualified radiographers in Namibia regarding image interpretation of plain radiographs of the chest and appendicular skeleton". Both objectives utilised a quantitative approach, and the data were analysed using SPSS version 26. Subsection 4.4.1 will present results for Objective 5, while subsection 4.4.2 will present results for Objective 6.

4.4.1 Knowledge of common radiographic abnormalities among radiographers

Here, the results of the radiographers' current knowledge regarding radiographic patterns of common abnormalities of the chest and appendicular skeleton are presented. A self-administered questionnaire was used to collect data from radiographers working at the three research sites. Of the 45 possible participants, 38 were available at the time of data collection, and a total of 33 participated in this study strand. Among the 12 radiographers who did not participate in the study, seven (7) were on long-term leave, three (3) were heads of departments, and two (2) did not consent to participate, giving a response rate of 82.5%. The results will be presented as follows: univariate analysis, including demographic data; bivariate analysis, including inferential analysis for testing the significance of any association.

4.4.1.1. Demographic characteristics of radiographers

The demographic characteristics of the radiographers who participated in this study strand include the participant's gender, age, highest qualification, employment rank, years of experience, and hospital of employment, and these are presented in Table 4.22.

Table 4.17: Demographic characteristics of radiographers

Demographic characteristics		***Frequency n (%)***
Gender	Male	10 (30.3%)
	Female	23 (69.7%)
Age	21-25 years	8 (24.2%)
	26-30 years	11 (33.3%)
	31-35 years	8 (24.2%)
	36-40 years	3 (9.1%)
	41 and above	3 (9.1%)
Highest qualification	Certificate	5 (15.2%)
	Diploma	3 (9.1%)
	Degree	25 (75.8%)
Employment rank	Assistant radiographer	5 (15.2%)
	Junior radiographer	14 (42.4%)
	Senior radiographer	13 (39.4%)
	Chief radiographer	1 (3.0%)
Years of experience	0-5 years	18 (54.5%)
	6-10 years	9 (27.3%)
	11 and above	6 (18.2%)
Hospital of appointment	Hospital 1	6 (18.2%)
	Hospital 2	11 (33.3%)
	Hospital 3	16 (48.5%)
Area of specialisation	General	1 (3.0%)
	CT	12 (36.4%)
	Not any	19 (57.6%)
	Mammography	1 (3.0%)
Primary daily role	General	26 (78.8%)
	CT	7 (21.2%)

The majority of the radiographers were female (69.7%), had a degree (75.8%), had less than 5 years of work experience (54.5%), had no specialisation (57.6%), and worked primarily in general radiography (78.8%). A total of 33.3% were aged between 26 and 30 years, while 42.4% were employed as junior radiographers (Table 4.17).

4.4.1.2. Radiographer image interpretation training

Radiographers were asked to indicate details of their image interpretation training and the results are shown in Table 4.18.

Table 4.18: Radiographer image interpretation training

Training Variables		*Frequency n (%)*
Content covered during training	Yes	33 (100%)
	No	
Mode of delivery	Theoretical	29 (87.9%)
	Clinical	4 (12.1%)
Theory mode of assessment	Yes	21 (63.6%)
	No	12 (36.4%)
Clinical mode of assessment	Yes	31 (93.9%)
	No	2 (6.1%)
Adequacy of content	Adequate	12 (36.4%)
	Inadequate	21 (63.6%)
Need for further training	Yes	31 (93.9%)
	No	2 (6.1%)

The majority of the radiographers indicated that image interpretation training was more theoretical (87.9%), and inadequate (63.6%), requiring further training (93.9%).

4.4.1.3. The areas where further image interpretation training is needed among radiographers

Figure 4.9 presents the areas identified by radiographers for further training to enhance image interpretation skills. From the results, pathology (84.4%), abnormality detection (66.7%), medical communication (54.5%), and image characteristics (51.5%) were identified by the majority of radiographers as areas requiring further training to enhance image interpretation skills.

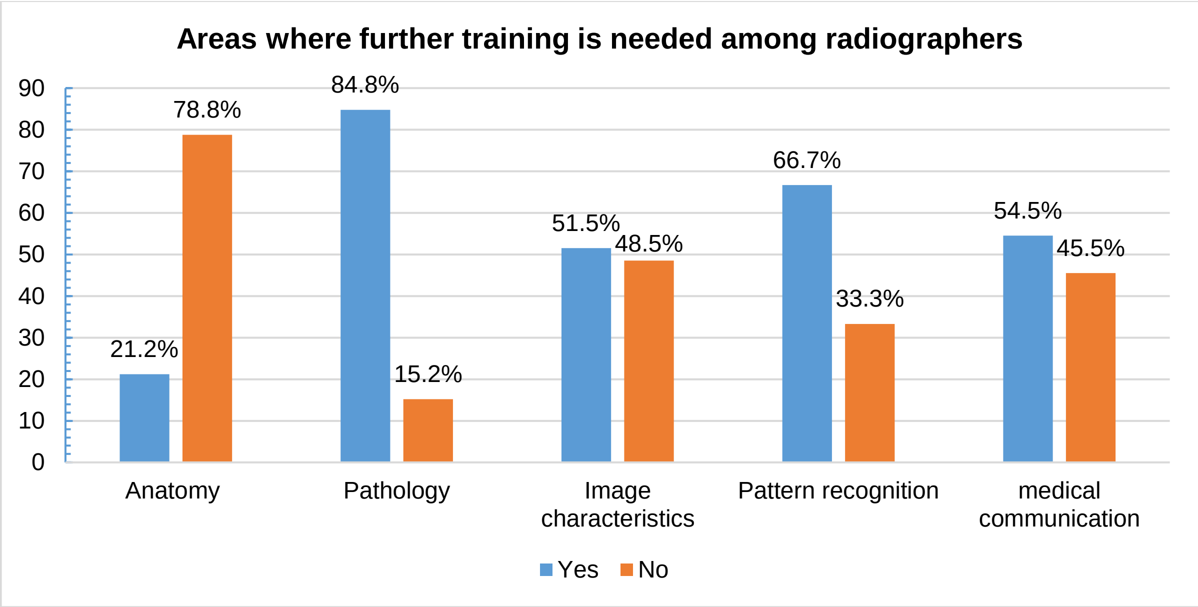

Figure 4.9: The areas where further image interpretation training is needed

4.4.1.4. Additional post-graduation image interpretation skills gained and their drivers

Most radiographers (60.6%) indicated that they gained additional image interpretation skills at work and the facilitators/drivers of such skills gains are shown in Figure 4.10.

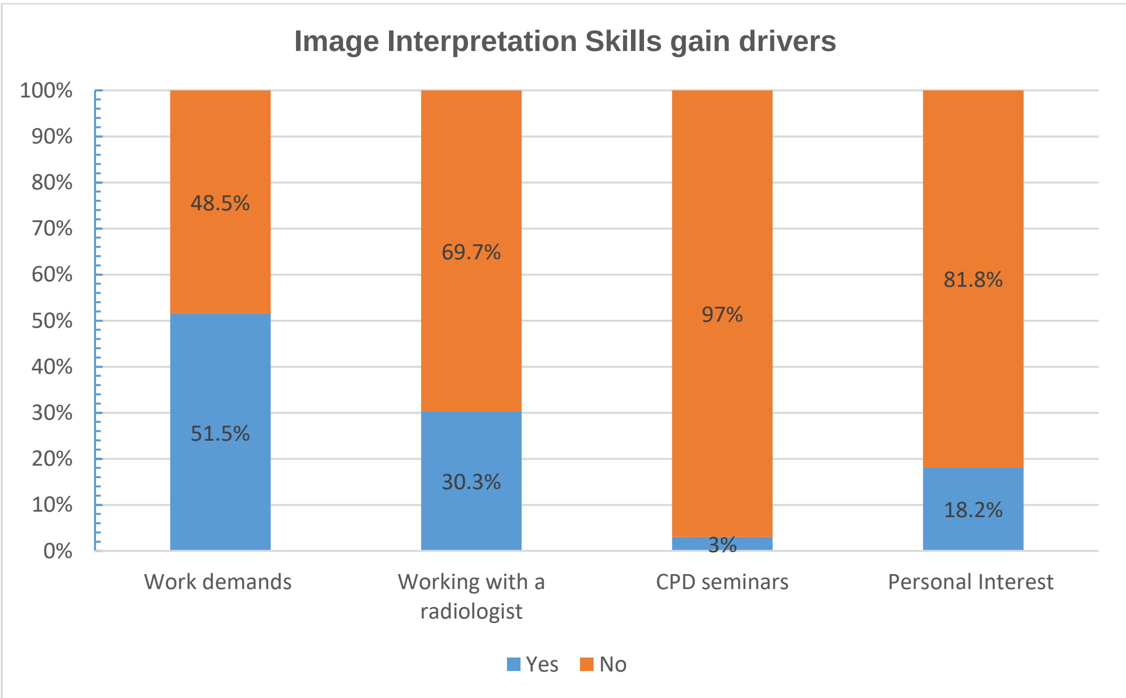

Figure 4.10: Additional post-graduation image interpretation skills gained and their drivers

From Figure 4.10, work demands (51.5%) were the most common driver of additional skills gain indicated by the radiographers.

4.4.1.5. Radiographer knowledge of chest X-ray pathology patterns

The results from the assessment of radiographers' knowledge of chest pathology are shown in Table 4.19.

Table 4.19: Radiographer knowledge of chest x-ray pathology patterns

Chest pathology knowledge statement	Disagree n (%)	Agree n (%)
1. Soft patchy, ill-defined alveolar infiltrates or pulmonary densities indicate pneumonia	17 (51.5%)	**16 (48.5%)**
2. Sharp costophrenic angles on an erect chest radiograph are a sign of pleural effusion	**15 (45.5%)**	18 (54.5%)
3. Patchy areas of consolidation in the lower lobes of the lung indicate aspiration pneumonia	18 (54.5%)	**15 (45.5%)**
4. A small area of consolidation anywhere in a lung — but often in a mid or upper zone with unilateral lymph node enlargement raises the suspicion of primary PTB	16 (48.5%)	**17 (51.5%**)
5. Consolidation with/without cavitation and apical/posterior segments of an upper lobe involvement is typical of secondary TB	20 (60.6%)	**13 (39.4%)**
6. Unilateral lung nodules of varying sizes are typical of lung metastases	**18 (54.5%)**	15 (45.5%)
7. A normal chest radiograph does not completely rule out miliary PTB	16 (48.5%)	**17 (51.5%)**
8. The cardiac shadow size is affected by the difference in the depth of inspiration	21 (63.6%)	**12 (36.4%)**
9. Chest radiograph appearances have a definitive role in the precise assessment of heart chamber enlargement	**18 (54.5%)**	15 (45.5%)
10. When one dome of the diaphragm is depressed, flattened, or inverted, and the mediastinum displaced towards the opposite side coupled with radiolucency of that hemithorax it indicates tension pneumothorax	20 (60.6%)	**13 (39.4%)**
11. The outline of the mediastinum widens in size between middle and old age	13 (39.4%)	**20 (60.6%)**
12. Poor inspiration on a PA chest radiograph can cause hilar bulking and increased lower lung zone opacification	22 (66.7%)	**11 (33.3%)**
13. Consolidation describes the filling of the air spaces of the lung with material other than air, usually, water, pus, or blood	16 (48.5%)	**17 (51.5%)**
14. The side of mediastinal shift can distinguish total lung collapse from large pleural effusion	21 (63.6%)	**12 (36.4%)**
15. Asymmetry in lung density (blackness) may be due to patient rotation.	13 (39.4%)	**20 (60.6%)**

***Bold indicates a correct answer**

The majority of radiographers failed to recognise that the cardiac shadow size is affected by the difference in depth of inspiration (63.6%), that poor inspiration on a posteroanterior (PA) chest radiograph can cause hilar bulking and increased lower lung zone opacification (66.7%), or that the side of mediastinal shift can distinguish total lung collapse from a large pleural effusion (63.6%). Furthermore, 51.5% failed to indicate that soft, patchy, poorly defined alveolar infiltrates or pulmonary densities indicate pneumonia.

4.4.1.6. Radiographer knowledge of common joint pathologies

Radiographers were asked to match the name of the joint pathologies with an explanation of their radiographic appearance as shown in Table 4.20.

Table 4.20: Radiographer knowledge of common joint pathologies

Joint pathology Statement	Possible name of pathology				
	Osteoporosis	**Osteosarcoma**	**Osteoarthritis**	**Rheumatoid arthritis**	**Juvenile chronic arthritis**
Irregular joint space narrowing with small bony spurs	0 (0%)	0 (0%)	**18* (54.5%)**	5 (15.2%)	10 (30.3%)
Soft tissue swelling, with osteoporosis around the joint and metaphysis with possible joint space loss and erosions	4 (12.1%)	1 (3%)	11 (33.3%)	8 (24.2%)	**9 (27.3%)**
Soft tissue swelling (fusiform) around affected joints with joint space narrowing and gross deformity and subluxation	2 (6.1%)	4 (12.1%)	2 (6.1%)	**18 (54.5%)**	7 (21.2%)
Uniform decrease in bone density with a prominence of primary trabeculae and thinning bone cortex	**26 (78.8%)**	0 (0%)	1 (3%)	1 (3%)	5 (15.2%)
A destructive lesion with a 'moth-eaten' appearance1 with streaks of soft tissue calcification known as the 'sunburst' appearance	1 (3%)	**28 (84.8%)**	1 (3%)	1 (3%)	2 (6.1%)

***Bold indicates the correct answer**

More than half of the radiographers were able to identify the correct statement defining osteoarthritis (54.5%), rheumatoid arthritis (54.5%), osteoporosis (78.8%), and osteosarcoma (84.8%). Less than half could identify the definition of juvenile chronic arthritis (27.3%), with the majority confusing it with osteoarthritis (33.3%).

4.4.1.7. Radiographers' knowledge of fracture types

Radiographers were asked to match the names of the fracture types with an explanation of their radiographic appearance as shown in Table 4.21.

Table 4.21: Radiographers' knowledge of fracture types

Fracture knowledge Statement	Possible name of fracture					
	Colles' fracture	**Smith's fracture**	**Monteggia fracture**	**Galeazzi fracture**	**Greenstick fracture**	**Stress fracture**
The ulnar shaft is fractured and there is an associated dislocation of the proximal radius at the elbow.	2 (6.1%)	12 (36.4%)	**13*** **(39.4%)**	4 (12.1%)	1 (3%)	1 (3%)
There is a fracture of the shaft of the radius bone with dorsal displacement of the ulna at the wrist joint	12 (36.4%)	1 (3%)	8 (24.2%)	**9** **(27.3%)**	1 (3%)	2 (6.1%)
There is palmar angulation of the distal radius	7 (21.2%)	**9** **(27.3%)**	1 (3%)	9 (27.3%)	4 (12.1%)	3 (9.1%)
There is a distal radius fracture with dorsal angulation to produce the classic dinner fork deformity	**11** **(33.3%)**	7 (21.2%)	7 (21.2%)	3 (9.1%)	1 (3%)	4 (12.1%)
A thin transverse/oblique radiolucent line or fluffy callus formation without evidence of a fracture line	0 (0%)	3 (9.1%)	2 (6.1%)	4 (12.1%)	10 (30.3%)	**14** **(42.4%)**
A fracture where the cortex is broken on one side and buckled on the other with a bending deformity concave to the buckled side	1 (3%)	1 (3%)	2 (6.1%)	4 (12.1%)	**16** **(48.5%)**	9 (27.3%)

***Bold indicates the correct answer**

A few radiographers were able to identify the correct radiological appearance of the Galeazzi fracture (27.3%), Smith's fracture (27.3%), Monteggia fracture (39.4%), Colle's fracture (33.3%), stress fracture (42.4%), and Greenstick fracture (48.5%). The remainder of the results are shown in Table 4.21.

4.4.1.8. Radiographer knowledge of fracture classification

Radiographers were asked to match the fracture classification with the radiographic appearances as shown in Table 4.22.

Table 4.22: Radiographer knowledge of fracture classification

Fracture classification Statement	Possible fracture classification								
	Complete	**In-complete**	**Displaced**	**Un-displaced**	**Closed**	**Open**	**Dislocated Joint**	**Subluxation**	**Comminuted fracture**
The fractured bone fragments are closely opposed with minimal deformity	1 (3%)	10 (30.3%)	2 (6.1%)	**10 (30.3%)**	2 (6.1%)	1 (3%)	1 (3%)	6 (18.2%)	0 (0%)
No communication between fracture and skin surface	2 (6.1%)	2 (6.1%)	0 (0%)	1 (3%)	**25 (75.8%)**	2 (6.1%)	0 (0%)	1 (3%)	0 (0%)
The portion of the bone cortex remains intact	2 (6.1%)	**12 (36.4%)**	2 (6.1%)	11 (33.3%)	3 (9.1%)	3 (9.1%)	0 (0%)	0 (0%)	0 (0%)
There is a discontinuity between two or more bone fragments	**17 (51,4%)**	3 (9.1%)	7 (21.2%)	1 (3%)	0 (0%)	0 (0%)	2 (6.1%)	1 (3%)	2 (6.1%)
There is space between bone fragments of a fracture causing deformity	6 (18.2%)	3 (9.1%)	**14 (42.4%)**	1 (3%)	0 (0%)	1 (3%)	6 (18.2%)	2 (6.1%)	0 (0%)
A fracture of a long bone resulting in three or more bone fragments	3 (9.1%)	0 (0%)	2 (6.1%)	0 (0%)	1 (3%)	0 (0%)	0 (0%)	2 (6.1%)	**25 (75.8%)**
When the articular surfaces are partly displaced but retain some contact with each other	0 (0%)	2 (6.1%)	1 (3%)	9 (27.3%)	1 (3%)	1 (3%)	3 (9.1%)	**13 (39.4%)**	3 (9.1%)
A wound extends from the skin surface to the fracture	0 (0%)	1 (3%)	0 (0%)	0 (0%)	1 (3%)	**27 (81.8%)**	2 (6.1%)	1 (3%)	1 (3%)
Articular surfaces are wholly displaced so that apposition between them is lost	2 (6.1%)	0 (0%)	5 (15.2%)	0 (0%)	0 (0%)	1 (3%)	**16 (48.5%)**	7 (21.2%)	2 (6.1%)

Most of the radiographers were able to identify the correct statement defining a closed fracture (75.8%), a comminuted fracture (75.8%) and an open fracture (81.8%) (Table 4.22).

4.4.1.9. Radiographer level of knowledge regarding chest abnormalities

The overall knowledge of the radiographers on chest abnormalities was computed by scoring the responses as follows: 1 for an incorrect answer and 2 for a correct answer. These scores were summed up to make the participant's overall score, as informed by previous literature (Ramli et al., 2018; Murad et al., 2016). The scores ranged from a minimum of 15 to a maximum of 30 points. Using a modified median split method, the scores were then categorised into three levels with equal class width as follows: a score of 15–19 = low knowledge level; a score of 20–25 = adequate knowledge level; and a score of 26–30 = high knowledge level (DeCoster et al., 2011; Iacobucci et al., 2015). The results of this analysis are shown in Figure 4.11.

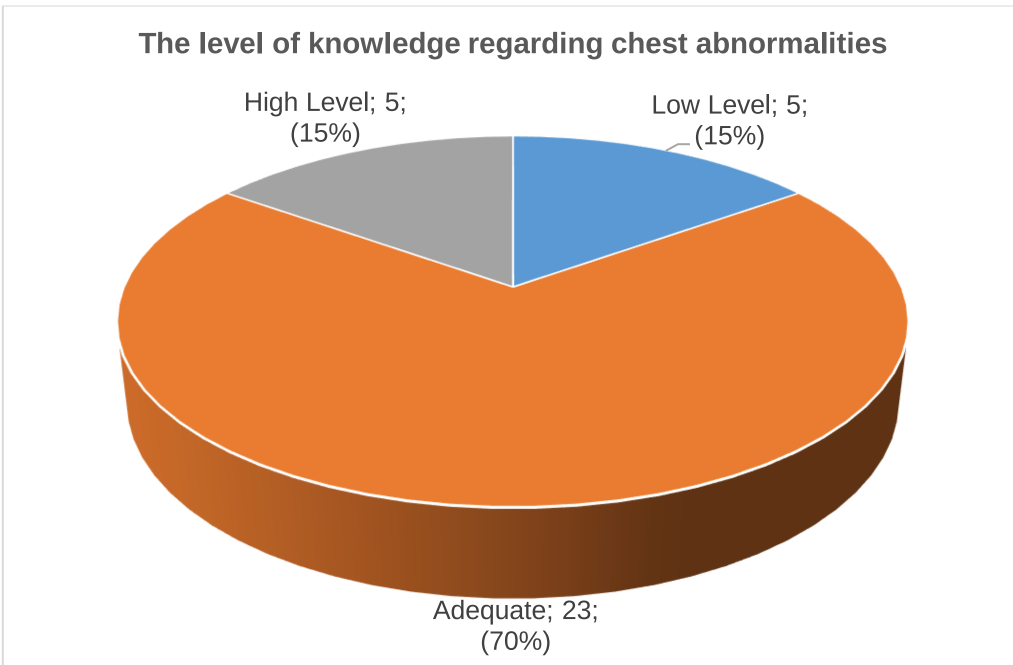

Figure 4.11: Radiographer level of knowledge regarding chest abnormalities

The majority of radiographers (70%) showed an adequate level of knowledge regarding chest abnormalities with 15% showing either a high or low level of knowledge.

4.4.1.10. Radiographer level of knowledge regarding appendicular abnormalities

To compute the level of knowledge regarding appendicular abnormalities, responses given in the three sections (fracture classification, joint pathologies, and fracture types) were combined. Each correct answer was coded with a 2, while all incorrect answers were coded with a 1. The scores were then summed up to make a participant's total score, which ranged from a minimum of 20 to a maximum of 40. The total score was then classified as follows: a score of 20–26 = low knowledge level. A score of 27–33 indicates an adequate knowledge level, and a score of 34–40 indicates a high knowledge level. The results are shown in Figure 4.12.

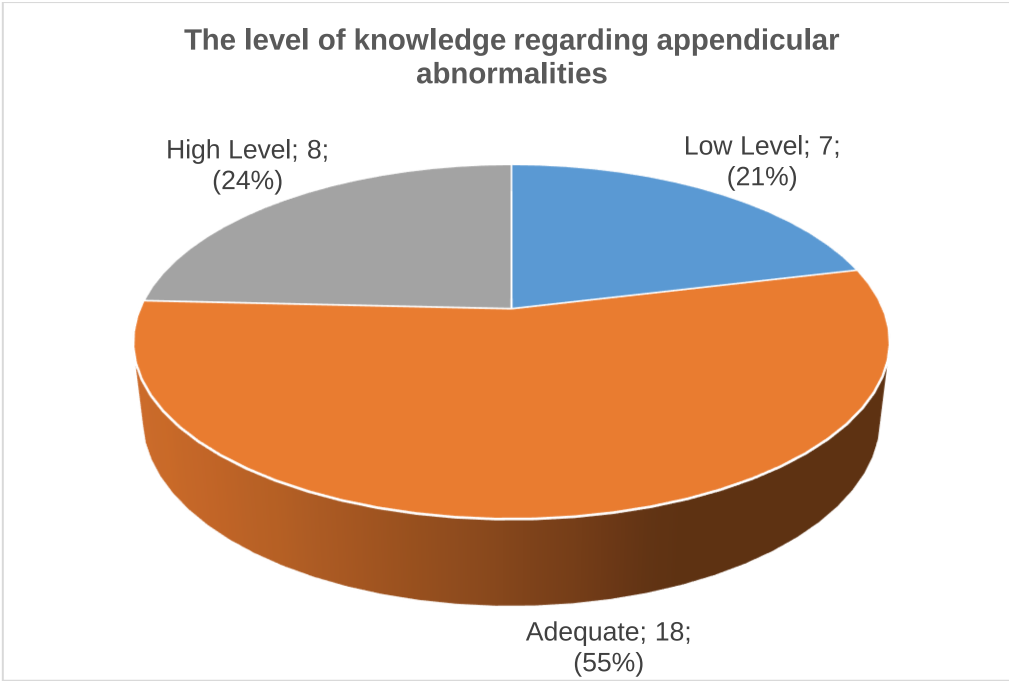

Figure 4.12: Radiographer level of knowledge regarding appendicular abnormalities

A total of 55% of the radiographers demonstrated an adequate level of knowledge of appendicular abnormalities, with 24% exhibiting a high level of knowledge and 21% showing a low level of knowledge.

4.4.1.11. Radiographer's overall knowledge of both chest and appendicular abnormalities.

The computed scores for knowledge of chest abnormalities were added to the appendicular abnormalities knowledge scores to make the overall score for each participant. These scores ranged from a minimum of 35 to a maximum of 70 points. They were further categorised to generate overall knowledge levels as follows: an overall score of 35–46 = low knowledge level; a score of 47–58 = adequate knowledge level; and a score of 59–70 = high knowledge level. Figure 4.13 presents the results.

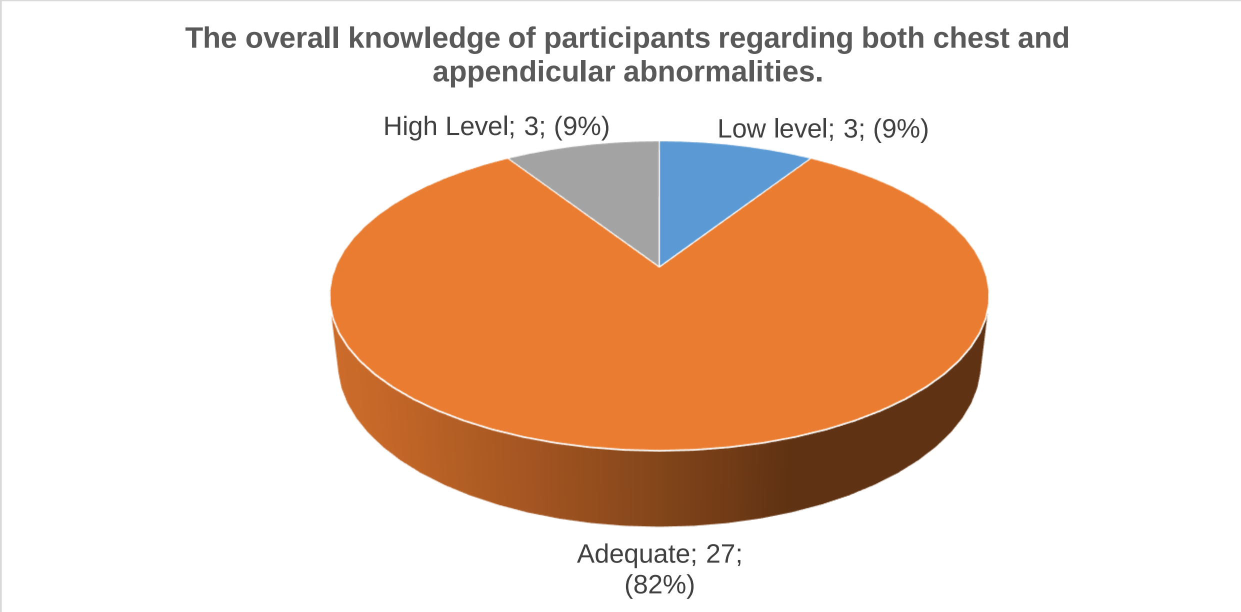

Figure 4.13: Radiographer's overall knowledge of both chest and appendicular abnormalities

Only 9% of the radiographers showed a combined high level of knowledge with the majority (82%) having an adequate level of knowledge.

4.4.1.12. Association between demographic characteristics and knowledge levels

The association between the various demographic characteristics of radiographers and their chest, appendicular, and overall knowledge levels were analysed using the Independent-Samples Kruskal-Wallis Test. The alpha level was set at p=0.05 for all analyses. The results of these analyses are shown in Table 4.23.

Table 4.23: Association between demographic characteristics and knowledge

Demographic characteristic	Chest abnormalities Knowledge Level	Appendicular abnormalities Knowledge level	Overall Knowledge Level
Age	p=0.834	p=0.674	p=0.890
Employment Rank	p=0.863	**p=0.022***	p=0.053
Highest qualification	p=0.634	**p=0.017***	p=0.062
Years of experience	p=0.417	p=0.480	p=0.738
Hospital of appointment	**p=0.001***	p=0.174	p=0.103

*** Further analyses were conducted (see Tables 4.24 to 4.26)**

The age and years of experience of the radiographer did not show any statistically significant association with the three levels of knowledge as shown in Table 4.28. The employment rank (p = 0.022) and highest qualification (p = 0.017) of the radiographers showed a statistically significant association with the level of knowledge of appendicular abnormalities. Furthermore, the hospital of appointment was statistically significantly associated with the level of knowledge of chest abnormalities (p = 0.001).

4.4.1.13. Further analysis of significant Independent-Samples Kruskal-Wallis Test results

When the independent-samples Kruskal-Wallis Test produces a significant result, post-hoc analyses are warranted to understand the group-to-group association. In this study, the pairwise Mann-Whitney U test was conducted as a post-hoc test (the alpha level was set at 0.05). To control for the Family Wise Error Rate (FWER), the Dunn-Bonferroni correction was applied. The results of the post-hoc tests are shown in Tables 4.29–4.31.

Table 4.24: Employment rank vs level of knowledge on appendicular abnormalities

Sample 1-Sample 2	**Test Statistic**	**Std. Error**	**Std. Test Statistic**	**Sig.**	**Dunn-Bonferroni Adj. Sig.**
Chief radiographer-Assistant radiographer	0.300	10.532	0.028	0.977	1.000
Chief radiographer-Junior radiographer	12.214	9.952	1.227	0.220	1.000
Chief radiographer-Senior radiographer	14.654	9.977	1.469	0.142	0.851
Assistant radiographer-Junior radiographer	-11.914	5.009	-2.379	0.017	0.104
Assistant radiographer-Senior radiographer	-14.354	5.059	-2.837	0.005	**0.027**
Junior radiographer-Senior radiographer	-2.440	3.703	-0.659	0.510	1.000

The results show (Table 4.24) that there was a statistically significant difference in appendicular abnormalities knowledge level between the Assistant radiographers and the Senior radiographers (p=0.027) even after applying the Dunn-Bonferroni correction.

Table 4.25: Qualification vs level of knowledge on appendicular abnormalities

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Dunn-Bonferroni Adj. Sig.
Certificate-Diploma	-7.867	7.021	-1.120	0.263	0.788
Certificate-Degree	-13.180	4.710	-2.798	0.005	**0.015**
Diploma-Degree	-5.313	5.875	-0.904	0.366	1.000

A statistically significant difference was observed in the levels of knowledge regarding appendicular abnormalities between radiographers holding a certificate and those with a degree (p=0.015), even after applying the Dunn-Bonferroni correction, as demonstrated in Table 4.25.

Table 4.26: Hospital of employment vs level of knowledge on chest abnormalities

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Dunn-Bonferroni Adj. Sig.
Hospital 1 – Hospital 2	-2.750	4.856	-0.566	0.571	1.000
Hospital 1 – Hospital 3	-14.094	4.581	-3.077	0.002	**0.006**
Hospital 2 – Hospital 3	-11.344	3.748	-3.027	0.002	**0.007**

There was a statistically significant difference in chest abnormalities knowledge levels between radiographers working at Hospital 1 and those at Hospital 3 (p=0.006) and radiographers working at Hospital 2 and those at Hospital 3 (p=0.007).

4.4.2. The competencies of radiographers in interpreting chest and appendicular radiographs

A total of 31 radiographers participated in this study strand, where they reviewed chest and appendicular radiographs for assessment of abnormalities using the what, where, and how methods as suggested by Harcus and Stevens (Harcus & Stevens, 2021). The total expected sample size was 40 radiographers, giving a response rate of 78%. The results will be presented as follows: demographic data, univariate analysis of responses per each radiograph, assessment of accuracy per each radiograph and in total, as well as sensitivity measures per region.

4.4.2.1. Demographic characteristics of the radiographers

The demographic characteristics of the radiographers are presented in Table 4.27.

Table 4.27: Demographic characteristics of the radiographers

Demographic characteristics		***Frequency n (%)***
Gender	Male	8 (25.8%)
	Female	23 (74.2%)
Age	21-25 years	6 (19.4%)
	26-30 years	12 (38.7%)
	31-35 years	8 (25.8%)
	36-40 years	3 (9.7%)
	41 and above	3 (6.5%)
Highest qualification	Certificate	3 (9.7%)
	Diploma	5 (12.9%)
	Degree	24 (77.4%)
Employment rank	Assistant radiographer	3 (9.7%)
	Junior radiographer	10 (32.3%)
	Senior radiographer	18 (58.1%)
Years of experience	0-5 years	17 (54.8%)
	6-10 years	8 (25.8%)
	11 and above	6 (19.4%)
Hospital of appointment	WCH	8 (25.8%)
	KIH	11 (35.5%)
	OIH	12 (38.7%)
Area of specialisation	CT	15 (48.4%)
	Not any	15 (48.4%)
	Interventional	1 (3.2%)
Primary daily role	General	20 (64.5%)
	CT	5 (16.1%)
	CT and General	5 (16.1%)
	Interventional	1 (3.2%)

The results in Table 4.27 showed that 74.2% were females; 38.7% were aged between 26 and 30 years; 77.4% had a degree; 58.1% were employed as senior radiographers and 64.5% worked primarily in general radiography.

4.4.2.2. Identification of chest image abnormalities

For each chest radiograph, the radiographers were asked to indicate whether the radiograph exhibited an abnormality or not, and to provide their confidence level in their response. The results are presented in Table 4.28.

Table 4.28: Identification of chest pathology and the radiographer's confidence

Image No.	Presence of Image abnormality	Level of confidence in the identification of chest abnormalities			
		No Conf*	Minimal Conf*	Mod Conf*	High Conf*
Chest 1	Yes (100%)	0(0.0%)	2 (6.5%)	9 (29.0%)	20 (64.5%)
Chest 2	Yes (100%)	1 (3.2%)	3 (9.7%)	5 (16.1%)	22 (71.0%)
Chest 3	Yes (93.5%)	0 (0.0%)	5(17.2%)	7 (24.1%)	17 (58.6%)
	No (6.5%)	0 (0.0%)	1 (50.0%)	0 (0.0%)	1 (50.0%)
Chest 4	Yes (100%)	3 (9.7%)	2 (6.5%)	12 (38.7%)	14 (45.2%)
Chest 5	Yes (100%)	0 (0.0%)	3 (9.7%)	5 (16.1%)	23 (74.2%)
Chest 6	Yes (100%)	0 (0.0%)	2 (6.5%)	6 (19.4%)	23 (74.2%)
Chest 7	Yes (100%)	0 (0.0%)	2 (6.5%)	2 (6.5%)	27 (87.1%)
Chest 8	Yes (100%)	0 (0.0%)	4 (12.9%)	5 (16.1%)	22 (71.0%)
Chest 9	Yes (100%)	0 (0.0%)	2 (6.5%)	6 (19.4%)	23 (74.2%)
Chest 10	No (100%)	1 (3.2%)	1 (3.2%)	12 (38.7%)	17 (54.8%)

Conf* = Confidence

More than 70% of the radiographers had high confidence in the presence of abnormalities in six of the chest images. However, only 54.8% had high confidence in the absence of abnormalities in image number 10.

4.4.2.3. Image interpretation of chest abnormalities present on the radiographs

Radiographers were requested to evaluate 10 chest radiographs and identify the name of the abnormality, its location, and its presentation. The accurate and anticipated responses are provided in Appendix O. Tables 4.29 to 4.38 display the outcomes for each radiograph concerning these three aspects.

Table 4.29: Interpretation of chest image 1 elements

The element assessed	**Participant's Response**	**Number of participants**	**(%)**
Name of the abnormality **(WHAT)**	Pneumonia	22	71.0
	Lung consolidation	5	16.1
	Lung Mass	2	6.5
	Lung Nodules	1	3.2
	Not Sure	1	3.2
Location of the abnormality **(WHERE)**	Right lower lobe	30	96.8
	Both Lungs	1	3.2
Presentation of the abnormality **(HOW)**	White patchy area	10	32.3
	Radiopaque area on RLL	11	35.5
	Loss of density on RLL	4	12.9
	Slight consolidation	4	12.9
	Not sure	2	6.5

The majority of the radiographers identified the abnormality as pneumonia (71%) in the right lower lobe (96.8%). Only 35.5% indicated the presentation as a radiopaque area on the right lower lobe, while 32.3% highlighted it as a white patchy area.

Table 4.30: Interpretation of chest image 2 elements

The element assessed	**Participant's Response**	**Number of participants**	**(%)**
Name of the abnormality **(WHAT)**	Pleural effusion	27	87.1
	Pneumothorax	3	9.7
	Pneumoperitoneum	1	3.2
Location of the abnormality **(WHERE)**	Right lower lobe	27	87.1
	Right lung	1	3.2
	Left Lower Lung	3	9.7
Presentation of the abnormality **(HOW)**	Blunted costophrenic angle	23	74.2
	Blunted costophrenic and cardio phrenic angles	5	16.1
	Not sure	2	6.5
	Radiopaque air below the right diaphragm	1	3.2

Most radiographers indicated the abnormality as pleural effusion (87.1%) in the right lower lobe (87.1%) showing a blunted costophrenic angle (74.2%).

