Radiography Observed: An Ethnographic Study Exploring Contemporary Radiographic Practice.

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Abstract

This study explores the day-to-day application of digital radiography (DR) within the X-ray environment. This study presents the voices of the radiographers' untold views, attitudes and experiences of DR through the process of observing, listening, retelling and interpreting junior and senior radiographers' responses. There were three stages to this ethnographic study. Firstly, exploring 'what radiographers did' environment by observing clinical practices. This provided 'first-hand' experience of action-in-process. Secondly, 22 semi-structured interviews were undertaken, directed by emerging themes and informal discussions from the clinical observations. Semi-structured interviews provided an understanding of the experiences, behaviours and attitudes of radiographers providing a deeper understanding of the relationship between practice and context. Thirdly, X-ray experiments were undertaken contributing to 'what had been seen and said by participants'. This data was later triangulated to support the research objectives outlined in this PhD research. Observation and interview data were analysed using thematic analysis and grouped into four overarching categories; learning, radiographer challenges, ionising radiation and patient care delivery. X-ray experimental data was inputted into SPSS and later coded. The qualitative data had numerous codes, which generated themes and could be linked in order to generate theoretical descriptions. Multiple-linear regression analysis and Pearson's Correlation provide statistically significant values ($p < 0.001$) for the experimental models contributing to 'what had been seen and said' by radiographers in the clinical environment. This thesis provides new insights into general radiographic practices using advancing technology. The conclusions that can be drawn from the empirical data is that advancing technology has impacted the day-to-day practices of diagnostic radiographers. Complex phenomena include; current knowledge and understanding, the practice of keeping doses 'as low as reasonably practicable' and impact on patient care delivery. These insights suggest that healthcare and academic environments may require additional support in the aim of delivering optimum patient care.

<u>Glossary</u>

Accident and Emergency department (A&E) - A department specialising in acute care for patients presenting without appointment. A&E departments are generally found in hospitals or other primary care centre.

Agenda for Change (AfC) – The restructure of the pay and working conditions for NHS workers putting them onto a single pay spine.

Assistant Practitioner – A member of healthcare staff who assists radiographers and radiologists with radiographic examinations during their day-today practices.

Cassette Radiography (CR) – Cassette radiography is a radiographic cassette that houses an imaging plate made of photostimulable phosphor. The image that is taken is transferred onto the computer system to be viewed.

Computed Tomography (CT) – Computed tomography is an imaging method using X-rays to produce tomographic images. It can examine body organs and structures that can be enhanced using contrast agents.

Continuing professional development (CPD) – Healthcare professionals are required to maintain their competency. CPD allows professionals to do this by attending courses, reading articles and reflecting on their clinical practice. Each radiographer should have and maintain a CPD portfolio.

Deoxyribonucleic acid (DNA) – Is a self-replicating material which is present in nearly all living organisms as the main constituent of chromosomes. It is the carrier of genetic information.

Deterministic effects – In diagnostic radiography 'deterministic effects' generally occur after high-dose acute exposure and thought to arise from the killing of large groups of cells in the tissues concerned, leading to functional deterioration in the organs affected.

Dual energy X-ray absorptiometry (DEXA) – DEXA scans are a type of scan used to diagnose osteoporosis. It is often used to assess the risk of osteoporosis developing in women aged over 50 and men aged over 60. It uses X-rays to identify low bone mineral density in order to limit the occurrence of bone fractures.

Diagnostic Radiographer – Employ a range of different imaging techniques and sophisticated equipment to produce high quality images of an injury or disease.

Digital radiography (DR) - DR captures the image of the patient directly onto a flat panel detector without the use of a cassette. This image is transferred directly onto a computer system removing the need to leave the patient and process elsewhere.

Ethnography - First pioneered in the field of socio-cultural anthropology to learn and understand cultural phenomena, which reflects the knowledge and system of means guiding the life of a cultural group.

Fluoroscopy - An image intensifier that uses X-rays producing a live image feed that is displayed on a TV screen often used in operating theatres to produce live images during surgical procedures.

General X-ray – The main part of the imaging department where plain radiographic images are carried out and the hub for organizing theatre and mobile examinations.

Hospital – Undertake many procedures managing and treating various diseases and injury and often have accident and emergency departments to deal with immediate and urgent threats to health.

Health and Care Professions Council (HCPC) - The Health and Care Professions Council (HPC) is a UK health regulator set up to protect the public. It aims to do this by setting and maintaining standards of proficiency and conduct for the professions it regulates. It currently regulates fourteen professions including Diagnostic Radiography.

Imaging Department - A department in a hospital that consists of varying imaging modalities (X-ray, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasound, Breast Screening and Radio Nuclide Imaging (RNI)).

Imaging modalities – Different methods of imaging the body, for example general radiography and computed tomography are different imaging modalities.

Inpatient – A patient admitted into hospital that has been allocated a bed.

Interprofessional learning (IPL) – Interprofessional learning allows people from different professional groups to learn with, from and about one another.

Interventional procedures – Interventional procedures, also known as vascular and interventional radiology is a medical specialty providing invasive image-guided diagnosis and treatment of diseases affecting organs within the human body. It uses ionising radiation and can be undertaken by a number or medical specialists, such as radiologists, general surgeons and cardiologists.

Ionising Radiation (Medical Exposure) Regulations 2000 (IR(ME)R 2000) - The IR(ME)R (2000) came into force on 13th May 2000 to implement the European Directive 97/43/Euratom (The Medical Exposures Directive). These regulations aim to keep doses 'as low a reasonably practicable' through correct application by X-ray operators.

Life Span Study (LSS) – The Life Span Study is a research program investigating life-long health effects based on epidemiologic studies. Its objective is to investigate the long-term effects of A-bomb radiation on causes of death and incidence of cancer.

Linear-no threshold – The linear-no threshold module (LNT) is a model used in radiation protection to quantify radiation exposure and set regulatory limits. It assumes that the long term, biological damage cause by ionising radiation is directly proportional to radiation dose thus no safe level of ionising radiation.

Magnetic Resonance Imaging (MRI) – An imaging modality that uses nuclear magnetic resonance to produce images of the molecules that makes up a substance. MRI is an alternative imaging modality used in medicine to diagnose disorders of body structures that may not show using X-rays.

Mammography – An X-ray imaging procedure using low-energy X-rays to examine the human breast and is used as both a diagnostic and screening tool.

Nuclear Medicine – Nuclear medicine involves the use of radioactive substances in the diagnosis and treatment of disease.

Out-of-hours – Outside the hours of 9-5 Monday to Friday.

Outpatient – A patient that visits the hospital from outside, normally from their own home, attending a clinic.

Picture Archiving and Communications System (PACS) – PACS uses a combination of hardware and software dedicated to the short and long term storage, retrieval, management, distribution, and presentation of medical images. Electronic images and reports are transmitted digitally via PACS; this eliminates the need to manually file, retrieve, or transport film jackets.

Practitioner – A practitioner is someone who is engaged in a specialism including medicine. Radiographers are often regarded as practitioners and are required in accordance with IR(ME)R 2000 to justify radiological examinations.

Protocol – Protocols govern the radiological examinations in the clinical environment. They provide local guidance to individual radiographers and assistant practitioners to practice in accordance with the employers' rules.

Radiobiology – A branch of science concerned with the effects of ionising radiation on biological tissues and living organisms. It is a combination of two disciplines: radiation physics and biology.

Radiographic projections – A detailed description of how to position the patient, image receptor and X-ray tube in order to achieve a diagnostic image.

Radiographic reporting – the writing of a report is performed to identify any findings from the radiographic images obtained during an imaging procedure.

Radiographic technique - The radiographic technique is delivered to ensure an optimum radiation level is given to the patient in order to obtain an image of diagnostic quality. These include the correct amount, energy, distance and collimation in order to produce the optimum radiographic technique.

Radioisotope scanning – Radioactive substances are intravenously administered to patients. A specific radioactive material targets a particular organ, releasing radioactive material. The radioactive photons are collated in aid to diagnose a pathology.

Radiologist – Doctors specially educated to utilise an array of imaging technologies to diagnose or treat disease.

Red dot system – A red dot can be placed on a radiograph by a radiographer to indicate an abnormality.

Radiotherapy – Uses high levels of radiation doses to treat cancer and other diseases.

Referring clinician (referrer) – A health care practitioner that refers the patient for a radiographic examination and completes the X-ray request form in accordance with IR(ME)R 2000.

Reflective practice – Looking (back) at ones practice and learning from it.

Reflexivity – Thinking about oneself, in terms of research this term is used when considering the role of the researcher in the research.

Society and College of Radiographers (SCoR) - The charitable subsidiary of the Society of Radiographers. The College's objectives are directed towards education, research and other activities in support of the science and practice of radiography.

Stochastic effects – Stochastic effects are the main late health effects that are expected to occur in populations exposed to ionising radiation; somatic risks dominate the overall estimate of health detriment. For somatic and genetic effects the probability of their occurrence, but not their severity, is taken to depend on the radiation dose.

Ultrasound – An imaging modality using ultrasonic frequencies to produce images of the body, commonly used to image pregnant women but can be used to treat and diagnose other disease.

Viewing area – Part of general radiography whereby staff work from and view their images. The X-ray rooms are normally joined to this area.

X-ray Operators – An individual that can undertake a radiological exposure under the supervision of a radiographic practitioner. For example assistant practitioners and students are X-ray operators that can perform radiological examinations.

X-ray tube - A vacuum tube producing X-rays through thermic emission from the cathode and accelerated towards the anode. It can be moved by the operators in various positions to image the patient.

Introduction

Purpose of PhD study

The purpose of this PhD is to explore contemporary general radiographic practices in a general imaging environment. The use of ionising radiation in medicine continues to increase with X-ray exposures remaining the largest artificial source to human beings contributing between 10% and 20% (Martin *et al,* 2009). Current estimates suggest that 4 billion procedures are performed annually worldwide (UNSCEAR, 2010). Since the discovery of ionising radiation its uses in medicine has significantly increased. Five yearly reviews continue to monitor the frequency of radiological examinations. From April 1997 to March 1998 the Health Protection Agency (HPA) (2000) assessed all types of radiological examinations undertaken in the United Kingdom (UK). The results identified that 41.5 million medical and dental X-ray examinations were conducted between 1997-1998, corresponding to 704 examinations per 1000 inhabitants. The latest results estimated that 46 million medical and dental X-ray examinations were carried out across the UK, an increase of 10 per cent since 1997 with significant increases in computed tomography (CT), interventional and mammographic examinations (HPA, 2011). In the past two decades technological advances have occurred within the radiography profession. The development of technology in general radiography has altered the collection of X-ray photons, which produces the radiographic image. The terminology is traditionally split into two categories, cassette radiography (CR) and digital radiography (DR) (Kotter and Langer, 2002), which replaced conventional X-ray film. In short, 'CR' uses a photostimulable luminescent technology to capture X-ray photons, later 'processed' into digital data whereas 'DR' uses detectors that indirectly or directly convert X-ray photons into digital data using a thin-film transistor (TFT). Throughout this thesis 'CR' and 'DR' are both used to identify the technologies within the clinical environment. These taxonomies are important to identify, firstly because of the differences in technological hardware and secondly the interchangeable use by radiographers, which can impact a patient's experience.

Advances in CR and DR were generally accepted to facilitate the reduction of ionising radiation and improve patient experience (Philips, 2013). However, little research has explored 'what radiographers do' with CR and DR units in the X-ray environment. This is important because current estimates suggest that general radiography (combined with fluoroscopy) constitute 90% of all radiological examinations undertaken in the radiology department (Health Protection Agency*,* 2011). This number is likely to increase as emergency departments in England recorded 20.5 million attendances during 2009-2010, with the large majority (19.8 million) being new rather than follow-up attendances (Hardy and Snaith, 2011). Thus with increasing demands placed upon general radiological services throughout the UK this PhD study sought to explore the general radiographic environment and the technology used (CR and DR) to explore the effects of healthcare delivery.

Evidence claims that individual X-ray doses have reduced in practice following the introduction of advanced technologies (CR and DR) (Herrmann, 2008), yet when working as a diagnostic radiographer, it was noticed that not all staff (including myself) understood the technological difference of DR (and CR) because most radiographers received minimal training as part of their radiographic education (Patefield, 2010). Carter and Veale (2010) claim that a lack of education in radiographic technology may produce instances of operator error and increase patient doses. The primary focus of this PhD work was to explore the impact of DR during a radiographers day-to-day practices within the X-ray environment.

Research questions

This PhD research explores contemporary radiographic practices using the research methodology 'ethnography'. As a practicing radiographer this research position offered a significant advantage within the clinical environment to collect detailed research data. The research questions were as followed:

1) What is the current knowledge and understanding of DR in the clinical environment?
2) What impact does advancing technology have on the delivery of patient care?
3) How effective is contemporary practice at dose and image optimisation?
4) What does this tell us about DR in contemporary radiographic practice?

The aim was to explore radiographers' clinical practices using the latest technology (DR) within the general radiography environment to develop new knowledge for practice. The first objective of this PhD study aimed to examine government policies, primary sources and research publications relating to DR, radiobiology, radiation protection and the use of DR in practice. Further research objectives developed throughout the study based on current literature in chapter two. This resulted in the exploration of a radiographers' knowledge and understanding of DR, the impact of advancing technology (CR and DR) on patient care and an examination into the optimal delivery of ionising radiation to produce images of diagnostic quality.

The rationale of this PhD study is grounded by the potential hazard patients are exposed to when undergoing radiological examinations. Ionising radiation may damage a patient's health adding to the risk of developing cancer (Hall and Giaccia, 2006). X-ray examinations differ in 'additional risk' ranging from 1 in 1,000,000 to 1 in 1,000 thus generally accepted that no safe dose exists (ICRP, 2007). Radiographic practices in the UK are governed by legislation ensuring dose optimisation by keeping doses 'as low as reasonably practicable' (ALARP) (Ionising Radiations (Medical Exposure) Regulations, 2011). The importance to optimise ionising radiation in contemporary practices is arguably a problematic one following the introduction of DR (and CR). Both DR and CR provide an alternative method to capturing X-ray photons. Conventional X-ray film would illustrate when an inappropriate radiographic exposure had been used, for example images were 'too white' or 'too black' when 'too little' or 'too much' radiation was used resulting in under or overexposure. However the International Atomic Energy Agency (IAEA) (2010) identify that DR (and CR) may always provide the operator with a 'good image' since it is able to compensate for wrong settings even if the dose is higher than necessary, thus not indicating whether a patient has been unnecessarily overexposed. This is discussed later in chapter two (section 2.4). More recently, it is argued that since operators and observers tend to favour excellent image quality a patients radiation dose may increase, thus a higher exposure than normal is selected for a particular examination, referred to as 'exposure creep' or 'dose creep' (Seeram, *et al,* 2013). This strengthens the argument that standards of radiographic procedures should, therefore, be revisited in order to ensure the optimal use and application of radiographic practices (Ween, *et al,* 2009). The rationale for this PhD study is grounded in the potential dichotomy facing radiographers in the clinical environment, because while further advances in radiographic technology (DR) may facilitate dose reduction the International Commission on Radiological Protection (2005a) argue that without appropriate research and education DR also has the potential to increase radiation doses. Thus while the application and use of DR could improve image quality and facilitate dose optimisation, this thesis explores contemporary radiographic practices in order to contribute to existing knowledge and inform radiographers during their day-to-day practices.

Chapter One: Introducing me as the researcher

Chapter one provides an insight into 'me as the researcher'. In this chapter I examine my own values and beliefs in relation to the concepts discussed within this PhD thesis. My reflections reveal that my personal and professional experiences have impacted on the values and beliefs I hold. Firstly, I discuss the impact of my father's diagnosis of throat cancer and how his illness provided an additional viewpoint of the medical imaging department. Secondly, I explore the importance of mentoring and support throughout my secondary and tertiary education, justifying the importance of support and mentoring in radiography learning. Thirdly, I explore 'self' as the healthcare professional and how my own values and beliefs were influence by workplace cultures. This chapter argues that as individuals we have our own values and beliefs that will impact on our own professional practices. Because values and beliefs may be historically laden and culturally constructed it is important to consider 'values and beliefs' as an important part of the construction of this PhD thesis.

Chapter Two: Literature Review

In chapter two an assessment of the current radiographic literature is critically discussed identifying a gap concerning the application and use of radiographic practices within a DR (and CR) environment. The review identifies little research exploring 'how radiographers conduct radiographic examinations' using DR. Historically medical practitioners and medical physicists undertook research within radiography, however as a practicing diagnostic radiographer this chapter discusses the importance of current knowledge in association with contemporary practices. Radiobiology, which informs radiation protection measures within the clinical environment are discussed providing a sound rationale ensuring that ionising radiation remains optimised. Whilst the introduction of advancing technology (CR and DR) provides the potential for dose reduction it is argued that innovative technology could be facilitating 'dose creep'. It discusses the 'technological push' and 'demand pull' theory and how this may have impacted general radiography. Person-centredness is discussed because it is generally accepted that healthcare professionals should deliver holistic care to individuals whilst being treated and cared for thus aligning themselves with the National Health Services core values and beliefs. Workplace culture is discussed because of the potential impact it can have on behaviours and actions of staff. This is important to consider within diagnostic radiography because alternate actions or behaviours may facilitate poor practice, which can then become the ‘cultural norm’. This review strengthens the importance of observing radiographic practice and best answering the research objectives. This informed the research methodology discussed in chapter three.

Chapter Three: Methodology

Chapter three discusses the research methodology undertaken within the radiographic environment(s). My epistemological and ontological viewpoint is considered describing my philosophical outlook of the research undertaken and how it supports the methodology. Ethnography as the research methodology explored a range of practices associated with DR (and CR) within the radiographic environment. It provided the tools to explore the local cultures in accordance with the research objectives inductively using participant observation, observing ‘what radiographers did’. Later semi-structured interviews were undertaken based on ‘what had been seen’ discussing topical themes that emerged from the participant observations. X-ray experiments using DR technology were performed contributing to the overall conclusions adding relevance to this PhD study and to the field of diagnostic radiography because it could be mimicked in future research. Within this chapter I discuss my dual role, as the ethnographer and radiographer termed the ‘ethno-radiographer’ highlighting the advantages and disadvantages of undertaking research within one’s own discipline. Throughout the methodology I discuss the importance of reflexivity both in and out of the research environment and how this facilitated my research position and data collection.

Chapter Four: Findings

This chapter presents the research findings collected throughout the PhD research. It portrays the cultures of radiographic practices using advanced technology. Central to the findings were the values and beliefs of radiographers. This core variable suggests that the values and beliefs of radiographers were not unified within the clinical environment, which impact on the actions and behaviours of radiographers. X-ray experiments and statistical data are illustrated contributing to the overall findings. Statistical analysis using SPSS were performed to predict increases and decreases to dose area product and correlations between dose area product and exposure indexes. The empirical findings were triangulated to provide a holistic picture of the clinical environment, which is argued to enable professional reflexivity. Rigour and validity of the empirical data uncovered is critically discussed ensuring ‘trustworthiness’ of the data later portrayed in empirical chapters.

Chapter Five: Contemporary issues effecting radiographers learning in the clinical environment.

Chapter five examines the contemporary issues surrounding radiographers’ knowledge and understanding using advancing technology. It highlights educational issues within higher education and within the clinical department and how this can be cascaded to student radiographers, hindering their clinical development. An important finding was that radiographers were often required to ‘learn on the job’, thus receiving an inappropriate level of knowledge and understanding, arguably questioning their professional competency. This chapter seeks to argue that advanced technologies could be ‘deskilling’ the radiography profession whereby radiographers may ‘know how’ to take an X-rays, but fail to ‘understand how’ it has been acquired thus failing to perform general radiographic examinations optimally.

Chapter Six: Person-centred approach: The facilitation and hindrances in general radiography

Chapter six discusses the facilitation and hindrances of patient care within the radiographic environment. The chapter examines how advancing technology can impact radiographic practice by alleviating time pressures in the clinical environment. On the one hand this chapter highlights that patients may be pleased with the ‘speed’ of their radiological examinations within the clinical environment, yet on the other hand DR raises professional challenges for some radiographers with anxious patients seeking an immediate diagnosis due to the instant image display. The empirical data from the participants suggests that the DR environment may resemble that of an industrial environment with radiographers concerned about the time pressures and the importance DR plays in this process, resulting in a lack of person-centredness amongst radiographers. This chapter provides a comparative insight into the dual use of CR and DR technology, which can enhance the patients experience during radiographic examinations.

Chapter Seven: Radiography Observed: Optimising ionising radiation

Chapter seven examines current issues impacting the optimisation of ionising radiation within the clinical environment. It highlights the actions and behaviours of radiographers that are attributing to the known phenomenon 'dose creep'. There is a discussion surrounding radiography as an 'art and science', which suggests a review of the terms used in diagnostic radiography and how it may help combat 'dose creep' through critical reflection. This chapter suggests that the use of DR may facilitate new radiographic errors, and near misses in comparison with CR. Additionally, a subculture of 'radiological myths' may be attributing to an increase in patient dose but until now were kept 'hidden' within the clinical environment.

Limitations to this PhD Research

The limitations of this PhD work are outlined in this section of the thesis. It highlights some important weaknesses inherent throughout this PhD research and thus important for readers and prospective researchers to consider. A central component of this PhD research was the researcher in the clinical field. Experiences are discussed that arguably impacted both researcher and participants upon data collection. The limitations provide an original illustration of the data collection methods employed across the multi-sites explored in this PhD work.

Chapter Eight: Conclusions

This concluding chapter evaluates the main findings of the PhD study undertaken. The empirical evidence is discussed and concluded in three broad areas, radiographer learning, delivery of patient care and the optimisation of ionising radiation. Each section aims to provide sound conclusions based on the empirical evidence derived from the research methodology. The impact of the latest innovative technology (DR) is discussed because although advancing technologies are generally accepted to facilitate healthcare, it is argued that this may be hindering the delivery of radiographic practice. The value of ethnography as a research methodology is discussed highlighting how it may facilitate future radiographic research and research in other health disciplines. The discussions in this concluding chapter provide an original outlook of radiographic practice in contemporary healthcare that contributes to existing knowledge with an aim of delivering optimum patient care.

Recommendations

Recommendations are outlined in this section following the PhD research conclusions. The recommendations are directly linked to the findings uncovered in this thesis and are offered to radiology managers, educators/researchers and diagnostic radiographers.

The Radiographic Environment

Diagnostic radiographers provide a wide range of imaging procedures to patients, including general imaging, computed tomography (CT), dual energy X-ray absorptiometry (DEXA) bone density, mammography, magnetic resonance imaging (MRI), radioisotope scanning and ultrasound imaging, each employing a range of techniques providing images of diagnostic quality. This PhD study explores general radiographic practices in the clinical environment. The development of CR and DR technology in general radiography has provided additional security, less moving and handling of X-ray films and enhanced image quality (Carter and Adler, 2013). Historically the 'processing' of X-ray film required staff to 'wash', 'fix', and 'dry' films prior to sending it to the referring clinicians for diagnosis, yet today CR and DR technologies process and display digital images to physicians in several minutes. Whilst this reaffirms the technological importance for patients and staff within the National Health Service (NHS) (NHS, 2013) the primary focus in this PhD research is exploring DR, the latest technological advancement within the general radiographic environment.

X-rays are a form of ionising radiation used in diagnostic radiography that have short wavelengths (beyond ultraviolet), passing through matter to varying degrees depending on the density (Graham and Cloke, 2006). X-rays branch into the 'natural sciences' and in radiography are produced by an X-ray tube accelerating electrons towards a tungsten anode target. On impact with the target they undergo sudden deceleration to produce X-rays and heat and pass through the patient providing visual representations of their internal structures (Graham and Cloke, 2006). The NHS continuously strives to 'work at the limit of science – bringing the highest levels of human knowledge and skill to save lives and improve health' (NHS Constitution, 2013:2). Advancing technology and the production of X-rays remain central to a radiographers practice and predicted to continue to act as a significant aid in diagnosis management for all medical specialties (NHS, 2013). Radiographers work to professional and ethical codes of conduct, setting out and underpinning values and principles to promote, maintain and disseminate the highest quality of care to patients (SCoR, 2010, SCoR, 2013), yet these values and principles are debated in later chapters of this PhD thesis. In a recent publication Whitaker (2013:1) questions 'who are diagnostic radiographers', fearing that radiographers will continue to be misunderstood, with the profession failing to reach its full potential. The Society and College of Radiographers (SCoR) (2013:1) assert that the best radiography students 'have a balance between good understanding of the sciences and a genuinely caring attitude' suggesting sound collaboration between scientific understandings and an empathic attitude towards patients. The advancement of technology however within diagnostic radiography provides an additional sociological interest discussed throughout this PhD thesis. The sociologist Harry Braverman (1974:319) argued that maximising technological control can minimise the autonomy of workers:

> *'The more science is incorporated into technology, the less science the worker possesses; and the more machinery that has been developed as an aid to labour, the more labour becomes a servant of machinery'.*

The extent to which autonomy is minimised for radiographers and the extent in which it impacts clinical practice and patient care was a primary focus throughout this PhD thesis and discussed in chapters five, six and seven. This required close engagement with radiographers exploring 'what they did and how they did it'. Subject matters generally differ between 'science' and 'sociology', the former studying 'nature' and the latter studying 'people and social groups' (Gabe *et al,* 2006). Medicine has historically relied on science to inform medical practices (Gabe *et al,* 2006), however medical sociology can produce knowledge exploring the actions and interactions of healthcare professionals and the social or cultural effects of medical practice (Bird *et al* 2000; Scambler, 2008). Thus it was important throughout this thesis to consider both 'nature' and 'people' following recent failures at the Mid Staffordshire Hospital (2014), suggesting a change in healthcare culture: 'the failure of the system shown in this report suggests a fundamental culture change is needed' (Francis, 2013:5). Hospitals are regarded as institutions providing specialist medical care and services for the general public. Cockerham (1978:201) reported that hospitals have passed through four distinct phases of development: 'centres of religious practice; as poorhouses; as deathhouses and as centres of medical technology'. Radiology is a medical specialty aiming to facilitate an improvement in health using imaging technology to diagnose and treat disease and is regarded as one of the 'most expanding specialties' in recent years (NHS, 2013:1). In short the conjecture in this PhD study explores phenomena at the intersection of both social and radiographic sciences in the general radiography environment with the aim to add to existing knowledge enhancing patient care delivery.

Chapter One: Introducing me as the researcher

"Craftsmanship is the centre of yourself and you are personally involved in every intellectual product upon which you may work. To say that you 'have experience' means, for one thing, that your past plays into and affects your present, and that defines your capacity for future experience."

(Wright Mills [1959] 2000:196 cited in Howatson-Jones, 2010:16).

1.1. Introduction

The aim of this chapter is to explore the development of my own human life and journey of becoming a diagnostic radiographer and educator in higher education. It is important to consider because 'who I am' and 'what I bring' to this PhD research is arguably constructed by my own experiences. This chapter will discuss some personal and professional experiences that have impacted on my own values and beliefs and how they relate to the concepts discussed throughout this PhD work. Howatson-Jones (2010:16) reflects on her own life story in describing her experiences and the journey of her PhD research, interrogating what she brought to it in order to avoid taking her own 'data' for granted. This is important to consider because my values and beliefs throughout this PhD will inform my relationships with participants, colleagues and patients.

1.2. Biography: 'Who I am' and my values and beliefs

It is generally accepted that as human beings we have our own values and beliefs, which we develop throughout the course of our lives. Additionally, our family, friends, community and experiences contribute to our sense of 'who we are' and 'how we view the world' (Manley *et al,* 2011). Prior to undertaking a critical literature review and discussion of the research methodology I will consider 'who I am' as the researcher and the values and beliefs I hold in relation to the concepts discussed throughout this PhD research. This is important for two reasons. Firstly, it can help identify to readers my position as the researcher in the context of the data. Secondly, it can help strengthen rationales for the concepts discussed throughout this PhD work using 'values and beliefs' as a core variable. Savin-Baden and Major (2013:68) assert that 'qualitative researchers should know and be able to articulate who they are and what they believe personally, so that they may understand and acknowledge how these factors in turn influence the research'.

I am currently employed in a higher education institution delivering radiography education. I also maintain clinical competencies by undertaking 'bank radiography' shifts. Upon embarking onto the PhD studentship program at Canterbury Christ Church University (2010) I had little experience as a diagnostic radiographer (one year) and looking back I remained both the novice researcher and radiographer. The person 'I was then' is arguably not the same person 'I am now' and following life experiences these have impacted on the values and beliefs I hold. Savin-Baden and Major (2013) maintain that 'personal stance' is not static and tends to change, move and grow as people's views about life, culture and identity shift. Whilst my personal values have been 'constructed' it is important to discuss these in detail because they are closely connected to 'knowing self' and based on the assumption that 'before we can help others we need to have insight into how we function as a person' (McCormack and McCance, 2006:475). It is argued that the 'values and beliefs' of a researcher are central to a 'researchers position' in the context of his/her research because beliefs and values affect the way research is designed, planned, undertaken and written up (Savin-Baden and Major, 2013:82). Contemplating one's values and beliefs involves questions surrounding in what ways education and life experiences have influenced the way I think about my research (Howatson-Jones, 2010; ibid). Because this can help interrogate my deeply held beliefs about undertaking this PhD research it will be discussed in relation to the broad concepts discussed throughout this PhD thesis.

1.2.1. Family and illness

My sister and I were raised in a working class home by my father and mother. My father (a builder) and mother (shop assistant) did what many parents do, support, encourage and prepare their children for adulthood. Historically we spent many days together as a family and this is something I am continuously grateful for. As a family our lives were impacted dramatically following my father's diagnosis of cancer in June 2014. My father was diagnosed with a squamous cell carcinoma in the throat (primary source of cancer unknown). The news had emotional effects on our family, unsure of his prognosis. Because of my experiences as a diagnostic radiographer I was often asked by my mother and father to accompany them during outpatient appointments and attend radiotherapy sessions in order to clarify terminology and ask 'anything that came to mind'. Throughout his appointments I often observed the 'person-centred' and ‘family-centred’ approaches often cited in nursing literature (McCormack *et al,* 2010). On occasions we were consulted as ‘a family’ because we were told that we would all play a ‘big part’ in his journey of treatment, care and recovery. Throughout his radiotherapy and chemotherapy treatment I began to understand the complexity and ramifications of cancer treatment and the impact it can have on family members. My mother, a shop assistant now became my father’s full time carer, administering palliative drugs when appropriate whilst managing his day-to-day concerns. As a diagnostic radiographer my experiences with patients are often short when compared to other health professions, limiting my experiences of a patients treatment and recovery. However after experiencing first-hand cancer treatment and management it altered my perspective of ‘the patient’, and the family members who remain unselfishly immersed in their day-to-day care. Additionally, this altered my perspective of radiological and magnetic resonance examinations following observations and later discussions with my father. The skills developed throughout data collection of this PhD research helped me question the experiences my father underwent. These were both insightful as a family member and as a diagnostic radiographer. Firstly the experiences of the radiological contrast injected intravenously during his CT scan gave him an intense ‘warm feeling’ throughout his body, which he mentioned he had not been informed of and thus remained confused by the biological sensation occurring after his injection. In support, the speed of ‘the scan’ remained a surprise to him. He felt that the time of the scan (five minutes) did not reflect the ‘waiting time’ to underdo the examination (approximately two weeks) thus questioned why it ‘takes so long to fit everybody in’. Secondly, during his MRI examination he was required to place his head centrally in the magnet. This resulted in him lying flat in the bore of the magnetic for an approximate time of 45 minutes, feeling increasingly claustrophobic. Additionally, he mentioned the important part I played being allowed to sit within the ‘Faraday cage’ (inside MRI room) during his MRI scan, enabling him to focus on a ‘subject’ taking his mind off the uncomfortable and claustrophobic environment. At this stage I was observing radiographic healthcare from ‘the other side’ and after conversations with my father it allowed me to critically reflect on what we do as diagnostic radiographers and how our actions and communications impact on the experiences of patients. In relation to the concepts discussed in this thesis this strengthens the argument that sound communication, treatment and care of patients (and family members) should be considered for all examinations because patients may feel increasingly anxious about their imaging procedure(s). Like my father, patients may be undergoing scans to explore the ‘extent’ of their illness or pathology. In short my father’s journey and my experiences as a family member have allowed me to think more holistically about patients and their family members entering the imaging environment. Patients, like my father are likely to experience a wide range of emotions and concerns in attempts to uncover their suspected pathology. Because cross sectional imaging is central to early diagnosis and staging of cancerous tissues my experiences as a close family member will impact on my communication with patients. It has encouraged me to listen carefully to the concerns of patients and the concerns of family members. The 'family centredness' experienced has highlighted the importance of involving family members in the care and treatment throughout imaging procedures I undertake because family members often play an central role in the care and management of patients arriving into radiology departments.

1.2.2. Experiences of education

My experiences of education significantly contribute to the values and beliefs I hold as a radiographer and educator. Prior to commencing my secondary education I was required to undertake an academic examination, commonly known as the '11 plus exam' in the south east of England. This examination would assess my academic level at eleven years of age, leading me to undergo either 'grammar' or 'independent' education at a selected secondary school, the former superior to the latter. My failure of the '11 plus' exam was a disappointing outcome for me (and my family) and therefore required me to attend an 'independent school'. This was disappointing because it was generally accepted that grammar school pupils were more successful at attending higher education (BBC News, 2005). However, on reflection my experiences within the independent school were important to my own values and beliefs. Two experiences stand out. The first was my mathematics teacher, who commenced employment during key stage level four. He immediately assured us that we could achieve a 'C' at GCSE prior to entering the final year of key stage level four. The second involved my history teacher who introduced me to the importance of reading and writing, providing detailed feedback of my GCSE assignment and personally mentoring my progress, ensuring I succeeded in producing a sound piece of GCSE work. Retrospectively I achieved a C one year earlier than anticipated in mathematics and achieved a B grade at GCSE in history. Looking back I realise the values and beliefs of the individual teachers due to their desire to teach and develop students instilling a philosophy that 'every student who enters my classroom can succeed' (Buyck, 2003:1). This was achieved by firstly offering extra curricula activities such as 'Saturday morning workshops' and 'after school clubs' in the aim of providing success to the students involved in acquiring sound GCSE grades. Secondly, their constructivist beliefs created a stimulating, challenging, and individually adapted learning environment, supporting my construction of knowledge by means of one-to-one tuition, group discussion, and graphical demonstrations. Not only did this reveal alternate methods of learning to achieve my aims it also suggests that the practices delivered by these teachers were 'shaped by their pedagogical and cultural traditions' (OECD, 2009:93).

After completing my secondary education I moved onto a foundation college to begin my National Vocation Qualification NVQ (level 2) and Higher National Certificate (HNC) studies in computing. This was part of an apprenticeship undertaken within a multi-national pharmaceutical company. This environment was new to me; my 'working role' involved supporting chemists in research laboratories with any 'IT issues' encountered. I began studying for my NVQ and HNC within a two year period, the latter more academically challenging. During my apprenticeship I often stood out from others because I was undertaking two academic qualifications, whereas my peers were undertaking the mandatory NVQ qualification, essential in all apprenticeships. At times this was challenging, encompassing both academic and work duties in order to fulfill the apprenticeship. Initially due to the level of the HNC I would often struggle with modules such as 'computer programming' and 'networking systems' as I had little knowledge or understanding of these areas at sixteen years of age. Additionally, the pedagogy was often teacher-centred with knowledge delivered by means of lectures, requiring self-study on subject areas. At sixteen years of age this was my first experience of self-directed study. I had little connection with this new learning environment whereby I was required to 'go away and learn subject material and feedback'. This required self-discipline that I was unfamiliar with. On reflection without the sound mentoring and support from my apprenticeship supervisor and tutors at the college I may not have passed HNC with success. Howatson-Jones (2010:19) similarly reported difficulties with learning in a new environment acknowledging how it caused her 'work to suffer' leading her to leave her course of study. Without the support of key members during this apprenticeship my learning would have been hindered with the possibility of course failure, thus preventing my entry into higher education. Looking back my experiences of both secondary and tertiary education demonstrate two central tenets. Firstly, depending on our levels of knowledge and understanding individuals may require additional support and mentoring regarding aspects of professional work. Secondly, as an educator my aim is to instill a similar philosophy experienced by my previous teachers, tutors and mentors that allowed me to develop and achieve a BSc (Hons) degree in diagnostic radiography.

1.2.3. The X-ray environment

Upon embarking into a career as a diagnostic radiographer I had no previous experiences working in a caring environment. At twenty-one years of age and as a student radiographer I began to observe vulnerable and ill patients following instances of direct trauma and progressive pathological diseases. My desire to become a radiographer was based on two perspectives. Firstly, I wanted to care for people and secondly optimise technology and science to facilitate this. The person centred nursing framework advocated by McCormack and McCance (2010) claims that clarity of values and beliefs are important to consider for healthcare professionals working within their professional environments. Manley (2004:55) maintains that ‘values determine what people think ought to be done’ and are closely linked with moral and ethical codes, whereas beliefs are ‘what people think is true or not true’ (ibid:55). As a radiography student and recent graduate I felt that whilst working as part of a healthcare team we treated patients holistically and delivered optimum levels of ionising radiation to produce images of diagnostic quality. These basic assumptions involve the interpretation of beliefs plus values and emotions and are generally understood as accepted truths that are held unconsciously (Brown, 1998). However, McCormack and McCance (2010:54) argue that one cannot question the values and beliefs underpinning our own assumptions and thus one should observe ‘them in action’. The link between clarifying values and beliefs and workplace culture is described by Manley (2004:54):

> *“Values and beliefs contribute to shared meanings, understandings and expectations which are tactic and distinctive to a particular group and passed on to new members… they underpin the way things are done within any cultural focus.”*

Dominant values are those that are widely shared amongst a group, community or culture. In a more recent publication, Manley *et al* (2011:1) assert that culture is influential in delivering care that is person-centred, clinically effective and continually improving in response to a changing context. McCormack and McCance (2010:55) provide an example whereby nursing staff found themselves in task-orientated ways whereby the ward became focused on the busyness of tasks expected to be completed by the end of each shift, thus becoming the ‘cultural norm’. Throughout my radiographic learning I became immersed within one professional group. Further, upon graduating I was employed within this professional group whereby I continued my clinical practiced as a diagnostic radiographer prior to embarking on the PhD studentship. A recent study by the HCPC (2014:14) reported that professionalism is based on well-established, or even innate personal qualities and values and beliefs, as identified by participants:

> *“To me, people’s values underpin everything they do as a professional… and so, from my point of view, professionalism has come from before I even entered the profession.”*
>
> *“I think you have a core belief as well, it’s your core standards of what you think is acceptable and not acceptable”.*

Whilst I believed I was conforming to ‘professionalism’ as described above, looking back I was unaware of the cultural influences impacting my clinical practice. As maintained by Manley *et al* (2011) our values and beliefs are interconnected with the workplace culture and form our behaviours and attitudes. This was important following the implementation and delivery of ionising radiation. On reflection, my observations as a diagnostic radiographer questioned the use of ionising radiation and application of person-centred care in the clinical environment following advances in technology. It is reported that following the introduction of CR and DR, not all radiographers (including myself) fully understood the advances of this technological change (Patefield, 2010). Looking back, I felt that I lacked optimum knowledge and/or understanding to operate DR equipment effectively as a diagnostic radiographer. Thus throughout my day-to-day practices I, like others discussed in later chapters would conform to practices that were arguably suboptimum, leading to increases of ionising radiation. My ‘personal stance’ was central to embarking on this PhD topic within the general radiography environment because it aimed to uncover and clarify my concerns as a healthcare professional (Savin-Baden and Major, 2013). At the time this may have been associated with becoming part of the ‘cultural norm’ and throughout this PhD journey I reflect on the relevance of cultural influences on my ‘personal stance‘ and how it impacted on my own dose optimisation practices to patients. As healthcare professionals we should not impose our own values and beliefs on patients, we should work with patients in relation to what is right for them. As autonomous professionals we should exercise sound judgment and decision making through a complex process of assessment and action involving the interaction of knowledge, experience, values and practical skills. This remains a central focus throughout this PhD research because failure to become autonomous arguably neglects 'what is right' for the patient. Since embarking on the PhD in 2010, my values and beliefs on the use of technology in accordance with ionising radiation have developed as part of 'my own professional journey' (West, 2001). Radiographers should remain autonomous regardless of advancing technology ensuring that ionising radiation is kept in accordance with the theoretical linear-no threshold dose response model (ICRP, 2012). At present I continue to work as a senior radiographer, research within my own profession and educate at higher education, which continues to impact on my own radiographic practice. My focus throughout this PhD work reinforces the importance of reflecting in and on practice and also 'on self' because it has the potential to uncover strongly held personal and professional values and beliefs and can enhance understanding of our own actions and the influences of workplace culture. Central to my own personal and professional 'enlightenment', it is essential to highlight the actions and behaviours of radiographers' and their values and beliefs in the field of diagnostic radiography. This consideration is essential because challenges often arise when espoused values (values we talk about) do not match the behaviours we see in practice.

1.3. Conclusion

This chapter sought to clarify 'who I am' as the researcher and my values and beliefs held. I have discussed experiences in my life that have shaped my own values and beliefs towards patient care, the value of support and mentoring students in education and the impact on optimum use of ionising radiation. Exploring my own values and beliefs were central to my actions and behaviours as a diagnostic radiographer and researcher. This processes has enabled me to critically self-reflect on my life experiences and understand the impact it has on 'who I am'. I have discussed the development of my own values and beliefs following personal experiences and the 'journey' of embarking onto the PhD study and becoming an educator. Thus whilst the actions and behaviours of individuals are documented in this thesis it arguably strengthens the rationale that values and beliefs of individuals are not 'set in stone' and can develop through self-reflection. It is important to consider that if radiographers reflect 'auto/biographically' this could promote a more holistic approach to radiographers' actions and behaviours thus having a positive impact on person-centered delivery. Additionally, the important interconnection between culture and values and beliefs supports the rationale that in order to understand the values and beliefs of radiographers an in-depth understanding of the radiographic culture is required.

Chapter Two: Literature Review

2.1. Introduction

This chapter aims to review literature of radiobiological evidence, current radiation protection measures, advancements in imaging technology, patient care delivery and research and education in radiography. The review will discuss literature currently informing and legislating radiographic practice in the United Kingdom (UK). Further, this chapter identifies problematic issues surrounding contemporary general radiographic practices thus identifying a gap to advance existing knowledge that can inform the radiographic profession.

2.2. Radiobiology: The linear-no threshold debate

All life has a cellular basis, if a man weighs 70kg his body will consist of approximately 7×10^{13} cells, which contain structures that are defined as the 'the building blocks of life' and the basic unit of reproduction (Becker *et al,* 2009). Cells in tissues may undergo one of three processes: they can divide and grow in number, they can stay alive without dividing, and they can die by apoptosis (programmed cell death) or necrosis. These can occur at different rates, higher in children, which slow when we get older (Becker *et al,* 2009). These make children more sensitive to radiobiological effects as they have a greater number of dividing cells and thus potential effects are increased later in life (Schonfeld *et al,* 2011; Seeram *et al,* 2013). An illustration and description of the mammalian cell can be found in appendix one (p.296) for the reader illustrating the cells common features and internal structures. Ionising radiation is radiation composed of particles that carry enough kinetic energy to typically remove electrons, protons or neutrons from an atom or molecule. Such events can alter chemical bonds and are considered the most damaging form of radiation due to their high frequency (Graham and Cloke, 2006). When an X-ray beam passes through a patient they receive a dose of ionising radiation, absorbed dose is a measure of the amount of energy from ionising radiation deposited in a mass of some material (i.e. a patient). The unit of absorbed dose is 'Gray' (Gy) which is defined as a dose of one joule per kilogram (Jkg^{-1}) (Graham and Cloke, 2006). Dose Area Product (DAP) is a multiplication of the dose and the area exposed, expressed in $Gycm^2$ and recorded after general radiographic exposures as X-ray units are fitted with DAP meters thus the most convenient method of monitoring patient doses. The 'effective dose' is measured in Sieverts (Sv), introduced by the ICRP (1991) because different organs in the human body have different sensitivities to radiation and although all tissues are radiosensitive; some are more sensitive than others (ICRP, 1992) e.g. breast tissue is recognised more sensitive to the gonads (ICRP, 2012). Radiographic examinations such as 'hands' and 'wrists' are defined as 'negligible dose' in comparison with other radiological exams and give an effective dose of less than 0.1 millisievert (mSv). This is an accumulation of other types of background radiation a person receives over their lifetime from sources including the sun, outer space, radioactive materials present in the earth, buildings, the food and water we consume and radioactive gases present in the air equating to on average 2.7 mSv per year (Graham and Cloke, 2006). These natural background sources provide patients and healthcare professionals a benchmark to explain the risks associated with certain radiological examinations (Calman, 1996) because life on earth has evolved amongst this continuous exposure to background radiation. Comparisons are available to the reader in appendix two (p.297). Ionising radiation exposure is linked with popular fictional comic book characters including the Hulk, Spider Man and Teenage Mutant Nina Turtles; however ionising radiation can alter chemical bonds and are considered the most damaging forms of radiation due to their high frequency (Graham and Cloke, 2006). Radiobiology is the field of science that studies the effects of ionising radiation on cells, generally classified into two categories, *deterministic* and *stochastic*.

Deterministic effects: Deterministic effects occur following high doses of ionising radiation due to the killing and malfunction of biological cells (Hall and Giaccia, 2006). Some medical procedures exploit the hazardous effects of ionising radiation with radiotherapy successfully contributing to 28% of the lives saved to cancer when compared to other treatments (Chemotherapy 4% and Surgery 68%), saving 5000 lives annually in England (Cooper, 2011). Deterministic effects are generalised by a threshold dose below which no detrimental effects are seen. Muller (1927) first demonstrated this measuring mutation rates in the Drosophila fruit fly using X-rays to demonstrate a dose-response relationship. Examples of deterministic effects in humans include cataract of the lens, cell depletion in the bone marrow leading to haematological deficiencies and impairment of fertility (Nias, 1998; Hall and Giaccia, 2006). Radiological procedures have demonstrated deterministic effects on patients, ranging from visually noticeable reddening of the skin at 2Gy, to painful deep necrotic ulcers at 18Gy (Vlietstra, 2004). The objectives outlined by the ICRP (2012) are in general to prevent deterministic effects in humans and to restrict stochastic risks to acceptable levels.

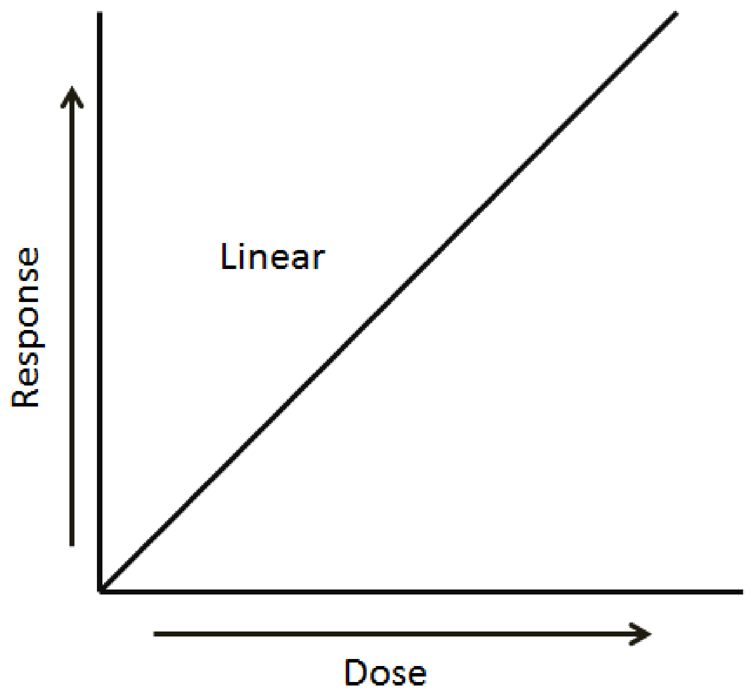
Stochastic effects: Radiation-induced cancer, cognitive decline and heart disease are examples of stochastic effects. Stochastic effects are demonstrated in forms of non-ionising radiation, for example infrared radiation from an electric radiator may be beneficial but too much heat will burn. Similarly exposure to ultraviolet (UV) provides a valued source of vitamin D, however it is a known carcinogen and through 'exciting' orbital electrons overexposure to UV can result in skin damaged (Tortora and Grabowski, 2003), increasing the chances of developing certain forms of skin cancer by inducing gene mutations through deoxyribonucleic acid (DNA) damage (BAD, 2008; SCoR, 2010; NICE, 2011). In the UK more than 1 in 3 people will develop some form of cancer during their lifetime and since the mid-1970s cancer incidence rates in the UK have risen by 22% in males and 42% in females (Sasieni *et al,* 2011). Regardless of the underlying cause, cancer development is a complicated process involving up to ten stages over a period of years or even decades (Tortora and Grabowski, 2003). The risks associated with X-ray examinations explored in this PhD thesis are termed 'negligible', 'minimal' and 'very low risk' (Calman, 1996) and stochastic due to their probability of occurrence increasing with dose. The term 'stochastic' is used to describe detrimental effects for which there is 'no threshold' dose with the severity independent of radiation dose (ICRP, 2012), however this argument remains highly controversial.

Attempts to understand the induction of stochastic cancers in diagnostic radiography have been debated for decades. Within the current radiobiological paradigm it is generally accepted that a safe radiation exposure (however small) does not exist (ICRP, 2012:1), thus remaining a central tenet during a radiographer's day-to-day clinical practices:

> *"The primary aim of radiological protection is to provide an appropriate standard of protection for man without unduly limiting the beneficial actions giving rise to radiation exposure. This aim cannot be achieved on the basis of scientific concepts alone. All those concerned with radiological protection have to make value judgements about the relative importance of different kinds of risk and about the balancing of risks and benefits."*

This view stems from the hypothetical linear-no threshold (LNT) dose response model assuming that the long term biological damage to ionising radiation is proportionate to radiation dose received (see graph one). Because 'this aim cannot be achieved on the basis of scientific concepts alone' (ICRP, 2012:1), it is used to legislate radiographic practices in numerous countries (including the UK) suggesting that every photon or particle of ionising radiation has the same random and independent chance of initiating a significant DNA lesion, potentially leading to a pre-neoplastic cell (ICRP, 1992; ICRP, 2007; ICRP, 2012). The radiobiological effects on a cell can include a break in one or both strands of the DNA, with a double-strand break more important biologically. The main mechanism of a radiation induced double-strand break is through oxidative stress resulting from the formation of reactive oxygen species (ROS) through ionisation of water molecules. ROS include hydrogen peroxide (H_20_2) superoxide (O_2-) and hydroxyl radicals (−OH). It is the interactions of two double-strand breaks which result in a range of outcomes including cell death, chromosome ring formation, deletions and translocations and potential cancer, thus the principal target of radiation damage (Hall and Giaccia, 2006; Prise and O'Sullivan, 2009; Harbron, 2012).

Graph One: LNT dose response model



Rothkamm and Löbrich (2003) support the LNT model suggesting that a cancer induced by 1Gy is no worse than one induced by 0.1Gy, but the probability of its induction is increased. Brenner *et al* (2003) concur suggesting that by decreasing a dose, say by a factor of 10 will result in proportionately fewer electron tracks and fewer hit cells, therefore decreasing the number of damaged cells by a factor of 10 decreases the biological response by the same factor of 10 (decreasing linearly with decreasing dose). Harbron (2011b:26) recently used the 'National Lottery' as a 'linear-no threshold' example arguing that 'providing you are exposed to the 'risk factor' at all – buying a ticket – there is no minimum number you need to buy to win', even though the odds of winning are negligible (1 in 14 million). In the UK health agencies have estimated that between 100-250 deaths occur each year from cancers directly related to medical exposures (Royal College of Radiologists and National Radiological Protection Board, 1990), but methodological difficulties are inherent in quantifying cancer risks in low-dose epidemiological studies lower than 10 mSv (doses in diagnostic radiography) (Brenner *et al,* 2003). Little *et al* (2009:1) argue that 'linearity may be (almost) the best we can do' because if the current LNT model is to be rejected then an alternative model needs to take its place in order for radiographers to base their radiation protection practices (Little *et al,* 2009). This is important following recent reports suggesting an increased risk of cancer induction during 'negligible risk' dental examinations (Macrae, 2012) and 'low risk' computed tomography (CT) examinations (Wang, 2009). Further, Schonfeld *et al* (2011) highlighted the associated risk between ionising radiation and thyroid cancer among children concluding that national and international efforts are required to raise awareness of paediatric sensitivity to radiation in order to maximize the benefit of procedures involving radiation while minimising harm.

Evidence continues to suggest increasing risks to adult and paediatric patients and because science fails to disprove the hypothetical LNT model, ionising radiation should not be regarded as 'safe' (ICRP, 2012). The difficulties to prove small increased risks are generally accepted where there is substantial natural variation from one population to another (Harbron, 2011). The most useful information has come from human epidemiology studies of the atomic bombings in Japan in 1945 (UNSCEAR, 2006a). Survivors were able to recall exactly where they were at the time of the explosions thus enabling modeling techniques to determine the dose each survivor received. To improve estimates, replica Japanese houses were built and exposed to nuclear explosions to determine the level of shielding they provided for occupants (Schull, 1995). The data was correlated with recorded health effects, forming what is known as the Life Span Study (LSS). In 2000 the LSS had recorded 479 excess solid cancers and 93 excess cases of leukaemia among the survivors of Hiroshima and Nagasaki (UNSCEAR, 2006a). However these excess malignancies are only detectable between 5 to over 50 years later as around 25% of excess cancer deaths recorded in the LSS have arisen between 1991 and 2000, 46-55 years after the bombings (UNSCEAR, 2006b). Results of animal and plant studies suggest a potential for inducement of genetic effects by ionising radiation (UNSCEAR, 2001) with the possibility for genetic effects remaining theoretically possible in humans (Schull, 1995; UNSCEAR, 2001; Boice *et al,* 2003; Monson *et al,* 2006; WHO, 2006; UNSCER, 2006). Findings of a large cohort known as the Oxford study suggest the association of increased cancer rates with doses greater than 10 mSv (UNSCEAR, 2006b), however no convincing evidence of radiation related genetic damage has emerged among the 27,000 children of atomic bomb survivors (Schull, 1995; Miller *et al,* 2010) with similar effects from the Chernobyl disaster (IAEA, 2005; Bennett *et al,* 2006) and offspring of patients treated with radiotherapy for childhood cancer (Boice *et al,* 2003). Little evidence remains highlighting radiation-induced testicular cancer (Bushberg *et al,* 2002) and only limited evidence of radiation-induced ovarian cancer (UNSCEAR, 2006) thus reinforcing the importance to consider protecting the gonads during radiographic examinations.

Despite data from the LSS and other publications the LNT dose response model is currently debated within radiobiology. Since its introduction in the 1960s it is argued that the theories and models of risk require some modification as scientific understanding of radiation and cancers have improved (French Academy of Sciences; Farlie and Resnikoff, 1997; Monson *et al,* 2006; Allison, 2009). Allison (2009) claims that because no adverse effects have been observed in humans exposed to less than 100 mSv there should be no concern regarding radiation levels delivered during diagnostic radiography i.e. 0.1-20 mSv. It is argued that for most biological affects the relationship between dose and effect is not linear, e.g. if paracetamol were administered to a group of subjects at low doses there would be no response, but as the dose increased the effects on the subjects would be proportional to the dose (Monson *et al,* 2006; Allison, 2009). Similarly, the world wide web (Corrice, 2011) reports the benefits of low-dose radiation, comparing ionising radiation with Iron, Magnesium and Zinc arguing that although these substances can be life threatening at high doses, at low doses they are essential for good health, found in vitamins (ibid). Publications suggest that the risk of developing cancer following acute or cumulative doses at so-called ‘low doses’ of 100 mSv or less are simply eliminated and only at higher doses are attempts of DNA repair made, with the subsequent risk of repair failure and carcinogenesis (Aurengo *et al,* 2005; Monson *et al,* 2006). These arguments suggest that cancer risk is much lower than predicted by the LNT model. In addition there has been the introduction of a new model in radiobiology in the last 10-15 years known as 'hormesis' predicting that low levels of radiation are not harmful and yet may even have beneficial effects to cells by reducing spontaneous cancer risk (Luckey, 2003; Vaiserman, 2010). At the cellular level 'apoptosis' is known to be part of a complex system of communication governing basic cellular activity coordinating cell actions that respond to their microenvironment and argued as the basis of development, tissue repair, immunity as well as normal tissue homeostasis. When a cell suffers DNA damage through irradiation the cell can enter apoptosis via the activity of the p53 protein, which switches off replication of the cell in order to allow extra time for the repair of the DNA damage. If the repair fails the p53 gene may trigger cell suicide by apoptosis (Becker *et al,* 2009). Foray *et al* (1995) identified that at low dose rates of 0.01Gy a small fraction of double-strand breaks in the DNA were slowly repaired. Mothersill and Seymour (2004) indicated that cells not directly exposed to radiation show responses that may be part of a higher order of homeostatic control. The adaptive responses had shown to occur when cells were previously exposed to a low 'priming' dose of as little as 0.001 mGy exhibiting increased resistance to subsequent higher doses, which provides the argument and mechanism by which hormetic responses to radiation may occur (ibid). Audette-Stuart *et al* (2011) concluded that a decreased sensitivity to radiation damage was seen in liver cells from frogs collected in their natural environment suggesting that some stressors was acting to induce protection of DNA from the effects of high dose radiation exposure.

These views are in contrast with the current hypothetical LNT model proposed by the ICRP over 50 years ago, which remains to inform radiation safety today. Allison (2009) argues that the current safety rate proposed by the ICRP is an estimate of the extent to which the current radiation safety regime is over-protective in respect of dose rates. It could be argued that this 'over-protective model' has impacted individuals whom have been exposed to 'lower levels' of ionising radiation, such as the Chernobyl disaster in 1986. Reports suggest that it was not the 'radiobiological affects' that affected the individuals *per se* but the 'potential radiobiological affects' as mental health issues are now accepted as the largest public health problem created by the Chernobyl accident, resulting in 70% of the evacuees having depression and 40% of these individuals having alcohol problems (Horizon BBC 2004; WHO 2005). Similarly hazards facing pregnant (or non-pregnant) healthcare professionals including chemicals, drugs, needles, viruses, bacteria and pathogens when compared to ionising radiation, 'rank at the very bottom of the list!' (Strubler, 2004:66). Moreover, contrasting views are arising within the radiographic community. A joint publication made by the British Institute of Radiology and the Royal College of Radiologists titled 'airport scanners are safe' (SCoR, 2011:1) arguably disagrees with the current LNT dose response model claiming 'no safe radiation dose' (ICRP, 2012). The word 'safe' implies that an individual is protected from or not exposed to any danger or risk (Oxford English Dictionary, 2011), which a senior radiographer asserted; 'there's no such thing as a safe X-ray' in a newspaper article titled 'Hospital radiographer blasts 'naked' body scanners at Manchester Airport (Manchester Evening News, 2011), which remains advocated by the ICRP (2011:284).

> *"It must be realised that neither dose and risk constraints nor reference levels represent a demarcation between 'safe' and 'dangerous' or reflect a step change in the associate health risk for individuals."*

This suggests that the unknown hazards associated with low levels of ionising radiation may influence individuals' actions and perspectives, which is considered within this PhD research in later chapters. In summary the radiobiological effects at low levels are currently debated, but current evidence fails to disprove the hypothetical LNT dose response model proposed by the ICRP, thus radiation levels should not be viewed as 'safe'. It has been suggested that low levels of ionising radiation could have beneficial effects; however the risk of most radiation-induced endpoint will decrease linearly, without a threshold to even negligible doses used in diagnostic radiography. Thus because 'scientific evidence' fails to inform us, as healthcare professionals it is arguably a radiographers responsibility to recognise limitations within the radiobiological paradigm and strive to optimise radiation doses where applicable. Further this review highlights a gap in current literature exploring the beliefs, attitudes and feelings held by diagnostic radiographers regarding low levels of ionising radiation, thus an aim of this PhD research.

2.3. Radiation protection: Contemporary principles and methods of dose optimisation

The debate surrounding radiobiological effects at low levels of ionising radiation has been discussed and remains the current basis for protecting patients in medicine today with the possibility that every photon of ionising radiation has the same random and independent chance of initiating a significant DNA lesion, potentially leading to a pre-neoplastic cell (ICRP, 1992; ICRP, 2007). The ICRP bases its radiation protection philosophy on three principles, justification, optimisation and limitations to individuals exposed to ionising radiation. In the 1980s this remained a voluntary act and the ICRP recommended that radiation doses should be kept 'as low as reasonably achievable' (ALARA) (later adapted to 'as low as reasonably practicable' (ALARP)). The three principles aim to minimise radiation exposures to patients, operators and others (ICRP, 1992) and are used by various radiation protection organisations worldwide including the Health Protection Agency (HPA), National Council on Radiation Protection (NCRP) and RPB-Canada, providing guidance for the safe use of radiation in medicine. Later the European Directives (97/43/Euratom and 96/29/Euratom) required member States such as the UK to bring into force the laws, regulations and administrative provisions necessary to comply with the two Directives (ICRP, 2007; ICRU, 2012). The directives ensured that optimum radiation doses became legislative practice on 1st January 2000 ensuring that the use and control of ionising radiation was performed and recorded (Ionising Radiation Regulations, 1999). Additionally, the Ionising Radiation (Medical Exposure) Regulations (IR(ME)R) were released on 13th May 2000 replacing the 'Protection of Persons Undergoing Medical Examinations or Treatment' with additional amendments in 2006 and 2011. Today it requires healthcare practitioners to play a pivotal role in the protection of service users, staff and members of the public from the perceived risks of ionising radiation while ensuring optimum image quality.

Currently the medical use of ionising radiation constitutes more than 99.9% of radiation exposure to the world's population from man-made sources and in 2007 it was estimated that 4 billion radiological procedures were performed annually worldwide (UNSCEAR, 2010). Following the implementation of legislative practice and requirement for radiographers to protect individuals from all levels of radiation the use of X-rays in the UK has continued to increase (HPA, 2011). Since the discovery of the X-ray in 1895 over a century ago the diagnostic use of X-rays has been routinely used in all forms of general radiography, fluoroscopy and computed tomography (CT) (Harvey, 2008). In 2008 it had been estimated that 46 million medical and dental X-ray examinations were performed, an increase in 10% since the previous study in 1997 (HPA, 2011). The study revealed that the average annual radiation dose to each member of the public from all diagnostic X-rays had increased from 0.33 mSv in 1997, to 0.4 mSv and it is estimated that 1.2 million X-ray examinations were taken in independent hospitals in 2008, representing a rise of 40% since 1997. It is estimated that this number will continue to increase as X-ray departments continue to work closely with accident and emergency (A&E) departments, outpatient clinics and inpatient referrals. In 2009-2010 a record number of patients (20.5 million) in the UK attended A&E (Hardy and Snaith, 2011), thus resulting in an increase of almost five per cent from the previous year (Smith, 2010). The continuing use and increase in radiological procedures worldwide has raised concerns regarding the cumulative doses some patients are receiving. Previously it was argued that the LNT dose response model is an 'over-protection' of current radiation limits as doses below 100 mSv are not assumed to cause any harm to patients and rarely exceeded in diagnostic procedures (Allison, 2009). In recent cases patients are receiving cumulative radiation doses exceeding 100 mSv (Rehani *et al,* 2012). Arguably such cumulative dose levels have resulted in patients undergoing scores of CT and interventional procedures (Berrington de Gonzalez, 2007) within a few years with some cases reaching up to 1Sv resulting in radiation-skin injury (erythema or hair loss) and are now reported every month or two in the United States of America (Holmberg *et al,* 2010). Following the sudden increases in radiation exposure over the past decade it required additional consideration and in 2006 the International Atomic Energy Agency (IAEA) (2013) introduced the 'smart card' project for individual medical exposure tracking, currently named 'SmartRadTrack', which was welcome amongst 76 countries worldwide (IAEA, 2013). This suggests that while the use of ionising radiation in medicine is continuing to increase, with patients exceeding 100 mSv, further reflection on all clinical practices to optimise radiation doses may be required in order to keep doses 'as low as reasonably practicable' throughout.

The clinical benefits of undergoing X-rays have been reported (Dalrymple-Hay *et al,* 2002) with some doses remaining lower than the estimated annual exposure from background sources (2.7 mSv). However this is not to say that radiation is 'safe' (ICRP, 2007) hence all exposures require justification (ibid) and monitoring of diagnostic reference levels by relevant agencies (ICRP, 2007; HPA, 2011; RCR and SCoR, 2007). Ionising radiation in medicine remains the single most important artificial contribution to humans (Graham and Cloke, 2006). In disciplines such as medicine risks are embedded, decisions are made by referring clinicians and practitioners daily such as patient referrals for specific treatments, undergoing a particular procedure or taking a particular drug; each outweighed by the chances of something beneficial happening. In diagnostic radiography a patient may present with a suspected scaphoid injury, the chances of something 'good' happening is that while undergoing the X-ray examination a fracture is positively identified, which can be treated and managed effectively. The chances of something bad happening if not X-rayed can lead to complications including avascular necrosis, non-union of bone fragments and post-traumatic arthritis (Kumar and Clark, 2012). Thus through justification the risks associated with ionising radiation do not exist and prevent the 'hazard' (radiation) becoming active, however once the 'hazard' becomes active it is the responsibility of the radiographer to keep radiation doses 'as low as reasonably practicable' (ALARP) whilst maintaining an image of diagnostic quality (IR(ME)R, 2000). It could be argued that whilst radiographers are responsible for risk/benefit decisions they are required to minimise the risk whilst producing the benefits, yet unnecessary exposures can arise from medical procedures that are not justified for a specific objective. Further, medical exposures that are not appropriately optimised for the situation can lead to unnecessary radiobiological risks (Holmberg *et al,* 2010). Thus it is important in this PhD study to examine the current techniques used in the clinical environment to ascertain their appropriateness in general radiography.

Radiographers are responsible for maintaining the health, safety and welfare of their patients in the radiographic environment (SCoR, 2008) because many patients are not guided or instructed regarding the hazards of radiation and long-term potential damage (Rassin *et al,* 2005). It is a requirement for referring physicians to inform patients of risks associated with ionising radiation (IR(ME)R, 2000). A study by Bosanquet *et al* (2011) concluded that although the general knowledge of radiation exposure amongst doctors remains poor there is a suggestion that there is an improvement in the general appreciation of radiation doses. Although this suggests a lack in knowledge, Matthews *et al* (2013:6) recently aimed to establish how common paediatric radiography examinations were performed in Ireland. They reported that findings were 'encouraging' with strong indications of the pivotal importance of the radiographer's input to justification and optimisation (ibid). The studies demonstrate positive developments in radiographic practice. A focus of this PhD study is to explore the actions, beliefs and attitudes of radiographers optimising radiation dose in order to further understand whether feelings, beliefs and attitudes affect professional practices and are discussed in chapter seven. The Commission for European Communities (CEC) published recommendations in attempts to minimise radiographic parameters and achieve sound radiographic images for both adult (ECE, 1996a) and paediatric examinations (ECE, 1996b) in general radiography. Radiographic literature has focused on the use of lead due to its high atomic number (Z = 82) thus providing significant photoelectric absorption for energies used within the diagnostic range reducing doses to radiosensitive organs (Eyden, 2001; Whitely *et al,* 2005; Clancy *et al,* 2010). This has subsequently led to the manufacturing of lead-rubber devices, including gonad shields, lead-rubber sheets, lead-aprons and lead-rubber gloves for use within clinical environments to keep ionising radiation ALARP (Williams and Adams, 2006; Ball and Moore*,* 2008). Similarly studies have suggested that irradiating patients in the posterior anterior (PA) projection rather than the anterior posterior (AP) for sacroiliac examinations significantly reduces dose to the gonads (Mekis *et al,* 2010). Other techniques such as the X-ray operators' choice of beam kilovoltage (kVp) for adult examinations (Fung and Gilboy, 2001), paediatric examinations (Guo *et al,* 2013), beam filtration (Hamer *et al,* 2004; Samei *et al,* 2005), strict operator collimation (Powys *et al,* 2012) and source to image detector (SID) (Dilger *et al,* 1997; Doolan *et al,* 2004) have demonstrated dose optimisation for general radiographic examinations whilst maintaining optimum image quality. X-ray experimentation has provided a valued contribution of knowledge for X-ray operators within the clinical environment and because medical exposures do present risks, there is a general focus to reduce ionising radiation. The publications above provide valued insight of radiographic techniques however in recognition of a 'potential slip' in standards clinical audits are required in radiographic practices, described as a:

> *"Systematic examination or review of medical radiological procedures which seeks to improve the quality and outcome of patient care through structural review whereby radiological practices, procedures, and results are examined against agreed standards if necessary".*
>
> (European directive 97/43/Euratom, 1997:2).

Several studies have demonstrated sound compliance with national diagnostic reference levels within diagnostic radiology (Livingston *et al,* 2008; White *et al,* 2013). These studies demonstrate adaptations with positive outcomes from the conventional radiographic techniques demonstrated in radiographic literature (Whitley *et al* 2005; Sutherland and Thomson, 2007). Brennan *et al* (2004) suggest that such an implementation of dose reduction techniques would allow for an important reduction in collective dose, but Rassin *et al* (2005) demonstrated that only 65% of radiographers were adequately protecting patients from radiation exposure to organs not undergoing examination during X-ray examinations. This is supported by others who suggest differences in radiographic techniques from one X-ray environment to another (Brennan and Johnston, 2002; Rainford *et al,* 2007) revealing that individuals do differ in decision-making in different circumstances (Arnold *et al,* 1998). While differences in applied knowledge may be apparent in the clinical environment, Heyer *et al* (2010) highlight an existential issue concerning referring physicians whereby paediatricians were unable to correctly estimate the radiological dose for numerous radiological examinations, arguably a failure in applying radiation safety. Holmberg *et al* (2010:4) assert that it is important to increase communication between clinicians and healthcare professionals in radiological practice who are knowledgeable in effective dose reduction strategies, because for high standards to be achieved in radiographic practice radiographers must be aware of how their own day-to-day practices compare with such objective research evidence.

2.4. Advancing technology: The impact on general radiographic practices

Medicine is an ever changing field and is becoming increasingly reliant upon technical equipment and practices (Becker *et al,* 1961; Fett, 2000). Similarly the use of X-rays in medical applications aims to provide new techniques and refinement for better image quality for both static and dynamic examinations. Currently advanced technologies acquire X-ray images of diagnostic quality within the general radiography environment and are traditionally split into two categories, cassette radiography (CR) and digital radiography (DR) (Kotter and Langer, 2002) replacing conventional X-ray film. These taxonomies are commonly accepted and are used throughout this PhD thesis. Today flat detectors have gained field in both radiography and fluoroscopy, replacing film screen (FS), CR and image intensifiers (Seeram, 2011). The detector classification is related to the conversion of X-ray photons into an electric charge and can use a direct or indirect process to convert X-rays into electrical charges using a thin-film transistor (TFT) array. Direct conversion detectors have an X-ray photoconductor, such as amorphous selenium (a-Se) converting X-ray photons directly into electrical charges. Indirect conversion systems use two-stage techniques for conversion consisting of a scintillator, usually cesium iodide (CsI) that converts X-rays into visible light, then into an electrical charge by means of an amorphous silicon photodiode array (Carter and Veale, 2010). The digital X-ray detector is the key component of a DR system and consists of pixel sizes affecting the systems resolution with typical ranges from 127-200µm (Lança and Silva, 2009b) providing optimal detective quantum efficiency (DQE) which is established as the most suitable parameter for describing the imaging performance of a digital imaging device (Ranger *et al,* 2007). Digital detectors that have higher sensitivity or higher detective quantum efficiency values allow for better image quality at all frequencies showing the ability to represent both small and large image structures (Huysmans *et al,* 1997; Hintze *et al,* 2002). Other digital advances in the UK have included the radiology information system (RIS), used for administrative purposes that include communicating and managing patient data, patient registration, scheduling radiological examinations and the creation of radiological reports. In support the Picture, Archiving and Communication System (PACS) is commonly used for electronic storage, retrieval, distribution, communication, display, and processing of medical imaging data. The radiographic profession has seen dramatic advances in technology since the discovery of the X-ray over a century ago and whilst its implementation has improved better ergonomics, patient access, and image quality for radiologists and reporting radiographers (Seibert, 1999; Holmes *et al,* 2004; Spahn, 2005) this PhD study aims to explore the issues 'on the ground' within the general imaging environment uncovering how technological advances may facilitate and hinder radiographers during their day-to-day practices.

Modern information and communication technologies provide an array of tools for collecting, processing and distributing information from which clinicians, researchers, administrators, policy makers in health and the public can benefit. In Radiology departments technologies have substantially relieved tensions by capturing X-rays electronically, which are archived and readily retrievable through rapid searching capabilities. However, it could be argued that a paradox exists within the health care environment whereby polar tensions exist in information overload alongside information gaps experienced by healthcare professionals (Ho *et al,* 2004; Murphy, 2006). Following the widespread recognition of the role of technology in economic growth (Solow, 1956) a debate emerged in the 1960s and 1970s about whether the rate and direction of technological change has been more heavily influenced by changes in market demand or by advances in science and technology (Nemet, 2009). It was argued that demand drives the rate and direction of innovation and changes in market conditions creating opportunities for firms to invest in innovation to satisfy unmet needs (ibid). The theory of 'technology push' and 'demand pull' remains to be a catalyst for debate amongst historians and economists of science and technology (Schumpeter, 1969; Nemet, 2009). Academics have responded to the technology-push and demand-pull debate recognising that it is not simply that both factors contribute, they also interact (Arthur, 2007). Mowery and Rosenerg (1979) claim that the technology-push and demand-pull theory are 'necessary, but not sufficient, for innovation to result; both must exist simultaneously' (Mowery and Rsenberg, 1979). It is generally accepted that social development is achieved by technology alone and that technology has become the driving force in healthcare as we enter the 21st century (Murphy, 2006). The development of technology in general radiography has progressed rapidly in recent years. The continued improvement of image storage, ‘bit depth’, image matrix and crystal structure of DR hardware is generally accepted to enhance the delivery of radiographic practice (Seeram, 2013). Ho *et al* (2004) argue that practitioners may remain in a passive role as information receivers as technology is ‘pushed’ into working environments. This is important to consider because radiographers may be ‘thrown into the deep end’ following a ‘technological push’ of new hardware and may not have an appropriate understanding to support their day-to-day clinical practices. Murphy (2006:170) identifies that radiography as a profession has failed to ‘critique or inquire into what is after all a technology driven environment and as a result there is inadequate consideration of radiological technology that examines its emergence or impact on both society and the profession itself’, thus an important aspect to consider in this PhD research. ‘Market pull’ innovations are arguably adapting to the changing characteristics of the industry in diagnostic radiography (Di Stefano *et al,* 2012), such as improving the ease of radiological examinations and reduction in radiation doses. This is documented by one X-ray vendor that introduces a new piece of DR equipment asserting that: ‘exams are done easier and may result in fewer retakes and a low X-ray dose for your patients’ (Philips DR Brochure 2011:3). As diagnostic radiography embarks into the 21st century it could be argued that both technological-push and demand-pull are interconnected and thus collectively impact on current radiographic practices and culture. It is this social interaction with new technology that is the decisive factor in a general imaging procedure, which aims to be explored in this PhD work. Murphy (2006:170) supports this view identifying ‘soft technology’ as central to understanding the impact of technology on values, politics, patient care and the humanistic interactions. This is important to consider because anthropologists, sociologists, historians and economists have repeatedly shown that technologies transform societies, alter relations of production and implicate organisational forms (Blau *et al* 1976 cited in Barley, 1986). Barley’ (1986) observation of Computed Tomography (CT) practices revealed that technology is but one among many elements of social context that can influence patterns of action. Barley (1986) concluded that CT scanners became social objects to radiographers and radiologists whose meanings were defined by the context of their use with technical uncertainty and complexity socially constructed in the clinical setting even when identical technologies were deployed. This is an important consideration in this PhD research because it suggests that identical general radiographic technology may uncover different outcomes in respect to the local cultures within the radiography department. It is important to consider the use of ‘multi-sited research’ to allude to the different outcomes technology can have on individual radiographic department(s).

Radiographic work itself is highly structured, production-orientated and technical with an image-centered activity (Strudwick *et al,* 2011c) and due to the increasing demand noted earlier, this has subsequently led to an increase in costs, which have risen rapidly in many parts of the world for the last 30 years (Hofmann and Lysdahl, 2006). The use of digital technology to undertake X-ray examinations is used by a number of different healthcare professionals including radiologists, radiographers, assistant practitioners and dentists. Advances in capturing X-ray photons digitally have eliminated the need for manual handling of films, light boxes, envelopes and elimination of chemical pollution with the heavy and usually dusty archive work becoming redundant. Therefore whilst the X-ray environment advances technologically facilitating the production and transportation of X-ray images are there other elements that may affect the clinical environment and the patients care? Diagnostic radiography is often generally viewed as conservative and resistant to change (Messer and Meldrum, 2001), however the digitalisation and rapid expansion of diagnostic radiography coincided with continuing demands for radiographic services suggests that the work of radiographers has become more complex (Brown, 2004; Larsson *et al,* 2007). Research in Sweden suggests that since the introduction of digital technology, boundaries between the radiologists and radiographers in the work environment have dissolved (Uffmann and Schaefer-Prokop, 2009) altering the culture of the department and its routines (Saranummi *et al,* 2001; Siegel and Reiner, 2002). For example Uffmann and Schaefer-Prokop (2009) demonstrated unnecessary collimation during their fieldwork with advanced technology observing 'post-exposure' images on PACS.

It is reported that advances in technology can facilitate workflow improvements within the clinical environment (May *et al,* 2000) however research has suggested that advances in technology do not necessarily guarantee a similar advance in patient care (Crowe, 2008) as it can often be ignored or overlooked as the focus of the radiographer can be directed largely towards the technology and not the patient. Thus while the development of equipment and production of radiographic images could significantly affect a workplace culture (Beals *et al,* 1977; Manley *et al*, 2011), the exploration of DR and the impact on radiographers practices became a key focus in this PhD study. Adler (1990) claimed that because scans such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Position Emission Tomography (PET) and Single Photon Emission Computed Tomography (SPECT) are more complex compared to general radiography this has impacted on the care delivered to patients distancing the radiographer from their patients. Studies have begun to concentrate on the patients' experiences in relation to the technological changes in cross-sectional imaging modalities (Chesson *et al,* 2002a; Murphy, 2006; Munn and Jordan, 2011), yet this study explores the general imaging environment. Radiographers have previously been criticised for viewing patients as a translucent screen upon which to find diagnostic issues within (Gadow, 1982) and more recently suggested as a ‘hit and run’ process (Murphy, 2009). Murphy (2001) argues that instead of laying claim to a strict definition about technology, the unfolding paradoxes and characteristics of technology in medical imaging should be further understood. Few studies have explored general radiography as a culture using advanced technologies and thus in support to Murphy’ argument the exploration of contemporary radiographic technology could provide additional perspectives on patients experiences as general radiography constitutes to approximately 90% of the workload completed by staff in the radiology department (HPA, 2011). Moreover because it is the radiographers’ social interaction and not the hard technology that is the decisive factor in any imaging procedure (Murphy, 2006) this PhD thesis aims to explore the interaction between radiographer and ‘fix-detector’ technology and its impact on patient care.

Willis *et al* (2004) argue that DR is subject to many of the same inaccuracies as film screen (FS) and regardless of the acquisition technology sound radiographic practices should be based on fundamental radiographic principles e.g. kVp, mAs, SID, collimation, central-ray alignment and positioning of detector. However errors including malpositioning, patient motion, incorrect patient identification markers, incorrect examination and double exposure (Willis *et al,* 1996) are still present amongst advanced technologies. Dekker (2011:122) is of the opinion that in fields such as medicine, positivist views encourage practitioners to view ‘an error as a failure of character – you weren’t careful enough’, however reviewing human error from socially-constructed theoretical model can be instructive. New pitfalls in dentistry have emerged; Berkhout *et al* (2003) identified the ease for dental practitioners to take additional radiographs in a relatively short period of time suggesting that there may be a temptation for dental practitioners to take more digital radiographs than actually required due to its fast acquisition. The main reasons for repeat examinations amongst radiographers in FS were exposure and patient positioning (Arvanitis *et al,* 1991; Nixon *et al,* 1995; Peer *et al,* 1999). More recently Sheung-ling Lau *et al* (2004) demonstrated that rejected images using digital imaging were mainly due to positioning errors (55.4%) whereas with FS exposure errors (38.6%) and positioning errors (28.2%) were the most common. This suggests that while a reduction in repeat radiographs is noted following the implementation of digital technology within the general radiography environment alternate issues may be arising from the use of DR.

The introduction of DR systems has been recognised as an important step in numerous publications offering significant dose reduction in chest (Trotzer *et al,* 2002; Bacher *et al,* 2003) and skeletal (Strotzer *et al,* 1998a; Völk *et al,* 2000; Geijer *et al,* 2001; Geijer, 2002) radiography offering between 33-80% dose reduction without compromising image quality (depending on the clinical query) (Carlton and Alder, 2013). Manning-Stanley *et al* (2012) recently identified a dose reduction technique by switching the current automatic exposure control recommendations for pelvic radiography resulting in a significant (36.8%) reduction in mean radiation dose with no loss in observable image quality. These studies support the paradigm shift from the principle of 'image quality as good as possible' to 'image quality as good as needed' (Uffmann and Schaefer-Prokop, 2009) thus keeping doses ALARP. However the detector must receive enough X-rays to make a sound diagnostic image because a reduction in exposure cannot make up for extra noise, loss in subject contrast and signal out of its range of adjustment (Huda *et al,* 1996; Willis *et al,* 2004).

The balance between delivered radiation dose and the production of an optimal X-ray image can be optimised with digital technologies conforming to the ALARP principle. Conversely McEntee *et al* (2004) suggest that current practices may not be appropriate because they have not had sufficient time to adapt as exposure factors and imaging techniques known to be suitable for FS (and CR) are used with DR under the assumption that they are appropriate. For example, Livingston *et al* (2008) concluded that DR can reduce the radiation doses to paediatric patients, but a recent initiative 'Image Gently' aims to refocus professional attention to digital radiography in its 'Back to Basics' campaign for paediatric examinations (Image Gently, 2014:1) in order to prevent the occurrence of dose creep with advancing technologies. This suggests that following the demonstration of dose reduction techniques, initiatives such as 'image gently' alludes to 'something else' impacting the radiographers approach to dose optimisation. One argument could be that evidence based radiography (EBR) is not yet used widely in radiography and that research evidence still seems to be lacking among radiographers with 68.6% of radiographers rating their knowledge of EBP as "poor" while 22.9% rated it as "midpoint" and only 8.6% rated it as high (Upton and Upton, 2006). This lack of EBR may become more problematic with increasing use of digital technologies because X-ray films historically illustrated inappropriate radiographic techniques with X-ray films appearing 'too white' or 'too black' when too little or too much radiation was used resulting in an under or overexposed film. A digital detector for example can have a dynamic range of 1:10.000 (higher than FS systems 1:30), providing a greater exposure latitude and contrast resolution (Antonuk *et al,* 1992; Hufton *et al,* 1998; Spahn *et al,* 2000) superior than that of FS and CR. This is a key concern for exposure error and increases in radiation dose (Carter and Veale, 2010) because 'film blackening' would indicate an 'overexposure' with FS. However, this no longer exists in digital systems as studies suggest that the transitional process from film screen (FS) to digital could increase patient doses by up to 40-103% (Vaño *et al,* 2007) with DR systems auto-correcting exposures by up to 500% (McConnell, 2011). Therefore a 10-fold overexposure may not be recognised as 'too black' on a digital radiograph and thus images deemed 'diagnostic' by the operator even though the patient may have been overexposed (Persliden, 2004; Uffmann and Schaefer-Prokop, 2009; IAEA, 2010). Thus whilst it is recognised that individual X-ray examination doses may have reduced in practice (Herrmann, 2008) the technological advances can provide the operator with a 'diagnostic image' since it is able to compensate for wrong settings (IAEA, 2010) suggesting that due to a lack of education there may be instances of operator error increasing patient exposures (Carter and Veale 2010). Matthews *et al* (2013) recently reported that radiographers were more likely to collimate closely to the relevant anatomy when the receptor is smaller. A recent publication reports the potential for dose creep on a chest phantom varying the exposure factors and source to image distance. In their conclusion the authors suggest that further research should be conducted investigating the potential for dose creep (Ma *et al,* 2013), something which this PhD research aims to undertake.

X-ray operators may be unknowingly 'overexposing' patients, but the exposure index (EI) provides the operator 'feedback' on the appropriateness of the radiographic technique employed. The EI estimates the signal-to-noise ratio providing a numerical indication of the image quality produced. The EI estimates the measure of radiation transmitted through the patient onto the detector (IEC, 2008) however Warren-Forward *et al* (2007) warn that the manufactures recommended range of EI values may not be optimal and are often set to high. Gibson and Davidson (2011) demonstrated that over a 43-month period radiographers were not using the EI and 'dose creep' was taking place supporting Cohen's *et al* (2012) recent argument that while the EI has demonstrated limitations in its use it can still be used as a guideline for radiographers in the clinical environment.

This discussion has demonstrated contrasting aspects of advancing technology in the general imaging environment because whilst DR has the potential to reduce doses in practice, without appropriate research and education it also has the potential to increase them (ICRP, 2005). A current gap exists in the literature around the observation of clinical practice that could provide additional insights of the behaviours of radiographers in a DR environment. Seeram (2011) suggests that “exposure or dose creep” may be encouraged due to operators favouring excellent image quality, however image quality may be one of a number of phenomena effecting exposure or dose creep in the clinical environment. These issues are explored within this PhD thesis highlighting radiographers’ current radiographic techniques and their application of current knowledge and understanding using DR, a central tenet to the ALARP principle (Ween *et al,* 2009; Seibert and Morin, 2011; Baker, 2012). The arrival of new technology should not diminish the need for enhancing current knowledge and practice (Bick and Lenzen, 1999; Busch, 2004), thus a primary focus of this PhD research is to identify current attitudes and behaviours associated with DR and how it may impact on the patient, the radiographic department and the future of the profession.

2.5. Person-centred care: Exploring ‘what radiographers do and how they do it’

The National Health Service (NHS) was created out of the ideal that sound healthcare should be available to all regardless of wealth and based on three core principles; to meet the needs of everyone; be free at the point of delivery and be based on clinical need, not ability to pay (NHS, 2013a). In the NHS a large number of people continue to be successfully cared for and treated for (Vincent *et al,* 2001). A patient is a person that receives health care services and is often in an ill or injured state in need of treatment by a physician, nurse and allied health professional. The word ‘patient’ derives from the Latin word ‘patiens’, meaning ‘I am suffering’ and akin to the Greek verb ‘to suffer’. It is generally accepted that patients remain at the centre of their healthcare and that care is delivered to the highest of standards of excellence and professionalism, which is effective and focused on the patient experience (NHS Constitution, 2010). A recent report investigating the ‘Stafford Hospital’ incident (Francis, 2013:1) revealed a significant lack in patient care and dignity coincided with overworked staff, later claimed as the ‘worst in NHS history’ (ibid:1). The concept of person-centred care is an important element to consider in this PhD thesis ensuring optimum delivery of care. Academics have generally pointed away from the more widely used term ‘patient-centred care’ (Ekman *et al,* 2011). Person-centred care (PCC) refers to an approach that guides practice of medicine and healthcare to deliver optimum patient care and is widely advocated as a key component of effective illness management. 'Person-centredness' is generally used rather than patient-centredness because it recognises a set of values underpinning patient-centred approaches are the same as those that underpin good staff relationships (Manley *et al,* 2011:10). In nursing literature person-centredness is associated with nurses listening to a person's story, engaging with them in meaningful dialogue and recognise them as human beings with dignity and honor in their unique beliefs and values (McCance *et al,* 2011; Manley, *et al,* 2011). For PCC to be experienced in a consistent and continuous way by patients/residents, families and professionals McCormack *et al* (2010:106) maintain that 'the culture of practice has to support ways of practicing that enables care teams to flourish'. This is important to consider in diagnostic radiography because whilst the word 'patient' is akin to Latin meaning 'to suffer', a 'suffering patient' is likely to vary depending on the referral pathway within diagnostic radiography, thus considering the patient as 'a person' who is an individual may facilitate the care and treatment offered to individuals in the general radiographic environment. Further, it is important to consider the radiographers views of the person-centred approach, for example, can PCC be delivered optimally in contemporary practices? Ekman *et al* (2011) claim that patients are persons and should not be reduced to their disease alone. This argument is grounded in the belief that PCC relates to a broad overarching (or underpinning) ethical idea that patients should be 'treated as persons' (Entwistle and Watt (2013:29). Frank (2013:59) concurs, 'PCC is the king of care that promotes patients person-al capabilities, which are a subset of human capability and those associated with the concepts of persons being treated as persons'. This holistic approach to caring is instilled early on in healthcare professionals' education, yet the mentality of the workplace culture has been reported to impact on nursing practices. For example, Nilson *et al* (2012) suggest that prior experiences of learning and present work cultures can erect barriers to reflect on and learn from care experiences. This PhD research aims to explore the 'person-centred culture' within the general radiographic environment using advanced technology, which may promote reflexivity amongst practitioners. McCormack *et al* (2010) support such an exploration because person-centred cultures can maximise the potential of individuals for thriving as they change the way they engage with others at individual, team/group, community and societal levels. This is important because if attitudes and behaviours are put into words this may allow current and pre-registered radiographers to reflect on their own radiographic practices in the aim of delivering optimum PCC (Howatson-Jones *et al,* 2013). In diagnostic radiography, there is little qualitative research exploring the actions of radiographers within the general radiographic environment. The narratives in chapter six may provide radiography learners and practitioners not only an insight into radiographic culture but a perspective previously untold within the clinical environment (ibid). Love and Kelly (2011:128) identified that nurses should look beyond the short-term task accomplishment and towards the long-term goal of person-centredness in practice with admonishments of 'it takes too much time to be person-centered' and 'it's too hard'. This task-orientated perspective identified is explored in this PhD research to provide insight into persons undergoing radiographic examinations. This is important because human beings have reason, will, feelings and needs and healthcare professionals should engage the person as an active partner in his/her care and treatment' (Ekman *et al,* 2011:249). Additionally, Entwistle and Watt (2013:32) reported that patients were treated 'not as a person but rather as a lump of meat, a number, or a thing on a conveyor belt'. This unfortunate finding does not resonate with the NHS Constitution, nor the values and beliefs that underpin it. Nor does it conform to a healthcare professional's ethical code of conduct. Howatson-Jones *et al* (2013) concluded that it is in the interest of organisations and educational institutions to develop cultures that encourage learning and reflection in order to maximise the potential of staff and learners and ultimately the care they provide. In short, it is important to consider the radiographic culture(s) of a general imaging environment(s) in order to bring out sustained development of clinical practice and PCC (McCormack *et al,* 2010:96).

Other elements of healthcare practice is the significant number of errors and other forms of harm reported in the NHS (NPSA, 2005) suggesting that 10% of patients admitted into hospital are subjected to a safety incident whereby half could have been prevented (Vincent *et al,* 2001; NSPA, 2004). The National Patient Safety Agency (2004:1) defines patient safety as:

> *"Any unintended or unexpected incident which could have or did lead to harm for one or more patients receiving NHS funded care".*

Healthcare professionals are taught to practice without errors however 'adverse events', ranging from near misses to loss of life can occur within hospital environments (Carrafiello *et al,* 2012). Near misses are not commonly reported in healthcare practices because the staff involved fear they may be blamed, criticised and viewed as incompetent and face possible litigation (Balka *et al,* 2007). Errors in radiotherapy have been reported (Yeung *et al,* 2005) whereby if left uncorrected leave errors in treatment and can be extremely serious due to the potential effects of high radiation doses. Radiation exposures in radiotherapy are considerably higher than those used in diagnostic radiography, however any diagnostic exposure substantially greater than the intended dose, either exceeding the established diagnostic reference level or those arising as a result of equipment or operator fault should be investigated (ICRP, 1996; IAEA, 2011). It is generally accepted that humans make errors and happen in the medical professions (National Institute of Medicine (NIM), 1999). The NIM (1999:1) maintain that 'to err is human' however following continuous healthcare errors this continuously ignites concerns surrounding hospital and patient safety (Balka *et al,* 2007) hence important to consider throughout this PhD work. Further, following the recent integration of advancing technologies within general radiography departments, this PhD study explored the beliefs amongst radiographers examining how DR contributes to patient safety within the clinical environment.

Technology and equipment are often recognised as contributors to patient care and adverse incidents (generally seen as a performing factor), such as the facilitation to dispense drugs by physicians. Technology is rarely identified as the source of medical error or adverse event (Chapuis *et al,* 2010), but in the United States of America (USA) it is reported that technical complications account for 13% of adverse incidents, the third largest category (Rooney *et al,* 2002). Thus due to the continuing advances of technology in diagnostic radiography following the 'connecting for health' strategy, technical complications may be apparent for radiographers within the DR environment (Lança and Silva, 2009b). This supports Bauer's (2003:84) argument, 'while automation holds substantial promise for improved safety, error experts caution that all technology introduces the potential for new and different errors'. Historically in medical culture it was believed that mistakes should not be made and were indicative of personal and professional failure, however this view may lead to overt denials of errors occurring within the healthcare environment (Messer and Meldrum, 1995). In contemporary healthcare it is argued that a cultural change is essential to recognise, manage, and learn from errors in the National Health Service (NHS) to improve patient outcomes (Chief Medical Officer, 2000). No manager wishes for their department to be held up as an example of an organisation that makes errors, however Larsson *et al* (2009) argue that if knowledge is not reflected there is a substantial risk that radiation dose and images will not be optimum. Thus as radiographic examinations continue to increase (HPA, 2011) with radiographers reported to have sound knowledge and understanding of image production (SCoR, 2013) this PhD research revisits the competency of radiographic practitioners who deliver care to patients. This is important following the suggestion that a lack of research and education may increase radiation doses in the clinical environment (ICRP, 2005), hence an important area of inquiry in this exploratory PhD thesis aiming to facilitate sound patient care.

Studies exploring how healthcare professionals operate and practice have been demonstrated (Jensen, 1989; Greenfield *et al,* 2007 and Adams *et al* 2008), including the complex nature of the patient-practitioner interaction (Kerr *et al,* 1997; Allen, 2004). Little research has been undertaken exploring general radiography practice following the introduction of digital technologies. In the last 10-15 years a proposed research framework has sought to explore and to more clearly define 'what radiographers do and how they do it' (Adams and Smith, 2003:194). This alternative perspective can investigate new and challenging areas in radiography practice including the use of ionising radiation on patients in the clinical environment (Adams and Smith, 2003; Freudenberg *et al* 2009). For example, Murphy (2009) discusses the radiographic profession as a 'performance' using theatrical concepts in order to elucidate the social world, known as 'dramaturgy'. This article highlights that as medical technology evolves radiographers must be aware of the social phenomena surrounding them, including the physical lay-out of the room being the 'stage for the performance' (ibid: 39). This insight was important for this study due to the development of the radiographic profession technologically and professionally in the last 20-30 years aiming to provide a unique insight through observation of the general radiographic 'arena' in order to capture the 'performance' of radiographers in a contemporary context and the impact on patient care delivery. In general, experimental research designs demonstrate 'practical aids' to radiographers in their clinical environments at reducing radiation doses however since Adams and Smiths (2003) proposal a significant lack of literature remains exploring experiences of radiographers performing radiographic examinations in the clinical environment in the UK (Munn and Jordan, 2011). Throughout this PhD research a primary focused emerged, to explore radiographers' experiences upon conducting general radiographic examinations enabling a holistic outlook of patient and practitioner experiences with advancing technology.

Research by Stewart-Lord *et al* (2013) explored the perceptions and experiences of assistant practitioners (APs) within numerous radiographic departments, the study highlighted supervision constraints surrounding ethical and legal accountability in the APs role. In addition Lundvall *et al* (2014) recently conducted a phenomenological study in Sweden highlighting the main responsibilities in the radiography process covering both safety aspects for the patient and issues related to how to obtain optimal image quality, taking into account the patient's needs and ability to cooperate. The findings in Lundvall *et al* study demonstrated that the production phase is experienced as an autonomous professional area that must be considered in relation to the professional scope of Sweden. As new areas of interest are explored this literature review is limited in publications exploring attitudes, behaviours and beliefs of advancing technologies and its impact on patient care delivery within the clinical environment. This PhD study aims to illuminate and improve patient care and the profession. For example Vaughan' (1996) study exploring cultural patterns at the National Aeronautics and Space Administration (NASA) observed patterns that contributed to accidents on missions and identified the normalisation of deviance whereby small changes and new behaviours gradually became the norm. Similarly this research wishes to explore practices that can be improved upon because whilst it is generally accepted that radiographic practices are as valid with DR as they were with CR and FS in delivering optimum patient care (Uffmann and Schaefer, 2009) this area of knowledge in relation to DR remains unexplored.

The exploration of radiographic practices can add to existing knowledge gaining an insight into a radiographers' world. Radiographers are in a unique position of interceding between patient and potentially threatening heath care technology (Adams and Smith, 2003). Technological advancements may constitute a challenge for radiographers and other healthcare staff, including image acquisition, management of patient doses and digital image quality (Lança and Silva, 2009). This PhD research seeks to inform policy and clinical practice behaviour (Morse *et al,* 1996; Ng and White, 2005) recognising whether practitioners require additional support in current knowledge and understanding (Lança and Silva 2009b). The importance of exploring contemporary practices is essential because radiographers historically had little control over the procedures they performed (Polworth, 1982) and were considered subordinate to radiologists (Barley, 1986; Campeau, 1999). Yet in contemporary practices radiographers have more responsibilities in the clinical environment, such as ensuring optimum dose levels and embarking on advanced practice. Fridell *et al* (2007) highlight that radiographers' work in greater isolation, justify radiological requests, assess image quality and sometimes provide a diagnosis prior to sending patients home. Thus while diagnostic radiography in the past has struggled to be recognised as a profession when compared to medicine or law (Freidson, 1994), the radiographic profession has progressed significantly in recent years. Further, radiography has progressed technologically with the development of other imaging modalities, such as CT, MRI, mammography, ultrasound and nuclear medicine, often requiring full time commitment by radiographers. An additional advancement within the radiographic environment is the reporting of medical images, this role was originally performed by hospital doctors (radiologists). Thus whilst in the past the radiographic profession may have struggled to become recognised as a profession this PhD study sought to examine the role of the radiographer within the general imaging department exploring how radiographers have adapted to professional developments and potential impact on patient care.

As radiographers take on advancing roles such as ‘image interpretation’ documenting clinical conclusions, Nightingale and Hogg (2003) argue that radiographers will need to be more reflexive in viewing their images. This progression in image interpretation is supported by the SCoR (2011) with numerous undergraduate programmes preparing students to interpret images of suspected injury or pathology, however it could be argued whether the core principles in the radiographic profession have been lost. For example radiographers have historically required ‘to know and understand’ the principles in producing an X-ray image of diagnostic quality using an optimum level of ionising radiation. However due to the rapid introduction of DR technologies this PhD study sought to explore current knowledge and understanding within the clinical environment and challenge whether radiographers believed their practices remains optimum. Image interpretation is considered an important factor in professional development, yet a central tenet of radiographic practice is to maintain patient safety by delivering optimum radiation doses and continue to develop such practices to provide quality care (Kim *et al,* 2011) because patients believe that staff will protect them from unnecessary exposure to radiation (Rassin *et al* 2005). It could be argued that the role of the radiographer is in danger of shifting ‘too far’ towards becoming image interpretation experts and moving away from the image acquisition experts, arguably failing to protect and limit doses to patients. This remains imperative because general radiography constitutes to approximately 90% of examinations performed in the medical imaging department thus our responsibility as healthcare professionals to undertake research that expands our knowledge, forestalls poor performance, adverse incidents and ensures that lessons are learned in our practice and shared if poor practice is identified (Department of Health, 2005).

In summary, this section has discussed the importance of putting patients first. The recent Mid Staffordshire incident (2014) illustrated a diminishment in patient care failing to conform to the principles outlined by the NHS Constitution. It is generally accepted that patient care remains at the centre of radiographic practice however following recent technological developments and the requirement for radiographers to ‘report X-ray images’ it could be argued that radiographers may be failing to adhere to core principles i.e. the optimisation of X-ray images, thus arguably failing to conform to optimum patient care delivery. Little research has explored the practitioner-patient relationship within the general X-ray room, but this section highlights the importance to more clearly define 'what radiographers do and how they do it' in order to reflect on technological advances and continue to deliver optimum patient care.

2.6. Research, workplace and education: Cultural studies facilitating radiographic practice.

Traditionally knowledge used by radiographers has been a result of research undertaken by medical physicists and medical practitioners (Adams and Smith, 2003), with little research undertaken by radiographers (Scutter, 2002; Scutter and Halkett, 2003; Sim and Radloff, 2009; Probst *et al,* 2011). Price *et al* (2010) maintain that high quality clinical education and training is key to the provision of safe and effective practice in diagnostic radiography (Price *et al,* 2010); with an increased focus on the manner in which clinical skills are learnt and that learning opportunities are present within the clinical setting (Williams *et al,* 2006). It is generally accepted that radiographers have considerable knowledge to carry out their work (NHS, 2013b) producing radiographs of optimum diagnostic quality due to an awareness of the fundamental physics used in image production (Easton, 2009). MacKay *et al* (2008) revealed that radiographers graduating from their degree program were prepared for practice with strengths in image interpretation and patient care however weaknesses remained in skull, traumatic radiography and the ability to justify request forms. Recently, computer simulation has been integrated into radiography education, allowing students to use virtual scenarios enabling the development and awareness of equipment controls, understanding concepts, learning terminology and developing basic clinical skills (Cosson, 2012). Cosson (2012) demonstrated that radiographic techniques such as source to image distance (SID) and collimation had improved amongst radiography students using computer simulation in higher education. Griffiths (2012:6) supports this claim suggesting that work-based learning is interconnect requiring a 'blended' approach that includes self-assessment and e-learning to accommodate learning, yet Ferris (2009) highlights that little emphasis is reported on the progression of general radiographic practice. In current higher education and clinical placement learning, students undertake 27 weeks observing and practicing general radiography, which involves undertaking radiographic assessments and the collection of 'radiographic examinations' before registering as a diagnostic radiographer. Radiography teaching today often resides in lecture theatres, whereby the responsibility for the curriculum determines both delivery methods and content (Sluming, 1996) becoming a desirable approach for research-led teaching (DoH, 2003; DoH, 2006). It is generally accepted that radiography students should receive the appropriate education within the clinical environment; however few studies identify what students may encounter during their clinical placements (Murphy, 2008). Murphy (2011:137) recently highlighted that radiography students with dyslexia had had to deal with 'discrimination and a lack of understanding' from clinical staff and other students within the clinical environment. Recent advances in technology have required radiographers to be able to deal with advancing equipment and be responsive to the continuous technological development within their field (Jordan, 1995; Hafslund *et al,* 2008). This PhD study aims to explore learning within the clinical environment following Pratt and Adam' (2003) claim that a 'hidden curriculum' may exist. This is a central topic for this PhD research due to the known benefits training and education can have on organisations and employees in terms of improved employee skills, knowledge, attitudes, and behaviours (Jensen, 2001; Treven, 2003; Sommerville, 2007). Further, it can enhance staff performance (Brown, 1994), job satisfaction, productivity and profitability (Hughey and Mussnug, 1997).

Evidence-based practice (EBP) has become essential in health care because it enables the use of best evidence in making decisions about the individual care of patients (Flores-Mateo and Argimon, 2007). It is claimed that practical and personal barriers are reported amongst allied health educators in performing academic research (Elliott *et al,* 2009; Williams, 2013). Additionally, the use of research evidence in radiography may also be hindered by inadequate knowledge and competence, lack of training or support from colleagues or the organisation and inadequate skills in critical appraisal (Hafslund *et al,* 2008; Elliott *et al,* 2009). It remains imperative to continue the growth of professional knowledge to 'excel in the provision of best patient care by supporting radiographers to appraise evidence and implement best practice' (SCoR, 2010:2). Adams and Smith (2003) highlight three subject areas: intra-professional, inter-professional and clinical practice (patient and health delivery) within their proposed research framework. These areas are important because within radiography there are sub-groups and the differences between sub-groups may be central to internal professional debates surrounding the professional organisation, practice guidelines, professional behavior and educational priorities (Adams and Smith, 2003). Thus in order to understand internal issues facing and affecting the radiography community now and in the future an investigation into the perceptions and experiences of a number of the sub-groups is currently required. More recently, research in diagnostic radiography has moved from practically non-existent to a core academic module in universities across the UK in response to the continued five-year plan (SCoR, 2010) with established peer-reviewed and impact-rated radiography journals publishing radiography research specific to the profession. Poor involvement in research may include a lack of understanding of the research process, lack of confidence in undertaking research, lack of time and lack of financial support from employers to pursue research (Sim and Radloff, 2009). Scutter and Halkett (2003) claim that it is the general poor attitude towards research in radiography whereby practitioners are resistance to change. In addition to this reluctance amongst radiographic members Harbron (2012:33) asserts that while the LNT remains pivotal in radiographic practice, research exploring dose reduction methods may no longer be appropriate:

> "*Although essence of the LNT model still holds, a strict interpretation for the purposes of risk assessment and research in radiation protection no longer appears to be appropriate".*

The suggestion that research in radiation protection may no longer be appropriate following the debate in section 2.3 could further hinder the profession. Paterson (2012a) claims that there has not been a greater need for excellent research and education for the radiographic profession providing evidence-based service delivery solutions. General radiographic practices (combined with fluoroscopic examinations) approximately contribute to 19% of the collective doses patients receive in medicine, thus significantly lower when compared to CT (42%) (HPA, 2009; UNSCEAR, 2010), but the LNT module is yet to be disproved plus as individual doses continue to rise research in all modalities involving ionising radiation should be kept ALARP. Recently, there has been renewed emphasis on the importance of appropriate justification, optimisation and dose limitation for CT procedures (Holmberg *et al,* 2013), yet as general radiographic examinations still constitute for approximately 90% of medical imaging examinations failure to continue research excellence in general radiography arguably prohibits the progression of radiographic research 'as a whole'. For example uncovering 'what happens to a culture adapting to an advancing technology' in the general radiographic environment may present similar behaviours, beliefs and attitudes within other clinical environments where technology continues to advance. Thus exploring the culture of dose optimisation in general radiography will encourage new discussions in other medical imaging and healthcare environments, such as computed tomography, fluoroscopically-guided, therapeutic and interventional procedures such as percutaneous coronary interventions (cardiology interventional procedure). Such an understanding will inform and enhance a radiographers and radiologists practice within their environments whereby patients still receive radiation-induced skin burns and deep ulcerations which require skin grafts, adding to considerable distress to patients (Vlietstra *et al,* 2004). It could highlight 'dose optimisation' opportunities to patients and further limit dose to staff exposed to ionising radiation. Therefore exploring the 'culture' in this PhD thesis not only provides an insight into a radiographers' world, it adds to existing methodological knowledge providing an insight into the rapidly advancing field of diagnostic radiography, where new concepts and research techniques provide the 'building blocks' of theories, which connect research and theory to practice (Ahonen, 2007). In nursing Loke *et al* (2014:137) call for an 'urgent review of the existing nursing curriculum as well as organisational culture and infrastructure'. Thus this PhD study does not merely aim to further expand the radiographers' knowledge and understanding based on the research objectives, it aims to provide a methodological framework (chapter three) for others to review and employ if necessary. For radiography this may become increasingly important within healthcare because it can provide a framework for issues allowing practitioners to stay up-to-date with current best practices within their field (Alderson and Hogg, 2003).

In the 20th century 'culture' emerged as a central concept in anthropology, encompassing the range of human phenomena that cannot be attributed to genetic inheritance (Malinowski, 1923). The term 'medical anthropology' first used by Scotch (1963) described this discrete field of study within medical environments. Culture is predominantly accustomed to a literary or artistic heritage with prevailing values and ethos of a particular nation, but hospitals have cultural significances due to their complex organisational structures, and diverse specialised functions within the number of professional roles. Vincent (2010:272) cites Schein (1985:272) identifying the complexity in which organisational culture may impact on behaviour or performance:

> *"1) shared basic assumptions that are 2) invented, discovered or developed by a given group as it 3) learns to cope with its problem of external adaptation and internal integration in ways that 4) have worked well enough to be considered valid and therefore 5) can be taught to new members of the group as the 6) correct way to perceive, think feel in relation to those problems."*

Culture dates back to almost a century in anthropological literature. It was first described by Sir Edward Tylor: 'culture… is that complex whole which includes knowledge, beliefs, arts, morals, law, customs and any other capabilities and habits acquires by [a human] as a member of society' (Tylor, 1884). During the past decade, researchers have applied the same ideas and concepts to workplaces. The way in which attitudes are expressed within a specific organisation is described as a 'corporate' or 'workplace culture'. One generally accepted and widely cited definition of workplace culture is provided by Smircich (1983:339):

> *"Workplace cultures revolve around the shared values and attitudes and the shared experiences that validate them. A culture includes everything that is learned and shared by its members: its social heritage and rules of behaviour, its own customs and traditions, jargon and stories."*

Since 2000, there has been increasing attention on workplace cultures within healthcare (Manley *et al,* 2011). Diagnostic radiography departments have their own workplace cultures and have similarities. For example, radiographic projections imaging the human body are generally accepted amongst radiographers and radiologists globally, thus represent a professional culture (Trompenaars and Hampden-Turner, 2012). Williams (1976) asserts that if culture 'is the way of life of people, then it seems that studying workplace culture might not end in the reception area' (Williams 1976 cited in Westwood and Rhodes, 2007:85) suggesting that close engagement is required with radiographers. Drennan (1992:3) defines workplace culture as 'the way things are done around here' encompassing a shared understanding of beliefs and actions obtained through group socialisation and learning. Workplace culture is considered important within healthcare industry because the culture may affect the nature and quality of the services to patients (Manley *et al,* 2011). The World Health Organization (2008:vii) maintains that workplace cultures are key to understanding factors that can prevent the mistreatment of people because without recognition of incidences they may continue to be 'overlooked'. It is 'the culture' that is the one attribute of practice context that can provide key information to generate hypotheses around 'what [strategies] might work, for whom [may] and in what circumstances [will they work]?' (Pawseon & Tilley 1997:39 cited in McCormack *et al,* 2002). One example is the use of advancing technology in radiography departments. For example technologies work by the same universal rules, even on the moon, but when applied through humanistic interaction and workplace cultures technologies are in danger of becoming handicapped (Trampeanaars and Hampden-Turner, 2012). It could be argued that following recent advances in technology 'ways of doing things, ways of talking, beliefs, values, power relations' may have altered in radiographic environments because culture is not about individuals but about social contexts that influence the way people behave and the social norms that are accepted and expected (Manley *et al,* 2011). Eckert and McConnell-Ginet (1992:464) affirm that a 'community of practice' has been defined as 'an aggregate of people who come together around mutual engagement in an endeavor', thus alternate practices may emerge within a radiographic workplace culture(s) thus exploration of such practices may enlighten areas of the profession currently hidden. In recent years healthcare and social care organisations have introduced whistle-blowing policies in an attempt to guide employees who wish to report concerns about malpractice at work (Jones and Kelly, 2014). In one study it was reported that 70% or poor care observed by nurses were reported (Moore and McAuliffe, 2010:166), yet authors from another study revealed that whistle blowing was creating a 'culture of silence' (Moore and McAuliffe 2012:333). The term 'safety culture' emerged following the nuclear accident in Chernobyl (IAEA, 1986), and is generally recognised and remains prominent in hospitals, nuclear power stations and aeronautics (Vincent, 2010). Reiman and Rollenhagen (2014) claim that looking at an organisation and its safety culture will most likely bring about important insights, however it should not be taken as an all-encompassing truth about the workplace. An example of poor workplace culture had emerged at NASA. A gradual acceptance of more risk became standard behavior in the interest of perceived efficiency and on-time schedules, with boundaries pushed to new extremes without referring to critical reasoning (Jones and Kelly, 2014). Further, verbal complaints and memos sent by engineers to signal potential dangerous events were apparently ignored or dismissed by management at all levels (ibid). This is an important consideration in this PhD thesis due to increasing patient numbers attending radiological departments, which may facilitate an inferior quality of care in order to meet time schedules. Norms and values are reflected in culture and Trampeanaars and Hampden-Turner (2012:31) express that norms are the mutual sense a group has of what is 'right' and 'wrong'. Norms can develop on a formal level as written laws and on an informal level as social control, whereas values on the other hand determine the definition of 'good' and 'bad' and are therefore closely related to the ideas shared by a group (ibid:31). Gherardi *et al* (1998) introduced the concept of 'situated curriculum', which is part of a learning curriculum, in order to address the pattern of learning opportunities available to newcomers within a specific workplace culture. The situated curriculum is embedded in the general habits and traditions of the community and it is situated and tacitly transmitted from one generation to the next. Little research has explored these areas of radiographic practice in general radiography; therefore this study aims to provide insight into the norms and values placed of what is 'right' and ‘wrong’ with insight into learning behaviours, which may lead to ‘bad habits’ with DR. This is important because ineffective and toxic cultures ‘have resulted in serious implications for patient outcomes and staff well-being’ (Manley *et al,* 2011:2). Workplace cultures can install such things as rules, myths, stories and special language defined as ’ways of thinking, behaving, and believing that members have in common’ (Thomas *et al,* 1990:18 cited in Wilson *et al,* 2005). This is important to consider in this PhD research because a workplace culture could facilitate a gradual acceptance of radiation misuse or other hidden practices, which could increase risks to both patients and staff. The ‘culture of silence’ identified in the nursing literature may resonate within radiography environments, whereby errors of practice are ‘covered up’ or ‘hushed’ in order to conceal the actions of healthcare professionals. Jones and Kelly (2014) recognise the importance of uncovering such practices as it can present opportunities to practitioners who can learn and reflect in an open and supportive workplace culture. Manley *et al* (2011) comprehensive review of healthcare literature and policies suggest that cultural change is achieved though leadership and team work, which can enhance patient safety and person-centredness in caring environments (Manley *et al,* 2011:2). Promoting workplace culture that fosters an open communication between staff and managers may encourage more foresight and confronting issues that may otherwise remain unvoiced by staff or ignored by managers (ibid). It is evident from the literature above that workplace culture is multifaceted and may impact on individuals and/or groups of healthcare professionals’ behavior in the workplace, which may impact of patient care. In short, the exploration of workplace culture(s) in this PhD research is paramount to answering the research objectives and aims to highlight radiographic practices and encourage more openness about errors and potential suboptimal care in diagnostic radiography.

Previous exploratory research in healthcare environments include Becker’ *et al* (1961) study of medical students ‘becoming doctors’, uncovering aspects such as patient care, staff attitudes and professional boundaries. Nursing anthropology has been used to explore cultural significances associated with various illnesses and exploring impact on individual patients and their community (Kay, 1977; Estroff, 1981). Key nursing studies have focused on a specific problem within contexts such as the traditional birth attendants among the Annang of Nigeria and comparing them with practices in the United States of America (USA) (Brink, 1982). The exploration of individuals with the human immunodeficiency virus (HIV) and the meaning of drug use among these individuals have contributed to existing knowledge in community nurses (Carr, 1996). Bungay’s (2001) PhD thesis examined the patients’ pathway in the diagnosis and treatment of breast cancer providing a deeper understanding of the practices and treatment through the patients care. These studies in alternate disciplines to diagnostic radiography highlight the importance of exploratory research that can add to existing knowledge. In diagnostic radiography there have been few observational studies examining elements of radiographic practice as previous research activity undertaken has largely stemmed from the positivist paradigm (Munn and Jordan, 2011) where hypotheses are tested through quantitative research designs to test hypotheses, control variables, measures, which identifies cause and effect (Murphy and Yielder, 2006; Murphy, 2009; Munn and Jordan, 2011). While quantitative methods of investigation have been used in exploring cultural aspects in health settings, Hammersley and Aktinson (2007) maintain that it is unlikely to elicit deeper aspects of an organisations culture such as the core assumptions or beliefs held by the staff. Cultural differences can be interpreted in terms of the beliefs people hold about the way the world works and about one another, in addition this area of research arguably remains a central tenet to the development of professional knowledge and understanding. Previous studies exploring culture in the field of diagnostic radiography include Larsson *et al* (2009) research focused upon the cultural implications of the picture, archiving, communication system on diagnostic radiographers' clinical practice. The study used observations and in-depth interviews with the radiographers highlighting essential topics including communication and relationships amongst peers identifying the radiographers ability to work more independently, perform new activities, leading to an increase in responsibility that provided a high level of prestige. Similarly Tillack and Breiman (2012) examined the technological challenges associated with PACS among radiologists and a community of clinical subspecialists using semi-structured interviews and three months of participant observation, highlighting concerns that had not been previously identified in radiography research. Strudwick' (2011) thesis investigated the culture of the imaging department using participant observation and interviews, which produced subsequent publications discussing a 'blame culture' within the radiographic profession (Strudwick *et al* 2011b) and suggestion to potential barriers involving technology that may have subsequent impact on patient care (Murphy, 2005; Strudwick *et al,* 2011c).

The use of cultural studies and medical sociology in radiography can explore behaviour (what people do), cultural knowledge (what people know) and cultural artifacts (what people make and use) providing an insight into the knowledge, customs, objects, events and activities that are shared in a group (Becker *et al,* 1961; Adams and Smith, 2003). In Strudwick' (in press) recent review of cultural studies she identifies that imaging technology, X-ray equipment and radiographic images are artefacts within the workplace culture. This PhD study explores the cultural implications of advancing technology surrounding dose optimisation, patient care delivery and clinical learning. These previous studies provide a valued insight into the radiographers' daily practices and experiences which Ng and White (2005:263) suggest is important to help inform the future of the profession:

> *"Knowledge of the experiences of the early practitioners and the changes they have witnessed in the course of their career could help shed light on what those practices were like, how they have informed current practice and might inform the direction of future practice."*

The exploration of a radiographers day-to-day practices using DR can provide insight into behaviours, attitudes and beliefs towards optimising radiation. It is an important consideration within higher education aiming to deliver speicalised knowledge via professional organisation, codes of professional conduct, autonomy and altruism (Millerson, 1973; Hartley and Ellis, 1999; Sim and Radloff, 2008; SCoR, 2008). Lim (2003) argues that organisational culture can affect loyalty, motivation and performance of members but also overall effectiveness. Additionally, because organisations have become more complex, knowledge may become increasingly fragmented, difficult to locate, share and subsequently redundant, inconsistent or not used at all (Ellingsen, 2003). Other issues such as work-related stress (WRS) is reported in approximately 428,000 individuals in Britain and believed to be at a level that was making them ill (HSE, 2012), thus organisations imposing excessive pressure on employees may have reduced efficiency and decrease cost effective working (Spiers, 2003). Thus as significant pressures could be placed on diagnostic radiography services resulting in increased waiting times adding further demands to healthcare professionals (Rees and Cooper, 1992; Tennant, 2001; Raj, 2006) this PhD study uses 'ethnography' as a research methodology to explore the culture of the general radiography environment. In this PhD thesis the use of ethnography provides a valued insight into the healthcare environment providing a range of understanding as well as cultural engagement with the participants in learning about their knowledge and understanding, attitudes, behaviours, beliefs and concerns on specific topics underexplored. Participating in research is mainly positive among healthcare professionals (Thiel and Ghosh, 2008) and this PhD study aims to support previous research undertaken in the field of radiography with the aim of adding to existing knowledge and enhance patient care delivery.