Table 4.31: Interpretation of chest Image 3 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Pneumothorax	26	83.9
	Normal	2	6.5
	Collapsed lung	2	6.5
	Not sure	1	3.2
Location of the abnormality **(WHERE)**	Entire Left lung	13	41.9
	Normal	2	6.5
	Right lung	15	48.4
	Nor Sure	1	3.2
Presentation of the abnormality **(HOW)**	Absence of lung markings	20	64.5
	Normal	2	6.5
	Air in the oblique fissure	1	3.2
	Air in the pleural cavity	7	22.6
	Not Sure	1	3.2

The majority of radiographers identified the radiograph as having a pneumothorax (83.9%) due to the absence of lung markings (64.5%) whilst 6.5% indicated it as normal.

Table 4.32: Interpretation of chest Image 4 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Congested Cardiac Failure	2	6.5
	Mass	9	29.0
	Not sure	4	12.9
	Lymphoma	1	3.2
	Pneumonia	4	12.9
	Aortic aneurysm	6	19.4
	Respiratory tract infection	1	3.2
	Pneumothorax	1	3.2
	COPD	1	3.2
	Emphysema	2	6.5
Location of the abnormality **(WHERE)**	Mediastinum	13	41.9
	Not sure	3	9.7
	Right upper lobe	4	12.9
	Aortic arch and hilar	6	19.4
	Both lungs	4	12.9
	Below right diaphragm	1	3.2
Presentation of the abnormality **(HOW)**	Loss of cardiac Silhouette	2	6.5
	Mass in the mediastinal area	7	22.6
	Not sure	4	12.9
	Enlarged aortic arch	8	25.8
	Consolidation on RUL	1	3.2
	Prominent lung markings	1	3.2
	Mediastinal shift	6	19.4
	Flattened diaphragms	2	6.5

Twenty-nine percent (29%) of the radiographers indicated the abnormality as a mass in the mediastinum (41.9%) appearing as an enlarged aortic arch (25.8%).

Table 4.33: Interpretation of chest image 5 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Pneumoperitoneum	23	74.2
	Not sure	1	3.2
	Pneumothorax	3	9.7
	Haemothorax	2	6.5
	Peritonitis	2	6.5
Location of the abnormality **(WHERE)**	Bilateral peritoneal space	31	100.0
Presentation of the abnormality **(HOW)**	Gas under the diaphragm	25	80.6
	Dolphin sign	1	3.2
	Radiolucent layer below the diaphragm	5	16.1

Most radiographers (74.2%) indicated pneumoperitoneum as the abnormality in both lungs (100%) and showing as a gas under the diaphragm (80.6%).

Table 4.34: Interpretation of chest image 6 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Pleural effusion	25	80.6
	Consolidation	1	3.2
	Lung inflammation	1	3.2
	Atelectasis	2	6.5
	Hemithorax	2	6.5
Location of the abnormality **(WHERE)**	Right lung	31	100.0
Presentation of the abnormality **(HOW)**	Blunted costophrenic and cardio phrenic angles	18	58.1
	collapsed right lower lobe	3	9.7
	Opacification of the RLL	7	22.6
	Consolidation in the RL	2	6.5
	Not sure	1	3.2

All radiographers stated that the abnormality was in the right lung (100%) with over half showing knowledge of blunted cost phrenic and cardio phrenic angles (58.1%). Most indicated the abnormality as pleural effusion (80.6%).

Table 4.35: Interpretation of chest image 7 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Miliary TB	30	96.8
	Pneumonia	1	3.2
Location of the abnormality **(WHERE)**	Entire left and right lungs	31	100.0
Presentation of the abnormality **(HOW)**	Multiple small nodules	20	64.5
	Patchy infiltrates on both lungs	10	32.3
	Uniform size nodules	1	3.2

Most radiographers identified the abnormality as Miliary TB (96.8%) in both lungs (100%). The majority (64.5%) identified the appearance as multiple small nodules with others (32.3%) stating it as patchy infiltrates on both lungs.

Table 4.36: Interpretation of chest image 8 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Tuberculosis	15	48.4
	Pneumonia	6	19.4
	Consolidation	9	29.0
	Lung Mass	1	3.2
Location of the abnormality **(WHERE)**	Left Upper lobe	29	93.5
	Right side cavity lesion	1	3.2
	Right upper lobe	1	3.2
Presentation of the abnormality **(HOW)**	Consolidation and white patches	14	45.2
	Opacities on Left upper lobe	13	41.9
	Lung scarring on Left upper lobe	3	9.7
	Not sure	1	3.2

A total of 48.4% of the radiographers indicated TB as an abnormality on the radiograph on the left upper lobe (93.5%) and appeared as consolidation and white patches (45.2%) or opacities on the left upper lung (41.9%).

Table 4.37: Interpretation of chest image 9 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Cardiomegaly	26	83.9
	CCF	4	12.9
	Pericardial Effusion	1	3.2
Location of the abnormality **(WHERE)**	Heart	31	100.0
Presentation of the abnormality **(HOW)**	Enlarged cardiac shadow	31	100.0

All radiographers (100%) indicated that the abnormality was in the heart and showed an enlarged cardiac shadow. The majority identified this as cardiomegaly (83.9%) while others identified it as congested cardiac failure (CCF) (12.9%) and pericardial effusion (3.2%).

Table 4.38: Interpretation of chest image 10 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Normal	31	100.0
Location of the abnormality **(WHERE)**	Normal	31	100.0
Presentation of the abnormality **(HOW)**	Normal	31	100.0

All radiographers (100%) identified the radiograph as a normal image.

4.4.2.4. Identification of appendicular image abnormalities

For each appendicular radiograph, the radiographers were asked to indicate whether the image had an abnormality or not and their level of confidence in their answer. The results are shown in Table 4.39.

Table 4.39: Identification of appendicular abnormality and the radiographer's confidence level

Image No.	Presence of Image Abnormality	Level of confidence in identification of appendicular abnormality			
		No Conf*	Minimal Conf*	Mod Conf*	High Conf*
App 1	Yes (100%)	2 (6.5%)	0 (0.0%)	1 (3.2%)	28 (90.3%)
App 2	Yes (100%)	0 (0.0%)	1 (3.2%)	3 (9.7%)	27 (87.1%)
App 3	Yes (93.5%)	1 (3.4%)	1 (3.4%)	2 (6.9%)	25 (86.2%)
	No (6.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (100.0%)
App 4	Yes (100%)	1 (3.2%)	0 (0.0%)	2 (6.5%)	28 90.3(%)
App 5	Yes (100%)	0 (0.0%)	1 (3.2%)	1 (3.2%)	29 (93.5%)
App 6	Yes (100%)	1 (3.2%)	1 (3.2%)	3 (9.7%)	26 (83.9%)
App 7	Yes (71%)	2 (9.1%)	3 (13.6%)	9 (40.9%)	8 (36.4%)
	No (29%)	0 (0.0%)	2 (22.2%)	6 (22.2%)	5 (55.6%)
App 8	Yes (80.6%)	0 (0.0%)	2 (8.0%)	5 (20.0%)	18 (72.0%)
	No (19.4%)	0 (0.0%)	2 (33.3%)	0 (0.0%)	4 (66.7%)
App 9	Yes (100%)	0 (0.0%)	2 (6.5%)	2 (6.5%)	27 (87.1%)
App 10	No (100%)	0 (0.0%)	1 (3.2%)	11 (35.5%)	19 (61.3%)

Conf* = Confidence

Most of the radiographers indicated high confidence (above 70%) in the presence of pathologies on eight of the appendicular images. However, only 36.4% had high confidence regarding the presence of abnormality in image number seven.

4.4.2.5. Image interpretation of appendicular abnormalities on the radiographs

Radiographers were asked to assess 10 appendicular radiographs and indicate the name of the abnormality, where it was located, and how it was presenting. The accurate and anticipated responses are provided in Appendix P. Tables 4.40 to 4.49 indicate the results per each of the radiographs for the three aspects.

Table 4.40: Interpretation of appendicular image 1 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Colle's fracture	9	29.0
	Smith's Fracture	3	9.7
	Proximal radius fracture	1	3.2
	Radius fracture	11	35.5
	Wrist Fracture	7	22.6
Location of the abnormality **(WHERE)**	Fracture distal radius	16	51.6
	Fracture radial head	11	35.5
	Fracture distal ulna	1	3.2
	Fracture proximal radius	3	9.7
Presentation of the abnormality **(HOW)**	Dinner fork appearance	12	38.7
	Transverse fracture on the radius	2	6.5
	Fractures of both the radius and ulnar	1	3.2
	Fracture of the ulna	1	3.2
	Displaced radial fracture	15	48.4

A total of 15 (48.4%) of the radiographers indicated the abnormality as a displaced fracture, while 12 (38.7%) highlighted it as a dinner fork appearance. On the location, 16 (51.6%) indicated the distal radius. The abnormality was identified as just a radius fracture (35.5%), while others identified it as Colle's fracture (29.0%) and wrist fracture (22.6%).

Table 4.41: Interpretation of appendicular image 2 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Fracture	31	100.0
Location of the abnormality **(WHERE)**	Mid-clavicle	31	100.0
Presentation of the abnormality **(HOW)**	A complete fracture with Moderate displacement	30	96.8
	Not sure	1	3.2

All radiographers (100%) indicated that the radiograph had a mid-clavicular fracture.

Table 4.42: Interpretation of appendicular image 3 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Monteggia fracture	7	22.6
	Fracture	5	16.1
	Fracture of Ulna	19	61.3
Location of the abnormality **(WHERE)**	Mid-ulnar bone	27	87.1
	Proximal ulna fracture with radial head dislocation	3	9.7
	Mid radial shaft	1	3.2
Presentation of the abnormality **(HOW)**	Severe displacement with radial head dislocation	13	41.9
	Transverse fracture	6	19.4
	Complete mid-shaft fracture of the ulna	12	38.7

A mid-ulna fracture (87.1%) with severe displacement (41.9%) was identified as an abnormality on the radiograph by most of the radiographers.

Table 4.43: Interpretation of appendicular image 4 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Fracture	10	32.3
	The neck of the femur fracture	11	35.5
	Right Hip fracture	8	25.8
	Intra-trochanter fracture	1	3.2
	Fracture femur	1	3.2
Location of the abnormality **(WHERE)**	Neck of femur	15	48.4
	Femoral head	5	16.1
	Right Hip	11	35.5
Presentation of the abnormality **(HOW)**	Mild displacement	10	32.3
	not sure	2	6.5
	Nondisplaced fracture	13	41.9
	Reduced fracture of the femoral head	6	19.4

A fractured neck of the femur (48.4%) with no displacement (41.9%) was indicated as an abnormality by a higher proportion of radiographers.

Table 4.44: Interpretation of appendicular image 5 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Oblique fracture	3	9.7
	Lateral malleoli fracture	11	35.5
	fracture	3	9.7
	Ankle fracture	4	12.9
	Distal fibula	10	32.3
Location of the abnormality **(WHERE)**	Distal fibula	19	61.3
	lateral malleolus	10	32.3
	Distal tibia	1	3.2
	Ankle	1	3.2
Presentation of the abnormality **(HOW)**	Fracture with no displacement	17	54.8
	Not sure	1	3.2
	linear fracture	1	3.2
	Oblique fracture	12	38.7

About 35.5% of the radiographers, identified the abnormality as a lateral malleoli fracture (35.5%) with no displacement (54.8%). Most radiographers also indicated the location of the fracture as the distal fibula (61.3%).

Table 4.45: Interpretation of appendicular image 6 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Stress fracture	2	6.5
	Fracture	6	19.4
	Mid ulna fracture	4	12.9
	Fracture of the radius	8	25.8
	Fracture proximal ulna	5	16.1
	Greenstick fracture	6	19.4
Location of the abnormality **(WHERE)**	Radius bone	11	35.5
	Ulnar bone	13	41.9
	Proximal fibula	1	3.2
	proximal radius	3	9.7
	Proximal ulna	3	9.7
Presentation of the abnormality **(HOW)**	Fracture with no displacement	17	54.8
	Incomplete fracture	14	45.2

A greater proportion of the radiographers indicated that there was a fracture on the ulna bone (41.9%) with no displacement (54.8%) or showing an incomplete fracture (45.2%). Others indicated the radius bone as the location of the fracture (35.5%).

Table 4.46: Interpretation of appendicular image 7 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Normal Knee joint	9	29.0
	Fracture	1	3.2
	Patella Dislocation	15	48.4
	Knee joint effusion	2	6.5
	Femoral condyle deformity	4	12.9
Location of the abnormality **(WHERE)**	Normal Knee joint	7	22.6
	Displaced patella	9	29.0
	Around the knee joint and patella	9	29.0
	Distal femur	6	19.4
Presentation of the abnormality **(HOW)**	Normal Knee joint	10	32.3
	Displaced patella	15	48.4
	A hyper-dense area around the joint	2	6.5
	Not sure	2	6.5
	Condyle deformity	2	6.5

Patella dislocation (48.4%) showing as a displaced patella (29%) was indicated as the abnormality of the radiograph by the radiographers among other responses.

Table 4.47: Interpretation of appendicular image 8 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Fracture	26	83.9
	Not sure	2	6.5
	Normal	2	6.5
	Arthritis	1	3.2
Location of the abnormality **(WHERE)**	Fifth metacarpal	28	90.3
	Normal	3	9.7
Presentation of the abnormality **(HOW)**	Fracture with no displacement	14	45.2
	Oblique fracture	9	29.0
	Boxer's fracture	3	9.7
	Not sure	2	6.5
	Normal	2	6.5
	Arthritis onset	1	3.2

Most of the radiographers indicated that there was a fracture (83.9%) on the radiograph on the fifth metacarpal (90.3%).

Table 4.48: Interpretation of appendicular image 9 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Osteomyelitis	23	74.2
	Osteoporosis	5	16.1
	Osteosarcoma	1	3.2
	Healing fracture	2	6.5
Location of the abnormality **(WHERE)**	Distal tibia bone	27	87.1
	On the whole bone	2	6.5
	Fibula	2	6.5
Presentation of the abnormality **(HOW)**	Severe bone demineralisation	10	32.3
	Loss of bone trabecula and cortex density	15	48.4
	Degenerative bone disease	2	6.5
	Softening and inflammation of the bone	4	12.9

The majority of radiographers identified the abnormality on the radiograph as osteomyelitis (74.2%) on the distal tibia bone (87.1%).

Table 4.49: Interpretation of appendicular image 10 elements

The element assessed	Participant's Response	Number of participants	(%)
Name of the abnormality **(WHAT)**	Normal foot	31	100.0
Location of the abnormality **(WHERE)**	Normal foot	31	100.0
Presentation of the abnormality **(HOW)**	Normal foot	31	100.0

All radiographers (100%) identified the image as a normal radiograph.

4.4.2.6. Abnormality detection ability and confidence levels of radiographers

The ability of the radiographers to identify the presence of an abnormality on the radiograph (similar to red dotting) was assessed by their accuracy and sensitivity for the chest, appendicular, and overall. The results are shown in Figure 4.14 using the minimum, mean, and maximum of each measure.

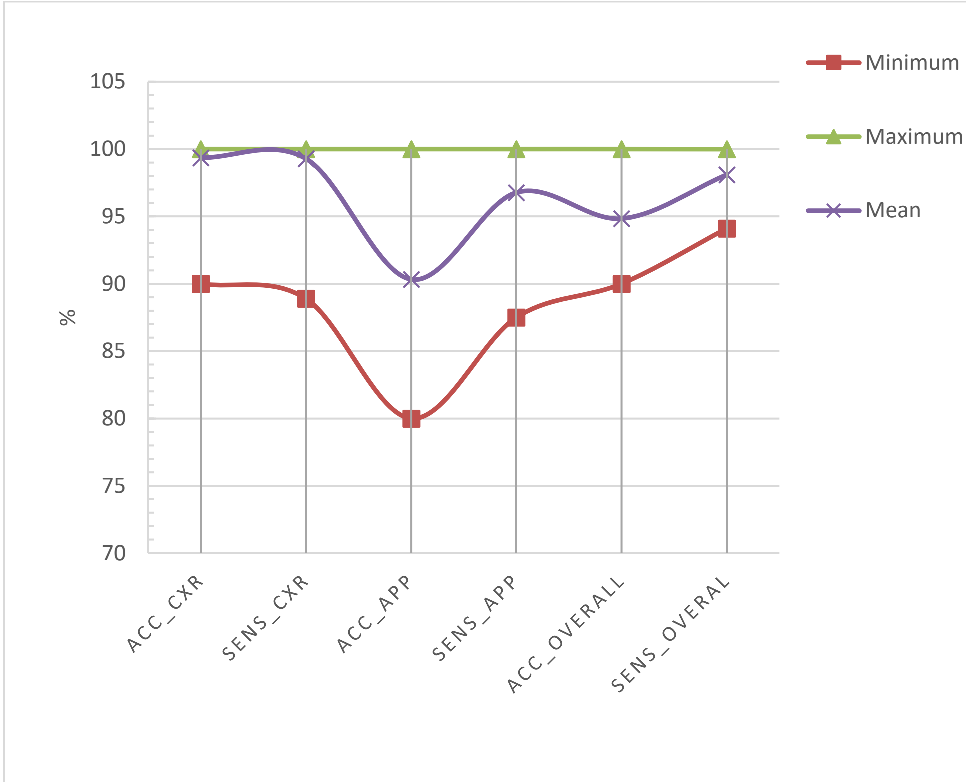

Figure 4.14: Red-dotting ability of the radiographers

The mean abnormality detection accuracy and sensitivity were very high at 99.35% and 99.28% for the chest images while for the appendicular images, it was 90.32% and 96.77% respectively. Overall, the accuracy was 94.83% and the sensitivity was 98.09%. The overall abnormality detection confidence levels are shown in Figure 15 below.

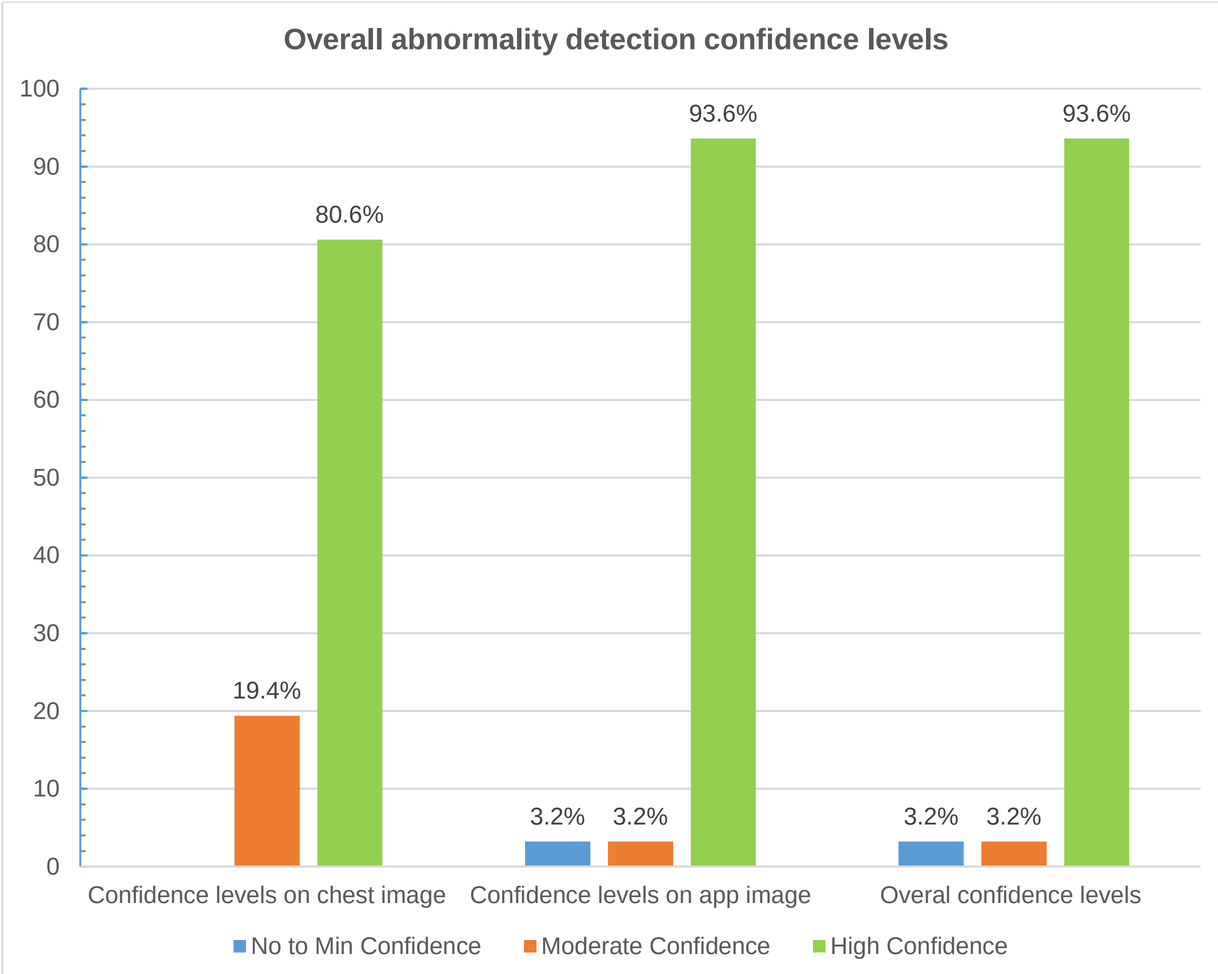

Figure 4.15: The overall abnormality detection confidence level

The majority of the radiographers showed a high confidence level in their abnormality detection ability for the chest (80.6%) and appendicular (93.6%) images. Overall, 93.6% perceived their abnormality detection confidence to be high for both chest and appendicular images.

4.4.2.7. Name of the chest abnormality and the confidence levels of radiographers

The name of the chest abnormality given by the radiographer was classified as correct (for primary abnormality and its differential diagnosis) and incorrect (where no link to image findings was present) and summarised with the confidence levels per radiograph as shown in Table 4.50.

Table 4.50: Name of the chest abnormality and the confidence levels

Image No.	Image Abnormality		Level of confidence on the name of the chest abnormality			
			No Conf*	Slight Conf*	Mod Conf*	High Conf*
Chest 1	Incorrect	4 (12.9%)	1 (25.0%)	1 (25.0%)	2 (50.0%)	0 (0.0%)
	Correct	27 (87.1%)	1 (3.7%)	7 (25.9%)	10 (37.0%)	9 (33.3%)
Chest 2	Incorrect	4 (12.9%)	1 (25.0%)	1 (25.0%)	2 (50.0%)	0 (0.0%)
	Correct	27 (87.1%)	2 (7.4%)	7 (25.9%)	6 (22.2%)	12 (44.4%)
Chest 3	Incorrect	5 (16.1%)	2 (40.0%)	1 (20.0%)	2 (40.0%)	0 (0.0%)
	Correct	26 (83.9%)	0 (0.0%)	5 (19.2%)	10 (38.5%)	11 (42.3%)
Chest 4	Incorrect	19 (61.3%)	5 (26.3%)	3 (15.8%)	8 (42.1%)	3 (15.8%)
	Correct	12 (38.7%)	2 (16.7%)	5 (41.7%)	5 (41.7%)	0 0.0(%)
Chest 5	Incorrect	8 (25.8%)	0 (0.0%)	2 (25.0%)	6 (75.0%)	0 (0.0%)
	Correct	23 (74.2%)	1 (4.3%)	3 (13.0%)	6 (26.1%)	13 (56.5%)
Chest 6	Incorrect	6 (19.4%)	1 (16.7%)	1 (16.7%)	3 (50.0%)	1 (16.7%)
	Correct	25 (80.6%)	2 (8.0%)	2 (8.0%)	2 (8.0%)	19 (76.0%)
Chest 7	Incorrect	1 (3.2%)	0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)
	Correct	30 (96.8%)	0 (0.0%)	4 (13.3%)	6 (20.0%)	20 (66.7%)
Chest 8	Incorrect	7 (22.6%)	2 (28.6%)	2 (28.6%)	2 (28.6%)	1 (14.3%)
	Correct	24 (77.4%)	2 (8.3%)	5 (20.8%)	8 (33.3%)	9 (37.5%)
Chest 9	Incorrect	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Correct	31 (100%)	1 (3.2%)	7 (22.6%)	10 (32.3%)	13 (41.9%)
Chest 10	Incorrect	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Correct	31 (100%)	1 (3.2%)	1 (3.2%)	11 (35.5%)	18 (58.1%)

The majority of the radiographers who correctly identified the abnormality, as compared to the radiologist's report, had moderate to high confidence in the name of the abnormality they identified. However, only 9 (33.3%) of those who correctly identified the abnormality on image number 1 did so with high confidence. For the normal image number 10, 58.1% of the radiographers had high confidence in their correct answer.

4.4.2.8. Name of the appendicular abnormality and the confidence levels of radiographers

The name of the appendicular abnormality given by the radiographer was classified as correct (for primary abnormality and its differential diagnosis) and incorrect (where no link to image findings was present) and summarised with the confidence levels per image as shown in Table 4.51.

Table 4.51: Name of the appendicular abnormality and the confidence level

Image No.	Image Abnormality		Level of confidence on name of appendicular abnormality			
			No Conf*	Slight Conf*	Mod Conf*	High Conf*
App 1	Incorrect	4 (12.9%)	1 (25.0%)	2 (50.0%)	1 (25.0%)	0 (0.0%)
	Correct	27 (87.1%)	2 (7.4%)	0 (0.0%)	4 (14.8%)	21 (77.8%)
App 2	Incorrect	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Correct	31 (100%)	0 (0.0%)	1 (3.2%)	4 (12.9%)	26 (83.9%)
App 3	Incorrect	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Correct	31 (100%)	1 (3.2%)	2 (6.5%)	5 (16.1%)	23 (74.2%)
App 4	Incorrect	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Correct	31 (100%)	0 (0.0%)	4 (12.9%)	3 (9.7%)	24 (77.4%)
App 5	Incorrect	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Correct	31 (100%)	0 (0.0%)	4 (12.9%)	4 (12.9%)	23 (74.2%)
App 6	Incorrect	15 (58.4%)	0 (0.0%)	1 (6.7%)	4 (26.7%)	10 (66.7%)
	Correct	16 (51.6%)	0 (0.0%)	3 (18.8%)	2 (12.5%)	11 (68.8%)
App 7	Incorrect	22 (71.0%)	0 (0.0%)	7 (31.8%)	10 (45.5%)	5 (22.7%)
	Correct	9 (28.0%)	0 (0.0%)	2 (22.2%)	2 (22.2%)	5 (55.6%)
App 8	Incorrect	5 (16.1%)	0 (0.0%)	0 (0.0%)	2 (40.0%)	3 (60.0%)
	Correct	26 (83.9%)	0 (0.0%)	3 (11.5%)	8 (30.8%)	15 (57.7%)
App 9	Incorrect	8 (25.8%)	2 (25.0%)	1 (12.5%)	3 (37.5%)	2 (25.0%)
	Correct	23 (74.3%)	1 (4.3%)	1 (4.3%)	7 (30.4%)	14 (60.9%)
App 10	Incorrect	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Correct	31 (100%)	1 (3.2%)	4 (12.9%)	8 (25.8%)	18 (58.1%)

The majority (71%) of radiographers incorrectly identified the abnormality on radiograph number 7 which was a normal knee image, and they did so with a slight (31.8%) and moderate (45.5%) confidence. The overall abnormality naming confidence levels are shown in Figure 4.16 below.

4.4.2.9 Confidence levels of radiographers in naming the image abnormality

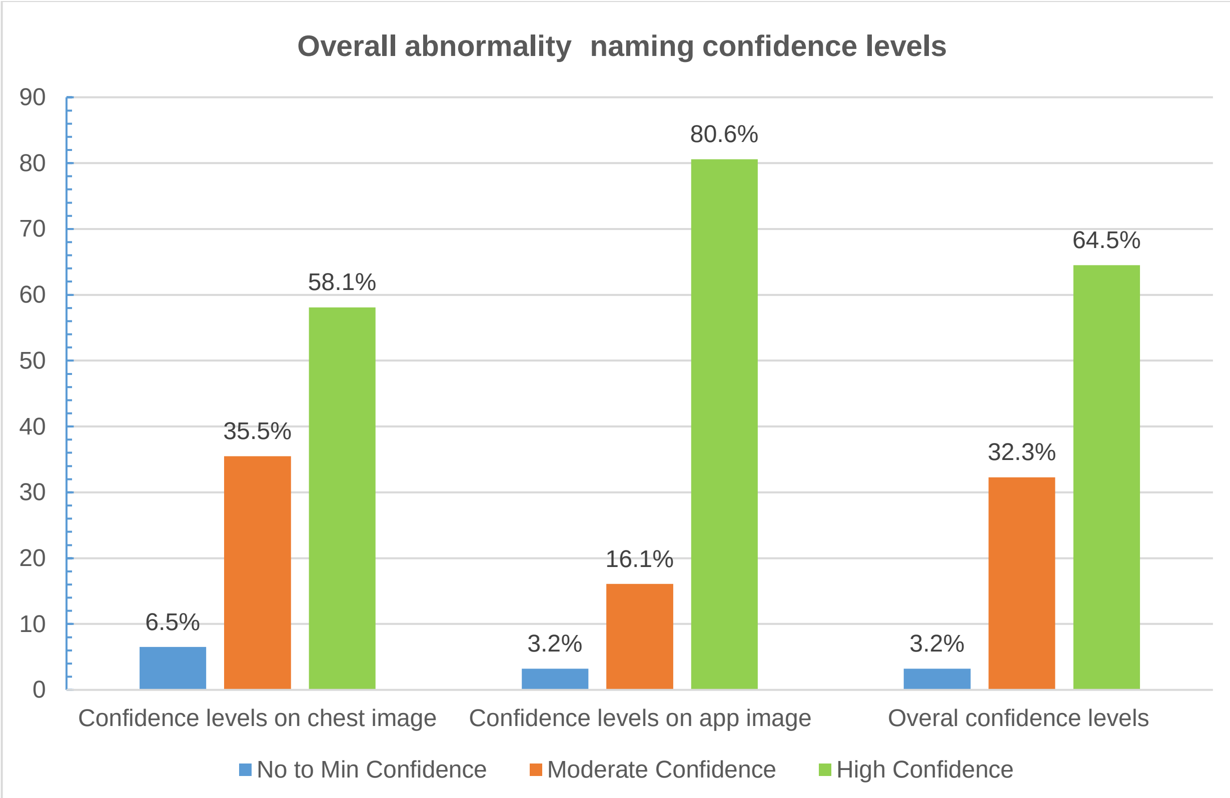

Figure 4.16: Abnormality naming confidence level of radiographers

More radiographers showed a high confidence level in naming the abnormality on appendicular images compared to the chest image (80.6% vs 58.1%) with 64.5% showing a high confidence level for both.

4.4.2.10 Combined confidence levels of radiographers

The combined confidence levels were calculated for abnormality detection and abnormality naming for the chest, appendicular and both images. The results are presented in the figure below.

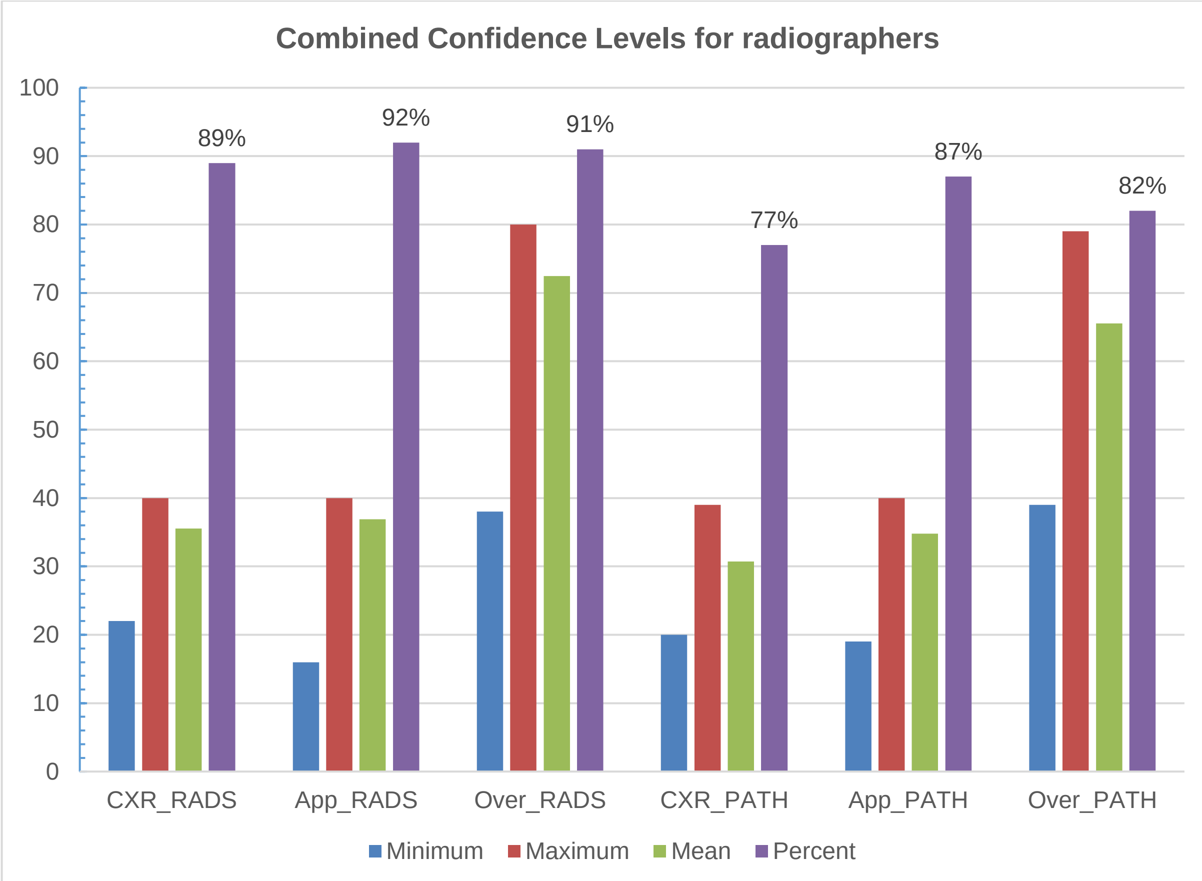

Figure 4.17: Combined Confidence Levels of radiographers

The radiographers showed high mean confidence levels for abnormality detection in the chest (89%), appendicular (92%), and combined (91%). The mean confidence levels on the naming of abnormalities were 77% for chest, 87% for appendicular, and 82% for combined images. Further analysis with Kruskal-Wallis showed that there was a significant difference in abnormality detection confidence level between those with certificates and those with diplomas ($p = 0.028$), between those working as assistant radiographers and those working as senior radiographers ($p = 0.033$). Those working as junior radiographers and those working as senior radiographers showed a significant difference in abnormality naming ($p = 0.032$).

4.4.2.11. Accuracy of anatomy identified on the images

The ability of the radiographers to identify the anatomy with the abnormality on the images was further assessed and presented as accuracy for chest and appendicular images as shown in the table below.

Table 4.52: Accuracy of anatomy identified on the images

		Image number									
		1 (%)	**2 (%)**	**3 (%)**	**4 (%)**	**5 (%)**	**6 (%)**	**7 (%)**	**8 (%)**	**9 (%)**	**10 (%)**
Chest anatomy identified	Correct	96.8	90.3	48.4	61.3	100	100	100	6.5	100	100
	Incorrect	3.2	9.7	51.6	38.7	0.0	0.0	0.0	93.5	0.0	0.0
Appendicular Anatomy identified	Correct	51.6	100	9.7	64.5	96.8	45.2	22.6	90.3	87.1	100
	Incorrect	48.4	0.0	90.3	35.5	3.2	54.8	77.4	9.7	12.9	0.0

The ability to identify the chest anatomy of interest ranged from 6.5% to 100% while for appendicular anatomy, it ranged from 9.7% to 100%. The performance across the ten images is shown in Figure 4.18.