2.7. Conclusion

In conclusion, this critical review has demonstrated an important gap in the literature concerning the experiences and attitudes of radiographers operating DR equipment; optimising ionising radiation and delivery of sound person-centred care. Recent publications have reported the potential for ionising radiation to be misused in practice (Carlton and Adler, 2013; Seeram *et al,* 2013; Ma *et al,* 2013), yet research continues to demonstrate new methods and techniques informing clinical practice that can reduce doses to patients whilst providing images of diagnostic quality. The rationale to keep doses ALARP is grounded from the hypothetical LNT dose response model thus central to a radiographers clinical practices, however this could be problematic due to advancing technologies in the clinical environment raising concerns regarding the possibility of 'dose creep' (Seeram *et al,* 2013). This PhD study aims to 'bridge the gap' between 'what is recommended' by the evidence above with 'what is currently performed' within the general radiography environment. The notion that workplace culture is 'the way we do things around here' is central to consider because it may highlight alternate aspects of learning, application of radiographic techniques and delivery of person-centred care. This PhD work aims to uncover 'what is being done' in the general radiographic environment(s) because after all radiography is a technologically driven environment. The theory of technological push/demand pull strengthens the importance of exploring how radiographers operate with advancing technologies in the clinical environment highlighting potential professional paradoxes that could impact on radiographic practices. Ethnography allows the identification and reflection of phenomena highlighted within this critical literature review enabling the production of original research that can provide insight into the radiographic profession. It can open future discussions concerning general radiography and take steps to reduce or eliminate certain actions or practices to move the profession forward delivering optimum person-centredness. An exploratory research model will contribute to our understanding of the radiographic profession in the general radiographic environment and will ultimately develop our understanding and inform the future management of radiographic practice.

Chapter Three: Methodology

3.1. Introduction

This chapter discusses the methods used in the fieldwork for this PhD. A methodology refers to principles and ideas on which researchers base their procedures and strategies (Holloway and Wheeler, 2002). Thus whilst the research methods are discussed, this chapter addresses 'the ideas' behind method selection and how it enabled the researcher to answer the research objectives. The previous chapter identified a gap within the literature surrounding the behaviours, attitudes and beliefs of exploring 'what radiographers do; how they do it and what they know about' DR and its application in the clinical environment. This chapter discusses the use of ethnography within diagnostic radiography research and how it facilitated data collection answering the research objectives. Throughout this chapter I discuss my positionality as both a radiographer and ethnographer and how it on occasions facilitated and hindered my presence in the field. In short this ethnographic methodology provided me with the opportunity to seek information from both inductive and hypothetical deductive reasoning involving radiographic practices in order to answer the research objectives and add to existing knowledge.

3.2. Ontological and epistemological viewpoint

At a philosophical level it has been claimed that dichotomies exist between qualitative and quantitative research paradigms (Hammersley, 1992), each an 'entire constellation of beliefs, values, techniques and so on shared with members of a given community' allowing researchers to commit to different ontological and epistemological positions (Kuhn, 1962:162). My ontological and epistemological viewpoint is now discussed. Ontology is the science or theory of being. It concerns the question of how the world is built: is there a 'real' world out there that is independent of our knowledge of it? Two distinctions are made: firstly, there is a real world that is independent from our knowledge and upon these foundations life is built – hence the expression 'foundationalism' (Courvallis, 2004). Secondly, there is no 'real' world but the world is socially and discursively constructed and hence dependent from a particular time or culture. Epistemology is the theory of knowledge (ibid). An 'epistemological position' reflects the 'view of what we can know about the world and how we can know it' (Marsh *et al,* 2002:19). There are two major distinctions within epistemology. Firstly, it is possible to acquire knowledge about the world unmediated and with no interferences. This implies that objectivity is possible, because everyone observes things in the same way. Secondly that observation is never objective but always 'affected by the social constructs of 'reality' (Benton and Craib, 2001). These two distinctions in relation to ontology and epistemology are generally accepted to have nothing in common. Positivism adopts the foundationalist ontology and thus an according epistemology. Developed from the empiricist tradition from the natural sciences, which maintains that it is possible to observe everything that happens and understand it as such without any mediation. The opposite position is taken by interpretivists that argue it is not possible to make objective statement about the real world because there is no such thing as a 'real world' and that it is only socially constructed, with an ontological position that is clearly anti-foundationalist (Weber, 1946:152). Some researchers see themselves on one side or the other of quantitative/qualitative paradigm. Sherman and Webb (1988:13) claim that the 'compatibility and the call for cooperation between qualitative and quantitative enquiry cannot be sustained since the two approaches come close to speaking different languages'. Yet, Pring (2002:44) argues that these sharp divisions are often 'institutionalised', with members of one 'institution' attacking members of the other.

Whilst researchers may hold indifferent positions and believe that the worldviews of qualitative and quantitative research remains incompatible, the Chicago School of Sociology historically recognised the collaborative use of both research paradigms as we cannot guarantee valid or direct knowledge of the real world (Hammersley, 1992). My ontological and epistemological viewpoint throughout this PhD thesis primarily fits with social constructionism and interpretivism coincided with a small but relevant quantitative element deriving from the positivist tradition. My justification for this perspective is grounded in the professional ethos of healthcare professionals, in particular diagnostic radiographers. Constructionism forms our experiences, history, culture, use of language, knowledge and social action and are all interconnected and over time lead to shared meanings (Brewer, 2000). This is arguably important towards the delivery of person-centred care whereby student radiographers (and other healthcare professionals) 'learn by observing', learning through the experiences of others and their social interactions with individuals (including patients) and medical devices surrounding them within the clinical environment. In support, Benton and Craib (2001:91) maintain that 'positivist methods can perhaps help us understand some aspects of human social life', hence the contribution of X-ray experiments within this PhD work because it is the 'social interaction with natural sciences' that can impact the delivery of optimum ionising radiation levels. Hammersley and Atkinson (2007) argue that a lack of paradigmatic thinking can obscure the breadth and depth of issues and arguments involved in the methodology of social research, thus impeding the extension of knowledge. Numerous authors have successfully combined qualitative and quantitative methodologies in a number of healthcare studies (Knafl, 1988; Morse, 1991; Casbeer and Verhoef, 1997; Morgan, 1998; Bungay, 2001; Candy *et al,* 2011; Badger *et al,* 2012), which continue to explore and contribute to the development of theory and workplace interventions in the clinical environment (Medical Research Council, 2008). It is important to consider and reflect on paradigmatic approaches in healthcare research because the development of research accompanying academic development has been punctuated by 'paradigm wars' in the field of nursing (Griffiths and Norman, 2013:583). However, whilst the paradigm war may not end, there is a degree of recognition that they can both contribute to a single research study (Holliday, 2004). West (2001) in his 'auto/biographical' study of inner city doctors maintained that 'research is always and inevitably a work of fiction' (West, 2001:39). In short, the use of social constructionism, interpretivism and contribution from a positivist tradition all theoretically remains the 'work of fiction' with a focus of developing knowledge, understanding and cultural underpinnings of the general radiographic environment.

This ontological and epistemological viewpoint facilitated the exploration of specific findings, discussed in later chapters of this PhD research. Firstly, the use of symbolic interactionism provided insight into individuals realities, created by attaching meaning to situations and symbols such as words, dress and objects in the X-ray environment (Rock, 1979:227). For example, through participant observation symbolic interactionism was used to express meanings and beliefs of X-ray technology, use of lead protection and use of ionising radiation. It offered meanings to specific clinical situations that involved patients receiving care, all central to the exploration of 'what radiographers do and how they do it' (Adams and Smith, 2003:194). In the work of Goffman (1968:154) the instrumentalism of symbolic interactionism becomes clear: 'I use myself as a tool in my relationship with others, doing my best to manage the impressions I make on others in order to achieve my purposes' (Goffman, 1968:154). Thus as a radiographer, educator and researcher symbolic interactionism allowed me to engage with radiographers in the clinical environment. For example, my personal and professional experiences with participants and interactions with technologies arguably links to symbolic interactionism because it facilitated an insider perspective enabling me to engage in the professional world of diagnostic radiographers and construct realities of radiographic practice. Baszanger (1997:30) asserts that 'the world of medicine has boundaries set by a body of theoretical knowledge'. This knowledge has historically developed based on theories 'grounded' from medical practices. This arguably resonates within the field of diagnostic radiography and thus important to consider because little research explores radiographic practices. Hence the use of 'grounded theory', developed by Barney Glaser and Anselm Strauss (1967) was central to the development of the findings uncovered throughout this PhD work. The 'exploratory' approach of this PhD work required first hand contact allowing the development of theoretical social processes 'grounded' on the lives of individuals. Strauss (1987) maintains that the process of induction, deduction and verification are essential in grounded theory. Throughout this PhD thesis I employed a 'grounded theory approach' that facilitated a progressive and reflexive 'journey' throughout. The use of induction, deduction and verification were adopted to 'map my ethnographic journey', illustrated in figure five (p.74). This allowed me to inductively observe 'what radiographers did in the clinical setting', which enabled hypothetical deduction of X-ray experimentation, later enabling verification through triangulation of research data contributing to the overall findings and answering the research objectives. This methodological approach to grounded theory enabled me to interpret 'data as I went along' and illustrates the diverse understandings of data collection methods and research findings that occur during ethnographic research. It provided flexibility to 'go back and forth' within the data strengthening and focusing subsequent methods, which could be linked back to the research objectives. Further, Glaser and Strauss (1967:246) identify that grounded theory can have practical applications whereby doctors and nurses may change their clinical context upon telling a patient they have a terminal illness, which allows them to respond more honestly. This is known as the 'awareness context'. Similarly, I was required to be aware of radiographic contexts. My awareness of particular occurrences facilitated the research process by holistically acting and reacting to situations with participants. For example, participants would ask me about a particular 'X-ray exposure' or 'what I would do in a particular situation?'. More importantly I would alert radiographers to incorrect settings selected on the DR console, such as a wrong detector selected prior to the radiographer exposing. Further incidences are reflected in section 3.5.5 discussing my role I term the 'ethno-radiographer'. These practical adaptations facilitated my relationships with participants, which allowed them to respond more honestly about their original query or concern. This highlights that grounded theory had 'practical applications' throughout this ethnographic fieldwork whereby my own reflexivity as a radiographer and researcher influenced my own behaviour and actions thus impacting the data collected (Glaser and Strauss, 1967:246). Charmaz (1997:35) alludes to the use of 'grounded theory steps' in her research objectives. In this PhD research 'steps' were used throughout, which are discussed further in this chapter (3.5). Theorists rarely discussed or acknowledged the use of a 'mixed-method approach' (Sale *et al,* 2002), however I now discuss the use of X-ray experiments 'within an ethnographic sphere'.

3.3. Ethnography: Collaboration of research methods

The identified gap within the radiographic literature in the previous chapter focused this study to employ an ethnographic methodology. Generally ethnographic data takes the form of observations, interviews and examination of documents aiming to explore a culture amongst a group (Holloway and Wheeler, 2002:136). Following this position my initial response deemed this methodology as a 'mixed method approach' based on the general philosophical positions associated with 'ethnography' (naturalism) and the 'scientific experiment' (positivism). Hammersley (1992:186) claims that 'all research involves both deduction and induction in the broad sense of those terms; in all research we move from ideas to data as well as data to ideas'. The hypothetical-deductive element and divide was initially grounded by my own epistemology as a diagnostic radiographer. Published papers often use controlled 'scientific equipment' in 'controlled environments' informing radiographers of new knowledge produced in a laboratory environment, often transferable to the clinical environment. Initially I had concluded that a 'mixed method approach' would answer the research objectives. Hammersley (1992:162) recognises the 'stark contrast between experiments and ethnographic research' because while experimenters study artificial settings, ethnographers study 'natural settings'. However to treat these as natural and scientific is to forget that social research is itself part of the social world, something that never should be forgotten (O'Reilly, 2011). The competing paradigms have 'created barriers to that free flow of communication that is an essential requirement for scientific progress' (Hammersley and Atkinson 2007:234) thus suggesting an alternate approach to the logic of ethnography that incorporates both interpretivism and positivism depending on the goals, circumstances and judgements about the consequences of actions in a research study. Holloway and Wheeler (2002:19) term this a 'sequential strategy', whereby ethnography is used to explore the research environment and then on the basis of the participant observation develop other research methods in order to examine the healthcare practices observed. An approach adopted in this PhD thesis.

The ethnographer in qualitative research arguably adopts a ‘person-centred’ and ‘holistic’ picture helping to develop an understanding of human experiences in the clinical environment. This role is also important for healthcare professionals who focus on care, communication and interaction. This suggests a connection between a radiographers ‘ethics and code of conduct’ (the philosophy) (SCoR, 2008) with the qualitative researcher whereby professionalism, commitment, patience, understanding and trust are considered vital throughout. Further, radiographers use inductive thinking to clinically assess patients prior to irradiation. Radiographers interpret their social environment and the patient leading them to subjectively set a radiation exposure. Other aspects such as the type of radiographic positioning required, infection control methods needed and type of injury and risk of cross contamination all adds to the full picture of a patient’s treatment and management. In addition, diagnostic radiography is a ‘scientific discipline’ historically relying upon experimental publications to provide insight into optimal techniques, as ionising radiation remains undetected to the human senses. I do not suggest that we should revert from two paradigms to one, nor however should the variety of approaches be regarded as stemming simply from fundamental philosophical or political commitment (O’Reilly, 2011). Firstly ethnography and X-ray experimentation can be undertaken depending on what one wishes to know or to find out to relate to a theory in one’s own field, as ethnographers themselves do not decide before hand the questions to ask (Hammersley and Atkinson, 2007). Secondly as a radiographer and ethnographer my ability to triangulate research paradigms by means of induction, deduction and reflexivity is arguably a central tenet to radiographic practice. For example it can question what one knows, how such knowledge has been acquired, the degree of certainty of such knowledge and what further lines of inquiry are implied (Hammersley and Atkinson, 2007) in order to uncover the complex nature of clinical practice and potentially improve a patient’s care. The use of ethnography and experimentation is thus not a ‘mixed approach’; ethnography has been used as an ‘umbrella methodology’ encompassing the use of induction and hypothetical-deduction to capture radiographic practices with the aim of contributing to existing knowledge (O’Reilly, 2011). The notion of reflexivity is that all social research and indeed all social life is founded upon participant observation (ibid), thus in this study there was more to be gained by collaborating observations, interviews and X-ray experiments answering the research objectives and adding to existing knowledge (Hammersley and Atkinson, 2007). The ‘triangulation between-methods’ was used to present specific phenomena within the clinical environment (Denzin 1978:301) and discussed in later chapters (seven and eight). In the proceeding headings of this methodology chapter ‘X-ray experiments remain a subheading under ‘ethnography’ as it is seen as collaborative rather than dichotomous approach in my own epistemological and ontological viewpoint.

3.4. The study

The research study was conducted in two National Health Service (NHS) Trusts in the south east of England. The study required close engagement with radiographers in their clinical setting to explore the cultural impact of DR. The qualitative method 'ethnography' was used to explore the environment documenting cultural phenomena within the general imaging environment. The research involved various members of staff including radiographers, assistant practitioners, clerical and managerial staff. Approximately between 2-6 radiographers were present in the DR environment at any one time consisting of varying experiences and expertise. During the fieldwork I was continually reflexive, adjusting where necessary in order to collect the appropriate data to answer the research questions. Throughout, I did not assume levels of education, ideas and perspectives of the research participants and remained committed to an open approach to allow the ethnographic data to emerge and be collected on an interactive basis with the staff.

3.4.1. Selection of sites

The hospital sites were selected based upon the clinical use of DR in the clinical environment(s). Sites at Trust one (A, B and D) were 'circled out' by the researcher due to previous working relationships and easily contactable, with site A the preferred site because it provided better access for experimentation and established working history, which Hammersley and Atkinson (2007:41) identify as 'casing the joint'. Choosing the research site(s) were important in the time presented on the PhD scholarship. Researchers often choose a setting where they are already members, know the people and have good familiarity with the scene, termed 'opportunistic' research and 'member-research' (NCRM, 2013:10). The selection of sites proved problematic in deciding whether to perform an intensive or extensive study on participants within the DR environment, for example selecting one site and observing over a period of time or observing multiple sites but over a shorter period of time? It was decided to observe over a shorter period of time and observe as many operators as possible to explore how DR was used in the clinical environment. This decision allowed the researcher to explore a range of attitudes and behaviours of clinical staff in their clinical environments, thus able to determine common themes. Figures one and two below demonstrate the sites in Trust one and Trust two that had DR capability, totaling to an inclusion of four research sites in this PhD study.

Figure One: NHS Trust One

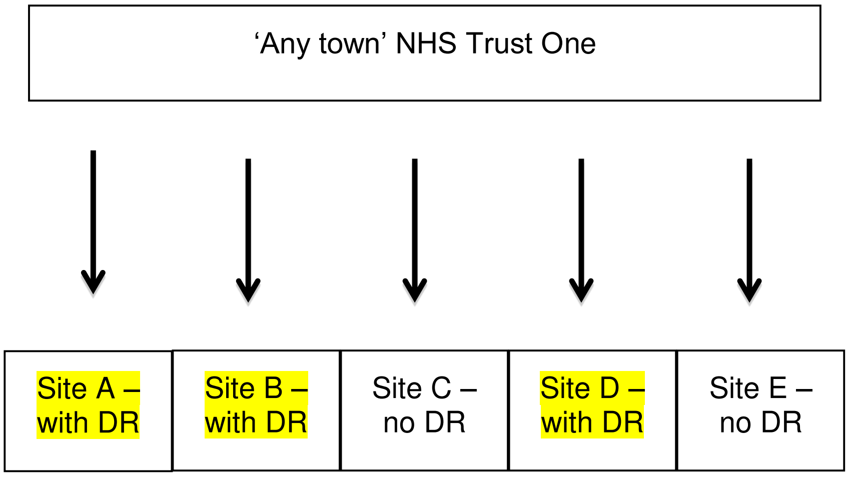
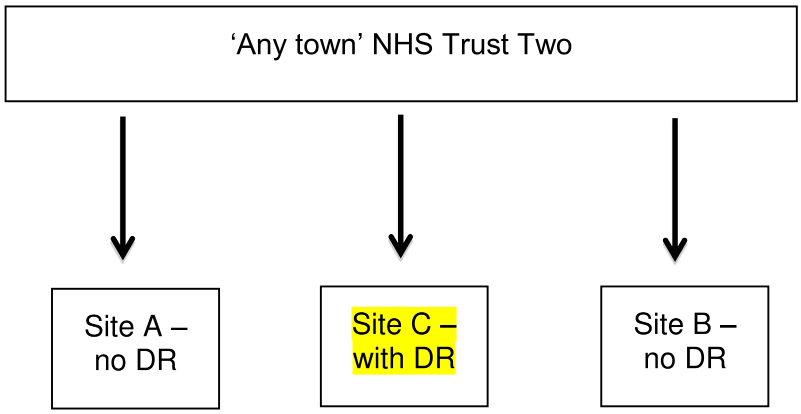


Figure Two: NHS Trust Two



Sites A, B, C and D were chosen from the two NHS hospital Trusts by the researcher because DR was installed and clinically used.

3.4.2. Access to the field

Approval to collect research data was sought separately at each hospital site establishing contact with relevant gatekeepers (Bailey, 1996). To request access to 'NHS Trust one' I approached the superintendent radiographer at 'site A' by sending a formal letter printed on headed notepaper from the University's Graduate School requesting a meeting to discuss the possibility of undertaking research within their X-ray department. I had known the superintendent for approximately four years, three years as a student radiographer and one year working as a full time diagnostic radiographer. I later received a response requesting my attendance with herself and the principal radiographer of the Trust. The initial discussions lead the principal radiographer to question 'why do you want to watch my radiographers?', this presented an immediate nervousness about my proposed research topic. After discussing my research and presenting presentation slides I clarified that I would not be 'spying' and merely 'exploring the culture following the implementation of DR in the clinical environment'. After this meeting the gatekeepers allowed the study to proceed in the Trust welcoming the research. The principal radiographer was very helpful in providing numerous forms and provided other gatekeepers details because I would need to liaise with them in order to negotiate access to the other sites within the Trust. There were elements of self-interest and manipulation in the negotiations and discussions with key participants because I knew that empirical data from the observations may raise problematic discussions in the later chapters because 'being a radiographer' I was aware of certain pitfalls and dangers associated with DR.

After establishing access different procedures were required in order to gain access to the NHS Foundation Trusts. In Trust one a 'license to operate' was required, yet in Trust Two a 'research passport' was required. The 'license to operate' and 'research passport' both provided me with an 'honorary contract' to undertake research in the NHS Trusts however it highlighted that different Trusts may have different procedures in place to gain access. I was requested by the research and development teams at each Trust to provide a personal criminal record bureau check, participant consent forms, participant information sheets, research protocol, and patient information sheets. Formal meetings were necessary to discuss the research topic with each Clinical Director. After successful negotiations with numerous individuals formal letters were issued by the Clinical Division Director in Trust One and the Chief Medical Director in Trust Two confirming access to undertake the research, which could then begin immediately. In Trust one I was provided 6 months to undertake the research and one year to undertake the research in Trust two, illustrated by figures three and four (p.66 and 67). Following the acceptance to undertake the research the negotiations of access did not stop there, gaining access was a process of continual re-negotiation, bargaining, and establishing trustful relations with gatekeepers and those whom were to be studied (Lee, 1992; Blackman and Commane, 2012).

Figure Three: Application to Trust one

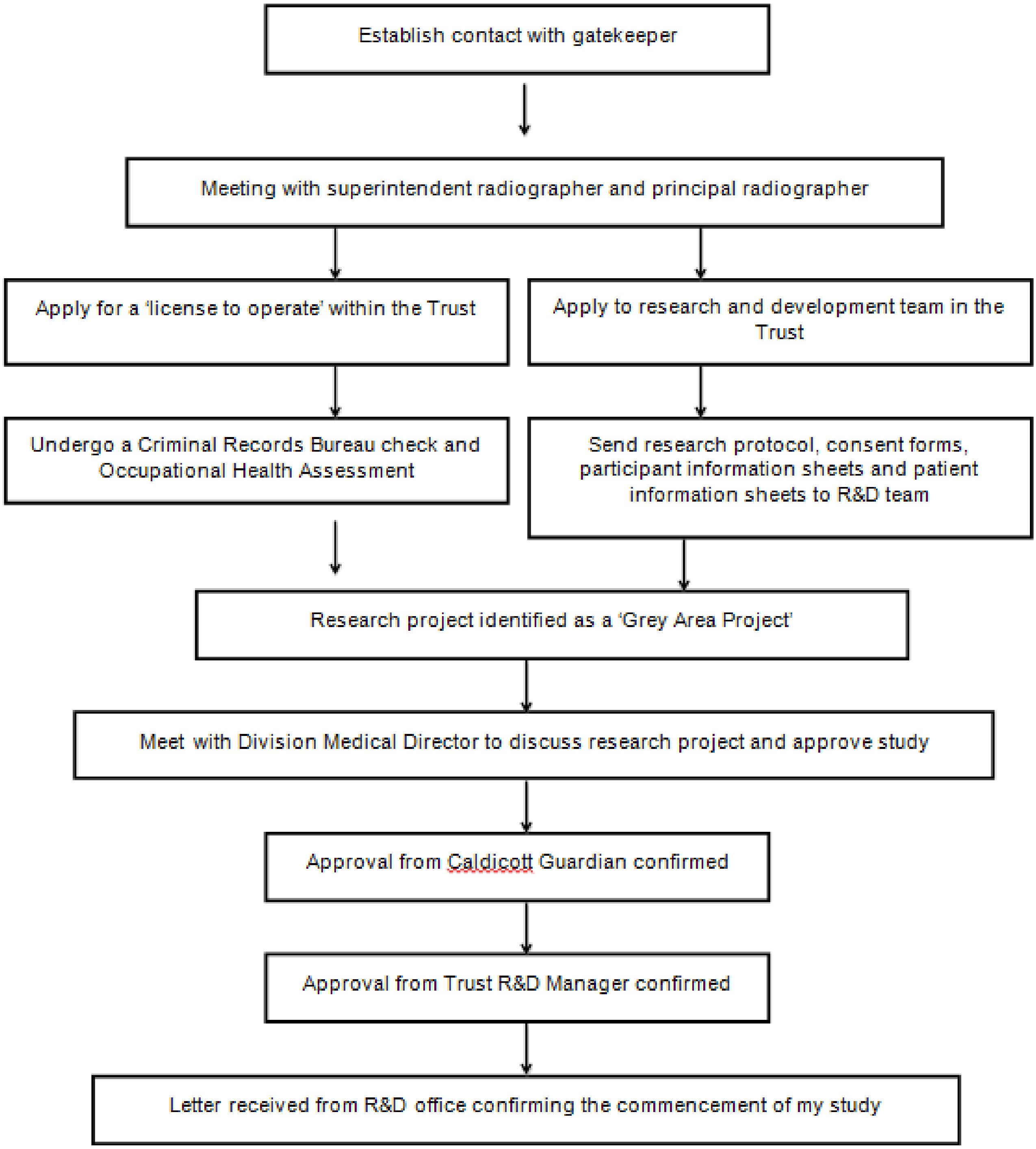
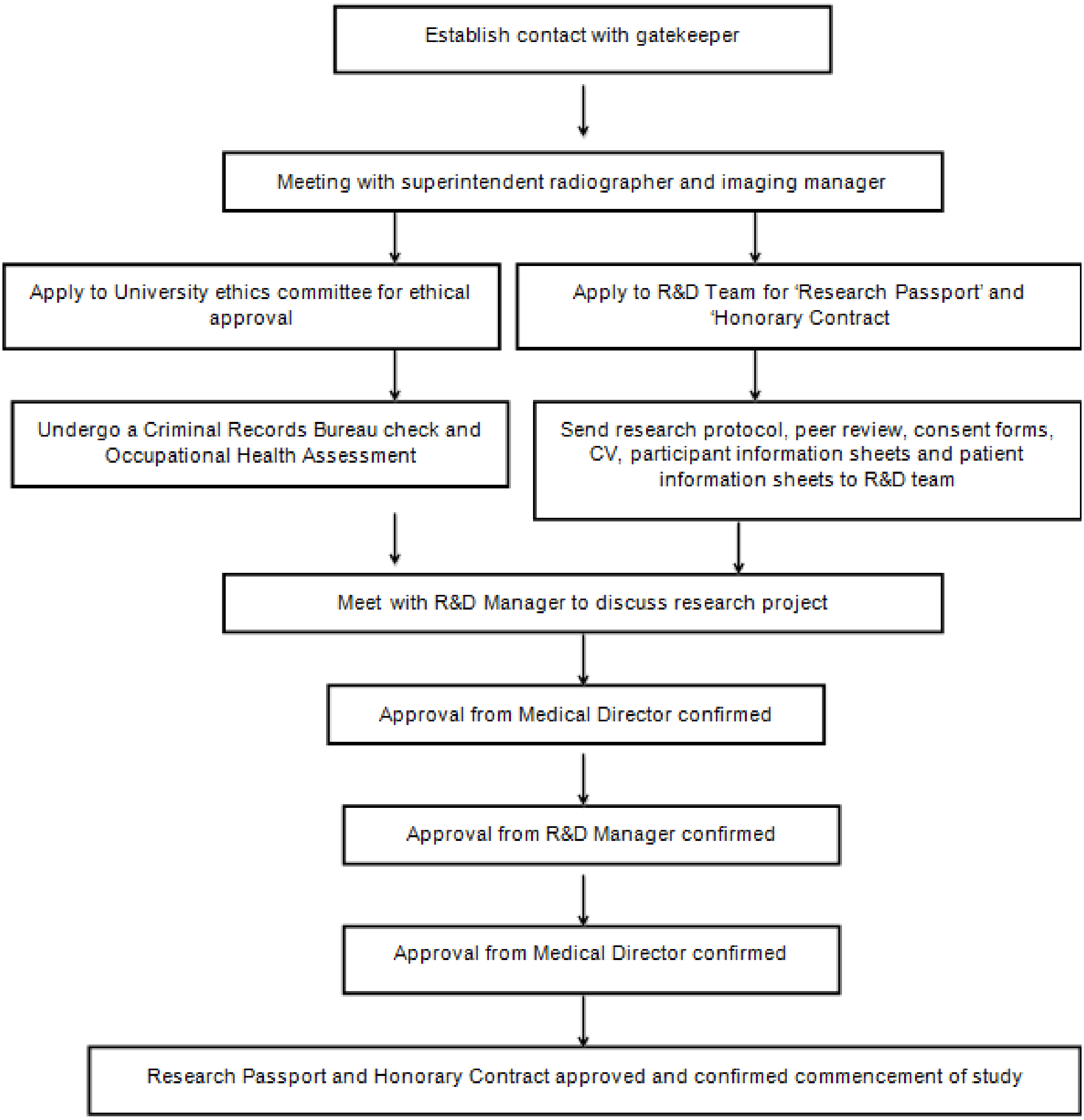


Figure Four: Application to Trust two



3.4.3. Ethical considerations

Ethical applications were submitted to the individual 'research and development' departments in each NHS Trust with an additional application sent for ethical review at Canterbury Christ Church University. Ethnography relies on the first hand experiences of other people's lives, thus with careful consideration the core ethical principle in this research was the respect for every individual (Pole and Morrison, 2003; O'Reilly, 2011) throughout the different stages of the research:

> *"It is essential that existing sources of evidence especially systematically reviews are considered carefully prior to undertaking research. Research which duplicates other work unnecessarily of which is not of sufficient quality to contribute something useful to existing knowledge is in itself unethical."*
>
> (Department of Health 2005:13)

Participants were considered throughout this study because at any point they could feel vulnerable. The research aimed to explore their clinical practices thus could be reluctant to make negative comments in fear that their colleagues identified their comments or actions. Observations were vital in this PhD research yet the observation of unsafe practice had to be considered, particularly when studying in your own practice (Rudge, 1995; Dixon-Woods, 2003). To overcome this I decided to ensure a safe environment for myself and others with an obligation to intervene if a patient or member of staff were at risk with instances of malpractice reported to the departmental manager in accordance with the hospital Trust policy. Ethical consideration was important in relation to the patient, because although they were not directly involved with the research *per se*, their involvement remained and thus consent was sought. It was decided that patient consent would be requested verbally, with my role compared to the role of a student radiographer whereby students observe patients undergoing various radiographic procedures for educational purposes and require verbal consent from patients prior to their radiographic examination commencing (Nursing and Midwifery Council, 2013). In support 'patient information sheets' and 'departmental posters' were distributed in the X-ray waiting rooms at each of the sites allowing the patient the opportunity to inform a member of staff if they did not want a researcher present during their radiographic examination, these examples can be found in appendices four (p.300-301) and five (p.302) for the reader.

Consent: At each research site every effort was made to ensure that participants made an informed decision about taking part in the research and did not feel obliged to do so because of a previous professional/personal relationship and/or because the senior managers had given me permission for me to work in the imaging department. A participant information sheet (PIS) and consent form were distributed by electronic mail by the superintendent radiographers at each site making all potential participants aware of the research objectives. This method of distribution was more effective than face-to-face discussions due to the recent introduction of various shift patterns radiographers were currently undertaking, thus it was difficult to speak to all participants simultaneously at each site. I made it aware to participants that they did not need to take part if necessary and even if they did want to take part they could leave the research at any time. The PIS and written consent forms can be found in appendices six (p.303-305) and seven (p.306). Throughout the data collection at the four research sites only 3 staff members requested not be observed or interviewed. Therefore agreement and consent to participate in the imaging department(s) was strong as 37 staff consented, which left it easy to ensure that those staff that did not consent were avoided during the observations and also not asked to interview.

Ensuring no harm: Throughout the undertaking of this PhD research a primary focus was to ensure that no harm came to any member of staff and/or patient. It was decided that any form of mal-practice would be highlighted and then reported to the line manager at the responsible site. During the initial data collection (site B) one incident occurred whilst undertaking observations as an elderly patient fell from a chair whilst undergoing an X-ray examination. This immediately illustrated that as a member of the 'radiographic community' I would not be able to take on a 'novice role'. The operator (an assistant practitioner) came behind the protective lead screen and the patient fell off his chair, hitting his head on the floor. The assistant practitioner (and I) intervened to ensure that the patient was not injured and I continued to help the assistant practitioner in moving the patient into a stable sitting position followed by placing him in a hospital chair. I felt that this intervention was essential in preventing any further physical harm to the patient or assistant practitioner. I felt I had a statutory and moral obligation as I still remained a 'practicing practitioner', although an 'ethnographer' I remained the most senior person in that X-ray room! Other studies have reported the dilemma of observing practice whereby intervention has been necessary (Hobbs and May, 1993; McGarry, 2007). This intervention proved a dilemma throughout the research because of instances whereby I would intervene pre-empting a mistake from the practitioner as they would have unnecessarily exposed a patient to ionising radiation and thus posed a potential radiation risk. I felt that I had a 'level of care' of which I would be required to intervene, which Johnson (2004: 254) calls the 'intervention dilemma', the physical bottom line in which a researcher feels they must intervene. This would have resulted in any patient or staff member being physically harmed or at an increased risk to ionising radiation. Therefore I did intervene on occasions and the individual operators did thank me as I prevented particular events from occurring. These accounts identify that research undertaken within the healthcare environment presents a range of challenges that can impact on numerous patient demographics. Moreover it illustrates the unpredictable nature within the X-ray room as radiological exams are undertaken on various patients with varying physical and metal conditions. In short ethnography in an X-ray environment requires the individual to be prepared for all situations in order to prevent any further harm to patients, staff members or oneself. Other aspects which included less than satisfactory practice in relation to communication with particular patients and with other members of staff, which as a researcher and radiographer I found it difficult to stand by and observe, however throughout these interactions it was not my role as a researcher to intervene.

'Ensuring no harm' is arguably a cultural issue too. At 'site D' a senior radiographer questioned my presence as the researcher in the X-ray viewing room stating 'have you nothing better to do than watch us at work?' (Observation 01/11/12: Audio note). On reflection the senior radiographer was not happy with my presence in the field, therefore to ensure no harm I asked 'if there was an issue with me being here then I could leave if he so wished'. He explained that because the department was busy 'it would be a good idea to come back another day'. I left the field on his request however this illustrated that participants can become hostile within the clinical environment. In order to prevent any further disruption I returned as suggested on a different day to perform further observations. On reflection I felt that because the department was busy radiographers were placed under increasing pressures, thus creating a 'bad atmosphere', of which I became part of. Additionally because I was 'not physically helping out' with the workload I was arguably seen as a hindrance, someone who was 'in the way', which may have facilitated such remarks from the senior radiographer. On reflection I began to realise that this particular environment was not suitable for observing radiographers (see appendix eight for department layout, p.307-310). This highlights that not all environments in the study were suitable places for participant observation; this is discussed later in this chapter.

Confidentiality: The confidentiality of information was paramount in this PhD study. I initially decided to be open with my note taking, leaving them in the 'viewing area' for participants to see throughout the observations. This approach was found to be useful in Strudwicks' (2009) research, resulting in the participants feeling less threatened. However as the research developed I felt it increasingly uncomfortable leaving my notes 'lying around' as I would be collecting data that highlighted pitfalls and 'near misses' and felt that this could be seen as 'grassing on my colleagues' (Blackman, 1997). To reduce elements of anxiety consenting participants were reassured that the information they provided would be treated confidentially and that their contributions would remain anonymised in any publications or reports stemming from the study. No patient demographics were documented during the observations and all documentation was securely stored on my personally secured student drive at Canterbury Christ Church University. Names of staff were anonymised by their profession, grade and provided with a gender specific pseudonym, which are later used in the empirical chapters.

3.5. Ethnography

As discussed in section 3.3 this PhD study considers 'ethnography' as the 'overarching methodology' providing a flexible approach integral to the research objectives. Crucially the nature of this research and in particular its relationship to practice allowed me to get closer to social reality uncovering radiographic practices (Hammersley, 1992). The methods included:

1) Participant observation: Observing contemporary radiographic practices noting 'what the radiographers did'.

2) In-depth semi-structure interviews: Explored key themes derived from the clinical observations and uncovering deeper meanings into 'what had been seen'.

3) X-ray experiments: Reflecting on specific radiographic examinations observed to contribute to 'what had been seen' with 'what had been said' regarding specific phenomena.

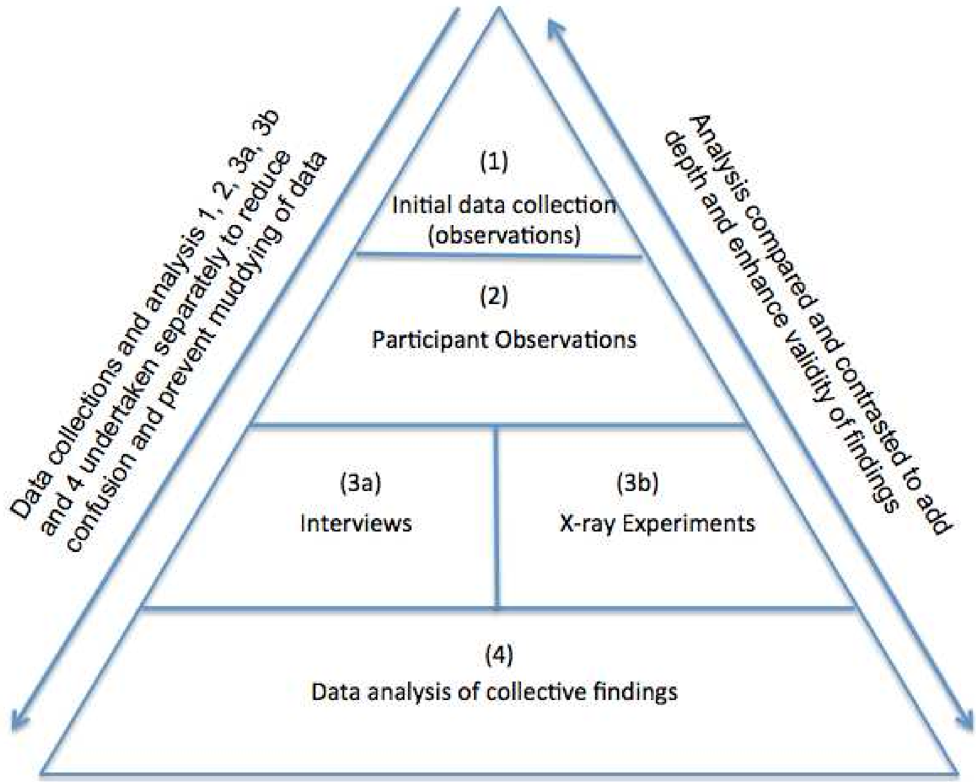
Ethnography offered a valued insight into a specific culture(s) underexplored within radiographic practice in the United Kingdom (UK). It was first pioneered in the field of socio-cultural anthropology deriving from Greek words 'ethnos' (folk/people) and 'grapho' (to write) to learn and understand cultural phenomena which reflects the knowledge and system of means guiding the life of a cultural group (Philipsen, 1992; Creswell, 2007). This holistic approach to culture is cited in the early work of the Chicago School of Sociology, creating an ethnographic mosaic using a variety of methods to better understand the social and cultural world (Blackman, 2010). Ethnography is qualitative and open-ended providing an 'umbrella' framework, which encompassed quantitative methods and analysis and enhances the understanding of relationships between practices, value systems and the organisational (and even societal) context (Atkinson and Hammersley, 2007).

Ethnography is a tool that explored the world from the practitioners and patients' perspective. Hammersely (1992:35) terms this 'practitioner ethnography' following its recent uses in education and other professional disciplines. The ethnographic methods applied in radiography made it possible to recognise the distinction between 'what people say they do and what they actually do', which is crucial for effective and beneficial workplace redesign. The use of social constructionism and interpretivism allowed the ethnographic fieldwork to explore the knowledge, understanding and cultural underpinnings of the imaging department (Brewer, 2000). Interpretivism identifies and searches for patterns of descriptive meanings helping to understand the participants view. Constructionism is a form of interpretive research (Taylor, 2002), which states that meaning is not discovered but constructed (Crotty, 2005). Constructionism forms our experiences, history, culture, use of language, knowledge and social action and are all interconnected and over time lead to shared meanings (Brewer, 2000). Grounded theory, developed by Barney Glaser and Anselm Strauss (1967) was adopted for this PhD study identifying social phenomena by direct first hand contact developing theories of social processes 'grounded' on the lives of individuals when experiencing the processes. In diagnostic radiography this body of knowledge may be linked in many ways in the clinical environment thus theory is developed inductively to explain human behaviours or processes by observation (Woodgate, 2001). Methodologically grounded theory provided the flexibility to 'go back and forth' within the data strengthening my conclusions and linking back to the research objectives. Charmaz (1997:35) alludes to the use of 'grounded theory steps' answering her research objectives. Similarly, 'steps' were used throughout this PhD research, which included:

1) Examining informal discussions with participants and 'what had been observed' in the clinical environment.
2) Construct analytical categories with 'what had been observed' and the informal discussions had.
3) Conduct interviews and X-ray experiments on phenomena 'observed' whilst reflecting on initial interview responses, later refine categories for further interviews.
4) Linking 'what had been observed' with 'what radiographers had said' about particular phenomena, contributed with X-ray experimentation.

This exploratory approach to 'discover theory' is supported by Strauss and Corbin (1997:64) whereby 'scholars are thinkers and keep thinking, which is after all the exciting part of your research', which is paramount of a grounded theory methodology. This approach in this PhD research is reflected in figure five (p.74), illustrating the procedural steps undertaken within this ethnographic methodology. As demonstrated I commenced with 'initial data collection', which enabled reflection of data collection methods and informal discussions. Participant observations allowed me to collect rich data investigating 'what radiographers do with DR and how they do it', thus leading onto interviews with radiographers and X-ray experiments using a phantom limb. The use of interviews and X-ray experiments were conducted in order to 'clarify the situations being uncover' in the clinical environment, reducing any observer bias in data collection.

Figure Five: Data collection and analysis process



The inductive and deductive approach is becoming wide spread in disciplines such as physiotherapy and radiography (Henwood, 1996) used to study healthcare professionals effectiveness in managing clinical cases (Mellion and Tovin, 2002) and patient-practitioner interactions (Bryne, 2001). Theoretical sampling is one of the characteristics of grounded theory in which data collection and constant comparative analysis takes place concurrently to drive the sampling process to select participants that can help develop a theory reflecting variation, process and density (Henwood, 1996; Mellion and Tovin, 2002), thus attaining data saturation. Symbolic interactionism means that individuals' realities are created through attaching meaning to situations and symbols such as words, dress, hairstyles or objects of worship, which in turn are used to express their meanings or beliefs (Rock, 1979). Although an individual' reality is unique in nature, symbolic meanings are shared among groups and the basis of actions and interactions. Through symbolic interactionism researchers see the interactions with multiple others, patients and staff and in addition X-ray equipment regarding 'operator actions', which are similarly attached to symbolic interactionism, advancing our understanding of technology and the 'actions of others' within the specific culture.

The aim of ethnography is to provide thick descriptions of patterns of behaviour belonging to individuals and groups within a particular culture (Geertz, 1973; Agar, 1986; Bernard, 1994). It can play a pivotal role to a professional group that seeks to understand the behaviour of its members (Massey, 1990). Saks and Alsop (2010) argue that ethnography can be more integral to professional groups that seek to yield understanding of the behaviour and practices of its members', illuminating hitherto covert patterns of behaviour and decision-making in the field. The fieldwork contexualised behaviour and decision-making in a particular work domain during a recurring but delimited time such as a normal working day (Pole and Morrison, 2003) seeking to understand participants actions and their experiences of the world through observing the participants by learning about people by learning from them (Roper and Shapira, 2000). The intention of the fieldwork was to gain a rich description of radiographic practices from participant observations, tracing the process of 'definition of the situation' (Holloway and Wheeler, 2002:153) and interpret the findings and understand the basis of this PhD. This supported the humanistic discovery aiming to capture and understand naturally occurring world activities in real-world settings (Bailey, 1997) because it was believed that radiography had its own culture in the development of digital technology in the clinical environment. In order to collect the necessary data my aim was to 'immerse' myself within the radiographic culture(s). This immersion and inductive approach facilitated the development of theories that were later explored by means of semi-structured interviews and X-ray experiments.

3.5.1. Initial data collection

The first stage of data collection began at 'site B'. Initial data collection provided an insight into the way data would be collected, my physical position and how I would immerse myself into the culture of the department(s). Because I was already part of the radiographic culture, as a locum radiographer in the two NHS Trusts I would be aware of boundaries and barriers associated with general radiographic practice. However, this did not assist my initial data collection with participants at site B. For example speaking with the gatekeeper prior to undertaking research at site B, I requested the distribution of the PIS to prospective participants explaining the intention of the PhD research. On the first day of observation members of staff had not read their emails and knew nothing of my aims in the field. I ensured that in future I had numerous copies of the

PIS, consent forms, patient information sheets and posters available if necessary in order to explain my intentions and 'what I hoped to achieve'. The initial data collection demonstrated the importance of 'note taking' during the observations and reflected my ignorance because I was unaware how this would develop into a 'delicate method of data collection'. I created an A4 'scientific sheet' with information 'I' required. This approach did not fit to such data collection in the field as recording radiographers' techniques displayed elements of hostility, with comments such as 'are we doing well enough for you?'. Hammersley and Atkinson (2007:91) describe this as a 'culture shock' that puts the ethnographer in immediate confrontation with his/her participants. The 'scientific sheet' became a problematic tool for data collection in the field and in response I exchanged it for a 'blank' A5 notebook from my rucksack. At this stage of the research I had not intended to use statistical analysis, however following the initial data collection I had observed that radiographic techniques may have been used inappropriately. The ethnographic methods illustrated that a statistical analysis would need to be sought. This initial data collection provided an insight into the 'field research' later proving essential for the remaining observations at other research sites. A detailed account on the development of note taking is discussed next.

Development of note taking: A reflexive approach was carried out on the materials gathered and the tools used to gather the materials (Atkinson and Hammersley, 2007). As described above note taking took place within the X-ray room. There were elements left out of the data observed and what was included or left out of the field notes depended on the problems I pursued at the time such as taking detailed field notes of a wrist examination (Burgess *et al,* 1961). Hammersley and Atkinson (2007:146) support such actions claiming that satisfactory note taking needs to be worked at, as fieldworkers will have to ask 'what to write down, how to write down and when to write down'. The incorrect method of using a 'scientific sheet' to collect the appropriate data can be seen in appendix nine (p.310-311). This method presumed that the data in an ethnographic study needed to be collected in a preformatted 'scientific' way, however whilst in the 'ethnographic' position this method of data collection proved highly intrusive to the research participants and obstructive in understanding the cultural underpinnings within a research environment (Blackman, 2007). Hammersley (1992:21) supports this claiming that 'if ethnographers are to pursue the development and testing of theory they will need at the very least to coordinate their studies in a systematic way and may need to modify their data collection and analytic procedures'. This 'refocussing' was important as participants identified the scientific sheet as a form of 'questioning their practice', which later encouraged some operators to alter their techniques to suit the research. Firstly it became impractical, due to its size, carrying around an A4 sheet in a folder hindered my position in the field where participants requested clinical assistance. Secondly it lacked space to document the cultural aspects surrounding the use of optimising ionising radiation in practice and the clinical department as a whole based on the nine dimensions (Spradley, 1980). A 'grid' was created in the back of the A5 notebook that documented the specific X-ray examinations, see appendix ten (p.313) for a scanned copy of alternate notes. Moreover as the observations continued similar practices were beginning to be identified, such as a radiographer 'cropping' an X-ray image post exposure, adjusting the exposure factors or adjusting the brightness and contrast of an X-ray image post exposure. This coincided with the speed at which a typical radiographic examination would take, on occasions in under one minute! Thus following the speed in which an X-ray procedure could be taken I decided to create a time saving strategy, creating shapes to represent specific actions made by the operator, this concept provided an increased amount of time in the field (Wolfinger, 2002) as illustrated in table one.

Table One: Shortcut symbols used in data collection

Action made by operator	Symbol
Operators altering exposure factors.	Ø
Operators adjusting contrast and brightness setting post exposure.	□
Operator 'cropping' X-ray image post exposure.	∆

The notion of recording data using 'short hand' tactics was recognised in Barley' (1986) research observing practices of computed tomography (CT) scanning. It provided the researcher the tool to capture actions of events first hand. Throughout the remaining observations in this PhD research the developments in data collection played a pivotal role in documenting the cultural and scientific information at sites 'A', 'B' and 'C' in a short space of time. This allowed me to gather data in a way that informed the interview schedule and laboratory experiments. Moreover it later enhanced the analysis of data, as particular actions made by the operators would be identifiable culturally during the radiographic examinations. On other occasions I felt that the continuous 'note taking' of actions made by radiographers were perceived as a potential threat, because in the X-ray room it was generally myself and the radiographer, and by 'scribbling' information when they were operating felt on various occasions ‘rude’. Thus note taking developed into ‘on the spot’ note taking (Hammersley and Atkinson 2007:147) not only across each site but with different radiographers’. Therefore on occasions I felt it necessary to have my notebook out and then would find it necessary on some occasions to leave my notepad out of sight. To more junior radiographers for example I felt like I had more ‘power‘ and was more ‘in control’ of the note taking, whereas for more senior radiographers I felt ‘rude’ questioning their authority and senior titles, some of whom had trained me as a student radiographer.

At site ‘D’ the method of data collection altered once more, due to the immediate hostility encountered by senior staff members. To ensure that I continued to work within my ethical boundaries and due to my ‘position’ in the field (see appendix eight p. 307-310) I decided not to record data ‘pen and paper’. This decision was made from previous observations at other sites, such as encounters of participants questioning ‘what I was writing’. Therefore I decided to dictate my research findings with an audio device. The environment at ‘Site D’ proved problematic as it became difficult to ‘physically observe’. To appreciate this a graphical layout in appendix eight (p.307-310) (site D) depicts the researcher primarily in the ‘viewing area’ due to 3-4 radiographers continually being present behind the ‘small’ protective lead screen at any one time, thus restricting access to the X-ray room and thus observing radiographic practices. After several days of difficult observation, I had decided to leave the environment after two days of observation due to no original data being collected and thus fully saturated.

3.5.2. Participant observation

Following initial data collection I aimed for complete immersion as a ‘participant observer’ at the remaining three research sites. Barley (1986:83) acknowledges that to map emergent patterns of action and interpretation accurately requires at least partial reliance on participant observation to record interactions. The observations were detailed in the nine dimensions identified by Burgess (1993) and included the features identified in table two (p.79). Observations are an integral part of the healthcare process within the context of healthcare delivery; all healthcare professionals start and end with observation when a patient is in their care. The observations were vital in this process as Larsson *et al* (2009) highlight; how work is done in radiographic departments depends on the individuals’ knowledge as well as on his or her openness, flexibility, service-mindedness, willingness to develop professionally, and triggers for doing certain things.

Table Two: Features included in observations

Features Identified	Features of X-ray Environment
1. Space	Identification of the surrounding layout of imaging department to the other clinical rooms and areas.
2. Actors	The people involved in the situation and their names (staff).
3. Activities	The various related activities of people in the setting (roles).
4. Objects	The physical elements present e.g. in the X-ray room, viewing room and waiting areas.
5. Acts	The actions of individuals, professionals and patients.
6. Events	Particular activities of individuals, such as those within the X-ray room.
7. Time	The time sequence in performing a DR examination and finishing it.
8. Goals	The activities people are trying to accomplish in particular situations.
9.Feelings	Emotions in particular contexts.

Throughout this method I explored how work was undertaken in relation to optimising radiation protection. It allowed me to have first-hand experience of action-in-process (Adams and Tovey, 2000). Hammersley (1992:128) identifies that the term ‘enlightenment’ implies that practitioners are in the dark and need the light of research before they can see where they are and in which direction they are going in. Similarly through immersion I felt that participant observation was ‘the key’ at highlighting dimensions posed by the research objectives, such as interactions, relationships and events (Sak and Allsop, 2010). The observations allowed me to ‘enter’ into the radiographers’ world, reacquaint with known colleagues and introduce myself to new ones, which allowed me to discuss my intentions and research objectives. Following the observations this not only provided a platform for the interview transcript, similarly I felt it encouraged members to feel less threatened at attending a one-on-one interview. The use of observations in a culture of interest provides information essential to an understanding of that culture documenting the practices and interaction among organisational actors (Spindler and Hammond, 2000). I observed the behaviour of others and informally discussed topics focusing the research in 'what was going on' and 'how I intended to explore this further'. My position was predominantly 'participant as observer', however this role became blurred into 'observer as participant', which facilitated the open recognition of the research objectives (Pole and Morrison, 2003) and allowed the observation of cultures, which helped in understanding them. The purpose of this method was to depict the cultural and technical factors that occurred during radiographic examinations in order to help overcome the discrepancy between 'what people say they do and what they actually do'. The observations were performed on various days of the week within 15 weeks. I maintained sound liaisons with gatekeepers to ensure my presence in the field remained appropriate. Table three demonstrates the observation time spent at each research site.

Table Three: Observation record at each hospital site

Site A	Site B	Site C	Site D
24/08/12 AM	12/07/12 AM	07/08/12 AM	01/11/12 AM
24/08/12 PM	12/07/12 PM	07/08/12 PM	01/11/12 PM
31/08/12AM	18/07/12 AM	10/08/12 AM	08/11/12 AM
31/08/12 PM	18/07/12 PM	10/08/12 PM	08/11/12 PM
07/09/12 AM	30/07/12 AM	23/08/12 AM	
07/09/12 PM	30/07/12 PM	23/08/12 PM	
28/09/12 AM	21/08/12 AM	28/08/12 AM	
28/09/12 PM	21/08/12 PM	28/08/12 PM	
05/10/12 AM		05/09/12 AM	
05/10/12 PM		05/09/12 PM	
16/10/12 AM		10/09/12 AM	
16/10/12 PM		10/09/12 PM	
22/10/12 AM			
22/10/12 PM			

Sampling: The four research sites were chosen because they had integrated DR systems that were used on a day-to-day basis. In 'Trust one' (sites A, B and D) were established with DR with the first installation occurring in 2004 and consisted of seven DR machines in total. In contrast 'Trust two' had recently installed their first DR system in 2011 and remained the only DR unit within the Trust. The sample satisfied several criteria for this study through the inclusion of both academic and community hospitals of varying size and location in the South of England, willingness to participate in the study and varying experiences with DR technology. The decision on 'who to observe' and for how long varied according to the individual research sites, for example at site A, B and D numerous DR rooms were granted access. I did strategically carry out observations at all research sites predominately at site A due to known relationships with participants and distance from researchers home address. Site C had the only DR technology within the Trust, which made it easier for the placement of the ethnographer. One disadvantage was that it supported outpatients only. Thus at site C I was not able to observe radiographers using DR within the accident and emergency, 'GP patients' or 'in-patients' context. This affected data saturation in each NHS Trust, for example at sites 'A', 'B' and 'D' participants varied in seniority, thus providing a general range of radiographers. However at site C participants often consisted of the same participants on the days of observation due to the departmental shift patterns thus data saturation and sample size were smaller at Trust two when compared with Trust one and as a result ended earlier than expected (Charmaz, 2006).

Data collection: To collect observational data within the hospital environment I would attach myself to a DR room and its surrounding clinical areas 'shadowing' participants throughout their daily activities. Where informed consent was forthcoming data collection of the observations were undertaken and it was estimated in total that 30-40 operators were observed using DR over 19 days (approximately 142 hrs.). On a typical 09:00 – 17:00 working day, the observation commenced at 09:00 and ended at 12:00, I would break for lunch, gather notes and then begin the second observational block from 12:30 to 17:00. Data was collected throughout the day and on occasions with and without the notepad. For example, when in the staff room taking lunch, I would sit with participants and they would discuss radiographic and personal aspects, such as the new shift system, which regularly became a topic of conversation. These occasions of 'time out' in the staff room or the 'viewing area' provided me with the opportunity of 'small talk' amongst participants and previous colleagues. These social interactions became a major source of data collection. Furthermore, I would remain in the X-ray rooms when radiological examinations were undertaken and would move accordingly when a DR room became in use. Throughout the observations data was collected using an A5 note pad at sites 'A', 'B', 'C', and audio notes taken at site 'D'. Whilst my presence as an ethnographer was overt, there were elements of covert note taking. Burgess (1990) reports when researchers have had to dash to the toilet to jot down notes. I was not dissimilar, at site D due to the ‘tension’ felt between a number of participants I felt it necessary to leave the ‘clinical area’ in order to record my data in private, thus dashing to the nearest toilet and recording notes on my digital dictaphone as any form of note taking ‘within the immediate vicinity of participants’ in my view would have been extremely uncomfortable and highly intrusive.

An example of the transcribed observational data can be found in appendix eleven (p.314-323). It was the intention to document as much as possible in the research field whilst continually reflecting on the data collated. Throughout the note taking I would record my own feelings and thoughts throughout the study. Site ‘D’ remained problematic because of the layout where radiographic rooms are open to the viewing room. Furthermore there was limited space behind the protective lead screen and because there were several operators behind this protective screen I felt like a ‘spare part’ as I failed to place myself in an ‘appropriate location’ in which I felt comfortable. The data documented the social setting and intimate detail of the culture/events of interest (Pole and Morrison, 2003) in order to build on theoretical propositions for the development of the interview schedule (Saks and Allsop, 2010) and laboratory experiments. It was decided to collect specific data important to the study and thus leave certain aspects out. For example, for the laboratory experiments intimate technical data about ‘what the operator did’ to obtain an image of diagnostic quality, such as exposure factors, source to image distance (SID) and collimation (field size). This data provided the development of the experimental method and can be found in appendix twelve (p.323-326). In addition I aimed to uncover cultural phenomena, thus I set ‘mini objectives’ throughout the observations by ensuring a recorded ‘number’ of upper limb examinations. This realistic approach was important because the collection of ‘unused’ data would not have contributed to the overall study and may have caused further intrusion and harm to the participants. In addition the method of obtaining the experimental data differed with different X-ray equipment. For example when recording radiographic techniques at sites ‘A’, ‘B’, and ‘D’ I was required to ‘physically walk’ to the X-ray tube next to the patient to note the SID and collimation dimensions from the LCD display on the X-ray tube, whereas at site ‘C’ the SID and collimation information was displayed behind the protective lead screen on a monitor thus felt less intrusive.

Throughout the observations some participants altered their actions upon being observed and this was verbally expressed too, for example operators became increasingly self-aware of their working behaviour such as ensuring that the SID was set to precisely 100cm (after discussing that it should be) illustrating the halo

(Hawthorne) effect (Burgess, 1993). The best evidence however to suggest that my presence did not noticeably alter all participants behaviours lies in the fact that they were willing to practice in a way that some other radiographers may have disapproved of whilst in their presence, these are discussed in chapters seven and eight. Furthermore, participants saw me in different ways; some were often unaware of my presence in the viewing room, while others would see me as 'judging their clinical practice'. The majority recognised that this study provided the opportunity to add to existing knowledge.

3.5.3. Interviews

I conducted 22 semi-structured interviews across two NHS trusts (sites A and C). Sites A and C were selected due to the frequency of observations performed coincided with the rapport developed with individual staff members. The observations provided detailed accounts relevant to DR in the clinical environment; the general themes were interactive and sensitive to the language and concepts used by the interviewee (Denzin and Lincoln, 1998). The interviews were directed by a list of potential questions of themes observed during the observations and were interactive and sensitive to the language and concepts used by the interviewee (Denzin and Lincoln 1998). This schedule provided an understanding of the experiences, behaviours and attitudes of radiographers in the clinical environment through face-to-face discussions, which could be hidden in actual clinical practices (Hammersley, 1998) providing this thesis with a deeper understanding of the relationship between practice and context (Burgess, 1993). Interviews provided considerable data generation and the 'semi-structure style' of interviewing allowed a set of topics to form questions in the course of conversation; 'conversations with purpose' (Burgess, 1984:102). The interviews were conducted under the following headings and supported with an interview schedule (see appendix thirteen p.327-328) to aid the researcher to deliver particular questions in a particular order, these included:

- General questions about how long radiographers had been working with DR and the education and training received within the imaging department and at higher education.
- Identification of areas in which DR hinders and facilitates their radiographic practices and the affects it has on the profession and the implications for future practice.

- The patient experience within a DR environment and the effects it may have towards patient care.
- Operator techniques, such as radiation protection, collimation, exposure indices and adjustment of brightness and contrast of X-ray images.
- Limitations of the digital equipment.
- Workflow issues with the use of DR in practice.

Informal interviewing occurred with various members of staff in the clinical environment. I was approached by participants in the clinical environment who highlighted certain issues experienced within the DR environment knowing I was undertaking research. Moreover the informal process facilitated those senior members including superintendents who felt that they did not have sufficient time to formally 'sit down' and discuss issues formally. The informal discussions provided valued insight into the observed patterns of behaviour within the clinical environment (Roper and Shapira, 2000) and have been used in later chapters. Attention was placed upon the observed practice and explored with interviewees exploring behavior, meanings and understandings of the events that took place. Although a schedule was developed for the interviews it was not used as a structured questionnaire but acted more as an *aide mémoire* to ensure that similar topics were covered in all the interviews with any omissions checked at the end of the interview (Bailey, 1996). This approach allowed the interview to remain flexible as topics would arise in different orders and therefore the research would move to that topic. On this basis it enabled the research participants to ask and answer questions that I had not previously considered.

Sampling: The intention was to interview a sample of 20-25 participants in this PhD study across two research sites (A and C). Participants at sites B and D were not approached for interview because it was important to find the 'right people' to study in terms of theory development (Brannen cited in NCRM, 2013:16) and with the majority of observations conducted at sites A and C I deemed it unnecessary to pursue any further research at other sites. This method of theoretical sampling aimed to inform the research questions and build on the criteria identified during the observations, helping develop theory (Glaser and Strauss, 1967). My 'knee jerk' reaction was to merely take as many interviews as possible as it would somehow seem 'better' (NCRM 2013:5) and arguably at times I would possibly postpone my analysis of the interviews by undertaking 'just one more interview'. However interviews did cease following data saturation when I had interrogated the purpose of their research objectives (NCRM, 2013). The radiographers interviewed varied in professional experience. The variation of experiences was important in this study, as it could provide various points of view, producing rich and varied data. For example it was important to consider radiographers who had rarely used FS and conversely important to interview senior radiographers' whom had used FS in order to identify any differences in practice amongst junior and senior radiographers.

When considering whom to interview I sampled participants from 'those I knew' and had 'social ties' beginning with direct personal contacts, which I felt aided 'others' to come forward having 'little to fear'. This also facilitated the recruitment of 'new participants' (those previously unobserved). When I interviewed 'friends' their persona had changed in front of the audio recorder and immediately became less vocal within the 'interview environment'. Other participants were chosen who had been friendly towards me and were interested in the topic supported by those I had built a sound rapport with throughout the observations. For some (who I had observed) I received responses such as 'I'm a bit busy at the moment' and 'how about next week?' For some recently qualified radiographers they believed the interview to be a 'test of knowledge' regarding me as the expert (Burgess, 1990). I appreciated their concerns and would move onto another participant, this ad hoc approach led me to 'pull participants off the corridor' during the quieter periods in the X-ray environment. On reflection a sufficient number of staff had been selected in accordance with the research objectives, stemming across two hospital sites with varying experiences and viewpoints, tables four and five (p.86-87) identifies the participants, their job title, clinical experience and gender specific pseudonym. Rather than specifying a precise sample size the researcher continued interviewing until the analytical themes derived from the data become 'saturated', i.e. until new themes stopped emerging from the interviews (Glaser and Strauss, 1967; Saks and Allsop, 2010).

Table Four: Participants – Site 'A'

Pseudonym	Participant ID	Gender	Title and Grade	Experience
Margaret	DR1	Female	Band 7 Practitioner – reporting radiographer	18 years
Eric	DR2	Male	Band 6 Practitioner – works in general and cardiac suite	9 years
Bernard	DR3	Male	Band 6 Practitioner – works in general radiography	8 years
Sebastian	DR4	Male	Band 5 Practitioner – works in general radiography	2 years
Rosemary	DR5	Female	Band 6 Practitioner – works in general and CT	7 years
Sharon	DR6	Female	Band 6 Practitioner – works in general area and CT	12 years
Fred	DR7	Male	Band 6 Practitioner – works in general and CT	5 years
Harold	DR8	Male	Band 6 Practitioner – Works in general and cardiac suite	9 years
Michael	DR9	Male	Band 5 Practitioner – works in general area and cardiac suite	2 years

Table Five: Participants – Site 'C'

Pseudonym	Participant ID	Gender	Title and Role	Experience
Geoff	DR1	Male	Band 6 Practitioner -works in general area	5 years
Elizabeth	DR2	Female	Superintendent Practitioner (Band 7) – works in angiography	6 years
Terry	DR3	Male	Band 6 Practitioner – works in general department	7 years
Mick	DR4	Male	Band 6 Practitioner – works in general radiography and CT	5 years
Victoria	DR5	Female	Band 5 Practitioner – works in general radiography	1 year

Abigail	DR6	Female	Band 5 Practitioner – works in general radiography	11 years
Kirsty	DR7	Female	Band 5 Practitioner – works in general radiography	2 years
Helen	DR8	Female	Band 5 Practitioner – works in general radiography and cardiac suite	2 years
Danny	DR9	Male	Band 5 Practitioner – works in general radiography	8 months
Alex	DR10	Male	Band 5 Practitioner – works in general radiography and MRI	4 years
James	DR11	Male	Band 6 Practitioner – works in general area and CT	3 years
Annabelle	DR12	Female	Band 7 Practitioner – Reporting Radiographer	7 years
Emile	DR13	Male	Band 5 Practitioner – works in general radiography	9 months

Data collection: The interviews had taken approximately 3 months to complete. The undertaking of interviews varied at each site as one to four interviews could be performed in any one day. This was due to the unpredictable nature of the X-ray emergency department, thus I would visit the research sites on specific days. For example at site A I would attend Thursday and Friday as outpatient clinics were limited and thus the radiographers less busy. At site C I attended Saturday and Sunday as the radiographers that worked in the DR room often worked weekends. The interviews ranged from 25-60 minutes each, the first taking 25 minutes with concerns that I may not have gathered enough data. During the initial interviews some radiographers discussed their lack of empathy, care and failure to optimise radiation doses, this often 'drained' me emotionally hearing the day-to-day 'qualms' of radiographers and how it can affect their radiographic practices and care to patients. Throughout the interviews I was sometimes considered an 'expert'; however I was often surprised by this assumption because while I had developed certain knowledge I did often feel unequipped to answer such information. For example, during one interview a participant began to question 'when and where is it appropriate to place lead on a patient?' While as a researcher and radiographer I would reference certain studies, I did feel 'lost at sea' in answering specific questions with full conviction.

As the data was transcribed information and debates emerged about the research process, findings and my abilities as an interviewer. I had learnt that I talked too much during the interview and would interrupt the informant unnecessarily. On reflection it proved problematic to transcribe. Gradually I learnt to speak less and from the transcripts it was clear that I did talk less in later interviews (Pole and Morrison, 2003). Initially I had carried out some interviews in an unsuitable location, with building work being carried out next door, the noise pollution lead to the temporary abandonment of an interview. We were required to move to an alternate location, this later impacted the transcription therefore I was correct to change the location of interviews as data would have been missed. Following this a quiet vacant office was selected for optimal audio recordings and also provided confidentiality for participants. On occasions interviews were abandoned because participants were required urgently for a 'clinical matter' thus postponed and continued at a later date. Interviews were recorded verbatim using a digital audio recorder. I found this device appropriate in order to transcribe the data accordingly as the individual files could be removed and played in a media player and 'slowed down' to transcribed effectively. Some participants were more aware of the recording device, periodically looking at it prior to answering a question, this highlighted that participants were aware of their actions and I felt this did influence some respondents responses, for some this produced short answers, not in depth and reflected on the time taken to complete their interview. Throughout this thesis words from research participants' are presented verbatim in order to have an accurate account of the formal interviews undertaken to preserve the meaning for the analysis (Burgess, 1993 and Saks and Allsop, 2010). Benton and Craib (2001) claim that one should take note of the things that exist in the social world such as dialectic and communication boundaries because these are defined by our culture and language. Thus gaps or uncertainties in the quotations are clearly indicated in this thesis, including 'pause', 'laughs' and 'Ummmmms' representing the context of the participants' responses (Hammersley and Atkinson, 2007). During the transcriptions difficulties were noted as participants speaking English as a second language were difficult to transcribe. Thus words unrecognisable to the author were noted in the transcripts as 'unclear'. The transcriptions were emailed to participants allowing them to verify the transcripts, with a time frame on each email stating that 'no response within 30 days would assume that the transcript was verified by the participants'. An example of one of the transcriptions can be found in appendix fourteen (p.329-349).

Developing the interviews: The topics and questions were formed as a result of the informal discussions and observations identified within the clinical environment. Throughout the interviews I continuously reflected on the topics identified by the participants and further topics were incorporated into the interview schedule. In early interviews I would not listen carefully to the respondents' answers as I appeared more conscious of keeping to the interview schedule while conscious of the time the interview was taking up. With little postgraduate experience my interview techniques altered upon interviewing senior radiographers with extensive experience. For example although the interview transcript provided the script my interview technique primarily aimed to 'seek guidance', delicately questioning their radiographic techniques, thus preventing a defensive barrier from the participant. In contrast I felt more comfortable discussing radiographic techniques with radiographers with similar experience and who I had previously collaborated with clinically. The initial interviews were in-depth interviews allowing the participant to 'tell me your story….'. As the interviews developed I was able to 'fine tune' the questions and after completing five interviews I would listen, transcribe and note the responses to certain phenomena and develop the interview schedule accordingly. Burgess (1990) claims that the quality of your data is dependent on the quality of the relationship you build with the people being interviewed. Additionally I felt that my own reflexivity was essential before and throughout the interviews, impacting on the discussion and approachability among the participants (Howatson-Jones, 2010). For example, I felt that my time spent 'in the field' as a researcher and radiographer facilitated my relationships with participants because as rapport developed over time I was able to question 'more personal' phenomena relating to DR and its application towards patient care delivery. In short, the interview became like an informal conversation with additional probes added where appropriate. The interview schedule (final version) can be found in appendix thirteen (p.327-328).

3.5.4. X-ray experiments

The qualitative data collected during the participant observations informed the X-ray experiments at sites A and C. Hammersley and Atkinson (2007:90) speak of the collaboration between ethnographers and alternate methodological approaches, 'it is worth noting that these strategies are complementary, not mutually exclusive'. Each DR room was selected based on its availability 'out of hours' as other rooms were in 24 hour use providing emergency radiographic care. Upon approval from each gatekeeper, radiographic experiments were conducted at site A (hand) and site C (wrist). The experimental design developed as a result of the ethnographers feelings towards the qualitative data (ibid). This was part of the reflexivity throughout the data collection whereby I assessed linkages with practice using observations, interviews and experiments triangulating across different data sources and stages of the research (Denzin, 1978; Howatson-Jones, 2010). Burgess (1990:110) is of the opinion that hypothesis should develop from the ethnographic work rather than provide restrictions and distortions from its inception, because in observing people's behaviour we derive hypothesis from our cultural knowledge to describe and explain their actions. In support Hammersley and Atkinson (2007:15) identify that experimentation is a way of 'trying things out', put to the world 'what would happen if', they argue that experimentation in this form is normal in everyday life and the 'genuine experience', thus collaborative in the ethnographic methodology. The experimental design was not only based on inductive theories from participant observation (Couvalis, 1999); it subjected my theories to rigorous test in the field, which evolved as part of the social world capturing a holistic picture of the clinical environment through ethnography.

Aim: The aim of the experiments were to complement 'what I had observed' with 'what radiographers had said' about phenomena in the clinical environment. In order to discuss the variations observed it was necessary to test them in the actual clinical setting using the DR systems. The specific hypotheses were to test collimation and source to image distance (SID) and its effects on the dose area product (DAP) with the exposure index (EI) a strong indicator of dose delivered to the patient.

The objectives of the X-ray experiments were to:

- Reflect on collected observational data and design X-ray experiments based on 'what the radiographers did…'
- Perform quality assurance tests on DR equipment ensuring that the doses delivered during the experiments were the 'expected doses'.
- Perform experiments in designated DR rooms at sites A and C to mimic the radiographic practice observed.
- Organise, code data and perform statistical analysis using SPSS.

Throughout the observations, the common independent variables altered by operators were collimation and SID. Reflecting on the data observed it was decided to increase the SID by increments of 5 cm from the lowest to the highest values observed for hand and wrist. In addition, it was decided to select the collimation based on the smallest and largest dimensions for each radiographic projection observed in practice, followed by a median value. The anthropomorphic images produced were stored securely and safely archived to each hospitals PACS (picture, archive, communication, system) however the 'image quality' was not explored in this PhD study because it is not within the scope of this thesis nor does it answer the research objectives. No ethical considerations were required for the X-ray experiments as no patients were involved and my first supervisor and I were present during the experiments.

The DR equipment contained two flat panel digital detectors, one horizontally mounted in a table and other vertically mounted on a supporting structure. Table six (p.92) details the equipment for the reader for comparison. The digital detectors were single panelled (non-tiled) amorphous silicon detectors with a Cesium Iodide scintillator (CsI). The CsI, with its needle like crystal-line structure together with the small pixel size provides a high detective quantum efficiency (DQE) of more than 60% at zero line pairs per millimeter and a sound modulation transfer function (MTF). Detective quantum efficiency is the most important single parameter, which reflects image quality and depends on spatial frequency. The detector converts the analog signal into a digital signal with an image depth of 14 Bits.

Quality assurance: Quality assurance (QA) checks were performed on the digital equipment in accordance with local protocols. The QA checks ensured that the exposures delivered in the experiments were the expected exposures. The tests were used to identify any improper central X-ray misalignment, which may distort a radiographic image and/or increase in output of the kVp and mAs thus potentially effecting dose (or image quality) (IPEM, 2010). It ensured that no change in radiation output had occurred due to ageing, drift, component failure or miscalibration (ibid). The QA tests undertaken prior to experimentation conformed to current safety measures and deemed the equipment safe and optimum in its delivery of ionising radiation (IPEM 2010). The results and graphs are illustrated in appendix fifteen (p.350-359).

Table Six: Digital Radiography Equipment

Site A - Equipment Specifications	Site C - Equipment Specifications
Make/Model: Philips Digital Diagnost System 1.5 Focal Spot Size: 0.6 and 1.20 mm Grids: Oscillating grid Table and Wall Matrix size: 3000 x 3000 pixels Active Area: 43cm x 43cm Bit depth: 14 Bit	Make/Model: GE Healthcare Discovery XR650 Focal Spot Size: 0.6 and 1.25 mm Grids: Table 100cm focus | Wall 100cm, 130cm and 180cm focus Matrix size: 2022 x 2022 pixels Active Area: 41cm x 41cm Bit depth: 14 Bit

Anthropomorphic phantom: A hand/wrist anthropomorphic phantom was used for the experiments and whilst no ethical approval was required I did document it in the original research protocol in order to provide an overview of the study. The anthropomorphic phantom limb was designed such that radiation absorption was similar to that of real patients (Williams and Adams, 2006). The phantom material contains a density of 0.985 g/cm^3, an effective atomic number of 7.3, identical to human tissues and contents i.e. muscle, fat and bone thus absorbing radiation in manner similar to the human body (Williams and Adams 2006). Positioning and centering of the anthropomorphic phantom was undertaken using aids including radiolucent sponges and lead in order to mimic a patient's radiographic position on the digital detector (see figure six, p.93). The parameters under investigation were set up and centering on the limb was accomplished following the radiographic literature (Whitley *et al,* 2005).

Recording dose and exposure index (EI): The DAP and EI readings were measured from the DR console in the clinical environment. The DAP unit was recorded in this study because this was the method and unit collated by radiographers during the observations and used for the routine monitoring of patient dose (NRPB, 1990). The exposure index (EI) was a secondary dependent variable collated, this can be used to evaluate dose and was present within the clinical rooms as a guide to the operators. Three exposures for each individual technique were performed to increase the validity of the findings. The EI values obtained during the experiments differed at sites A and C, table seven (p.93) provides a visual account for the reader.

Figure Six: The positioning of the anthropomorphic phantom during X-ray experiments

Table Seven: EI value and relationship to DAP

DAP	Site A - Philips DR EI	Site C – General Electric DR EI
Low	400	0.50
↓	↓	↓
High	125	1.50

3.5.5. ‘Ethno-radiographer’: Reflexivity in the field

When ethnography is a research tool of an investigation, the researcher becomes the key instrument for data collection (Ragucci, 1972; Burgess, 1984; Morse, 1989; Hammersly and Aktinson, 2007), with status characteristics (race, sex, ethnicity, age, sexual orientation and social class) becoming relevant to the production of knowledge

(Burgess, 1993 and Bailey, 1996). The importance of using this approach was to provide a deep description of the culture of a particular group in action. This led to an opportunity to understand the group through immersion into their culture i.e. participating in the specific culture for an extended period of time. However this part of ethnography in turn becomes its contradiction. Since the application of ethnography can be either from an etic (outsider's view) or emic (insiders's view) perspective, for the etic approach it is difficult for the outsider to establish a relationship with the participants and gain permission to immerse themselves into a group and hence cannot be an ethnographic study. As a radiographer my perspective was emic providing insight into the radiographic profession. Becker *et al* (1961:15) remind the reader 'this is how things look and feel down under', although it feels like a true setting, its merely an account of those professions and their practices at a point in time and that there would be no organisation in which things look the same from all positions. Clifford and Marcus (1986) concur, maintaining that ethnography similarly captures partial moments in time. Richardson and St. Pierre (2005) identify crystallisation as a process of undertaking exploratory research because we need to acknowledge that there are many dimensions in which to approach the world (just as a crystal has many facets and dimensions) and what we see depends on our viewpoint and perspective. The emic approach facilitated the study allowing me to identify key points within the clinical environment that could be explored throughout this PhD study.

Researcher positionality: My position in the field is important to discuss because whilst ethnographic research explores the social action and deeper elements of participants, my relationship with participants was an issue which inevitably pervaded all aspects (Holliday, 2007). My 'physical position' (6 foot man) ethnographer at the research sites are depicted in appendix eight (p.307-310) and often proved problematic in the clinical environment. On reflection the 'protective lead screen' in which a radiographer places him/herself behind limiting their radiological dose became 'key' to positioning. For example, at site D it proved difficult to observe radiographic examinations merely due to the layout of the clinical department (Bowling, 2004). In addition the protective lead screen was extremely small in comparison to other sites, thus my placement merely involved being in the 'viewing area' behind the X-ray rooms. At sites A, B and C I found myself 'tucked away' in a corner behind the protective screen as the space was significantly larger and thus able to accommodate myself, and other members of staff undertaking clinical work. Site D was particularly difficult to observe and as discussed above led to leaving the field earlier than envisaged. This highlights that environmental and cultural contexts in which the researcher is exposed adds to the complexity of the ethnographic fieldwork but similarly strengthened it. For example the protective lead screen at site A was considerably larger than other sites, this facilitated my 'position' in the field, allowing me to 'keep out of the way' having little impact on the operators and their day-to-day tasks. On reflection prospective researchers that aim to conduct ethnographic fieldwork within an X-ray room should consider their 'potential site' prior to undertaking field work as it may influence the relationships and data collection of the study.

Due to my physical presence 'in the field' the aim of my role as a researcher was to remain objective, accessible and friendly whilst reducing the possibility of 'going native' (Hammersley and Atkinson, 2007:100). Ethnographers may adopt a variety of roles however my aim throughout was to maintain a more or less marginal position. The ethnographer must be intellectually poised between 'familiarity and strangeness', while socially poised between 'stranger' and 'friend' (ibid: 100). While I acknowledge my 'connection' with numerous participants throughout the thesis becoming the 'friend' my choice to undertake advanced postgraduate study alienated me amongst my peers and others as participants often questioned: 'why on earth did you decide to do that?' and 'what do you intend to do after it?'. This alternate approach to my career undertaking a PhD helped me distance myself from the research participants allowing me to 'become the stranger amongst other radiographers', thus allowing me to 'ask the unfamiliar' and 'ask the obvious'. This research identified areas of practice in which my presence was as an advantage in the field as I had an obligation to protect the participants and patients as a registered healthcare professional by abiding to my professional code of practice outlined by the Society of Radiographers (2008:3):

> *"You must conduct yourself with honour and dignity and demonstrate trustworthiness and integrity in both your personal and professional life in order to maintain the widest public trust and confidence in the profession".*

On reflection I developed a moral stance within the fieldwork. It is generally accepted that individuals entering a healthcare profession generally want to care for people (Bolderston *et al* 2010 cites Goldins' 1979:190). Throughout this PhD research I felt I had moral and professional obligations to patients and participants, which resulted in leaving my 'research position' to aid where appropriate. Glaser and Strauss (1967:246) identify the 'awareness context' doctors and nurses have over their forms of interaction for those people involved in a 'dying situation'. Similarly, I was required to approach situations holistically, controlling my own forms of interaction with participants, aiding them where necessary. Participants would ask me about a particular 'X-ray exposure' or 'what would you do in this situation?'. More importantly I would alert radiographers to incorrect settings selected on the DR console, such as a wrong detector selected (discussed further in chapter seven) prior to the radiographer exposing. If I had not made the operators aware of this incorrect selection a patient would have likely received a dose of radiation with no X-ray image produced. Another example included the light-beam collimation (LBD) box 'opening up' due to the selection of another radiographic examination on the DR console with the operator unaware of the actions taking place from the equipment. This would have given the patient an increased dose of ionising radiation and reduced image quality (Jeffery, 1997), which was something professionally and morally I did not allow. This highlights that grounded theory had 'practical applications' throughout the ethnographic fieldwork whereby my own reflexivity as a radiographer and researcher influenced my own behaviour and actions thus impacting the data collected (Glaser and Strauss, 1967:246). Other aspects of the 'ethno-radiographer' role included conforming to 'bad practices' whereby upon request I would inform the operator 'how to crop' an image or 'how to adjust the brightness and contrast' of the image, generally seen as inappropriate radiographic practice. Whilst in the field and arguably conforming to suboptimal practices I felt like a corresponding sense of 'betrayal' or at least divided loyalties to my 'ethnographer position'. In contrast my betrayal did not stop there, during my 'locum radiographer' role I would apply typical practices and use specific functions comparable to those identified in chapter seven amongst the participants, later reflected in my field diary:

Field Diary: *"Working as a radiographer I would initially use the similar functions available to me 'masking' improper collimation, pay little attention to the SID and rarely use lead protection on numerous patients. Upon reflection and continuous observations I realised I had performed and maybe even contributed to suboptimal practices thus facilitating the 'way things were done around there'. On reflection this allowed me to become part of the culture, 'fit into the norm of everyday practices', yet on the other hand by realising my faults I was obliged to remain within my ethical boundaries and later began to take note of my practices, trying to apply stricter collimation, carefully select exposure factors and apply carefully SID positioning."*

On reflection my ignorance towards my own radiographic practices was arguably important throughout this study as it allowed me to resonate and 'fit in' with participants I did not know that well. For example as 'the locum radiographer' I began to work with others building sound relationships and 'as the radiographer' (prior to becoming the ethnographer) I took part in the 'suboptimal' practices highlighted in chapter seven. However as my role altered to what I refer to as the 'ethno-radiographer' my positionality changed, and through continuous reflection I began to note the suboptimal practices in others that impacted my own practice. Howatson-Jones (2010) identifies how adopting an autobiographical approach can enable different elements of the research process to be brought together, including the researchers struggles. Howatson-Jones (2012:47) further discusses how a 'learning biography' can provide the student a strategy to evaluate their contribution to learning, how to undertake learning and how they can develop further. Similarly the 'ethno-radiographer' position and continuous reflexivity continued throughout this PhD study facilitating my own practices and positionality, allowing me to become more objective to the actions and behaviours around me (ibid). Moreover as I remained employed at sites A and C I naturally felt less informal around some participants, which had a direct impact on the way the participants acted. At these sites I 'the ethnographer' would become 'the radiographer' as reflected in my field diary:

Field Diary: *"An assistant practitioner (AP) was positioning a radiographic projection (an angled view of the scaphoid examination). The AP experienced difficulties undertaking this projection and asked for my help. I verbally explained the technique I would employ for the patient before intervening however the AP insisted that I demonstrated it to her asking my advice and with other staff extremely busy I decided to intervene. I became 'the radiographer', I had to come out from behind the screen and position the patient while advising the AP of the technique I was employing. This felt uncomfortable at first however I was aiding the AP and the patient thus felt essential in order for the patient to receive the appropriate images of diagnostic quality diagnosis."*

This example highlights the danger of 'going native' within the clinical environment. It identified that being 'in the field' in your own discipline opens the research to more complex and nuanced understandings of issues. However whilst I would intervene I felt it facilitated my 'presence' and 'reason for being there' as I was able to explore and aid participants where appropriate, providing guidance and reduce the possibility of work related stress (Akroyd *et al,* 2002). This empathic attitude allowed me to listen to staff members, absorb their problems and provide a voice to the participants involved in this study (West, 2000), arguably gaining a deeper insight into the clinical environment (Randle *et al,* 2007; Verrier and Harvey, 2010). Furthermore, it reinforced the argument that remaining objective in my own professional field remained problematic but in fact was further engaging with participants using the digital technology which highlighted other areas of concern. In addition failing to aid the patient and participants could be interpreted as a diminishment in care and responsibility from the researcher due to the professional ethos governed and required by healthcare professionals.

I became more reflexive in my dual role aiming to understand the process whilst critically examining power relations in the data collection and interpretation (Jones *et al,* 1997). This was first highlighted by the numerous 'labels' I attached to individuals in the clinical environment. For example 'informant', 'participant', 'healthcare professional' and 'radiographer' were used interchangeably throughout. By becoming more reflexive under the conditions of ethnography I later removed the term 'informant' because I felt that all individuals involved in this PhD study had 'participated' with me in this PhD research and had not merely 'informed' it. I had built rapport with the participants involved in my fieldwork thus throughout this PhD thesis I use terms 'participant' 'radiographer' and 'healthcare profession' interchangeably providing an holistic picture of the individuals involved in this PhD work. Secondly this highlighted my own individual stance during the fieldwork whereby I played the 'friend' and the 'professional' simultaneously depending on the individual participant (Blackman, 2007). Throughout the research some participants would be well known, some more than others, some whom I had collaborated on my undergraduate degree and some I had collaborated working as a radiographer. Therefore there was an element of professional/personal relationship with the participants from previous experiences and I would involve myself in personal discussions, listening to their concerns where appropriate. At 'site C' I had socialised with the participants outside of work, attending various social events including an invitation to the 'Christmas party'. At 27 years of age I would attend 'night clubs', drink alcohol socially, this allowed me to 'get closer' and became part of a 'social group'. Emotional well-being and self-identity became fieldwork opportunities being personal with subjects, creating bonds of commitment for both researcher and researched. Burgess (1990:71) claims that the 'value of all field research and perhaps all research regardless of methods is to measure these dimensions, its contribution to empirical findings, to theory and to social change'. Therefore whilst I developed 'friendships' and thus felt more comfortable around certain individuals in the field, this allowed more in-depth questioning about their clinical practice providing insightful empirical findings. It would have been naïve to believe that I became the 'insider' or that the relationships throughout the research were ever fully equal, however 'who I was' and the interactions I developed with individuals helped form the relations of trust that are important in the field (Holliday, 2007). In addition this felt more comfortable as a researcher asking problematic questions to 'friends' due to the common ground established (Nagar and Raju, 2003) and because I knew their personalities I was aware of the type of responses they may provide (Haraway, 1991). Therefore using this to my advantage it produced flexibility in the research environment, for example I would feel much more comfortable taking notes in front of them. On occasions it would be entertaining, whereby jokes were shared and expressed as 'friendly banter'. Whilst it is argued that ethnographers must strenuously avoid 'feeling at home' (Hammersley and Atkinson 2007:102), this was not apparent with all participants during the observations whereby I had not attained sound relations often feeling cautious regarding my research objectives. At sites A and C my 'informal research role' allowed the participants to feel less threatened by my presence and facilitated data collection. Conversely, there were occasions where I was required to become 'more formal', such as approaching 'friends' to sign the informed consent sheet, this felt intrusive possibly hindering the relationship through the 'reality of research'. At the other research sites (B and D) a majority of the staff were not known to me and I felt comfortable asking for informed consent, the informed consent sheet was a method of 'keeping me safe' in the thought that I had been undertaking the ethical duties appropriately. Moreover once the informed consent sheet was signed, although it may have allowed me to feel 'safer' it altered the interactions with staff allowing the researcher to develop a relationship and act more informally around the 'consenting participant'.

As the study developed I became immersed in the clinical environment. This was advantageous allowing me to ask in-depth questions about specific operators practice or ask their opinion on a particular area of interest. Peake and Trotz (1999:37) support this acknowledging that one's positionality or subjectivity should not mean abandoning fieldwork, it can 'strengthen our commitment to conduct sound research based on building relations of mutual respect and recognition'. This became apparent as I began to engage with the participants more often, their patterns of behaviour would change at all sites and I felt I could ask more regarding 'sensitive' topics relating to practice. Kobayashi (2003) supports the concept that being reflexive is not about one's own positionality to self-indulge but to reflect on how one is inserted in grids of power relations and how that influences methods, interpretations and knowledge production. Therefore although during the research I had been concerned with attempting to remain objective at all costs, becoming the radiographer and ethnographer strengthened my position in the field in developing relations and trust with the participants. This was discovered in the work of Sultana (2007) who identified that through reflecting on her positionality *vis-à-vis* the way others constructed her identity helped in more fully engaging reflexivity, which enabled engagement with the research process.

The 'white coat': It is generally accepted that researchers should have an acceptable appearance, which includes dress, demeanor and speech (Coffey, 1999). Throughout the research I ensured that every effort was put into 'blending in' and becoming part of the clinical environment (Becker *et al,* 1961). Hammersley and Atkinson (1995:83) discuss the role of 'impression management' through dress, speech and demeanour, as well as the presentation of 'different selves' in different research environments. In the research environment(s) I wore smart trousers, a short sleeved shirt (for infection control purposes) and shoes. I decided not to wear a clinical uniform in order to remain separate from staff, thus attempting to remain objective due to working relations developed previously with certain members as attaching a uniform may have encourage 'radiographic practice' and thus prevented the research. My attire was a symbol justifying my presence as a 'researcher' and not a 'radiographer' and throughout the research at sites B, C and D this attire was generally accepted by all gatekeepers during observations and interviews. However, following a discussion with the gatekeeper at site A she requested that I wore a 'white doctors laboratory coat' throughout the observations. Dress or clothing can be shared as a symbol of culture (Pole and Morrison 2003), however Allen (2004:18) asserts that 'uniform is a signifier of group membership, status and rank'. Therefore as the only individual in a white coat it remained difficult to be part of the culture and environment and on reflection did not help the researcher 'fit in'. It had a significant impact on the research participants and patients. The participants would comment on the 'white coat' as a symbol of my research degree; 'here comes the Prof' or 'here comes the nutty professor'. There were also occasions whereby some participants found it intimidating especially more senior staff members claiming 'no-one wears a white coat anymore'. My presence in the 'white coat' had an impact on the patients also, following radiographic examinations patients would ask me what I found from their X-ray, for example a patient with persistent chest pain would ask if 'everything was clear?', thus impacting on the patient, confusing me with a medical doctor who could provide an imminent diagnosis for their symptoms. Becker *et al* (1961) observations of medical students identified that the physician in the 'white coat' presents the most powerful figure within a clinical environment. This supports a figure of power I had obtained in the clinical environment;

a sense of ‘seriousness’, ‘professionalism’ and anxiety amongst colleagues and patients through association of the ‘white coat’, whereas previously shirt and trousers alone had little effect on participants reactions in the clinical setting. Although wearing the ‘white coat’ proved problematic in the clinical environment I was requested to wear it by the superintendent radiographer of the general radiography department thus felt unable to remove this item of clothing. Whilst the ‘white coat’ illustrated attrition amongst some members in the field it did facilitate data collection, helping me remain ‘the scientist’ as visitors and prospective students would wear the ‘white coat’ and simply be ‘observing radiographic practice’ with no input required. Hammersley and Atkinson (2007:79) concur suggesting that such forms of dress are reported to ‘give off’ the message that the ethnographer seeks to maintain the position of an acceptable marginal member. This allowed me to ‘sit back’, observe and collect data whilst engaging in informal discussions. Moreover the feeling of anxiety in which the ‘white coat’ made me feel may have had further implications if I had not known the key participants in this study. The research in general is an intrusive topic and with the added attire a ‘stranger’ entering their clinical environment may have felt more threatened thus I feel my historical relations with the participants did help considerably in collecting the research data and preventing any added discomfort in the field.

3.5.6. Data analysis

The research was approached in an open manner and refined as the nature of radiographic practice began to emerge. This PhD study was conducted in the natural clinical environment assuming that ‘reality is constructed, multidimensional and ever-changing and that there is no such thing as a single, immutable reality waiting to be observed and measured’ (Miles and Huberman, 1994:262). Glaser and Strauss (1967:40) support this suggesting that the general relations are discovered ‘in vivo’ through participant observation, that is ‘the fieldworker literally sees them occurring’. This thesis is an ethnographic report crafting the moments observed at each site representing the participants voice (Allan, 2006) through the researcher’s voice. It was decided to present the data as raw as possible in later chapters in order for the reader to review the interpretations of the data presented and the data analysis process. Within the analysis I provide site specific contexts about each research site which are important to consider due to the significant differences technologically and the individual experiences of performing radiological examinations.

As the research progressed additional developments were made and implemented throughout. I continually moved ‘back and forth’ between the methods and the emerging data thus providing an ‘on-going’ analysis developing my own voice and actions through reflexivity and positionality (Holliday, 2007; Howatson-Jones, 2010; Murphy and Yielder, 2010). Observations were transcribed on the evening of data collection for it to remain ‘current’ in the authors mind whilst providing valued insight into the radiographers’ world. This reflexive process allowed me to continuously reflect on the observational data, which would later impact on interviews and experimental data. The observational data ‘developed’ throughout the development of this thesis, for example data that was not ‘that obvious’ in the beginning became relevant upon analysing the interviews, authors field diary and writing up the empirical chapters. This highlights that whilst participant observation data was collected and analysed ‘at the beginning’ it continually impacted the overall analysis following data from interviewees, X-ray experiments, researcher’s field diary and conversations with friends and colleagues. Thus the ‘observational data’ presented in the empirical chapters is a ‘refinement’ providing a holistic picture to the readers.

Ethnography can provide detailed account on clinical practice, patient and health delivery issues which can focus on the patients or healthcare professionals’ perceptions (Adams and Smith, 2003). It was important to systematically search, arrange and make sense of the data (Brewer, 2000). Research data was transcribed into a word processing application, dated and indexed with spelling and grammatical errors searched and corrected, with participants’ voices (formally and informally) presented in the form of quotations. Files were printed, categorised and grouped into the research sites in specific folders to prepare easy reading. I did not use a ‘qualitative analysis computer program’ thus preferred a word processing application coincided with hard copies to make notes and assign relevant codes to emerging themes. Each line of text was reviewed and coded by the researcher and reread using thematic analysis, which produced general themes. Emerging themes were structured using a coding framework involving data reduction, data display and conclusion drawing/verification (Miles and Huberman, 1994). Upon ‘sorting’ of the themes, four overarching categories emerged: ‘learning’, ‘radiographer challenges’, ‘ionising radiation’ and ‘patient care delivery’. Themes were later printed on A4 paper, ‘cut out’ and placed on A1 pieces of card, whereby theory could then be linked across the themes. Colour pencils were used to cross reference themes, which provided the basis of theory development. Grounded theory supported the generation of theory development through comprehensive explanations of phenomena that were grounded in data, thus demonstrating relevance in the clinical environment (Glaser and Strauss, 1967) and applied throughout this PhD study by means of induction, deduction and verification (Strauss, 1987). Thus although grounded theory does not start with hypothesis I did have 'hunches' (Holloway and Wheeler, 2002:155) and after collecting the initial data and establishing relationships, provisional hypotheses were conceived from grounded theory (Glaser and Strauss, 1967). In chapters five, six and seven observations and interview data are presented to provide the reader with the context, such as whether 'it is done in public' and 'what is done in private' (Hammersley and Atkinson 2007:192). In support the experimental results at sites A and C were entered and organised into SPSS and coded, preparing statistical analyses. Hammersley (1992:90) speaks of collaboration between ethnographers and survey methods in that 'it is worth noting that these strategies are complementary not mutually exclusive'. Thus SPSS provided me with 'the tool' to run Pearson Correlations to examine correlations between DAP and EI and multiple regression analyses on independent variables to predict effects of collimation and SID on DAP (Tabachnick and Fidell, 2007) with separate analyses conduced for each body part. The X-ray experiments were complementary in this thesis and formed part of the whole data analysis in this exploratory methodology. Moreover 'triangulating' the research methods allowed me to approach particular phenomena from different angles, for example as 'cropping' was grounded from the observations, this analysis prompted further exploration through interviewing and X-ray experimentation. Hammersley and Atkinson (2007:198) claim that relying on a source can present a danger because if 'diverse kinds of data lead to the same conclusion, one can be little more confident in that conclusion'. Thus it could be argued that analysing specific phenomena using different kinds of data can further develop theory thus enhancing the 'reflective practitioner' in a radiographic environment.

3.6. Leaving the field

Upon collecting the relevant data through observations, interviews and X-ray experiments I had decided to leave the field of research. I had enjoyed the research and it was sad to leave the different departments as a researcher. I was grateful to all of those who participated in this study. In Strudwicks (2011) thesis she identifies the attachment experienced with her participants and the sad feeling upon leaving the environment. I had not only left research participants, but also friends and colleagues behind, however I did feel that I had a positive impact on the teams in my approach to research and had become part of the team. Firstly, when I would challenge or ask a specific question, it allowed the radiographers to reflect themselves as professionals in their own practice. Secondly, since undertaking the research I have been asked (personally) to 'cover a few shifts' at each of the sites. On the last days I thanked all staff and wrote personal emails to all the gatekeepers for their patience and acceptance during this research process.

3.7. Conclusion

The use and selection of ethnography has illustrated a unique insight into various cultures within the radiographic profession. My epistemological and ontological position has been discussed and whilst the research objectives were initially believed to be addressed using a 'mixed method' approach, in light of the 'exploratory' use of ethnography this chapter has illustrated an exciting method of enquiry into the generation of knowledge in the field of diagnostic radiography that combines methods such as participant observation, interviews and X-ray experimentation. This methodological position facilitated by symbolic interactionism and a 'grounded theory approach' provides an original illustration concerning subject matters such as current training and education, use of ionising radiation and the delivery of person-centred care, discussed in chapters five, six and seven. This chapter discussed the importance of positionality and reflexivity throughout this ethnographic research as I engaged with new and existing relations as the 'ethno-radiographer', facilitating rich data and building on existing knowledge. In contrast this chapter recognises the challenges ethnographers may encounter researching within their own field. For example, I experienced conflict and questioning by numerous members of staff, highlighting that although ethnographic fieldwork can be informative for practice, it can be seen as an invasion into a radiographers practice. Through preparation, reflection and working within the ethical codes of conduct, elements of 'intrusion' were resolved amicably and professionally. It is important to consider that within qualitative methods person-centred care is integrally related to the grounded theory approach towards the data analysis enabling a thick description to emerge. In this sense ethnography was a sound methodology of choice to both promote and support the exploration of radiographic practices in a person-centred care environment because of ethnography's core concern with participatory methods and empathy to aid reflexivity. This methodology sought to provide a new approach to research in radiography that could underpin medical imaging practices for the development of the profession.

Chapter Four: Findings

4.1. Introduction

The main focus of this PhD study was to explore the clinical practices of radiographers following the introduction of digital radiography (DR). The previous chapter discussed the importance of using ethnography as a methodology to explore the clinical environment and uncover original phenomena. The values and beliefs of the researcher identified in chapter one were central how the 'ethno-radiographer' behaved, practiced, collected and interpreted findings. Similarly the values and beliefs of radiographers were central in uncovering 'how radiographers felt and behaved in the clinical environment' thus described as a core variable in this chapter. Rigour and validity of the research findings are considered, providing a systematic approach to the research data strengthening its relevance and importance to the field of diagnostic radiography.

4.2. Values and Beliefs

In chapter one the values and beliefs of the researcher were important to consider because it provided insight into the researchers potential impact on both clinical and educational approaches. Values and beliefs connect the categories in this PhD work and were inherent in the radiographic environment(s). It is evident from the research findings that values and beliefs were not clearly defined within general radiography. They often differed amongst individuals resulting in varying actions and behaviours in the use of ionising radiation and approaches to person-centred care. The core category depicted in figure seven (p.108) illustrates 'values and beliefs' acting as a unifying category of the workplace culture within this PhD research (Wilson *et al,* 2005:34). The findings show that there were alternate views and attitudes towards phenomena within the radiographic environment supporting the view that 'values and beliefs' do vary amongst individuals. The findings and critical reflection in chapter one suggests that for practice reform and improved person-centeredness, strategies uncovering the values and beliefs of radiographers may develop a collective vision or philosophy of sound radiographic practice in the future.

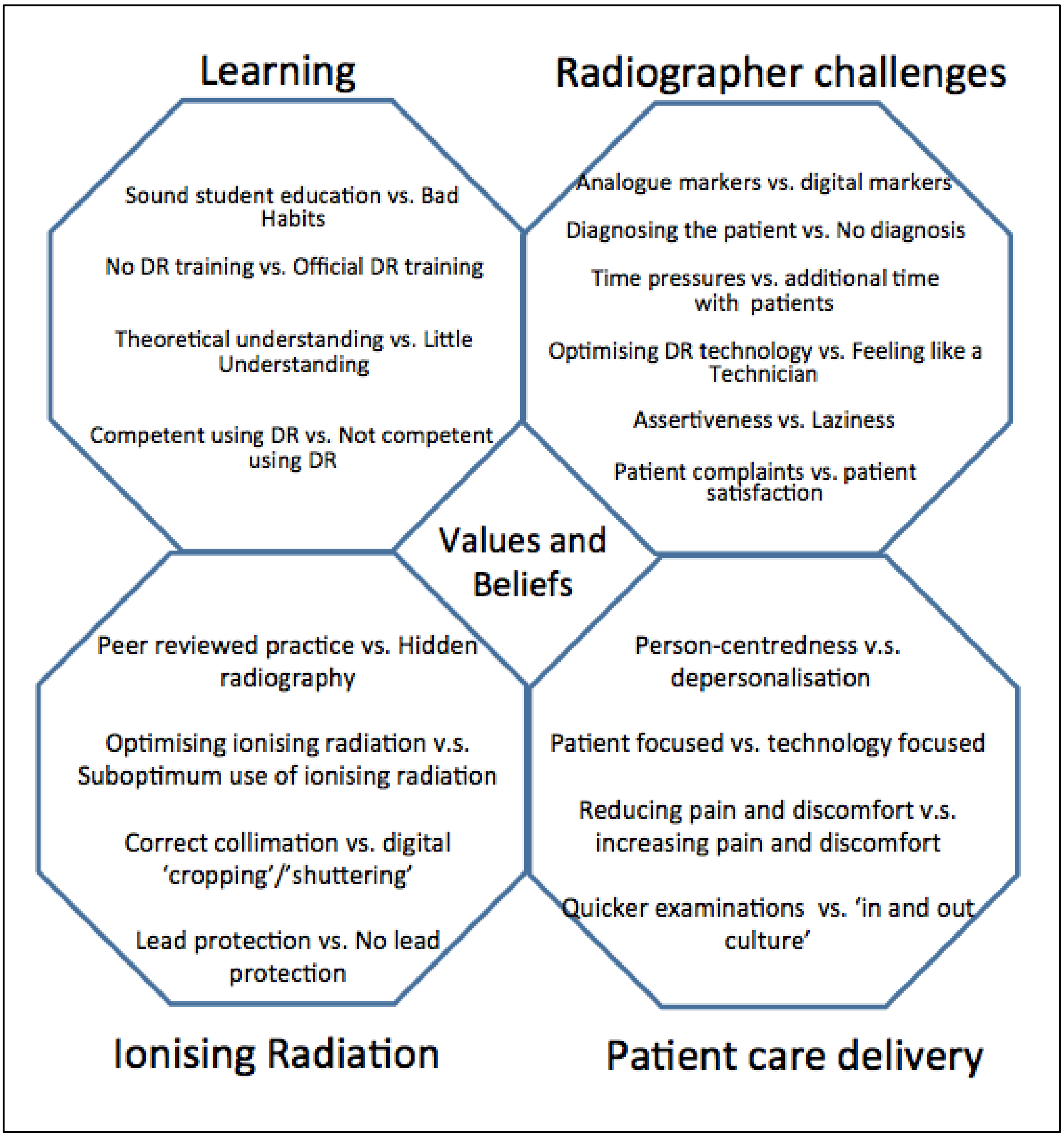
4.3. Observations and interviews

Findings from the qualitative data were collated and analysed. Following complete immersion within the data 'codes' were assigned to key words and phrases, producing general themes. 'Sorting' of the themes were undertaken and placed in overarching categories. Each category contained central themes in the initial analysis of the data and can be seen in appendix sixteen (p.360). The overarching categories derived from the thematic analysis were:

1. Learning
2. Radiographer challenges
3. Ionising Radiation
4. Patient care delivery

Themes within each category were compared with one another and interconnected across categories, enabling the development of theoretical descriptions (see appendix sixteen, p.361). This enabled the identification of central themes coincided with the core variable 'values and beliefs' (Streubert and Carpenter, 1995). Values and beliefs were central to the authors views and attitudes as a radiographer, researcher and educator as discussed in chapter one. Thus values and beliefs of radiographers were similarly central to this PhD research uncovering views, attitudes and behaviours of radiographers as it could impact on radiographic practices and the delivery of person-centred care. Wilson *et al* (2005:27) conclude that understanding values and beliefs is an important part of understanding a workplace culture and attempts at changing workplace cultures should start from the clarification of values held among staff in that culture. It is evident in subsequent chapters that the values and beliefs of radiographers are central to workplace practices and subsequently any potential workplace reform. Categories, with their related central themes are outlined in figure seven (p.107), together with descriptors from radiographers highlighting the contradictions within the data and the tensions that existed in a radiographic environment. Empirical chapters five, six and seven provide in-depth descriptive and analytic discussions of the data that emerged throughout the qualitative methods. The length of quotations varies demonstrating the numerous responses from participants, providing the context for the data (Glaser and Strauss, 1967). Literature was sought contributing to the overall analysis in order to tell the story to the reader (Hammersley, 1998).

Figure Seven: Depiction of culture within diagnostic radiography environment



The four overarching categories presented in figure seven are interconnected and focused into three empirical chapters (five, six and seven) within this PhD thesis. This was important in this ethnographic research because whilst 'radiographer challenges' were highlighted categorically, it was significant to discuss how these impacted on aspects of patient care and/or the optimisation of ionising radiation, in order to provide an holistic account of the clinical environment (Hammersley and Atkinson, 2007). For example, whilst radiographers highlighted 'time pressures' as an issue within contemporary practice, this arguably links to aspects of 'patient care delivery' within the imaging department. Because some radiographers were under increasing 'time pressures' clinically, this often required radiographers to perform radiographic examinations quickly, arguably facilitating an 'in and out' culture, which some patients may experience as unfriendly or uncaring. Section 6.3. (p.152-158) discusses this by cross-referencing themes within the two categories, providing an holistic picture of the radiographic environment. A further illustration whereby themes were cross-referenced enhancing empirical discussions concerns 'analogue markers vs. digital markers'. For example, whilst the placement of an anatomical side marker remained a challenge for some radiographers in the clinical environment it is arguably linked with potential increases of ionising radiation. Because radiographers often failed to place analogue markers within the primary X-ray beam, this lead to confusion of radiographic anatomy upon interpretation, whereby the patients 'left' or 'right' is undistinguishable. This may lead to increases of radiological doses due to the need of repeating radiographs to ascertain a patient's radiographic anatomy. This is discussed further in section 7.4. (p.188-198). Denzin (1997:129) reports on how ethnographic researchers enter the same terrain as 'storytellers' when writing about social, cultural and medical situations. By interlinking and focusing on the four overarching categories within three empirical chapters the aim has been to provide a feasible account or 'story' based on the observations and discussions undertaken within the radiographic community.

4.4. X-ray experiments

X-ray experiments were conducted as part of this ethnographic study facilitating 'the triangulation' of exploring 'what radiographers were observed doing'. For example during observations it was noticed that 'collimation' and 'source to image distance' (SID) were amongst the commonly altered radiographic techniques during hand and wrist examinations. A central theme uncovered as part of the qualitative research was the suboptimal use of collimation whereby radiographers would 'mask' inappropriate collimation 'post exposure' by using digital software. It was decided to test the effects of collimation and measure its potential impact on dose area product (DAP). Similarly, during observations the SID was observed at varying heights amongst numerous radiographers, which may be regarded as suboptimal as the radiation delivered could be 'too much' or 'too little'. These phenomena were important to explore experimentally using an anthropomorphic phantom in a controlled X-ray environment because it could support or refute actions undertaken by radiographers. Collimation and SID are discussed further and considered as part of this ethnographic study in chapter seven (7.2. p.170-173) whereby data from observations and interviews are triangulated contributing to the research objectives. Multiple linear regression analysis was used to statistically predict the effects of collimation and SID on DAP and are represented in tables eight and nine. A sample of the experimental data from sites A and C are presented in appendix seventeen for the reader (p.362-372), contributing to 'the actions' undertaken by the radiographers.

Table Eight: Prediction of collimation and SID on DAP (hand)

	Site A					
	Hand					
	Standardised Coefficients	***t***	***sr*²**	***F***	**df**	***R*²**
	Beta					
Collimation	**.89**	**25.42**	**78%**	**392.16**	**41**	**.95*****
SID	**-.41**	**-11.76**	**17%**			

***$p < 0.001$

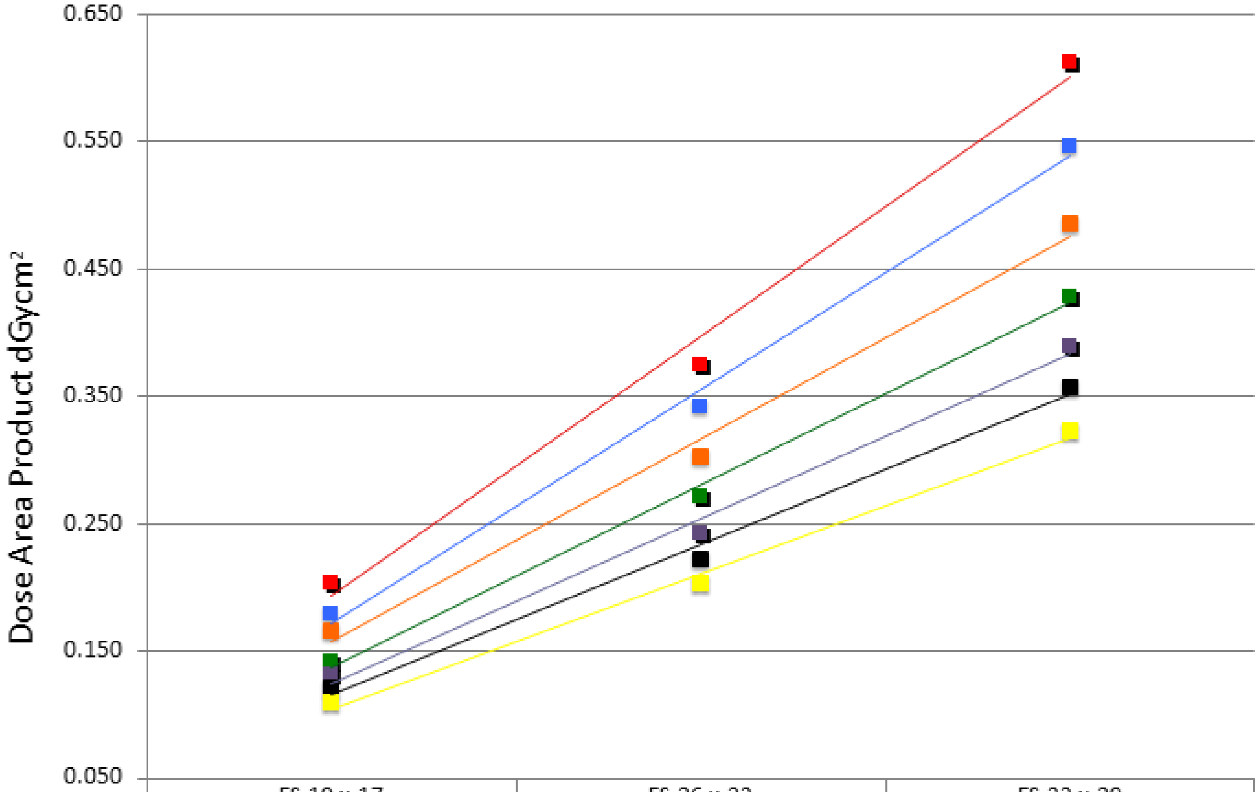
Table Nine: Prediction of collimation and SID on DAP (wrist)

	Site C					
	Wrist					
	Standardised Coefficients	***t***	**sr²**	***F***	**df**	***R*²**
	Beta					
Collimation	**.88*****	**15.43**	**77%**	**135.64**	**41**	**.86*****
SID	**-.33*****	**-5.74**	**10%**			

***$p < 0.001$

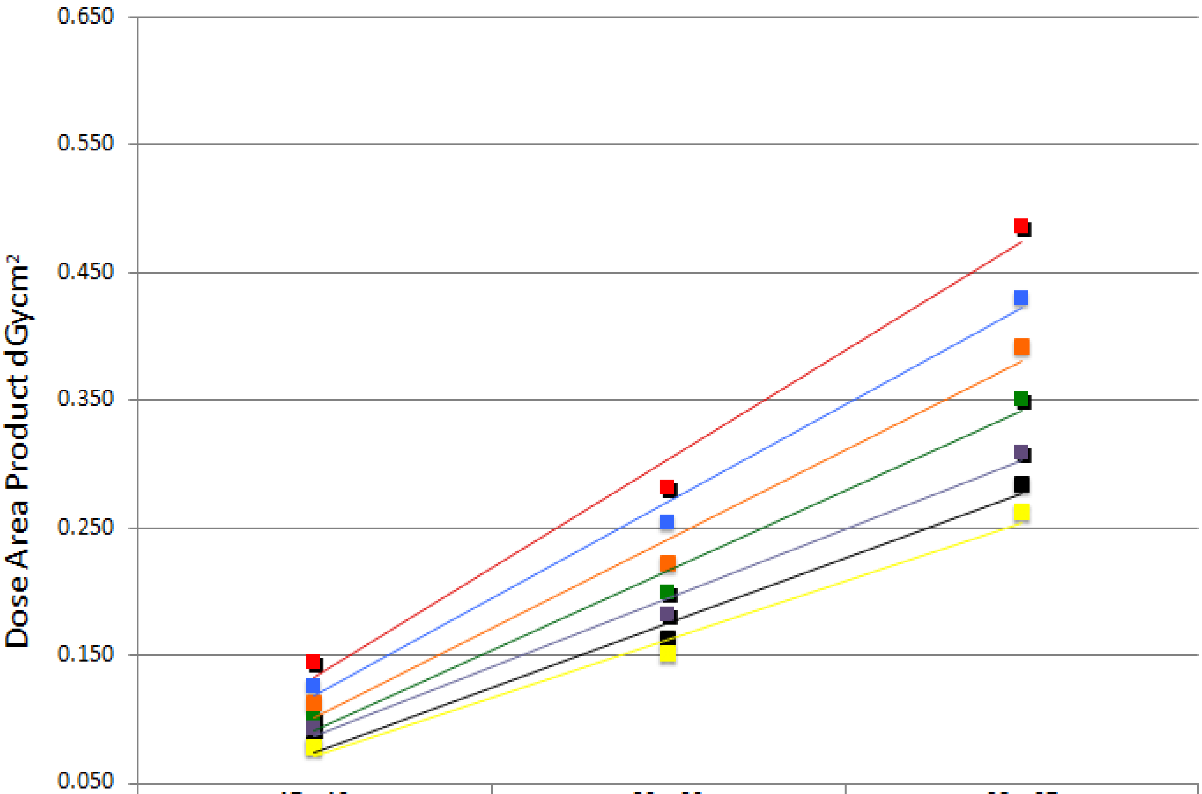
The multiple regression analysis above shows that collimation was the strongest positive predictor of the experimental models at both sites. This means that increases of collimation significantly increased DAP to the hand, $\beta = .89$, $t(41) = 25.42$, $p < 0.001$ and wrist, $\beta = .88$, $t(41) = 15.43$, $p < 0.001$ phantom used in this PhD study, thus remaining an important technique to keep radiation doses 'as low as reasonably practicable' (ALARP). This strongly proposes that increases of collimation observed by radiographers and 'masking' post-exposure radiographs can increase radiation doses to patients within the clinical environment. Additionally, the multiple regression analysis predicted that increases in SID significantly reduced DAP to the hand, $\beta = -.41$, $t(41) = -11.76$, $p < 0.001$ and wrist, $\beta = -.33$, $t(41) = -5.74$, $p < 0.001$ phantom, as illustrated by the negative predictors. This strongly suggests that a reduction to SID can increase radiation dose to patients and an increase in SID can reduce radiation dose to patients. This means that where radiographers were observed not conforming to strict SID practices in general radiography, patients are likely to receive 'higher radiation doses than necessary' due to the X-ray source being in close proximately to patients. On the other hand radiographers may be unknowingly underexposing patients which may result in less diagnostic images. These findings are discussed further in collaboration with the qualitative data uncovered as part of this PhD work in chapter seven. Graphs two, three, four and five below demonstrate the positive correlation and are illustrated on pages 111-114. The multiple regression analysis also illustrates that when predicting dose it is the collimation which has been more important than SID in predicting an increase in DAP, strengthening the importance of strict collimation when aiming to optimise ionising radiation levels in contemporary practices.