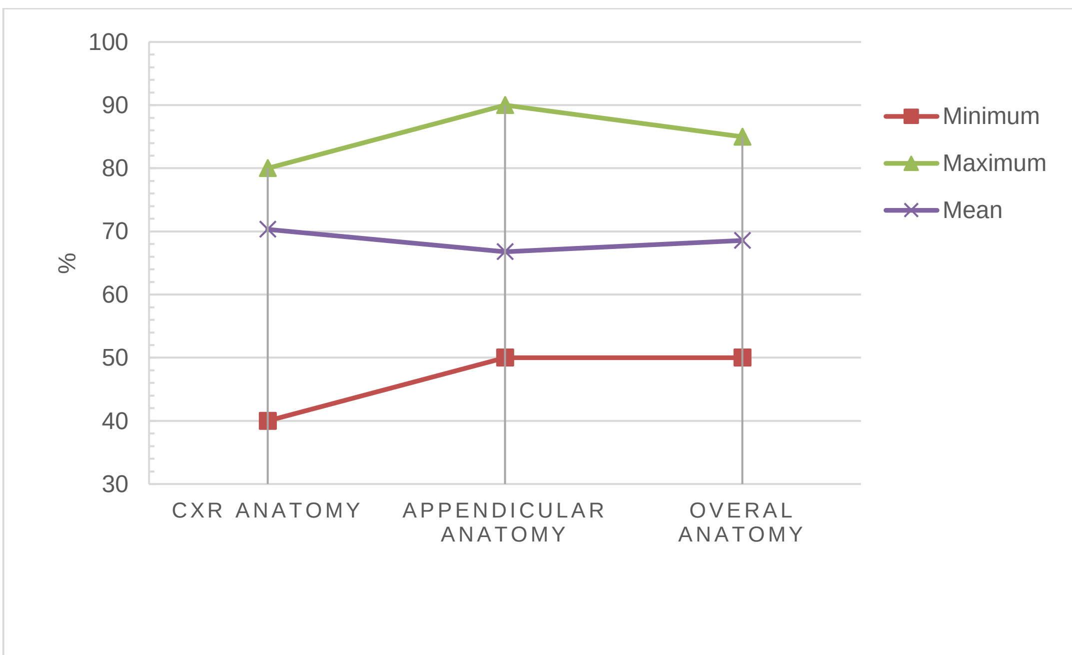

Figure 4.18: Accuracy of anatomy identification

The mean accuracy when identifying chest anatomy of interest was 70.32% (min=40%; max=80%) while for appendicular anatomy it was 66.77% (min=50%; max=90%). Overall, the mean accuracy for identifying the relevant anatomy was 68.55% (min=50%; max=85%).

4.4.2.12. Accuracy of image abnormality description

The ability of the radiographers to describe the identified abnormality on the images was further assessed and presented as accuracy for chest and appendicular images as shown below.

Table 4.53: Accuracy of image abnormality description

		Image number									
		1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	6 (%)	7 (%)	8 (%)	9 (%)	10 (%)
Chest abnormality description	Correct	67.7	90.3	87.1	74.2	100	87.1	100	45.2	100	100
	Incorrect	32.3	9.7	12.9	25.8	0.0	12.9	0.0	54.8	0.0	0.0
Appendicular abnormality description	Correct	96.8	96.8	80.6	32.3	96.8	54.8	32.3	83.9	100	100
	Incorrect	3.2	3.2	19.4	67.7	3.2	45.2	67.7	16.1	0.0	0.0

The ability to describe the identified chest abnormalities ranged from 45.2% to 100% while for appendicular anatomy, it ranged from 32.3% to 100%. The performance across the ten images is shown in the figure below.

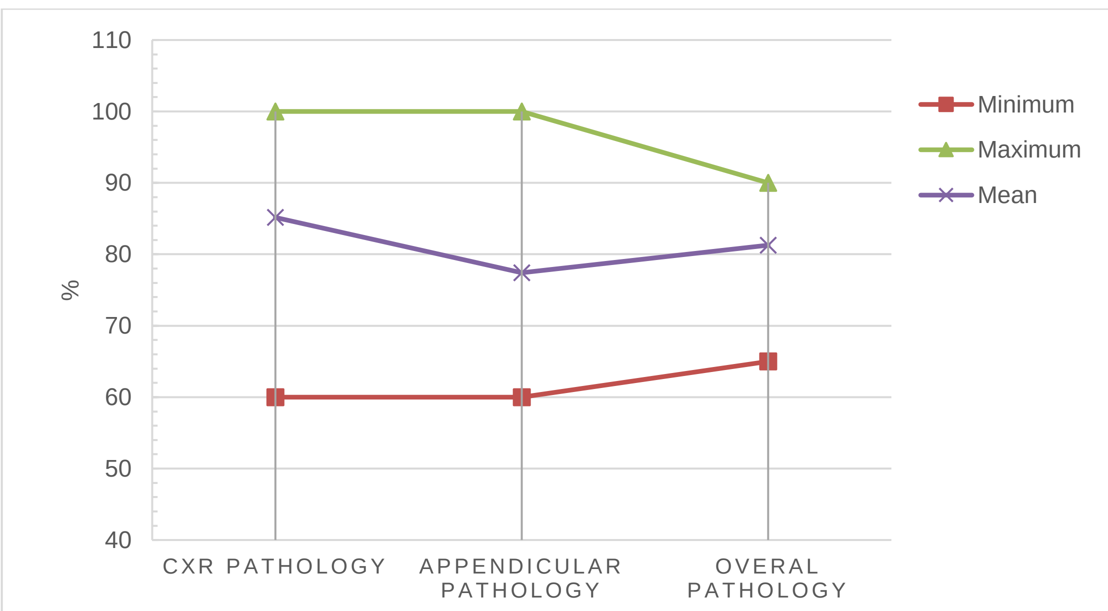

Figure 4.19: Accuracy of abnormality description

Radiographers' mean accuracy when describing identified chest abnormalities was 85.16% (min=60%; max=100%) while for appendicular it was 77.42% (min=60%; max=100%). Overall, the mean accuracy for describing the abnormalities was 81.29% (min=65%; max=90%).

4.4.2.13. Image interpretation accuracy by radiographers

The accuracy of image interpretation was calculated for the chest and appendicular regions separately and combined using the methods suggested by Baratloo et al., (2015). The results are shown in Figure 4:20 to Figure 4.22

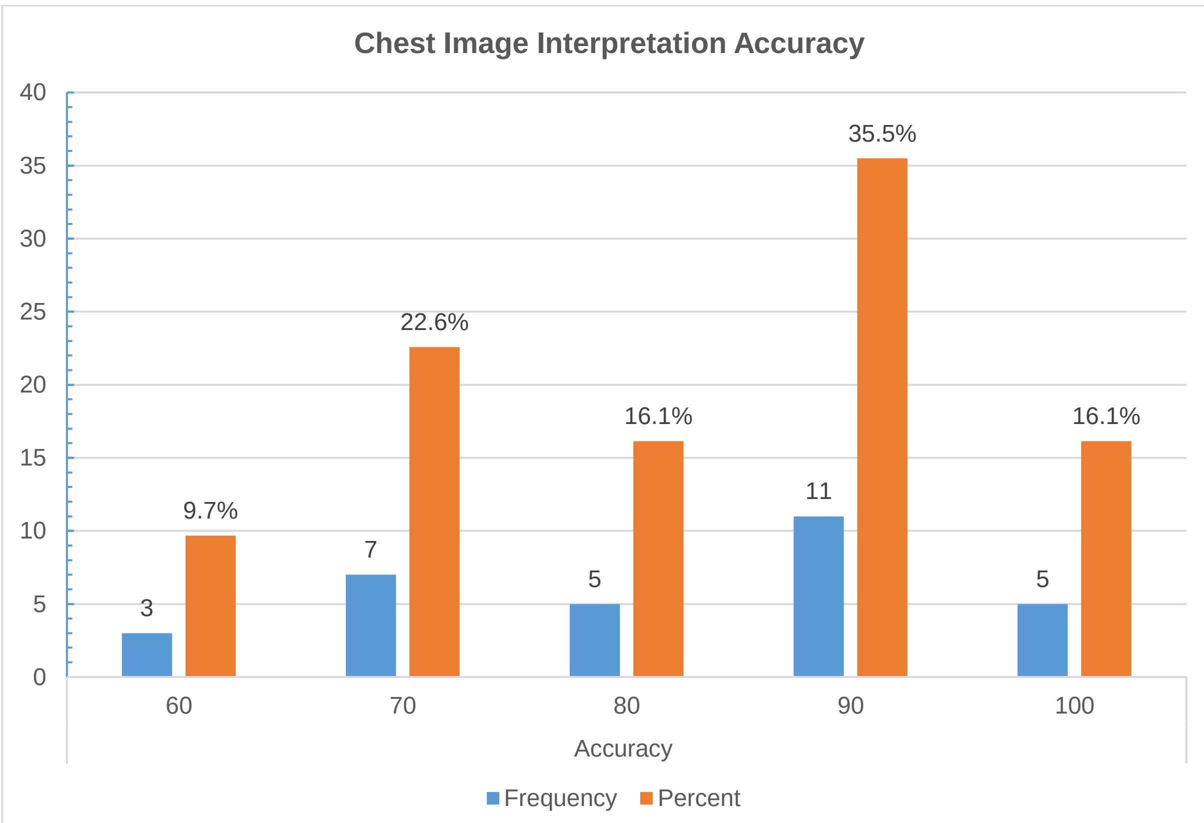

Figure 4.20: Chest Image Interpretation Accuracy

From the figure, 35.5% and 16.1% of the radiographers respectively demonstrated 90% and 100% accuracy in the interpretation of abnormalities on the chest images. The minimum accuracy was 60% and the maximum was 100% with a mean of 82.58% (SD=12.64).

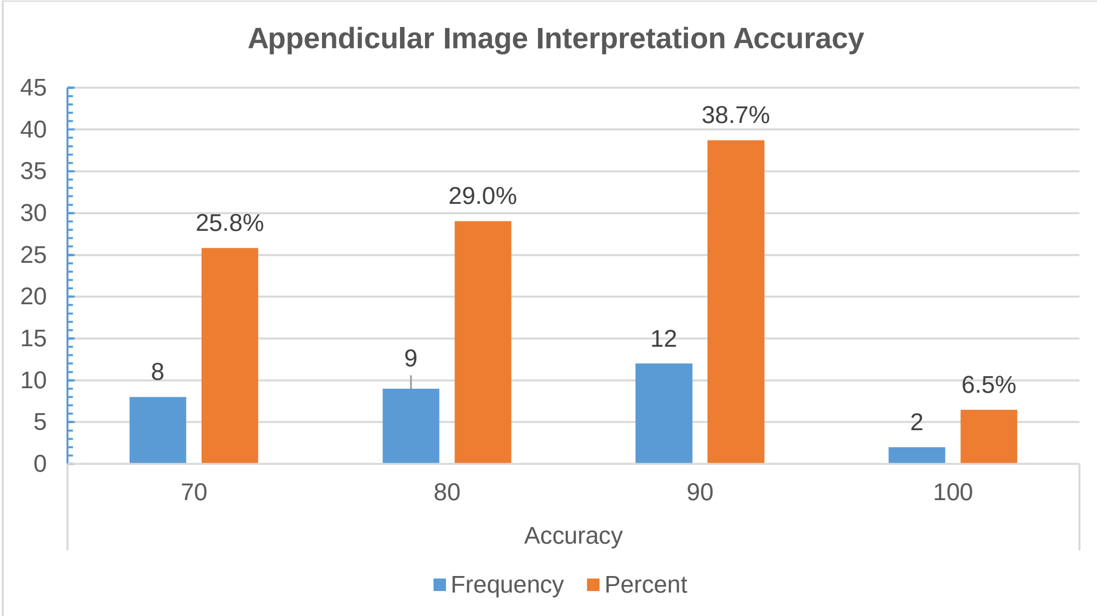

Figure 4.21: Appendicular Image Interpretation Accuracy

Of the radiographers, 38.7% and 6.5% showed 90% and 100% accuracy in interpreting the abnormalities on the appendicular images. The minimum accuracy was 70% and the maximum was 100% with a mean of 82.58% (SD=9.29).

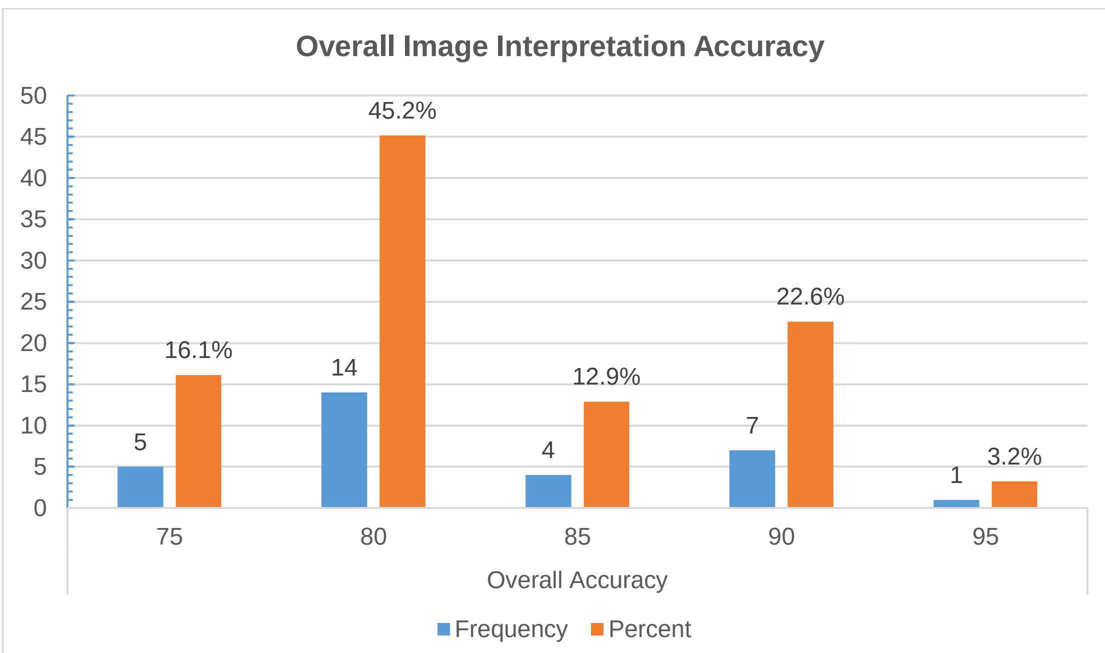

Figure 4.22: Overall Image Interpretation Accuracy

From the figure, 83.9% of the radiographers showed 80% and above accuracy in overall image interpretation. The minimum overall accuracy was 75% and the maximum was 95% with a mean of 82.58% (SD=5.60).

4.4.2.14. Radiographer image interpretation sensitivity

The sensitivity of image interpretation was calculated for the chest and appendicular regions separately and combined using the methods suggested by Baratloo et al., (, 2015). Sensitivity in this study was calculated as the radiographer's ability to identify abnormalities in images when they are actually present. The results are shown in Figure 4.23 to Figure 4.25.

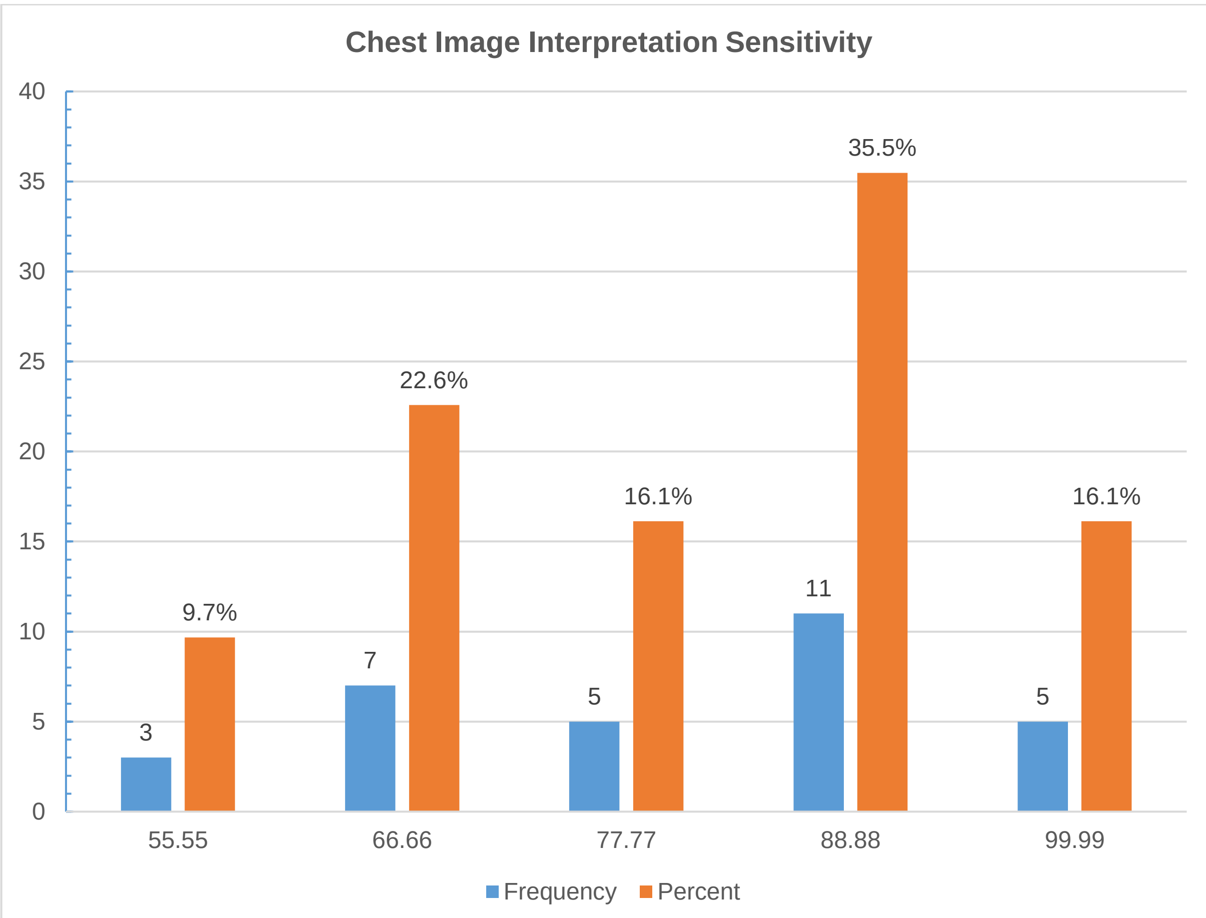

Figure 4.23: Chest Image Interpretation Sensitivity

The minimum sensitivity was 55.55% and the maximum was 99.99%. The mean sensitivity for the chest was 80.64% (SD=14.04).

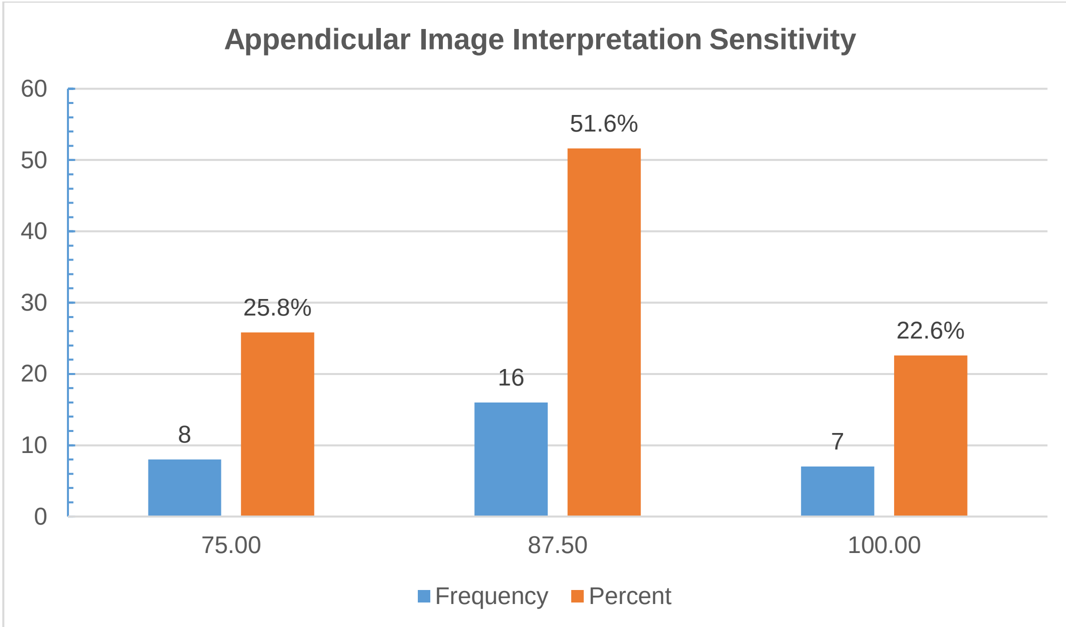

Figure 4.24: Appendicular Image Interpretation Sensitivity

The minimum sensitivity was 75.00% and the maximum was 100.00%. The mean sensitivity for the chest was 87.10% (SD=8.83).

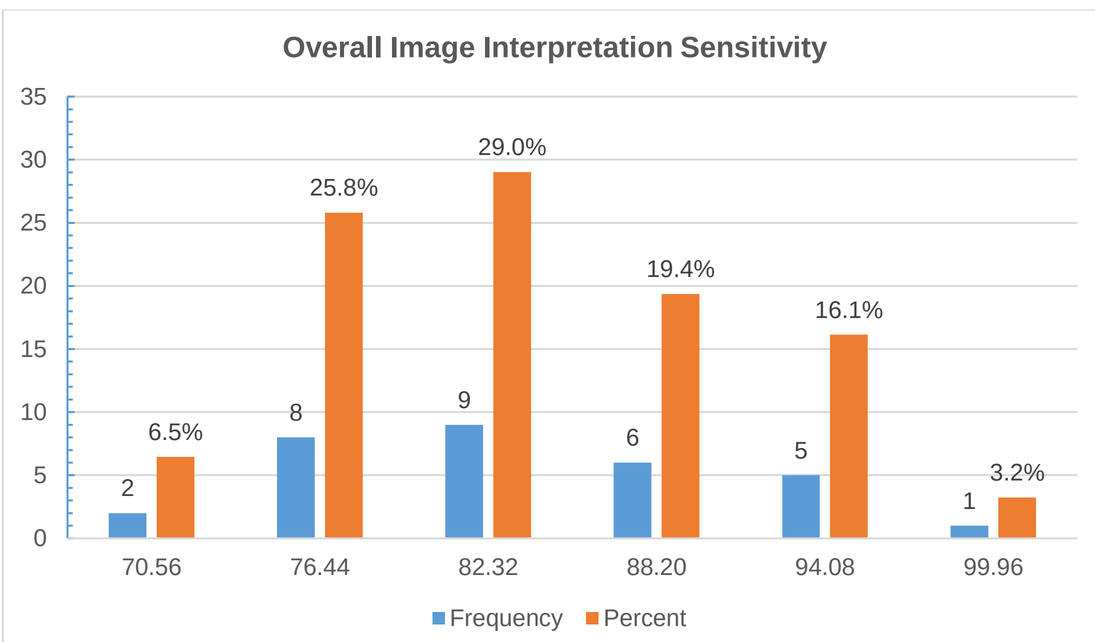

Figure 4.25: Overall Image Interpretation Sensitivity

The minimum sensitivity was 70.56% and the maximum was 99.96%. The mean sensitivity for the chest was 83.65% (SD=7.55).

4.4.2.15. Red-dotting accuracy and demographic characteristics

The association between the red-dotting (RD) ability of the radiographers and the various demographic characteristics was tested using the Independent-Samples Kruskal-Wallis Test at an alpha level of 0.05. Where significance was detected, post-hoc pairwise comparisons were performed using the Mann-Whitney U test coupled with a Dunn–Bonferroni correction to adjust for the Family Wise Error Rate (FWER). The results (p values) are shown in the tables below.

Table 4.54: Red-dotting accuracy and demographic characteristics

Demographic Characteristics	RD Accuracy	RD Sensitivity	Anatomy Identification Accuracy	Abnormality Description Accuracy
Employment rank	0.113	0.416	**0.026**	0.352
Highest Qualification	**0.042**	0.094	**0.026**	0.634
Years of experience	0.096	0.088	1.000	0.440
Hospital of appointment	**0.019**	0.518	0.083	0.871

A statistically significant association was noted between employment rank and anatomy identification (p=0.026), highest qualification and RD accuracy (p=0.042) and Anatomy identification (p=0.026) as well as hospital of appointment and RD accuracy (p=0.019).

<u>Pairwise comparisons for employment rank and anatomy accuracy</u>

Table 4.55: Pairwise comparisons for employment rank and Anatomy accuracy

Sample 1-Sample 2	Standard Test Statistic	Significance	Adjusted Sig.
Junior radiographer-Senior radiographer	-0.362	0.717	1.000
Junior radiographer-Assistant radiographer	2.607	**0.009**	**0.027**
Senior radiographer-Assistant radiographer	2.522	0.012	0.035

There was a statistically significant difference in the ability to identify the anatomy with abnormality between junior radiographers and assistant radiographers (p=0.027) after correcting for FWER.

Pairwise comparisons for highest qualification and RD accuracy

Table 4.56: Pairwise comparisons for highest qualification and RD accuracy

Sample 1-Sample 2	Standard Test Statistic	Significance	Adjusted Sig.
Diploma-Degree	-1.414	0.157	0.472
Diploma-Certificate	2.516	**0.012**	**0.036**
Degree-Certificate	1.891	0.059	0.176

Regarding the ability to detect images with abnormalities, a statistically significant difference was observed between certificate and diploma-qualified radiographers (p=0.036).

Pairwise comparisons for highest qualification and anatomy accuracy

Table 4.57: Pairwise comparisons for highest qualification and anatomy accuracy

Sample 1-Sample 2	Standard Test Statistic	Significance	Adjusted Sig.
Degree-Diploma	0.340	0.734	1.000
Degree-Certificate	2.695	**0.007**	**0.021**
Diploma-Certificate	1.921	0.055	0.164

In terms of the ability to name the anatomy with abnormalities, there was a statistically significant difference between certificate and diploma-qualified radiographers (p=0.021).

Pairwise comparisons for the hospital of employment and RD accuracy

Table 4.58: Pairwise comparisons for the hospital and RD accuracy

Sample 1-Sample 2	Standard Test Statistic	Significance	Adjusted Sig.
Hospital 1 – Hospital 2	0.878	0.380	1.000
Hospital 2 – Hospital 3	-2.774	**0.006**	**0.017**
Hospital 1 – Hospital 3	-1.644	0.100	0.301

On the ability to detect images with abnormalities, a statistically significant difference was found between radiographers at Hospital 2 and those at Hospital 3 (p=0.017).

4.4.2.16. Image interpretation accuracy versus demographic characteristics

The association between demographic characteristics and the levels of image interpretation accuracy for chest and appendicular radiographs as well as the overall accuracy was tested using the Independent-Samples Kruskal-Wallis Test at an alpha level of 0.05. Where significance was detected, post-hoc pairwise comparisons were performed using the Mann-Whitney U test coupled with Dunn–Bonferroni [a] correction to adjust for Family Wise Error Rate (FWER). The results (p values) are shown in Table 4:59.

Table 4.59: Image interpretation accuracy versus demographic characteristics

Demographic Characteristics	Chest II Accuracy	Appendicular II Accuracy	Overall, II Accuracy
Employment rank	**0.044**	0.227	0.338
Highest Qualification	0.075	0.369	0.202
Years of experience	0.400	0.608	0.670
Hospital of appointment	0.426	**0.012**	0.549

Employment rank (p=0.044) was statistically significantly associated with chest image interpretation accuracy while hospital of appointment (p=0.012) showed an association with appendicular image interpretation accuracy. All other associations were not statistically significant. A pairwise comparison was done for the two significant associations as indicated in Table 4.60 and Table 4.61.

Table 4.60: Pairwise comparisons for employment rank

Sample 1-Sample 2	Standard Test Statistic	Significance	Adjusted Sig.
Assistant radiographer-Senior radiographer	-9.833	0.073	0.219
Assistant radiographer-Junior radiographer	-14.333	**0.013**	**0.040**
Senior radiographer-Junior radiographer	4.500	0.194	0.583

Statistically significant differences in chest II accuracy were shown between the Assistant radiographer and the Junior radiographer ranks before and after FWER correction (p=0.013 – p=0.040).

Table 4.61: Pairwise comparisons for the hospital of appointment

Sample 1-Sample 2	Standard Test Statistic	Significance	Adjusted Sig.
Hospital 1 – Hospital 2	3.903	0.330	0.991
Hospital 2 – Hospital 3	-10.549	**0.003**	**0.010**
Hospital 1 – Hospital 3	-6.646	0.092	0.275

Statistically significant differences in appendicular image interpretation accuracy were shown between Hospital 2 and Hospital 3 before and after FWER correction (p=0.003 – p=0.010).

4.4.2.17. Image interpretation sensitivity vs. demographic characteristics

The association between demographic characteristics and the levels of image interpretation sensitivity for chest and appendicular radiographs as well as the overall sensitivity was tested using the Independent-Samples Kruskal-Wallis Test at an alpha level of 0.05. Where significance was detected, post-hoc pairwise comparisons were performed using the Mann-Whitney U test coupled with a Dunn–Bonferroni correction to adjust for the Family Wise Error Rate (FWER). The results (p values) are shown in Table 4.62.

Table 4.62: Image interpretation sensitivity vs. demographic characteristics

Demographic Characteristics	Chest II Sensitivity	Appendicular II Sensitivity	Overall II Sensitivity
Employment rank	**0.044**	0.274	0.215
Highest Qualification	0.075	0.553	0.133
Years of experience	0.400	0.710	0.677
Hospital of appointment	0.426	0.106	0.982

The employment ranks of the radiographers showed a statistically significant association with chest image interpretation sensitivity (p=0.044). However, no other associations were found to be statistically significant. A pairwise comparison was conducted for the significant association, and the results are presented in Table 4.63.

Table 4.63: Pairwise comparisons for employment rank

Sample 1-Sample 2	Standard Test Statistic	Significance	Adjusted Sig.
Assistant radiographer-Senior radiographer	-9.833	0.073	0.219
Assistant radiographer-Junior radiographer	-14.333	**0.013**	**0.040**
Senior radiographer-Junior radiographer	4.500	0.194	0.583

There was a statistically significant difference in chest image interpretation between the Assistant radiographer and the Junior radiographer ranks before and after FWER correction (p=0.013 – p=0.040).

4.5 Section 4: Experiences of image interpretation education – the educator and student perception

The results of the experiences of both lecturers and recent graduates from the participating HEI will be presented in this section. The approach for both groups was qualitative, aiming to unearth deeper insights into how image interpretation education is incorporated into the Bachelor of Radiography degree at the participating HEI. The first objective was to "explore and describe the perceptions and experiences of radiography educators regarding the preparedness of graduates to take up image interpretation roles," and the other was to "explore and describe the perceptions and experiences of recent graduates regarding their preparedness to take up image interpretation roles." Subsection 4.5.1 will present results from recent graduates, while subsection 4.5.2 will present results from educators. All analysis was performed using Atlas.ti version 9.

4.5.1 The experiences of recent graduates regarding image interpretation training

The objective of this aspect of the study was to conduct interviews with all 2020 graduates in order to gain insights into their image interpretation training experience. The cohort was a total of 12 graduates, of whom 10 were traced and recruited into the study, allowing for sufficient participants to reach data saturation. The other two could not be traced either by the researcher or classmates, as their contact details were no longer valid. All the participants were employed at the time of data collection.

4.5.1.1 Approach to data analysis

The data analysis approach was based on Colaizzi's seven steps of data analysis for descriptive phenomenology, as this aspect of the study aimed to explore and describe the experiences of recent graduates regarding the image interpretation training, they received during their degree programme. This approach was based on describing the findings from the study with minimum researcher interference while maximising bracketing (Holloway & Wheeler, 2010). The application of this method was explained in full in Chapter Three section 3.9.2.4. The resultant themes and their subthemes are presented in the form of a thematic map in Figure 4.26.

4.5.1.2. Participants' demographic characteristics

All ten participants were recent graduates within two years of qualifying and working in state or private imaging departments in Namibia. Table 4.64 shows the demographic characteristics of the participants including their age, gender, work experience and context of employment.

Table 4.64: Demographic characteristics of recent graduates

Demographic Characteristic		Number (%)
Gender	Male	2 (20%)
	Female	8 (80%)
Age	24 years and below	8 (80%)
	25 to 30 years	2 (20%)
Work experience	4 to 12 months	6 (60%)
	13 to 14 months	4 (40%)
Work context	State	6 (60%)
	Private	4 (40%)

The majority of the participants were females (80%), with only two males in the group (20%). The age of the participants ranged from a minimum of 23 years to a maximum of 27 years, with the majority (80%) aged 24 years and below. The work experience ranged from 4 months to 13 months with the majority (60%) having 1 year or less. Most (60%) were working for state imaging departments.

4.5.1.3. Themes and subthemes

Two themes and a total of six subthemes emerged from the data analysis. The themes and subthemes are detailed in Table 4.65 below.

Table 4.65: Themes and subthemes - Experiences of recent graduates

Themes	Subthemes
Theme 1: Teaching and Learning	1.1 Teaching approach
	1.2 Clinical Education
	1.3 Assessment strategy
Theme 2: Paradoxical reality	2.1 Practitioner role modelling
	2.2 Skills utilisation
	2.3 Skills Impact

4.5.1.4. Thematic mapping

Figure 4.26 provides a visual map of the themes and sub-themes that emerged as experiences of recent graduates.

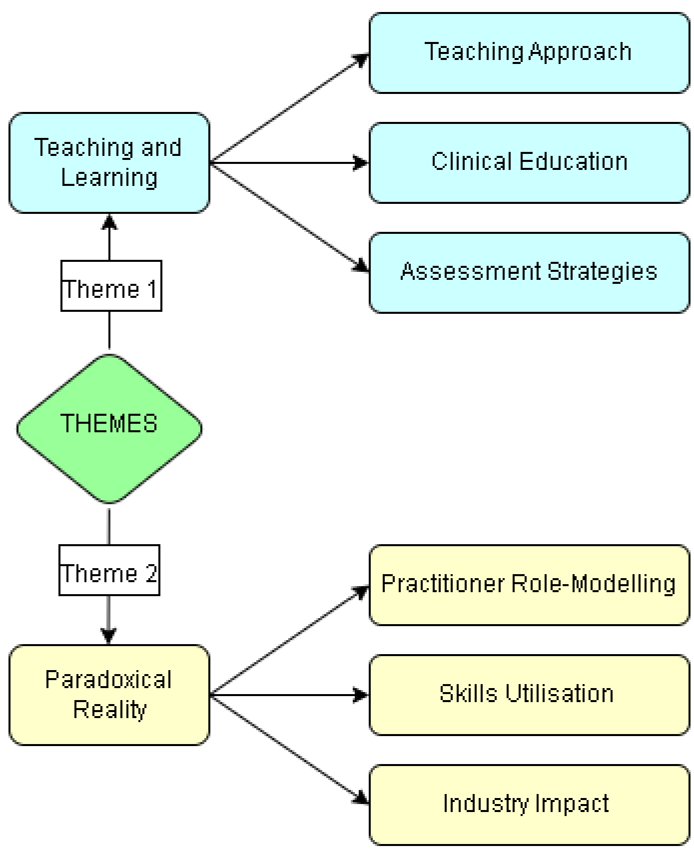

Figure 4.26: Thematic Map - Experiences of Recent Graduates

4.5.1.5. Theme 1 – Teaching and learning

The experiences of recent graduates in this study were shaped and affected by the teaching and learning processes adopted and utilised during their four years of training. This included the content and the way it was delivered (the teaching approach), the way the competencies were built during experiential learning (clinical education), and the way teaching and learning were assessed (the assessment strategy).

4.5.1.6. Subtheme 1.1: Teaching approach

This sub-theme related to the comprehensiveness of the image interpretation content that was taught to recent graduates (curriculum coverage) and how this content was delivered (pedagogy). The participants agreed that, from their experience, the curriculum content was not comprehensive enough to build the necessary skills in image interpretation. Some of the participants said:

> *"Image interpretation was not enough because at University, we were only taught a few pathologies, but not all of them…" (GP4)*

> *"Image interpretation at university, we didn't do a lot of it as students were like we did a whole module that is designed to facilitate image interpretation. So, my perception is that image interpretation was not taught fully to the student." (GP7)*

Furthermore, the participants felt that though the module is practical and skill-based, the teaching methods were more theoretical with insufficient use of images as highlighted in two example quotations below.

> *"Yes, in my opinion, image interpretation wasn't more practical, it was more theoretical, and more of defining pathologies or how to see pathologies on x-rays." (GP7)*

> *"The delivery of the content was mostly theoretical, though there were some images shown, we mostly only focused on this module during theory classes." (GP8)*

Though this content was delivered in a predominantly didactic mode, the students were expected to practically apply this knowledge in the image interpretation of pathologies on radiographs, as reflected in the following quotes:

> *"But yes, you're taught how to describe it and how the pathology appears. So, if you know how the pathology appears, then you'd know how to describe it." (GP3)*

“We were expected to know how to identify the different pathologies mainly on the chest image.” (GP9)

4.5.1.7. Subtheme 1.2 – Clinical Education

In this study, the participants reflected on their experience of image interpretation during clinical placements and noted that this was given limited focus and attention, as shown below.

“Uh, not really in the practical area because in the practical area, we never really focus on the image pathology.” (GP1)

“I think image interpretation was not tied to any practical work.” (GP5)

“I would say there was no focus on that. Like mostly what usually used to happen is that you go into the x-ray room and do your x-rays, based on analysis of the anatomy.” (GP7)

Participants further noted that the main focus of clinical training was on the development of technical skills at the expense of other skills, such as image interpretation. Below are some of their sentiments.