Graph Two: DP Hand – Dose effects on SID & Field Size



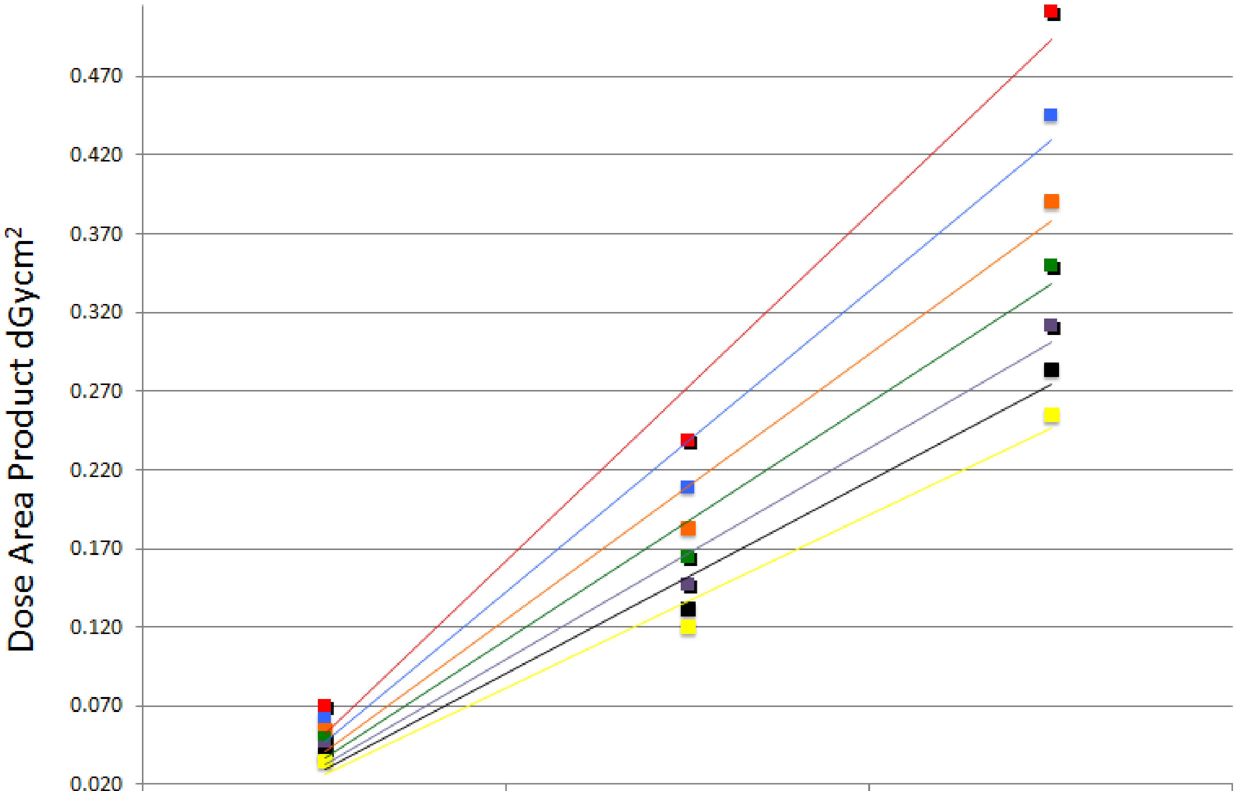
	FS 19 x 17	FS 26 x 23	FS 33 x 29
SID (80 cm)	0.204	0.375	0.612
SID (85 cm)	0.179	0.342	0.546
SID (90 cm)	0.165	0.301	0.484
SID (95 cm)	0.142	0.272	0.429
SID (100 cm)	0.131	0.242	0.389
SID (105 cm)	0.121	0.222	0.358
SID (110 cm)	0.108	0.202	0.322

Graph Three: Oblique Hand – Dose effects on SID & Field Size



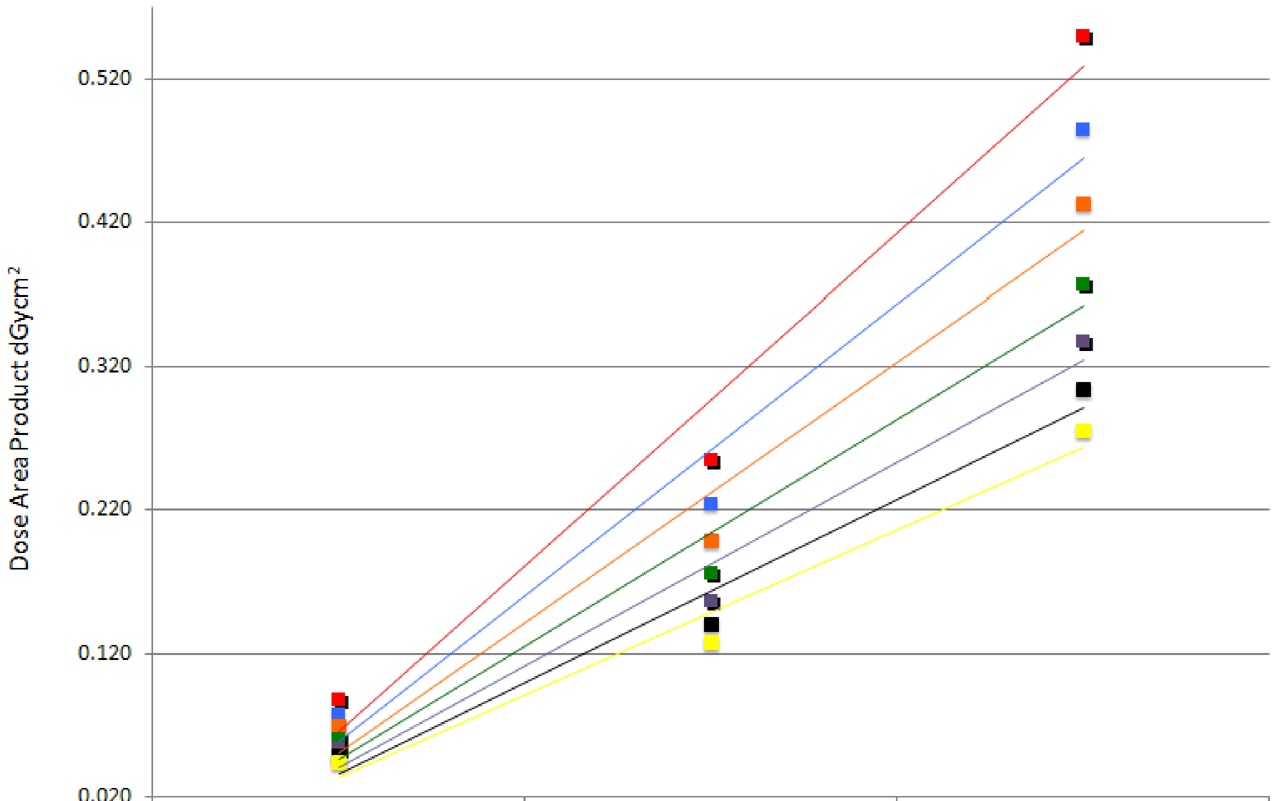
	17 x 13	22 x 20	28 x 27
SID (80 cm)	0.144	0.281	0.486
SID (85 cm)	0.126	0.254	0.430
SID (90 cm)	0.112	0.221	0.391
SID (95 cm)	0.100	0.199	0.351
SID (100 cm)	0.093	0.182	0.309
SID (105 cm)	0.081	0.163	0.284
SID (110 cm)	0.077	0.150	0.261

Graph Four: DP Wrist – Effects on SID & Field Size



	FS 8 x 11	FS 16 x 18	FS 24 x 25
SID (75 cm)	0.070	0.238	0.511
SID (80 cm)	0.062	0.209	0.445
SID (85 cm)	0.054	0.183	0.391
SID (90 cm)	0.049	0.164	0.350
SID (95 cm)	0.043	0.147	0.311
SID (100 cm)	0.039	0.132	0.284
SID (105 cm)	0.035	0.12	0.255

Graph Five: Lateral Wrist – Dose effects on SID & Field Size



	FS 8 x 11	FS 13 x 19	FS 20 x 26
SID (75 cm)	0.088	0.255	0.550
SID (80 cm)	0.078	0.224	0.484
SID (85 cm)	0.069	0.198	0.432
SID (90 cm)	0.061	0.176	0.377
SID (95 cm)	0.054	0.157	0.337
SID (100 cm)	0.049	0.14	0.304
SID (105 cm)	0.045	0.128	0.275

The dependent variables presented to X-ray operators in the DR environment were DAP and exposure index (EI). During observations and informal discussions it was noted that some operators might not refer to the EI value upon delivering radiation exposures to patients. Further, some radiographers acknowledged their inability to locate the EI value. This was important to consider because the EI value is a numerical measure that can assess if a patient has been over or underexposed by a radiographer. To understand the correlation between DAP and EI a Pearson's correlation analysis was undertaken. The strength of the linear dependency is shown in table ten (p.115).

The analysis highlights that at site 'A' DAP and EI were strongly negatively correlated $r(40) = -.69$, $p < 0.001$ demonstrating that the higher the DAP at site 'A' the lower the

EI. In contrast, at site 'C' the relationship demonstrates that a high DAP in practice will produce a high EI and is strongly positively correlated $r(40) = .69$, $p < 0.001$. Whilst these demonstrate negative and positive correlations this is represented by differing numerical values illustrated by the DR equipment (as noted in section 3.5.4. see table 7 p.93). The analysis demonstrates a strong correlation between DAP and EI values highlighting that the EI value strongly correlates with DAP. This data contributes to the overall qualitative findings and are discussed further in chapter seven (7.3. p.185).

Table Ten: Pearson's Correlation (DAP and EI)

	Site A		**Site C**	
	Hand		**Wrist**	
	r	**df**	**r**	**df**
DAP and EI	**-.69*** **	**40**	**.69*** **	**40**

********p* **< 0.001**

4.5. Rigour and Validity

It is claimed that both novice and experienced qualitative researchers often struggle with the term 'qualitative rigour' (Thomas and Magilvy, 2011:151). Murphy and Yielder (2010) suggest that the term 'rigour' should be replaced by the 'goodness criteria' or 'trustworthiness criteria', however because these are not used by all researchers they can create an immediate impression of a simplified and non-systematic approach. Rigour in qualitative terms is a way to establish trust or confidence in the findings of a research study to repeat a study with different research sample. 'Replication' is not a term used in qualitative research because like a river, the water is not the same even if ones stance and perspective from the bank is from the same spot (Thomas and Magilvy, 2011:154). The term rigour means stiffness, from the Latin word 'rigere' to be stiff and implies rigidity, harshness, strict permission, unyielding or inflexible. Thus, the term 'qualitative rigour' has been argued as an oxymoron, considering that qualitative research is a journey of explanation and discovery moving back and forth between design and implementation (Murphy and Yeilder, 2010; Thomas and Magilvy, 2011). In the classic work of naturalistic enquiry Lincoln and Guba (1985:290) explain the basic questions of qualitative research rigour:

'How can an inquirer persuade his or her audiences (including self) that the findings or an inquiry are worth paying attention to, worth taking account of?'

Maxwell (1992:284) resonates with Lincoln and Guba maintaining that 'validity is not an inherent property of a particular method, but pertains to the data, accounts, or conclusions reached by using that method in a particular context for a particular purpose'. Philosophically it is generally accepted that a single, generalisable, external 'truth' held and perceived by all would be impossible. The author and readers of this PhD thesis have his/her own personal perspectives seen through a lens of differing cultures, experiences, environmental and other contextual influences (Thomas and Magilvy, 2011). Rolfe (2006:305) asserts that a study is trustworthy if and only if the reader of the research report judges it to be so. In order to test the 'trustworthiness' of the qualitative research undertaken in this PhD work, credibility, dependability, transferability and confirmability are considered because they are generally accepted terms assessing rigor and validity (Lincoln and Guba, 1985; Denzin and Lincoln, 1994; Murphy and Yielder, 2010; Thomas and Magilvy, 2011) and the most useful criterion appropriate within the radiography qualitative framework (Adams and Smith, 2003; Murphy and Yeilder, 2010:65).

Achievement of credibility occurs by checking for representativeness of the data. To establish credibility qualitative data transcripts were read and analysed looking for similarities within and across the participants. Krefting (1991:218) supports this claiming that 'a qualitative study is considered credible when it presents an accurate description or interpretation of the human experience that people who also share the same experience would immediately recognise'. One strategy to strengthen the credibility includes peer debriefing and examination of publications at national and international conferences (Murphy and Yielder, 2010; Thomas and Magilvy, 2011) discussing empirical findings (Hayre, 2014a; Hayre, 2014b; Hayre, 2015a: Hayre, 2015b). Credibility was further enhanced by the prolonged engagement with research participants as both researcher and locum radiographer (Sharts-Hopko, 2002). Sharts-Hopko (2002:85) maintains that the findings of a study can be shared with the participants so that they can determine the accuracy of the research report commonly referred to as 'member checks'. The use of electronic mail enabled interview transcripts to be sent to participants allowing them to confirm or refute any discrepancies. The prolonged observations coincided with professional and social relationships facilitated rapport with research participants in the role as the 'ethno-radiographer'. My role as 'the locum radiographer' and 'the researcher' added to the credibility of this study because informants could contact me at any stage of the research if they had concerns over 'what had been said' or 'what I had observed' (Sharts-Hopko, 2002). Further, after 'leaving the field' I remained contactable by means of mobile telephone, social media (i.e. facebook) and 'locum shifts' undertaken as a diagnostic radiographer. This dual role developed 'trust' with the participants because without persistent fieldwork and prolonged engagement with participants 'delicate' subjects may not have been explored (Clissett, 2008). Member checks additionally occurred as part of triangulating observational data with participants during interviews. The rational for triangulation data is that 'it attempts to overcome any inherent weaknesses or bias of a single research strategy' (Tuckett, 2005:31). Triangulation included discussions regarding suboptimal practices such as 'cropping' and lack of autonomy regarding exposure factors. The observations were complemented with open-ended questioning in one-to-one interviews with radiographers 'quizzing' them on the actions observed, with some concurring on such incidences. A further source of periphery data were the observations in other radiographic environments as a locum radiographer, whereby the actions observed by other radiographers in numerous hospitals in the United Kingdom could be compared with observations in this PhD study, again an essential part of triangulation (Holliday, 2007:43). There were also informal discussions held with lecturers and researchers at conferences and within the University regarding the actions observed. Thus the interconnected data within this PhD work were strengthened by triangulating with the periphery and equally interconnected in a wider radiographic context.

Transferability is the ability to transfer research findings or methods from one group to another. Lincoln and Guba (1985:290) assert that transferability 'determines the extent to which the findings of a particular inquiry have applicability in other contexts or with other subjects/participants' and is equivalent to external validity in quantitative research. One strategy establishing transferability is providing dense descriptions of the population studied by providing descriptions of demographics and geographical boundaries of the study (Thomas and Magilvy, 2011). The in-depth descriptive accounts provided in chapter three demonstrate an original insight for prospective researchers aiming to undertake multi-sited research within a healthcare environment(s). It highlights the difficulties encountered and discusses methods that facilitated and hindered the researcher and participants. Transferability can present challenges in qualitative research as studies are small and often concentrate on one research environment, however whilst it is generally accepted that not all radiographic techniques and procedures are identical from one clinical environment to the next (Brennan and Johnston 2002; Rainford *et al* 2007; McEntee and Kinsella 2010) this study aimed to explore the impact of DR at multiple radiographic sites. The use of 'multi-site ethnography' explored cultural practices involving science and technology and is generally recognised as a method that provides a valued insight into the environments under investigation highlighting numerous complex cultural phenomena (Marcus 1998; Colerman and Hellermann 2011). Furthermore it could be argued that disciplines including diagnostic radiography that sit in a more public sphere require 'multi-site social constructionism' in order to highlight different cultural phenomena in similar clinical environments. Thus whilst observations produced reoccurring themes in different radiographic departments illustrating a common theme and 'common ground' between research environments, this naturalistic enquiry, which has individual subjective meaning only concerns case-to-case transfer, not a generalisation to the wider population (Murphy and Yielder, 2010:65). In short this PhD work provided the 'lived experiences' of numerous diagnostic radiographers providing a unique insight into various cultural behaviours that may provide similar occurrences in other radiological environments.

Dependability was achieved by a clear audit trail. It is generally accepted that an audit trail is inherent within a methodology of qualitative research (Murphy and Yielder 2010:65; Thomas and Magilvy, 2011:153). Reflexive data analysis and discussions provided an assessment of the assumptions made throughout the methodology. Raw data such as field notes and the development of field notes surmise and enhance the dependability of the data (Emden and Sandelowski, 1999). Thus by following the audit trails through to the final discussions, the emerging theoretical descriptions become apparent. My interactions with participants throughout this PhD study were complex requiring a holistic approach. I reflect on key features of interactions, emerging changes to the research design together with a justification for the decisions made enabling the readers to follow the process undertaken whilst conducting multi-sited ethnography. In conducting multi-sited research one finds oneself with all sorts of cross-cutting and contradictory personal commitments, which are resolved perhaps ambivalently (Marcus 1988). Marcus (1998:98) claims that when conducting multi-sited ethnography researchers may become the 'ethnographer-activist' renegotiating identities in different sites as one learns more about a slice of the world system. Similarly, my identity at each site was unique and individualistic due to previous experiences. At site A I was previously employed full time and undertook occasional locum shifts, at sites B and D I had experience as a student radiographer and at site C

I was perhaps regarded as member of staff due to my 'fix term' position as a locum radiographer. At sites I had developed more rapport it felt I would be 'working with' participants, yet others 'working against', thus depending on my personal position I would 'shift' my persona within the fieldwork depending on the research site and those participants taking part. This highlights that although my goal was to provide unity throughout the fieldwork I provide a sense of activism in my role throughout this research study.

Confirmability refers to the degree to which the results can be collaborated or confirmed by others (Murphy and Yielder, 2010). Sharts-Hopko (2002:85) affirm that confirmability refers to the adequacy of information reported from the research questions and protocol for data collection through the raw data, through various stages in the analysis of data to the interpretation of findings. It is generally accepted that different researchers might produce different constructions with the same data (Glaser and Strauss, 1967) yet it should be possible to trace constructions and assertions to their original sources and made available to outside reviewers of the study (Guba and Lincoln, 1989). Throughout this PhD research my biographical and reflexive accounts provided a sense of awareness and openness. Reflexivity requires a self-critical attitude on the part of the researcher about any preconceptions affecting the research (Lincoln and Guba, 1985; Murphy and Yielder, 2010:65-66). Firstly, this is inherent throughout the methodological chapter, providing an audit trail that includes raw data from data collection methods through to data transcriptions (appendix 8-13, pages 307-328). Secondly, the empirical and concluding chapter connects emerging concepts, relationships and interpretations and is supported with existing literature with a focus on the original research questions (Lincoln and Guba, 1985:319-320). This reaffirms that the interpretations and conclusions derive from the data (Tobin and Begley, 2004) whilst taking into account individual subjectivity or bias. A central tenet of confirmability was the recognition of my role and involvement with participants in this study, acting upon my positionality to inform the research outcomes and collect data professionally and ethically (Holliday, 2007; Murphy and Yielder, 2010:65-66).

The use of ethnography provides the exploration of social life and in-depth accounts of social action, something that quantitative methods would not have provided. In ethnography there is a tendency to describe and characterize events rather than quantifying them (Kirk and Miller, 1986). Adams and Smith (2003:194) argue the urgent need for qualitative research methodologies within diagnostic radiography to 'define more clearly what radiographers do and how they do it'. The criteria above judges' qualitative research and are put forward as an alternative to more traditional quantitative-orientated criteria revealing how I managed the subjectivity inherent within the qualitative research paradigm. It has been argued methodologically that whilst ethnography is exploratory, events may be quantified. The contribution from the positivist tradition facilitated 'exploratory methods' by quantifying radiographic phenomena, which is argued as an important aspect to consider in future radiographic research due to X-rays falling into the natural sciences. The philosophical discussion in section 3.3 (p.60) argues the importance of collaborating paradigms in diagnostic radiography, which could be applied to the radiography research framework to study the intra-professional issues, inter-professional issues and clinical practice (Adams and Smith, 2003). Reliability of X-ray experiments undertaken describes how far a particular test procedure or tool such as observations will produce similar results in different circumstances assuming that no other factors are altered (Roberts *et al,* 2006). The quantification of X-ray experiments in this PhD research also highlight an existential application. It is proposed that the experimental findings provide a reflexive outlook not only to the actions and behaviours of radiographers, but of the researcher. In chapter one I discuss professional actions resembling the observed actions by radiographers in this PhD study. On reflection the X-ray experiments not only provide critical reflection to the actions and views of radiographers but to the researcher as a practicing healthcare professional. The statistical tests arguably reaffirm the importance of strict adherence to radiographic technique thus arguably central to the rigor and validity of this PhD work. The reliability and validity of the experiments were tested using statistical analysis questioning how likely results could be misleading (*p*-values) thus estimating how accurate measurements are and thus their usefulness in later chapters (ibid). The strong predictions and correlations undertaken using statistical analysis strengthens the argument that quantitative forms of analysis can highlight key aspects of radiographic practices. This approach best equipped the researcher to answer the research questions because the ethnographic methods provided a holistic account of the social life of radiographers, contributed with an experimental design that can support professional reflexivity (Tobin and Begley, 2004).

4.6. Conclusion

This chapter has presented the research findings and discussed the methods of analysis undertaken as part of this PhD study. Central to the findings were the values and beliefs of radiographers. Values and beliefs were central to the researchers' personal and professional development throughout this PhD journey and could be insightful amongst other radiographers. 'Values and beliefs' as a core variable identified that the values and beliefs were not unified amongst radiographers and impacted on the workplace culture and day-to-day practices of radiographers delivering person-centred care. Qualitative methods facilitated an inductive exploration of radiographic practice, which were contributed with quantification using X-ray experiments. Participant observation and semi-structure interviews generated theoretical descriptions and uncovered wide spread phenomena. X-ray experimentation contributed to 'what had been seen' and 'what had been said' about certain phenomena significantly predicting the effects of SID and collimation on DAP and correlations between DAP and EI at research sites A and C. Rigour and validity of the empirical data has been considered in this chapter strengthening the integrity and assumptions of the research methods, data and authenticity of the researcher in relation to the context and outcomes of this PhD research. This is important to identify for it to carry 'conviction and strength' to readers (Long and Johnson, 2000:35). The next three chapters provide detailed discussions based on the empirical findings supported with thick descriptions uncovered from research setting that can be linked back to clinical practice.

<u>Chapter Five: Contemporary issues affecting radiographers learning in the clinical environment.</u>

5.1. Introduction

This chapter discusses contemporary issues affecting a radiographers learning in the clinical environment. It is generally accepted that radiographers have sound knowledge and understanding to produce images of diagnostic quality (SCoR, 2013). Radiographic examinations are continuing to increase, coincided with advancing radiographic technology. In chapter two the dangers associated with digital radiographic technology were highlighted suggesting that without continuing research and education doses may increase (ICRP, 2005). This chapter discusses issues impacting a radiographers' learning within the clinical environment impacting their day-to-day clinical practices. This chapter uses the empirical data to uncover and analyse current attitudes and beliefs held about the training and education received by radiographers. It further examines 'on the job' learning, potential deskilling of the profession and issues surrounding current competency of diagnostic radiographers.

5.2. "On the job": Learning digital radiography

Learning can be identified as an overarching term where education, training and development takes place (Garavan 1997; Kitson 2003). Training is identified as 'a learning activity that is designed for immediate impact, for the job or role that one does at present' (Kitson, 2003:23). Rosemary describes her 'technological transition' of advancing technology within the clinical environment with recognition of little departmental support:

Rosemary: *If I remember back, it was quite a quick transition from CR to DR. I mean, we had the machines where you put the cassettes through. And one day, they were gone, basically. It was like, "Oh, get used to DR".*

Rosemary's description provides an insight into the installation of advancing technology, moreover it suggests that radiographers may be required to 'hit the ground running' with technology upon its arrival. Gibbs (2011:155) investigations demonstrated the ‘two-way communication problems generally between higher education institutions and clinical staff’ with higher education institutions not always communicating adequately with clinical staff and conversely clinical staff not always communicating their needs to higher education institutions. Further, while ‘experts’ may use factual knowledge to solve problems and apply scientific formulae in an educational setting they may not be able to apply this into ‘real-life’ situations (Chi *et al,* 1981). Radiographers Victoria and Sharon identify their struggles applying theoretical knowledge in the clinical environment suggesting that a practical approach is required in order for them to learn effectively.

Victoria: *I would need to be doing them sort of together, if you see what I mean. Like putting it into practice - the education side of it and the theory behind it is not going to sink in for me until I get that training on the equipment.*

Sharon: *I’m one of those that is better learning on the job, really. I can read any number of books, but I don’t always apply it. It’s like driving a car - I wouldn’t read a book on it; I’m better off doing it. I’m a practical person.*

This resonates with Overmans (1994:62) statement that ‘what people hear they forget, what they see they remember, what they do they understand’. It is generally accepted that radiographers need to be able to deal with advancing equipment and be responsive to the continuous technological development within their field (Jordan, 1995; Hafslund *et al,* 2008). Price *et al* (2010) are of the opinion that high quality clinical education and training is key to the provision of safe and effective practice in diagnostic radiography; with an increased focus on the manner in which clinical skills are learnt and that learning opportunities are present within the clinical setting (Williams *et al,* 2006). The delivery of digital radiography (DR) training for radiographers was a positive experience for Fred and Harold at site A asserting that no additional training would have further benefited their day-to-day clinical use:

Fred: *I think the department’s training was fine. You’re training to the equipment you have at the time, and with the range of CR and DR rooms at that stage (it’s all DR now), you actually had quite a good mix. So I don’t think any extra formal training or anything would have really benefited over the introduction to the rooms that they generally give students anyway.*

Harold: *Yes, I'd have said so. It was part of the induction pack. It's a tick list of things that you have to work through. They have to be ticked off and signed by a Band 6 or above. How to change exposure factors, how to select your patient, the nuts and bolts of how to move the tube around, and the idiosyncrasies of the different rooms - despite the fact that they're all from the same manufacturer, we've got slight differences between the three rooms that are flagged up on the induction sheet.*

Fred and Harold experienced sound departmental training following the installation of a DR system. This was supported with 'induction packs' and 'tick lists', ensuring that key features of the equipment were understood by the radiographers. This demonstrates that within general radiographic practices radiographers are required to relearn 'tube movements' and the 'nuts and bolts' of advancing technology to ensure optimum practical use. Mick (site C) similarly felt that his training with the 'applications specialist' prepared him for the use of the DR equipment for clinical use whilst being able to 'fix things if they go wrong'.

Mick: *I had training, which was done by the trainer in the room, essentially to say you're competent in every aspect to use that room, and to know where all the buttons are and what all of the programs do. And how to fix things if they go wrong.*

In contrast to the effective clinical training above radiographers from sites A and C expressed that they had not received 'official' or 'formal' training on the DR equipment resulting in radiographers having to learn DR 'on the job' and 'learn as they went along':

Sharon: *Well, it was on the job training isn't it? So you're coming into it from scratch - just "this is how it works". There wasn't any sit-down - "this is DR, this is how this works" - it was "position there, and take the picture". You just pick it up from there. There wasn't any formal training - it was what you were here for, just to learn on the job anyway.*

Rosemary: *Yes, obviously they teach you how to adapt your technique at uni, but that was obviously more for CR purposes. So you were sort of learning on the job really.*

Helen: *I didn't get any official training to use the DR equipment here - I just worked with a lot of different people, spent quite a lot of time in there as you know, and just gradually* *picked it up, really. But yes, I would have liked to have had some proper training.*

This highlights that some radiographers do not receive 'official' training in the clinical environment and are required to 'get along' demonstrating a lack of congruity amongst healthcare professionals. Training carries many benefits by which organisations and employees are rewarded in terms of improved employee skills, knowledge, attitudes, and behaviours (Jensen, 2001; Treven, 2003; Sommerville, 2007). Training can enhance staff performance (Brown, 1994), job satisfaction, productivity and profitability (Hughey and Mussnug, 1997), but this study has recognised that some radiographers may not be receiving the benefits associated with 'official training'. The data highlights that some radiographers may be in subordinate positions compared to colleagues that have received official training. Additionally, the lack of clinical support claimed by radiographers required radiographers to receive 'anecdotal tips' from peers in the aim of achieving 'the basics' from the DR system:

Annabelle: *The two radiographers that did have some training from the specialists that came in - they weren't able to give the kind of comprehensive training on it that I would have liked. It's very much been on the job training, and just work it out as you go. With anecdotal tips and passed down skills from other radiographers who have spent more time in the room.*

Kirsty: *There was a lot of stuff I don't know about in there, but I could do the basics, I could run clinics and do most things I think.*

It could be assumed that radiographers receive appropriate training on new X-ray equipment ensuring optimum job performance, yet the views above demonstrate a 'learning as you going along' approach. This is significant because it demonstrates that some radiographers may not be receiving adequate training to optimise their clinical practices. Annabelle above felt that the 'cascade training' delivered by the radiographer could have been more 'comprehensive' in applying her day-to-day practices. Geoff (a core trainer and senior radiographer) provides insight recognising his own faults when cascading knowledge to other radiographers, failing to pass down essential information:

Geoff: *For example, if I took someone in there to pass on the information to them, I don't give them every part of the* *information that was passed on to me. You can't retain it all.*

This suggests that the method of cascading knowledge and understanding to other radiographers is problematic in the clinical environment because those radiographers receiving suboptimal learning potentially lack critical knowledge associated with using the DR equipment. This illustrates that as technology continues to advance within the radiographic environment 'core trainers' may need additional support from the application specialists ensuring sound training to all X-ray operators and periodically reviewed preventing radiographers simply 'learning on the job'. In addition, Victoria claimed that her delivery of cascade training is hindered if the department becomes busy, consequently impacting the training delivered to her trainee:

Victoria: *But I suppose if you've got someone in there who's training, there's a tendency to just get them to book in. And I would just be like "Oh, I'll do them all, because we're busy". And I can't train them, and because if I were to leave them to do them, it would take ages. And they'll be asking me questions anyway. "Oh, it's not doing this - what am I doing wrong?" So that's happened. So that has a knock-on effect on their training in a sense, doesn't it?*

This suggests that workplace pressures and stress factors influence the delivery of sound DR training within the clinical environment. As this remains problematic for healthcare professionals, how may this affect a radiography student? The experiences of radiography students have been examined in higher education (HE) (Foster, 2008), however Murphy (2008) reports that few studies have identified what students may encounter during their clinical placements. In a more recent publication Murphy (2011:137) highlights that radiography students with dyslexia had had to deal with 'discrimination and a lack of understanding' from clinical staff and other students within the clinical environment. In current HE and clinical placement learning, students undertake 27 weeks observing and practicing general radiography, which involves undertaking radiographic assessments and the collection of 'radiographic examinations' before registering as healthcare professionals. It is generally accepted that radiography students should receive an appropriate level of education within the clinical environment, however Pratt and Adams (2003) claim that a 'hidden curriculum' may exist. An 'official curriculum' consists of guidelines and recommendations documented by the Society of Radiographers (SCoR) and Health and Care Professions Council (HCPC). A 'hidden curriculum' however may exist within the clinical environment whereby clinical staff bias their clinical teaching to students guided by a particular set of behaviours or attitudes. Van Deven *et al* (2013:887) identified a 'hidden curriculum' with radiologists as radiologists often work in isolation; the authors concluded that such isolation may fail to 'recognise what they (radiologists) do not know'. In this PhD study a 'hidden curriculum' was acknowledged by Bernard and Kirsty at sites A and C:

Bernard: *We should be teaching them the correct way, and they're going to pick up on our bad habits. And we [then] can't blame them if they're doing it that way, if they're going to just be copying. So we need to set the example really, don't we?*

Kirsty: *It's definitely down to the way you're trained in practice. That's the key issue. Its learned behaviour, isn't it? You watch your peers, and you do as they do... So if I don't do something perfectly well, and I'm teaching somebody else, it's not going to be passed down.*

This insight identifies the dangers associated with 'learned behaviour' as radiography students may 'watch, learn and replicate' behaviour performed by their 'clinical teachers'. Although this may provide students with an 'active' educational experience preparing them for professional life in a hospital environment it may not meet the standards of education and training set out by the SCoR and HCPC. The move to educate radiographers from 'diploma' to 'degree' suggested that radiographers should offer services, which are relevant and offer value for money whilst maintaining quality standards. However Kirsty recollects her experiences as a student undergoing clinical training in a DR environment and suggests the student experience is not an 'active' one with her experiences of feeling 'left out':

Kirsty: *I think as a student you're sort of in the background and you're not using it so much.*

Other student radiographers may feel 'left out'; this was supported by an informal discussion and recorded in the field diary with the superintendent radiographer at site D:

Field Diary: *A senior radiographer expressed the educational issues for radiography students during busy periods in general radiography as students may be sent from the learning environment to the hospital library due to the demand and pressures places on the department. This additional pressure placed on radiographers would prevent students* *from undertaking radiographic examinations and thus potentially affecting their learning.*

These educational concerns were expressed by radiographers at site C who often felt that the relationships with their students were hindered in the healthcare environment. Radiographers acknowledged that a students' learning may be suboptimal and 'ad hoc' because radiographers felt unable to 'pass on' sound knowledge due to the demands of workflow coincided with the lack of knowledge and understanding radiographers have with DR:

Geoff: *They might not learn. So you need an environment for them to be able to learn properly. It's very difficult - this is an example of a department where it's very difficult for students to… for you to get a one-to-one with a student and pass on knowledge - it's very difficult.*

Terry: *I'm not sure that students get the best… It's a bit sort of ad hoc, the way that DR is used here. So that's probably not very positive... the negative things for students here in relation to DR I think are failures in the training of staff in DR within this hospital. If you can't really explain it to yourself, then you can't explain it to anyone else.*

Elizabeth: *As a student you like it when a radiographer takes you aside and while the patient's still sitting in the waiting room, you just go through a bit of anatomy and teaching… Because it's a bit of a quicker system, you'll be expected to still keep up that speed, even though you've got a student with you. So maybe their practical teaching will decrease a little bit. You don't have time in the viewing room to go and stand with them and go through the anatomy, because it's in the room.*

The data suggests that the introduction of advanced technology in the radiographic environment can affect a student's education. It highlights that there could be a 'disconnect' between theoretical knowledge and the application of practical skills because radiographers do not possess the knowledge and understanding themselves. Students approximately undertake 27 weeks of 'general radiographic practice' during their undergraduate degree; however this data demonstrates that students may not receive optimum learning during this period, thus potentially hindering their development of becoming sound healthcare professionals. The integration and use of DR in this study has highlighted that the relationships between the radiographer and student radiographer could be impacted within the clinical environment. Although experiential learning for radiography students is undertaken by radiographers in order to develop clinical judgments and decision making skills in their daily interaction with patients, this data suggests that radiographers are merely ‘getting by’ due to inappropriate training received in the clinical environment. The concerns expressed among radiographers’ supports the argument that ‘actual’ clinical practice may not be the ‘best’ practice (Brown *et al* 2004; Flores-Mateo and Argimon, 2007), which is unfortunately cascaded onto student radiographers.

5.3. Digital radiography: Deskilling the profession?

In recent years medical imaging technologies have developed in all imaging modalities within the hospital environment. It is generally accepted that modalities such as computed tomography (CT), magnetic resonance imaging (MRI), ultrasound and nuclear medicine are ‘specialisms’ (Easton, 2009) which may be regarded as ‘exclusive’ or ‘exceptional’ (Oxford Dictionary 2010). These often require radiographers to undertake post qualification training with radiographers often moving into their chosen ‘specialty’; however the fundamental purpose of a radiographer’s professional education is to achieve occupational competence in their clinical practice. It is generally accepted that practitioners operating X-ray equipment have a sound knowledge base and understand the production of a digital radiograph and the awareness of the fundamental physics used in image production (Easton, 2009). In the United Kingdom (UK) radiographers have a pivotal role in modern health care (Hendry, 2013). Paterson (2012b) asserts that high quality graduates are needed to provide the workforce of the future and central to the development of the radiographic profession. However Braverman (1974:319) argues that the introduction of advancing technologies can ‘deskill’ a skilled profession: ‘the more science is incorporated into technology, the less science the worker possesses; and the more machinery that has been developed as an aid to labour, the more labour becomes a servant of machinery’. Diagnostic radiography has undergone enormous changes, both educationally and professionally, including teaching sites, learning methods, curriculum, professional status, educational funding and public expectations (Malamateniou, 2009), yet are radiographers being deskilled? Student radiographers spend on average between 46-67 weeks of learning in the clinical environment (Pratt and Adams, 2003) and since the educational shift from the traditional ‘hospital experience’ to the ‘University experience’ and award of ‘diploma’ to the award of a ‘degree’ radiography teaching today often resides in lecture theatres, whereby the responsibility for the curriculum determines both delivery methods and content (Sluming, 1996) becoming a desirable approach for research-led teaching (DoH, 2003; DoH, 2006). In addition interprofessional education (IPE) is now undertaken in academic institutions involving members of different professional groups, for example attention on 'collaborative practice' has been to focus on the practicalities enabling teams drawn from various professions to work together and serve as a central feature of optimal patient care (Eraut, 1994). It is generally accepted that radiography students learn to reflect on clinical observations in practice, experiment and develop better understandings and formulate answers to verify the scientific concepts observed (White, 1988; Hartman and Glasglow, 2002). This pedagogical approach aims to educate and prepare individuals to understand problems through a critical understanding (Hughey and Mussnug, 1997) and is considered a broader term than training (Davidson and Marco, 1999):

> *"Training for instance, can be associated with 'learning by doing' whereas education is more synonymous with 'learning by thinking'; development involves learning thinking, doing and feeling."*
>
> (Garavan, 1997: 42)

Studies have previously recognised that students can experience 'surface' and 'deep' learning (Marton, 1975; Marton and Saljo, 1976) for example students may know 'how to do something' but may not understand 'the principles in how it was done'. It is perceived that radiographers need considerable knowledge of technology to carry out their work (NHS, 2013b). The joint validation committee (JVC) aims to produce graduates that are safe and competent to practice and are composed of representatives from the SCoR and HCPC reviewing and monitoring the pre-registration undergraduate courses for diagnostic radiography. This learner-centred paradigm encourages learners to become independent and actively involved and responsible for their learning. This paradigm shift from teacher-centred to learner-centred education requires students to be involved in the decision-making processes (Gqweta, 2012). Requirements for radiography education and training are outlined by the Health Care Professions Council (HCPC) (HCPC, 2009) with collaboration from the Quality Assurance Agency (QAA) accrediting courses against set benchmarks, such as the 'identification of abnormalities in medical images'. Currently, radiographers' undertake barium enema sessions; administer injections; undertake radiographer review clinics and provide medico-legally radiological reports from ultrasound, isotope, radiological and contrast imaging (White and McKay, 2002). Image interpretation is an essential element of radiographic proficiency and often used in selection procedures for newly qualified staff during interviews. With the advancement of 'reporting' continuing for radiographers, are the core principles associated with diagnostic radiography becoming increasingly fragmented? Empirical studies in other health disciplines including medicine (Jones *et al,* 2002) and nursing (Failla *et al,* 1999) have investigated the learning outcomes of students in the clinical environment, however little research remains within radiography (MacKay *et al* 2008). It is reported that advancements in technology have resulted in an increase in quality-conscious radiographers expecting to fulfil the technological challenges while possessing patient skills (Malamateniou, 2009). Mick a senior radiographer felt that DR should be part of the University curriculum:

Mick: *I think it [DR] should be part of university, because it's the university that trains students in the first place before they become qualified. And we have to have an idea of what we're going to face at the end of the day when we come up for placement.*

Recent graduates Rosemary, Alex and Geoff affirm the importance of receiving theoretical DR knowledge at University, providing them with an appropriate level of understanding, facilitating the use of DR in the clinical environment:

Rosemary: *It all [taught theory at University] helped towards us learning on the job. As I said, once I qualified, then obviously that helps me learn more about it as we've worked on the job. Because it was quite easy once DR had been put into place here - then I found it quite easy to get used to it after being trained and just run with it, basically. It was fine.*

Alex: *It was part of the curriculum to understand the difference between CR and DR - the difference in image acquisition.*

Geoff: *I think the university taught us everything. They covered everything. Because they basically teach you all the products that are involved, what the products are made up of - the detectors, how they're produced, how they're manufactured, what they do.*

It has been argued that academic institutions may tend to emphasise the value of 'fitness for award' rather than 'fitness for practice' (Williams and Berry, 1999; Williams and Berry, 2000). In diagnostic radiography Vosper *et al* (2005) identified that 114

(92.7%) of the total number of respondents felt that their radiography degree from the University of Hertfordshire had equipped them for their working life. In contrast, recent graduates at sites A and C in this PhD study identified that the introduction of DR in the clinical environment presented challenges due to the insufficient knowledge and understanding received at University:

Fred:	*There wasn't anything really in depth about DR at all…there wasn't really a huge amount of focus on how you obtain the images. There was quite a lot about processing film and stuff, which I know that they withdrew after our year [2009].*
Kirsty:	*Very little. There wasn't a great deal at all. It was mentioned, but it wasn't in-depth. It could have been better in hindsight.*
Abigail	*It wasn't extensive [DR education at University] - it was like sort of pros and cons, comparison to CR. It wasn't anything in-depth.*
Danny:	*I think it was OK. I wouldn't say that it was kind of, you know… It wasn't in-depth. Not in-depth.*

Previous studies have highlighted that newly qualified radiographers' may struggle to justify radiological requests (McKay *et al* 2008) and perform radiographic duties in theatre (Feusi *et al* 2006). The data above highlights that radiographers may struggle with the essential underlying principles of advanced technology due to a lack of theoretical knowledge and understanding. It could be argued that this lack of knowledge and understanding prohibits recent graduates from producing 'images of optimum diagnostic quality', a central tenet to the ALARP principle and recognised by participants in this PhD research:

Elizabeth:	*I don't know any of the aspects of it behind how it works. I think that's a lack of knowledge that we don't actually have [sic].*
Emile:	*Because up to now - I have to be honest with you - I still don't quite understand the concept. Though I can imagine what is going on I would like to know. Maybe it's not within my level, but you'd want to know the technical side of things a bit more, so that you understand the process.*

Annabelle: *Definitely. And I think I can honestly say that I don't have the necessary understanding and I am using it without that knowledge. And I think it's important.*

The data highlights that while some radiographers 'know how' to undertake general radiographic examinations, they lack understanding of digital technology and image acquisition. Howatson-Jones (2012) recently identified that some students become dependent on dominant forms of knowledge, such as scientific evidence, which means they fail to recognise alternatives. The empirical evidence above suggests that some radiographers undertaking radiographic examinations using DR may not fully understand 'how the diagnostic image is acquired' thus arguably undermining the central tenets of radiographic practice. Furthermore, whilst increasing importance surrounds interprofessional education that encourages a more effective collaboration between health and social care professionals ensuring a seamless service of patient-centred care (DoH, 2000; DoH, 2001; DoH, 2003; Milburn and Colyer, 2008) the understanding of core principles remains essential in order for radiographers to conform to the professional codes of conduct and contribute to the interprofessional discussions and delivery of patient care. Hackman and Oldham (1975) describe the mental challenges that an employee may associate with work activities:

1) Task identity (the extent to which an individual can see their work from beginning to end).
2) Task significance (the degree to which the work is seen as important).
3) Skill variety (how much the role allows individuals to undertake a variety of tasks and use their skills).
4) Autonomy (how much individuals can make decisions about how to do their job)
5) Feedback (how much the job itself provides information about how well the work has been completed).

Ferris (2009) identified 'deskilling' within radiography attributing it to the removal of 'reporting sessions' amongst radiographers:

"…they [radiologists] just took it [reporting] off us" (p.81).

However in this PhD study an alternate dimension of 'deskilling' is noted as participants from sites A and C felt that the introduction of DR made participants question whether their skill base was essential in general radiography as images could be 'produced without as much knowledge', thus arguably facilitating mental challenges in diagnostic radiography amongst radiographers because the technology 'does the image for them':

Harold: *Well, I do think in some respects initially, it kind of led everyone to question whether the skill base in our profession was as high as it used to be, to achieve the same results. In that we can produce an image without as much knowledge.*

Fred: *It's de-skilling a bit, because it does take away… It applies to CR as well - the fact that you don't have to be so close on your doses as you would with film.*

Elizabeth: *The skill has gone down from being a radiographer using plain film, to DR… You sort of become reliant on the technology to do the image for you.*

Terry: *With digital type technologies, there's always that worry that you're going to bump your dose up. Or bump your exposure up in order to ensure that [you're getting] an acceptable image. You can see that as deskilling in professional.*

In the fieldwork it was found that some radiographers feel less enthusiastic about general radiography due to the radiographers' current beliefs regarding the skill required to produce a diagnostic image. Previously it was accepted that if a radiographer performed competently in film screen then there would be no need to be concerned with what he or she knows (Jessup, 1990). Yet in contemporary radiography practice this remains problematic as individuals who have not had the theoretical understanding or ability to articulate the underpinning knowledge associated with DR may still display effective levels of professional practice in producing X-ray images thus becoming reliant on the technology due to a lack of understanding. The danger associated with DR is expressed by Eric as a 'disadvantage' for students learning DR in comparison to film exposures because with DR you could give 'any old exposure':

Eric: *I think you're at a disadvantage being a student learning radiography on digital. Because you don't get to learn film exposures. You can just give any old exposure virtually and you'll get a picture. On film, you have to be pretty much spot on within 5 kV or mA.*

The data suggests that the removal of conventional film has limited a student radiographers ability to use exposure factors optimally. Ferris (2009) suggests that little emphasis is reported on the progression of general radiographic practice, yet this PhD thesis highlights that technological advances may be affecting job satisfaction as radiographic practices historically required a strict application of knowledge by selecting an appropriate radiographic technique. Moreover, as the radiographic profession extends into other areas such as image interpretation, treatment simulation, video fluoroscopy, barium studies and angiography, Milburn and Colyer (2008) assert that an educational philosophy supporting changes in practice must be one that continues to value professional knowledge and expertise. Thus although radiographic reporting is an established practice amongst radiographers in the UK and undertaken in general, CT, MRI, mammography and screening procedures, this research highlights that educational support should remain for general radiography as radiographers with little understanding in the future could become 'deskilled' in a modality that remains to undertake approximately 90% of all imaging procedures in a hospital environment. It is suggested that further reflection is required amongst higher education and clinical institutions as alternate pedagogical methods may be required to inform radiographers in the clinical environment and prospective radiographers in producing healthcare professionals that are 'fit for practice' in the future.

5.4. Are radiographers competent practitioners?

'Competency' is defined as the ability to do something successfully or efficiently (Oxford Dictionary, 2010). In general there have been many changes in information technology (IT), including home computer and domestic electrical devices. As technology advances in health, barriers have been identified. Clamp *et al* (2006) revealed low level IT competencies amongst surgeons, while Bartholomew and Curtis (2004) recognised that nurses saw IT as a distraction away from their more established work patterns. Other aspects such as organisational resources, lack of time, lack of education (Koivunen *et al,* 2008) and age (Coiera, 1998) are all reported barriers in the use of advancing technology. Radiography degree programmes are under increasing pressures to ensure that graduates not only have the necessary academic development but the practice based skills required by their registering authorities and employers (Ng *et al,* 2008). This suggests that practitioner competency is paramount and an essential requirement for all healthcare professionals which are regulated by professional bodies in order to meet the standards for training, professional skills, behaviour and health (HCPC, 2013). The HCPC (2013:1) assert that healthcare professionals should also continue their professional development and defined as:

> *'A range of learning activities through which health and care professionals maintain and develop throughout their career to ensure that they retain their capacity to practice safely, effectively and legally within their evolving scope of practice'.*

This PhD research has highlighted training and educational concerns for radiographers, but how does this affect their clinical competency? Professional competency in nursing has been regarded as a controversial issue with no accepted definition (Khomeiran *et al,* 2006). This debate is grounded in the belief that it is impossible to reduce the professionals role to a series of tasks and functions without taking into account the individuals personal beliefs, attitudes and experiences including their creativity, sensitivity and intuition. Professions such as nursing and medicine lead the way into research demonstrating the transition of nursing and medical students to healthcare practitioners (Ross and Clifford, 2002). Recently Howatson-Jones (2012:2) reported that nurses' may be 'learning by mistakes' within the clinical environment. Similarly the radiography curriculum in higher education institutions remains strongly vocational and professionally orientated preparing undergraduate students to become professionally knowledgeable and competent. Payne and Nixon (2001) highlighted that clinical demand required newly qualified radiographers to 'hit-the-ground running' and adapt to pressures and stresses within the clinical environment. Furthermore, Upton and Upton (2006) claimed that radiographers rate their abilities lower than medical physicists with 68.6% of radiographers rating their knowledge as being "poor" and knowledge of clinical effectiveness and evidence-based lower than physiotherapists, psychologists and dieticians. MacKay *et al* (2008) identified that radiographers graduating from their degree program were well prepared for practice with strengths in image interpretation and patient care however weaknesses remained in skull, traumatic radiography and the ability to justify request forms. It is generally accepted that the dynamic nature and context of clinical practice requires the profession to provide adequate support and monitoring for its newly qualified members; who may struggle with 'learning about the job', 'learning about the organisation' and 'learning about self' (Holden and Hamblett, 2007). A number of participants (junior and senior) at site C expressed their lack of confidence using the DR technology during radiographic examinations:

Annabelle: *I was going to say, I don't think I feel fully confident. I think I feel confident that I can get by. Which I still find a bit disconcerting. And I still occasionally have to call somebody and say "I can't get it to work on the table - I don't know what I'm doing wrong." So I don't think I am confident in there yet, to be honest.*

Terry: *Sometimes a detector won't lock in, and because of a lack of familiarity you can't work it out. You don't feel very confident moving it… "I'll just be a minute" I'm sure that affects the patient's experience to some degree - they're sort of saying "who is this incompetent idiot operating this equipment?*

Mick: *I think with that system, there is. Unfortunately so. I think compared to some other units that I've used previously, the GE system doesn't fill you with confidence when it gets a bit finicky.*

In contrast, participants at site A did not share the feelings expressed by the participants at site C as Margaret, Eric and Sebastian felt confident using DR equipment within the hospital as it facilitated their clinical practices.

Margaret: *I would say a couple of days to feel confident with the system, and I would say maybe a month to feel confident to work in the EI parameters.*

Eric: *About an hour. Well actually, I don't remember not being confident. It just didn't bother me. Because to me, it was something that was making the job a lot easier. It wasn't something that was making the job harder, it was making it a hell of a lot easier.*

Sebastian: *I think it took me [to feel confident] about a couple of weeks, three or four weeks. That's how I felt.*

The data resonates with Rogers *et al* (2010) survey suggesting that there is no clear indication that confidence is affected by age amongst diagnostic radiographers using the picture, archiving and communication (PACS) and radiology information (RIS) systems. Additionally, participants at site C expressed concerns with their ability to perform specific radiographic examinations including 'long leg examinations' and 'whole spine examinations':

Terry: *There are still elements of it that I'm not confident in using. Particularly the long leg and long spine stitched together type things. I still haven't done any, and I've been here for years.*

Abigale: *There are still things in there that I'm not overly… Only recently, it's been like the long legs and long spines.*

The difficulties identified by Terry and Abigail were often observed in the field work by a number of participants in the clinical environment that resulted in an increase in waiting times for patients:

Observation: *The radiographers in this DR environment are unable to perform a 'long leg' examination. The two radiographers assigned to work in the DR room could not obtain an image of diagnostic quality and as a result many patients were sent away. Although an experienced radiographer was consulted to solve the issue the problem remained unresolved. Following many attempts another member of member of staff was consulted and correctly moved the equipment into position. This selection allowed the radiographers to undertake the X-ray however there were many staff members who lacked the competency to set up and perform the 'long leg' procedure. This led to approximately 40 minutes delay in the patients examination and prevent other patients from been seen quicker as they were diverted to the main department. The radiographer who knew how to set this procedure up did so in approximately two minutes.*

One senior radiographer approached me whilst working as a locum radiographer at site C and informally expressed the action he took, as he was unable to perform the 'long leg' examination on his own:

Field Diary: *The senior radiographer acknowledged that he was unable to perform a 'long leg examination' for an outpatient outside the departments normal working hours, as he and his colleagues failed to correctly set-up and perform the examination required by the referring clinician. This resulted in the patient needing to rebook their appointment on an alternate date later in the week.*

The findings suggest that radiographers may lack key skills to obtain certain images of diagnostic quality, resulting in patient dissatisfaction due to recalling the patient. It also highlights that practitioner competency may be 'culturally specific' due to differences in DR equipment, training, type of radiographic exam and level of knowledge held by the practicing radiographer. Historically (1970s) it was reported that radiographers received no formal mentoring and although it impacted 'confidence' levels associated with the technical component of the job (Decker, 2009), Price (2008) reports of a 'get on with it attitude' associated with radiographers in the clinical environment. This 'get on with it attitude' was felt by Abigail using DR, she states:

Abigail: *It was just sort of "Do it". Are you happy by lunchtime? If you are, you're on your own!*

This suggests that some radiographers may lack support and mentoring in specific environments. Importantly, this PhD work highlights that the 'get on with it attitude' could encourage 'hidden practices' for those who lack confidence with the DR environment or machinery. For example Terry felt that the DR environment facilitated the production of suboptimal practices due to a lack of critical reflection, facilitating a potential 'slip' in his own radiographic standards because no one has previously approached him for putting poor radiographs through:

Terry: *Now one of the problems is if you're in a difficult environment and you're putting through films that perhaps are rushed and you think you shouldn't be putting through, but they're going through and they're not getting criticised, there's no pick-up on that coming back to you. Next time [it's] "Well that last one was acceptable, so…" So you get that slip in standards. And supervision helps bring that back.*

While Terry suggests that DR may be facilitating 'hidden practices', Margaret claims that DR allows radiographers to 'sneak in and sneak out' without an X-ray image being optimal:

Margaret: *Yes, I think it's having a big impact on the standard of radiography. I really do. I really feel that it's become a sneaky kind of radiography - you can sneak in and do things, and sneak out again. Whereas of course in the olden days, even with CR, you can't get away so easily. Because people can see your images. When you had films and viewing boxes, it was even worse." Everybody would see them. So you were constantly being judged by your peers.*

The data suggests that advancing technology has altered the 'working dynamics' of radiographers in the general radiography environment, thus arguably impacting on practitioner competency. For example, historically the 'viewing area' facilitated critical assessment for radiographers, judging the quality of X-ray images produced, yet DR displays images within the X-ray room allowing radiographers to assess their own clinical work. This 'lone working' may encourage 'hidden' or 'sneaky' radiographic practices whereby suboptimal images fail to be recognised, potentially impacting on a patients diagnosis. Further, it may hinder the competency of radiographers because if DR facilitates 'hidden' practices radiographers may be unknowingly performing suboptimal images that are unnoticed. Because DR can 'shut' the radiographer off from the world and their peers, clinical environments will need to find alternate approaches to monitor and assess image quality in order to ensure practitioner competency.

Evidence-based practice (EBP) has become essential in health care because it enables the use of the best evidence in making decisions about the individual care of patients (Flores-Mateo and Argimon, 2007). However a lack of time or other resources has been reported as a common barrier to EBP among radiographers, sonographers and among other health care professionals (Elliott *et al,* 2009). The use of research evidence in radiography (identified in chapter two) may also be hindered by inadequate knowledge and competence, lack of training or support from colleagues or the organisation and inadequate skills in critical appraisal (Hafslund *et al,* 2008; Elliott *et al,* 2009). This lack of applying research evidence was identified by participants at sites A and C (Harold, Michael and Terry) recognising that while they may 'know how' to take an X-ray using a DR system, 'understanding why' and using it optimally remains a challenge for them:

Harold: *Yes, I suppose to get it to work would only take maybe twenty minutes of training. To get it to produce an image. Optimising performance is another matter in terms of exposure factors and one thing and another. That's a bit more tricky.*

Michael: *And it needs to be very focused training, so "You're doing this examination - hang on, you can do it this way." It's one thing having a general knowledge of how it all works, but it's another thing specifically saying "What that means is you can do this" all of a sudden. You can change the kV a lot more, and you can do this and you can do that.*

Terry: *No - for me, it's education and training issues really. Like you were asking earlier if there's any way you'd adapt your technique: maybe there is, but I don't know enough about the system - would using a greater distance and a harder portion of the beam affect your exposure? I can't* *make those judgements, because I've not been educated enough, and I think.*

The views above demonstrate that practicing radiographers require additional support 'connecting theory with practice'. Chapter two identified appropriate dose optimising techniques with DR, yet radiographers failed to acknowledge this evidence based research. Other participants in this PhD research felt that they needed to be 'inventive' to 'see what happens', whereas another radiographer was reluctant to 'play around' suggesting a lack of autonomy following the introduction of DR:

Michael: *And you have to be a bit inventive with things and sometimes have a play around to see what happens with stuff, and see how it does change the image."*

Elizabeth: *You feel like you're changing exposure factors even less than with CR. You rely on what's pre-set on there. It's not really a hindrance, but it takes away from your job a little bit. You become more of a technician, don't you? You're like "Oh, I don't feel like I know enough to adapt the actual exposure factors and use the extra buttons on the system." Because I have a lack of knowledge.*

The data suggests that although some radiographers express their competency 'performing' examinations with DR, there is an element of concern amongst senior and junior members of staff. A competent radiographer is a practitioner who arguably operates and delivers the optimum radiation dose whilst upholding person-centred care. This PhD work reveals that some radiographers require additional support in the clinical environment. It suggests new challenges within contemporary radiographic practice whereby the practical application of radiographic techniques are not optimum, thus failing to 'connect theory with practice'. This raises concerns in an imaging modality that constitutes approximately 90% of all radiological examinations whereby staff acknowledge a lack in professional ability to perform their task to optimally deliver radiation using DR and as a result facilitates the feeling of a 'technician'.

5.6. Conclusion

Diagnostic radiographers entering into the profession are required to be competent in several areas of clinical practice. This chapter has identified that junior and senior radiographers may feel that they do not possess the adequate knowledge and understanding to use DR equipment optimally in the clinical environment. The key issues participants identified suggest a lack of ‘official’ training within the clinical environment coincided with a lack of theoretical knowledge from their academic institutions. This absence of training and education highlighted competency issues as radiographers felt they lacked confidence using the DR equipment, which could result in ‘hidden’ or ‘sneaky’ practices. At site C specific issues with ‘long leg’ and ‘whole spine’ examinations were noted, resulting in suboptimum patient care and subsequent increases in patient waiting times. In addition radiographers reported concerns applying theoretical knowledge and understanding, which hindered the student radiographers learning in the clinical environment. The general acceptance that ‘HCPC registered radiographers’ are ‘fit to practice’ could be debated because whilst radiographers ‘know how to take an X-ray using DR’, some radiographers lack knowledge and understanding to optimally produce X-rays of diagnostic quality in accordance with the ALARP principle. The daily practices of radiographers ‘getting along’ illustrates that although DR technology provides enhanced images it highlights that the professional may be deskilled, a concept that will hinder future developments for professionals and care to patients. Thus while the transition from ‘student to practitioner’ is reported as a ‘transitional phase’ this chapter has identified that continuous support and education in the clinical environment is required in order to inform radiographers and use the equipment optimally.

Chapter Six: Person-centred approach: The facilitation and hindrances in general radiography

6.1. Introduction

Despite the ubiquitous use of the term 'caring', Beck (1999:24) identifies 'caring' as a 'complex, elusive concept to define'. It is generally accepted that to be cared for is a basic human need (Peabody, 1927; Maslow, 1970). A central tenet of the patient-centred care was the movement, which 'consciously adopts the patient's perspective…above what matters' (Gerteis *et al,* 1993:28). Person-centredness' is generally used rather than patient-centredness because this recognises the set of values underpinning patient centred approaches are the same as those that underpin good staff relationships (Manley *et al,* 2011:10). This unselfish approach relates to the principle of altruism, the practice and principle of concern and welfare of others. Altruism is one of the fundamental expectations of a healthcare profession (Stevenson *et al,* 2001) whereby ethically individuals are morally obliged to benefit others. This chapter will explore elements of person-centred delivery within the general radiography (DR) environment using the empirical data to explore the changes that have aspired following the introduction of advanced technologies. The data presented will highlight time pressures and the affects these can have on a radiographer's clinical practices, followed by the use of DR and the effects it can have on the delivery of patient care.