“In practical areas, if you have your image with all the diagnostic qualities there, you pass it. We never went into details to say this is effusion but in theory, we were taught that this is how effusion looks…” (GP1)

“I remember when we were in the department with radiographers, the only thing they emphasise is making sure your positioning is fine.” (GP2)

The participants also experienced limited supervision in the development of image interpretation skills from qualified radiographers as these were rarely applied in practice, as shown in the quotations below.

“The years when we were students, we were not really overshadowed and given that much attention to say, okay, you have learnt this in theory, let us apply it here in the clinical setting. So, most of the time, we found ourselves in the clinical setting just to clear the benches, just because the hospitals were full.” (GP5)

“The only problem came in the clinical setting with the people who were supposed to supervise us and so on. So sometimes we show images or like now we've come to a point where we know what we're looking for and we show images, and we pass them. But we didn't really pay much attention to what was happening on the image.” (GP10)

4.5.1.8. Subtheme 1.3: Assessment Strategy

The participants shared their reflections on the assessments related to image interpretation, highlighting that these assessments were primarily conducted within the classroom setting.

> *"Okay, assessments were actually more theoretical. Of course, there were times when we were given an image and there were also times when we were given a case study." (GP3)*

> *"Assessment was through written tests and written exams in the pathology module." (GP5)*

> *"Assessment was like you write a theoretical examination and, in that examination, there might be like two or three images of a different or certain pathology." (GP7)*

Furthermore, participants also mention other assessment methods that were applied in evaluating teaching and learning of image interpretation content as follows:

> *"And we also used to do presentations. You get a case study and then you present on the pathology, how it looks on a radiograph, and then you give your findings." (GP4)*

> *"Yes, there were also pathology case studies. Okay. I remember clearly, we would get assessments according to the pathology." (GP6*)

When it comes to practical or clinical evaluations of radiographic techniques that were conducted with an actual patient at the hospital, the participants indicated that there was limited inclusion of the image interpretation content aspects in these evaluations, as shown below:

> *"If I recall well during clinical evaluations, I remember only being asked to label certain anatomy, but it wasn't for me to interpret the patterns, even if I see a pathology, interpretation was not an emphasis there." (GP2)*

> *"I think image interpretation was not tied to any practical work." (GP5)*

4.5.1.9. Theme 2 – Paradoxical reality

A paradoxical reality is a depiction of the contradictory status of the situation, in this case, image interpretation practice, at a specific time. The practice of image interpretation during training and after graduation resulted in paradoxical experiences of reality among recent graduates. This was reflected by participants' experiences of mentorship (practitioner role modelling), the application of skills in practice (skills utilisation), and the relevance of those skills (skills impact).

4.5.1.10. Subtheme 2.1: Practitioner role modelling

The participants indicated that qualified radiographers, who were the role models in clinical practice, did not consistently practice or focus on image interpretation during their day-to-day work or when supervising them as students. The following were some of the sentiments echoed by the participants.

> *"The years when we were students, we were not really overshadowed and given that much attention to say, okay, you have learnt this in theory, let us apply it here in the clinical setting..." (GP5)*

> *"I can say, it's the radiographers because when we were in the department, the main goal was like to get a perfect diagnostic image and not worry about the pathology that was there." (GP3)*

Some of the graduates pointed out that there was an obvious gap in the translation of theory to practice due to inconsistencies between expectation and reality, as indicated below.

> *"In clinical practice, I would say there was a theory-to-practice gap. Yes." (GP5)*

> *"There was no opportunity for you to come and say this is what I see on the image." (GP7)*

> *"It could have been easier if we were both taught about it in practical and in theory because, in practice, we can relate more than in theory, so it was a bit challenging." (GP9)*

Due to limited guidance and role modelling on image interpretation during clinical practice, the recent graduates experienced organic skills development in this aspect based on the personal interests of the individual, as shown below.

> *"During our normal clinical practice, no there wasn't focus on image interpretation unless it's, of course, you yourself focusing on that as an individual or with other students." (GP3)*

> *"There was no guidance unless if you take it up yourself, then you will go like, okay, this is what I see, this is what I don't see." (GP7)*

4.5.1.11. Subtheme 2.2: Skills Utilisation

Though the graduates highlighted a limited focus on image interpretation during clinical training, most of them had experiences where they were asked to demonstrate skills and knowledge of image interpretation to support the referrers, especially where there are no radiologists.

"Yes, it was because the doctor was not able to see what was wrong with the x-rays. So, they came to ask for my opinion, and I was able to pinpoint what exactly was wrong with the x-ray." (GP8)

"Yes, the doctors usually come and ask, what do you think is wrong with the patient and, I give my point of view like I see there is a certain abnormality with this and that…" (GP9)

"And sometimes it doesn't have to be the referring doctor asking for advice. Sometimes if I see something wrong, I can go to the doctor and advise that there is something there." (GP10)

Though there seemingly was excitement from contributing to patient management through image interpretation, the recent graduates also had inadequacies due to limited knowledge and skills in image interpretation. They stated the following:

"We need more training especially in practice because what we did at University was the theory." (GP1)

"Uh, fairly, I think there is still much revision and practice that needs to be put in place to be able to identify all these many pathologies that we were taught in the theoretical settings." (GP5)

"In terms of interpreting images, definitely I think that there is a need for more training." (GP9)

4.5.1.12. Subtheme 2.3: Industry Impact

In this study, the recent graduates experienced a high skill impact factor mainly due to contextual relevance. For most of them who were working in smaller towns, the absence of a radiologist created a practice void that radiographers can and are expected to fill. This creates a paradox, as they indicated that they were ill-prepared for this purpose during their training. Some of their voices are reflected in the quotes below.

"Some of the medical doctors don't have enough skills to read x-rays and I think it will be so helpful to the patient if a radiographer can now also assess the image and advise them on what may be happening...." (GP1)

"Where I am currently working it's a village town, so you barely get a specialist. So, something like having, a radiographer to report even the simple plain x-rays would really just lessen the burden for the doctors." (GP6)

All recent graduates cited limited training and skills in image interpretation but when faced with a contextual demand for skill application and role extension, the graduates indicated that they were willing to learn and upgrade their skills through continuous professional development or postgraduate training, as reflected below.

> *"I really would like to study film reporting of the images. I really want to study something like an assistant radiologist or something if there is something like that. I'll be reporting even just chest x-rays." (GP1)*
>
> *"Yes, I will be interested in training, it's an interesting area, and I think that I will be interested in knowing more about the pathologies..." (GP4)*
>
> *"Yes. I would be interested in training because I feel like I'm required to do more than just producing quality x-rays, I also need to understand and advise on what will be shown, on the x-rays." (GP7)*

4.5.2 The perceptions and experiences of radiography educators regarding the preparedness of graduates to take up image interpretation roles.

The study section aimed to conduct interviews with all the lecturers engaged in teaching the Bachelor of Radiography degree at the participating HEI. A total of 6 participants were eligible for inclusion in the study, of whom 5 were available during the data collection phase. One lecturer was away on study leave and could not participate in the study. All five lecturers gave their voluntary consent to participate.

4.5.2.1. Approach to data analysis

The data analysis for this objective was based on exploring the preparedness of radiography graduates to take up image interpretation roles from the educators' perspective. To enable this, the directed content analysis approach was used to guide the analysis and derive meaning and conclusions from the data as explained in Chapter Three section 3.9.2.3. The relationships between the themes and the sub-themes were defined and mapped as shown in Figure 4.27.

4.5.2.2. Demographic Characteristics of Radiography Lecturers

Table 4.66 shows the demographic characteristics of the radiography lecturers who participated in the study.

Table 4.66:Radiography Lecturers' demographic characteristics

Demographic Characteristic		Number (%)
Gender	Males	2 (40%)
	Females	3 (60%)
Rank	Assistant lecturer	2 (40%)
	Lecturer	3 (60%)

There were three females (60%) and two males (40%) who participated in the study of whom three (60%) were lecturers and two (40%) were assistant lecturers All participants had more than 3 years of working experience as radiography educators.

4.5.2.3. Themes and subthemes from the lecturers

Two themes and seven subthemes emerged from the data analysis as shown in Table 4.67.

Table 4.67: Themes and subthemes from the lecturers

Themes	Subthemes
Theme 1: Teaching and Learning	1.1 Teaching approach
	1.2 Clinical Education
	1.3 Assessment strategy
Theme 2: Paradoxical reality	2.1 Practitioner role modelling
	2.2 Skills relevance
	2.3 Industry Alignment
	2.4 Regulatory prescripts

4.5.2.4. Thematic mapping – Lecturer experiences

Using the coding matrix, a thematic map was developed as shown in Figure 4.27

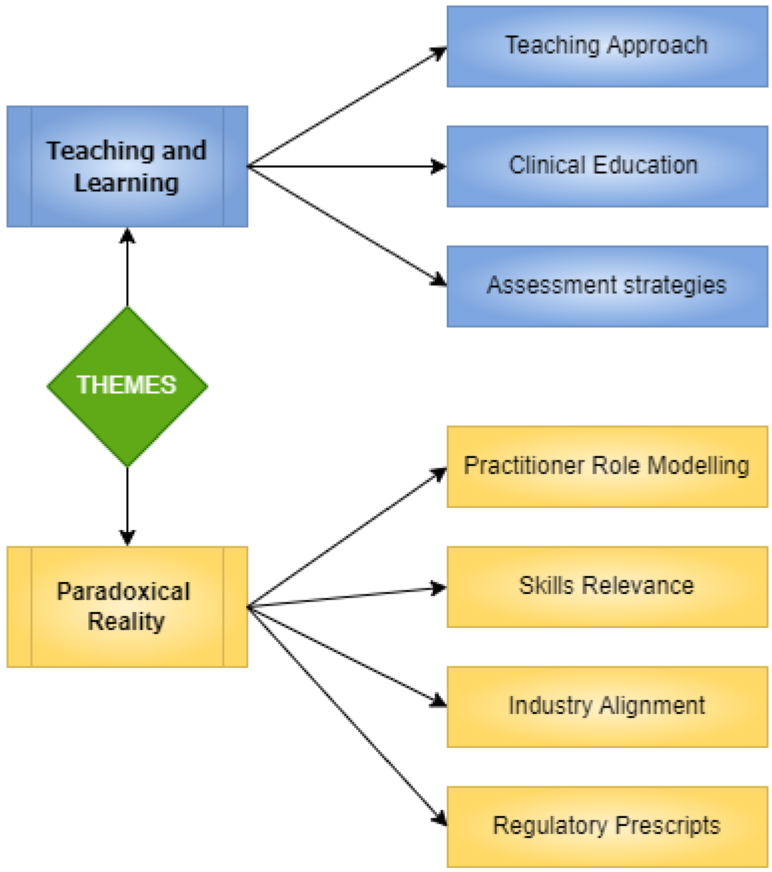

Figure 4.27: Thematic mapping – Lecturers' experiences

4.5.2.5. Theme 1 – Teaching and Learning

Teaching in higher education is guided by a curriculum that outlines the modules or courses to be covered. For each module, specific learning outcomes are defined, along with the pedagogical approach to achieve those outcomes It is the outcomes that prescribe the content and methods of teaching and assessment that are supposed to be applied for each module or course. The experiences of the radiography lectures also covered teaching and learning, specifically looking at the teaching approach, clinical education, and assessment strategies.

4.5.2.6. Subtheme 1.1: Teaching approach

The radiography lecturers all indicated that the image interpretation content was delivered in a predominantly theoretical form utilising a didactic approach as indicated in the quotations below.

> *“. The students get didactic lectures in class, where they will be basically taught about the different body systems.” (LP1)*

“Yes, the module, although it is taught using, or with the aid of practical aids or radiographs, the module is completely theoretical. Theory is important because it is the basis of the practice.” (LP4)

They further reiterated that there is a specific module that focuses on radiographic pathology, orienting the student to different pathologies and radiographic appearances. However, there was also a consensus that the depth of coverage is not enough as reflected in the statements below.

“I think, of two things, number one being the depth of learning that the students receive or teaching that they receive from the lecturer or the curriculum which is not enough.” (LP4)

“Well, they have a subject, I forgot now what the name is, but they have a subject where they cover image interpretation, but it's not extensive, It's more of an introductory type of subject.” (LP5)

4.5.2.7. Subtheme 1.2 Clinical Education

Clinical education is important in the training of radiographers as it allows students to develop the professional competencies required to practice. While the theory builds the foundation, sufficient clinical exposure is necessary to build competence. The radiography lecturers indicated that there is limited focus on building image interpretation skills when students are in clinical practice as demonstrated by the following statements:

“I do have to say that I don't think enough emphasis is placed on image interpretation because we are not orientated at this point in time to do a proper image interpretation and actually having the goal of writing a report.” (LP3)

“No, not during routine clinical practice, there is no focus on image interpretation, it is actually one of the lacking skills.” (LP5)

There were also indications that the clinical training relating to image interpretation was not structured in a way that allowed everyone to learn and know similar pathologies but was mainly based on incidental teaching with those available or involved benefiting.

“…it is difficult sometimes that we don't have enough time to sit with a group of students and teach them the pathologies during clinical practice.” (LP2)

“So, the less the incidence is of the student encountering a specific case, that also influences basically the student's knowledge on that specific pathology, at the moment because it's more incidental.” (LP2)

Regardless of the limited exposure during teaching and clinical practice, there is an expectation that the students, even from their first year, should be able to identify and distinguish a normal radiograph from an abnormal one as echoed below:

“I think the main thing that we are focusing on at the moment is for a graduate or for a student to be able to identify the abnormal from the normal.” (LP2)

“Well, currently they just learn to identify abnormal and normal radiographs, depending on the projections that they take and following certain patterns to determine if there's an abnormality.” (LP5)

4.5.2.8. Subtheme 1.3: Assessment Strategy

The radiography lectures indicated that the assessments are mainly class-based and incorporate the use of radiographs, on which students are supposed to interpret the radiographic appearances. Below are examples of direct quotations from the lecturers.

“The assessment for image interpretation, normally they will have an image and then we will provide a small or brief history on the image for the students to correlate the history to the appearance that is on the image and that is how they will do their assessment.” (LP1)

“…also, with the tests or the examinations, they would get images to interpret. But mainly it is OSCEs and clinical evaluations where you can really test their knowledge on image interpretation.” (LP5)

Regarding other clinical examinations, the lecturers acknowledged that the clinical assessments, specifically the clinical evaluations in this context, also included elements of image interpretation assessment. However, they noted that the focus on this aspect was relatively limited. They indicated that the clinical evaluations are more focused on technical radiography skills, and image interpretation takes up an insignificant slot, contributing very few marks as highlighted below:

“…and then a small section within the clinical evaluation, then just focuses on pathology. If my memory serves me correctly, it's about two or four marks of the complete evaluation tool.” (LP2)

"I think there the emphasis is not on the image interpretation that much as it should be. I think we concentrate more on the technical part and the production of the image…" (LP3)

4.5.2.9. Theme 2 – Paradoxical reality

Similar, to the student experiences, this theme relates to the inconsistencies in the image interpretation realities between the academic and clinical departments. The different image interpretation expectations between these two entities make it somehow difficult for the students to gain image interpretation skills in a coordinated and standardised manner. Practitioner role modelling, skills relevance, industry alignment, as well as regulatory prescripts emerged as subthemes that reflect a paradoxical reality in the practice of image interpretation.

4.5.2.10. Subtheme 2.1: Practitioner role modelling

This relates to the position of qualified radiographers, both lecturers and clinicians, as role models for students where their practice and focus are taken to represent the expectations of radiographers after graduation. In this study, the radiography lecturers recognised the lack of focus on image interpretation as being due to their limited knowledge of image interpretation. Thus, it may be difficult to impart knowledge to the next person when one perceives what one knows to be inadequate, as indicated below.

"I also feel that we as lecturers, lack knowledge of radiographic pathology. I honestly believe we don't know, for example, as much as a radiologist would know." (LP2)

The lecturers also recognised the role of the clinical radiographers in imparting skills and building competencies in the students during the period of training through their supervision and clinical monitoring exercises. However, they also noted that there is a limited contribution from the radiographers regarding image interpretation, as highlighted below:

"So, when thinking in terms of image interpretation, our radiographers actually don't care about that because they feel their primary responsibility is to produce an image." (LP2)

"…so, there's no learning taking place between radiographer and student radiographer because they already don't do it, meaning that the students will also not get a chance to do it." (LP4)

Furthermore, the lecturers also noted the absence of radiologists on the imaging floor as an impediment to the development of image interpretation skills, as they can step in and provide concrete guidance on complex pathologies when available. However, due to staff shortages, this hasn't been achieved in years. In addition, the clinical meetings between the lecturers, clinical radiographers, radiologists, and students would also serve as a platform to develop image interpretation skills and knowledge if conducted regularly.

> *"I think it would be very good if radiologists and staff in the hospital together with us who are there every day can at least have two weekly or monthly interactive sessions where we discuss specific pathology." (LP2)*

> *"That is compounded by the fact that the students don't really spend a lot of time with the radiologists, … And I do believe that our students could heavily benefit from it when it comes to image interpretation training." (LP4)*

4.5.2.11. Subtheme 2.2: Skills relevance

The subtheme was about the relevance of image interpretation skills within the medical industry. The lecturers recognised the clinical practice gap that exists in image interpretation as a result of the shortage of radiologists locally. Most importantly, they identified the radiographer as well positioned to fill this gap though currently there may be a limitation due to inadequate training. Some of the sentiments echoed by participants are given below.

> *"So, I think there is room for improvement because in our country we have a shortage of radiologists and I think radiographers if they're trained well, can really add to the workforce." (LP1)*

> *"We don't have enough radiologists in the hospitals and our current skills as radiographers, are not helping the situation." (LP4)*

The lecturers also recognised that even if image interpretation skills are relevant and needed currently, the level of training that the radiographers receive is inadequate to build their skills and competencies to the required level for proper practice. Thus, the training programme has not responded adequately to allow the graduates to better respond to the needs of the industry, as indicated below:

> *"So, I think currently they're not maybe trained sufficiently, but I think there's a need for industry alignment…" (LP1)*

> *"So, I think our emphasis is, is more on producing the image, but not really the interpretation of the image at this point." (LP3)*

"I think there'll be more training needed there to actually make a thorough diagnosis to say, this is what, …" (LP5)

4.5.2.12. Subtheme 2.3: Industry Alignment

Primarily, this subtheme focused on the perception of the radiography lectures on how well the training programme meets and responds to the needs of the local industry. The lecturers acknowledged the need for image interpretation skills among radiographers but indicated that the training was not comprehensive enough to meet the industry's demand for these skills.

"Our training currently isn't meeting the needs of the industry in terms of image interpretation at all." (LP4)

"Well, I don't think training is really meeting the need currently." (LP5)

There was also a general agreement among the lecturers that the curriculum is not well aligned with international trends in radiography and will thus not deliver enough image interpretation content to build these skills. Below are two statements from the participants.

"I think at the moment; we are really lacking behind with regard to image interpretation. When we look at the first and second world countries, how they've progressed, and those radiographers have even got a certain degree of being able to report and film reading." (LP2)

"So, I think we are, not aligned internationally, …." (LP4)

4.5.2.13. Subtheme 2.4: Regulatory Prescripts

Radiography is a regulated profession in Namibia through the Allied Health Professions Council of Namibia (AHPCNA). The regulatory council, AHPCNA, is mandated by law to protect the citizens of Namibia from any potential harm that may arise during the practice of health professions, including radiography. For radiography, various instruments are in place, such as the gazetted regulations and scope of practice that prescribe the boundaries of professional practice. The lecturers indicated that the current regulations for radiographers prevent the full implementation of image interpretation by radiographers as this is deemed to be outside their scope of practice. Below are the remarks made by some of the lecturers.

"…even if our students were really having the skills, I think there's a lack of a framework of what they can do clinically…" (LP1)

“I think we are heavily crippled by policies and legal frameworks. Those really are spanners in the progression of the profession.” (LP4)

“But there's, no actual, obligation for radiographers to interpret images mainly because it's not really part of our scope as radiographers.” (LP5)

4.6 Conclusions

This chapter presented a comprehensive overview of the study's results, organised into distinct sections that demonstrated their interrelationships and connections. Both quantitative results and qualitative findings were presented using appropriate formats and guided by the frameworks established in Chapter Three. Furthermore, Chapter Four establishes a solid foundation for addressing the objectives outlined in Chapter One and contributes to the discussion chapter, which explores the integration of these results into the existing body of knowledge in the field of radiography.

CHAPTER 5 : DISCUSSION OF RESULTS

5.1 Introduction

This chapter will present a discussion of the results and findings presented in Chapter Four in relation to the existing literature, aiming to establish their contextual meaning and contribution to the body of knowledge. The conceptual framework and structure established and used in chapter four will guide the discussion of the results and findings. The discussion, as part of the convergent parallel design, integrates the results from the various approaches, as applicable, to obtain a holistic picture of the phenomenon under study. Literature control and support are provided to show how the findings relate to what is already known and established and what the study is contributing to that body of knowledge. The following table outlines the order in which the results will be discussed.

Table 5.1: Outline of the discussion

Section	Focus area	Objectives
Section 5.2:	Image interpretation system design, capacity, and efficiency	1 and 2
Section 5.3:	Impact of image interpretation on patient management – a referrer's perspective	3 and 4
Section 5.4:	Preparedness of radiographers to adopt new roles in image interpretation	5 and 6
Section 5.5:	Experiences of image interpretation education – a lecturer-student perception	7 and 8

5.2 Image interpretation system design, capacity, and efficiency

5.2.1The image interpretation system design of the imaging departments

These departments, as is typical for radiology departments within a hospital, were set up to provide service and support to other departments attending to inpatients and outpatients. The operational design of the three imaging departments showed similarities, as they all fell under the jurisdiction of the same ministry. Similarly, the staffing levels in these departments were comparable and reflected a state of understaffing. This understaffing was highlighted in the Health Care Workforce Status Report of 2022, which indicated a high vacancy rate of 32% (Ministry of Health and Social Services, 2022). All three departments followed the traditional medical-oriented structure as previously described by Mcconnell and Smith (2008), where the radiologist, as a physician, was central and in charge of the department. The observations indicated that while radiologists were not highly visible on the work floor due to reporting workload, they remained engaged in departmental operations and exerted influence over various processes (Gunn et al., 2015). In line with the traditional image interpretation systems, the departments also operated under a three-step sequential system that included procedure ordering or requests by a medical doctor, procedure execution by a radiographer, and procedure reporting by the radiologist. This clearly demonstrated alignment with the demarcation of the roles and responsibilities of each health professional involved in the imaging chain (Lundvall et al., 2021; Towbin et al., 2017). Though this image interpretation system appeared to be failing to satisfy both the referrer's and patients' demands or needs, there appeared to be limited efforts to remedy the situation from within the departments or hospitals. Consequently, the role of image interpretation continued to be solely designated to the radiologist, while the radiographers were tasked with the technical aspects of image acquisition and production, reflecting a medical-oriented approach (Mcconnell & Smith, 2008). This is also typical of the traditional scope of practice of a radiographer, where there is limited recognition of informal and on-the-job training or role extension in response to clinical challenges (IIRRT, 2019; ASRT, 2017). There was a limited application of role extension by radiographers which is partly due to practice restrictions imposed by the professional regulatory body.

In terms of their daily operations, all three imaging departments were not working at their full capacity as some of the imaging equipment, such as fluoroscopy units (two departments) and mammography machines (all departments), were non-functioning and awaiting replacement. Furthermore, all departments had limited IT infrastructure, which compromised hospital-wide communication of radiology outputs. All this is typical of under-resourced settings where there is usually underfunding in the public sector, including the health sector, thereby compromising service delivery (Cowan et al., 2021; Owumi & Eboh, 2021). In such under-resourced contexts, funds such as those meant for equipment procurement may be reassigned and taken up by other priority demands such as COVID-19, which require immediate national action (Olufadewa et al., 2021; Rosenthal et al., 2020). This has resulted in compromised service delivery within the imaging departments and was reported by radiologists as one of the factors affecting reporting efficiency.

5.2.2 Image interpretation capacity of the departments

The study findings clearly demonstrated a lack of capacity within the imaging departments to cope with the image interpretation demands. With a combined daily average of 95 procedures per department requiring image interpretation, it has become almost impossible to cope with the workload or clear the backlog. The radiologists further reported that the number of procedures has been gradually increasing over the past three years, a trend that is expected to continue due to increased reliance on medical imaging, a scenario they termed ‘medicine with imaging’. This is consistent with reports in the literature indicating increased use of medical imaging services globally, particularly high-end imaging modalities such as CT and MRI (Smith-Bindman et al., 2019; Adejoh et al., 2018; Bell et al., 2018). Positive factors contributing to this include the technological advances that have made images clearer and more accurate, increased diagnostic efficacy and increased access and availability of imaging services (Winder et al., 2021; Lysdahl & Hofmann, 2009). However, limited referrer knowledge of the application of imaging as well as defensive medicine, has been reported to contribute to unnecessary requests for imaging procedures (Alchallah et al., 2020; Kainberger & Kainberger, 2016). All this will result in radiologists failing to cope with image interpretation demands, as witnessed in the current study. Further capacitating these departments by addressing the installation and repair of non-functional equipment, without addressing the existing staff shortages, would exacerbate the challenges faced in image interpretation. This is particularly critical for procedures such as fluoroscopy and mammography, where a radiologist's report on the images is required.

The severe shortage of radiologists within the three departments was a critical factor affecting the capacity to provide image interpretation services. With one radiologist in charge of image interpretation at two hospitals with a combined daily average of 180 procedures, it becomes unrealistic for them to fully satisfy this service demand. This is consistent with previous reports that documented a global shortage of radiologists spanning both well-resourced and under-resourced countries, failing to meet service demands (Halliday & Maskell, 2020; Rosman et al., 2019; Piper, 1999). In the current study, this shortage resulted in radiologists only focusing on interpreting CT images, of which they only managed to report an average of 29.7% of the CT procedures during the period of review. This perpetuates an ongoing backlog that would be challenging to alleviate if the current situation persists, potentially leading to severe consequences. However, this is not peculiar to the current study context but has also been a global concern and driver for health sector reforms and role extension (Kim & MacKinnon, 2018; Yates et al., 2018). Different imaging departments have explored and implemented various strategies aimed at enhancing image interpretation capacity and mitigating reporting backlogs in light of the shortages of radiologists (Stevens et al., 2021; Culpan et al., 2019; Kansagra et al., 2016).

5.2.3 The efficiency of the image interpretation system in the state hospitals

In medical imaging, efficiency can be reflected by the radiology turnaround time (RTAT), which can be defined as the amount of time between the completion of image acquisition (printing of images or on RIS) and the availability of an image interpretation report (Mehta et al., 2000). In this study, the image interpretation system was divided into three pathways, namely, conventional imaging, CT, and other procedures. Only a few medical examinations received reporting for plain images, as radiologists prioritised image interpretation for CT scans, which they deemed too complex for general practitioners to interpret. Among the reported CT procedures, more than 28% took longer than 21 days to be reported. A survey among emergency department chairs in the US indicated that they expect a RTAT of below 30 minutes for effective decision-making support (Rathnayake et al., 2017). The Royal Australian and New Zealand College of Radiologists also recommends RTAT for various procedures ranging from a few minutes for plain images to approximately 10 minutes for CT scans (Pitman et al., 2018). Therefore, the local system is not meeting international standards in terms of timely image interpretation reports, which is adversely affecting the process's efficiency and resulting in backlogs comparable to those reported in the UK (Hobson & Parris, 2017). Various factors have been reported to affect RTAT, and in the current study, high workload, limited IT equipment and staff shortages were reported as the main factors. These are similar to some of the factors cited in previous reports, which included reporting workload, the complexity of cases and modalities, the radiologist’s speed, time spent teaching, the use of structured or unstructured reporting, PACS system stability, the design of workflow, non-image interpretation roles and sub-specialisation (Zabel et al., 2020; Rathnayake et al., 2017; Mehta et al., 2000). Various efforts can be implemented to mitigate these factors and increase RTAT, and in the current study, participants recommended an increase in the number of reporting radiologists as one of the main measures. Although this would be ideal, it will be difficult to achieve in the local context due to a lack of capacity in radiology training. Moreover, colleges in South Africa, where radiology training is provided in the region, along with the majority of Sub-Saharan Africa, have been struggling to meet the regional demand and are likely to continue facing challenges in the near future (Iyawe et al., 2021; Rabinowitz & Pretorius, 2005). Other suggestions from the participants included utilising radiographers through role extension and installing a fully functional PACS system to improve image interpretation efficiency. These are similar to mitigating efforts reported in previous studies to have had a positive impact on efficiency, RTAT and backlog reduction (Almutairi et al., 2021; Baltruschat et al., 2021; Stevens et al., 2021; Culpan et al., 2019). Though these efforts are effective, there is a need for their contextualisation in the local environment, including providing the necessary education and support. Hence, it is crucial to modify the design of the image interpretation system, allowing radiographers to engage in the process through diverse pathways in line with their education and training. Additionally, it is important to consider other mechanisms for process improvement, such as enhancing staffing levels to bolster human capacity, upgrading technological infrastructure, and providing comprehensive training for medical doctors in image interpretation. This comprehensive approach holds the potential to enhance the capacity and efficiency of the image interpretation process in these departments.

5.3 Impact of image interpretation on patient management – the referrer's perspective

Medical image interpretation is one of the core outputs of the diagnostic imaging departments within health facilities. Traditionally entrusted to the radiologist, image interpretation usually culminates in the production of a definitive report that communicates diagnostic findings from the images to the referrer for use in patient management decisions. Thus, image interpretation reports, along with other diagnostic tools and services available in the healthcare setting, are thought to contribute significantly to patient diagnosis (Bruno et al., 2017). However, for this benefit to be reaped, the process must be performed on time, and the results must be communicated efficiently and accurately (Ogura et al., 2018). Due to the continuous evolution of medical imaging and its increased utilisation, this has been difficult to achieve, especially with the current chronic shortage of radiologists around the globe (Kubik-Huch et al., 2020; Masood et al., 2020; Rimmer, 2017). This has resulted in huge backlogs of unreported medical images or very late reporting, which have serious ramifications for patient management (Stevens et al., 2021; Culpan et al., 2019). Non-radiologists, such as medical doctors, and in some cases radiographers, have stepped into the gap and taken over some aspects of image interpretation to aid in the diagnostic process and facilitate effective patient management (Verrier et al., 2022; Wood, 2022). Though this might have been a stop-gap measure when it was conceived, its existence for decades now justifies the transition of this radiographer role extension into a permanent support system. However, before this can be realised, it is important to evaluate the performance and preparation of those involved, such as medical doctors.

5.3.1. Image interpretation training and roles of the referrer

Most doctors who were surveyed in the current study indicated that they had training in conventional imaging as well as CT image interpretation. However, the training provided, while touching upon the fundamental principles of image interpretation, was insufficient for fully developing image interpretation competencies, as expressed by one participant: *"We did not really* *go into details of image interpretation" (DP6).* Most doctors shared similar sentiments, which emphasised the collective recognition of the need for additional training and reinforcement to develop sufficient skills of image interpretation for clinical application*: "We need training on how to interpret..." (DP2).* This finding is not peculiar to the current study context, as various previous authors have reported the inadequacy of radiology content taught during medical training. A Danish study reported that junior doctors do not have the minimum fundamental knowledge of image interpretation of chest abnormalities required for clinical practice (Christiansen et al., 2014). Others have reported a wide variation in image interpretation content between different training institutions, thus creating variations in the fundamental knowledge of image interpretation (Bell et al., 2019; Lewis et al., 2016). Generally, medical graduates have been deemed unprepared for image interpretation roles in clinical practice due to these deficiencies in training (Chew et al., 2020). This is similar to our local context, as the training programme does not have comprehensive content on image interpretation but a single semester module in their third year, that introduces students to the basics of image interpretation.

Despite the shortcomings identified in training, the doctors in the current study indicated that they partake significantly in image interpretation, especially of conventional imaging procedures, which are seldom reported by radiologists. *"We are interpreting general x-rays, and some CT scans," (DP5),* revealed one participant, reflecting the additional role surveyed doctors undertook beyond conventional image interpretation due to the shortage of radiologists. Similarly, studies in the literature have shown that there is an over-reliance on medical doctors in image interpretation across the globe due to a shortage of radiologists or unending backlogs. A survey in South Africa reported that junior medical practitioners were required to interpret chest images and manage patients according to their diagnosis at district hospitals due to the absence of radiologists (Sethole et al., 2020). Where challenging cases are encountered, consultation is sought from other colleagues and in complex cases, from radiologists in tertiary hospitals, which may in turn delay treatment (Sethole et al., 2020). Similarly, in Malaysia, medical officers were required to evaluate and rule out any abnormalities on chest X-rays for medical examinations even though they didn't have comprehensive training or compulsory radiology attendance during their internship years (Daud et al., 2018). The same expectations are placed upon junior doctors in Australia and the UK, despite both countries having similar inadequacies in training (Samara et al., 2021; Glenn-Cox et al., 2019). On the other hand, the Royal College of Radiologists in the UK has taken significant steps to mitigate inconsistencies in radiology teaching content across different universities by producing a standard radiology curriculum for undergraduate medical programmes

(Bell et al., 2019; Glenn-Cox et al., 2019). In most countries, however, this standardisation is yet to be achieved, including in the current study setting where, the determination of the content and teaching modes is at the discretion of the teaching university (Glenn-Cox et al., 2019). This presents a potential disconnection between the preparation of the graduates and their expected roles in practice, which may increase the risk of misdiagnosis or mismanagement of patients due to poor image interpretation. As the role of medical doctors in image interpretation is slowly becoming a permanent solution to mitigate the effects of the radiologist shortage, there must be an initiation of dialogue between the training universities and the clinical practice supervisors to align the image interpretation training of medical doctors with current and future expectations, thereby allowing them to execute this role to expected standards. This is particularly true for under-resourced settings such as Namibia, where a significant increase in the number of radiologists is not expected in the short to medium term due to a lack of training capacity.

5.3.2. Diagnostic performance of the image interpretation system

Diagnostic performance is a summative measure of how a system or process, such as image interpretation, is performing in comparison to expected standards (Sardanelli & Di Leo, 2009). In image interpretation, indicators such as the turnaround time and the quality of the reports, are often used to measure diagnostic performance. Only a few doctors (1.1%) in the current study indicated that the image interpretation report was always on time, with the rest indicating that it was either sometimes on time (44.56%) or not on time at all 34.43%). *"We are in the Intensive Care Unit, so they prioritise us," (DP7),* highlighted one participant, illustrating how the active triaging system during reporting creates the perception of timelier image interpretation in critical care and intensive care units. This prioritisation could influence the perceived timeliness of image interpretation by a few participants in comparison to other units. During the individual interviews, the doctors also reported that the image interpretation process was very long and could take up to three months for a CT scan report to be ready. However, participants also noted that persistent follow-up could result in a shorter reporting time: *"I as a doctor have to constantly pressurise the radiologist to report this on time" (DP2),* This would have been expected, as during the time of the current study, there was only one radiologist assisted by two medical officers serving two tertiary hospitals that conduct over 200 procedures daily. This is a typical finding in public hospitals in under-resourced settings where there is a severe shortage of health professionals such as radiologists and underfunding of the health sector (Owumi & Eboh, 2021; Masaba et al., 2020). This ultimately creates a huge backlog of essential procedures that need image interpretation, which contributes directly to the turnaround time. Though turnaround time for reporting is dependent on several variables, RANZR stipulates that the majority of radiography images should take less than 30 minutes to report, with no procedure taking more than one hour (Pitman et al., 2018). This would translate to a minimum capacity of 16 interpretation reports within an eight-hour working day for a radiologist. Considering the current study's context with an average of 90 procedures performed daily, this scenario would lead to 74 (82%) unreported procedures, contributing to the daily backlog. Hence, without addressing all the variables that impact RTAT, it remains unfeasible to report all daily procedures due to staffing constraints, leading to the accumulation of backlogs over time and consequently longer turnaround times. This situation is further exacerbated by the absence of other supporting systems, such as high-resolution viewing monitors, HIS, RIS, and PACS, in the local study context. *"We don't have a HIS or RIS to help streamline things,"* (H1:P7), as indicated by one of the radiologists, highlighted the significant role these elements play in enhancing the efficiency of the image interpretation process as this is currently paper-based (Almutairi et al., 2021).

Another element of diagnostic performance is the quality of the image interpretation report as evaluated by the end user, in this case, the medical doctors. Here, the doctors indicated how often they agreed with the image interpretation report when it was provided. Responses were noted as ranging from not at all (24.2%) to yes always (48.4%) when considering images from conventional imaging that were reported, probably reflecting both the experience and exposure of the doctors who responded to the survey. Clinical experience has been shown to affect image interpretation ability among doctors in a previous study that assessed their competency when evaluating a chest image for abnormalities (Jimah et al., 2020). Furthermore, it could also be an indication of the true quality of the reports that are generated from the imaging departments due to the use of less qualified and experienced medical officers to assist the radiologist in reporting. It was, however, not clear whose reports, between the radiologist and medical officer, had discrepancies, and that may need further investigation. The disagreement may also reflect a mismatch between the expectations of the referrers and the outputs from the imaging departments in terms of the report format. The image interpretation report serves as the sole means of communication between the radiologist and the referrer regarding the results of image interpretation. Therefore, it is essential for the report to be clear and concise in order to facilitate better understanding. The structure of the image interpretation report, the complexity of the language used, and the length of the report are some of the factors reported in the literature that contribute to the dissatisfaction of referrers with these reports (Mityul et al., 2018). When this happens, it reflects communication failure, which might lead to patient mismanagement and possible malpractice lawsuits for both parties (Whang et al., 2013). The ability to communicate the diagnosis and its differentials on an image interpretation report is a crucial factor in the use of that report in patient management and may require focused attention during undergraduate medical training and active review during practice (Hartung et al., 2020).

In terms of CT reports, the doctors in this study showed a higher level of agreement (70.5%) with the image interpretation reports, indicating fewer disagreements, compared to the conventional imaging reports (48.4%). This might be because of the complexity of the CT cross-sectional images, which may be difficult to assess for the doctors: *"CT images are mainly reported by consultant radiologists just because it's an advanced imaging modality" (H1: P7)*. Furthermore, the observed results may be attributed to the fact that CT images were mainly interpreted by radiologists, potentially enhancing the quality of the reports, and leading to higher agreement with referrers. It was not investigated to ascertain whether the disagreements with the findings of the report were solely the medical doctors' opinion or the result of a combined review that included the sub-speciality consultant as well. There is therefore a need for further research to fully understand this discrepancy and improve the quality of the image interpretation service. From the literature, it has been shown that medical doctors feel less confident in interpreting CT images due to inadequate preparation during training (Bell et al., 2019). In another study, emergency doctors' (with no specific radiology training) performance during head CT image interpretation was the lowest compared to neuro-radiographers and neuro-radiologists due to their limited exposure to CT images (Gallagher et al., 2014). This agrees with the current study, as doctors indicated during interviews that there was limited training in CT: *"We were not taught in-depth, they were not really specific" (DP1)*. It can thus be considered easier to agree with the findings when one does not have the knowledge and ability to do one's assessment of abnormalities in the images. This tendency to agree with the results and disregard possible contradictory evidence may be attributed to confirmation bias, which can arise from limited knowledge and confidence in interpreting the findings (Nickerson, 1998). However, it is also possible that the findings reflect a high standard of image interpretation reporting by the radiologist on the CT images, which reduces the likelihood of errors and disagreements. In addition, it is important to note that the doctors' opinions were measured through a survey, and their actual ability and competency to interpret both conventional imaging and CT images have never been practically assessed in the study context. Assessing their skills in image interpretation is equally important to fully understand the experiences reflected in the current survey.

5.3.3. Diagnostic outcome of the image interpretation system

The diagnostic outcome is an indicator of how the image interpretation report affected diagnostic decision-making and contributed to the final diagnosis. One of the elements considered in this study was the contribution of the image interpretation report to building the confidence of the referrer regarding the diagnosis. Confidence is a reflection of an individual's belief in their ability to deal with a situation properly or successfully, and in this case, making a diagnosis (Hecimovich & Volet, 2009). A few of the doctors surveyed (32.3 %) indicated a change in confidence regarding the patient's diagnosis after reviewing the plain image interpretation reports. This could be due to the limited number of reports on conventional imaging compared to the unreported proportion (only 12.7%). Thus, it might have been difficult for doctors to form an opinion about the change in confidence when they haven't had much experience with plain image reports. A different trend was noted with the CT images, where a higher proportion of the doctors (58.6%) indicated a change in their confidence regarding patient diagnosis after reviewing the image interpretation report. This may also reflect a lack of experience among doctors regarding abnormality detection on CT images and their sole reliance on the radiologist's report for diagnosis and management. Confidence is an important element in medical practice, which, when combined with the appropriate competence, can enhance clinical decision-making (Gottlieb et al., 2021). When one is less competent, they usually exhibit less confidence in making a decision, such as a diagnosis, and transfer that responsibility to another, a radiologist in this instance, whom they trust and have confidence in regarding their ability to make such a diagnosis. Thus, the radiologist's image interpretation report (as a proxy for the radiologist) will act to increase the confidence of the less experienced medical doctor in making a diagnosis, as typically seen in team-based settings such as healthcare (Gottlieb et al., 2021). The perceived confidence building after reviewing CT reports is not a peculiar finding in the current study context but a reflection of the multi-professional support system inherent in healthcare settings that places the patient at the centre. In a previous study in the USA, assessing the change in physician decision-making after a CT scan, the authors reported significant changes in patient diagnosis and high post-CT diagnostic confidence among physicians (Pandharipande et al., 2015). They concluded that CT results prompted changes in patient diagnosis and management decisions while significantly reducing and eliminating doubt and uncertainty. Similarly, another study reported an increase in diagnostic and management decisions after reviewing CT reports, especially with embedded supporting images (Iyer et al., 2010). The above therefore shows the relative importance of the image interpretation reports in building the diagnostic confidence of the referrer when making a diagnosis or management decision from radiology images. Though in the current study this was more apparent for CT reports, the same impact on confidence can be extrapolated to plain images where referrers have low level of experience in image interpretation.

When it comes to the perceived effect of the image interpretation report on the need for additional diagnostic procedures or the extent to which it complements other procedures, the doctors who completed the survey seem to have a wide range of opinions. Most of the doctors did not think that image interpretation completely removed the need for other diagnostic procedures for plain imaging procedures (91.4% for chest and 83.8% for forearm/hand). However, this was more pronounced for CT, where the majority believed that image interpretation sometimes removes the need for additional procedures (68.4% for the head, 60.8% for the chest and 58.2% for the abdomen). A previous study assessing the conclusiveness of CT reports in diagnosing pleural malignancy concluded that a CT scan alone may report the absence of malignancy while it may be present, at least 33% of the time (negative prediction value of 65%) (Hallifax et al., 2015). Another study reported that CT scan reports of the abdomen in cases of acute abdominal pain provided conclusive reports for 96.8% of the cases, with 0.7% being incorrect diagnoses (Strömberg et al., 2007). Furthermore, literature has also shown that the experience of the radiologists interpreting the CT images plays a crucial role in the overall conclusiveness of the report, in addition to the type of pathology under investigation and the quality of the CT images being reported (Garg et al., 2021; Braun et al., 2015; Abujudeh et al., 2009). The solitary practice of radiologists, commonly seen in under-resourced settings such as Namibia due to staff shortages, is also a risk factor that may affect the conclusiveness of scan reports (Abujudeh et al., 2009). In some instances, however, diagnostic imaging procedures such as CT can provide conclusive reports that automatically direct patient management (Biesbroek et al., 2013). Imaging procedures, like most diagnostic procedures in medicine, play a crucial role in patient management but require other tests and procedures to provide complementary data that can help explain or understand the image interpretation report. It is therefore not surprising that the doctors in this study had a wide range of views regarding the conclusiveness of the CT reports, as these were reviewed by different doctors and pertained to different pathologies as well. It may be imperative to empirically determine the diagnostic accuracy and utility of various CT procedures separately in this context to avoid unjustified exposures and to guide clinical management.

5.3.4. Effectiveness of the image interpretation system – the referrer's view

Most of the doctors indicated that when an image interpretation report is available, it always contributes to patient diagnosis (55.7%) and patient management (57%). A similar proportion of doctors believed that image interpretation reports contributed to diagnosis (44.3%) or patient management (40.5%) only occasionally. This may be due to those inconclusive reports where there will be a need to continue with diagnostic tests such as a biopsy or other laboratory test that will ultimately provide a definitive result (Gupta et al., 2017; Sersté et al., 2012). On the contrary, the presence of a subset of doctors who perceived no contribution of image interpretation to patient management raises questions about the rationale behind utilising imaging procedures like CT in the initial stages. According to the literature, there has been an increase in the use of CT imaging over the last decade, which has been accompanied by an increase in unjustified procedures (ten Brinke et al., 2021; Salerno et al., 2019). This is also a pertinent problem in under-resourced settings due to the radiologists' absence, who would usually act as the gatekeepers by making justification decisions. Against this background, it is not surprising that just above half of the doctors also thought that the cost of image interpretation was justified for some of the cases, as this might be based on the overall justification of the imaging procedure.

It is also important to note that it's not only a positive diagnosis on an image interpretation report that contributes to patient diagnosis or management. A normal image interpretation report may also contribute to diagnosis by eliminating or ruling out the presence of certain or suspected pathologies and fine-focusing the subsequent diagnostic tests. It was therefore assumed that doctors who participated in this study considered the positive value of a normal image interpretation report on the overall diagnostic process.

Overall, the doctors felt that they were experiencing poor radiology service marked by long turnaround times for the reports, as discussed in the previous sections, as well as compromised patient management. Compromised patient management in this context occurs when doctors cannot make decisions or are delayed in making them due to the absence of or a delay in getting the image interpretation report. Doctors in the current study pointed out that there were instances when they could not make a cancer diagnosis or treatment plan without image interpretation reports. This delay had repercussions on the disease prognosis, as one participant explained, *"We could not even treat this patient surgically anymore; we had to send the patient for palliative care" (DP2).* Significant delays in image interpretation (more than three months), can significantly reduce the survival of critical patients (Sud et al., 2020). It is therefore important that active solutions are explored to reduce the delay in image interpretation and provide effective support to the referrers to avoid compromising health delivery and patient management.

5.3.5. Radiographer role – can it improve the image interpretation system?

The doctors who took part in the interviews also highlighted how the role of radiographers can impact the image interpretation process. The primary role highlighted by the participants was limited on-the-job support from the radiographers, as evidenced by poor-quality images: *“Sometimes our x-rays are rotated, sometimes they are overexposed” (DP7).* They believed that because they work with limited information, this would have an impact on their ability to interpret images. The main purpose of medical imaging is to facilitate diagnosis through the production of quality images of internal anatomy that are invisible to the naked eye (Strudwick, 2014). The radiographers possess knowledge of and utilise complex radiation-emitting machines combined with high levels of patient care to interact with the patient and produce high-quality images consistent with the patient's condition during that time of image acquisition (Strudwick, 2014). It is therefore expected that the quality of the images produced should reflect the best possible diagnostic quality for the specific patient condition and must be able to provide answers to the clinical question under investigation. When the images are of poor quality, as indicated in the current study, it reduces or eliminates their clinical utility, rendering the whole imaging process useless and unjustified. The knowledge and ability to produce quality images have been reported as one of the core elements of a radiographer’s professional work (Lundvall et al., 2014). When a departure from this professional standard is observed, as indicated in this study by a participant stating, *" Rotated x-rays because babies cannot lie still" (DP9),* it is essential to conduct a comprehensive analysis of the identified shortcomings. Afterwards, appropriate corrective measures, such as continuous development programmes, should be considered to address these issues effectively. Internal quality assurance systems, such as a clinical audit, should be in place or be capacitated to identify and recognise such deviations in quality before they affect patient diagnosis or management. To complement this, active dialogue should be encouraged between the radiographers and the referrers to discuss such shortcomings and optimise imaging quality while putting the patient at the centre of care. Similarly, the same approach can be used for procedure requests and image interpretation where discussion can be done in a team spirit that places the patient at the centre as suggested by one participant who said, *“I think we just need teamwork to interpret x-rays” (DP10)*. Collaborative efforts and effective teamwork have been reported to significantly enhance the overall performance of health systems, while promoting the provision of high-quality care (Rosen et al., 2018).

Regarding image interpretation, most of the doctors interviewed indicated that the radiographers were participating in this process through informal and unrecognised channels. Some of the doctors indicated that they consult the radiographer for their opinion of image abnormalities, and their contribution is usually meaningful and appreciated: *“Yes, I did. It was very helpful” (DP7)*. They emphasised that input from radiographers about potential abnormalities on images is valuable, aiding in diagnosis formulation: *"Yes, it will be helpful, I have a foundation that I can build on" (DP8).* This can be considered a good preliminary indicator of the readiness of the contextual environment to accept and adopt the role of a radiographer in image interpretation, however, a follow-up and large-scale assessment might be necessary. Similarly, reports in the literature show that the role of the radiographer in image interpretation is easily acceptable, especially where there are no other viable solutions to image interpretation challenges. In agreement with this finding is a study conducted in South Africa among emergency physicians, in which the majority agreed that having a reporting radiographer interpret images after hours (when the radiologist is absent) will significantly aid in patient flows and free up their time to focus on patient management (Chetty et al., 2020). Similarly, a study in the UK’s emergency departments also reported that radiographer-led immediate reporting could significantly improve productivity in these departments and can be a cost-effective approach to image interpretation where there are budgetary constraints (Hardy, Hutton, et al., 2013). In under-resourced settings, such as the current study context, there is underfunding of the health sector and a lack of capacity to train or employ adequate radiologists, making the use of a radiographer in image interpretation one of the viable and cost-effective approaches to solving the service delivery challenges. Clinicians in the UK’s emergency departments also indicated that immediate image interpretation by radiographers can improve the quality of service provided in these departments and reduce image interpretation errors (Snaith & Hardy, 2013). Similarly, the provision of a comment on a radiograph was reported to improve the image interpretation accuracy of emergency department practitioners compared to when no comment was given (Stevens & Thompson, 2020). These literature findings mirror the current study findings, in which the doctors interviewed stated that a comment from the radiographer will guide them in image interpretation and serve as a second opinion, potentially contributing to error reduction. This indicted a potential image interpretation role for radiographers as indicated by: *“It will also help doctors in reducing the delay in diagnosing patients. It is something we can build on” (DP6)*. In addition, doctors in under-resourced settings are typically overworked, especially in a public hospital, due to high patient volumes and low staff complement, making them prone to exhaustion and burnout, which are both risk factors for practice errors (Rajan & Engelbrecht, 2018). Utilising radiographers in image interpretation may therefore provide partial relief from clinical pressure in addition to providing doctors with an opportunity to develop their image interpretation skills (Snaith & Hardy, 2013). Different pathways of radiographer image interpretation have also been reported to have other multiple benefits, including providing a safety net for referrers, reducing patient waiting times, and reducing radiologist workload (Harcus & Stevens, 2021; Murphy & Neep, 2018).

The successful implementation of image interpretation by radiographers requires support from the radiographers themselves and their willingness to undergo training, as necessary. This has been shown in Jordan, where both the radiographers and the radiologists supported the extended role of the radiographers in image interpretation using the RADS (Oglat et al., 2023). Similarly, in Kenya, a survey of 145 radiographers demonstrated that they were willing to undergo additional training in image interpretation of the chest and musculoskeletal system to supplement the radiologist shortage (Rugut, 2016). The same sentiments were also echoed among Zambian radiographers, who were recently assessed on their willingness to get training and assist the radiologist in reporting conventional imaging procedures (Bwanga, Chanda, et al., 2021). The above studies have demonstrated the readiness of radiographers to support and supplement radiologists in image interpretation and their willingness to undergo further training to enhance this function. The informal participation of radiographers in image interpretation as reported by the doctors in the current study may indicate their readiness to partake in formal image interpretation when the system is adjusted to cater for and allow this practice. Therefore, as witnessed elsewhere, the participation of radiographers in image interpretation in the current study context may be beneficial to both the referrers and the patients while also enhancing the quality of health care.

5.4: Preparedness of radiographers to adopt new roles in image interpretation

Image interpretation ability by radiographers is a skill founded on adequate education, training, and supervision during undergraduate training. Depending on the nature of training, content coverage, and intended outcomes, radiographers may be able to identify and label abnormalities on the image or provide a written comment about the identified abnormality as part of image interpretation (Neep et al., 2019; Murphy & Neep, 2018). In addition to undergraduate training, some postgraduate programmes have been developed to focus on image interpretation in some European countries (Hardy & Snaith, 2009). This section will discuss the knowledge of common radiographic patterns, the ability to identify pathology on images, and the associated confidence of radiographers from three public hospitals in Namibia.

The radiographers in this study had one of the three levels of qualifications acceptable for professional registration with the local Health Professions Council. These were the two-year certificate, for those registered and working as radiography assistants; the three-year diploma; and the four-year degree, for those registered and working as diagnostic radiographers. These three reflect a variation in the level of training, content covered, and core competencies that previous studies recognised as typical within and across countries (McNulty et al., 2021; McNulty et al., 2017). Currently, only one HEI is training radiographers at the degree level in Namibia, another vocational training centre that used to train radiography certificate holders in the past, ceased to do so in 2018. Furthermore, the HEI was used to train radiographers at the diploma level, which was then transformed into the current four-year degree in 2009. This accounts for most of the radiographers who were young and had a degree qualification. As previously reported, the bachelor's degree is now considered the most common entrance qualification to radiography across the globe (McNulty et al., 2021). All the radiographers in the study indicated that image interpretation was part of their training curriculum but was more theoretical than practical. The inclusion of image interpretation, likely as pattern recognition, across all three levels of qualifications, can be deemed a positive move in terms of preparing students for possible future roles in image interpretation. Similarly, a survey conducted in the UK reported that all higher education institutions in their study included image interpretation as part of both their pre-registration and post-registration training programmes (Hardy & Snaith, 2009). In the UK study, the authors reported a variation in the type of image interpretation education provided across institutions, ranging from formal lectures to a mere expectation of clinical practice. Similarly, in the current study, individuals pursuing a degree would receive formal lectures in image interpretation as part of curriculum modules, whereas those pursuing a certificate would fulfil this requirement through clinical practice. The training focus, competency developed, and assessment methods for the various qualifications are also expected to show some variation in the local context of this study, as previously reported by Hardy and Snaith in the UK. (Hardy & Snaith, 2009).

The inclusion of image interpretation content in the training programmes was considered positive; however, most of the participants (63.6%) indicated that this content was inadequate to meet clinical demands. Most of them indicated that they would need further training (93.9%) in areas such as pathology (84.8%), pattern recognition (66.7%), medical communication (54.5%), and image characteristics (51.5%). This may be due to the different levels of qualifications the participants had, which prescribed different content and outcomes, though this effect was not further assessed. Additionally, it was noteworthy that the participants made a non-specific reference to anatomy as an area requiring further training, which serves as a crucial foundation for image interpretation. Their performance during image interpretation also demonstrated an average accuracy of anatomical knowledge at 68.55%, highlighting the need for additional training and reinforcement in this area. The current finding aligns with previous studies conducted among recent graduates in Singapore and the UK. These studies revealed that although undergraduate training provides knowledge and skill acquisition in image interpretation, it may not sufficiently instil the confidence necessary for radiographers to actively participate in abnormality detection schemes (Tay & Wright, 2018; Wright & Reeves, 2017). In contrast to this finding, a recent survey across England reported that the majority of radiographers who participated in their study considered the radiographic abnormality detection training they received at the undergraduate level to be adequate (Stevens & White, 2018). As image interpretation is well formalised in England and Europe, there might be more clinical opportunities for students to participate and build their skills during training, which may significantly increase their competency and confidence upon graduation. This is different in the current study context, where image interpretation by radiographers is yet to be formally recognised, thus imposing a limitation on the clinical training of this skill. Inadequate image interpretation training was previously identified as one of the main barriers to participation in image interpretation among radiographers (Lancaster & Hardy, 2012). When undergraduate training proves inadequate to prepare graduates for roles in image interpretation, postgraduate training through various forms and modes can be pursued to further enhance radiographer competencies and meet the expectations in practice. Postgraduate training has demonstrated the ability to increase knowledge, accuracy, as well as sensitivity and specificity in image interpretation among radiographers (Del Gante et al., 2021; Møller Christensen et al., 2020; Stevens & Thompson, 2018; Tay & Wright, 2018). Internationally, postgraduate training opportunities are available for radiographers to upgrade and upskill to the required and preferred levels in order to meet the service demands. Currently, no higher education institutions in Namibia offer postgraduate training, however, some regional HEIs (within SADC) have introduced image interpretation courses for radiographers, providing a pathway through which such training can be accessed. As the evidence of clinical demand continues to grow, it can serve as motivation for the development and introduction of similar postgraduate programmes within local higher education institutions in Namibia.

5.4.1. Radiographers' knowledge of chest and appendicular pathologies

Most radiographers (70%) demonstrated an adequate level of knowledge regarding chest pathologies and their radiographic patterns. This is because the plain chest X-ray procedure is the most commonly requested and performed procedure in the three departments under study due to the high prevalence of cardio-thoracic diseases, especially tuberculosis, and their poor management in the country (Kibuule et al., 2020). Knowledge of these pathologies is considered crucial as it forms the basis for describing pathological patterns on the images. However, as common as chest procedures are, they are one of the most complex and challenging to interpret due to the wide range of densities of the anatomical structures and their inherent superimposition during two-dimensional imaging, as well as the wide range of potential pathologies (Small, 2021; Ekpo et al., 2015). Regarding appendicular pathologies, more than half of the radiographers (55%) showed adequate knowledge. This was a combination of fracture types, fracture classification, and common joint pathologies. As most of the radiographers indicated that their training was inadequate in terms of image interpretation, it was not surprising that only a few exhibited a high level of knowledge of the image patterns and pathologies. This finding aligns with a previous study conducted in Australia, which demonstrated that undergraduate training does not adequately equip graduates with the necessary knowledge and vocabulary to accurately describe pathological findings on plain appendicular images (McConnell et al., 2013). The assessment of knowledge in the current study was done by presenting a structured description of the image patterns that mimic a certain pathology in a similar way a radiographer would describe that finding, which might not have been fully covered during training. Furthermore, the assessment also took more of a theoretical approach, requiring participants to either recall theoretical knowledge covered during training or any such knowledge that was actively used in practice. The former was most likely, as there is limited image interpretation in clinical practice by radiographers in this context, thus exposing participants to potential recall bias.

Radiographers from Hospital Three showed significant differences in their knowledge of chest pathologies compared to those from Hospitals One and Two. This could possibly be attributed to the increased interaction observed between the radiologists and the radiographers at Hospital Three compared to Hospitals One and Two. This enhanced interaction might have facilitated the development of improved image interpretation vocabulary among the radiographers, potentially leading to higher scores during the knowledge assessment. Limited radiographer-radiologist interaction has been linked to poor performance in image interpretation by radiographers in a previous study in Nigeria (Ekpo et al., 2015). The radiographer's rank (senior radiographer vs.

assistant radiographer – p=0.027) and level of education (degree vs. certificate – p=0.015), which are to an extent synonymous, demonstrated a significant effect on knowledge of appendicular pathologies. This is because the duration of training and depth of content coverage are significantly different between the two qualifications, which then results in differences in knowledge of image interpretation.

5.4.2. Radiographers' Image Interpretation Competencies

Radiographers' competencies in image interpretation were grouped into three major aspects: chest, appendicular skeleton, and combined overall. For each of the groups, the ability to triage (identify normal vs. abnormal images similar to RADS) and the ability to describe (naming, location, and describing) were assessed for accuracy and sensitivity. As there were few normal images, one in each of the two sets, specificity values were not calculated for this study. The main focus of the study was to determine the abnormality detection ability of the radiographers, and the two calculated indices, accuracy, and sensitivity, will be able to demonstrate that. A radiologist's image interpretation was used as a reference for all the assessments discussed below.

Abnormality detection by radiographers is considered a form of triaging that radiographers apply daily as part of routine image assessment to classify images as normal or abnormal. In this case, it is usually done to determine the need for additional or supplementary projections to better visualise a possible abnormality or pathology (Bontrager & Lampignano, 2014). It is thus typically composed of two components: the ability to notice the deviation of an image's appearance from the expected normal appearance and the ability to pinpoint the anatomy responsible for this deviation (referred to as "location sensitivity"). Location sensitivity is a crucial element of image interpretation as it ensures that the pathology described is correctly identified on the image and not based on guesswork (Ekpo et al., 2015). Abnormality detection in this study was similar to RADS or red-dotting, where radiographers would identify an abnormality and append a red dot or star to alert the referrer but without any further explanation of the pathology (Murphy & Neep, 2018; Yates et al., 2018).

In the current study, radiographers showed a mean abnormality detection accuracy of 99.35% and an abnormality detection sensitivity of 99.28% on chest images. Both accuracy and sensitivity were very high considering the other reports in the literature. An earlier study in the UK assessing the ability of radiographers to triage radiographs using RADS reported a mean sensitivity of 78% and a specificity of 91% (Renwick et al., 1991). However, significant changes in radiographer education and practice have taken place between the time of that (1991) and the current study (2022), which may explain the difference in findings between these studies. Another study also looking at the abnormality detection ability of radiographers on chest images at a specialised cardiothoracic centre reported a much higher sensitivity of 90% and specificity of 99% after assessing pre- and post-operation chest images (Sonnex et al., 2001). As this was a specialised centre, the radiographers had increased exposure to abnormal chest images during the pre- and post-operation chest assessments, which may account for their increased awareness of chest abnormalities. The ability of radiographers to identify abnormalities in images has also been reported in other UK hospitals with a sensitivity of 88% (Brealey et al., 2006). Furthermore, a recent study in Fiji, assessing the accuracy of chest image interpretation by radiographers without any postgraduate training in image interpretation, reported a mean accuracy of 81.6% and sensitivity of 89.5% (Lata et al., 2022). The abnormality detection accuracy on the chest images by radiographers in the current study was also higher when compared to other healthcare professionals who routinely review or utilise chest images in their functions. A study among junior doctors and medical students in Australia reported an overall abnormality detection accuracy of 57.6% and 56.1%, respectively (Cheung et al., 2018). Other similar studies also showed low abnormality detection accuracy among junior doctors when interpreting chest images, citing various reasons including differences in the training curriculum, poor clinical supervision, high workload, and low confidence (Christiansen et al., 2014; Satia et al., 2013). Though this has not been evaluated in the local context, poor performance in chest image interpretation by junior doctors has been established to be a huge cross-cutting problem that may have negative consequences on patient management (Cheung et al., 2018). Thus, radiographers could assist and collaborate with the referrers to increase abnormality detection accuracy when their knowledge and skills are adequate, as previously reported in the UK (Kelly et al., 2012).

For appendicular images, radiographers in this study showed a mean abnormality detection accuracy of 90.32% and a sensitivity of 96.77%. These findings are comparable to a previous study that used 369 images to assess radiographers' ability to triage trauma radiographs in South Africa and reported an abnormality detection accuracy of 93.7% and sensitivity of 74.4% (Hlongwane & Pitcher, 2013). Another similar study reported a lower sensitivity of 80.4% among Australian radiographers when applying red dotting to appendicular images to detect the presence or absence of fractures (Brown & Leschke, 2012). In their study, a larger sample of images (3638) with a wide range of fracture types was used (Brown & Leschke, 2012) than in the current study, which used only ten appendicular images. Similarly, a recent UK study among 23 radiographers also used a bigger sample of images, totalling 762 skeletal trauma images, and reported an abnormality detection accuracy of 90% with a lower sensitivity of 72% among radiographers (Verrier et al., 2022). However, in sharp contrast to the current study findings, a Ghanaian study among eight radiographers used a sample of 30 skeletal images and reported a pre-training abnormality detection accuracy of 68.8% and a sensitivity of 69.2%, which later increased to 83.3% for both during post-training assessment (Ofori-Manteaw & Dzidzornu, 2019). The overall abnormality detection accuracy and sensitivity (combining chest and appendicular images) were 94.83% and 98.09%, respectively. The ability of radiographers to distinguish abnormal from normal image appearance is a combination of theoretical knowledge and clinical experience. Knowledge created through formalised or on-the-job training can significantly improve the performance of radiographers in image interpretation, as previously shown in the literature (Ofori-Manteaw & Dzidzornu, 2019; Stevens & Thompson, 2018; Hazell et al., 2015). Furthermore, the adoption and formalisation of image interpretation schemes in clinical practice create an opportunity for radiographers to grasp and develop relevant skills during training, as seen in countries such as the UK (Harcus & Stevens, 2023; Hewis et al., 2022). In under-resourced settings and Sub-Saharan countries such as Namibia, limited or no progress has been made towards implementation of radiographer abnormality detection schemes, and this limits the clinical exposure of students to image interpretation practice during training, which may reflect lower performances and confidence when later assessed in practice (Bwanga et al., 2020; Ohagwu et al., 2021). Furthermore, the differences in research design, radiographer sample size and characteristics, and the image sample sizes and pathology variety may explain the differences in abnormality detection accuracy and sensitivity obtained in the current study compared to other similar studies (Verrier et al., 2022; Ofori-Manteaw & Dzidzornu, 2019; Brown & Leschke, 2012). It may be hypothesised from the results that the local training programmes are providing adequate foundational knowledge of abnormality detection among the radiographers due to their higher performances, though this may need further investigation. However, the qualification of the radiographer was shown to significantly affect their abnormality detection ability ($p=0.042$), with this effect being significant between the certificate and diploma holders ($p=0.036$). The differences in training content and duration between the two qualifications were therefore significant enough to affect the abnormality detection abilities of the graduates of these programmes. Similarly, a recent study in the UK reported significant differences in pre-registration image interpretation training, which the authors assumed would reflect different levels of knowledge, skills, and confidence in clinical practice among radiography graduates (Hewis et al., 2022). Furthermore, there was a significant difference in performance between radiographers at hospitals two and three, which may reflect differences in clinical exposure, practice, and informal expectations between these hospitals.

For the abnormality location, the radiographers were asked to indicate the name of the anatomy affected by the pathology or abnormality. They showed a mean accuracy of 70.32% for chest images, 66.77% for appendicular images, and 68.55% for both sets of images. Previously, radiographers working in the public sector of an under-resourced country were reported to have a location sensitivity of 84.1% when interpreting chest images (Ekpo et al., 2015). Another study among 51 graduate radiographers in Uganda reported a location sensitivity of 88.7% during the interpretation of 50 chest images (Mubuuke et al., 2019). Education and clinical exposure are some of the significant factors that affect the ability to distinguish abnormal from normal image findings among practitioners, including radiographers (Piper & Paterson, 2009). Comprehensive knowledge of anatomy and the radiological appearance of such anatomy is needed by radiographers for accuracy in localising abnormalities. Thus, adequate foundation knowledge should be given to undergraduate students, which can then be supplemented with on-the-job training or short courses in image interpretation. Due to the complexities of the chest image, the pathology must be accurately located for it to be correctly described.

In terms of interpretation of the abnormalities on chest images, the radiographers showed a mean accuracy of 82.58% (range 60%-100%) and a mean sensitivity of 80.64% (range 55.5%-99.9%). These findings show a higher mean accuracy compared to a similar study in Fiji among radiographers without postgraduate image interpretation training, where their mean accuracy was 33.6% (Lata et al., 2022), and another study from South Africa that focused on the paediatric chest for TB diagnosis and reported a sensitivity of 47% among radiographers (Semakula-Katende et al., 2016). However, the results from the current study were comparable to those from a similar study in Nigeria, which reported a chest image interpretation accuracy of 92.3% and a sensitivity of 89.8% among the radiographers (Ohagwu et al., 2021), as well as another study from South Africa that reported a sensitivity above 80% (Gqweta, 2013). In Ghana, a sensitivity of 76.6% was reported among graduate radiographers during chest image interpretation. This variation in performance may be due to inherent differences in image interpretation training within the undergraduate programmes between the different contexts as well as non-uniform clinical exposure. The radiographers in this study had some image interpretation training during their undergraduate training, though they indicated that this was not enough. This was reflected in the results as the employment rank, based on the qualifications and experience, showed a significant difference in chest image interpretation accuracy (p=0.040) between the assistant radiographer (a certificate holder) and the junior radiographer (a degree holder). Education was previously identified as one of the barriers to the effective implementation of image interpretation among radiographers in the UK (Lancaster & Hardy, 2012). Radiographers with additional postgraduate training in image interpretation have also been shown in the literature to interpret images with high sensitivity and specificity, which is comparable to the level of the radiologist (Semakula-Katende et al., 2016; Piper et al., 2014; Woznitza et al., 2014). Radiographers in the current study showed a high level of performance in image interpretation of the chest based on the undergraduate training they received, thus clearly demonstrating a potential for the introduction of role extension into image interpretation in public sector hospitals. However, carefully crafted, and administered image interpretation content needs to be considered to significantly improve radiographer performance in chest image interpretation.

Regarding the appendicular images, the radiographers in this study had an accuracy of 82.58% and a sensitivity of 87.10% in naming the abnormality. The sensitivity was higher than what was recorded for the chest, even though the chest is the most common procedure in the department. It also cements the notion expressed by previous authors that the chest image is complex and challenging to interpret compared to other regions of the body (Mubuuke et al., 2019; Ekpo et al., 2015; Piper et al., 2014). These findings are comparable to those of a similar South African study that assessed the pre- and post-training musculoskeletal image interpretation abilities of radiographers. The authors reported a pre-training accuracy and sensitivity of 71.04% and 83.73%, which later increased to 78% and 87.28% after training, respectively (Hazell et al., 2015). Another study, again in South Africa, reported a very high accuracy of 93.7% and a bit lower sensitivity of 74.4% among radiographers interpreting trauma images after hours (Hlongwane & Pitcher, 2013). In their study, the experience was reported to be a significant factor in determining the image interpretation ability of the radiographers, an effect that was not observed in the current study. Experience, which reflects the number of years in clinical practice, increased knowledge and awareness of pathology patterns and resulted in a sensitivity of 89.7%, which was similar to that of radiologists in a previous study (Hlongwane & Pitcher, 2013). Similarly, radiographers showed higher accuracy and sensitivity (81.5% and 86.3%) when compared to junior doctors (67.8% and 68.7%) during the interpretation of acute trauma images (du Plessis & Pitcher, 2015). Other studies have also shown a higher accuracy and sensitivity for radiographers compared to nurses and casualty officers when interpreting appendicular images (Lockwood & Pittock, 2019; Ofori-Manteaw & Dzidzornu, 2019). The current study findings and those from other studies in the literature are very encouraging and supportive of a potential role for radiographers in appendicular image interpretation and show how relevant this role might be in supporting referrers. Most importantly, the current study findings are based on knowledge gained primarily through undergraduate training and supplemented by clinical practice and experience, lending confidence in the training content. Furthermore, it presents a potential window for improvement in accuracy and sensitivity through postgraduate training, both formal (through HEIs) and informal (through on-the-job training). Additional training has been previously reported to significantly improve both the accuracy and sensitivity of appendicular image interpretation by radiographers (Ofori-Manteaw & Dzidzornu, 2019; Stevens & White, 2018; Hazell et al., 2015).

In addition to knowledge and competencies, confidence is a crucial aspect that may enable radiographers to clinically practice image interpretation. Confidence is defined as the self-belief and feeling of faith in an individual's ability to do something (Lea & Bradbery, 2020). In the study context, confidence can be defined as faith in one's ability to perform image interpretation with accuracy. Radiographers in this study were asked to indicate their confidence level in abnormality detection (red dotting) and abnormality naming. The mean overall abnormality detection confidence level was 91%, with a slightly higher confidence level reported for appendicular images (92%), compared to chest images (89%). There was, however, a reduction in the confidence levels across the three domains regarding the naming of the abnormality on the images; 82% overall; 87% for appendicular images and 77% for chest images. These findings are not peculiar to the current study context but are similar to what other studies have reported in the literature. Literature has shown that radiographers report higher confidence levels regarding abnormality detection, which usually shows a decrease in abnormality naming and description. A study by Stevens and White (2018) reported that most radiographers in their study showed a high confidence level in their abnormality detection ability, which was reduced slightly when they considered their abnormality description ability. They reported a weak but statistically significant correlation between the perceived confidence level of the radiographers and their university training, as well as exposure to image interpretation in clinical practice. In Australia, the majority of radiographers in one study reported a high level of perceived self-confidence in abnormality detection, which also decreased when it came to abnormality description (Neep et al., 2014a). However, this Australian study used an online survey approach, unlike the current study, which used actual images where radiographers indicated their confidence levels in the answers that they had given. The authors also highlighted the importance of confidence building during training to facilitate the practice of image interpretation by radiographers (Neep et al., 2014a). In the current study, there was a significant difference noted in abnormality detection confidence levels between those with a certificate and those with a diploma (p=0.028). This may reflect the nature and depth of content covered during training because the two different programmes have different content and duration. A similar study in Ghana comparing the competencies and confidence levels of radiographers and doctors in image interpretation reported low confidence in abnormality detection and description among radiographers before training in image interpretation (Ofori-Manteaw & Dzidzornu, 2019). Both abnormality detection and description confidence levels increased significantly on the post-training assessment feedback, highlighting the importance of training in building confidence during image interpretation practice by radiographers (Ofori-Manteaw & Dzidzornu, 2019).

The above studies highlighted that abnormality detection and abnormality naming confidence levels seem to be significantly affected by the nature of the training the radiographers received as well as the clinical exposure that they encountered during clinical rotations. This underscores the importance of creating a comprehensive foundation during university training by providing the necessary knowledge and information regarding image interpretation, which can be further enhanced and cemented through active application in clinical practice. Adequate and comprehensive undergraduate and postgraduate training has been reported to be crucial in building the confidence needed before radiographers practice image interpretation (Stevens & White, 2018). In addition to building the necessary knowledge, skills, and competencies of image interpretation, focus and attention should also be directed towards building the necessary confidence to apply these skills in clinical practice. High image interpretation confidence has been positively associated with high image interpretation accuracy in a previous study (Neep et al., 2017). Furthermore, a lack of confidence can impede the successful implementation of image interpretation by radiographers in clinical practice (Culpan et al., 2019; Stevens & White, 2018).