6.2. Time Pressures and Culture of the Red Dot: The impact on health care

In the National Health Service (NHS) patients are considered the most important people in the healthcare community receiving help in preserving health through solving health-related problems (Ehrlich and Coakes, 2012; Field, 2012). The continuing demands placed on the NHS suggest that more will be expected for less (DoH, 2004). Currently radiographers spend short periods of time with patients but remain essential throughout a patient's treatment and care (Gahan, 2010). Approximately 96% of all patients entering a hospital may be expected to undergo an imaging procedure (Dowd and Ott, 1998), thus albeit brief radiographers remain central to a patients care pathway, acknowledged by Reeves and Decker (2012:78):

> *"It is a specialised role, offering both responsibility (in the use of radiation) and variety. It is a caring role but tends*

to be characterised by less time or close involvement with patients, when compared to other professions".

The role of the radiographer is characterised as one where less time is spent with patients. Today patients are more active in their care and have the right to participate individually and collectively in the planning and implementation of their health care. Ehrlich and Coakes (2012) advocate that a key focus of the radiographers' role is devotion providing a high quality all-rounded service for each and every individual patient. Historically radiographers were excluded from expressing opinions on radiographs, yet in 1995 over half of radiology departments in the United Kingdom (UK) had a 'red dot' system in place, which indicated a suspected injury on radiographic images (Loughran, 1994). This 'red dot' service increased to 81% in 2004 suggesting that Hospital Trusts embraced this development of the radiographic profession, noticeably facilitating patient care. Further, in 2006 the Society of Radiographers (SCoR) envisaged that radiographers would be able to make 'initial interpretation' on trauma radiographs by 2010, supported by the Health Care Professions Council (2003) and Quality Assurance Agency (2001). This benchmark for radiographers did not state that radiographers should be able to provide definitive image reports but promotes role development into a 'middle ground' between 'red dot' and definitive reporting. Grant (2006) claims that uncertainties regarding 'radiographer commenting' may be apparent due to the rapid technological advances in medical imaging, but little research remains examining the impact of abnormality detection by radiographers in the clinical environment (SCoR, 2011). Howard (2013) identified that participants performing 'radiographic commenting' claimed to have received little in the way of training and would embrace education. Howard' qualitative methods concentrated on interviews and focus groups. The observations performed throughout this PhD work highlight an additional theme. Patients often requested whether 'anything was wrong' with their X-ray due to the immediate image display to the radiographer often placing them 'in the spot light':

Observation*:* *Patients often requested whether abnormalities were identifiable on the patients radiograph. The anxiety surrounding the patients' possible pathology prompts the patient to request for an immediate diagnosis. However radiographers would explain that they are not the ones who diagnose the films and said that the images would be reviewed in A&E or sent back to their GP in 7 to 10 working days. Occasionally radiographers would mention that there was 'nothing obvious'.*

In one study the introduction of DR was reported to enable 'quicker checking of images whilst the patient was still in the room', allowing patients to feel 'calm' (Martin *et al,* 2013:5). The data in this PhD research reveals conflicts between 'what patients want to know' and 'what the radiographer can tell them'. For example Abigail a junior radiographer identified that the DR room made her feel 'uncomfortable' when a parent is positioned behind the lead screen, while Annabelle (a reporting radiographer) felt that DR facilitated 'abnormality detection' as she was able to alleviate any anxiety the patient would have:

Abigail: *My main thing in the DR room is when I feel uncomfortable when I get adults in with children. Parents are like "Oooh!" And they see it and they start thinking to themselves "Oh, well that doesn't look any better than before." Or "What's that?" And it's difficult.*

Annabelle: *The speed of it, the fact that they know we're looking at it straight away - they find it very impressive. So from their point of view, hopefully it's a good experience and it's nice and quick and they think we've got the best of the technology and that gives them more faith in us.*

The data identifies that radiographers may be put into challenging situations when using DR. It highlights that radiographers with little image interpretation experience may be encouraged to provide an immediate diagnosis. It suggests that radiographers may be expected to 'perform' in a scenario whereby they do not have sufficient knowledge, understanding or confidence to do so. Additionally, while some radiographers with adequate knowledge may provide a comment for patients this may add confusion for patients as they may 'not be told next time' if their X-ray examination is undertake by a junior radiographer for example. Previously, film screen (FS) and cassette radiography (CR) allowed radiographers to view and interpret image quality in alternative locations. For example, 'films' and 'cassettes' would be moved from the X-ray room, processed and viewed in the 'viewing area' away from patients thus removing the pressure to provide an immediate diagnosis, as highlighted by Abigail:

Abigail: *And it's difficult. Because it's there, whereas in CR you take it out of the room and process it don't you. So that's not really an issue. When you're in the CR room, they ask to see them and you go "Oh no, I can't – sorry".*

The processing of films and cassettes in alternate locations arguably 'split' the radiographic examination into two elements, 'image acquisition' and the 'detection of abnormalities'. This questionably removed the 'inquisitiveness' posed by patients, parents or carers requesting to 'have a look' or 'quiz' the radiographer of any health issues. The introduction of advancing technology arguably interconnects both 'image acquisition' and 'detection of abnormalities' during radiographic examinations. Thus recognition of this cultural transformation with DR emphasises the need to adequately prepare radiographers in order to manage patients queries appropriately within the clinical environment.

In 2001 undergraduate radiography programmes began to prepare students for image interpretation (Quality Assurance Agency, 2001). However 'abnormality detection' in diagnostic radiography is still considered voluntary in the majority (73.9%) of hospitals, thus presenting confusion surrounding the voluntary nature of 'abnormality detection' (Hampshire, 2007; SCoR, 2011). It is generally accepted that the voluntary application of 'abnormality detection' impedes on the level of consistency and reliance accident and emergency and minor injury departments place on 'abnormality detection' (Diamond, 2000; SCoR, 2011). In this PhD research Trust One no longer practiced 'red dotting'. Radiographers at Trust Two however continued to 'red dot' radiographs yet Emile and Geoff at site C reported how 'time pressures' hindered their ability to 'see if that's your best image' with their 'routine practices' merely ensuring that the images produced were clear and acceptable, without providing a diagnostic opinion:

Emile: *You get into this routine where you just bring in the patient and do the X-ray, and you don't have time to really look at their X-ray - time to see if that's your best image that you could come out with.*

Geoff: *Yes, you don't have much time to look at the images in that sense. As long as your image is clear and acceptable, then you send it through.*

The radiographers' highlight a lack of 'time' to critically reflect on the 'image quality' produced in the DR environment, suggesting that radiographers may place 'waiting times' above image evaluation. Because 'red dotting' remains to be undertaken voluntarily in the majority (73.9%) of hospitals radiographers may be under increasing pressures to 'red dot' whilst aiming to keep waiting times to a minimum. This presents a potential paradox in contemporary radiographic practice whereby increasing time pressures encourage radiographers to 'just bring the next patient in' thus reducing the autonomy of radiographers critically evaluating images for abnormalities. Bringing the patient 'in and out' may further impede a radiographers ability to evaluate a diagnostic image and may facilitate 'missed pathology'. The continuation to employ 'red dotting' with the possible introduction of 'radiographer commenting' may be more problematic in general radiography than previously envisaged. Radiographic departments will need to holistically review their general radiographic workflow ensuring that clinical abnormalities and comments can be optimally identified without hindering patient care delivery.

The introduction of immediate image acquisition arguably presents new challenges for image evaluation in the general radiographic environment. However participants at sites A and C recognised 'speed' and 'time' as important factors with DR enabling X-ray examinations to be completed in shorter periods of time when compared to previous image capturing methods, thus essential for managing clinical workflow:

Rosemary: *I think DR is brilliant and I don't think we'd cope without it with the number of patients that we're doing, and the demand of X-rays that we're getting. We're probably doing way over half more than we were doing six years ago. So in that respect, it's far quicker for us, and you can see the image straight away on the system, send it straight away… For the doctors, it's quicker. For everyone it's quicker really."*

Michael: *It definitely increases the workflow. I think if we had three CR rooms, we wouldn't be able to do the workload that we have here at the moment, personally. I think you'd need four or five CR rooms.*

Emile: *I think it helps with patient waiting times, and the workflow is much quicker…it's less time to go and process it. Unlike with CR, where you wait for it to come out and then if there's any mistake, you have to go back again and do it.*

Here it is suggested that advancing technology can facilitate 'workflow' in the radiography environment due to the speed of image production. These views and attitudes of radiographers in this study support Martin *et al* (2013) conclusions in that members of staff were satisfied delivering care using advancing technology within the general imaging environment. It is argued that the NHS rarely encounters examples where demand exceeds capacity (Audit Commission, 2002; Martin *et al,* 2003), but radiology departments remain criticised for 'bottlenecking' the patients' pathway (Garvey *et al,* 2003) whereby work is built up toward a deadline and not completed. Bertakis and Azari (2011) argue that staff have limited control over workflow and may come under increasing pressures to provide such quality of care. Increasing pressures were commonly observed at sites A and C:

Observation: *During busy periods radiographers often worked under increasing time pressures and were often conscious of increasing waiting times for other patients in pain and discomfort. They would often work at pace in order to reduce waiting times for patients.*

The importance of DR was expressed by participants at sites A and C because it provided radiographers with the ability to get the patients 'in and out' and 'get it over and done quickly' deeming it advantageous with paediatric and agitated patients in the clinical environment:

Michael: *With kids it makes it easier because you can set everything up before and get them in and… "That's alright, that's alright…" get them out and then… it's quick. That's sometimes very important with kids… If they're going to get distressed, the longer they're in there the more distressed they'll get.*

Rosemary: *The thing is with radiography; you want to get the best image possible for the patient and the doctor, because you want a quick diagnosis for the patients to get their care as quick as they can.*

Margaret: *With agitated patients. You get it over and done with quickly. Yes, I would say it has facilitated it in that respect. If you have somebody old, you're not messing, you know what I mean?*

Abigail: *Any chests would be great. But male chests in there are just in and out. It's great in there. Brilliant [sic].*

DR can provide an 'in and out' culture among radiographers, but what impact can this have on the delivery of healthcare to patients? Crawford and Brown (2011:3) suggest that 'fast healthcare' could be a characterisation of current healthcare service in the NHS and propose numerous practical strategies to facilitate the fast paced care. From the field work the accounts expressed by the radiographers could be attributed as poor practice because less time is being spent with the patient thus new methods of communication may be required for radiography to facilitate the demand in radiological services. There is significant value on patient experiences within the NHS (DoH, 2009); the two common complaints since 1996 have been 'communication' and 'attitudes of staff' (National Statistics, 2010). The recognition to satisfy patients has continuously evolved within the NHS (Hulka *et al,* 1971) with patient-centred care considered a proxy for high quality interpersonal care (Bertakis and Azari, 2011). There is a lack of research evidence associated with person-centred care and improved patient outcomes in general radiography, yet Geoff a senior radiographer felt that the speed of DR acquiring an image enhances his delivery of care to patients because he can communicate longer with patients and ensure the correct information is delivered to them:

Geoff: *You've got so much time with the patient. You've got more time to explain things, because you know you can always catch up. You know, like there's no pressure on you meeting your targets with your appointment times and all that. If you've got a ten-minute slot for every patient, you can absolutely do an X-ray within five minutes. And the other five minutes is spent on patient care and talking to the patient, and giving them directions on how to get the reports.*

Geoff provides a positive narrative of advancing technology facilitating his radiographic practice providing more time with his patients. Other participants describe their 'humanistic' relationships and interactions with patients regardless of advancing technology suggesting that it does not impact on the healthcare delivered:

Alex: *As far as patient care goes in my opinion, it's really about the staff interaction with the patients. I can't really think how the equipment itself would affect the patient, because I don't see how it impacts patient care. I think the input of the equipment is just the technical aspect.*

Terry: *I think it wouldn't make any difference, to be honest…even if you're in CR and DR there is a relationship. It will be still the same with CR and DR.*

Kirsty: *I don't think it affects their care anymore than any other X-ray technique. They get a diagnostic image, which the consultant/doctor can view. It's probably a positive thing, because it's done very quickly. Their care pathway should be a quicker transgression [sic] from consultant room to X-ray and back to consultant.*

Although participants in this study felt that patient care was not affected by advancing technology, Reeves and Decker (2012) reported that (with CR) radiographers do deliver care in a shorter period of time, which can distance themselves from patients, something which Murphy (2006) recognised as a 'blip' or 'hit and run' culture.

Participants in this PhD research acknowledged ‘time pressures’ in the DR environment, resulting in participants questioning whether they delivered optimum care as patients would often be ‘rushed’ or ‘hurried’ throughout their X-ray examinations as commented upon by radiographers:

Victoria: *I always try and be really nice, and obviously sometimes though you are rushing and I suppose you do try and just say “Right, let’s knock these out - get them in, get them out, get them done.” And you probably don’t spend as much time with them as you’d like, because you know people keeping are waiting.*

Emile: *Yes, you do alter your [practice] because you’re aware that you’ve got patients waiting. And you want to reduce that waiting time. And also with the patient - they come in and they want to talk to you and you try and say “come on, sit down!” And you can’t explain to them “OK, we’re going to do three X-rays for you - one lateral…” So that they know what to expect. You just go there and move their hand that way. You just go into auto mode - “take a seat, quick, quick!”.*

Rosemary: *You don’t have a lot of time with the patient nowadays. If it’s busy, it’s literally one in; one out…it’s like a bit of a conveyor belt. It’s not nice for the patient I don’t think, having to be quick. It does look like we’re not caring very much”. “And you just want to hurry them up. Trying to open the door when they’re trying to get their shoes on… they think, “Oh, I’ll be quick.” You don’t want to make them feel like that, but you can see the queue outside, and it’s pressure on you as well. As I’ve said, the last few years have been like that - a lot more patients to deal with. And I suppose the care has gone down somewhat.*

Margaret: *On the one hand it’s better because it’s quicker and more efficient. Maybe on the other hand, it’s not as good because you’re pushing them in and out much faster, so you have very little communication with them if you know what I mean. Your communication time with your patient is now reduced.*

The radiographers suggest that increases in work pressures can reduce the practitioner-patient relationship by encouraging ‘them out of the door’ and failing to correctly inform patients of ‘what is going to happen to them and why’ thus arguably delivering an inferior quality of care. This supports Murphy’ (2006) suggestion of a potential diminishment in care due to the primary focus being on maximum efficiency and throughput in other radiographic modalities. Thus although professionals should aim to communicate with their patients by actively listening and responding to the patients' verbal and non-verbal cues tailouring the patients' needs (Halkett *et al,* 2011), radiographers may fail to meet the patients' needs within the general radiographic environment following an advancement in technology. Because time pressures potentially impact on communication, attitude and behaviour of radiographers participants at sites A and C acknowledge that time pressures in general radiography occasionally lead to radiation incidents, administrative errors and near misses throughout their day-to-day clinical practices, as discussed below:

Emile: *Only after you finish [the X-ray exam] that you think "Oh no, he didn't sign that" or the consultant has written "left knee" or "left hand" and you've already set the table and the patient is lying there and saying "no, it's my right!" Just because you're going quickly. Yes. One should normally check anyway. If you're not busy, you double check - you say "is it your left we're doing" and they say yes - they confirm that it's the left. And if it's not, they'll tell you: "no, it's not my left - it's my right". But because you're busy, you just look at the form [and go] "OK, it's the left - please take a seat". You say it's for the left and if they're sensible enough, they'll say "Why are we doing my left?" [But] some of them, they just sit there [and let] you do it. And they'll say "Oh, how about my right? It's my right." And you've already done it [sic]. Near misses, yes. Quite a few near misses. I don't want to lie - when it's really busy, I've had… maybe because I was just starting and all the confusion of getting used to it - I've had cases with so many mistakes where the patient details are wrong, the date of birth is not right… The left and right thing - that's very, very common, I've learned in DR. So every time, I have to double check with the patient.*

Bernard: *We're quite rushed, and if the person is going to set the room up, it's really easy to click onto somebody else's name. And when you're put under pressure for the amount that we do, that can happen regularly sometimes. And then you have all the rigmarole of sorting it out. So I'd say that was one of the major problems."*

Terry: *However, I think - like in any job - if you've got that thing of not enough time to do your job properly, which has certainly been the case here at times… it's generally been more staffing issues than other things, but whether within DR or CR, I think there have been times here when people have been under so much pressure that for example, that a piece of work that would perhaps have*

> *got repeated at a different point in the day when things were quieter… perhaps "ankle or there's only a bit of the talus - I'll let that go through", rather than repeating it and getting a full ankle.*

The data suggests that radiographers in the DR environment are exposed to 'latent failures' whereby busy environments present excess pressures for radiographers, thus impacting on the patients care (Rix *et al,* 2003). The responses above reveal the individualistic difficulties encountered trying to keep 'on top' of their clinical workload, some which arguably result in suboptimum practices. The nature of general radiography has historically been a small component of the patients' hospital treatment and management. It is accepted that although DR can facilitate the delivery of healthcare providing additional time with patients, radiographers may provide 'fast paced radiography' aiming of keep waiting times to a minimum. During busy periods participants acknowledge the delivery of suboptimum care as patients were often 'hurried' or 'rushed' out of the X-ray room, suggesting that radiographers engage into an 'autopilot' response, which may appear uncaring. Lastly, participants felt that significant time pressures did not allow them to perform their radiographic tasks appropriately, which lead to radiation, administration and technical errors within the clinical environment. These accounts suggest that during busy periods the delivery of patient care within general radiography could be suboptimum in contemporary practices. This is a concern in an imaging modality that approximately constitutes 90% of all radiographic examinations undertaken clinically.

6.3. General radiography: A hospital or industrial environment?

Diagnostic radiographers require a scientific understanding underpinning the advancing technology; it is also argued that radiographers require the professional and social skills to interact with their patients (Ehrlich and Coakes, 2012). It is generally accepted that advances in technology can increase patient satisfaction (Silverman *et al,* 2005), but organisational culture may impose pressures, which can reduce efficiency and decrease cost effective working (Health and Safety Executive, 2007) with psychological morbidity present among 27% of healthcare professionals, higher when compared to the general population (Borrill *et al,* 1996). An increase in hours and pace of work can result in psychological strain on staff as healthcare begins to resemble 'a production line' (Bridge and Jenkinson, 2003) thus yielding negative experiences and frustration with radiographers in the clinical environment (Kutner *et al,* 1999). An observation made at each research site revealed that radiographic examinations could be performed in quick succession:

Observation: *Radiographic examinations requiring one X-ray projection on ambulant patients could be completed in several minutes. Staff members would assist colleagues with manual handling, image acquisition and administrative tasks in order to ensure patient waiting times were not increased. It illustrated that sound team working in a digital environment allowed staff to perform X-ray examinations in a considerably short period of time.*

The relationship between the radiographer and patient has arguably been the sole focus on the technical aspects of the examination (Booth and Manning, 2006). Participants at sites A and C acknowledged that radiographic practices can mimic that of a 'production line'. Radiographers reported to 'pre-empt' the use of a specific technology based on their working shift, or patients mental, infectious or injured state in order to obtain a diagnostic image 'quickly', providing patients with the 'quickest care' possible:

Sharon: *If they're non-compos mentis, you can just slide them over onto the table. They won't know any better.*

Terry: *I think you could make a decision based on that - I can see how you would look at someone and say "well, I think that CR or DR would be more suited.*

Helen: *When I was training, if someone was very ill, they might be inclined to do CR very quickly, get it done, get the patient back to where they needed to be, rather than fiddling around locking things in and pat sliding and things like that.*

Elizabeth: *Yes, I'd use DR because it's a lot quicker - get them in and out…you could probably clean a detector a lot easier than you could a CR plate, to be honest. Whereas a CR plate has got little gaps.*

Emile: *It's different for a patient with - say - MRSA, where you want them [to be X-rayed] quickly to minimise any contamination or whatever.*

Michael: *There's always that pressure, isn't there? If you're on a night shift, what would feel like [busyness] on a night shift is a huge number of people. If there's six people sitting there, it feels like nothing. Sometimes on a night shift, someone will come down for an abdomen, and you're just "they're having that done on the trolley" And how can you handle them if you're spending half an hour trying to pull people out of A&E and getting porters down? It's better for their care to get them done and get them the care they need.*

On the one hand the data suggests that radiographers may favour CR or DR technology to facilitate the radiographic care of patients. For example, buy selecting CR over DR may reduce risks of cross-contamination, and manual handling. On the other hand it reveals that radiographers aim to perform general radiographic examinations 'quicker' in the clinical environment. This is reinforced by a senior radiographer (Margaret) who maintained that the technological advances in contemporary radiographic practices resembled that of a 'sausage factory', whereas in the past CR and FS provided additional time with patients due to 'processing time', thus able to listen to her patients' needs:

Margaret: *Because they're now more sausage factories. Before, you would have to get them in, sit them on the table, get the cassette and pop it through. They would stay there, you'd come back, have a chat, da-da-da, get them off. And you'd only send them out if you were really busy... If we were on CR, we'd keep them on the table, wouldn't we? And she would have said something to me - she'd have said "Oh, my heel is sore as well" and I would have had time to absorb what the patient was telling me, and respond. Whereas now, I often don't have time.*

This highlights a cultural difference within contemporary practices using DR, whereby clinical healthcare is comparable to an 'industrial environment' with the patient seen as a 'product' and part of a manufacturing process. This 'industrial perception' is supported by Geoff and Victoria who recognise the importance to 'get twenty patients in ten minutes' with concerns surrounding less ambulant patients in wheelchairs recognising that they would take longer:

Geoff: *I think one of the major advantages is the ease of use, which facilitates patient throughput as well. Even the volume of work and the demand… if you compare that to CR, you can easily get twenty patients in ten minutes… in terms of patient throughput, we are experiencing high numbers of patients - high numbers of X-ray requests.*

And the only way you can meet them is by either employing high numbers of staff, or if you come up with things like digital, which is quick. You can pretty much do so many patients within a short period of time compared to CR.

Victoria: *You've got to prioritise these ambulance patients… And they're in a wheelchair and you know they're going to take even longer.*

These comments may go against current philosophical viewpoints associated with 'caring' and 'person-centredness' for the ill and vulnerable in a hospital environment (Sorlie *et al,* 2000), suggesting an 'industrialisation of medical care', yet recent evidence suggests that not all patient groups may be equally responsive to a person-centred approach. Boer *et al* (2013) reported that patients may consider patient-centred care to be of above average importance, compared to other aspects of their care experiences including waiting times, activities to monitor disease, medication, accommodation, privacy, and care following discharge from hospital. Similarly research demonstrates that younger and older cancer patients differ regarding the type of information they like to receive about their cancer treatment (Janssen *et al,* 2007) with 'patient-centred care' considered more important by patients who were younger, female, well-educated and healthier (Krupat, 2006; Boer *et al,* 2013). Within medical imaging Mathers *et al* (2011) reported experiences of men with prostate cancer highlighting that patients were more concerned with their diagnosis and treatment rather than the attendance of imaging procedures and was seen as a 'means to an end' and 'routine'. This suggests that patients' entering the X-ray environment may differ in the care they wish to receive from the radiographer, as suggested by a respondent in Bolderston *et al* (2010:202) study:

"Caring is different because when you're going in for a one time X-ray or something like that, you don't expect that much care. I want you to scan it and get me out of there, quick and easy."

Therefore do patients undergoing digital radiography see their examinations as a means to an end? Historically radiographers have continuously aimed to reduce the objectification of patients due to the potential technological-humanistic role of both technologist and carer (McKenna-Adler, 1990) ensuring a sense of emotional and physical comfort as 'caring is the very essence of radiologic technology' (Ireland and Hansen, 1978:240). Terry, however acknowledges the potential to further 'depersonalise' patients with advancing technology due to the increased speed in which examinations can be acquired using DR:

Terry: *Well, radiography has always been a relatively brief intervention. Part of it is that ability to interact quickly with somebody. If it's getting even faster and you've got less time again with the patient, then that… I suppose there may be an element of depersonalisation there. Perhaps there's a tendency amongst radiographers to depersonalise patients anyway - the reductionist thing of "there's a foot in the waiting room". So if we're having even less time with them, there is a danger of even more reductionalism, a more production line type… "get the foot in and out", sort of thing".*

Technological advances can facilitate workflow improvements (May *et al,* 2000), but this may present a paradox towards patient care within general radiography. For example the data suggests that as technology advances less time is required to produce an image of diagnostic quality, reducing the practitioner-patient interaction thus encouraging depersonalisation amongst radiographers. Conversely, it was found that radiographers saw that some patients were significantly impressed with the speed in which their diagnostic X-ray examinations were acquired and sent to the referring clinician:

Terry: *Well, sometimes for the patient, their amusement to see how it is working more quickly - they come in and it's done, and they're going. So they're more like "Wow!" Every time when they come in they say that.*

Mick: *I think the experience… because from my experiences, when I've X-rayed patients these days, they are like "that's fast compared to..*

Rosemary: *They're always shocked at how quickly we do the X-rays. "Oh, is that it?", and "Oh, there's no film nowadays"… and it's like "No, no film now!" So I think viewing the public's opinion I think they'd be quite happy with how we do it nowadays. It's a lot quicker for them.*

The data above may support the argument that the 'caring' component of a radiotherapists' role is seen as 'the distinguishing factor that sets radiation therapy apart from the other radiologic science disciplines' (Bolderson *et al,* 2010:205) due to the amount of time diagnostic radiographers spend with their patients (Steves, 1993). However Murphy's (2001:197) study reported that patients undergoing computed tomography (CT) and magnetic resonance imaging (MRI) examinations were satisfied about the procedures and level of care received within the imaging department by both radiographers and nurses:

CTMALE1: *The girls [radiographers] were lovely. It didn't worry me at all, I wasn't frightened, it was very pleasant to be honest.*

MRFEM2: *The nurses, or whoever they were, they were absolutely smashing, they came over as very caring, very concerned… I mean I know it is their job to be caring, but they actually sounded very concerned and were really nice.*

Thus with increasing 'time pressures' how may this impact radiographers? Radiographers are able to undertake general radiographic examinations with greater speed due to technological advances; however this places contradictory pressures on both professionals and patients. For example, if patients prefer faster radiological examinations radiographers may become increasingly pressurised to perform examinations quickly in order to meet the demands or both employer and patient. This arguably can facilitate reductions in patient contact and care. One concern is that students entering a healthcare profession often want to care or help a person, which provides a significant source of professional satisfaction. Bolderston *et al* (2010) cites Goldins' (1979:190) definition of caring in reference to diagnostic radiographers as:

> *"Providing emotional support, explaining the procedure in a manner the patient can understand, permitting the patient to express emotion, actively listening to a patient's concerns and responding in an empathetic manner and recognising the patient as a unique individual rather than just another care."*

Sound holistic care should be delivered throughout all radiographic procedures (Ehrlich and Coakes, 2012) yet job satisfaction may be diminishing in diagnostic radiography. Hutton and Eddy (2012) investigated job satisfaction with therapeutic radiographers identifying 'workflow' as having a significant impact on job satisfaction. In this study the delivery of care described by Goldin (1979) may be more problematic for radiographers and patients alike. For example with increasing pressures placed on medical imaging departments, increasing public expectations, ambitious guidelines, targets and penalties resulting from the NHS Plan (2000) and NHS Cancer Plan (2006) radiographers may feel under increasing pressures to perform optimally. It has been found that radiographic environments have previously been reported to be isolating and depersonalising environments for patients making them feel alone (Faithfull and Wells, 2003). On a similar note, the fieldwork discovered that patients may place 'waiting times' above the care they receive, viewing diagnostic procedures as a 'means to an end'. Elizabeth, a senior radiographer describes how radiographers may feel isolated in the working environment even though it may provide a positive experience for the patient:

Elizabeth: *Yes, that's what I think. The patient might not mind as they're - like you say - getting their appointment done quicker. But from our point of view, you spend less time with the patient, and you're in a room… sometimes you could be in the room on your own. Because you don't really need a second person with you. And it could become quite a lonely job. And like you say, a conveyor belt system - in and out. Yes.*

The data highlights that advances in technology may isolate individuals in the general imaging environment, potentially impacting job satisfaction. A study of sixteen NHS hospitals compared the management of occupational problems and stress amongst diagnostic and therapy radiographers (Casselden, 1988). It identified that professionals in both groups were working in stressful environments and that inter-staff communication was the greatest source of stress in the diagnostic workgroup. More recently following the impact of Agenda for Change less than 10% of radiographers had positive views relating to this additional impact on the profession, with band 5 and 6 radiographers being most dissatisfied (Edwards *et al,* 2009). Whilst the Royal College of Radiologists (RCR) and Society and College of Radiographers (2007) highlighted significant incidences of work related stress in radiography, this PhD work suggests that radiographers may face additional challenges regarding job satisfaction with advancing technology.

This section has argued that the hospital environment may resemble that of an industrial environment as radiographers undertake 'twenty patients in ten minutes' with 'wheelchair' patients taking longer to accommodate. Patients are generally impressed with the speed of the examinations however further research is required exploring patients experiences undergoing general radiographic examinations. The DR environment may similarly facilitate a lack in job satisfaction whereby 'loneliness' and lack of opportunities to provide holistic patient care in the so called 'sausage factory'. Whilst radiographers may be under increasing pressures within the clinical environment to accommodate patients, radiographers may also require additional support to address not only the needs of the patient but for themselves.

6.4. Care and Technology: Shoehorning patient care?

In healthcare the concept of caring is prevalent in logos, visions and mission statements of many institutions, health authorities, professional bodies and organisations including diagnostic radiography (Buchanan, 1992). The X-ray environment is familiar for the radiographer but may appear 'alien' to patients undergoing radiographic examinations:

Observation: *For a radiographer the clinical environment is common place, however for the patient the clinical setting may provide anxiety and confusion, the setting is unlike any ward and or outpatient department or appointment, X-ray equipment suspends from the ceiling often situated in a dark room whereby technology and operator examine the patient. There are no windows; the environment is cold due regulated temperate control because of advances in new radiographic technology. The DR equipment can be 'pre-set', mechanically moving into the desired position by the operator, something previously uncommon in the medical imaging department. Throughout the X-ray examinations the operator determines the correct anatomical area to irradiate, delivering the acceptable level of radiation required. Recent advances in technology allow the operator to control these functionalities via a remote control within the X-ray room, thus limiting an element of patient contact.*

The X-ray environment is a diagnostic environment that aims to acquire detailed images of the human body. As the environment has developed technologically, the delivery of patient care remains a central tenet of radiographic practice. Howatson-Jones (2001) identified that extrinsic forces, such as pressure, combined with intrinsic disease such as vascular problems can overwhelm tissue tolerance and initiate tissue damage during radiological procedures. The author suggests that a Vacufix mattress complies most closely with requirements for an X-ray table mattress and reduce pressure for the patient (ibid). This demonstrates that advances in equipment can facilitate patient comfort and care, yet authors have argued that the development of technology can be seen as an obstacle to patient care (Benfield, 1979; Cockburn, 1985). Following the introduction of DR chapter two revealed few publications attempting to ascertain the behaviours and attitudes of diagnostic radiographers surrounding the concept of caring. This is essential because radiographers are often in control in their environment i.e. 'they (radiographer) are considered to have the right to give directions, orders, make rules, and prescribe treatments' (Hewison, 1995:79), however studies suggest that technology can provide a barrier to patient care. Murphy (2001) investigated the experiences of men undergoing complex cross sectional imaging such as CT and MRI whereby the needs of the patient were sometimes forgotten with technology being described as the barrier to communication between staff and patient. In radiotherapy Colyer (2005) warned that while the profession is developing a high degree of technical specialism, which is increasingly valued as the central role of radiation therapists in the treatment pathway, the profession is in danger of relying on this technology to sustain its role in favour of other affective skills such as emotional and informational support. Patients attending a hospital may be exposed to new situations whereby the staff may be the patients' only source of information to their condition and an important source of support and comfort. In medical imaging patients' have been reported to feel fear (Murphy, 2001), claustrophobia (Davies and Channon, 2004) and dehumanisation (Murphy, 2006) and although the X-ray environment contains distractions such as paintings and magazines reported to alleviate pain (Keefe *et al,* 1994) and anxiety (Ong and Austoker, 1997) the radiographic environment treats and cares a variety of patient demographics and medical conditions. This is explained from the following observation:

Observation: *Patients would arrive into the X-ray room by various transportation methods with various medical conditions. Each patient was unique by their age, suspected illness and injury. Due to the patients vulnerable state patients were often observed to be in vulnerable positions, which may include mental capacity, patients' mobility, and risk of infection. The junior and senior radiographers were observed providing patient care with specific consideration to those in pain and discomfort. Radiographers reassure their patients and keeping them calm and warm where necessary throughout their radiographic examinations. Throughout the examinations radiographers explain and discuss the methods required to move the patient, positioning them appropriately in order to obtain an image of diagnostic quality.*

Sound patient care was observed in the clinical environment; similarly some radiographers felt that DR facilitated the patients' care due to the immediate image acquisition available with DR, which coincided with the ease of repeating an X-ray exposure whilst the patient remained in their radiographic position. Fred and Margaret expressed this during their interviews maintaining it facilitated patient care helping them build rapport with the patient, unlike CR which required patients to be left in an unfamiliar environment:

Margaret:	*You don't have to leave the room, you don't have to disappear. You're there the whole time with your patient. And I think from that point of view that is better for the patient.*
Fred:	*Because of you not abandoning the patient in the room. Especially nervous patients, [they] aren't being left alone in a scary room. So it does help that rapport with the patient. You see the images straight away, so you can help reassure patients quickly, you haven't got to leave the room and leave the patient unattended for two or three minutes at a time, like you do with CR.*

In the fieldwork it was discovered that while diagnostic radiographers claim to be patient centred, it can be argued that this claim may not be borne out by reality as patients can be seen as a translucent screen upon which a radiographer peers to find a diagnostic entity (Coulehan, 1985). For Alder and Carlton (2007) the production of a diagnostic image is the long-term goal with the humanistic interaction being the short-term goal amongst radiographers supporting Strudwick *et al* (2011) argument that the diagnostic image can be at the centre of radiography practice and not the patient. This view that radiographic practice is centred on obtaining a diagnostic image was recognised by participants at site A, as CR and fixed-detector technology were available in all clinical rooms. Sharon, Rosemary and Michael felt that the selection of CR technology facilitated their patients' care in the clinical room with patients with decreased mobility and physical or mental impairment:

Observation:	*More often ambulant patients would undergo DR as they may be required to move into position for the operator due to the fix detectors. However for non-ambulant patients the preferred method of image acquisition was CR in order to reduce patient movement and enhance flexibility whilst obtaining and image of diagnostic quality.*
Sharon:	*Really, the only thing again is if they're so unwell that we end up using CR. Because you can't get them over to the DR. The pathology doesn't really change what you use - it's more how much pain or how unwell they are. If they're very unwell, then you don't want to move them too much.*

Rosemary: *Yes… it's difficult. I mean if the patient's basically unconscious, usually you can't move them. If the doctor's with them and they've intubated and whatnot and it's going to be far more difficult to move them onto our bed to get good image quality, then if it's a case of just doing a chest X-ray, then you try and get the best CR image quality that you can, because there's more risk in moving the patient sometimes, than leaving them where they are.*

Michael: *Sometimes it's easier to get a CR cassette out and just pop it straight under their arm. Especially if someone's really injured - you go straight back to the CR.*

Here radiographers are 'image focused' to obtain a diagnostic image. The dual use of CR and DR at site A suggests that radiographers may be 'technologically-focused' selecting the 'appropriate' technology to acquire a patients' image in a safe manner. This suggests that radiographers are 'patient focused' in the clinical environment using technology to accommodate the patients' needs. Patients are reliant on health professionals performing tasks effectively (Feldman-Stewart *et al,* 2005) particularly when they may feel anxious about the symptoms they are experiencing. Kirsty and Emile highlight that they would ensure that optimum technology is selected regardless of a patients' hygiene for example:

Kirsty: *I don't really think it makes any difference to whether it's DR or CR, whether a patient is as savoury as you might wish. It's got no bearing on it. It's a room and equipment. And us. That's a personal preference. We'd like them all to come in smelling fragrant [laughter]. But it doesn't affect the way we examine them, does it? Doesn't make any difference.*

Emile: *But for a smelly patient, I wouldn't… No, no - I wouldn't do that. I'd do the best I can. I mean, people have different preferences. Some prefer CR or whatever. I'd use the one that I prefer - that I feel is the one where I'd get a good image. Whether it's time consuming or not.*

Radiographers in this fieldwork highlight the importance of combining technology, holistically considering the patients' conditions and illness within the clinical environment. But other participants at sites A and C acknowledge a potential lack of patient care as patients may be 'shoehorned' within the DR environment in attempts to obtain an image using fixed detectors, whereas CR would reduce discomfort and answered the clinical question posed by the referring clinician:

Michael: *I think sometimes, when we try and shoehorn a patient into DR it makes the experience worse for the patient. Sometimes we try and use DR - we use the horizontal bucky and somebody's broken their arm or their elbow, and you sort of yank them over and you think "You will get the image on DR! When you could almost not move the patient at all. There are instances when we're yes, shoehorning a patient into DR is actually reducing the patient experience [sic]. And it makes it more unpleasant for the patient sometimes.*

Rosemary: *It's horrible to say, but you try not to cause them any pain but if you've got to get the best image possible, you're going to have to move them… And you don't want to keep getting them back up when doctors keep saying, "that's not good enough" and keep re-irradiating someone. You might as well get it done straight away.*

Michael: *You have to move them, and you have to be a lot more confident in saying "Right, your arm needs to be over here.*

Sharon: *For the digital maybe they do at the moment. That's true. If we're trying to use a digital instead of the CR, then yes, we might be trying to manipulate them to a specific position just to get the X-ray. So I suppose there could be a downside in that it's not as comfortable for them than having just a cassette shoved between them… There's a possibility of "She's being cruel, pushing me over to DR".*

Abigail: *The only thing I think that changes their experience is if they're in a chair and with a humerus and that, because it's such a big detector, it's uncomfortable putting a CR cassette behind the patient. And just to put that… I mean, it's so big. To put that behind them - I think that's uncomfortable or even worse. So I think that would change their experience.*

Here the use of advancing technologies in general radiography suggests that patient care can often be overlooked as the focus of the radiographer may be directed towards the technology and not the patient. This highlights that while skilled operators are 'doing it their way' it illustrates variation in quality and consistency of care. At the same time participants highlight that advancing technologies in the general radiographic environment may hinder a patients experiences and care because DR restricts the flexibility during radiographic examinations. A common theme identified amongst radiographers at sites A and C was 'patient movement' using DR. For example participants expressed a lack of flexibility associated with the fixed detectors, as patients were often required to move over detectors for the benefit of radiographic position due to the DR equipment requiring it to be 'locked in'. As a result participants felt that those patients struggling to move could be exposed to further discomfort and pain when compared to CR:

Eric: *They [the patient] have to lean across [the detector] too much.*

Kirsty: *Obviously you've got to move the patient … You can't necessarily just move the detector, because the free-stand one is a bit heavier and it's a bit more awkward to get in behind wheelchairs and things like that.*

Victoria: *If they're mobile patients, it's a lot easier. But as I say, sometimes even getting someone to move a fraction for a standing lumbar spine can be very difficult for them. You've got to move them, rather than the equipment. So sometimes I think for those people, it's not as easy always. Some people really struggle to move at all. Obviously you do your best for them, but… So yes, I think having to move the patient is sometimes not always good.*

Here it is demonstrated that advancing technology can restrict a radiographers' performance during certain radiographic examinations. Additionally it highlights that radiographic 'procedural set ups' preprogrammed by equipment manufactures may not be wholly optimising patient care delivery. Collaboration between radiographers and equipment manufactures could however facilitate the optimum use of advancing technology in a general radiographic environment due to the flexibility required to produce an image of diagnostic quality. Mick explains his difficulties at site C whereby DR is the only technology available in a clinical room and believes that because CR is not available a patients experience is hindered with the examination time prolonged:

Mick: *The patient's moving a lot more for our benefit, really…so in a way, some people might think you're more mean or subconsciously they're associating you with more pain, perhaps. Because of the fact that you're getting them to move, when they don't need to if it was in a CR environment, you would perhaps do it slightly differently. Recently I had a lady, and she was quite old and we had a lot of stuff to do. And she couldn't turn, and things like that. In which case, with the way the system works in that room, it was restricted for her. If she'd gone to the CR room, maybe perhaps she would have had a better patient experience… she would have spent less time unfortunately, in the CR room.*

Firstly this suggests that the single use of two 43 x 43 cm detectors in an X-ray environment can impact on the delivery of patient care radiographers provide in comparison to other environments (site A) whereby CR and DR can be used interchangeably. Secondly by undertaking radiological examinations using two tethered digital detectors highlights the complex needs of patients thus causing further discomfort. Participants at site C reported specific hindrances effecting the patients' experiences, including 'skyline knees' whereby patients were requested to hold the 'heavy' detector as participants failed to demonstrate an alternate positioning method to illustrate the anatomy:

Helen: *"With the skyline knees, getting people to hold something that's really heavy because you don't know how else to do it with that equipment. That's not good really. It's putting the needs of the room before the patient's needs, just to try and get the image. I think people might not take too kindly to doing something that's difficult or uncomfortable for them. Which is going to change the way they feel about you and their experience."*

Terry: *"The detector plate in the room is quite bulky. So some views - like skyline knees - if the patient isn't very mobile, skyline knees can be very difficult if you end up having to ask somebody to hold the plate".*

Kirsty: *"With the equipment we have here, I think the bulky floating cassettes really can be a problem. The skyline knees - we've had to think of different ways of doing things, so that people don't have to clutch onto the great big films. And sometimes you just can't use it.*

This suggests that radiographers using advancing technology may be failing to adapt and accommodate patients during specific radiographic projections, thus affecting the patients' experiences. It also suggests that radiographers may require additional training and education due to a lack of knowledge in 'how to better' acquire an image of diagnostic quality using DR in order to prevent added discomfort to patients. Thus whilst the DR environment may illustrate concerns for radiographers and patients alike, the assumption that patients can tolerate specific examinations by 'shoehorning' them into radiographic positions highlights that the 'most appropriate' methods to obtain a diagnostic image with DR may not be fulfilled. Radiographers only receive a brief X-ray request form with clinical information justifying the radiological examination alone; thus with limited information about their patients radiographers do not receive information regarding the patients' mobility or mental state. Other healthcare professionals use 'history-taking' to formulate a patient's diagnosis or determine what further tests might be required to achieve a definitive diagnosis (Roter and Hall, 2006). In this PhD research radiographers assess a patient's mobility or condition upon entering the X-ray room and thus decide the appropriate methods of obtaining an image of diagnostic quality 'on the spot', as acknowledged by Rosemary:

Rosemary: *You have to assess it - as soon as the patient gets into the room, you have to assess what your plan is.*

The implications for assessing patients in the X-ray room were highlighted by participants at site C as X-ray examinations were on occasions abandoned because the fix-detector technology failed to accommodate patients in wheelchairs or could not be tolerated by patients.

Abigail: *We've had patients in where they're fixed in their position, and we've got them onto the table, and it's just been impossible to do it. I can't remember exactly what it was for now, but it had to go round to CR because we just couldn't do it. The detector was too heavy for anyone to hold… they wouldn't have been diagnostic. They wouldn't have been anything. So we did have to go back to CR because it was just impossible.*

Victoria: *There was a really difficult patient - she couldn't move at all - really elderly. But it was a humerus… In one of those wheelchairs where you can't take the back down - the handles wouldn't move, so you couldn't get the cassette there. They had to be taken to CR so you could use the equipment to position around them.*

Geoff: *If I had a patient in the DR room and I can't X-ray the patient for whatever reason - probably because the detector can't go on the trolley or the patient can't handle the detector because it's heavy or something like that - then I have to take them across to CR and do it in there.*

The data shows that radiographers may require additional support using 'fixed detector' technology in adapting radiographic techniques. It highlights the 'battles' radiographers and patients may experience in a sole tethered DR environment strengthening the concept (as at site A) that CR and DR should be combined where DR lacks flexibility to obtain images of diagnostic quality.

To summarise, the fieldwork shows that the introduction of advancing technologies can individually affect general radiographic practice, which arguably hinders patient care. Common advantages towards patient care include the ability to repeat X-ray exposures without leaving the patient, whereas common disadvantages related to 'shoehorning' patients whereby radiographers become 'technologically-focused' to get the 'best image possible' and not the 'optimum image required'. Radiographers using fixed detector technology may benefit ascertaining the patients history, such as mobility and suspected pathology prior to entering the X-ray room. The ability to select CR or DR depending on the patient's condition at site A was not available for radiographers at site C and thus lacked the flexibility to move around the patient forcing the patient to move on behalf of radiographers. Participants felt this placed the needs of the room before the needs of the patient resulting in an abandonment of X-ray examinations due to additional distress and discomfort among patients.

6.6. Conclusion

To conclude this chapter has illustrated that while DR can facilitate clinical workflow, patient care and minimise patient discomfort, there is a danger that contemporary radiographic practice is under increasing pressures within the NHS. Such pressures are impacting on the radiographers' ability to adequately review X-ray images using DR, thus placing pressures on the radiographers' to provide a 'red dot'. In addition it could be argued that general imaging is mimicked as an industrial environment rather than a caring environment where radiographers feel increasingly distant from their patients regarding clinical practice as a 'sausage factory' due to the workload and in keeping with lowering patient waiting times. Data from participants reported that this impacted on the delivery of optimum person-centred care as radiographers were reported to 'hurry' and 'rush' their patients allowing radiographers to go into 'autopilot', encouraging radiation errors, technical errors and near misses. The introduction of advanced technologies in general radiography led to radiographers becoming increasingly 'technology-focused', 'shoehorning' patients into radiographic positions which radiographers suggested could hinder their patients experiences and care. For those radiographers working with DR at site C the lack of flexibility 'placed the needs of the room before the needs of the patient' and resulted in numerous abandoned X-ray examinations, which increased waiting times and adding to additional distress and discomfort to individual patients.

Chapter Seven: Radiography Observed: Optimising ionising radiation

7.1. Introduction

This chapter explores contemporary dose optimising methods using digital radiography (DR) within the general imaging environment. While general radiographic (and fluoroscopic) examinations approximately account for 19% of the collective dose, they constitute up to 90% of radiological examinations undertaken in the clinical environment (HPA, 2010). In diagnostic radiography the 'radiographic technique' employed is used to obtain an image of diagnostic quality whilst ensuring that radiation doses arising from the exposure are kept 'as low as reasonably practicable' (ALARP) (IR(ME)R, 2000). The 'diagnostic image' should demonstrate the anatomy under consideration, correct positioning, centering of the X-ray beam and appropriate choice of exposure technique (Bontrager, 2014). In support protective tools and avoiding repeats are actions that radiographers control in the clinical environment (Jones *et al,* 2011). These concepts remain central tenets to a radiographers practice but as identifed in chapter two 'dose optimisation' in contemporary radiography required revisiting. The focus of this chapter will discuss the application of radiographic techniques and dose and image optimisation methods using DR. In addition, radiography as an 'art and science' will be discussed in the context of potential pitfalls within the DR environment and current application of lead protection.

7.2. 'Cranking up'; 'whacking up' and 'opening up': Dose creep in action

Due to the properties of ionising radiation, its use in medicine aims to be minimised limiting the probability of stochastic effects and the occurrence of deterministic effects. The three principles; justification, optimisation and dose limits ensure that radiological doses arising in medicine are kept to a minimum because although it is of great value in medicine it remains the largest artificial source of ionising radiation to the human race (ICRP, 1991; Graham and Cloke, 2006; ICRP, 2007). All radiological exposures require justification in the United Kingdom (UK), providing information to aid the patients' management or prognosis in order to outweigh potential detriments of the radiological exposure (IR(ME)R, 2000). These practices were commonly observed at all research sites in this study suggesting that sound justification of radiological examinations are undertaken in order for the X-ray exposure to benefit the patient:

Observation(s): *Patients referred for an X-ray examination would often discuss their mechanism and site of injury with the X-ray operator. On occasions X-ray exams offering no net benefit to the patient were not justified by practitioners. These included requests of incorrect body parts, comparison views and specific pathology that would not be detected using ionising radiation. These requests would not be performed in accordance with IR(ME)R. Thus radiographers prevented radiological exposures not benefiting the patient and the clinical question posed by the referring clinician.*

Following sound justification, two elements facilitate dose optimisation in the clinical environment; the manufacture design and X-ray operator use (Graham and Cloke, 2003). The day-to-day operation of equipment by X-ray operators should ensure that radiation arising is optimised whilst maintaining sound image quality. Geoff and Harold from sites A and C concur expressing that the optimisation of radiation is essential in their day-to-day clinical practices and that a lack of recognition is arguably a lack of patient care:

Geoff: *The dose has to come to your foremind [sic] every time you do an X-ray. If you don't think about doses, you don't think a lot of patients [sic].*

Harold: *Well, yes. The phrase "photon monkey" came up at one point - it was bandied about in A&E by some of the nurses. But I don't think it's applicable, purely because as radiographers we've been trained to protect the patient from radiation. We're the last stand - the last point of protection for the patient. And that part of our role needs to be taken seriously.*

Thus while radiographers are 'the last stand – the last point of protection' the delivery of radiographic techniques do differ from one hospital environment to another (Brennan and Johnston, 2002; Rainford *et al,* 2007; McEntee and Kinsella, 2010). This was observed across all sites:

Observations: *Throughout the observations the variations in radiographic techniques were apparent. This was supported by different 'set-ups' with pre-programmed techniques on the DR consoles, for example performing an AP shoulder examination on a central chamber was observed at site B in contrast to a manual exposure at site A. Similarly chest X-rays within Trust one were performed differently, at site D the use of high kVp* *techniques were used with lower kVp techniques used at site A. This observation suggested that acquiring an image of diagnostic quality varies within the radiographic environment.*

Radiographic techniques vary, yet radiographers are responsible for radiation safety during all radiographic procedures and aim to fulfill this obligation by adhering to legislation (IR(ME)R, 2000). The Health Protection Agency (HPA) (2011) reported a wide range (a factor of 10 for some procedures) in mean DAP (dose area product) values from one hospital to another. Several reasons may account for this, including differences in patient groups, varying techniques, different complexity of procedures and different equipment quality (Honey and Hogg, 2012). This empirical research provides an additional insight into factors that can impact on increases in DAP and the known phenomena 'dose creep' as reported in chapter two. In this study the independent variables commonly altered for 'small body parts' 'wrist' and 'hand' were source to image distance (SID) and collimation, demonstrated in appendix twelve (p.323-326). The observations revealed that whilst most radiographic examinations are accepted to be carried out at a SID of 100cm providing acceptable focus-to-skin distance, geometric unsharpness and preventing unnecessary thermal stress on the X-ray tube (Whitley *et al,* 2005) the SID did not observably remain constant amongst numerous operators within the clinical environment:

Observations: *A variation in SID was observed amongst various radiological examinations when the X-ray tube did not need to be 'locked' into position. As a result the SID varied amongst X-ray operators with distances varying between X-ray operators, i.e. 77cm to 120cm with little attention applied to the exposure factors, this suggested that operators do not confirm to strict SID rules during certain examinations within the clinical environment.*

The increase and decreases of SID can impact dose delivery to patients (Graham and Cloke, 2006) and because this was a common variation observed with selected examinations this was tested in the DR environment. Findings from X-ray experiments in chapter four strongly suggest that increases in SID strongly predict ($p < 0.001$) reductions to DAP on hand and wrist phantoms at sites A and C. Further, it strongly predicted ($p < 0.001$) increases to DAP following decreasing values of SID. This supports the argument that SID can impact on dose and highlights that a radiographers lack of awareness of SID can increase radiation doses to patients in the general radiography environment.

The collimator attachment to the X-ray tube emits visible light for the operator to localise and identify the direction of X-rays upon exposure. It is generally controlled by two lead shutters mounted within the device at different levels allowing operators the ability to 'collimate' the light box on the X-ray tube thus allowing operators to define the size and shape of the radiographic beam. Once the light source has been centred over the body part of interest the operator may vary the size of the radiation field to a specific interest of the patients' anatomy. Upon exposure the collimation size emits X-ray photons, which are primarily projected towards the body part and the image receptor. The importance of 'strict collimation' in diagnostic radiography can enhance radiographic image contrast (Jeffery, 1997) and reduce dose to the irradiated area (DAP) while limiting radiation scatter to other radiosensitive organs (Powys *et al,* 2012; Carlton and Adler, 2013). Studies have identified 'over-collimation' by observing images on the picture archiving and communication system (PACS) (Uffman and Schaefer-Prokop, 2009; Titley and Cosson, 2013) with specific interest to the clavicle (McEntee and Kinsella, 2010) and lumbar spine (Zetterberg and Espeland, 2011; Titley and Cosson, 2013). Thus whilst research has highlighted that 'collimation may be inefficient' (Titley and Cosson, 2013:5) little research has explored the radiographers' attitudes and behaviours of collimation within the clinical environment. This was important to explore because upon observing radiographic practice radiographers often 'cropped' or 'shuttered' the X-ray image 'post exposure' masking unnecessary collimation, arguably hiding improper radiographic techniques:

Observations: *The ability to 'crop' the X-ray image post exposure was observed during numerous radiographic examinations at all research sites. The frequency of cropping depended on the individual operators, some would crop an image by 1cm or others would crop more than 5cm. This tool provided operators the ability to produce an image which 'looked radiographically sound' although the radiation dose to the patient would have remained the same due to the area exposed.*

Radiographers were observed cropping radiographic images using DR. The data collated (appendix twelve p.323-326) demonstrated unnecessary over-collimation in relation to the radiographic examinations undertaken. Some radiographers in this PhD study maintained that 'cropping' the radiographic image was an indication of 'personal gain' and highlighted its 'dangers' facilitating 'poor practices', as discussed by radiographers:

Harold: *I tend not to do it, because I think - particularly in paediatric cases and possible NAI cases - it's dangerous, actually. And also it's not unheard of, that when you X-ray one part of the body, you see problems with another that even the radiographer didn't spot. I think it's dangerous - I don't think we should be doing it. And also I think as I say, in a sort of backwards logic if you allow it to any great extent, it does reduce people's ability to centre and collimate properly.*

James: *Firstly, I don't really follow the cropping. Because when I was training here, they had bad things to say about people who do that. So we don't really practise that. I think it's important to practise proper collimation - that's basic radiography. Again, just to make it look good. Make them look good as well. Personal [reasons]. It's not really going to affect the patient whether you crop it or not - it's not really for the patient's benefit. What's the point? It's for personal gain.*

Geoff: *It's down to poor practice, isn't it? Because if you do your radiography well, you know your positioning, you do your collimation right - why should you do the cropping? You understand? So it's down to poor practice. Nothing more than that.*

In contrast to the views above some radiographers at sites A and C admitted the ease of becoming 'lazy' and 'relaxed' about their collimation using DR knowing that the image could be 'cropped', hiding improper collimation. Additionally, participants felt that with DR they could 'open it out a bit more' or 'leave it a bit wide' ensuring they would get the image on and 'crop it afterwards' whereas with CR radiographers considered collimation more important because the ability to 'crop' was not available to the operator:

Michael: *It's easy to open it out... When you're doing something on CR, you do think suddenly "Ooh, I better not open it out too wide because I can't collimate on the CR and whatever I take is going to go through." Whereas you don't think that when you're on DR - the thought's not there.*

Rosemary: *The amount of times you think "Oh God, I've clipped a little bit off!" So you tend to leave it a little bit wide and you think "Oh, I'll just crop it afterwards." Which is not great - you know it's more radiation… definitely more radiation [laughs], but it's less radiation than doing it again.*

Emile: *Maybe speaking for myself, you become a bit relaxed about your collimation. Because you know you've got that back-up thing. It's subconscious - you just sort of think, "Oh, I'll crop it".*

Sharon: *But with CR you're more aware of it, even to the point of putting lead on to reduce scatter. But with DR you're not. It makes it too easy really, doesn't it? If you have poor collimation on CR it won't let you get away with it. Because cassettes are so sensitive - they're probably more sensitive than the old film. But with digital, you can be sloppy again. You don't have to collimate right.*

This data highlights that current software tools associated with advancing technologies can hinder the delivery of optimum ionising radiation during general radiography, which can impact on image quality for patients. The ability to 'open it up' and 'crop it later' suggests that current radiographic practices are 'hidden' as poor techniques can be 'hidden from view' and sent for reporting. The acknowledgement to 'over-collimate' and use the 'cropping' tool within the clinical environment suggests suboptimum use of ionising radiation. This suboptimum use is supported by findings from the experiments discussed in chapter four. The experiments demonstrated a strong prediction that increasing collimation significantly ($p < 0.001$) increased DAP to an anthropomorphic phantom throughout the X-ray experiments. This contribution from the experimental data supports the view that radiographers 'opening up the collimation' and 'cropping it afterwards' are not conforming to legislative practices ensuring that does are kept 'as low as reasonably practicable'. It also strengthens the argument that this is increasing DAP to patients who receive no added benefit.

It would appear that patients are unknowingly being exposed to unnecessary levels of ionising radiation, which could be prevented. Not only is this a diminishment in providing optimal healthcare it arguably increases a stochastic risk. The ability to hide improper collimation through 'cropping' was suggested by participants to prevent 'professional embarrassment' of improper collimation used by radiographers within the DR environment:

Emile: *Yes. "Or maybe if… sometimes you open, and you walk away and you think "oh, is that enough? I'll just open it up a bit more." And then you open up a bit more. It comes up, and it's over… you didn't collimate enough, so you end up cropping it. In DR, because you've got that option, I think… yes. You relax a little bit, I think. But in CR, rarely do you… I mean, unless you're maybe doing*

	paediatrics, then sometimes it can be… you want chest, you end up with maybe three quarters of the abdomen. That's when you really wish… But in most cases, you don't really… because you are collimating.
Danny:	*So if you do that exposure, then suddenly you see for example instead of - say - the ankle, you might see up to the knee - then obviously you see that it's kind of an embarrassment to send the whole thing to them. So in this case, maybe the cropping helps.*
Michael:	*You don't want somebody to look at it and go "Bloody hell, look at all that air they've got in there.*

Strudwick (in press) recently concluded that radiographers appear to take ownership of the images they produce, which allows radiographers to be sensitive about their images and seem to take negative judgments' personally. This PhD study supports this assertion highlighting that while radiographers are consciously aware of their radiographic techniques, radiographers may use cropping in fear of being 'picked out' for inappropriate techniques thus resulting in the use of post exposure tools.