The current study findings reflect high image interpretation confidence levels when compared to the image interpretation confidence levels of other healthcare professionals. A study assessing the confidence of senior dental students in the interpretation of dental radiographs reported low confidence, especially when the interpretation responsibility was solely on them (Pacheco-Pereira et al., 2019). However, there was an increase in interpretation confidence recorded following a blended learning training programme focusing on dental image interpretation (Pacheco-Pereira et al., 2019). Similarly, physiotherapists in the Bahamas were asked to indicate their confidence levels in interpreting different images from different radiology imaging modalities and indicated high confidence in interpreting conventional imaging images compared to other imaging modalities such as CT and MRI (Cato & Williams, 2021). As most of the imaging support needed by physiotherapists is plain images, it was not surprising that their confidence levels in image interpretation were very high due to repeated exposure. Routine participation in image interpretation can help build the confidence needed to participate effectively in this process, even for diagnostic radiographers. Furthermore, the increased clinical exposure contributed to an increase in the confidence levels of physiotherapists, especially those who were working in public hospital departments (Cato & Williams, 2021). In the current study, there were significant differences in abnormality detection confidence levels (p=0.033) and abnormality naming confidence levels (p=0.032) between assistant radiographers and senior radiographers, as well as junior radiographers and senior radiographers, respectively. The different employment ranks reflect differences in clinical experience and exposure, which may contribute to an increase in confidence among senior radiographers compared to junior radiographers.

5.5 Experiences of image interpretation education – the educator and student perception

The education of healthcare professionals, including radiographers, is competency-based, aiming to produce graduates capable of adapting to evolving healthcare systems and professional demands while embracing continuous education and development (Mann et al., 2018). To achieve this, most training programmes provide opportunities for students to integrate theory into practice through experiential learning as well as simulated scenarios (Naylor et al., 2015). This ensures that on graduation, the healthcare professional will have developed the necessary skills and competencies as expected by the regulatory and professional bodies as well as the industry stakeholders (Andersson et al., 2017). Image interpretation is one such skill in radiography that has developed over time and now requires graduates to develop the necessary competencies during training and complement these via continuous professional development in practice. However, this is not always possible, as evidenced by the participants' experiences in this study, due to various factors that may threaten to reduce the quality of graduates. The experiences of recent graduates and educators are essential in understanding the teaching and learning approaches as well as the clinical environment that shaped their journey. The two main themes that shaped the educators' and the graduates' experiences were the teaching and learning approaches as well as the clinical environment that presented a paradoxical reality. In this section, the experiences of recent graduates and educators will be discussed to highlight the strengths, weaknesses, and areas for improvement in the training programme.

5.5.1. Teaching and learning experiences

Teaching and learning are two critical aspects of education that define what needs to be taught and how it is taught to create an optimum environment for knowledge and skill acquisition by learners (Mukhalalati & Taylor, 2019). Teaching in higher education is prescribed by a curriculum that defines the modules and courses as well as the specific outcomes and competencies to be covered and developed respectively (Fraser & Bosanquet, 2007). It is these outcomes and competencies that prescribe the content and methods of teaching that are ideal for each module or course (Maher, 2004). The participants in this study (both educators and graduates) indicated that the content of image interpretation was inadequate regarding the depth and breadth of pathologies covered and that the teaching methods were not ideal for the expected outcomes and competencies. One of the graduates said, *"Image interpretation was not enough…" (GP4),* which was equally echoed by one of the educators who said, *"The depth of learning that the students receive was not enough" (LP4).* The alignment of teaching content and methods to curriculum outcomes is crucial to the provision of quality training to healthcare professionals and to ensure that graduates gain the necessary knowledge and skills to meet the demands of practice. In the context of image interpretation, this is an emerging and rapidly developing area of practice for radiographers, and curriculum review and updates may be warranted for the effective alignment of teaching and learning processes with the expected outcomes from the industry. Similarly, educators need to stay abreast of current trends in radiography training and keep their skills up-to-date through continuous professional development programmes which have been shown previously to be effective in building image interpretation skills (Smith et al., 2009; Mackay, 2006). This will ensure that educators can impart the relevant knowledge and skills to students, using the appropriate methods and techniques, during training. Furthermore, there is a need for investment in and adoption of modern teaching methods such as the use of image banks and online content that may increase the effectiveness of in-class teaching of clinical-related content.

Reinforcement of theoretical content and development of clinical competencies in image interpretation is achieved through a comprehensive and practice-based clinical education programme. Clinical education refers to a variety of activities designed to provide opportunities for learners to apply theoretical knowledge in performing diagnostic procedures, such as image interpretation, in a supervised setting to develop the necessary competencies (Law Insider, 2020). Participants in this study indicated, *"I think image interpretation was not tied to any practical work." (GP5),* highlighting that there was limited focus and attention on image interpretation skills and competencies development during clinical education, reducing the effectiveness of the clinical education programme in this aspect. The educators further highlighted the lack of a structured approach to teaching image interpretation during clinical practice as teaching this skill is currently incidental, and thus may result in non-uniform knowledge and skill gains among students: *“So, at the moment it's more incidental” (LP2)*. This is a reflection of the theory-to-practice gap due to limited opportunities to translate image interpretation knowledge into practical competencies (Shoghi et al., 2019). The hospital environment and the number of cases encountered during training have been reported to significantly affect the development of image interpretation skills even among radiology residents (Ravesloot et al., 2017). In the current study, the HEI had limited control over the routine operations of the clinical facilities because it only operated in partnership under a memorandum of understanding. Nonetheless, clinical training facilities should still be optimised, to facilitate image interpretation competency development among students. Although the training programme, like other healthcare programmes, aims to develop multiple competencies concurrently, it is crucial to prioritise the recognition, development, and assessment of essential clinical attributes in alignment with increasing clinical demands (Mann et al., 2018). Therefore, essential attributes of image interpretation should be included in clinical education in addition to the technical aspects of image production, which the study participants highlighted as the predominant and only focus currently.

Assessment is a key element of higher education and is meant to provide an indication of how the student has progressed in knowledge acquisition, direct the student towards self-learning and peer support, as well as provide a summary rating of the extent of knowledge acquired in line with the intended outcomes (Haider et al., 2017; Briggs et al., 2009). Assessment, therefore, provides an opportunity to check and verify that the right competencies have been developed according to the expectations. Assessment must be aligned with the teaching approach and module outcomes for it to be objective and effective. Participants expressed that the assessments were not well-aligned with the outcomes, as they were primarily classroom-oriented and lacked emphasis on practical image interpretation competencies; a graduate specifically highlighted this concern by stating, "*Assessment was through written tests and written exams in the pathology module*" *(GP5).* The assessments were mostly written examinations, which are deemed easy to administer and manage but may not be adequate for assessing hands-on skills (Humphrey-Murto et al., 2017). Though written examinations can be administered, image interpretation skills are better assessed with clinical or workplace-based examinations (Rutgers et al., 2019). There were also clinical evaluations, which are assessments designed to examine practical radiographic techniques, which included an almost insignificant component of image interpretation, as indicated by one of the educators who said, *"…and then a small section within the clinical evaluation, then just focuses on pathology" (LP2)*. As both radiographic technique and image interpretation skills are practically oriented, they should ideally be assessed similarly, and the sample of assessments should focus on the important competencies, not just the easy-to-assess ones (Humphrey-Murto et al., 2017). Objective assessments are crucial, as they can stimulate learning and improve the quality of the graduate after training (Haider et al., 2017).

5.5.2. Experiences of a paradoxical reality

Paradoxical reality is a combination of two critical words that aim to demonstrate an unusual state that is incongruent with expectations. A paradox in itself is a state or situation that is in contradiction with itself (Oxford University Press, 2021). Simplified, a paradox can refer to a situation with two opposing sides of its state. Reality, on the other hand, is the current status of things or situations at a specific point in time (McIntosh, 2013). The graduates experienced a paradoxical reality both as students during training and initially as qualified radiographers when they started working. It was clear that what the training curriculum had prepared them for was not exactly what they encountered in practice. Firstly, participants (both educators and graduates) indicated that there was limited practitioner role modelling regarding image interpretation during training. The graduates said, *"There was no opportunity for you to come and say, 'this is what I see on the image" (GP7),* while the educators said, *"…so, there's no learning taking place between radiographer and student radiographer" (LP4).* Role modelling is a common teaching method for healthcare workers that facilitates the transfer of knowledge, skills, and professional behaviour from the qualified practitioner to the student (Felstead, 2013; Cruess et al., 2008). As the practitioner did not pay attention to image interpretation, the students adopted the same norm as they mimicked and shadowed the practitioner and aimed to behave similarly to professionals (Vinales, 2015). Thus, the clinical facilities were not optimised to provide an ideal environment where students could apply their theoretical knowledge and gain both practical skills and confidence in image interpretation, as previously reported by Stevens and White (Stevens & White, 2018). However, the educators also highlighted a lack of will, skills, and competency in image interpretation among themselves and the radiographers in clinical practice as reflected in the following: *"… our radiographers actually don't care about that because they feel their primary responsibility is to produce an image" (LP2)*. This is possibly due to the belief among some radiographers that image interpretation is not their responsibility, as previously reported in the literature (Neep et al., 2014b). Furthermore, the lack of radiologists on the work floor to provide oversight and guidance in image interpretation was also noted as a barrier to teaching these skills to students. Regarding the presence of the radiologist on the floor, one of the educators said, "*Our students could greatly benefit from it when it comes to image interpretation training" (LP4).* Radiologists are the medical experts in image interpretation, and their presence and accessibility on the work floor would help the radiographers gain more practical knowledge and skills relating to image interpretation.

Additionally, there was a shift in expectations upon commencement of employment, where the graduates were now expected to use their image interpretation skills to support other healthcare professionals, especially in smaller departments where there were no radiologists. Thus, the participants were again faced with the reality that they had been inadequately prepared for during training as indicated by one of the graduates, *"Yes, the doctors usually come and ask, and I give my point of view …" (GP9)*. They suddenly realised their limitations in terms of knowledge and skills in image interpretation and that they should have covered more content during training; *"We need more training, especially in practice..." (GP1)*. In contrast, graduates in the UK, where image interpretation roles for radiographers have been formalised, show better preparedness for these clinical roles, with some minor variations in competencies (Stevens & White, 2018). There is therefore a need to review and update the training programme to ensure that it responds to local and international service needs and expectations in practice. However, undergraduate training may not be enough to build the spectrum of image interpretation competencies expected in practice, thus, continuous education and mentorship may be necessary to build comprehensive image interpretation skills (Wright & Reeves, 2017).

Furthermore, the graduates realised the need to upgrade their image interpretation knowledge and skills to match the expectations and demands in clinical departments and contribute to patient care and management. One of the graduates said, *"Yes. I would be interested in training because I feel like I'm required to do more than just producing quality x-rays, ..." (GP7).* Similarly, educators indicated that the training of radiographers at their institution is not well aligned with international trends regarding image interpretation and is not responding adequately to industry needs: *"… at the moment, we are really lagging behind with regard to image interpretation..." (LP2).* The gap in service provision and its potential impact became apparent as the graduates received requests for their opinion on image findings from the referrers, thereby presenting a paradox. Image interpretation by radiographers was therefore proving to be clinically relevant and having a potentially positive impact on patient outcomes. Although there are still restrictions on the practice of image interpretation by radiographers by the local health professions council, the environment is already creating positive pressure for its possible introduction in the near future (HPCNA, 2020). Educators also cited the restrictions by the local health regulator as potentially affecting the education and practice of image interpretation by radiographers: *"I think we are heavily crippled by policies and legal frameworks" (LP4).* There is, therefore, a need to review and analyse the regulatory framework guiding the practice of radiography in the local context and align it with professional developments, service demands, and education. However, there is a potential for radiographers' role extension into formal image interpretation, driven by increasing service and staff demands as well as the shortage of radiologists as cited in previous literature (Williams, 2006; Page et al., 2014; Piper, 1999).

5.6 Summary of Findings

The discussion has explained the findings from this study and integrated them with the literature to demonstrate how they align with existing knowledge and contribute to the body of knowledge. Based on the discussion, several findings can be drawn that contribute to the overall purpose and main question. The following table summarises the findings derived from the discussion and is based on the four sections of the conceptual framework used to analyse the findings. These findings were then taken into consideration during the modification of the image interpretation system in the subsequent chapter.

Table 5.2: Summary of Findings

Focus area	Findings
Image interpretation system design, capacity, and efficiency.	• The imaging departments in the public sector were following the medical-oriented approach, which places the radiologists in charge of both operations and image interpretation. • Radiographers in these departments were tasked with technical image production responsibilities, with limited role extension being practised. • There was a severe shortage of radiologists in public hospitals, which has had a huge effect on image interpretation. • All the departments were poorly equipped in terms of the machines and the supporting systems for imaging and image interpretation. • The image interpretation system was demarcated into conventional imaging, CT, and others. • Image interpretation was primarily reserved for CT procedures, with no conventional imaging image interpretation in all departments due to a lack of capacity.

	• There was a severe backlog of image interpretation, both for CT, conventional imaging, and other procedures, in all departments with a secondary long RTAT. • The role of the radiographer in image interpretation was not defined but could provide a possible solution.
Impact of image interpretation on patient management – a referrer's perspective.	• The current image interpretation system was rated poorly by medical doctors and was characterised by long delays and compromised patient management. • Medical doctors, including interns and medical officers, were entrusted with the responsibility of conventional imaging image interpretation as well as some CT procedures. • Image interpretation was associated with an increase in diagnostic confidence and agreement, for the CT procedures where it was consistently provided. • Most of the doctors indicated that when an image interpretation report is available, it always contributes to patient diagnosis and patient management. • The medical doctors indicated that they had inadequate image interpretation training during medical training, which was worsened by limited on-the-job support, and will need further training to be able to satisfy their image interpretation responsibilities. • Most of the medical doctors indicated that radiographers were informally participating and assisting them in image interpretation. • There was a general agreement among the doctors that the participation of radiographers in image interpretation via RADS or commenting would improve their image interpretation capacity and confidence.
Preparedness of radiographers to adopt new roles in image interpretation.	• Radiographers in the study indicated that they received image interpretation training but not to the required depth and breadth necessary in practice and, thus, will need additional training. • Most of the radiographers demonstrated average knowledge of both chest and appendicular pathologies, with those with a certificate performing much worse. • Most radiographers showed high accuracy and sensitivity in abnormality detection and naming/commenting for both the chest and appendicular images which, were affected by the level of radiography education. • There was low location accuracy and sensitivity by radiographers on both chest and appendicular images. • Radiographers had high confidence in abnormality detection, but it was slightly lower when it came to abnormality naming or commenting.

Experiences of image interpretation education – a lecturer-student perception.	• The educators and recent graduates indicated that the image interpretation content was not enough in terms of depth and breadth to meet the expectations in practice. • Both educators and recent graduates indicated that the teaching methods were not optimal for building and assessing competencies in image interpretation. • The educator and recent graduates agreed that there was a mismatch between in-class training, practical training, practice expectations and professional regulations regarding image interpretation by radiographers that needed to be aligned. • The recent graduates indicated a high interest in further studies focusing on image interpretation to alleviate radiologists shortage.

5.7. Limitations of findings

The study offered comprehensive insight into the identified problem; however, a few limitations need to be considered in the interpretation of the findings.

- The data sets for chest and appendicular images were composed of predominantly abnormal images (90%), making the calculation of specificity a challenge; thus, it was not reported in this study. However, the study reported accuracy and sensitivity, which were important indicators of competency.
- The coding of the interviews was done by the researcher, with some oversight by the supervisor. The addition of an independent coder can contribute to the thematic coding process, however, the value of this was not deemed sufficient to justify the funding required for this purpose.
- In the document review, the radiography training curriculum was not included. Upon reflection, it is evident that this could have provided valuable data, and its review should be incorporated into the implementation plan for curriculum revision.

5.8. Recommendations for further research

To continue building the evidence base that provides solutions to the image interpretation challenges, the following studies can be conducted in the same study context.

- An analytical study to measure the competencies of referring doctors on the interpretation of conventional imaging images.

- A study to measure the competencies of radiographers on the interpretation of conventional imaging images using a wide range of images in terms of quantity and abnormality and mimicking the normal-abnormal ratios in the departments.
- A detailed review of the local radiography training curriculum and the radiographer's scope of practice with benchmarking against other HEIs in the region and international trends in preparation for the advancement of role extension.

5.9. Conclusions

In conclusion, the challenges faced by public sector imaging departments in image interpretation are multifaceted and require a comprehensive approach to address. The shortage of radiologists and the non-functional support systems are significant barriers to effective image interpretation. These challenges not only impact the quality of patient care but also contribute to the dissatisfaction expressed by medical doctors regarding the current system.

One key area that needs attention is the training and education of healthcare professionals involved in image interpretation. The knowledge of radiographers in pathology indicates a need for additional training to enhance their competencies in this area. The current teaching approach and clinical education methods are not optimised for developing image interpretation skills, highlighting the need for a more tailored and effective training programme. Recent graduates in the field of radiography often feel unprepared for image interpretation roles, underscoring the importance of ongoing education and support to ensure that healthcare professionals are adequately equipped to meet the demands of their positions. By providing additional training and support, these graduates can develop the necessary skills and knowledge to positively impact patient management.

Overall, a comprehensive approach is needed to improve image interpretation in public sector imaging departments. This includes increasing the number of radiologists, improving equipment and support systems, enhancing training programmes, and providing ongoing education and support for healthcare professionals. Addressing these challenges can lead to an improvement in the quality of image interpretation, resulting in better patient management and outcomes in the public sector as will be demonstrated in the next chapter.

CHAPTER 6 : DEVELOPMENT OF A MODIFIED RADIOGRAPHIC IMAGE INTERPRETATION SYSTEM

6.1 Introduction

In this phase, a modified system was developed that allows the participation of radiographers in the process of image interpretation through the integration of their theoretical and clinical knowledge. A health system is composed of people or individuals, their actions, and organisations that are primarily focused on the promotion, restoration, and maintenance of health (WHO, 2007). In general, a health system's purpose is to improve the health outcomes of a population (Gilson, 2012). To optimise its function, a health system is composed of numerous sub-systems, such as the image interpretation system, which performs specialised functions. In this study, the image interpretation system was the system under investigation and using the results of phases one and two, the researcher modified and developed a comprehensive system that would enable radiographers to take on roles within that system. The design of this system was mainly based on the systems theory developed by Karl Ludwig von Bertalanffy (von Bertalanffy, 1968).

6.2 The fundamental principles of systems theory

A system can be defined as a self-contained unit that can function independently with its inputs and outputs as well as defined boundaries that demarcate the internal from the external environment (Mele et al., 2010). Systems theory, also known as general systems theory (GST), was the brainchild of Karl Ludwig von Bertalanffy, who was a philosopher and a biologist whose work emphasised the interconnectedness of all materials in the world (Pouvreau & Drack, 2007). Systems theory is composed of six elements that define the core principles behind the theory.

- The first principle of systems theory is that a system is an integrated whole made up of interdependent parts (Mele et al., 2010). Thus, the behaviour of parts of a system is complementary and affects other parts in some way.
- The second principle is that systems have boundaries, which distinguish them from their environment (Mele et al., 2010). The system boundary serves to define what a system can include and what it can exclude thereby distinguishing its internal from external environment (Johnson, 2019).
- The third principle is that a system can either be open or closed. An open system is considered a living system as it can interact with its environment, allowing an exchange of energy, matter, and information (von Bertalanffy, 1950; Mele et al., 2010). A closed system,

on the other hand, is self-contained and, apart from energy exchange, does not interact with its environment (Mele et al., 2010).

- The fourth principle is that a system can adjust and regulate its behaviour through feedback loops (Kast & Rosenzweig, 2017). The process by which a system receives information regarding its outputs and uses that information to modify its behaviour, either by adjusting the inputs or the process, is termed feedback.
- The fifth principle is that a system can exhibit emergent properties, which are properties that arise from the interactions of the individual parts of the system (De Wolf & Holvoet, 2005). Thus, the collective behaviour of the whole system's parts, due to their interaction, defines the emergent properties of the system.
- The sixth principle of a system is that it can be arranged in a hierarchical order, with smaller systems nesting within larger systems (Kast & Rosenzweig, 2017). Thus, a system can be viewed at different levels of analysis, with each level representing a different property or function of an organisation.

6.3 Application of systems theory in healthcare systems

Systems theory is an interdisciplinary framework that is used to study complex systems, including healthcare systems (Neuman, 2006). It is a useful tool for understanding the complex interrelationships between various multifaceted components of a healthcare system and the factors that influence its holistic functioning (Adam & De Savigny, 2012). In healthcare, especially in under-resourced settings, the application of systems theory can help address a variety of issues, such as patient safety, healthcare quality, and healthcare delivery, as it takes a more holistic approach than an isolated approach. A system in healthcare can be considered to be a collection of people, materials, processes, and technology working together to convert input into outputs in terms of service delivery (Clarkson et al., 2018). By that definition, a healthcare system is an open system, as it operates in a state of continuous interaction with its environment (Atun, 2012). Using systems theory, components of a healthcare system can be examined closely to understand how they relate to each other so as to better understand the system as a whole. Thus, the application of systems theory to healthcare can help identify areas where processes can be streamlined, communication can be improved, and quality of care can be enhanced (Adam & De Savigny, 2012). This can include identifying gaps in care, improving access to care, and developing new models of healthcare delivery that are more efficient and effective.

6.4 Medical Image interpretation as a healthcare system

The healthcare system is broad and complex and is composed of various mid- and low-level sub-systems that enable proper functioning and delivery of services to patients and clients adaptively and responsively (Sturmberg et al., 2012). The segmentation of systems allows for their proper optimisation to respond to service demands in real-time. One such sub-system is the image interpretation system which aims to provide radiological support to referrers. Image interpretation is a complex system on its own, composed of various processes and steps that are directed at supporting patient diagnosis and management. It is an important and integral part of the healthcare system because it helps to improve patient outcomes by enabling healthcare professionals to make accurate diagnoses and treatment plans. The image interpretation system is composed of six key elements: inputs, processes, outputs, the internal and external environment, as well as feedback loops defined below:

- Inputs: Inputs are the resources and materials that any system needs to function effectively and produce the desired outputs (The Open University, 2023).
- Processes: Processes are the activities that a system undertakes to transform the inputs into desired outputs (Aguilar-Savén, 2004).
- Outputs: Outputs are the results of the transformation of the inputs via different systematic processes (Cusins, 1994).
- Internal environment: The internal environment of a system is the immediate vicinity of its components that usually influence directly the performance of such a system (Twproject, 2023).
- External environment: The external environment of a system includes the elements that are outside of the system's immediate environment and control but can have a secondary impact on the nature and quality of its outputs (Houben et al., 1999).
- Feedback: The performance of a system is regulated via feedback loops that monitor the quantity and quality of the outputs and adjust the inputs and processes to maintain the desired production.

The fundamental structure of open system theory can be broken down into six key components: inputs, processes, outputs, the internal environment, and the external environment as well as feedback loops, as shown in Figure 6.1.

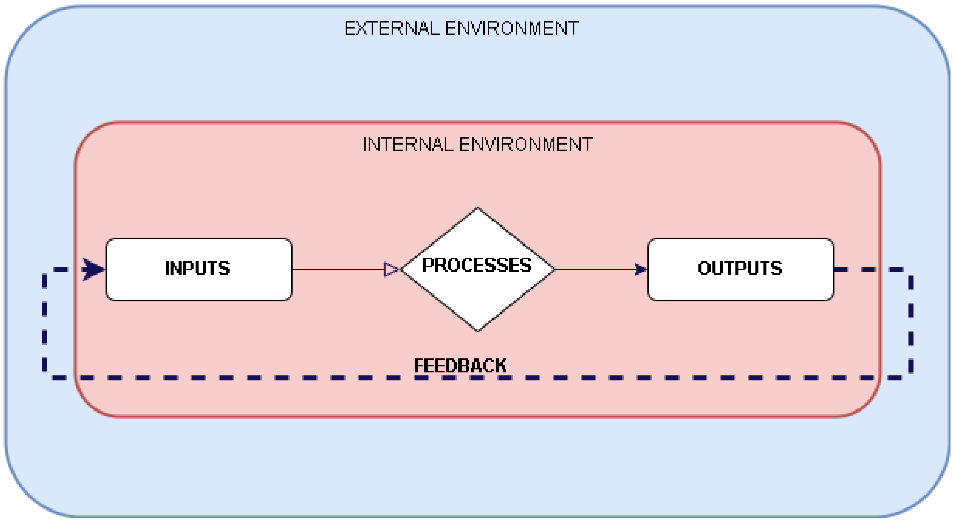

Figure 6.1: The fundamental structure of open system theory (drawn using MS Word)

The following table shows how the systems theory elements are applied to image interpretation.

Table 6.1: Image interpretation system components

Standard system component	**Image interpretation system components**
Inputs	Procedure requests Radiographers Radiologists Imaging systems
Processes	General imaging Advanced and special imaging QA image evaluation Image interpretation
Outputs	RADS PCE Written definitive image interpretation report
Internal environment	PACS RIS Support Staff SOPs
External environment	HIS Radiographer education Scope of Practice Referrers
Feedback	System Outputs User satisfaction

Inputs are the essential resources and elements that are needed for the system to function efficiently. These may include radiographers, radiologists, procedure requests, as well as the tools and equipment necessary to perform different functions in line with image interpretation. Processes are the tasks to be done that convert the inputs to outputs. This represents how radiographers' knowledge and competencies will be utilised using the tools and equipment to improve image interpretation, starting with the actual imaging, image evaluation, and image interpretation. Outputs are desired results that can be measured and will be released to the stakeholders, such as an image interpretation report. The internal environment consists of the departmental structures, processes, and definitions of radiographers' SOPs, while the external environment includes the patient referrers, the education system, and the radiographer's scope of practice, which may also affect how image interpretation is carried out. Feedback provides information about the effectiveness and efficiency of the image interpretation process from the external environment and service users leading to adjustments that may be necessary to optimise the process.

6.5 Current Image Interpretation System Status

The current status of the image interpretation system can be framed using the key components of the systems theory as established in Table 6.1 to enable system ratings across the different domains. The findings from phases one and two of this study, as well as information from the literature, were used to rate how the different aspects of the system were performing, enabling a clear identification of the areas where improvements, through modification, were necessary. Table 6.2 demonstrates the current status of the system using colour coding to depict the severity where deficiencies are evident. Green reflects components that are at their expected or optimum state, yellow is above average; orange is below expectation; and red is severe underperformance or crisis.

Inputs: In the current system, there is a high volume of imaging requests received daily spanning across all imaging modalities, which the number of radiographers is managing to satisfy as far as performing the procedure is concerned. However, for the imaging cycle to be completed, all these procedures need to be reported, and that is not possible due to capacity as there are only a few radiologists available for this purpose. Furthermore, the broken-down equipment restricts the selection of appropriate imaging tools to appropriately rule out pathology for certain patients. This adds unnecessary pressure on equipment that is still functional, such as CT, which requires more time to report. In general, the demand for imaging services on the input side is not well matched with the available capacity to ensure image interpretation is performed for all procedures.

Processes: The process is what converts the imaging requests into meaningful diagnostic guidance or support. Currently, the process is divided into two major steps: the imaging and the image interpretation components. The imaging step is subdivided into conventional imaging pathway, which is performed solely by radiographers with no radiologists' input, and advanced modality imaging, which is performed by the radiographers with active consultation of the radiologist (though not always available). The image interpretation step shows severe under-performance with no interpretation of conventional imaging and only interpretation of a few CT scans and special procedures by the radiologists. There is currently no involvement of radiographers in the image interpretation process.

Outputs: These are the diagnostic guidance and support, in various forms, that are sent back to the referrers to aid in decision-making or patient management. Currently, the outputs are only the definitive image interpretation reports of a few CT scans and special procedures produced by the radiologists. There is no red-dotting (RADS) or commenting (PCE) by radiographers.

Table 6.2:Current status of the Image interpretation system

Standard system component	**Image interpretation system components**	**Current status of the Image interpretation system**
Inputs	Procedure requests	High volumes of daily requests across different modalities
	Radiographers	Adequate to perform imaging functions
	Radiologists	Severe shortage in public hospitals
	Imaging systems	Multiple breakdowns that need replacement
Processes	General imaging	All procedures are done and finalised by the radiographers, with no radiologist consultation
	Advanced and special imaging	All procedures are done and finalised by the radiographers, with some consultation with the radiologists
	QA image evaluation	Performed by radiographers for all the procedures
	Image interpretation	This is done only for some CTs by radiologists No image interpretation for general imaging
Outputs	RADS	No formalised RADS system is in place
	PCE/Commenting	No PCE or commenting system is in place
	Definitive image interpretation report	Only approximately 30% of the CTs No conventional imaging image interpretation
Internal environment	PACS	Limited functionality
	RIS	Limited functionality
	Support Staff	Available but few to assist radiographers

	Departmental SOPs	No inclusion of image interpretation by radiographers
External environment	HIS	Non-functional
	Radiographer education	Limited image interpretation training that is insufficient to meet service demands Need further training
	Radiographers' Scope of Practice	No explicit provision is made for image interpretation by radiographers
	Referrers	Limited training in image interpretation Training and support are needed
Feedback	System Outputs User satisfaction	The image interpretation system is rated as poor Failing to cope with the demand

Internal environment: There is limited functionality of the IT systems (RIS and PACS) that are supposed to facilitate and optimise the imaging and image interpretation processes within the imaging departments. Furthermore, the current SOPs for radiographers were designed to conform to the medical-oriented structure that exists within these imaging departments. These restrict role extension and development among radiographers.

External environment: Currently, the scope of practice for radiographers and the HPCNA regulations do not explicitly mention image interpretation as one of the duties of a radiographer, although it can be implied from some of the provisions. The medical and radiography training programmes reflect some deficiencies in image interpretation training; however, radiographers showed high accuracy in the practice of RADS. There is also a HIS in place to optimise the image interpretation process and communication with the referrers.

Feedback: Currently, the feedback from users has been negative due to a lack of capacity for the system to adjust and respond to service demands.

6.6 Modification of the image interpretation system

Through the application of systems theory, there is a possibility for quality improvement as it enables a holistic view of the system and the relationship between the systemic components rather than the parts in isolation (Petula, 2005). Therefore, the image interpretation system can be improved through the application of systems theory to optimise the quantity and quality of its outputs. In line with the open system suppositions, the image interpretation system also needs to respond and adapt to external stimuli and pressure and embrace innovations and technology that support its functions. As seen in Table 6.2, the image interpretation system is composed of a combination of humans, physical materials (such as equipment), and non-physical components (such as software). The focus of this study is to modify the current system and optimise its performance through the use of radiographers, but the whole system will have to be reviewed and adjusted accordingly, in line with the holistic approach of the systems theory.

The main modification to the current image interpretation system will be the inclusion of radiographers in the process through the practice of RADS, PCE and clinical reporting. However, for this to be possible and effective, all elements of the image interpretation system listed in 6.2 will need to be adjusted to optimise the system's performance through radiographers' input. Some will have a direct effect, while others will have an indirect effect on the performance. Moreover, certain changes will be feasible for immediate implementation, while others, such as acquiring new equipment or increasing human resources, involve financial considerations that necessitate approval at the ministerial level. In Table 6.3, the researcher will present the modifications to the current system as evaluated in Table 6.2, to enable optimisation through the use of radiographers. The elements in red (severe underperformance) and orange (below expectation) are priority areas for improvement, however, those elements of the system operating above average or at optimum may also be enhanced. The proposed modifications will be presented for each element in a table along with the supporting justification for the proposed modifications. Green reflects components that are at their maximum or optimum state; yellow is above average; orange is below expectation; and red is severe underperformance or crisis.

6.6.1 System Inputs

Table 6.3 presents the proposed modifications to the image interpretation system's inputs.

Table 6.3: Proposed modifications to the system's inputs

Image interpretation system components	Current status of the Image interpretation system	Proposed System Modifications
Procedure requests	High volumes of daily requests across different modalities	Reduction in requests via appropriate training and use of imaging
Radiographers	Adequate to perform imaging functions	Increasing the number of radiographers to accommodate image interpretation
Radiologists	Severe shortage in public hospitals	Outsourcing radiologists through online platforms
Imaging systems	Multiple breakdowns that need replacement	Repair and replacement of equipment where necessary

Procedure requests	The number of imaging requests has been on the increase in general and particularly in the surveyed departments (Bushra et al., 2023). This contributes to an increase in workload for both imaging and image interpretation. A previous study in the same departments reported that most of the request forms were not properly completed and compromised the process of justification (Kuvare et al., 2022). Elsewhere, a significant number of imaging requests were found to be unjustified, especially when they were requested by inexperienced and junior doctors (Vicente-Guijarro et al., 2020; Denjagić et al., 2019; Salerno et al., 2019). Therefore, for the effective participation of radiographers in image interpretation, imaging requests should be reduced through effective justification and proper education of referrers. This will unlock additional time for radiographers to participate in image interpretation.
Radiographers	The number of radiographers needs to be increased to enable them to have enough time to participate in image interpretation. Effective image interpretation requires the radiographer to spend additional time analysing the image and making a decision on the presence or absence of an abnormality (Gao, 2020). While the department is currently managing to satisfy the imaging requests, this added task may result in a failure to meet this demand. Thus, in addition to reducing the number of requests, the number of radiographers will need to be slightly increased to cater for these additional tasks. Radiographers are readily available and present a cost-effective pathway to image interpretation, as previously reported (Hardy et al., 2016; Snaith & Hardy, 2014).
Radiologists	Efforts to increase the number of radiologists should be intensified, as there is a need for their guidance and oversight when radiographer image interpretation is implemented. Radiologists will need to be engaged for training, guidance, and monitoring, as well as for advice on difficult and challenging cases (Snaith et al., 2016). In the absence of local or regional training to meet capacity, the use of teleradiology services can be explored for this purpose (Hanna et al., 2020). Teleradiology can facilitate access to radiologists in different geographic locations, potentially enhancing the human capacity and efficiency of image interpretation (Hanna et al., 2020).

This approach will contribute to reducing turnaround time for reporting, thereby enhancing patient care and management, while also minimising associated costs (Salvi & Salvi, 2016; Kalyanpur, 2014). Furthermore, the departments should consider investing in AI models that can specifically provide interpretation assistance to radiologists, thereby reducing image interpretation times. This, in turn, will help increase capacity and reduce backlogs.

Imaging Systems

Repairing and replacing dysfunctional equipment is crucial for the success of image interpretation by radiographers. This is essential for ensuring the optimal utilisation of appropriate imaging modalities and avoiding unnecessary delays caused by congestion in modalities like conventional imaging. By appropriately distributing patients across modalities, the imaging system can be optimised, reducing pressure on the image interpretation process by radiographers. Furthermore, this approach enables cross-modality comparisons when multiple imaging techniques are applied, enhancing the image interpretation process.

6.6.2 System processes

Table 6.4 presents the proposed modifications to the image interpretation system's processes.

Table 6.4: Proposed modifications to the system's processes

Image interpretation system components	**Current status of the Image interpretation system**	**Proposed System Modifications**
General imaging	All procedures are done and finalised by the radiographers, with no image interpretation	Most procedures are done and finalised by the radiographers, with image interpretation by radiographers
Advanced and special imaging	All procedures are done and finalised by the radiographers, with some consultation with and reporting by the radiologists	All procedures are done and finalised by the radiographers, with some consultation and increased reporting by the radiologists
QA image evaluation	Performed by radiographers for all the procedures	Performed by radiographers for all the procedures

General imaging	This is the area where radiographer image interpretation will be primarily applied to improve image interpretation services within the study context. General imaging consists mainly of conventional imaging that contributed an average of 85% to the departmental workload, none of which were interpreted. The new system will see most of the conventional imaging images being interpreted by radiographers using RADS initially before transforming into PCE or commenting. Based on the study findings, radiographers in these departments showed high accuracy, sensitivity, and confidence when applying RADS compared to commenting. The implementation of RADS will enable the radiographer to increase their abnormality exposure and awareness, and this, coupled with additional training, may create the foundation to transition to PCE or commenting in the future.
Advanced imaging	Advanced imaging image interpretation will be increased and undertaken by radiologists as in the current system, as it entails a complex and deeper understanding of anatomy and pathology, especially when applied to CT. However, due to the high proportion of unreported CT scans in these departments, it may be worthwhile to have radiographers perform some image interpretation in this domain. To determine its feasibility, the capacity of CT radiographers in terms of accuracy, sensitivity, specificity, and confidence in image interpretation of defined areas will need to be evaluated. This, however, is one area that can significantly improve image interpretation by radiographers through the application of RADS, as highlighted by referrers.
Image evaluation	The production of quality radiographs is key to the accuracy and efficiency of the image interpretation process. The procedures should be optimised for pathology to enable a clear demonstration of the abnormalities during image interpretation. Poor image quality was reported as a challenge by referrers during image interpretation, which will also apply if radiographers are to perform this function. Therefore, effective QA systems must be in place to ensure high image quality, which will aid image interpretation by radiographers.

6.6.3 System outputs

Table 6.5 presents the proposed modifications to the image interpretation system's outputs.

Table 6.5: Proposed modifications to the system's outputs

Image interpretation system components	**Current status of the Image interpretation system**	**Proposed System Modifications**
RADS	No formalised RADS system is in place	A formalised RADS system is in place
PCE/Commenting	No PCE or commenting system is in place	Formalised PCE or commenting system in place for radiographers
Definitive image interpretation report	Only for approximately 30% of the CTs No conventional imaging image interpretation	Up to approximately 100% of the CTs are reported by radiographers and radiologists. Plain radiography images reported on by radiographers

RADS — RADS will be the main system output post-modification as it will be applied to the majority of the conventional imaging procedures, which are the highest contributors to imaging requests. This will be the first phase of system modification characterised by the direct involvement of radiographers in image interpretation to harness the benefits previously outlined in the literature (Murphy & Neep, 2018; Woznitza, 2014). This will primarily be the most significant change to the image interpretation system, utilising the current competencies demonstrated by the radiographers in this study and the existing regulatory framework, as this can be considered part of image evaluation. However, since the study did not include the full profile of conventional imaging images, it is also recommended that a secondary assessment be done to determine the performance of radiographers in the excluded areas. Furthermore, to enhance competency and confidence, a system of continuous professional development will be implemented simultaneously, coupled with a routine quality assurance programme that audits the image interpretation output from radiographers.

PCE/Commenting — This will be a second phase-image interpretation role that radiographers can assume in the local context, following a similar progression as previously highlighted in the literature (Stevens & Thompson, 2018; SCoR, 2016). However, due to limitations in training as reported by radiographers and educators, as well as marginally low accuracy and sensitivity shown in the practical assessment, radiographers will require additional training to meet the performance expectations for PCE or commenting output (Lockwood & Pittock, 2019). This training can be done in-house through a series of workshops and CPDs or formally through the HEI. It can also be through online platforms that have been developed with enough image banks to develop competency (Bustos et al., 2020). Training in its different forms has been shown to increase the performance of radiographers in PCE and commenting (Del Gante et al., 2021; Ofori-Manteaw & Dzidzornu, 2019; Williams et al., 2019; Hazell et al., 2015). As the advantages of PCE over RADS are well documented, the departments will need to implement the preparation for the transition to PCE simultaneously as RADS is implemented. The success of this transition, however, hinged on the positive engagement of external stakeholders such as the HEI, the Health Professions Council of Namibia, the radiologist, and the referrers. PCE as an output will mark a major step in the participation of radiographers in image interpretation in this context, with the direct benefits highlighted before in the literature (Harcus & Stevens, 2021; Thakkalpalli, 2019; Stevens & Thompson, 2018).

Definitive II Report

The image interpretation system can also be modified to enable radiographers to interpret images and produce a definitive report equivalent to that of the radiologist. This can be modality-specific but will be very beneficial in CT, where the image interpretation is considered much more complex. The participation of radiographers in clinical reporting will thus mark a huge and final phase of radiographers actively providing solutions to radiologist shortages while enhancing patient care and management. However, this is a medium- to long-term system adjustment that hinges on access to the necessary postgraduate training (some of which is now available online), the review of the regulations and scope of practice, and the appropriate definition of clinical reporting roles for the incumbent radiographers. Though medium- to long-term, the processes of gathering evidence, training, and necessary motivations and submission should be started simultaneously as RADS and PCE, as these take time to conclude.

6.6.4 System's internal environment

Table 6.6 presents the proposed modifications to the image interpretation system's internal environment.

Table 6.6: Proposed modifications to the system's internal environment

Image interpretation system components	Current status of the Image interpretation system	Proposed System Modifications
PACS	Limited functionality	Repair or replacement of the PACS
RIS	Limited functionality	Repair or replacement of the RIS
Support Staff	Available but few to assist radiographers	Additional support staff
Departmental SOPs	No inclusion of image interpretation by radiographers	Inclusion of image interpretation by radiographers

PACS and RIS

For radiographers in the imaging departments surveyed to effectively practice image interpretation, the radiology support systems and software, such as RIS and PACS, should be working optimally. Thus, these systems need to be repaired or replaced so that they can contribute to the success of the system modification. RIS will make it easier to track patients and their details within the department, while PACS will enhance record-keeping in a centralised manner that facilitates image retrieval and review. PACS also comes with an optimised viewing system, usually in the form of high-resolution monitors, which are essential for radiographers to be able to pick subtle changes in images. Image viewing equipment and monitors were reported to affect the performance of practitioners during image interpretation (Kallio-Pulkkinen et al., 2015; Kagadis et al., 2013).

Support staff

Additional support staff will be needed in the imaging department to alleviate the radiographers' excess administrative duties such as patient registration, records retrieval, and the booking and scheduling of patients for special procedures. These support staff can be general clerical staff or assistant radiographers, depending on the availability and area of need. This modification will result in radiographers having more time to focus on image interpretation for all of the conventional imaging procedures.

Departmental SoPs For radiographers to effectively participate in image interpretation, their roles to that effect must be well defined within the standard operating procedures (SoPs) of each specific department or the Ministry at large. Thus, driven by the local need, the SoPs can be developed to clearly stipulate and outline the expectations of the radiographers regarding image interpretation. This will ensure standardisation of and accountability for practice and avoid confusion among the referrers. While in its original form, RADS is voluntary, the departments can decide to make it mandatory to overcome some of the disadvantages of RADS reported in the literature (van de Venter & Friedrich-nel, 2021).

6.6.5 System's external environment

Table 6.7 presents the proposed modifications to the system's external environment.

Table 6.7: Proposed modifications to the system's external environment

Image interpretation system components	Current status of the Image interpretation system	Proposed System Modifications
HIS	Non-functional	Repair or replacement of the HIS
Radiographer education	Limited image interpretation training that is insufficient to meet service demands Need further training	Regular training of radiographers in image interpretation
Radiographers' Scope of Practice (SoP)	No explicit provision is made for image interpretation by radiographers	Inclusion of image interpretation in the radiographer's scope of practice
Referrers	Limited training in image interpretation Training and support are needed	Capacitation of referrers on image interpretation

HIS To improve the effectiveness and facilitate radiographer reporting at the three hospitals surveyed, it is recommended that the HIS be restored or replaced. This will enable easier communication and access to imaging results by referrers within the hospital. Referrers can seek immediate clarification where uncertainty exists regarding the abnormality suspected by the radiographers, allowing for immediate and active interaction that will positively impact patient care and management. It will also facilitate opportunities for active learning and continuous improvement for radiographers. However, in the absence of the HIS, radiographers can still perform their role of image interpretation, as is currently happening with radiologists; thus, the system is desired but not entirely essential.

Radiographer Edu.	To enable radiographers to participate competently and effectively in image interpretation, comprehensive training must be offered to all those willing to assume this role. In the short term, training can be provided to qualified radiographers through formal short courses, a series of workshops, or online training programmes that focus on image interpretation for conventional imaging. Secondly, in the long term, it is recommended to conduct a thorough review of the current undergraduate training programme offered by the local HEI in relation to image interpretation. This review should aim to incorporate additional content and assessments specifically focused on image interpretation, guided by industry demands and expectations. Such an update will guarantee that graduates possess the necessary knowledge and skills to effectively participate in image interpretation up to the level of the PCE. This will effectively provide a solution to conventional imaging image interpretation and align with international recommendations for image interpretation training at the undergraduate level (HCPC, 2018; SOR, 2013). Lastly, to further enable independent and definitive reporting by radiographers, it is recommended that the higher education institution (HEI) develop postgraduate programmes in image interpretation with a specific focus on modalities like CT and mammography.
Radiographer SoP	The scope of practice for radiographers as defined by the local regulator, AHPCNA, needs to be reviewed and adjusted in line with international professional trends and local service demands. This will enable radiographers to practice the three-tier system of image interpretation

	without concerns about breaching their scope of practice. Whilst radiographers can perform RADS as part of their image evaluation and patient advocacy exercise, PCE and clinical reporting require additional endorsement and acknowledgement from the AHPCNA, as was previously done in countries such as the UK (HCPC, 2018; SOR, 2013). To support this, it is important to collect evidence demonstrating the sufficiency of training and clinical competencies possessed by radiographers in image interpretation through diverse research methods within the local context. This evidence can then serve as motivation to advocate for the inclusion of various forms of image interpretation in the scope of practice for radiographers in the local context. This will provide a safety net for radiographers and help boost their confidence in clinical practice. Furthermore, the inclusion of image interpretation in the scope of practice can also facilitate effective practitioner role modelling during training, thus aiding in the preparation of students for image interpretation roles.
Referrers' training	The training of referrers is also essential for image interpretation by radiographers to be impactful. The referrers need to be able to decode the information communicated by the radiographers regarding image interpretation. For RADS, the radiographer will flag an abnormality, and the referrers should be capacitated to identify that abnormality with its differentials. A combined effort of image interpretation by radiographers and doctors has been shown to significantly improve image interpretation outcomes (Kelly et al., 2012).

6.6.6 System's feedback mechanism

Table 6.8 presents the proposed modifications to the system's feedback mechanism.

Table 6.8: Proposed modifications to the system's feedback mechanism

Image interpretation system components	**Current status of the Image interpretation system**	**Proposed System Modifications**
System Outputs	Image interpretation system rated as poor Failing to cope with the demand	Implement both internal and external feedback mechanisms to improve the system's performance

System Outputs

The outputs from the image interpretation process determine the success and effectiveness of the system. Thus, the contribution of the image interpretation system to patient diagnosis and patient management is crucial in measuring its success. The system will need to be responsive to the needs and demands of the stakeholders, who will base their actions on the outputs of the system. Internal feedback mechanisms should be in place to regulate the quality and quantity of system outputs and adjust system processes to maintain image interpretation at its peak. External feedback mechanisms should also be developed that enable direct feedback from the referrers on the image interpretation performance of the imaging departments, enabling system adjustments that maintain system outputs that meet the referrers' needs. In terms of radiographer image interpretation, an effective feedback mechanism will enable continuous learning and development and professional collaboration for the benefit of the patient.

6.7 Summarised map of stakeholders

The modifications described in the above section can be summarised by identifying the important aspects of the system they relate to. The figure below gives an outline of the key stakeholders to whom the modification will be applied in order for radiographers to participate effectively in image interpretation in the context of the study.

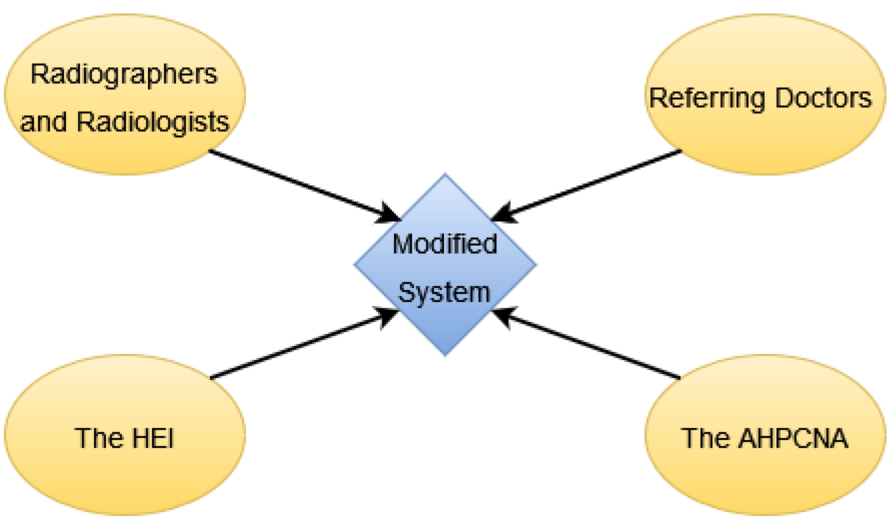

Figure 6.2: Summarised map of stakeholders

6.8 Conclusion

The modifications to the image interpretation system that are necessary to enable the effective participation of radiographers have been described in detail for all the relevant system elements. Based on their knowledge and competencies, these modifications will enable radiographers to immediately engage in the process or do so on a phased-in approach. The system theory was used as the guiding framework for the modifications aiming to optimise the system by adjusting its parts. Both practices of RADS and PCE were incorporated into the system with subsequent modifications to the support structure to ensure the sustainability of this new practice. Four key stakeholders were identified as modification pillars. These were as follows: radiographers and radiologists; medical doctors; the HEI; and the AHPCNA. These modifications will impact patient diagnosis and management as they provide a solution to the challenges highlighted by referrers. The approach to the implementation of these system modifications will be described in the next chapter.

CHAPTER 7 : IMPLEMENTATION PLAN FOR THE MODIFIED RADIOGRAPHIC IMAGE INTERPRETATION SYSTEM

7.1 Introduction

The previous chapter provided details of optimum modifications to the image interpretation system to enable the effective participation of radiographers. In this chapter, the implementation process for these proposed modifications will be discussed to guide and manage the transition process. This will enable the adoption and application of the modifications laid out in Chapter Six through the provision of a step-by-step guide. An implementation plan is crucial to enable the translation of research findings into clinical practice. It was reported previously that no matter how effective a clinical innovation is, its adoption and utilisation in practice are not guaranteed due to contextual factors (Bauer & Kirchner, 2020). The authors indicated that this has been a long-standing problem that needs to be carefully considered in the development of implementation plans that provide a roadmap for the integration of research findings into practice. In this chapter, the theoretical framework that will guide the implementation process will be discussed, and its application to the different phases will be explained.

7.2 Implementation theories

The implementation process or plan is a crucial step in the translation of research findings into practice and should be carefully planned in order to harness the desired outcomes (Fernandez et al., 2019). It is an important step that translates research investments into tangible benefits for end users and the population at large. Due to poor and ineffective implementation strategies, several research innovations are not translated into practice or remain incomplete or abandoned (Fernandez et al., 2019; Meyers et al., 2012). To mitigate this, various frameworks, theories, and models have been developed to guide and manage the implementation process ensuring the successful translation of research findings and innovations into practice. The selection and utilisation of these frameworks, theories and models are based on several factors, including the type of innovation and the context of the application. In healthcare, there are some common theories and frameworks used to guide implementation, as detailed in the table below.

Table 7.1: Common implementation theories

Theory/framework	Description	Author and year
The Diffusion of Innovations Theory	This theory describes the dissemination of new ideas or technology into a community through five stages: knowledge, persuasion, choice, execution, and confirmation.	Developed by Rogers (Rogers, 1962; Yu, 2022)
The Consolidated Framework for Implementation Research (CFIR)	This framework provides a broad view of and evaluates the factors that influence implementation success. It identifies and minimises barriers and facilitates progress.	Developed by a team of researchers (Damschroder et al., 2009)
The Promoting Action on Research Implementation in Health Services (PARiHS) Framework	The importance of three factors in successful implementation can be inferred from this theory: evidence, context, and facilitation.	Developed by a team of researchers (Kitson et al., 2008)
The Normalisation Process Theory (NPT	This model describes how new habits are embedded and become part of normal work procedures. It identifies four key elements that influence normalisation: coherence, collective action, reflexive monitoring, and cognitive participation.	Developed by Dr Carl May (May et al., 2009)
The Theory of Planned Behaviour	The proposed theory focuses on changing an individual's attitudes, subjective norms, and perceived behavioural control to influence behaviour. Therefore, it is suggested that behaviour change interventions should target these variables.	Developed by Icek Ajzen (Ajzen, 1991)

In this study, the researcher selected the Diffusion of Innovations Theory (Rogers, 1962; Yu, 2022) as the guiding theory for the implementation of the research findings.

7.3 The Diffusion of Innovations Theory

The diffusion of innovation theory is one of the commonly applied theories in implementation science that facilitates the translation of research findings into practice through a detailed explanation of how society responds to innovation (Yu, 2022; Vargo et al., 2020). The Diffusion of Innovation Theory can explain how new ideas and technologies spread throughout a population over time. It was first proposed by Everett Rogers in 1962 and has been applied in a variety of disciplines, including health care, public policy, and environmental sustainability (Greenhalgh et al., 2004). Recent research has shown the relevance of the theory to digital health and infectious diseases (Alhasan et al., 2022; Dolezel & McLeod, 2019). The theory identifies five steps in the innovation diffusion process: knowledge, persuasion, decision, implementation, and confirmation

(Rogers, 1962). Even though the steps are not always linear, the Diffusion of Innovation Theory remains a beneficial framework for analysing the complex, dynamic process of innovation diffusion and its impact on individuals, organisations, and society. The table below summarises the five steps of the diffusion of innovation theory.

Table 7.2: The Diffusion of Innovations Theory Steps

Step	Description
Knowledge	In this stage, individuals learn about innovation and the benefits it might offer. People seek information during this phase, including reading articles, attending conferences, or interviewing experts. Knowledge is critical to determining the rate of mental adoption and dissemination of innovation (Sahin & Rogers, 2006).
Persuasion	In the second stage of the diffusion of innovation theory, individuals are convinced of the value and advantages of the innovation. Persuasion may be accomplished through interpersonal communication, media exposure, or other channels. Various factors, including the source of the message and the image of credibility, can impact the effectiveness of persuasion (Bowen et al., 2012; Sahin & Rogers, 2006).
Decision	The third stage of the diffusion of innovation theory is the decision stage where individuals decide to adopt or reject the innovation. This decision is influenced by a variety of factors, including perceived benefits, compatibility with existing practices, and perceived risks. Decision-making is a complex process that involves weighing various factors and considering the potential consequences of adopting or rejecting an innovation (Dearing & Cox, 2018).
Implementation	Implementation is the fourth stage of the diffusion of innovation theory; individuals begin to put the innovation into practice at this stage. A range of factors can impact implementation, including the resources at your disposal, training and support, and perceived ease of use. According to Chiu, giving proper training and assistance to users can increase implementation success (Chiu et al., 2006).
Confirmation	The fifth and final stage of the diffusion of innovation theory is confirmation, in which individuals weigh the innovation and its outcomes. Confirmation can reinforce the choice to adopt or reject the innovation, or it can lead to a re-evaluation of the decision (Sahin & Rogers, 2006).

7.4 The implementation stage mapping

The figure below gives an outline of how the diffusion of innovation theory steps are linked and the summary of the constituencies.

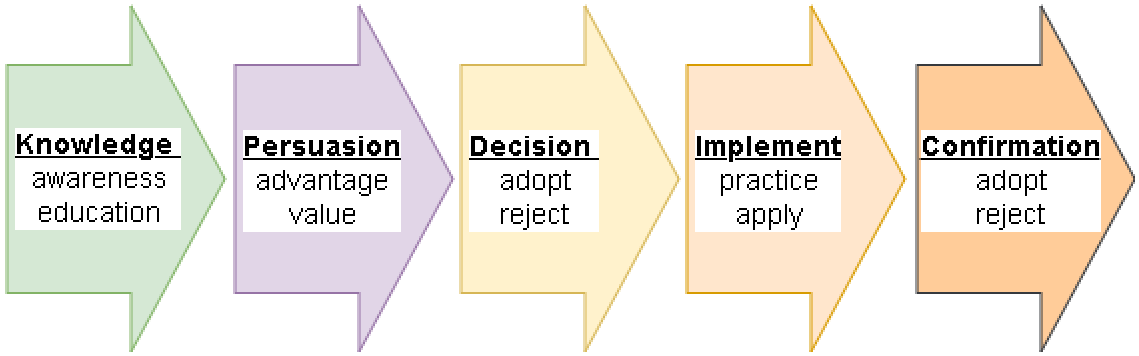

Figure 7.1: The implementation stage mapping

7.5 Implementation of the modified image interpretation system

The modified system is hinged on four pillars that define the key stakeholders in the implementation process. While some of the modifications are secondary and supportive, the primary pillars define those aspects that are crucial for the implementation of the innovation that will enable radiographers to participate in image interpretation, as discussed in the previous chapter. These pillars and critical stakeholders are as follows: 1. radiographers and radiologists; 2. referring doctors; 3. the HEI; and 4. the AHPCNA.

An adaptive phased approach will be adopted to facilitate the effective implementation and monitoring of the modified image interpretation system. This approach will also allow for continuous adjustments, improvements, and refinements in accordance with the principles of the diffusion of innovation theory (Vidgen et al., 2021). This will entail carefully planned and timed modifications of the various components of the system, allowing for feedback and feed-forward mechanisms. The phases will be applied differently for each stakeholder, as indicated below:

- Phase 1: Radiographers and Radiologists
- Phase 2: Referring doctors
- Phase 3: The higher education institution
- Phase 4: The Allied Health Professions Council of Namibia

For each of the phases, the five stages of the diffusion of innovation theory will be applied to target different components as applied to the stakeholder. The phases will be initiated and concluded in a flexible manner allowing for adaptability, and ongoing improvement throughout the implementation process. Therefore, the implementation of the phases will not necessarily follow a chronological order as indicated by their numbering, but will instead be influenced by various contextual factors, allowing for greater flexibility and adaptability. The next sections will detail the application of the diffusion of innovation stages for each of the phases.

7.5.1 Phase 1: Targeting Radiographers and Radiologists

This phase will focus on the radiographers as the primary drivers of the system modifications, as they have to practise image interpretation with the support of the radiologists. Radiographers will need to assume this role extension into image interpretation, as discussed in the previous chapter. The main outcome of this implementation phase will be the creation of knowledge and awareness up until a readiness to adopt and practice RADS and PCE as routine practices of radiography among the radiographers. Furthermore, the phase wants to create buy-in from the radiologists to provide support through training and supervision of the radiographers as they undertake RADS or PCE. The application of the five stages of diffusion of innovation theory is detailed below.

Table 7.3: Application of diffusion of innovation in Phase 1

DIT stage	Application
Knowledge	• Weekly morning or lunchtime seminars for one month to introduce RADS and PCE. • Share knowledge about what radiographer image interpretation is, including RADS and PCE. • Share knowledge about how and where RADS and PCE work, including reviewing published evidence. • Share knowledge of why it works in relation to the context and acceptable formats of communication.
Persuasion	• Select three champions per department, including the department heads, to drive and continue the reinforcement of the benefits of RADS and PCE during practice. • Champions will start experimenting with RADS and PCE to demonstrate their feasibility and benefits to the rest of the staff. • Champions will continue to allay fears and anxiety over the new expectations and practice changes.
Decision	• The decision will be guided by continuous reinforcement of the need for and benefits of RADS and PCE in the local context by selected champions.

	• Staff will decide on the adoption of RADS or volunteering for PCE training. • The decision will be guided by the trial and piloting of RADS and PCE.
Implementation	• RADS will be implemented upon the attainment of critical mass (50% acceptance). • A preliminary review will be conducted weekly for 4 weeks to assess the process and modify techniques where necessary. • Selected champions will continue to provide support and guidance. • Formal PCE training will be initiated, covering up to six months of guided training.
Confirmation	• Positive feedback regarding image interpretation is shared with the staff. • Monthly clinical meetings, facilitated by the champions, will continue to provide support. • Acceptance of RADS and PCE as routine practice in imaging departments.

7.5.2 Phase 2: Targeting the referring doctors

This implementation phase will target the referring doctors as the referrers and consumers of the image interpretation products. Any changes in the image interpretation system through the system modifications suggested in Chapter 6 will ultimately be utilised by the referring medical doctors; thus, their engagement is important at this stage. The expected outcome of this implementation phase is a reduction in imaging requests through training on proper triaging practice and risk-benefit analysis. Furthermore, the changes made in this phase will result in the doctor's ability to interpret images through training. Last but not least, the phase will also create awareness of RADS and PCE practice among radiographers and solicit input regarding the structure and effective communication channels of abnormal findings. The table below gives specific details on how the stages of the diffusion of innovation theory will be applied to produce these outcomes.

Table 7.4: Application of diffusion of innovation in Phase 2

DIT stage	**Application**
Knowledge	• Weekly morning or lunchtime seminars for one month to introduce referral protocols and effective triaging for medical imaging referrals. • Share knowledge about image interpretation challenges globally and locally, including the need for training. • Monthly CPD training sessions on image interpretation.

	• Share knowledge about RADS and PCE, including why they work and the contextual challenges and acceptable formats of communication.
Persuasion	• Select three champions per department, including the department heads, to drive and continue the reinforcement of adherence to the proper justification of imaging requests. • Champions will continue to allay fears and anxiety over the new expectations and practice changes. • Champions will start experimenting with RADS and PCE to demonstrate their benefits to the rest of the staff.
Decision	• The decision to reduce imaging referrals will be guided by the need to protect patients from radiation. • Staff will volunteer for image interpretation training to increase capacity. • The decision to utilise RADS or PCE will be supported via piloting and guidance by selected champions.
Implementation	• Image interpretation training will be implemented upon the attainment of critical mass (50% acceptance). • A preliminary review will be conducted monthly to assess image interpretation progress and provide feedback. • Champions will continue to provide support, guidance, and feedback to imaging departments through clinical meetings.
Confirmation	• Positive feedback regarding image interpretation is shared with the staff. • Monthly clinical meetings, facilitated by the champions, will continue to provide support. • Acceptance of RADS and PCE as routine outputs from imaging departments.

7.5.3 Phase 3: Targeting the Higher Education Institution

The third phase of implementation will focus on the HEI, aiming to consolidate the modifications applied in the previous phases. This will involve reinforcing the practice of image interpretation by radiographers and enhancing the training programme through the review and updating of the undergraduate curriculum. Thus, the modification in this phase targets the realignment of the curriculum for radiographer training to meet service expectations and international trends in image interpretation. This will ensure that radiographers are well-prepared for image interpretation roles in clinical practice. The specific details of the implementation process in this phase are detailed in the table below.

Table 7.5: Application of diffusion of innovation in Phase 3

DIT stage	Application
Knowledge	• Conduct a consultative meeting with the HEI and all critical stakeholders. • Present the findings from this study and the changing practice in imaging departments regarding image interpretation by radiographers. • Present evidence from other contexts regarding the effective preparation of graduates for image interpretation roles.
Persuasion	• Select an internal champion to provide more information and guidance. • Motivate a review of the curriculum to include comprehensive content on RADS and PCE. • Motivate for postgraduate programmes on image interpretation for radiographers.
Decision	• The curriculum is reviewed via active guidance by the selected champion. • Image interpretation content is adequately incorporated. • Development of postgraduate training in image interpretation by HEI.
Implementation	• The curriculum is implemented once changes are approved. • Launch of postgraduate training in image interpretation by HEI
Confirmation	• Acceptance and reinforcement of the new content through feedback from students and graduates. • Review of effectiveness through clinical meetings that include the HEI and imaging departments.

7.5.4 Phase 4: Targeting the Allied Health Professions Council of Namibia

In the fourth phase of implementing the modified system, the AHPCNA will become the primary stakeholder of interest, as they are responsible for regulating radiographic practice. This phase aims to formalise the practice of image interpretation by radiographers by including it in their scope of practice. As a result, the outcome of this phase will involve a comprehensive review and update of the regulations governing radiography practice by the AHPCNA. The evidence garnered from research and the successful implementation of the previous phases will serve as compelling motivation to support the review of the radiographers' scope of practice. The stages outlined in the diffusion of innovation theory will be applied, as outlined in the table below.

Table 7.6: Application of diffusion of innovation in Phase 4

DIT stage	Application
Knowledge	• Request and conduct a meeting with the AHPCNA and present information on image interpretation practice by radiographers globally. • Share knowledge of image interpretation challenges in the local context, including research findings. • Share knowledge on the changes in radiographer training and clinical practice in the local context regarding image interpretation.
Persuasion	• Motivate the review of regulations and scope of practice for radiographers through the education committee responsible for radiography. • Identify a champion to drive the process and supply additional information and support when needed by the AHPCNA. • Propose changes to regulations and the scope of practice that empower radiographers to partake in image interpretation.
Decision	• Guide the adoption of changes by the educational committee for radiography. • Submission and adoption of the reviewed regulations and scope of practice by the AHPCNA.
Implementation	• Formalisation of the new roles via workshops and other information dissemination platforms. • Full practice of image interpretation by radiographers.
Confirmation	• Regular audits of image interpretation practice to ensure effectiveness, enhance practice, and provide feedback to the Higher Education Institution and AHPCNA.

7.5.5 Effective feedback mechanisms

To enable sustainability and effective maintenance of the implemented system allowing radiographers to partake in image interpretation, effective feedback channels will be established as follows: the imaging department and the medical departments will have regular clinical meetings to review the performance of the systems and troubleshoot any challenges as they happen. Furthermore, joint meetings between the HEI, imaging, and medical departments will be scheduled annually to review performance and identify challenges that may require training interventions via the HEI. This will enable any change in practice or clinical developments to be factored into training and image interpretation practice by radiographers to ensure the system remains up to date with industry practice.

7.6 Conclusions

This chapter has outlined the implementation process for the system modifications that have been suggested in the previous structure to enable the effective practice of image interpretation by radiographers to support referrers and aid in alleviating the chronic shortage of radiologists in an under-resourced setting. The implementation plan for the modified system was developed based on the diffusion of innovation theory. Implementation was designed to be conducted in four phases, as follows: Phase 1: radiographers and radiologists; Phase 2: medical doctors; Phase 3: the HEI; and Phase 4: the AHPCNA. This will allow for controlled adjustments and adequate feedback. Furthermore, regular clinical and departmental meetings will be introduced to optimise system response to industry changes. These recommendations can be applied in any similar context where similar outcomes can be expected. However, implementation of the system modifications suggested in this study will not be an easy task. Implementation is a complex exercise that requires the collaboration and cooperation of the four key stakeholders covered in this chapter, through the establishment of steering committees. Thus, the success of these recommendations, or any similar effort, hinges on leadership and teamwork and the placement of the patient at the centre of these modifications.

Moreover, this chapter marks the culmination of the study's objectives, which have been successfully addressed and detailed in Chapters 5, 6, and 7. By exploring the challenges of the image interpretation system and proposing a collaborative approach that incorporates radiographers, the study has effectively addressed the main question and purpose. This knowledge significantly contributes to filling the existing gap in the literature concerning image interpretation practices within low-resource environments. Furthermore, the study underscores the efficacy of critical realism in unearthing concealed causal mechanisms underlying healthcare challenges, especially in image interpretation. It emphasizes the feasibility of exploring these challenges through a multiphase mixed-method approach, showcasing a comprehensive methodology.

CHAPTER 8 : RESEARCHER'S REFLECTION ON THE DOCTORAL JOURNEY

8.1 Introduction

Embarking on my doctoral journey, much like many others, came with its share of hurdles. The choice to pursue my doctoral studies was never an easy one, and it's something I can personally attest to. The decision was influenced by a combination of internal factors and external factors, including personal development goals, career and job demands, as well as professional aspirations. Navigating through the associated challenges demanded courage, unwavering determination, and an unyielding drive. Regardless of the motivations that fuel this pursuit, the journey was a blend of difficulties and exciting moments. As I approach completion, a remarkable transformation has indeed occurred, shaping me into a more perceptive individual armed with enhanced critical thinking skills to navigate life's complex landscapes. In this chapter, I will provide a concise overview of my journey throughout my doctoral studies.

8.2 Making the transformational decision

Deciding to pursue doctoral studies was not an overnight event for me. It was a well-calculated move resulting from months of endless thoughts about my future and career plans, a process that started almost a decade ago, in 2014. This being my second and successful attempt at getting acceptance and registering for a PhD, I would say it was a nurtured and mature decision to make at that point. Between 2014 and 2016, I prepared a proposal, albeit under the strict guidance of a mentor who was heading the project on which the proposal was to be embedded and managed to have it accepted at one of South Africa's HEIs. During the same phase, I was awarded a research scholarship that took me to the Gambia and the United Kingdom for training in research planning, execution, and management, all in preparation for the launch of my PhD. However, all the efforts were futile as the main grant expected to fund the PhD failed to come through. It was then that I made the decision to leave my home country, Zimbabwe, and joined the University of Namibia in the South West region of Africa as a lecturer in 2017. As this was a new environment, I took some time off to settle in and refocus my mind on what was feasible and practical to study within my new context. By the end of 2018, I started once again to pen down some new ideas of the possibilities until I arrived at image interpretation as the emerging future for radiography, where a gap existed that could be actively filled through research. Thus, I developed a concept and approached the Cape Peninsula University of Technology for their preliminary review of this as a potential PhD area. By mid-year 2019, the then Head of the Department wrote to me, informing me that I could submit a formal application based on the same concept paper, a process I immediately performed with full excitement and anticipation. That is the moment that marked the beginning of this journey, which was officially recognised on February 20, 2020, when I completed my registration at the Bellville Campus in Cape Town.

8.3 COVID-19 and the unforeseen delay

During the time I was registering and travelling back to Namibia, COVID-19 was starting to gain international attention, and most countries were starting to prepare for the emerging threat it presented amid a lot of uncertainty around the disease. The first few cases were then reported in South Africa and Namibia a few weeks later, triggering more panic and confusion among the people and governments on how to manage and control the spread of the infections. A few weeks later, the world went into total lockdown, which entailed most universities closing and sending students home, including CPUT. All this unfolded before I and my supervisor could have an opportunity to sit down and discuss my proposal and work out a plan for its development. Although registration had been completed, nothing much materialised for at least 5 months due to the hard lockdown imposed to try to minimise the infection rate. I was equally overwhelmed during that same period, and I'm quite sure nothing much would have materialised even if an opportunity to make some progress had been availed of. Like everyone else, I was worried about my safety and that of my family, especially now that I was in a foreign country and unable to travel. Additionally, my employer, the University of Namibia, decided to transfer to online teaching rather than closing, thus requiring all academic staff to make that transition within 14 days and resume teaching. It would have been impossible to make any meaningful progress amid all these demanding circumstances due to COVID-19. However, five months later, we managed to reinitiate contact and started the proposal development phase through online consultations and feedback from my supervisor. The process moved very well and culminated in the approval of the proposal in December 2020 and the subsequent release of the ethical clearance certificate in February 2021.

Once the ethical clearance certificate was released, it paved the way for the application for site permission through the research ethics office of the Ministry of Health and Social Services in Namibia, as the research involved three of the main hospitals in the country. This application was submitted in March 2021 with the expectation that feedback would be received in April 2021, with a normal turnaround time of 4 to 6 weeks. However, we were still at the peak of COVID-19 and normal working routines had not resumed. Most people were still working from home or working with limited staff, prioritising infection control. I, therefore, had to endure a painful wait of almost 6 months before I got my final response and approval to conduct my study at the three sites. I had to endure an additional month of waiting to get the green light from the medical superintendent of the two hospitals, while the third took almost 5 months to respond. Thus, in the aggregate, by the time I was cleared to start data collection, I had lost almost 12 months due to the delay and unforeseen effects of the COVID-19 pandemic. This was quite a toll in terms of progress and the targets I had for the completion of my studies, but it was beyond anyone's control.

8.4 Ethical impasses

Every research project, like my PhD in this instance, is only as good as the ethical principles applied to it. Thus, poor ethical conduct violates research principles and renders the study invalid and unusable. So, ethics plays a crucial role in defending the findings of a study and their scientific merit. The application of ethical principles in my study was not a big challenge as I had a good understanding of research ethics and their application from my experience as a member of one of our university's ethical review committees. This part went very smoothly for me with guidance from my supervisor, who is also a research ethics expert. The ethical applications in the proposal were well thought out. My first challenge only emerged during the application for site permission through our local Ministry of Health and Social Services, a process that took almost 7 months in total. The main ethical question I faced was: should I wait, or should I go ahead and start collecting data and rectify it later? Well, I had an ethical clearance from CPUT after all, right? The delay and its effect on my progress were mounting every day, putting pressure on me to find a workable solution. I had to keep tapping into my experience as a member of the research ethics committee to figure out what the right thing to do was in this kind of circumstance. Though I felt like I was losing precious time, I had to wait because that was the right thing to do according to ethical principles. It was an incidental test of my patience and my resolve as a researcher, and when I look back at it now, I'm happy with the decision I made.

The second ethical challenge I experienced was during the data collection process, where I had to constantly reflect and remind myself where I was in the process. There were fine lines between being the head of the department, a lecturer, and a researcher. For the different objectives that required interviews as a data collection method, I had to constantly bracket my perceptions and experiences to remain neutral and objective while limiting the effect of power over the participants. Some of the participants were fellow lecturers in the department where I was working, while others were former students whom I had also taught. However, through the bracketing process, where I would journal my thoughts and ideas before an interview, it was possible to remain objective and neutral. In addition, through member checking, summarising participants' feedback, and asking for their confirmation, the participants' experiences were captured independently of the researcher's. During data analysis, again, the same principle of bracketing was applied to ensure only the participant's experience remained prominent, in addition to horizontalization, where equal weight was applied to each participant's answer.

8.5 The blind spots and lessons leant

8.5.1 The foreign-to-foreign study-work dilemma

When I decided to study, I was in the middle of a 5-year work contract in Namibia, working as a lecturer, but my home country was Zimbabwe. At that time, my idea of a PhD was based in Zimbabwe and the initial proposal I developed and subsequently discussed with my supervisor was based in Harare, Zimbabwe. Thus, I was working in a foreign country, registered to study in another foreign country, and wanted to conduct my studies in my home country, creating a three-country paradox. During that first meeting with my supervisor, she indicated that this was going to be impossible to implement and that I should reconsider and focus on my studies where I was working. At the time, I couldn't understand why, but as time went on, it became clear that this was the best advice that enabled me to complete this thesis today. Taking COVID-19 aside, it would have been impossible to execute this study in my home country, judging from my experiences and the challenges I faced. These would have been magnified ten times, and I would have either quit or delayed completion significantly. I would thus like to appreciate the advice from my supervisor and say THANK YOU.