It is important for radiographers to keep doses in their foremind (Graham and Cloke, 2007). Radiographers control radiation exposure by selecting the appropriate kilovoltage (kVp), milliamperage (mA) and exposure time (s). These selections are often subjective, based on the region under examination, its thickness, density, pathology and whether a grid is inserted or not. However on observation the adjustments of kVp and mA/s were often altered depending on individual operators:

Observation:	*The adjustment of kVp and mA/s was observed by some radiographers, however others failed to adjust the exposure settings and relied solely on the 'pre-set' exposures for varying patients, including children.*

Participants at sites A and C acknowledged the importance of 'adjusting' their radiographic exposures in order to keep radiation dose to a minimum, thus suggesting that some radiographers holistically examine patients in attempts to keep radiation doses optimum:

Michael:	*I try to keep the mAs down as much as I can really… I feel that you can bring the kV up a bit, take a bit of the mAs off with DR.*

Geoff: *But with DR, it's so sensitive that you would tend to alter the kV more than the mAs. And that improves image quality as much as possible.*

Rosemary: *But yes, you obviously adapt it when you need to for either children or for things that need a bit more - for a bigger gentleman, say.*

Kirsty: *I'd adjust for children, a bariatric patient, or a really, really petite patient - patients who are really, really skinny.*

Elizabeth: *Obviously you adjust the exposure factors depending on the size and weight/mass of the patient. You do an image on one patient and then you learn from that how you could have adapted what you've done to make your next one that little bit better. Rather than being told "actually, if you use high kVs or whatever, then this reduces dose.*

The fieldwork showed that some radiographers aim to conform to the ALARP principle using advancing technology, yet 'dose creep' has been reported with advancing technology (Carter and Veale, 2010) suggesting an alternate in radiographic practices. The phenomena 'dose creep' was important to explore in this PhD research. The variation and application of radiographic techniques with advancing technologies was essential to uncover because the avoidance of unnecessary exposure remains central to a radiographer's practice and care delivered to patients, grounded in UK legislation:

> *"A health care professional who is entitled in accordance with the employer's procedures to take responsibility for an individual medical exposure".*
>
> (IR(ME)R, 2000:2)

It is generally accepted that radiographers are responsible for individual exposures in their clinical environments, but it is arguably not being performed optimally. The report 'Managing Patient Dose in Digital Radiology' (ICRP, 2004) was devised in an effort to educate operators on dose issues when imaging patients. Similarly clinical environments provide 'technique charts' to operators suggesting typical exposure factors (kVp, mAs and SID) for specific examinations, yet participants at sites A and C acknowledged that because the image quality was sound it encouraged them to unalter the 'pre-set' exposure on the DR console regardless of patients size or stature:

Bernard:	*So I was told just to use the pre-set, and not actually fiddle with it.*
James:	*So far I haven't actually adjusted any exposure factors, because compared to CR they're pretty low on exposure. So I think it's a good… I think they're pretty accurate, because I haven't had any problems with them.*
Helen:	*We tend not to change them too much in that room. No - I think we just tend to go with what's there. I've never had a problem with image quality or anything like that. Really, we should be a bit more careful with paediatrics - there are paediatric settings on there.*
Victoria:	*I suppose I don't change the exposures as much as I do in CR. I think because it is quite good image quality, and it's a lower dose as well. So I suppose I sort of trust it more in that way.*
Abigail:	*I know you can go up and down for small children and that, but unless it's a baby or something, I don't change them. I generally just leave them if it's just a child.*

Seeram *et al* (2013) argue that the selection of the most appropriate exposure factors is one of the fundamental options for implementing the ALARP principle. The data above shows that some radiographers may not manipulate exposures and thus fail to use subjective knowledge to inform their radiological exposures, arguably failing to conform to the ALARP principle. This PhD research highlights that by using pre-set exposures alone operators may unknowingly be under or over exposing their patients as pre-set exposures are often based on 'a medium adult' and thus not appropriate for larger or smaller patients. DR can reportedly overexpose a patient up to 500% (McConnell, 2011) providing the operator with a 'diagnostic image' compensating for the wrong settings (IAEA 2010), thus failure to reduce exposures for paediatric and infant patients amongst radiographers suggests that a 'higher than necessary dose' may be delivered. Uffmann and Schaefer-Prokop (2009) support this argument suggesting that dose increases due to inappropriate techniques may be unnoticed by practitioners in the digital environment, which this PhD thesis highlights. Paediatric and infant patients are known to be more sensitive to ionising radiation due to the increase in dividing cells (Hall and Giaccia, 2006) however radiographers may not be appropriately selecting the correct parameters because the image is objectively diagnostic. Radiographers at sites A and C acknowledged the ability to 'whack', 'crank', and 'bump' up their X-ray exposures while still being able to produce a diagnostic image:

Helen:	*Yes, but the important thing is that you can achieve the same image by whacking the exposure factors up.*
Harold:	*The one drawback of DR (and CR to an extent) is that you can basically bump up the exposure factors and if anything, it will improve the image, not make it worse.*
Bernard:	*The fact that you've got quite a large latitude in exposure factors - the adjustable nature of the images. It's the same as CR in that respect. Of course, there's always the danger of a certain laziness or a "I'll make sure this image will come out, by cranking up the exposure a bit.*
Terry:	*Particularly if it's busy and you're under pressure, then I think there is a tendency where you think "Right, if I set this to 1.2 mAs, that might be a bit under-exposed. If I set it at 2 mAs, it'll definitely be there.*

It is a radiographers responsibility to ensure that doses are kept to a minimum, however this study highlights that radiographers may be knowingly overexposing their patients ensuring they 'get the image first time around' thus avoiding a repeat. Terry suggests that 'time pressures' limit his evaluation of sound exposure selection and that by increasing it will reduce the possibility of having to do another exposure. This demonstrates a reduction in autonomy; moreover it suggests that operators are in danger of becoming 'lazy' within the DR environment due to technological advances. From the evidence it could be argued that the introduction of new technology can hinder radiographers professionally in keeping doses ALARP, thus increasing doses to patients. It is suggested that a 'cultural shift' may be occurring within general radiography environments thus caution should be taken from these findings as in the last year radiographers have been suspended from the HCPC register failing to demonstrate sound 'appropriate levels of exposure', 'radiographic technique' (HCPC, 2013b:1), 'not accurately making assessments of centering points and bony landmarks' and 'not making accurate assessments of collimation and Focus Film Distance' (HCPC, 2013c:1). This further highlights the importance of quality assurance in the DR environment promoting good practices supported by sound training and education. In other disciplines Davis *et al* (2005) examined dental practices and the inappropriate use of ionising radiation revealing that specific recommended dose reducing techniques such as sound collimation were not universally employed (ibid). Similarly in this PhD study some radiographers were not employing appropriate dose optimising techniques and although radiographers aim to optimise radiation operators may deliberately overexpose a patient, which is not only unacceptable but unethical clinical practice (Sherer *et al,* 2006).

This section has highlighted 'dose creep in action'. While it is generally reported that DR can lower radiation dose to patients in the clinical environment its uses and application in practice arguably remain problematic. Honey and Hogg (2012) identify the lack of literature surrounding 'dose creep' within the clinical environment, however this PhD research has provide key insights into the attitudes and feelings that may facilitate 'dose creep'. Firstly radiographers acknowledge the ability to 'open out' the collimation and 'crop' afterwards 'masking' improper collimation techniques, secondly radiographers recognised that they could 'bump up' their exposures to ensure the image is acquired first time.

7.3. Art and Science: The impact of digital radiography

In diagnostic radiography professionals use scientific knowledge to produce X-ray images. The previous section highlighted the application of 'scientific knowledge' and the dangers of using it sub-optimally. Carter and Veale (2010) claim that technological advances place radiological science among the most dynamic, expanding and high-demanding fields in medicine. Groover (1931:1) claimed that diagnostic radiography is both an 'art and science'; art because it required a degree of technical accuracy and science because it reached out into every field of medical knowledge. The association that radiography is an 'art and science' remains generally accepted for contemporary radiographic practices (BCTC, 2014:1). Inglis and Hughson (2005:17) maintain that the word 'art' is commonly taken to refer to a set of things that contain certain types of 'paintings, sculptures, books, theatrical and music performances'. Carlton and Adler (2013:227) regard radiography as an 'art form' because 'innovative adaptions of routine procedures should be considered technical artistry', such as 'reverse angles to produce a diagnostic quality modified image of a clavicle on a trauma patient who cannot be moved due to thoracic injuries'. This view suggests that the 'art form' associated with radiography is the 'practical innovation' of X-ray operators, however this PhD thesis suggests that the visual representation of radiographic images may be central to the 'art' of radiographic practice, which can impact dose optimisation in the clinical environment.

X-rays have been used to investigate and produce 'artwork' with demonstrations of flowers (Meyers, 2009) and everyday objects (Wright, 2011). Inglis and Hughson (2005:1) assert that 'looking at art is an excellent way of looking at a culture' because the sociology of art can investigate all the processes by which art is produced (Wolff, 1993; Inglis and Hughson, 2005) thus could provide further insights into the dose and image optimisation techniques used in radiography. Recommendations published by the Commission for European Communities (CEC) provide minimum parameters to achieve optimum image quality in adult (CEC, 1996) and paediatric patients (CEC, 1996). The production of a 'sound radiographic image' was observed in the clinical environment whereby radiographers 'crop' the image, masking improper collimation:

Observation: *Radiographers would use the 'cropping' tool post exposure on DR systems to hide over-collimated radiographs enabling them to 'tidy up' their images. Through informal discussions this resulted in the radiographers' recognition of practicing too much collimation to produce an image of diagnostic quality.*

This is supported by research participants at sites A and C whereby the use of the 'cropping' function facilitated operators with 'neat', 'tidy', 'pretty' pieces of art:

Sebastian: *We use it a lot to shutter the image. And there's no problem with it, but we enjoy it. It makes for a very tidy, good picture.*

Eric: *Well, because that's how they're meant to look. There's no need - you just crop it down. You just make it look pretty.*

Sebastian: *Sometimes you over-collimate it, and then you do the shutters to make it very sharp and good and tidy.*

Annabelle: *Because radiographers want their images to look luuuurvly!*

Fred: *Well, the main reason is to make the image look pretty. You want it looking neat and tidy.*

Here we see that radiographers identify their radiographs as 'art forms' through manipulating 'suitability'. Ingis and Hughson (2005:17) claim that 'what counts as 'art' in general, let alone as 'good art' is historically contingent and rooted in the life conditions of that group to which the people making classifications belong'. This arguably resonates with the views of participants in this PhD study whereby 'cropping' facilitated the aesthetic appearance of 'the textbook image' in fear of conforming to poor practices. Radiographers are individually responsible for producing images of diagnostic quality, but participants suggest that 'cropping' may help produce images that are 'socially acceptable' in the clinical environment supporting Wolffs (1993:61) claim that 'art forms' are generally produced by socially located individuals or groups. This demonstrates that radiographers may be increasingly conscious of 'image acceptance' amongst their peers, thus encouraging 'cropping' of radiographs post exposure. Importantly, there is a danger associated with the aesthetic appearance of X-ray images, whereby radiographers may forget the 'radiographic science' with patients receiving higher doses than necessary as demonstrated above. Helen who uses 'cropping' acknowledges this danger in her clinical practices acknowledging the increases in dose through improper collimation:

Helen: *If something I've done isn't very pretty or perfect, then I will crop it. Because you can - that's the only reason. You can crop your images, that kind of thing, so you might be inclined not to be as careful with your collimation. So any benefit you're getting with reducing dose you might over-collimate, and give them more dose anyway.*

It is argued that X-ray operators tend to favour excellent image quality thus increasing the radiation dose to patients, facilitating 'dose creep' (Willis, 2004; Uffmann and Schaefer-Prokop, 2009; Cohen, *et al* 2011; Seibert and Morin, 2011; Gibson and Davidson, 2012; Seeram *et al,* 2013). Additionally, the PhD research challenges the currently held view that the 'art' of diagnostic radiography is associated with the 'practical innovation' of X-ray operators (Carlton and Adler, 2013). Inglis and Hughson (2005:17) claim that art can be 'seen to be unique individual expressions of his/her temperament and personality', thus because X-ray operators tend to favour aesthetically sound images, this facilitates the use of 'masking' improper collimation, hidden from peers and other healthcare professionals.

The radiograph is formed when X-rays pass through the patient and are attenuated producing a 'silhouette' of the body part under investigation. Exposures using film screen (FS) demonstrated under or over exposed radiographs that had received too much or too little radiation. Overexposed radiographs using DR do not appear 'black' as previously demonstrated by FS and are adjusted by the computer and brought into the optimal range (Carlton and Adler, 2013). Image quality has historically been difficult to define due to the subjectivity held by the radiographer, however this may present further challenges with DR and may hinder the 'science' of radiographic practice. The benefits associated with DR include higher sensitivity allowing for better image quality and the ability to represent both small and large image structures (Huysmans *et al,* 1997; Hintze *et al,* 2002). In support Sebastian and Sharon identified the scientific advantages associated with DR technology providing 'high' quality images and dose reduction in the clinical environment:

Sebastian: *I think the DR system is having a lot of effect on what we're achieving at the end of the day. I think the diagnosis of the images that we eventually produce is getting very [high] quality [sic].*

Sharon: *I think it's been a pretty good system to be honest. And I think for dose reduction, I think it's helped quite a lot. It obviously provides very good images anyway - quality images as opposed to CR.*

The exposure index (EI) is the value produced following an X-ray exposure using DR and is based on the emerging photons hitting the digital detector that forms a reliable tool assessing whether the radiographic technique employed was appropriate (Schaefer-Prokop *et al,* 2008; Seibert and Morin, 2011). It is possible for operators to overexpose a patient and still produce an image of diagnostic quality; the EI quantifies the radiographic technique providing 'the key' to controlling exposure levels in the clinical environment (Seibert *et al,* 1996; Seibert and Morin, 2011). It could be argued that the EI is central to the 'radiographic science' historically associated with diagnostic radiography. In practice the EI was intermittently referenced by radiographers:

Observation: *The EI is intermittently referred to be radiographers. Some radiographers appeared to assess their image quality on the radiographic appearance alone, without recognition of the EI.*

Some radiographers at sites A and C found the EI useful upon reflecting on their radiographic technique, providing them a tool to ascertain an under or overexposed image:

Margaret: *Yes. So you can recognise an under-exposed film by looking at it, but for an over-exposed film, you've got to know what ball park your exposure index should be in.*

Sebastian: *On an average patient, most of them will put out exposures that are within the quoted exposure index range.*

Mick: *I think usually it's quite reliable in that DR room. It's hard in a way, because obviously it goes back to how I was taught and that. I'm much more accustomed to the Kodak and the Fuji exposure indexes for the CR units. You can look at it and say "That compares to what I've seen in the past". Because when I had my training, I don't remember the applications specialist saying "This is what it should be". In terms of consistency, it seems fairly consistent.*

This suggests that the EI provides valued feedback for some radiographers regarding the radiographic technique employed in the clinical environment. Uffmann *et al* (2008) found that X-ray operators understood the physical aspects of digital detectors, the EI as a control mechanism and other such technical parameters as methods of controlling 'dose creep', when attempting to optimise the imaging system. In contrast academics argue that further staff training and a better understanding is still required amongst X-ray operators regarding the EI to keep 'exposure creep' down (Warren-Forward *et al,* 2007; Gibson and Davidson, 2011). In the United Kingdom (UK) little research has been undertaken exploring the radiographers' attitudes and use of the EI in the clinical environment (Talaharla, 2013). This PhD study highlights that some participants from sites A and C only refer to the EI if the image produced is not 'observably' diagnostic on the DR console. Only then would they refer to the EI to assess the diagnostic quality of the image:

Bernard: *I tell you when I do use it - if the image doesn't look that good, then I'll look at it.*

Geoff: *The exposure index and that comes into play - if you did an X-ray at first and it wasn't a diagnostic image and then you say "How do I correct it?" you then go and refer to your exposure index and see what it says. And you say "OK, this is how it's going to guide me. It guides me now to make an adjustment and produce a diagnostic [image].*

Annabelle: *Erm, I don't regularly use it. I would probably look at it - to my shame, I would probably look at it when I thought there was a problem with the image, "Oh yes, I'm happy with that", or "Oh crumbs, why has that…?" So no, I don't* *really, apart from if I think "Hang on - this image doesn't look right to me." And then I would have a look.*

Thus some radiographers only reflect on the EI when the digital image is observably underexposed. Because DR can autocorrect an image that has been overexposed by up to a 500% (Carlton and Alder, 2012) the reluctance to reflect on the EI for all radiographic examinations suggests that radiographers may miss overexposures because of the technologies ability to resolve an overexposed image. Geoff, a senior radiographer highlighted this issue stating that '…you can have an absolutely high exposure index, and the image is still good'. As a result he felt he could not rely on the EI:

Geoff: *I don't think I rely on the exposure index a lot. Because sometimes you can have a low exposure index, but the image quality is good. Or you can have an absolutely high exposure index, and the image quality is still good… So the exposure index to me definitely doesn't make any difference.*

This highlights two issues; firstly it suggests that Geoff is unaware of the technologies ability to autocorrect images that have been overexposed, secondly whilst Geoff is believed to have produced 'radiographic art' (the image) of diagnostic quality, his lack of scientific knowledge and understanding of EIs arguably resembles 'false art' as it is likely that patients are being overexposed because of a lack of knowledge and understanding surrounding 'dose creep' in the clinical environment. More specifically senior and junior participants at site C recognised that they do not use the EI in their practice and judge the radiograph on their subjective knowledge alone without referring to the EI, with participants reporting difficulties in locating the EI and being able to decipher it, which may have resolved through proper training, as described below:

Danny: *I don't really go with the exposure index on DR. I do it in CR, because you can see the exposure index. But I never actually pay attention because even with the small exposure, you always have a proper image.*

Emile: *I don't really know… I know somebody showed me that it's within these figures which I don't remember. And I'm not sure they knew what the figure was. It's a range - I think it's got to be green or something? …But it's not enough training - I really can't tell about the index with DR.*

Victoria: *Probably not, actually… Because when I'm using CR, I always look at my exposure index. No. I don't actually [laughs]. I just look at the image and think "Yes, that looks OK." Obviously you look at the dose, but no I don't as much. No, it's true.*

Terry: *I don't, with DR. Again, I'm so unfamiliar with the system, I just look at the image quality. I know what my exposure factors are, I know what the dose is, and what I expect as a dose…I don't think I'd know how to look at the exposure index on that machine.*

Elizabeth: *I have not got a clue where to find the exposure index on a DR system! So I can't answer that question. If it was there, if I knew where it was, then I'd be able to… like with CR I can tell, but with DR I haven't got a clue. No one's ever taught me that. Yes, because there's no technical way of looking at it - I just go on my own experience of what an image should look like.*

It has been reported that the EI has limitations in its reliability including tube potentials, patient size, image processing time, collimation, filtration, patient positioning and AEC, gonadal shielding and prosthesis (Talaharla, 2013). However it is generally accepted that radiation exposures can be managed by applying the EI value in the clinical environment (Kishimoto *et al,* 2011). Participants at site C expressed their lack of use and application of EI values in the clinical environment, thus suggesting that the radiographers 'artwork' (the image) is 'visually assessed' alone. Wolff (1993:31) cites Hadjinicolaou' (1978) view claiming that 'the pleasure involved in viewing a picture is merely the coincidence of the ideology of that picture with that of the viewer'. This claim to perceive paintings as ideological could be transferred into the radiography environment following the findings detailed in this PhD research. Inglis and Hughson (2005:18) assert that 'de-centering' an artist from their artwork can show that 'art' is collectively rather than individually produced. For example by removing the artistic nature/association of the image within the clinical environment, it may provide a better understanding of the collective elements used to produce the visual appearance of the diagnostic image (Ingis and Hughson, 2005). It could be argued that if radiographers 'disassociate' themselves from their 'visual artwork' and 'reflect ideologically' this could facilitate a holistic outlook of the 'radiographic sciences' such as X-ray exposures, SID, and collimation used to produce the image and the EI. The two phantom experiments conducted in this PhD work highlighted that at site 'A' DAP and EI were strongly negatively correlated ($p < 0.001$) demonstrating that the higher the DAP at site 'A' the lower the EI. In contrast, at site ‘C’ the relationship demonstrated that a high DAP in practice would produce a high EI and is strongly positively correlated ($p < 0.001$). This suggests that while participants in this study state their reluctance and lack of awareness of using the EI in the clinical environment, the statistical analysis strongly suggest that radiation doses can provide valued feedback to operators illustrating whether the DAP is ‘too high’ or ‘too low’, thus identify whether too much or too little radiation had been used. Not only does this keep in accordance with the ALARP principle it can provide a valued tool for radiographers who can clinically reflect on radiographic techniques and decide whether a radiation exposure was too high or too low and in future adjust accordingly. Michael and Alex highlight their concerns surrounding the use of the EI at site A whereby its inconsistency on a day-to-day basis made them reluctant to use the EI questioning is ‘reliability’ and ‘user-friendliness’ in the clinical environment:

Alex: *I think one reason I didn’t really take on the idea of the exposure index was that I don’t think it’s really consistent all the time. You can produce a good image sometimes, when the exposure index seems off. So it’s not something I’ve given a lot of attention to. But in general, I don’t think it’s really down to an exact science. Sometimes the exposure reading can be good, and the image is bad visually. So I don’t know, maybe it’s something in the system or the technology itself. But I’ll say that it didn’t match or marry consistently enough for me to see it as reliable.*

Michael: *It’s not a specific set value, is it? And the same with the software on the system - when you do a spine, it’s got to be between 320 and 400. And when you’ve got to do a chest, it’s got to be about 400. And hands are different. Everything’s different…You really need a thing that gives you… “1,000 is the amount you want, 500 is too low and 1,500 is too high.” It’s not very user-friendly in regards to getting people to actually look at their exposures.*

Patiefield (2011) argues that although radiographic equipment provides exposure indices to guide X-ray operators, the companies do not explain its application to radiographic practice. The data from sites A and C in this research suggests that the use of the EI is not consistently employed by radiographers, facilitated by the varying ‘cultural’ implications with lack of knowledge, understanding and application in the clinical environment. The inconsistent application and reflection of the EI questions whether radiography remains a ‘science’ because although the application of radiographic techniques and EI may be problematic, Carter and Veale (2010) assert that the EI does provide a visual clue as to how much radiation was absorbed by the detector identifying an optimal technique. Peters and Brennan (2002:2385) concluded 'although dose levels to the patient have not been directly measured, it is safe to assume that a strong correlation exists between higher exposure indices and higher patient dose'. The argument that radiographic practice requires revisiting to ensure the optimal use of radiographic techniques (Ween *et al,* 2009) is strengthened by this PhD research because without appropriate research and education DR may continue to increase radiation doses to patients (ICRP, 2005). It is important for higher education institutions and clinical practices to collaborate on particular phenomena because this PhD research strongly suggests that the variability in delivering ionising radiation may not be optimum, which Terry acknowledges following a lack in 'understanding' and the requirement of a X-ray department that has a positive reflective culture:

Terry: *I think with anything - if you're trying to maximise your image quality and keep your doses as low as possible, if you haven't got a reasonable understanding of the processes that are going on, how can you hope to adjust those factors to their optimums?" it depends on the culture. In a positive, supportive culture people will look at it and say "look, you're not doing this quite right - perhaps look at your factors there and keep an eye on it.*

In the past diagnostic radiography has been accepted as an 'art and science' because X-ray operators require practical innovation (an artistic nature) and a sound scientific understanding to produce images of diagnostic quality. The 'art and science' of radiographic practice has arguably been separate from one another, yet in contemporary practices this PhD thesis argues that the 'art and science' of producing a diagnostic image may be more interconnected than previously thought. For example, radiographers may mask their images (artwork) to suite the aesthetic requirements of the 'typical text book image', however this 'aesthetic pleasing' impacts on hidden and suboptimum use of collimation in the clinical environment. Thus within a radiographic culture radiographers may need to 'disassociate' themselves from the aesthetic requirements of the image enabling them to 'reflect ideologically' on the X-ray image produced. This could enable radiographers to critically reflect on the important scientific factors used to produce an image of diagnostic quality, thus not accepting it at 'face value'. In the past over and underexposed films appeared too black or too white if too much or too little radiation was delivered, however the introduction of DR suggests that the notion of 'art and science' may be more problematic as radiographers may not fully apply or understand the key 'scientific' concepts within the clinical environment. Lastly, patients remain at the center of healthcare delivery however it could be argued that a failure to reassess the ‘art and science’ of radiographic practice may present professional paradoxes in attempts to keep doses ALARP.

7.4. To ‘Err is Human’: Assessing pitfalls in contemporary radiography

This section will discuss findings from the PhD fieldwork that illustrates alternate errors in diagnostic radiography, attributed to new technology, which can present new challenges to radiographers and managers in the clinical environment. For medicine there is sufficient evidence demonstrating that closing hospitals would do more harm than good to the people they serve and while accidents happen, there is no way to avoid them in their entirety (Kavaler and Speigel, 1997). Historically in medical culture it was believed that mistakes should not be performed and is indicative of personal and professional failure. Messer and Meldrum (2001) argue that this view could lead to overt denials of errors occurring within a healthcare environment. There has been a shift in medical culture that recognises, manages, and learns from errors in the National Health Service (NHS) (Chief Medical Officer, 2000). This research demonstrates an awareness of the potential pitfalls radiographers may face using advanced technologies. Through this awareness the future use of DR can be enhanced, preventing errors that facilitate the radiographers and the enhancement of patient care in the clinical environment. It is generally accepted that mistakes in radiology reporting are part of the human condition (Pinto *et al,* 2012) however errors in medicine have become headline news in recent years with legal action against hospital Trusts and physicians. Malpractice is an increasing problem in all industrialised countries and within all specialties including radiology, thus reducing risks has become central tenets in the NHS because humans are fallible and errors do occur. Errors are generally seen as being shaped and provoked by workplace culture, risk management or lack of resources.

The concept of radiological error is unfortunately reported as a familiar one (Toms, 2010). The common and often cited errors featured in radiological practice are the failures of detecting pathology, leading to misdiagnosis (Berlin, 1996; Cristofaro, 2007). Errors in radiological interpretation have been reported between 3-5% in general radiographic practice (Berlin, 2001), 30-90% for mammography (Berlin, 1999) and the detection of lung cancers (Muhm *et al,* 1983). The aim to reduce these errors is helped using computer-assisted detection (CAD) programs improving operator performance for detection and interpreting radiographs (Toms, 2010). Diagnostic radiology aims for the complete detection of all abnormalities in all imaging examinations, however the traditional view that errors in radiology exist solely with interpretation and the 'failure to diagnose' is not apparent following the introduction of technological advances. In radiotherapy there is increased emphasis working 'towards safer radiotherapy' (British Institute of Radiology *et al,* 2008:1) because of the high dose errors surrounding radiotherapy procedures (Yeung *et al,* 2005). In diagnostic radiography radiation doses are considerably lower in comparison to radiotherapy however any diagnostic exposure that is substantially greater than the intended dose either exceeding the diagnostic reference level or arising as a result of equipment or operator fault should be investigated (ICRP, 1996; IAEA, 2011).

Rushton *et al* (2013) have reported errors in diagnostic radiography concerning the production of dental radiographs concluding that further training was required amongst X-ray operators in order to optimise radiation doses. For general radiographic examinations it has been suggested that DR facilitates radiographic practice and patient care as 'exams are done easier and may result in fewer retakes and a low X-ray dose for your patients' (Philips DR Brochure 2011:3). In addition Murphy (2006:171) cites Freeman's claim that:

> *'The push from technologists who wish to promote technical advance is hard for society to resist, as new applications for these developments are identified continuously.'*

Technological advances can be seen as advantages, benefiting society. Participants at sites A and C concur reporting that DR facilitated their radiographic practice with regards to 'radiographic repeats' whereby patients remain in their radiographic position when a radiograph is reviewed, thus enabling 'fine adjustments' to correct the radiograph if necessary:

Emile: *You can quickly adjust because the patient is probably in the same position… with DR you can actually see as soon as the image comes out: you look at it and you think "Oh, I think I need to adjust my angle." You look at them and you think it's right, but then you look at the radiograph and you think "I think I need more angle" or whatever.*

Victoria: *And you know, if you don't get a great image, it's just so quick to do it again. You don't have to get the patient out and get them back in the room. So as long as it is all running smoothly, it can be quicker.*

Danny: *It used to be if you did a wrist and it was a bit internally rotated or something and you'd have to then go back out to the waiting room and get the person back in. Or they'd be waiting in the room while you were processing it. Whereas with DR it's so easy to go "externally rotated!" and it's there, straight away.*

Margaret: *If you need to do a repeat, the patient's pretty much sitting in the position that you've just previously done it in. So if you're doing an AP ankle, and you just needed to turn it in slightly more, you know what position you were in before, just to adapt it again.*

The advantages above suggest timesaving opportunities for radiographers in the clinical environment whereas CR or FS required radiographers to 'develop' the image in an alternate location, 'decide if a repeat was required and if so take the patient back into the X-ray room for a repeat X-ray'. Thus although 'the ease' of performing radiographic exams has become easier and appears to facilitate the radiographers examinations, a common observation was the application of DR software enhancing image quality preventing radiological repeats:

Observation: *When a radiographer produced a radiograph of inferior quality, he/she may alter the imaging brightness/contrast and deem the image diagnostically acceptable answering the clinical query.*

Participants support this observation from sites A and C acknowledging that DR often reduced their X-ray repeats due to software advances enabling radiographers to 'recover' underexposed images by manipulating the 'contrast and brightness' of the digital image:

Mick: *DR's got a lot more sort of recovery in it. The system can create a better image from when it's under-exposed. So sometimes it can be amber, but it's still a nice image which isn't worth repeating.*

Victoria: *Obviously it saves you re-X-raying them and re-irradiating them. If you want to just slightly change the image. That's the advantage.*

Margaret: *The reason why they're adjusting all the contrast and whatever is just to get a diagnostic image. If the image is diagnostic enough, then there's no point in doing all that.*

This helps explain Sheung-ling Lau *et al* (2004) findings reporting that a higher percentage of repeats occurred with film-screen in comparison to digital technologies, with the majority being positioning errors, not radiation exposure. Whilst software advances with DR may facilitate a reduction of repeat exposures amongst radiographers, Rosemary and Elizabeth recognised that using the tool to adjust the brightness and contrast of an image allowed them to become 'lazy' failing to select the appropriate radiation required and failing to correctly assess the EI:

Rosemary: *The disadvantage is that you don't necessarily look at the exposure index or think about your exposures enough because you think "well, I can just manipulate it afterwards, so it will be fine." So [laughs].*

Elizabeth: *You become lazy and you sort of rely on that tool, rather than actually using the right radiation in the first place to get as good an image as you can.*

This suggests that the ability to 'rely' and 'manipulate' the image using enhancing tools may prevent radiographers from following the basic principles to produce an image of diagnostic quality. Berkhout *et al* (2003) study identified that the installation of digital detectors in dental practices increased the amount of 'repeats' dentists performed due to the ease of acquiring the digital image (Berkhout *et al,* 2003). In diagnostic radiography repeating radiological examinations is often prevented following the correct use of radiographic projection, technique, collimation and positioning, all of which occur under direct control of the radiographer, something that Elizabeth felt was mimicked in her radiographic practices, regardless of technology:

Elizabeth: *If you're good enough anyway, you shouldn't have to do a repeat. I don't think for me… for me, it hasn't increased the amount of repeats that I've done. That's a good thing.*

DR is reported to facilitate a reduction in diagnostic repeats, but Victoria and Abigail acknowledge that the use of DR during their clinical practice may encourage radiological repeats. Victoria suggested that she may perform less repeats in a CR environment aiming to 'get it right first time' whereas with DR, because of speed in which an image can be captured it facilitated a 'hit and miss' approach to image acquisition as the operator could '…just do another if it's not quite right'. Abigail suggests that during her clinical practices she may be inclined to 'just take it (the image) and see what happens' if it doesn't look right due to the ease of repeating radiographs using DR:

Victoria: *Erm, I think it probably is, yes. Sometimes I think - you know, like earlier I was saying it's easy to do a repeat - sometimes I think are we giving more dose because it's so easy to do a repeat. Would you necessarily always do that repeat if it was CR and you had to get the patient back in? I've wondered that before, whether there would be as many repeats. It's still in the same position; you can just slightly adjust and… Also I think maybe with CR, you have to think a little bit more about your exposures, and try to get it right first time. Whereas [with DR] you might think "Well, I can just do another one if it's not quite right.*

Abigail: *I think with DR it's so easy to repeat something. It's so easy to do, and sometimes I've done it myself - where I've repeated something and I think "I don't think I would have repeated that if it was CR." Because you look at it differently and you think "The positioning - if I just turn that a tiny little bit…" and you think "Oh, just do it again." And before you know it, you've done it three times…So I think that DR is increasing the amount of repeats people do. Because I think it's just so easy to so easy to repeat, if you know that something's not quite right, you're so inclined to say "Oh, I'll just take it and see what happens." Whereas with the CR, you're more likely to just try and persevere a little bit more, because you don't want to get… in trouble. [laughs].*

The advances in technology have highlighted a reduction in radiographic examination time due to the fast image acquisition. This study supports the paradigm shift from acquiring an "image as good as possible" to acquiring an "image as good as needed" (Uffmann and Schaefer-Prokop, 2009). Radiographers in this PhD research expressed examples when they would send 'underexposed' radiographs to referring clinicians because it answered the clinical question. Conversely the fieldwork highlighted a potential pitfall for radiographers whereby they use the 'speed' of DR to their advantage failing to deliver the correct radiographic projection by 'seeing what happens' and then 'correcting it afterwards'. Thus radiographers may not appear to be critically evaluating the delivery of correct technique and merely 'hit and hoping' and observing the outcome.

Patient safety plays an important role in healthcare affecting the entire radiological pathway (Pinto *et al,* 2012). Peloschek *et al* (2009) suggested that the wide dissemination of DR had facilitated the clinical environment by producing enhanced images of diagnostic quality, yet this PhD study highlights problematic instances at a local level. A common error observed at site A was the incorrect selection of a digital detector on the DR console, which would deliver a radiation dose to a patient with no image acquired:

Observation: *A radiological dose had been delivered to a patient with no X-ray image. This increase in radiological exposure was due to the incorrect selection of a detector e.g. the 'table' detector was selected, however the patient was imaged on the 'wall detector'. As the 'wall' detector was unselected it was not activated and when the operator exposed the patient, the DAP produced a reading however there was no X-ray image. The patient has received a radiological dose without any benefit."*

This radiation incident observed at site A was a common theme expressed amongst radiographers. Participants acknowledged that during their daily practices this was a 'safety issue' and that the equipment should 'intelligently' know its position in the X-ray room preventing such radiation errors:

Fred: *There's one really annoying thing with the equipment that we use, which is that it will expose when it's not over a detector. Which everyone tends to comment on - it must know where it is in the room, yet it will still let you expose if you're not over the detectors. Sometimes you can have the wrong detector selected, and it will expose and give you no image.*

Michael: *Yes, because you can have the wrong detector selected as well, and end up really messing things up. It should intelligently know which detector it's pointing at. And at least suggest that you select the one that you're actually pointing the tube at. I mean, the point about preventing exposures when you're obviously pointing at the wrong detector - there has to be some technological improvement there, to try and prevent that from happening.*

Sharon: *Because they've got a dual system, so sometimes it'll let you expose even though it's not in the right place. The whole bucky can be in a completely different, random* *place. Its safety measures are backwards - they're actually anti-safety measures…even when you've got it linked up/locked in and it's not in the right place sometimes, it lets you expose. It won't let you know. It'll tell you that everything's OK and that it's happy, because it's all locked in. But it isn't.*

Harold: *No, not really. I mean, the point about preventing exposures when you're obviously pointing at the wrong detector - there has to be some technological improvement there, to try and prevent that from happening.*

Rosemary: *Well, they're radiological hazards, aren't they? And that's a clinical incident that shouldn't really be happening. But it does happen.*

The incidents identified above are radiological hazards occurring within the clinical environment. It shows that patients can receive 'higher than necessary' doses with no added benefit, thus arguably an extension to 'dose creep' within the clinical environment. Mankad *et al* (2009) reported that radiologists had not embraced personal error recording within the clinical environment. Similarly, throughout the observations in this PhD work radiographers were not observed 'error reporting' radiation incidents, later reflected in the researchers field diary:

Field Diary: *Throughout my time 'in the field' at site A I had not observed radiographers reporting the radiological error associated with the digital detectors. This highlighted that radiographers may be reluctant to 'error report' in fear of being blamed, thus such incidents were merely 'forgotten about'.*

Scalliet (2006) maintains that errors and anomalies can remain undetected for long periods. Malpractice is identified when a patient believes that improper medical care has resulted in bodily harm (Carraifella *et al,* 2012). Whilst an additional X-ray exposure could potentially cause harm it could be argued that because X-rays remain undetected to human senses, such errors in radiography are undistinguishable by the patient, thus unreported. Furthermore because radiographers failed to recognise and report this 'anti-safety' measure it arguably remains 'silent malpractice' within contemporary diagnostic radiography with a failure of delivering optimum radiation levels, conforming to the ALARP principle (IR(ME)R 2000).

The placement of anatomical side markers (ASM) in diagnostic radiography has been reportedly used since the beginning of the last century whereby brass ‘L’ and ‘R’ identified the anatomical side of the patient (Williams, 1903). The introduction of advanced technologies allows operators to add ‘digital markers’ representing the patients’ anatomical side post-exposure, yet the SCoR (2014:1) assert that ‘best practice is that ASM should be present in the primary beam for all images’. The importance of correct placement of anatomical markers is that it can cause harm to patients. For example surgeons in Wales removed a patient’s healthy kidney because markers were not place on the X-ray film; the patient later died (Dyer, 2005). Another example involved an infant child whereby a thoracotomy tube was inserted incorrectly in a patient with a pneumothorax. The radiologist could not determine the correct side because no anatomical representation was present (Finnbogason *et al,* 2001). It remains essential to place the correct ASM on radiographs, but in this PhD research radiographers were generally observed placing digital markers on radiographs post exposure at all research sites. An incorrect marker was observed at site A on a radiograph, which later required editing on the picture, archiving and communication system (PACS):

Observation: *Digital markers were used by junior and senior radiographers at all sites. At site B I had observed an operator placing an incorrect marker on an X-ray image, which required intervention from the researcher. I was thanked by the operator for noticing their mistake, moreover the operator had to ‘flip’ the image because the examination was performed on the wrong settings on the DR console thus automatically ‘flipped’ the image. This highlighted that a single incorrect selection made on the DR console could have ramifications for the operator and the patients.*

The importance of placing a marker ‘pre-exposure’ ensures that if an image is ‘flipped’ by the equipment the operator can identify the correct side of the patient. The incorrect selection on a DR console (i.e. anterior posterior examination on a posterior anterior performed projection) could mimic other physical anomalies such as dextrocardia or situs inversus due to the DR program automatically ‘flipping’ the image. Without previous imaging and lack of a lead ASM it would be almost impossible to confirm if a patient had either of these abnormalities or whether the image has been flipped by the technology (Miles, 2013b). Platt and Strudwick (2008) identified a reduction in the use of lead ASM following the introduction of advanced technologies, Taylor and Strudwick (2010) re-examined a wider range of examinations in the general environment correlating post-exposure ASMs on PACS highlighting a lack of ASM with facial bones and AP chest images. Miles (2013a) has investigated reasons why markers were not included in the primary beam, the three most frequent responses were: 'no marker used', 'marker in scatter outside of primary beam' and 'time was of the utmost importance'. Miles (2013b) in a later article concluded that the advancement in technology has declined clinical practice in relation to the application of ASMs. The research participants in this study felt that the digital markers facilitated the 'speed' required by radiographers within the clinical environment, to get the patient 'in and out'. Thus, radiographers felt it minimised cross infection and the incorrect placement of lead ASM over important anatomy, which led to repeat exposures:

Margaret: *I personally - nobody agrees with me - think there is no difference between putting your own marker on, and putting a digital marker on. If you're going to make a mistake, you'll make one.*

Rosemary: *I don't think there's anything wrong with putting one on afterwards. Because of the speed of your work and the high turnover of your work, you can get the wrong marker on the cassette or the DR. And yes, you can put the wrong marker on afterwards as well. I think either/or to be honest - both are equally fallible.*

Michael: *You can choose where you position it after you can see the image - you can make sure it's not over any bone or any other important anatomy. It's less bad for infection control.*

Bernard: *I think you should be able to pass them post-digitally, as long as you're putting your initials on. So I don't know what the problem is with putting the marker on afterwards, as long as your initials are on it. Because you're still saying "yes, that's the left side of the patient"… I'd rather put it on post while still in the room, than get it wrong and have to repeat because the marker is overlaying.*

This adds to previous studies highlighting that radiographers feel that digital markers facilitate their day-to-day clinical practice, which supports why 50% of audited images (n=150) in Miles (2013a) study only had some indication of a lead ASM within the primary beam (Miles 2013a). One radiographer did not see the issue using of digital markers in the clinical environment, as described below:

Margaret: *The only time I would say that you must put markers on - and it doesn't have to be a marker, is when you're doing things like bilateral hands, bilateral feet… Things like that, where you could actually accidentally flip it. If our machinery wasn't set up right – mandibles weren't at one stage - you had to put a marker on. But I don't understand what the fuss is about, quite frankly. Because if I'm going to make a mistake and put a right on a left or a left on a right, I'll do that whether I'm doing it digitally or whether I'm putting the markers on. If I'm in a divvy mood, it's going to happen [laughter]. It makes no difference. It doesn't seem logical to me - to me, it's like a step backwards. It's like going backwards - why are we doing this?*

This narrative suggests that the use of lead markers in a 'digital age' felt like a 'step backward'. The reporting radiographer recognised the possibility of the imaging being 'flipped', yet felt that it is not essential in all radiological examinations. A radiographers' code of professional conduct and ethics (SCoR, 2008) and Standards of Proficiency (HCPC, 2012) identify key provisions for good radiographic practice. Although no legislation exists forcing radiographers to use ASMs, new guidance by the SCoR (2014:1) reaffirms the importance of ASMs asserting that 'markers applied to an image at the post-processing stage should be regarded as a safety net and not as standard practice'. For Fred and Abigail they felt that the placement of ASM in the primary beam was important during their radiographic examinations, but recognised the reluctance to place ASMs:

Fred: *Yes - there's more scope for mistakes in post-exposure markers, obviously. There are implications with not having a marker put into the original image. Again, I think it comes down to laziness as well - laziness and losing markers. Those little plastic markers are quite easy to lose.*

Abigail: *I think it's laziness. Everyone's guilty of it. Sometimes, I think "Oh shit, I haven't put markers on!" But I do try and use mine as much as I can. But I do think it's laziness. A lot of people don't even have them on them.*

The use of digital and lead markers in radiographic practice have been identified in previous studies, however this PhD work highlights that the use of digital markers could be attributed to emerging cultures within individual clinical environments. The correct application of ASMs is a fundamental task in diagnostic radiography, reinforced by recent guidance from SCoR (2014) and literature in radiographic learning (Whitely *et al* 2005; Frank *et al* 2007). Thus although it is generally accepted that correct markers should be placed on every radiograph (Frank *et al,* 2007) failure to do so has led to radiographers being removed from the professional register (HCPC, 2005; HCPC, 2007). This PhD research demonstrates that digital markers could be becoming 'the cultural norm' in everyday practices amongst junior and senior radiographers and because there is a danger for images to automatically (by the equipment) or accidently (by the operator) become 'flipped', radiographic examinations may require repeating because an ASM was not used in the primary beam, thus increasing the radiation dose. Guidance of placing ASMs have been published by the SCoR however the fieldwork highlights that radiographers may require continued guidance and support on placing ASMs due to the problematic 'self-justification' radiographers claim facilitates patient care delivery in not placing ASMs within the primary beam.

Overall this section has highlighted new pitfalls following the introduction of DR within the general imaging department. DR has been reported to accommodate patients' needs providing quick repeats, which reduced time in the clinical environment, however there is a danger for some radiographers to 'position, expose and see what happens' and repeat if necessary. This suggests that the philosophy of 'getting it right first time' (NHS, 2013) may not be at the foremind of some radiographers. Further, 'site specific' phenomenon was highlighted whereby participants could irradiate a patient without projecting at the correct detector. Thus while safety features on other DR equipment (site C) (GE X-ray, 2013) prevented such errors this suggests that radiation errors may be 'site' or 'culture' specific due to variances in radiographic equipment. Lastly the placement of digital ASMs using advanced technology revealed contrasting attitudes in comparison to the SCoRs recent publication on ASM placement. The data suggests that radiographers may 'self-justify' the use of digital ASMs thus may require additional learning to support the placement of physical ASMs.

7.5. To protect or not protect?: Lead protection in general radiography

In chapter two it was discussed that although X-ray examinations may benefit patients, it is generally accepted that 'no safe dose' exists (ICRP, 2007) thus keeping radiation doses to a minimum is essential during an X-ray operators day-to-day practices. The severity of radiation risk depends on the amount of radiation received and the organs irradiated. Some organs within the human body are more radiosensitive than others (Graham and Cloke, 2003; ICRP, 2012). Methods to protect patients and staff in the clinical environment are used, which involve high atomic number devices such as gonad shields, flexible lead-rubber, lead-rubber aprons and lead rubber gloves (Ball and Moore*,* 2008)*.* The atomic number of lead is 82, its high density results in high photoelectric absorption, sufficient within diagnostic beam energies (ibid) and appropriate for reducing radiation exposures. The application of lead in diagnostic radiography is documented in the latest publication of 'Clark's positioning in radiography' depicting patients wearing protective measures whilst undergoing shoulder and distant extremities including the feet and ankle (Whitley *et al,* 2005). Publications have demonstrated significant dose reduction to radiosensitive organs with no observable impact on image quality (Clancy *et al,* 2010; Mekis *et al,* 2013). The ICRP (2000) claim that a lack of knowledge regarding the effects of radiation on developing foetus may lead to patient anxiety (ICRP, 2000) (for women) who might be more emotional and sensitive during pregnancy (Kumar and Robson, 1984). An inadvertent foetal irradiation to a distressed family member may feel that the hospital has a case of clinical negligence to answer, yet it is unlikely that such a case would succeed as the family must prove that the radiation caused harm to the foetus (Krovack and Nightingale, 2007). Thus while radiographers are not likely to be found guilty of causing damage by irradiation, practical, professional and ethical issues should be considered because radiographers are obliged to ensure and maintain the health, safety and welfare of their patients (SCoR, 2004). Moreover, if found responsible for inadvertently irradiating an unborn child radiographers could be answerable to employer or professional body disciplinary proceedings (Krovak and Nightingale, 2007) as patients themselves are not informed of the potential hazards associated with radiation (Rassin *et al,* 2005). Thus the philosophy to use lead protection in general radiography was expressed by participants at sites A and C who felt obliged to protect their patients during particular examinations:

Geoff: *The law of radiation protection applies to every radiation protection environment… For example, [someone] who has had previous abdomens and all that, I'd deem it necessary to protect their gonads or whatever. I'm going to use a gonad shield. It doesn't matter whether it's DR or CR. It's an individual thing. You have to use protection. You're using X-rays - protection is for the X-rays. It's radiation, isn't it? It's poor practice. It has to be used in every sense. We've got lead coats, we've got lead gonad shields…You have to use them when necessary.*

Sebastian: *We have an obligation to protect the patient. And we have to do it every time we're X-raying, apart from*

	peripheral… anything that's axial radiography, we have to protect the patient and think about some form of protection.
Alex:	*But as far as I know, if it's between the knee and the diaphragm then it's an issue, but generally speaking with extremity work, you don't really think about putting lead or anything.*
Rosemary:	*When I was taught at 'University', you were told to protect them and use lead." I mean, I have covered before, because I think that it's better to cover and to try and get it and just try and get it protected. Things like that.*

It is generally accepted that lead protection can be used to absorb ionising radiation and protect tissues (Williams and Adams, 2006). Some radiographers above identify 'when and when not' to apply lead protection during general radiographic examinations but do recognise the importance of using lead protection during certain general radiographic practices. A common observation made at all research sites was that lead protection was offered within the clinical X-ray rooms:

Observations:	*An array of radiation protection devices including lead gonad protectors and various sized lead-rubber devices were available in the clinical rooms in each of the hospital sites. However throughout the adult examinations lead protection was not observed to be implemented on any axial and appendicular examinations on patients aged between 18 – 75+ years of age.*

The lack of lead protection used during the participant observations led the researcher to question whether lead remained an essential tool for radiographers? It is claimed that if radiosensitive tissues are located in the image-acquisition field, they should be excluded whenever possible by the use of protective materials. Protection should be regularly employed in extremity radiography (Whitely *et al,* 2005) because patients believe that medical staff will protect them from unnecessary radiation exposure (Rassin *et al,* 2005). Individuals can differ in their decision-making (Arnold *et al,* 1998), which was highlighted in this PhD research whereby radiographers at sites A and C felt that a lack of lead use was 'not horrific' and because doses are minimal in comparison to computed tomography (CT). For example, participants state:

Sharon:	*Let's face it, it's not horrific if they don't use it [lead], is it?*

Margaret: *You're speaking to somebody who didn't use a lot of lead in the first place. If I do extremities, I always sit my patient straight on the table so the gonads are protected by the patient's legs.*

Michael: *I don't tend to use it [lead] a lot for a lot of things… Plus you're fostering more paranoia in the people you're X-raying, and making them uncomfortable. I think the doses that we're using for things like extremities and stuff are quite minimal in reality [compared] to what people get in CT and stuff. It seems people… now that CT is a lot more prevalent and you're doing things with a lot higher dose, you sort of think "What's the point of trying to protect someone from the scatter from a finger, when they're going to be blasted and have a CAT that's going to give them a one in a thousand chance of getting cancer?" It's such a massive difference.*

The data suggests that some radiographers' may be beginning to alter their attitudes towards radiation risks within general radiography suggesting that the use of lead could do 'more harm than good'. Vinorum (1998) study in Norway used interviews with radiographers discovering that the application of policies regarding pregnancy status was random across hospitals, lacking clarity, causing confusion, which resulted in only 50% (n= 5/10) of her respondents routinely following radiation protection recommendations. This is deemed unacceptable and may inadvertently lead to inconsistency for patients and at worst inadvertent radiation of the foetus (Krovak and Nightingale, 2007). This PhD study provides additional insight into contemporary attitudes and beliefs of diagnostic radiographers in the UK, for example a common theme identified amongst participants at sites A and C was the suggestion of 'new research' (which could not be found by the radiographers) suggesting that the use of lead was 'trapping/tunnelling' radiation dose to the patients and thus ceased to be used in all examinations in the clinical environment:

Eric: *'Named Radiologist' told me there's new research which says that it's better not to use lead protection, because it reflects it back and stuff like that.*

Rosemary: *But now we're told that it doesn't help, it traps the radiation. That's the last thing I heard, anyway. And so we stopped doing it.*

Annabelle: *I was told by a senior radiographer that there's no need to use lead on an adult patient, because research showed (whether this research is true or whether it's* *word of mouth, I don't know; I haven't seen the research) that if you put the lead on, then the scatter that goes into the patient can't come out of the patient. You're actually trapping it.*

Annabelle: *"Well, the reason it's not used locally is something we need to re-examine, because those that have been in charge of radiation protection here - specifically the RPAs - actually told us not to be using it. The reasons that were given were supposed to be linked to evidence-based research about this tunnel effect. Which none of us can actually find - this research? But we were told not to."*

These comments detail the issues surrounding the use of lead protection, which impact on its use in the clinical environment. It suggests that the use of lead protection is arguably 'socially constructed' using their own and others ideologies to justify the limited or lack of lead protection in practice. This may help explain Rassin *et al* (2005) conclusions that only 65% of radiographers adequately protected patients from radiation exposure to organs not undergoing examination. Further, it raises the issue that radiographers could be acting 'on instinct' or 'word of mouth' from colleagues, with little reference to evidence based research. For example Rosemary above asserted that she stopped using lead on patients because she heard it 'trapped' the radiation, however for a pregnant patients she claims to use lead following 'requests' from the expecting mother in order to protect her developing fetus:

Rosemary: *If it's a pregnant lady and you're doing something like an ankle, then I'll try and protect. Especially in the first trimester. I think any protection. I'm not just going to leave her unprotected. Because the patient often says "Are you going to cover me up?" You can't just say "Naah, it's fine!".*

This demonstrates that the attitudes and beliefs towards the application of lead protection may be individually conceptualised and employed if the patient questions 'are you going to cover me up?' Moreover this could present local challenges because if Rosemary decides to use lead protection on a pregnant patient for an ankle examination and another radiographer decides not to, based on their own understandings patients may begin to question 'what is actually best for my unborn child?' This lack of congruity regarding the application of lead was generally grounded by 'new research' at sites A and C, which prohibited its use, however this is arguably 'culturally constructed' due to developing attitudes and beliefs in contemporary radiographic practice. Following the theory of Mead (1939:99) he claims that 'there are an infinite number of possible perspectives and each will give a different definition to the parts and reveal different relations between them'. In support Burchell *et al* (2002:35) identifies that 'what is best may not be known, or there may be several solutions of nearly equal value. In some cases, medical experts may disagree because of predispositions due to training and experience'. The use of lead protection in this PhD work is an example of radiographers struggling with a phenomenon and associating their cultural values and beliefs within the clinical environment. The differing perspectives present a potential danger for radiographers within the same hospital or NHS Trust as it may highlight inconsistent knowledge that may arouse concerns with patients following the request: 'can I have lead during my X-ray? I had it last time!' This lack in general consensus regarding the use of lead protection on pregnant patients was highlight by Terry a senior radiographer who felt that lead protection is 'a personal choice':

Terry: *And also the issue with pregnancy, about the suggestion that in some way, lead may increase the dose, has been put forward. And I think that it's a bit… there seems to be a lack of consensus about which way to go forward. And I think it's just been left hanging. It's become more or less a sort of personal choice of radiographers, rather than clear policy guidelines. I think that when you're working at this level, what you want is clear guidance from the experts in dosimetry. And that's not available, or hasn't been available to us. And I think everybody is very confused. I think that confusion is leading to it not being used.*

It could be argued that the use of lead presents confusion in the clinical environment. For example when and where to place it raises the topic of 'lead protection' as a 'taboo' subject in the clinical environment. A common theme presented among participants was the claim that 'new research' (which had not been read by participants) identified that lead can 'trap/tunnel' radiation suggesting that 'lead protection' could be ignored. It is neither possible nor practical to drape every patient in lead, but there is a danger of overlooking the primary focus of keeping doses ALARP in the clinical environment and replacing it with 'radiological myths' or fantasies. Participants from sites A and C specify the danger of disregarding lead protection, attributing it to 'laziness' and 'learned behaviour':

Helen: *At uni we were always told to use it, but in practice you're always told not to. And I guess we all just follow suit, don't we? I think the reason that we say here is that the radiation can potentially go into the body and the lead* *can prevent it coming back out. I don't know how true that is. I guess that's something that we should look at properly, because it's quite important!*

Kirsty: *I think it's probably down to initial training. It's definitely down to the way you're trained in practice. It's definitely down to learned behaviour. Definitely. You watch your peers, and you do as they do.*

Victoria: *Because I've trained here throughout the whole three years that I trained, and I guess you just get into that way of working. Because nobody does it. Which is quite bad, really.*

Fred: *I think its just laziness to be honest. There is various research that shows for some examinations that lead can certainly not prevent radiation and can sometimes increase it. But I think that even though radiographers will cite that, I think generally it's laziness.*

It is generally accepted that lead protection can reduce radiation dose with publications supporting this conjecture (Eyden, 2001; Whitely *et al,* 2005; Clancy *et al,* 2010), however its uses observed in this PhD fieldwork remain problematic. The outcome of the PhD fieldwork highlights diversity combined with a lack of consensus amongst radiographers and other professionals regarding the application of lead in the clinical environment. The fabrication of 'new research' that 'traps/tunnels radiation' was claimed by radiographers, resulting in discarding its use. This illustrates that radiographers may be confused 'when or when not to use lead' during radiographic examinations. These individualistic approaches highlight that patients may receive different opinions from radiographers i.e. protecting the fetus of a pregnant mother, which in turn questions the reliability of the method used.

7.6. Conclusion

In conclusion, this chapter has explored contemporary attitudes and beliefs concerning dose and image optimisation using DR. DR is reported to produce improved images of diagnostic quality whilst reducing doses confirming to the ALARP principle. Radiographers may attempt to optimise radiation doses with DR, but this PhD study reveals 'dose creep in action' with radiographers' acknowledging suboptimum techniques, including over-collimation and improper exposure factor selection. Further, this chapter has argued that the 'art and science' of radiographic practice is interconnected within the digital era, rather than individualistic as previously suggested. This argument is grounded in the belief that because radiographers prefer the aesthetic 'textbook images' this may facilitate hidden and suboptimum use of collimation in the clinical environment. This chapter revealed that radiographers might be unaware of the capability DR has to 'autocorrect' an overexposed digital image leading to assume that the EI is unreliable, thus neglecting its use. It was argued that radiographers may need to 'disassociate' themselves from their 'artwork' (the image) enabling ideological reflection on the X-ray image produced, thus facilitating a radiographers critical reflection of the technical factors used to produce an image of diagnostic quality. Data from this PhD research reveals pitfalls with advancing technology such as the ease of 'repeating' radiological examinations facilitating 'hit and miss' practices, coincided with radiation incidents, whereby patients received increased doses with no added benefit, deemed by participants as 'anti-safety' measures. The use of lead protection was rarely used during the observations and radiographers often fabricated 'new research', with little evidence to support this 'trapping/tunneling' conjecture. The lack of consensus and disparity amongst the radiographers demonstrates that 'lead protection' can be a confusing topic with its application in the clinical environment problematic.

Limitations to this PhD research

This study has explored contemporary general radiographic practices using advancing technology. Whilst the findings uncovered in this PhD work should be considered within clinical and academic environments there were inherent limitations within the research:

- The findings relied on verbal consent from patients, yet this often remained obscure. On occasions radiographers failed to introduce ‘me as the researcher’. Some patients queried ‘who I was’, which prompted clarification from the radiographer. Whilst I did not have any direct involvement with patients if I had been introduced appropriately this may have aroused informal discussions with patients or discussions between the radiographer and patient regarding the research topic.
- Observational data was collected using field notes. On occasions I felt uncomfortable recording radiographers actions and behaviours because of radiographers questioning ‘I hope we are pleasing you?’ and ‘what are you scribbling about?’ Further, at site D audio notation was prefered because recording ‘written’ notes felt intrusive and inappropriate. Because note taking did cause some discomfort in the field (Blackman, 1997) I became selective in ‘what to note down and when it was appropriate to do so’. This required prioritising certain phenomena thus resulting in ‘picking and choosing’ what I believed to be more important in the context of the research topic.
- The data had been collected from four hospital sites across two National Health Service (NHS) Trusts in the United Kingdom. The study was large for an individual researcher and data collection took approximately six months to complete. The selection of research sites and staff facilitated data collection and diversity, yet this study cannot be generalised to all general radiography environments due to the small scale of the radiographers observed.
- This study has explored the practices of diagnostic radiographers within the clinical environment, but does not explore the educators, patients or student radiographers’ perspectives, feelings or attitudes in the context of advancing technology with general radiography.
- Whilst the X-ray experiments contributed to the overall study it was a small contribution in respect of the vast radiographic examinations undertaken within general radiography. The experiments were selected because of the available

tools within the university and based on the aim to complete this PhD research in three years.

Whilst acknowledging such limitations, this PhD research has provided insight into the general radiographic environment and the impact of advancing technologies. It has provided an original outlook into phenomena such as radiographer/student learning, person-centred delivery, and use of ionising radiation. It provides an introductory account of the general radiographic environment and how certain factors can impact a radiographer's clinical practice.

Chapter Eight: Conclusions

This PhD study set out to explore contemporary radiographic practices within the digital radiography (DR) environment. The research questions of the PhD will now be addressed in accordance to the findings of the study.