8.5.2 Research participant recruitment

I, like most researchers, assumed that once my ethical clearance and site permissions were granted, it would be all smooth sailing to the finish line, only to learn the hard way that this was never the case. Participant recruitment and data collection are never easy processes, nor are they under the researcher's control. It was one disappointment after another, and at one point I had to take a back seat and let the situation unfold itself due to exhaustion. The busy schedules of healthcare workers were also adding to the challenge, coupled with my rigid work schedule as well. I learned that the budgeting of time for recruitment and data collection must be as generous as possible to avoid disappointment and constant shifting of targets. My targets and milestones ended up being meaningless half the time due to circumstances beyond my control.

8.5.3 The wasted year

The path between university ethical clearance and site permission took almost a year, most of which I was just idle and not sure how to proceed. I wasn't sure whether I should be writing or if I should be waiting for the clearances to know if the study had a green light. Except for a few readings here and there, all that time went to waste. As I look back, it would have positively impacted my progress and completion had I used that time to write my first three chapters. My biggest lesson was that all supposedly free time will be paid for later. To capitalise, one needs to utilise all time productively. Having a good writing plan and sticking to it can save you pressure in the long run.

8.6 Family, Work and Study: The Tripartite Dilemma

The time that I got admission for my studies coincided with the phase where we had planned for family growth, and between 2018 and 2021, we successfully added three members to the family. This was quite a huge commitment in terms of energy and time compared to other equally competing responsibilities. This was worsened by being in a foreign country where the usual African family support is limited, thus magnifying that commitment by two to threefold. It was a very interesting and fascinating time, which, frankly, I was happy to go through. Further to this, an opportunity opened at work for a managerial post in 2021 (a year into my doctoral studies), and I applied without hesitation as I considered it a good chance for career growth. Indeed, it was a good career growth opportunity, as expected, but the energy and time commitment required were much more than I had anticipated. It took quite a toll, and it almost threatened to freeze my studies at one point. Now, after adding the family and work time and energy commitments, there was barely anything left for my studies at all. Either you are tired, or you don't have the time. All three aspects of my life were equally new, requiring me to familiarise myself and find my footing simultaneously. It was not easy, but I'm glad that I managed to weather it, though I would advise one to think about and weigh all aspects before taking on a similar challenge.

8.7 Finding the working formula – The Eureka Moment

Faced with the tripartite dilemma, I had to find a formula that would work without compromising existing commitments. I analysed my daytime schedules and tried to free up some afternoon time, but it couldn't work as there were too many ad-hoc commitments at work. The only time I could find was the night, which is already reserved for resting and replenishment of energy. Well, I had to sacrifice, as this was the only time I could be relieved of work and family commitments. Towards the end of my second year, I started taking an hour and a half of my sleep, waking up at 5 a.m., and utilising that time for my studies. It was quite amazing what I could do with that time and with set objectives. So, it quickly sank in and became a routine. However, as time went on and pressure mounted, this was no longer enough, so I started waking up at 4 a.m. to effectively harness two hours and a half before preparing for work. Again, the progress was amazing, and I quickly adapted. Fast-track it to four months before the expected completion, and I realised I wanted more and more time, but unfortunately, that time was only available during the night. I pushed back the wake-up time in the morning to 3 a.m., giving myself three and a half hours before preparing for work. This was now quite painful and proved to be unsustainable without compensation. Thus, I decided to change my bedtime from a standard 10 to 11 p.m. to effectively 8 to 9 p.m. to get at least 6 hours of sleep. Thus, my working formula was to use the early morning for my studies up to a maximum of three and a half hours before preparing for work with a significant sacrifice of evening-time activities, including social life. That worked for me but may not work for everyone. The journey will require some sacrifice, and the trick I learned a bit late is to determine what works for you as early as possible in the journey. I'm happy that I managed to find a working formula that enabled me to finish in good time.

8.8 Summary

Overall, this doctoral journey has been an amazing one. I had the opportunity to work with committed and experienced supervisors, and that lightened the road. I met with many academics and experienced researchers, including attending a wonderful writing retreat. Many aspects of personal growth were developed along the way, which may not have been examined but were transformative in the way I think and analyse life and work situations. The sacrifices and challenges I made and met were growth opportunities; I just had to remain positive and remind myself that they would come to pass. I feel I'm a better person than I was three years ago, and I'm more prepared for the challenges ahead of me, both professionally and in life.

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APPENDICES

Appendix A: Departmental data extraction form

Department code ……………   **Date**…………………. 2021

Topic: Image interpretation system for diagnostic radiography: a collaborative approach

By: Abel Karera   **Institution**: CPUT

	Data collection form					
Code	**Date of exam**	**CT number**	**Exam type**	**Status of reporting**	**Date sent for reporting**	**Date of collection of report**
1						
2						
3						
4						
5						
6						
7						
8						
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10						
11						
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14						
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16						
17						
18						
19						
20						

Appendix B: Interview Guide for HODs, Radiologists and Radiographers

Topic: Image interpretation system for diagnostic radiography: a collaborative approach

By: Abel Karera **Institution**: CPUT

Objective

To explore and describe the radiology image interpretation system within Namibia's state hospitals

Target population: Heads of Departments, Radiologists, and Radiographers

Interview number ……….

Preparation and introduction (To be completed by the researcher)

The seating arrangement will be face-face and the tape recorder turned on.

Thank you for taking the time to be interviewed and take part in this study. The interview will be about 25 to 45 minutes. As explained in the consent form, you don't need to include your name or other identifying information in your responses.

1. Demographic characteristics

Age	
Gender	
Rank	
Years of experience	
Hospital	

2. **Main question:** (To be answered by the interviewee)

Can you describe to me the image interpretation process in this department and hospital?

3. Sub questions:

a) Describe the procedures that are/are not reported in this department and why.
b) What are the challenges encountered during image interpretation in this department?
c) Do you have any suggestions to make on how the image interpretation system can be improved?
d) What roles are or can radiographers play in image interpretation?

Probing follow-up questions will be asked depending on the participant's response to clarify answers and improve understanding.

Appendix C: Research Questionnaire for Radiographers

Study topic: Image interpretation system for diagnostic radiography: a collaborative approach

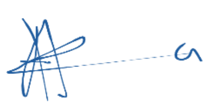
By: Abel Karera **Institution:** CPUT

Dear Radiographer

Thank you for agreeing to take part in this study. This part of the study will assess your educational background and theoretical knowledge of radiographic patterns of common radiographic pathologies of the chest and appendicular skeleton. You will be provided with various descriptions of radiographic patterns of the chest and appendicular skeleton for you to interpret and provide an answer to what they mean. The assessment is not intended to find fault in you as an individual, but to identify roles that you may be able to take in the image interpretation system as well as areas where additional training is needed. The results will contribute to the modification of the current radiology image interpretation system within state hospitals in Namibia.

You are urged to be honest and truthful so that the assessment is a true reflection of your skills and abilities.

Thank you



Abel Karera

Respondents' number ………….

SECTION A

Demographic characteristics (tick or enter response as necessary)

1. Indicate your Age (as of last birthday)………………………………………

2. Indicate your sex

Male	
Female	
Other	

3. Indicate your employment rank

Assistant radiographer	
Junior radiographer	
Senior radiographer	
Principal radiographer	
Chief radiographer	

4. Please indicate your highest Qualification

Certificate	
Diploma	
Degree	
Masters	

5. Indicate your number of years of experience to the nearest year…………………………

6. Do you have training in an area of specialisation in radiography?

Yes	
No	

7. If yes, provide the area of specialisation………………………………………………….
8. What is your primary day-day role ………………………………………………………
9. Indicate the hospital where you are appointed..……………………………………………...

SECTION B

Educational background (tick or enter response as necessary)

1. During your undergraduate training, did you cover content on pattern recognition or image evaluation to determine normal and abnormal radiographic features?

Yes	
No	

If yes to 1 above:

2. Explain how it was covered?...

3. How was it assessed/ examined? *(You can tick one or both)*

Theoretical (written tests)	
Clinical (image evaluations, OSCE)	

In your opinion:

4. Do you think the course content was adequate to build image interpretation skills for clinical practice?

Yes	
No	

5. Do you think radiography graduates need further training in image interpretation?

Yes	
No	

6. In what area of image interpretation do you think further training of radiographers is required?

Anatomy	
Pathology	
Image characteristics	
Pattern recognition	
Medical communication	

Any other ……………………………………………………………………………………

7. Did you gain additional skills in image interpretation after qualifying/during work?

Yes	
No	

8. If yes what facilitated this skills gain?

……
……………………………………………………………………………………

SECTION C Image Evaluation of the chest *(tick the correct response)*

The statements in the table relate to different radiographic appearances of the chest radiograph. Indicate by ticking, the statement you agree or disagree with.

	Statement	Disagree	Agree
1.	Soft patchy, ill-defined alveolar infiltrates or pulmonary densities indicate pneumonia		
2.	Sharp costophrenic angles on an erect chest radiograph are a sign of pleural effusion		
3.	Patchy areas of consolidation in the lower lobes of the lung indicate aspiration pneumonia		
4.	A small area of consolidation anywhere in a lung — but often in a mid or upper zone with unilateral lymph node enlargement raises the suspicion of primary PTB		
5.	Consolidation with/without cavitation and apical/posterior segments of an upper lobe involvement is typical of secondary TB		
6.	Unilateral lung nodules of varying sizes are typical of lung metastases		
7.	A normal chest radiograph does not completely rule out miliary PTB		
8.	The cardiac shadow size is affected by the difference in the depth of inspiration		
9.	Chest radiograph appearances have a definitive role in the precise assessment of heart chamber enlargement		
10.	When one dome of the diaphragm is depressed, flattened, or inverted, and the mediastinum displaced towards the opposite side coupled with radiolucency of that hemithorax it indicates tension pneumothorax		
11.	The outline of the mediastinum widens in size between middle and old age		
12.	Poor inspiration on a PA chest radiograph can cause hilar bulking and increased lower lung zone opacification		
13.	Consolidation describes the filling of the air spaces of the lung with material other than air, usually, water, pus, or blood		
14.	The side of mediastinal shift can distinguish total lung collapse from large pleural effusion		
15.	Asymmetry in lung density (blackness) may be due to patient rotation.		

SECTION D Image Evaluation for Appendicular Skeleton

For each of the terms in the first column, enter the correct number of the corresponding/correct radiographic appearance under the '**correct match**' column.

1. Fracture classification

Match the fracture classification in the first column to the radiographic appearance e.g., 7j

Radiographic appearance	**Correct match**	**Fracture classification**
1. The fractured bone fragments are closely opposed with minimal deformity		a. Complete
2. No communication between fracture and skin surface		b. Incomplete
3. The portion of the bone cortex remains intact		c. Displaced
4. There is a discontinuity between two or more bone fragments		d. Un-displaced
5. There is space between bone fragments of a fracture causing deformity		e. Closed
6. A fracture of a long bone resulting in three or more bone fragments		f. Open
7. When the articular surfaces are partly displaced but retain some contact with each other		g. Dislocated joint
8. A wound extends from the skin surface to the fracture		h. Subluxation
9. Articular surfaces are wholly displaced so that apposition between them is lost		i. Comminuted fracture

2. Joint pathologies

Match the type of joint pathology in the first column to the radiographic appearance e.g., 7j

Radiographic appearance	**Correct match**	**Type**
1. Irregular joint space narrowing with small bony spurs		a. Osteoporosis
2. Soft tissue swelling, with osteoporosis around the joint and metaphysis with possible joint space loss and erosions		b. Osteosarcoma
3. Soft tissue swelling (fusiform) around affected joints with joint space narrowing and gross deformity and subluxation		c. Osteoarthritis
4. Uniform decrease in bone density with a prominence of primary trabeculae and thinning bone cortex		d. Rheumatoid arthritis
5. A destructive lesion with a 'moth-eaten' appearance with streaks of soft tissue calcification known as the 'sunburst' appearance		e. Juvenile chronic arthritis

3. Fracture types

Match the type of fracture in the first column to the radiographic appearance e.g., 7j

Radiographic appearance	**Correct match**	**Fracture name**
1. The ulnar shaft is fractured and there is an associated dislocation of the proximal radius at the elbow.		a. Colles' fracture
2. There is a fracture of the shaft of the radius bone with dorsal displacement of the ulna at the wrist joint		b. Smith's fracture
3. There is palmar angulation of the distal radius		c. Monteggia fracture
4. There is a distal radius fracture with dorsal angulation to produce the classic dinner fork deformity		d. Galeazzi fracture
5. A thin transverse/oblique radiolucent line or fluffy callus formation without evidence of a fracture line		e. Greenstick fracture
6. A fracture where the cortex is broken on one side and buckled on the other with a bending deformity concave to the buckled side		f. Stress fracture

Thank you for your participation.

Appendix D: Radiographic image interpretation checklist

Study topic: Image interpretation system for diagnostic radiography: a collaborative approach

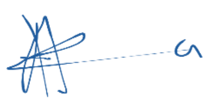
By: Abel Karera **Institution:** CPUT

Dear Radiographer

Thank you for agreeing to take part in this study. This part of the study will evaluate your clinical skills regarding image interpretation of plain radiographic images of the chest and appendicular skeleton. You will be provided with plain images of the chest and appendicular skeleton for you to evaluate and interpret so that you can provide a comprehensive description that can be used by the referring clinician. The assessment is not intended to find fault in you as an individual, but to identify roles that you may be able to take in the image interpretation system as well as areas where additional training is needed. Furthermore, it will contribute to the modification of the image interpretation system within state hospitals in Namibia. You are urged to be honest and truthful so that the assessment is a true reflection of your skills and abilities.

Don’t hesitate to contact the researcher if you need further clarification or explanation.

Thank you



Abel Karera

Respondents’ number ………….

Demographic characteristics

10. Indicate your Age (as of last birthday)………………………………………

11. Indicate your gender

Male	
Female	
Other	

12. Indicate your employment rank

Assistant radiographer	
Junior radiographer	
Senior radiographer	
Principal radiographer	
Chief radiographer	

13. Please indicate your highest Qualification

Certificate	
Diploma	
Degree	
Masters	

14. Indicate your number of years of experience to the nearest year…………………………

15. Do you have training in an area of specialisation in radiography?

Yes	
No	

16. If yes, provide the area of specialisation……………………………………………….

17. What is your primary day-day role ……………………………………………………

18. Indicate the hospital where you are working..…………………………………………..

Please evaluate the provided radiographs and complete Sections B and C, ensuring that the image number on the radiograph corresponds to the same section in the checklist.

Section B: Image Evaluation on chest radiographs *(x10 forms for each chest radiograph)*
Image B1

1. Is there an abnormality present on the radiograph?

Yes	
No	

2. How much confidence do you have in your answer to question 1?

No confidence	Slight confidence	Moderate confidence	High confidence

3. If yes to question 1, what is the possible pathology ………………………………………………………

4. How much confidence do you have in your answer to question 3?

No confidence	Slight confidence	Moderate confidence	High confidence

5. Can you describe where the pathology is present (if any) on the image in detail

………
………
………
………
………
………
…………………………………

Can you describe how the pathology is presenting (if any) on the image in detail

………
………
………
………
………
………
………
………
……………

Section C: Image Evaluation on appendicular skeleton radiographs *(x10 forms for each appendicular skeleton radiograph)*

Image C1

1. Is there an abnormality present on the radiograph?

Yes	
No	

2. How much confidence do you have in your answer to question 1?

No confidence	Slight confidence	Moderate confidence	High confidence

3. If yes to question 1, what is the possible pathology …………………………………………………

4. How much confidence do you have in your answer to question 3?

No confidence	Slight confidence	Moderate confidence	High confidence

5. Can you describe where the pathology is present (if any) on the image in detail

   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   …

6. Can you describe how the pathology is presenting (if any) on the image in detail

   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………

Appendix E: Research Questionnaire for Referring Doctors

Study topic: Image interpretation system for diagnostic radiography: a collaborative approach

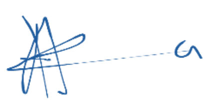
By: Abel Karera **Institution:** CPUT

Dear Doctor

Thank you for agreeing to take part in this study. This part of the study will assess the effectiveness of the radiology image interpretation systems in state hospitals. The assessment is not intended to find fault in an individual, but to identify areas where the system can be improved for optimum effectiveness and efficiency. In addition, areas that require further training and emphasis may also be identified. The results will also be used to assess areas where radiographers can take up roles within the system to improve it.

You are urged to be honest and truthful so that the assessment is a true reflection of the current effectiveness and efficiency of the radiology image interpretation system.

Thank you for your participation



Abel Karera
Contact number 0816586144
Email: akarera@unam.na / abelkarera@gmail.com

Respondents' number ………….

SECTION A

Demographic characteristics (tick or enter response as necessary)

19. Indicate your Age (as of last birthday)………………………………………

20. Indicate your gender

Male	
Female	
Other	

Employment and training

21. Indicate your employment rank

Medical Intern	
Junior Medical Officer	
Senior Medical Officer	
Consultant	

22. Please indicate your highest Qualification

MBChB or equivalent Degree	
MBChB or equivalent plus Postgraduate Diploma	
MBChB or equivalent plus Masters/MMED	

23. Indicate your number of years of experience to the nearest year…………………………

24. Do you have training in radiology image interpretation

Yes	
No	

25. If yes, provide the area of imaging…………………………………………………

26. Indicate the hospital where you are appointed………………………………………...

Section B - Diagnostic performance

1. Which of the following procedures do you request for a radiologist report (indicate by X)?

Procedure	No not at all	Yes sometimes	Yes always
a) Chest X-ray			
b) Shoulder X-ray			
c) Humerus/Elbow X-ray			
d) Forearm/hand X-ray			
e) Pelvis X-ray			
f) Femur/knee X-ray			
g) Leg/ankle/foot X-ray			
h) CT head			
i) CT chest			
j) CT abdomen			

2. Which procedures do you get a radiologist's report without requesting it (indicate by X)?

Procedure	No not at all	Yes sometimes	Yes always
a) Chest X-ray			
b) Shoulder X-ray			
c) Humerus/Elbow X-ray			
d) Forearm/hand X-ray			
e) Pelvis X-ray			
f) Femur/knee X-ray			
g) Leg/ankle/foot X-ray			
h) CT head			
i) CT chest			
j) CT abdomen			

3. Do you always agree with the radiologist's report for the following procedures (indicate by X)?

Procedure	No report is ever provided	No not at all	Yes sometimes	Yes always
k) Chest X-ray				
l) Shoulder X-ray				
m) Humerus/Elbow X-ray				
n) Forearm/hand X-ray				
o) Pelvis X-ray				
p) Femur/knee X-ray				
q) Leg/ankle/foot X-ray				
r) CT head				
s) CT chest				
t) CT abdomen				

4. Indicate how you agree with the statements below:

	No report is ever provided	No not at all	Yes sometimes	Yes always
a) The image interpretation report is on time				

Section C- Diagnostic outcome

1. For the following procedures, does an image interpretation report improve your confidence and understanding?

Procedure	No report is ever provided	No not at all	Yes sometimes	Yes always
a) Chest X-ray				
b) Shoulder X-ray				
c) Humerus/Elbow X-ray				
d) Forearm/hand X-ray				
e) Pelvis X-ray				
f) Femur/knee X-ray				
g) Leg/ankle/foot X-ray				
h) CT head				
i) CT chest				
j) CT abdomen				

2. For the following procedures, does an image interpretation report remove the need for further investigations?

Procedure	No report is ever provided	No not at all	Yes sometimes	Yes always
a) Chest X-ray				
b) Shoulder X-ray				
c) Humerus/Elbow X-ray				
d) Forearm/hand X-ray				
e) Pelvis X-ray				
f) Femur/knee X-ray				
g) Leg/ankle/foot X-ray				
h) CT head				
i) CT chest				
j) CT abdomen				

3. For the following procedures, does an image interpretation report complement other examinations?

Procedure	No report is ever provided	No not at all	Yes sometimes	Yes always
a) Chest X-ray				
b) Shoulder X-ray				
c) Humerus/Elbow X-ray				
d) Forearm/hand X-ray				
e) Pelvis X-ray				
f) Femur/knee X-ray				
g) Leg/ankle/foot X-ray				
h) CT head				
i) CT chest				
j) CT abdomen				

Section D - Overall outcomes

In general, when the image interpretation report is provided, does it:

Outcome		**No not at all**	**Yes sometimes**	**Yes always**
a) Therapeutic	Contribute to diagnosis			
	Contribute to patient management			
b) Societal	Justifies the cost of reporting			

Thank you for your participation

Appendix F: Interview Guide for Referring Doctors

Topic: Image interpretation system for diagnostic radiography: a collaborative approach

By: Abel Karera **Institution**: CPUT

Objective

To explore and describe the experience of referring doctors in state hospitals regarding the utilisation of the image interpretation system.

Target population: **Referring Doctors**

Interview number ……….

Preparation and introduction (To be completed by the researcher)

The seating arrangement will be face-face and the tape recorder turned on.

Thank you for taking the time to be interviewed and take part in this study. The interview will be about 25 to 45 minutes. As explained in the consent form, you don't need to include your name or other identifying information in your responses.

1. Demographic characteristics

Age	
Gender	
Rank	
Years of experience	
Hospital	

2. **Main question:** (To be answered by the interviewee)

What are your experiences regarding the utilisation of the image interpretation system at this hospital?

3. Sub questions:

1. Do you find it easy to interpret different types of radiographs?
2. Can you describe the challenges you encounter during the utilisation of unreported images?
3. In your opinion what areas do you require support during image interpretation?
4. Do you think preliminary clinical evaluation by radiographers can be of assistance and why?

Probing follow-up questions will be asked depending on the participants' responses to clarify answers and improve understanding.

Appendix G: Interview Guide for Lecturers

Topic: Image interpretation system for diagnostic radiography: a collaborative approach

By: Abel Karera **Institution**: CPUT

Objective

To explore and describe the perceptions and experiences of radiography educators regarding the preparedness of recent graduates to take up image interpretation roles.

Target population: Lecturers and clinical instructors

Interview number ……….

Preparation and introduction (To be completed by the researcher)

The seating arrangement will be face-face and the tape recorder turned on.

Thank you for taking the time to be interviewed and take part in this study. The interview will be about 25 to 45 minutes. As explained in the informed consent form, you don't need to include your name or other identifying information in your responses.

1. Demographic characteristics

Age	
Gender	
Rank	
Years of clinical experience	
Years of teaching experience	

2. **Main question:** (To be answered by the interviewee)

What are your experiences regarding the image interpretation skills training of graduate radiographers from your institution?

3. Sub questions:

a) Can you describe how the students are taught and assessed regarding image interpretation?
b) Can you describe how well-aligned is the curriculum with international trends in radiography with regard to image interpretation?
c) Which skills on preliminary clinical evaluation are incorporated into the program and how?
d) Can you describe how the training meets industry needs regarding image interpretation?

Appendix H: Interview Guide for recent graduates

Topic: Image interpretation system for diagnostic radiography: a collaborative approach

By: Abel Karera **Institution**: CPUT

Objective

To explore and describe the perceptions and experiences of recent graduates regarding their preparedness to take up image interpretation roles.

Target population: Recent graduates from the participating HEI

Interview number ……….

Preparation and introduction (To be completed by the researcher)

Thank you for taking the time to be interviewed and take part in this study. The interview will be about 25 to 45 minutes. As explained in the informed consent form, you don't need to include your name or other identifying information in your responses.

4. Demographic characteristics

Age	
Gender	
Rank	
Years of experience	
Hospital	

5. Main question: (To be answered by the interviewee)

What are your experiences and perceptions regarding image interpretation skills training?

6. Sub questions:

e) Can you describe how you were taught with regard to image interpretation?
f) Which skills on preliminary clinical evaluation did you cover in the program and how?
g) Can you explain how you were assessed for image interpretation competency?
h) Can you describe how you have been utilising your image interpretation skills at work and whether they meet the expectations?

Probing follow-up questions will be asked depending on the participants' responses to clarify answers and improve understanding.

Appendix I: Ethical Clearance Letters

HEALTH AND WELLNESS SCIENCES RESEARCH ETHICS COMMITTEE (HW-REC)
Registration Number NHREC: REC- 230408-014

P.O. Box 1906 • Bellville 7535 South Africa
Symphony Road Bellville 7535
Tel: +27 21 959 6917
Email: sethn@cput.ac.za

5 April 2022
REC Approval Reference No:
CPUT/HW-REC 2021/H10 (renewal)

Faculty of Health and Wellness Sciences

Dear Mr A Karera

Re: APPLICATION TO THE HW-REC FOR ETHICS CLEARANCE

Approval was granted by the Health and Wellness Sciences-REC to **Mr A Karera** for ethical clearance. This approval is for research activities related to research for **Mr A Karera** at Cape Peninsula University of Technology.

TITLE: **Image interpretation systems for diagnostic radiographers**

Supervisor: Prof P Engel-Hills

Comment:

Approval will not extend beyond 6 April 2023. An extension should be applied for 6 weeks before this expiry date should data collection and use/analysis of data, information and/or samples for this study continue beyond this date.

The investigator(s) should understand the ethical conditions under which they are authorized to carry out this study and they should be compliant to these conditions. It is required that the investigator(s) complete an **annual progress report** that should be submitted to the HWS-REC in December of that particular year, for the HWS-REC to be kept informed of the progress and of any problems you may have encountered.

Kind Regards

Carolynn Lackay
Chairperson – Research Ethics Committee
Faculty of Health and Wellness Sciences

Appendix J: Access Permission – Ministry of Health and Social Service

REPUBLIC OF NAMIBIA

MINISTRY OF HEALTH AND SOCIAL SERVICES

Ministerial Building
Harvey Street
Private Bag 13198, Windhoek

OFFICE OF THE EXECUTIVE DIRECTOR

Tel: No: 061 -203 2507
Fax No: 061-222 558
Andreas.Shipanga@mhss.gov.na

Ref: 17/3/3/AK
Enquiries: Mr. A. Shipanga

Date: 30 July 2021

Mr. Abel Karera
Private Bag 13301
Windhoek
Namibia

Dear Mr. Karera

Re: Image interpretation systems for diagnostic radiographers in Namibia.

1. Reference is made to your application to conduct the above-mentioned study.
2. The proposal has been evaluated and found to have merit.
3. **Kindly be informed that permission to conduct the study has been granted under the following conditions:**
   3.1 The data to be collected must only be used for academic purpose;
   3.2 No other data should be collected other than the data stated in the proposal;
   3.3 Stipulated ethical considerations in the protocol related to the protection of Human Subjects should be observed and adhered to, any violation thereof will lead to termination of the study at any stage;
   3.4 A quarterly report to be submitted to the Ministry's Research Unit;
   3.5 Preliminary findings to be submitted upon completion of the study;
   3.6 Final report to be submitted upon completion of the study;
   3.7 Separate permission should be sought from the Ministry for the publication of the findings.
4. All the cost implications that will result from this study will be the responsibility of the applicant and **not** of the MoHSS.

Yours sincerely,

BEN NANGOMBE
EXECUTIVE DIRECTOR

All official correspondence must be addressed to the Executive Director.

Appendix K: Hospital Permission Letter

Republic of Namibia

Ministry of Health and Social Services

Private Bag 13215 **WINDHOEK** Namibia	Intermediate Hospital Katutura Independence Avenue WINDHOEK	Telephone (061) 203 4004/5 Telefax (061) 222706

Enquiries: Dr. F. M. Shiweda

Date 27 August 2021

OFFICE OF THE MEDICAL SUPERINTENDENT

Mr. Abel Karera
Private Bag 13301
Windhoek
Namibia

Mr. A. Karera

RE: IMAGE INTERPRETATION SYSTEM FOR DIAGNOSTIC RADIOGRAPHERS IN NAMIBIA.

The above mentioned subject refers:

This office hereby grants you permission to do a research on image interpretation system for diagnostic Radiographers at Intermediate Hospital Katutura, Antenatal Clinic, Windhoek, Khomas Region, Namibia

Please provide this office with a copy of your findings.

Thank you

Yours in health,

[signature] 31 Aug 2021

DR. F. M. SHIWEDA
CHIEF MEDICAL OFFICER

MINISTRY OF HEALTH AND SOCIAL SERVICES
P/BAG 13215
31 -08- 2021
INTERMEDIATE HOSPITAL KATUTURA

Appendix L: Hospital Permission Letter

9-0/0001

REPUBLIC OF NAMIBIA

Ministry of Health and Social Services

Private Bag 13215		Tel. No. (061) 2033024
Windhoek	Harvey Street	Fax No. (061) 222886
Namibia	Windhoek	
Enquiries. Mrs. A.U. Mootu	Ref.17/3/3/AK	Date.01 September 2021

OFFICE OF THE MEDICAL SUPERINTENDENT

WINDHOEK CENTRAL HOSPITAL

Mr. Abel Karera
Cape Peninsula
University of technology
0816586144

Dear Mr. Karera

SUBJECT. PERMISSION TO CONDUCT A RESEARCH STUDY ON IMAGE INTERPRETATION SYSTEMS FOR DIAGNOSTIC RADIOGRAPHERS AT WINDHOEK CENTRAL HOSPITAL, NAMIBIA

1. Reference is made to your application to conduct the above-mentioned study.
2. This letter serves to inform you that permission has been granted for you to conduct a study on the above mentioned subject as you have requested and does not include any remuneration.

3. Patients/Clients information should be kept confidential at all times.

4. Copy of report to be submitted at Chief Medical Superintendent and Customer care office, Windhoek Central Hospital upon completion of the study.

Thank you.

Yours sincerely.

MINISTRY OF HEALTH AND SOCIAL SERVICES
Private Bag 13215
02-09-2021
Windhoek Namibia
CENTRAL HOSPITAL

DR. D. I. UIRAB
CHIEF MEDICAL SUPERINTENDENT

"Your Health, Our Concern"

Appendix M: UNAM Permission letter

SCHOOL OF ALLIED HEALTH SCIENCES
University of Namibia, Private Bag 13301, Windhoek, Namibia
Florence Nightingale Street, Windhoek North
☎ +264 61 206 3111/5071; URL.: http//www.unam.edu.na

UNAM
UNIVERSITY OF NAMIBIA

10 November 2021

RE: PERMISSION TO CONDUCT RESEARCH

Dear Mr. Abel Karera

Thank you for your interest in conducting your doctoral research on the topic of "Image Interpretation System for Diagnostic Radiographers" in the Department of Radiography. I am pleased to inform you that your research permission request has been approved.

We recognize the importance of your study and the potential impact it may have on the field of radiography. We support your efforts to advance the knowledge and skills of diagnostic radiographers in image interpretation.

Please be advised that you must comply with all ethical standards and regulations governing research at UNAM. If you require any assistance or guidance in this regard, please do not hesitate to contact me.

We wish you all the best in your research endeavours and look forward to seeing the outcomes of your study.

Sincerely yours,

Prof Cilas Wilders

Associate Dean: School of Allied Health Sciences

Appendix N: Participant Information Sheet and Consent Form

Study topic: Image interpretation system for diagnostic radiography: a collaborative approach

By: Abel Karera **Institution:** CPUT

Contact Number: +264 81 658 6144

You are being invited to take part in a research project in the fulfilment of a PhD in radiography. Please take some time to read the information presented here, which will explain the details of this project. Please ask the researcher any questions about any part of this project that you do not fully understand or would like more information about. It is very important that you are fully satisfied that you clearly understand what this research entails and how you could be involved. Also, your participation is **entirely voluntary,** and you are free to decline to participate or withdraw from the study at any point. If you decide to decline/withdraw from the study, this will not affect you negatively in any way whatsoever.

This study has been approved by the Faculty of Health and Wellness Sciences Research Ethics Committee at CPUT, and the Executive Director at the Ministry of Health and Social Service Namibia and will be conducted according to the ethical guidelines and principles of the International Declaration of Helsinki, South African Guidelines for Good Clinical Practice and Namibian National Research Ethics Guidelines.

The study aims to analyse the radiology image interpretation system in Namibia's state hospitals and to determine how this can be optimised through the possible practice of image interpretation by Namibian radiographers. The study will be conducted at three main referral hospitals in Namibia namely [redacted] as well as the [redacted]. The participants will consist of radiographers, radiologists, referring doctors and radiography lecturers. Radiographers will complete a questionnaire and evaluate radiographs while radiologists, doctors and lecturers will be interviewed. You have been invited to participate in the study because you are one of the members identified as the relevant population for this study.

If you are a radiographer, you will be asked to answer the questionnaire and checklist by yourself in an honest manner. This will take approximately 40 minutes of your time. If you are a radiologist, doctor, or lecturer you are requested to answer the interview questions honestly. The interview will take between 25 and 40 minutes. There is no immediate benefit to you for participation, but the results may contribute to improvement in the quality of imaging services. There are no physical risks expected from this study, however, psychological distress cannot be ruled out. If this happens, please notify the researcher so that supportive action can be taken.

The **researcher and supervisor** will have access to your collected data in anonymised form. You will not be required to provide your name on the questionnaire or during the interview. You will however be assigned a study code that cannot be linked to you. The collected raw data will be kept confidential in a locked office and access to it will be restricted using encryption and passwords. All interview recordings will be encrypted and stored in a password-protected laptop to ensure confidentiality. At the end of the project, the results will be reported anonymously and in aggregate form. You will not receive payment for participating in this study and there are no costs that you will incur during your participation. The study is going to benefit the radiography profession and the wider patient community in the long run through the implementation of some of the recommendations. Once the study is completed, a report of the results will be compiled, and you can request a copy by contacting the researcher.

You can contact the researcher, Abel Karera, on Tel +264 81 658 6144 or email akarera@unam.na or my supervisor, Professor Engel-Hills, by email at ENGELHILLSP@cput.ac.za if you have any further queries or encounter any problems. Alternatively, you can contact the research ethics committee secretariat, Ms Nomathemba Seth, by emailing SethN@cput.ac.za. You will receive a copy of this information and a consent form for your records.

Consent to participate in the study

I …………………………………..………… being a (please tick the appropriate box below)

Radiologist	
Doctor	
Radiographer	
Lecturer	

…agree to take part in a research study entitled: Image interpretation systems for diagnostic radiographers in Namibia.

I declare that:

a) I have read or had read to me this information and consent form and it is written in a language with which I am fluent and comfortable.

b) I have had a chance to ask questions and all my questions have been adequately answered.

c) I understand that taking part in this study is **voluntary** and I have not been pressurised to take part.

d) I may choose to leave the study at any time and will not be penalised or prejudiced in any way.

Signed at (*place*)........…........…………………on (*date*) …………...………

…………………………………   ……………………………………………………

Signature of participant   Name and Signature of witness

……………………………………………..

Signature of researcher

Consent to be recorded during the interview

I ………………………………….……… being a (please tick the appropriate box below)

Radiologist	
Doctor	
Radiographer	
Lecturer	

…agree to have the interview recorded using a voice recorder.

Signed at (*place*)........…........………………………… on (*date*) …………..…………

………………………… ………………………………………………

Signature of participant Name and Signature of witness

………………………………………

Signature of researcher

Appendix O: Correct chest abnormalities and description

Image No.	Abnormality Presence	What is the abnormality	Where is it	How is it presenting
1.	Yes	Pneumonia	Right lower lobe	Increased radiolucency
2.	Yes	Pleural effusion	Right side lung	Mild-blunted costophrenic angles
3.	Yes	Pneumothorax	Right-sided	Absence of lung markings
4.	Yes	Mass	Mediastinum	Enlarged mediastinum
5.	Yes	Air under the diaphragm	Bi-lateral below lungs	Large/severe – air under the diaphragm
6.	Yes	Pleural effusion	Right-sided	Severe-blunted costophrenic angles
7.	Yes	Miliary TB	Bilateral lungs	Severe multiple small nodules
8.	Yes	Pulmonary TB	Right lung	Moderate-sized cavity lesion
9.	Yes	Cardiomegaly	Heart	Moderate size enlargement
10.	No	Normal	Normal	Normal

Appendix P: Correct appendicular abnormalities and description

Image No.	Abnormality Presence	What is the abnormality	Where is it	How is it presenting
11.	Yes	Colles's fracture	Distal radius	Dinner fork appearance
12.	Yes	Fracture	Mid-clavicle	Moderate displacement of fracture ends
13.	Yes	Fracture / Monteggia	Proximal ulnar bone	Severe displacement with radial head dislocation
14.	Yes	Fracture	Femoral neck	Mild displacement of fracture ends
15.	Yes	Oblique fracture	Distal fibula	No displacement No joint widening
16.	Yes	Stress Fracture	Radius bone	No displacement
17.	No	Normal knee	Normal knee	Normal knee
18.	Yes	Fracture	Fifth metacarpal	Non-displaced
19.	Yes	Bone destruction /osteomyelitis	Distal tibia bone	Severe bone demineralization
20.	No	Normal foot	Normal foot	Normal foot