8.1. Suboptimal learning: Impact on radiographers and students.

This PhD study critically examined current knowledge and understanding of DR amongst radiographers within the clinical environment. This exploration was essential as it was claimed that not all radiographers understood the technological aspects of DR with complete certainty (Patfield, 2010). The following research question was explored:

1) *What is the current knowledge and understanding of DR in the clinical environment?*

The empirical data identified that a radiographers learning in both clinical and academic environments may be more problematic than previously thought. Whilst DR is reported to offer dose reduction opportunities during radiographic examinations (as identified in chapter two), supported by research and testimonials by manufacturers, some radiographers in this study felt that they did not fully 'know' or 'understand' DR technology. The data suggests that radiographers receive varying levels of training and education within their clinical environments and throughout their undergraduate studies. For example, although 'cascade training' was essential for some radiographers learning, the training was not congruent amongst all staff. This led to radiographers feeling 'lost at sea' with DR equipment, which required radiographers to 'learn on the job', 'working it out as they went along' and receiving 'anecdotal tips' from colleagues. This inappropriate level of training was reported to impact on some radiographers confidence and stress levels feeling suboptimal in their 'competency' as a diagnostic radiographer, not helped with the 'get on with it attitude'. This lack in professional competency and clinical support impacted the delivery of 'clinical learning' for radiography students. Students would adopt a 'learned behaviour' approach thus arguably receiving suboptimal education because the radiographers themselves felt they did not have the appropriate knowledge and understanding to explain and deliver the necessary information. Because of a lack of confidence reported by some radiographers this lead to 'hidden and sneaky' radiographic practices, whereby radiographers 'sneak in', perform a radiological examination and 'sneak out' again. This was in fear of being 'picked out' for suboptimal image quality. Historically images could be peer reviewed within CR and film screen environments, yet following advances in technology DR arguably facilitates a 'hidden workplace culture' within general radiography because images can be hidden from senior peers and sent for reporting. It was found that whilst individual departments are required to deliver and update radiographers, providing appropriate training on new equipment this was not commonplace. The findings suggest that suboptimal knowledge transfer may hinder the radiographer and his/her student who attempts to develop clinical practices. This suggests that within the contemporary radiographic environment a 'hidden curriculum' may exist whereby departments fail to accommodate both radiographer and student learning. This suggests that standards of student education in both healthcare and academia may need revisiting because radiographers may not be prepared for clinical practice as a diagnostic radiographer.

Whilst delivery of 'in-house training' may be suboptimal for some radiographers, another key theme from the data was the lack of academic theory reported amongst junior and senior radiographers. Recently graduating practitioners (2009-2012) at sites A and C felt that their higher education program had not appropriately equipped them with the knowledge and understanding of 'how X-ray images are acquired' using DR. This lack of knowledge and understanding highlighted a further obstacle in 'connecting theory with practice'. Radiographers felt that their lack of 'in-depth' knowledge and understanding was not optimum making them feel like 'technicians' not radiographers. This data suggests that as technology continues to advance in general radiography, without sound training and education the ability to 'connect theory with practice' may become increasingly fragmented leading to disparity amongst radiographers. Radiographers are required to 'know' and 'understand' key principles to acquire X-ray images of diagnostic quality (SCoR, 2013), however this PhD work suggests that some radiographers do not fully understand the principles in which a digital radiograph is acquired. Thus whilst radiographers may 'know how' to take X-rays using DR, they may fail to understand 'how it has been acquired'. This arguably suggests that radiographers are being deskilled in an imaging modality that constitutes approximately 90% of all radiological examinations undertaken within the radiology department. The continuation of suboptimal learning for radiographers may support the argument that radiographers are currently 'button pushers' or 'technicians'. A radiographers inability to 'know' and 'understand' how a radiograph is produced is essential in understanding the optimum radiation required to produce an image of diagnostic quality and meeting the needs of the patient and current UK legislation.

8.2. Person-centered care: The impact of digital radiography

The delivery of person-centred care is a central tenet in all healthcare professionals' clinical work. This PhD explored the clinical practices of radiographers using DR. An important objective was to explore the delivery of patient care examining the advantages and disadvantages associated with advancing technology. The second research question sought:

2) *What impact does advancing technology have on the delivery of patient care?*

Patients arriving into the radiology department are often in an ill and vulnerable state. A common issue identified amongst participants at sites A and C was the facilitation of 'workflow' using DR, allowing an instant image display, which reduced individual examination times. Although this reduction in waiting times was reported to facilitate anxious and infant patients, radiographers felt that on occasions they were required to 'hurry' patients 'out of the X-ray room' in order to 'get the next patient in'. This suggests 'putting the needs of workflow before the needs of the patient', arguably delivering an inferior quality of care and practitioner-patient interaction. It also arguably resembles an 'industrial' setting, not a caring environment as radiographers described the DR environment as a 'conveyor belt' and 'sausage factory' with an intended target to get 'twenty patients done in ten minutes'. It was found that the current workload and culture required radiographers to proceed into 'autopilot', in attempts to 'get the next patient in', which subsequently led radiographers acknowledging administrative and radiological errors during their day-to-day practices. This strongly suggests that an 'in and out culture' may exist within the general imaging environment with the focus on 'time' per examination, which arguably delivers an inferior quality of care to patients. Few studies have explored the role of abnormality detection in radiographic practice coincided with 'instant image display' of DR. Whilst this allowed some radiographers to view radiographs immediately providing an immediate diagnosis (reporting radiographers) to patients, it was problematic for some junior radiographers with limited knowledge and understanding of image evaluation. A number of junior radiographers felt 'uncomfortable' when anxious patients, carers or parents requested an immediate diagnosis of their radiograph. On this basis, for those radiographers without sufficient time to critically analyse radiographs suggests that increasing time pressures hindered the radiographers' ability to critically assess their patients radiograph. This is important to consider as it may hinder radiographer commenting in the future.

The thesis found that radiographers are 'image centred' during radiological examinations. Additionally, following the rapid introduction of technology this PhD study identified that radiographers may become 'technologically-focused' within an imaging modality, which may hinder or facilitate patient care. The amalgamation of both CR and DR technologies highlighted a sub-culture whereby radiographers at site A often selected DR or CR (or both) based on workflow, patient comfort and its 'ability to answer the clinical question' safely, thus arguably adopting a person-centred approached. Conversely, radiographers acknowledged their 'technological-focus' aiming to get the 'best image possible' with DR. This was reported to hinder the care of patients as radiographers would 'shoehorn' patients into uncomfortable positions in order to achieve 'excellent' image quality. This suggests that radiographers may not be aiming to achieve an optimum image of diagnostic quality on traumatic patients, thus resulting in suboptimum care and arguably a lack of person-centredness. This data illustrated that patient care could be overlooked as the main focus of the radiographer could be the use of the technology and workflow. In addition the PhD work identified that patient care may vary in different radiological departments depending on the sole or dual use of DR/CR technologies. At site C the sole use of DR (with tethered 43 x 43 cm detectors) highlighted that non-ambulant patients were required to move 'more for the radiographers benefit' as they lacked the availability of CR, which would have facilitated a 'work around', thus impeding the patients comfort and care whilst undergoing a general radiographic procedure. Patients at site C were often required to hold and support the 43 x 43 cm heavy detector for skyline knees on the table couch, as alternate methods were unknown to junior radiographers in this study. This showed that the hindrances associated with patient care can be affected by a culture in radiographic environments whereby the 'norm' can provide lack in flexibility, placing additional stress to radiographers leading to radiographers abandoning radiological examinations as image acquisition is deem 'unobtainable'.

8.3. Optimising ionising radiation: A dichotomy with new technology.

This PhD thesis explored dose optimising practices within the DR environment. This examination was essential because the literature suggests that DR can facilitate dose reduction. As a researcher and clinical radiographer it was noticed that advances in technology might impede dose reduction within the clinical environment. Thus the following research question was constructed:

3. *How effective is contemporary practice at dose and image optimisation?*

In the United Kingdom (UK) radiographers are required to keep radiation doses 'as low as reasonably practicable' (ALARP), however DR is reported to facilitate increases in radiation dose, commonly known as 'dose creep' (Seeram *et al,* 2013). The PhD fieldwork identified a suboptimum approach to dose optimisation. Through observations of DR in the clinical environment it was found that inappropriate techniques arguably impacted on radiation protection principles outlined by IR(ME)R (2000). This stemmed from clinical observations uncovering a lack of exposure adjustment and knowingly 'bumping up' or 'whacking up' exposures ensuring a diagnostic image 'first time'. Radiographers also acknowledged a lack of exposure manipulation, relying on manufacturer pre-set exposures thus failing to use subjective knowledge to adjust kVp and mA/s settings during adult and paediatric examinations. Furthermore, improper techniques highlighted a reluctance to employ strict collimation and source to image distance (SID). This thesis discovered that radiographers took advantage of software tools to 'shutter' or 'crop' radiographs post exposure masking improper collimation. Radiographers recognised that they have become 'lazy' and 'relaxed' about their collimation by leaving it 'a little bit wide' and 'opening it out a bit more' and 'cropping it afterwards'. Whilst radiographers felt this 'made the image look good' preventing 'professional embarrassment' it arguably contradicts the central tenets and role of the diagnostic radiographer. This lack of adherence to strict collimation and SID were tested on separate DR systems each contributing to the argument that a reduction in SID and large collimation (as observed) strongly predicted an increase in radiation dose (DAP) to patients. Thus the lack of applying strict radiographic techniques it is a strong indicator that these techniques facilitate 'dose creep' within the radiographic environment.

The exposure index (EI) can provide the radiographer with the necessary information to identify an 'over' or 'underexposed' image. It was identified that radiographers may ignore an underexposed image if it answers the clinical question, supporting the notion that radiographers in this study do ‘acquire images as good as needed’. Other radiographers acknowledged their lack of EI use and only refer to it if an image is grossly under or overexposed. Other radiographers failed to locate the EI on the DR system. The EI can contribute to ascertain whether an image is under or overexposed, however this study shows that its use remains inconsistent in contemporary practices. As technology advances, images will continue to be ‘auto-corrected’ following over-exposures. In this PhD research some radiographers were less inclined to ‘look’ at the EI value, with some failing to locate it. This could present challenges for radiographers critically assessing their own radiographic techniques at producing images of diagnostic quality. Whilst the use of the EI was not generally employed, phantom experiments at each research site demonstrated strong correlations between dose area product and exposure index suggesting that it can be used to monitor dose delivered to the patient. The general assertion that radiography is an ‘art and science’ may be more problematic and debatable in contemporary practices as it was found that radiographers struggle to conform to optimum levels of ionising radiation following the advancement in technology. In this thesis it was found that the ‘art and science’ of radiographic practice is more interconnected than previously described in the literature. Radiographers aim to produce sound pieces of radiographic ‘artwork’ (the diagnostic image); however radiographers suggested that the production of their radiographic image required ‘social acceptance’ amongst peers. The production of the ‘textbook image’ arguably results in the use of ‘cropping’ and ‘shuttering’ tools thus masking increased doses of ionising radiation. It is proposed that radiographers need to ‘ideologically reflect’ on the image produced, allowing for critical evaluation of radiographic techniques employed without merely conforming to aesthetic requirements.

An important outcome of the PhD study was the discovery of ‘pitfalls’ and ‘bad habits’ radiographers may fall into with DR in order to acquire diagnostic images. For example, radiographers suggest that the adjustment of brightness and contrast ‘post exposure’ on a digital system can facilitate a ‘relaxed’ approach to employing correct radiation doses. While this neglects the philosophy of ‘getting it right first time’ it also supports a ‘hit and miss’ approach by ‘just taking it (the image) and seeing what happens’, due to the ease of repeating with DR. This suggests that radiographers may not be ‘thinking’ about the positioning and technique with DR, whereas film screen encouraged a ‘get it right first time’ approach. The introduction of DR has highlighted potential local radiation hazards that require further investigation; the common fallible error at site A was the ability to irradiate a patient with zero net benefit through improper detector selection. This highlights that whilst the progression from FS to digital technologies facilitates a reduction in manual handling, lack of chemical use, image storage and image retrieval, it was found that developments in technology within the 'digital sphere' in general radiography can have alternate impacts on radiographic practices whereby 'silent malpractices' are arguably part of a 'cultural norm'. Therefore although DR can help reduce waiting times, advancing technology is affecting the radiographers' day-to-day practices, facilitating the production of radiological errors that require further investigation at a local and manufacturing level.

The use of lead protection is generally accepted to protect radiosensitive organs of individuals undergoing radiological examinations. However in this PhD work the application of lead protection remained problematic. The data identified that radiographers may 'socially construct' and 'self-justify' the lack of lead protection on patients during general radiographic examinations. A common theme identified amongst participants from sites A and C suggested a construction of 'radiological myths' and 'fantasies' justifying the removal of lead protection through the suggestion it traps/tunnels ionising radiation causing increased radiological dose. It was found that lead protection can be 'culturally constructed', whereby participants act on 'instinct', 'word of mouth' and thus conform to 'the norm of everyday practices' within the department. This thesis acknowledges that not every patient can be covered in lead for all radiographic examinations, but to remove it in its entirety by some or 'picking and choosing' its application may place radiographers in contentious positions locally and nationally if radiographers fail to conform to local protocols and evidence based research.

Evidence from the fieldwork aims to inform radiographic practices in producing optimum diagnostic images with a reduction in radiation dose, however these are not always adhered to using DR. This PhD work has identified that in order to develop and conform to current legislation radiographers and prospective radiographers may need to change their radiographic perspective through reflecting on the potential pitfalls, bad habits and radiographic techniques employed using DR in order to conform to ethical and professional codes of practice.

8.4. What does this tell us about digital radiography in contemporary radiographic practice?

This PhD research has provided insight into DR as an advancing technology and its application and use within the clinical environment. This thesis aimed to question aspects that concern me as a radiographer and researcher thus remained an important research question throughout this PhD work:

> 4. *What does this tell us about DR in contemporary radiographic practice?*

These issues are highlighted and through identifying such concerns, it can contribute to existing knowledge and continuously strive to provide optimum person-centred care. Three key points are identified below:

1. Lack of training and education.
2. Implications surrounding patient care.
3. Suboptimum use of ionising radiation.

Advancing technology can enhance image quality and deliver lower radiation doses, but this PhD found that within a local workplace culture(s) it may become increasingly problematic for radiographers, radiography students and patients. It was found that in an environment where radiographers are experiencing increasing 'time pressures' it could be argued that DR has facilitated the current demands and time pressures due to its fast image acquisition. Conversely, it could be argued that it has started a 'chain of events' that are beginning to alter radiographic workplace cutlures and affect the central tenets of ensuring ionising radiation is kept ALARP whilst ensuring optimum person-centred delivery.

Concerns surrounding advancing technologies amongst radiographers in this PhD study suggest that additional clinical and academic support may be required to enhance the radiographers and prospective radiographers learning. In this PhD research it was found that a lack of knowledge and understanding can affect the confidence and the application of dose optimisation amongst radiographers in the clinical environment. Thus, the core principles associated with diagnostic radiography are in danger of becoming fragmented following the advancement of technology because without continuing support there are increasing dangers that radiographers will make erroneous decisions, which may result in deskilling the profession and hindering patient care. This raises a concern because general radiography approximately constitutes 90% of all radiological examinations in the UK, thus without sound training and education the issues found in this research may resonate with other radiographers whereby DR is integrated into departments nationally and/or internationally.

For radiographers the ‘fast image acquisition’ associated with DR appeared to facilitate an ‘industrial setting’ not a ‘hospital environment’ as radiographers were conscious of ‘waiting times’, which led to radiographers ‘hurrying’ and ‘rushing’ patients out of the X-ray room. The time pressures not only resonates with an ‘in and out culture’ it uncovered a deeper account of the radiographers using DR to deliver person-centred care. Firstly it highlighted that some junior radiographers may feel ‘uncomfortable’ and ‘put under pressure’ to provide a diagnosis for a patient or parent/carer. Secondly in a DR environment radiographers may become ‘technologically-focused’ upon delivering patient care with some ‘shoehorning’ patients into uncomfortable positions, which could have been prevented by utilising a phosphorous cassette. This suggests that advancing technologies can impact on the delivery of patient care within a general imaging environment as radiographers focus their attention to attain ‘the image’. In response, radiology departments may need to assess their environments prior to purchasing DR technology and how it may impact on clinical workflow.

As technology changes evidence from this study has revealed that in the clinical environment radiographers can disassociate themselves from the ‘core radiographic techniques’ to produce an image of diagnostic quality, thus failing to conform to the ALARP principle. For instance participants recognised the ability to ‘bump up’ exposures and ‘open up’ collimation with DR as the image quality remained ‘diagnostic’. Similarly a lack of awareness regarding source to image distance (SID) highlighted that some radiographers may not adhere to the strict techniques in order to produce an image of diagnostic quality. The suboptimal techniques acknowledge by radiographers could be later ‘masked’ by the operators suggesting that by using DR the software can be used to ‘brighten up’ or ‘crop’ making the image ‘appear appropriate’. This shows that the acquisition and critical analysis of the digital image can be performed in an X-ray room without peer review suggesting that contemporary radiographic practices may be ‘hidden from others’, arguably facilitating suboptimal techniques and practices in the attempt to optimise radiation doses. A ‘reject analysis’ of radiographs may demonstrate positioning, artifacts and patient movement in the digital era, but other methods of quality assurance should be considered in order to prevent hidden radiographic techniques. Another finding resonates with the ‘hit and miss’ approach some radiographers identified during their radiographic practices whereby DR allowed radiographers to ‘quickly repeat’ if an inappropriate image was produced, thus possibly reducing the importance for sound radiographic technique in 'getting it right first time'.

The qualitative and quantitative data collected throughout this PhD thesis highlights that in contemporary radiographic practices, not all procedures and techniques are performed optimally. The introduction of DR has impacted on the culture associated with diagnostic radiography introducing new challenges and phenomena that are interconnected with one another. It could be argued that the introduction and development of new technology in diagnostic radiography has crystallized whereby we need to acknowledge the many dimensions associated with radiographic practice to deliver optimum patient care. Thus a 'multi-faceted' approach may be required by both clinical and higher education institutions in order to maintain optimum clinical practices in the future. It was found that whilst radiographers are legally obliged to conform to the three principles (justification, optimisation and dose limits), these are not always performed optimally. The phantom studies undertaken in this PhD research show an important contribution providing a reflexive outlook on the radiographic culture observed. Similarly phantom studies within the clinical environment could be performed reemphasising the importance of dose optimising methods such as strict collimation and correct SID.

8.5. The value of ethnography as a research methodology: The 'ethno-radiographer'

The value of ethnography as a research methodology is demonstrated by a number of outcomes of this PhD research. To understand 'how things were done' an exploratory methodology was required to study radiographers within their clinical environment. This approach enabled me to observe 'what radiographers did and how they did it' using participant observation to answer the research objectives. The key research instrument in ethnographic research is the researcher. Because aspects of the research remained sensitive, the ethnographic method allowed me to 'be me' utilising both professional and personal relationships to probe deeper into the actions, attitudes and beliefs held by radiographers in relation to certain phenomena. The ethnographic approach facilitated access to the field by being familiar with the research context, gatekeepers and the duties performed by radiographers. This meant that empathy was originally connected with the experiences of radiographers and gatekeepers in this PhD study, which continued throughout. Within qualitative methods person-centred care is integrally related to the grounded theory approach towards the data analysis enabling a thick description to emerge. In this sense the choice and application of ethnography both promoted and supported the exploration of radiographic practices in a person-centred care environment because of ethnography's core concern with participatory methods and empathy to aid reflexivity. In this sense being an ‘ethno-radiographer’ enabled the collection of rich data offering a thick description of people, places and performances in a clinical environment whilst maintaining an empathetic approach to those involved within the PhD research.

The use of ethnography in my own professional discipline required continuous reflexivity. As a practicing diagnostic radiographer I was never solely an ethnographer, thus both roles became ‘blurred’ allowing me to identify specific phenomena within certain contexts. This dual role described as an ‘ethno-radiographer’ allowed me to not only explore actions of people but allowed me to continuously reflect as a healthcare professional using my radiographic knowledge to contribute to the actions and attitudes identified throughout. The exploration and reflection of my own biography was important and interconnected throughout allowing me to critically engage with subject matters arising in the field. My biographical experiences enabled me to develop conversations ‘as things went along’, which became normalised through daily interactions, facilitated by being an insider. The application of ethnography in this thesis offers an additional insight whereby the use of X-ray experimentation can contribute to an overarching ethnographic methodology, whilst answering the research objectives. The use of both inductive and hypothetical deductive reasoning within this PhD study could be transferred into other imaging studies within the medical imaging department. For example in higher dose examinations such as interventional procedures and computed tomography (CT) observing the actions and uncovering the attitudes and beliefs of radiographers may provide additional insights into the optimisation of radiographic procedures. Arguably this may become increasingly pivotal in contemporary radiographic practices because as medical imaging procedures increase, with ionising radiation remaining the largest artificial contributor to the population it is our responsibility as radiographers to provide optimum radiological doses, produce images of diagnostic quality whilst maintaining sound person-centred care. The recent introduction of the ‘IAEA Smart Card’ (2012) that aims to record individual radiological doses may require continuous ethnographic research that explores culture and application of ionising radiation in order to continuously strive for optimum healthcare delivery.

Whilst ethnography could facilitate other research topics within the medical imaging department I feel that the value of reflexivity and biographical approaches would contribute, providing insight within contemporary practices. For example like the ethnographer, student radiographers begin their clinical learning through participant observation, learning by observing others. As the ‘ethno-radiographer’ I was not only able to reflect on the actions of others but also the actions of ‘self’. Throughout the observations, discussions and experimentation I arguably developed as a healthcare professional understanding the importance of conforming to sound radiographic practices. Similarly if radiography students reflect on the technical actions and attitudes of radiographers with contributions from X-ray experimentation at universities, student radiographers may learn to develop an awareness of the pitfalls pertaining to DR thus facilitating their learning whilst providing optimum holistic care to patients within the medical imaging environment.

Recommendations

The following recommendations are taken from the ethnographic fieldwork undertaken in this PhD study from two National Health Service (NHS) Trusts. The recommendations are now discussed with reference to key members of staff with future intentions:

Recommendations for Radiology Managers

The following recommendations are offered to radiology managers in the field of diagnostic radiography:

1. Given the advancing nature of technology within general radiography, radiology managers should critically assess the clinical advantages and disadvantages of advancing technology prior to procurement and installation. Aspects of consideration for technological upgrades and installations include equipment mobility, user-interface, patient comfort and radiation safety mechanisms facilitating a reduction in operator error. It is recommended that wireless detectors or CR technology accompany fixed detector technology in order to alleviate any discomfort to patients and anxiety amongst radiographers upon undertaking certain radiographic procedures. An holistic outlook of imaging technologies prior to equipment purchase would be of value to imaging managers in the pursuit of enhancing patient and operator experience.

2. Radiographer training and continuing professional development with new radiographic equipment should be strictly adhered to. Radiographers in this study were 'simply getting along' and 'picking things up as they went along' demonstrating inconsistency in radiographer competency. Radiographers must have the necessary training to competently undertaken radiographic examinations within the clinical environment. A clear audit trail of training records for X-ray staff should be a pre-requisite in the clinical environment where lone working is undertaken.

3. An exploration of other imaging modalities contributing to the optimum delivery of radiation doses could be investigated using this exploratory methodology. Computed tomography (CT) and angiography procedures contribute to approximately 80% of radiological doses received by individuals in the United Kingdom (UK) (Health Protection Agency, 2011), thus by considering 'what radiographers do and how they do it' in 'high dose' modalities would provide further insight into radiography departments, evaluating dose reducing strategies whilst ensuring optimum care delivery.

4. Historically quality assurance involved a senior radiographer 'going through the reject bin' or 'checking rejected images on CR systems' for poor positioning, exposure, movement and artifacts. Yet in contemporary radiographic practices it is recommended that quality assurance requires readdressing due to new pitfalls identified in the empirical chapters. Firstly, a 'silent malpractice' is suggested within diagnostic radiography concerning the potential to expose a patient without any net benefit following inappropriate detector selection identified. Secondly, radiographers may be instilling a philosophy that encourages radiological repeats facilitated by fast image acquisition as radiographers could expose a patient 'see what happens' and 'do another if it is not quite right' thus negating the 'get it right first time' approach, generally accepted in diagnostic radiography.

<u>Recommendations for Educators and Researchers</u>

The following recommendations are offered to educators and researchers in the field of diagnostic radiography:

1. It is argued within this PhD research that radiographers may become 'deskilled' in an imaging modality that consists of approximately 90% of all radiological examinations undertaken in the UK. In this context higher education institutions should reflect on current pedagogical approaches ensuring that sound knowledge and understanding is delivered to prospective radiographers enabling them to keep doses 'as low as reasonably practicable' (ALARP). It is suggested that the delivery of theoretical knowledge in conjunction with experimentation would help 'connect theory with practice' amongst prospective radiographers and help forestall poor radiographic techniques, a central tenet of radiographic practice.

2. The lack of confidence and competence identified by some radiographers suggests that students could be experiencing a ‘hidden curriculum’ within the general imaging environment. It is recommended that original research be undertaken exploring the learning experiences of student radiographers using advancing technology in contemporary radiography. This would contribute to existing knowledge and provide insight of knowledge transfer within the clinical environment. This would be of value to the radiography profession in order to reflect critically on the clinical pedagogy radiography students received.

3. In the methodology chapter it was argued how ethnography enabled inductive reasoning by means of participant observation(s) with contributions from X-ray experiments. This reflexive ethnographic journey could have a pedagogical significance for radiography students. For example, adopting a reflexive and biographical outlook throughout this thesis enabled a critical evaluation of ‘how I operated’ as a practitioner and person and how influences such as workplace culture impacted on my day-to-day practices. It is recommended that educators consider the influences of workplace cultures and how reflexivity and biographical approaches may support radiography students learning by observing ‘what radiographers do and how they do it’ whilst critically reflecting on controlled laboratory experimentation, self and cultures to develop sound healthcare delivery.

4. It is recommended that academic institutions challenge the commonly held view that the ‘art and science’ of radiography are separate and consider them interconnected. In this PhD work the findings suggest that radiographers may be using digital software to enhance image quality ensuring that images are ‘socially acceptable’ and that of a ‘textbook image’. This is important to consider because radiographers may not be critically evaluating image quality using the exposure index and/or their radiographic technique and thus may need to ‘ideologically disassociate’ themselves from ‘their image’ and review the radiographic technique employed.

5. Research exploring numerous clinical environments would identify the delivery of general radiographic practices in the UK. Further, research exploring alternate environments should include private hospitals providing additional insights of a radiographic culture. This is important following the latest report by the Health Protection Agency highlighting a 40% rise in radiological examinations within

independent hospitals since 1997 (HPA, 2011). Whilst general radiographic practices only constitute approximately 19% of all radiological doses within the medical imaging department, this PhD study has highlighted that these may not be delivered optimally.

Recommendations for Radiographers

The following recommendations are offered for practitioners in the field of diagnostic radiography:

1. Based on the research findings it is recommended that radiographers holistically consider patient's mobility and illness prior to undertaking their general radiographic examination(s). This is important in scenarios whereby 'fix-detector' technology is solely used in general radiography rooms thus potentially impacting on patients comfort and care by putting the needs of the room before the needs of the patient. In addition, it is recommended that radiographers consider obtaining 'images as good as needed' rather than 'shoehorning' patients into uncomfortable positions whereby they seek to achieve a diagnostic image with digital radiography.

2. This PhD research identified that radiographic practices could mimic that of an 'industrial environment' rather than a 'caring environment', arguably facilitating an 'in and out' culture. This could be seen as uncaring as radiographers 'hurried' and 'rushed' patients out of the general X-ray room(s). It is recommended that radiographers adopt a person-centred approach within the healthcare setting ensuring that the needs of the patient outweigh the needs of time pressures. Further research exploring the patients views, attitudes and expectations would add value in the clinical environment in order to support or refute claims that patients may view diagnostic imaging procedures 'as a means to an end'.

3. As technology continues to develop it is imperative that diagnostic radiographers remain autonomous in the use of ionising radiation. This PhD research highlights a danger following the suboptimum use of ionising radiation, facilitated by advancing technology. Whilst concerns may arguably be facilitated by workplace cultures, radiographers are individually responsible for strict exposure selection, source to

image distance (SID) and collimation thus it is recommended that all radiographers critically review their practices and ensuring their techniques conform to the 'as low as reasonably practicable' (ALARP) principle. It is recommended that radiographers support each other in a positive workplace culture and mentor where appropriate. The actions observed by radiographers are interconnected with the known phenomena 'dose creep' thus radiographers may require additional support regarding the relevance of dose creep and the association with advancing technologies.

4. Another challenge highlighted in this PhD work included 'red dotting' amongst junior radiographers. The clinical application of 'red dotting' may require further reflection by superintendent radiographers due to the inconsistency and anxiety felt amongst radiographers. It is recommended that further training or 'sit in sessions' with reporting radiographers are performed in order for junior radiographers to develop image interpretation skills and become confident in their ability to provide a 'red dot' or 'radiographic comment' in the future. This would provide a more uniformed approach to immediate image interpretation amongst radiographers within general imaging environment and remove any disparity whereby patients may or may not receive an immediate diagnosis.

5. Some radiographers in the clinical environment identified a lack of using lead protection during general radiographic examinations. Radiographers often constructed their own 'radiological myths' self-justifying their intermittent use of lead. It is recommended that radiographers unsure of the use of lead protection refer to local protocols and seek guidance from senior radiographers and radiation protection supervisors and advisers.

6. Recognising our own errors or near misses are important steps in becoming compliant and safe practitioners. Radiation errors and near misses observed were unreported in the clinical environment. It is recommended that radiographers' report radiographic errors and near misses, which could hinder a patient or member of staff. This will recognise potential pitfalls and allow for development of safe working radiographic practices with advancing technology.

Reflection of the PhD

Since starting the PhD in October 2010 it has presented numerous obstacles that have required elements of 'juggling things around', more notably the continuation of balancing clinical work with academic study. However the completion of this PhD thesis has allowed me to develop personally and professionally. Personally I feel a great sense of achievement, through hard work, determination and the support of my supervisors I have learnt a great deal whilst contributing to the radiographic profession. It has provided me with the ability to be more critical of my own radiographic practices and pedagogical approaches. It has developed my person-centred outlook, not just for patients but my colleagues and radiography students. I have recognised that we share a common goal; ensuring we perform optimally for the individuals we care for. Radiographers and educators should ensure that their colleagues and students are supported because by sharing and learning from new knowledge we can all develop personally and professionally and unite the radiographic community. Initially I had intended to complete a vast array of scientific experiments however a critical account of current literature identified that the originality of such research laid elsewhere. Being the key instrument of the research methods I am pleased to say I have enjoyed the ethnographic research, it has developed my communication skills, which I hope will support me in my future career.

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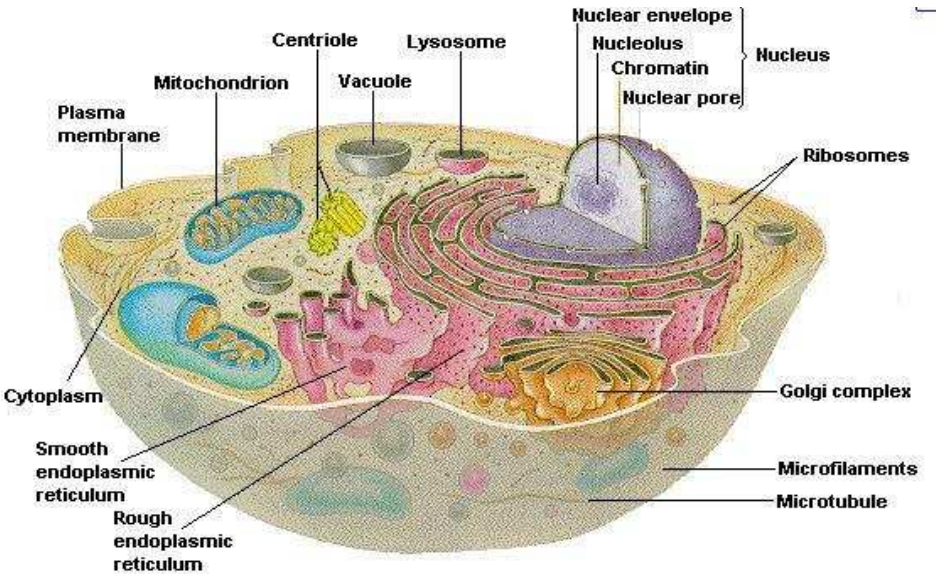
Appendices

Appendix 1: The Mammalian Cell



(Tortora and Grabowski, 2003 pp. 60)

Main parts of the cell

Cell Part	Description
Plasma membrane	The cells flexible outer surface, separating the cells internal environment from the external environment and regulates the flow of materials into and out of a cell.
Cytoplasm	Contains cellular contents between plasma membrane and nucleus, this compartment contains two components: cytosol and organelles. Cytosol contains water, dissolved solutes and suspended particles. Surrounded by cytosol are several difference types of organelles. Each type of organelle has a characteristic shape and specific function; examples are the cytoskeleton, ribosomes, endoplasmic reticulum, Golgi complex, lysosomes, peroxisomes and mitochondria.
Nucleus	Large organelle which houses the most of a cell's DNA, within the nucleus are the chromosomes, each consisting of a single molecule of DNA associated with several proteins. The chromosome contains thousands of hereditary units called genes that control most aspects of cellular structure.

(Adapted from Tortora and Grabowski 2003 and Becker *et al* 2009)

Appendix 2: Levels of risk for common X-ray examinations

X-ray examination and typical effective dose	Equivalent period of natural background radiation	Lifetime additional risk of cancer per examination	Mean probability estimated by lay person (%)
Chest 0.02 mSv Teeth <0.01 mSv Upper/Lower limbs <0.01 mSv	A few days	Negligible Risk Less than 1 in 1,000,000	8.5
Skull 0.07 mSv Head 0.07 mSv Neck 0.07 mSv	A few weeks	Minimal Risk 1 in 1,000,000 to 1 in 100,000	9.7
Hip 0.3 mSv Pelvis 0.7 mSv Breast (mammography) 0.8 mSv Abdomen 1 mSv Spine 1.3 mSv CT head 2.3 mSv	A few months to a year	Very Low Risk 1 in 100,000 to 1 in 10,000	10.7
Barium Meal 1.5 mSv Kidneys/Bladder (IVU) 2.5 mSv Barium Enema 7 mSv CT Chest 8 mSv CT Abdomen 10 mSv CT Chest, Abdo & Pelvis 23 mSv	A few years	Low Risk 1 in 10,000 to 1 in 1,000	17.2

(Adapted from Health Protection Agency 2009; Hall and Garcia 2006 and Berry 2004)

Appendix 3: Methodological Framework

Research Questions	Data Sources and Methods	Justification
1. What is the current knowledge and understanding of DR in the clinical environment?	• Literature review of government policies and research publications. • Observe operators using DR in their clinical environment undertaking numerous radiographic examinations on adult patients. • Informal and formal discussions with key participants discussing their knowledge and understanding of DR technology within the clinical environment.	• Literature review will develop my knowledge and understanding of current radiographic literature and dose optimisation methods, furthermore ethnographic literature will aim to develop the research methods employed. • Observing operators in their clinical environment and documenting actions will provide a valued insight into the application radiographic techniques and practices. This inductive approach will later inform the semi-structured interviews and any experiments selected by the researcher. • Informal and formal discussions (semi-structured interviews) will explore the operators' current knowledge and understanding of digital radiography highlighting any training and educational concerns within the clinical environment.
2. How does this knowledge and understanding impact on patient care? 3. How effective is current practice at dose and image	• Observing operators undertaking radiographic examinations on various ambulant and non-ambulant adult patients within the clinical environment. • Semi-structured interviews of operators providing the clinical care to patients. • Laboratory experiments contributing to the common techniques observed in the clinical environment.	• The observations of radiographic examinations observed will help to reveal how practitioners use their knowledge and understanding to obtain an image of diagnostic using DR and the implications this may have on patient care. • Informal and formal (semi-structured interviews) with operators will aim to provide detailed accounts of the use and application of dose optimisation methods observed in the clinical environment. Furthermore the discussion will seek to examine the impact advancing technology can have on patient care delivery. • Laboratory experiments using an anthropomorphic phantom can contribute to the

optimisation?		common variable techniques observed in the clinical environment.
4. What does this tell us about DR in contemporary radiographic practice?	• Examination of empirical evidence discussing the implications of advancing technology in contemporary radiographic practices.	• The author will use the empirical data collected to answer the following question. Through examining the cultural underpinnings of radiographic practice and digital radiography the author will provide arguments concerning the application of advancing technology.

Appendix 4: Patient Information Sheet

Patient Information Sheet

Researcher: Mr Christopher Hayre BSc (Hons) || *Supervisors:* Dr Alison Eyden, Dr Shane Blackman, Dr Kevin Carlton.

Study title: To explore radiographers' knowledge and understanding of dose and image optimisation in digital radiography (DR) with the aim of developing new knowledge for practice.

Invitation: PhD research is being performed in this X-ray department. Before you decide to take part it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and please raise any concerns that you may have.

What is the purpose of this project? As healthcare professionals our aim is to deliver the best possible care to you. The purpose of this project is to improve how we take X-rays. When you have an X-ray you receive a small dose of radiation, it is the purpose of this research to try and reduce this dose with new equipment available to us. In doing this we strive to deliver the best possible care to you and conform to current legislation ensuring that radiation doses should be kept 'as low as reasonable practicable' (ALARP).

What information is recorded about my X-ray? No personal details about you will be recorded. The only information recorded will be the technical information healthcare professionals use to create an X-ray image of you.

Why have you been chosen? You have been chosen because before I attempt to reduce X-ray doses I need to begin by observing the X-ray doses we currently use. The X-ray information obtained will then be used in a research laboratory where I will perform experiments on an X-ray model where I will attempt to reduce the X-ray doses without compromising the X-ray quality.

What will happen to me if I take part? If you agree to take part the researcher will observe your X-ray examination in the X-ray room behind the X-ray screen. As a result of this research no changes to your service or to your patient care will be affected as a result of this observation.

Do I have to take part? It is up to you to decide whether or not to take part. If you do decide to take part I will observe your X-ray examination behind the screen. You may also ask me to leave the X-ray room at any time during the examination, without giving a reason and it will not affect your care in anyway.

What are the possible benefits of taking part? Taking part will not benefit you individually but you will be improving our current knowledge and understanding of X-ray use. This improvement in knowledge and understanding will enable the researcher to potentially reduce radiation doses using technology, ultimately developing our profession and improving our care to patients.

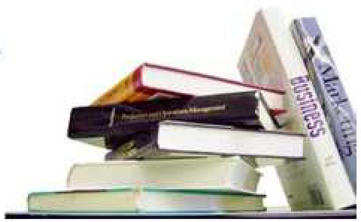
What will happen to the results of the research study? The results of the research study are part of a PhD project. The results will contribute to future academic studies and may inform radiographic departments nationally through publications in scientific peer reviewed journals. It is hoped that the results will be presented at the United Kingdom Radiology Conference and to other appropriate audiences.

Who is organising and funding the research? The researcher and his academic supervisors are all employees of Canterbury Christ Church University (CCCU). The research supervisors are senior academics at CCCU and the research is funded through CCCU PhD Graduate School Scholarship program from October 2010 – August 2013.

Thank you for taking the time to read this information leaflet, if you do have questions regarding this study then please ask a member of staff.

Appendix 5: Departmental Poster

There is an on-going research project taking place in this department by a PhD student from Canterbury Christ Church University. The student will be present behind the screen observing X-ray examinations, which will later inform other research methods in this study. The student will not alter or affect your examination in anyway and will remain as an observer however if you do not wish the student to observe your X-ray then please inform a member of staff and they will leave the room without this affecting your care. Thank you.



Appendix 6: Participant Information Sheet

Participant Information Sheet

Name of Researcher: Mr Chris Hayre
Supervisors: Dr Alison Eyden, Dr Shane Blackman and Dr Kevin Carlton
Chair: Professor Kate Springett

To explore radiographers' knowledge and understanding of dose and image optimisation in digital radiography (DR) with the aim of developing new knowledge for practice.

You are being invited to take part in a PhD research study. Before you decide to take part it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please ask (the researcher) if there is anything that is not clear or if you would like further information (contact Chris Hayre on 07967280876 or email c.hayre68@canterbury.ac.uk). Take time to decide whether or not you wish to take part and thank you for taking the time to read this.

1. What is the purpose of the project?

The purpose of this study is to develop dose reduction techniques using DR in order keep doses 'as low as reasonable practicable' (ALARP) to all patient groups whilst undergoing a medical radiation exposure. Medical exposures are the largest man made source ionising radiation to human beings and although it is identified that individual X-ray doses are reducing in practice, the Health Protection Agency recently identified that the average annual radiation dose to each member of the public has increased. The purpose of this study is to study your experiences with DR to date to find out whether it has facilitated or hindered certain areas of your radiographic practice; secondly, laboratory experiments using an anthropomorphic phantom (to mimic a patient) with suitable radiation detectors will be performed by the researcher, building on previous observations and knowledge to potentially develop new methods of dose reduction for practice. Finally it will be determined whether the technique used to produce the digital radiograph in the laboratory setting can practically and safely be incorporated into a clinical environment.

2. Why have I been chosen?

You have been chosen because your job role allows you to undertake radiographic examinations using digital radiography.

3. Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep (and be asked to sign a consent form). If you decide to take part you are still free to withdraw at any time, without penalty or loss of benefits, and without giving a reason.

4. What will happen to me if I take part?

If you agree to take part we will arrange a time and a place that is mutually convenient to conduct a short interview. The interview will be recorded and later transcribed, we anticipate that the interview could take between 30 and 40 minutes, but this is a rough guide. Secondly the researcher may observe you as an operator performing digital radiographic examinations on an adult patient.

5. What are the possible benefits or disadvantages of taking part?

Taking part will not benefit you individually but you will be contributing to our existing current knowledge and understanding of DR and its uses in practice which will enable the researcher to potentially reduce radiation doses using DR technology. There are evidently implications for the use of your time and we appreciate the help you will be giving us.

6. Will what I say in this study be kept confidential?

If you agree to take part in this study all information which is collected about you will be kept strictly confidential. All research members of the team and the person transcribing the audio recordings have signed a confidentiality agreement before commencing the study. The interview data will be anonymised and kept in accordance with the Data Protection Act 1998.

7. What will happen to the results of the research study?

The results of the research study will be used to build on our existing knowledge of DR. It is intended that the results could be further extended nationally within other radiographic departments and thus contributing to future academic studies through publications in peer reviewed journals. It is hoped that the results will presented at the United Kingdom Radiology Conference and to other appropriate audiences.

8. Who is organising and funding the research?

The research team are all employees of Canterbury Christ Church University (CCCU). The research supervisors are senior academics at CCCU and the research is funded through the CCCU PhD Graduate School Scholarship program over three years from October 2010 – Jan 2014.

9. Who has reviewed the study?

This study has been reviewed and approved by the CCCU Graduate School Research Degrees Sub-Committee. It has also been reviewed and approved by the Trusts Research and Development Department.

10. Contact for further information

If you require further information you can contact a member of the research team.

Research Team

c.hayre68@canterbury.ac.uk
kate.springett@canterbury.ac.uk
alison.eyden@canterbury.ac.uk
shane.blackman@canterbury.ac.uk
kevin.carlton@canterbury.ac.uk

Thank you for taking the time to read this information leaflet, if you do have any questions then please do not hesitate to contact me.

Appendix 7: Participant Consent Form

Participant Consent Form

Title of the Project: To explore radiographers' knowledge and understanding of dose and image optimisation in digital radiography (DR) with the aim of developing new knowledge for practice.

Name of Researcher: Christopher Hayre / Alison Eyden

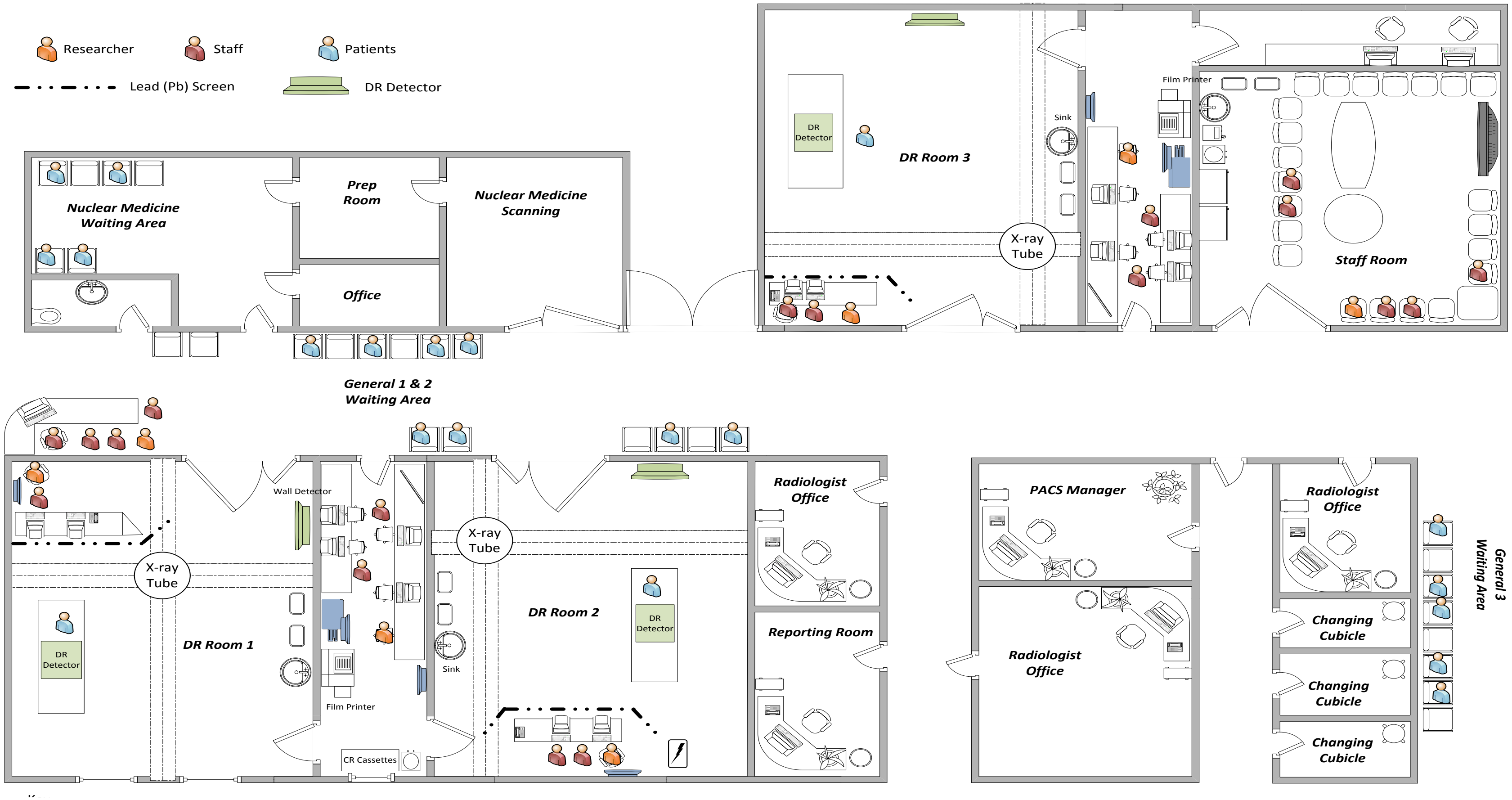
	Please initial box
I confirm that I have read or been informed of and understand the information sheet dated ……….……….. for the above study and have had an opportunity to ask questions.	☐
I have been informed that the confidentiality of the information I provide will be safeguarded and understand that I could not be identified in any report, and the audio recording of the interviews would be destroyed when the study is completed.	☐
I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected.	☐
Data Protection: I agree to the researcher processing data that I have supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.	☐
I agree to take part in the above study.	☐

______________________	____________	______________________
Name of Person	Date	Signature
Researcher	Date	Signature

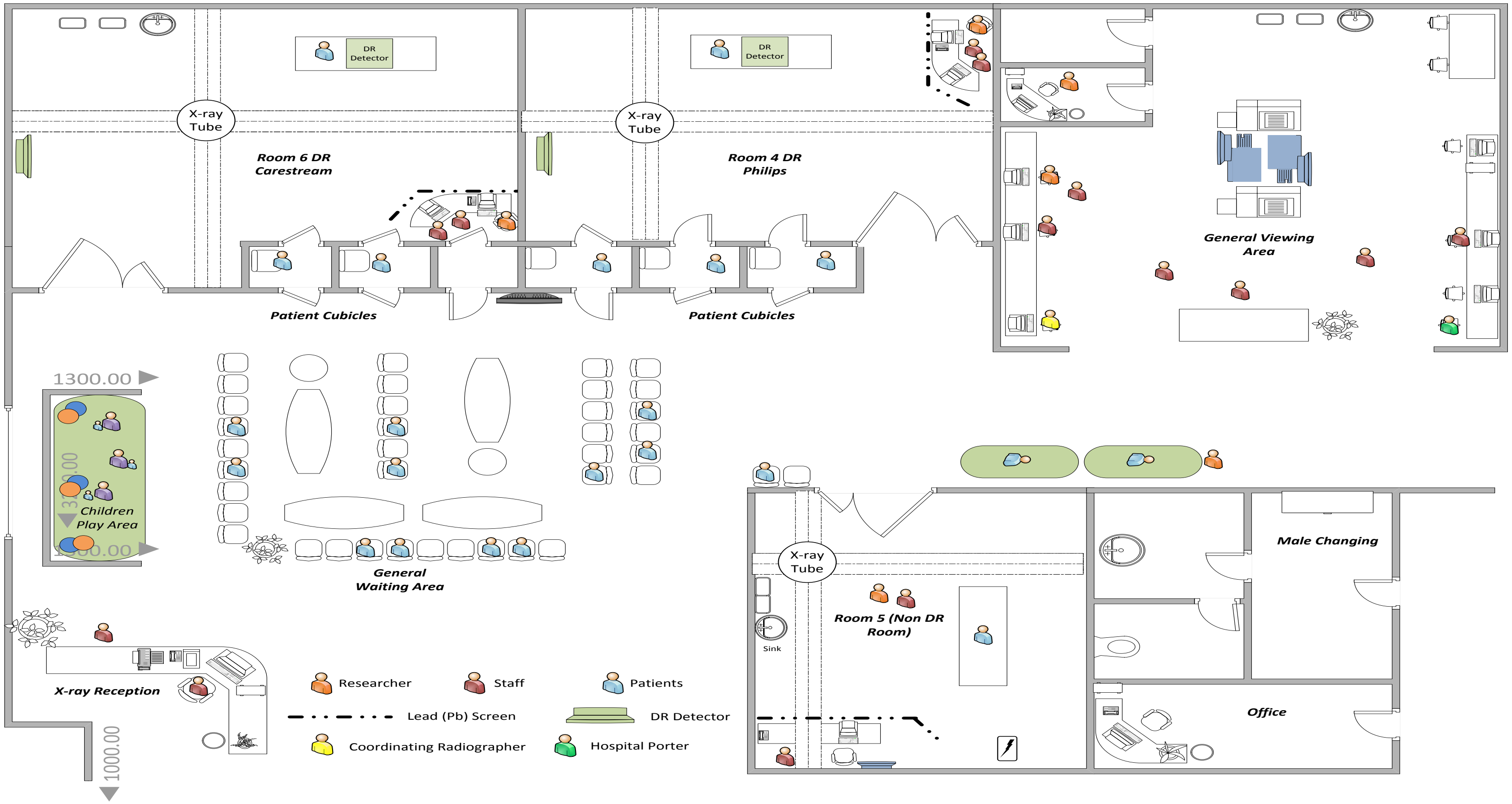
1 copy for participant; 1 copy for researcher

Appendix 8: Layout of general imaging sites A, B, C & D

Site A

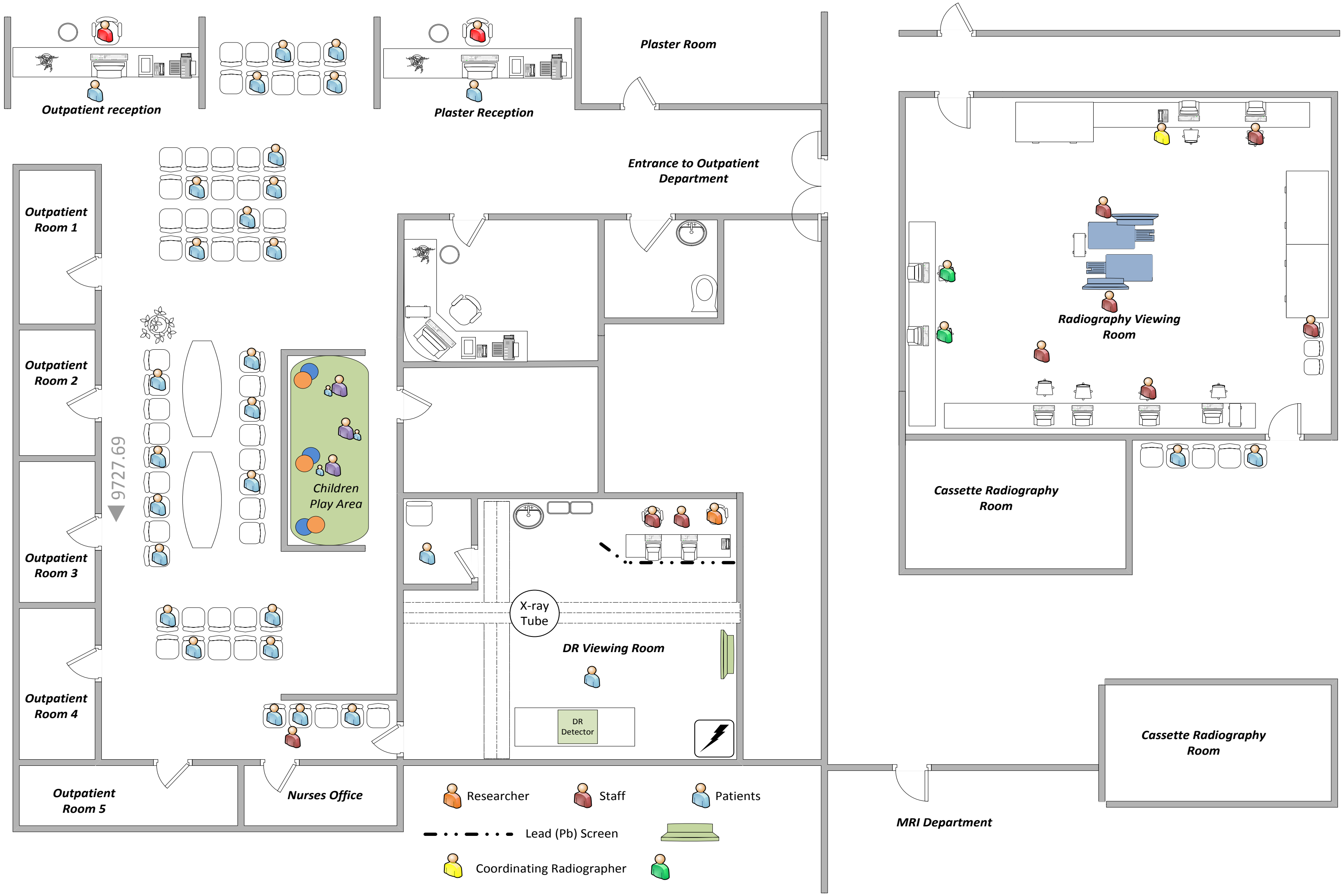


Site B



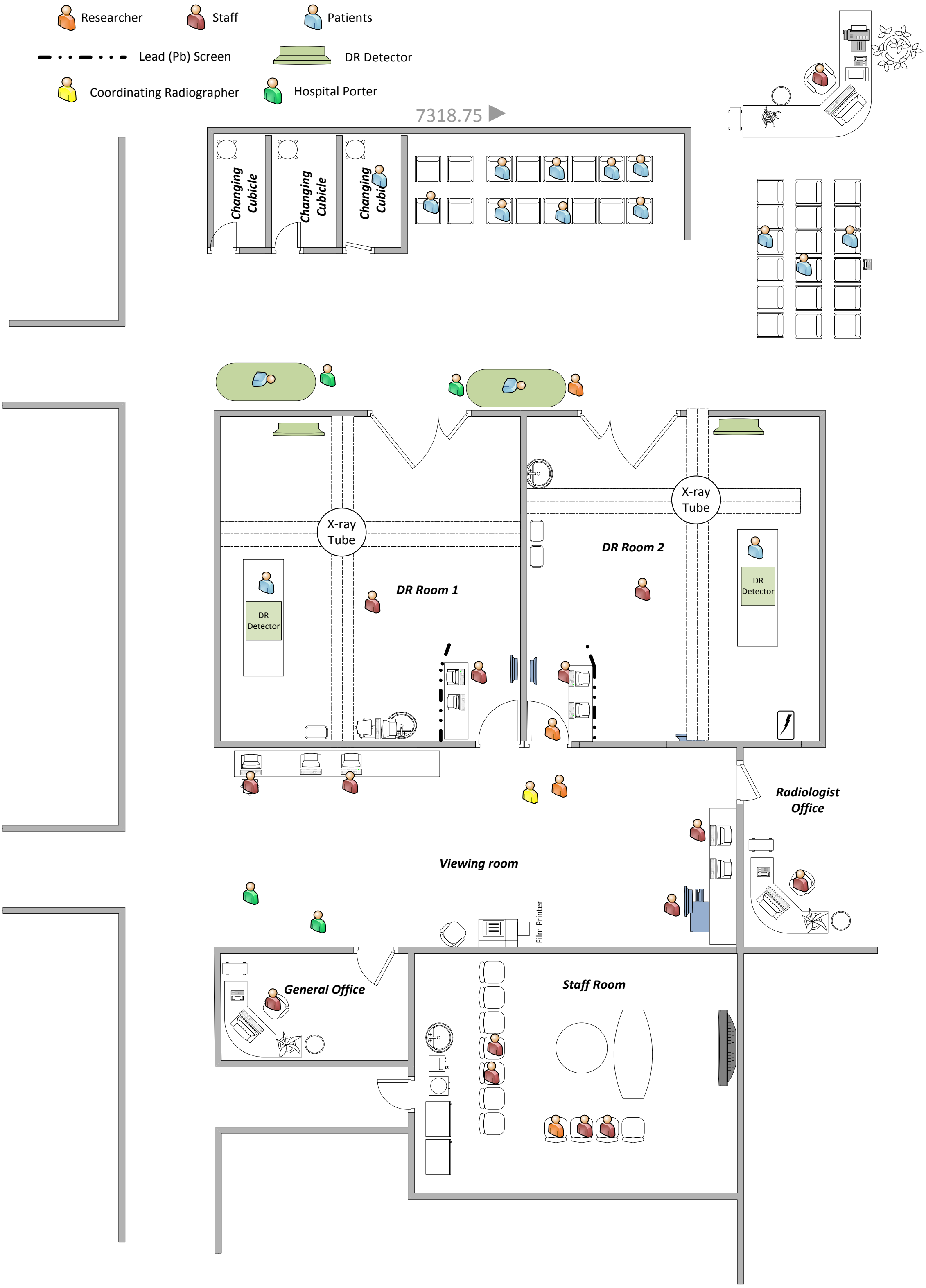
X-ray Tube
DR Detector
Room 6 DR Carestream
X-ray Tube
DR Detector
Room 4 DR Philips
General Viewing Area
Patient Cubicles
Patient Cubicles
1300.00
Children Play Area
General Waiting Area
X-ray Reception
1000.00
X-ray Tube
Room 5 (Non DR Room)
Sink
Male Changing
Office
Researcher
Staff
Patients
Lead (Pb) Screen
DR Detector
Coordinating Radiographer
Hospital Porter

Site C



Outpatient reception
Plaster Reception
Plaster Room
Entrance to Outpatient Department
Outpatient Room 1
Outpatient Room 2
Outpatient Room 3
Outpatient Room 4
Outpatient Room 5
9727.69
Children Play Area
Nurses Office
X-ray Tube
DR Viewing Room
DR Detector
Radiography Viewing Room
Cassette Radiography Room
Cassette Radiography Room
MRI Department
Researcher
Staff
Patients
Lead (Pb) Screen
Coordinating Radiographer

Site D



Researcher
Staff
Patients
Lead (Pb) Screen
DR Detector
Coordinating Radiographer
Hospital Porter
7318.75
Changing Cubicle
Changing Cubicle
Changing Cubi
X-ray Tube
X-ray Tube
DR Room 1
DR Room 2
DR Detector
DR Detector
Radiologist Office
Viewing room
Film Printer
General Office
Staff Room

Appendix 9: Initial Observation Data Sheet

Site: DR room:

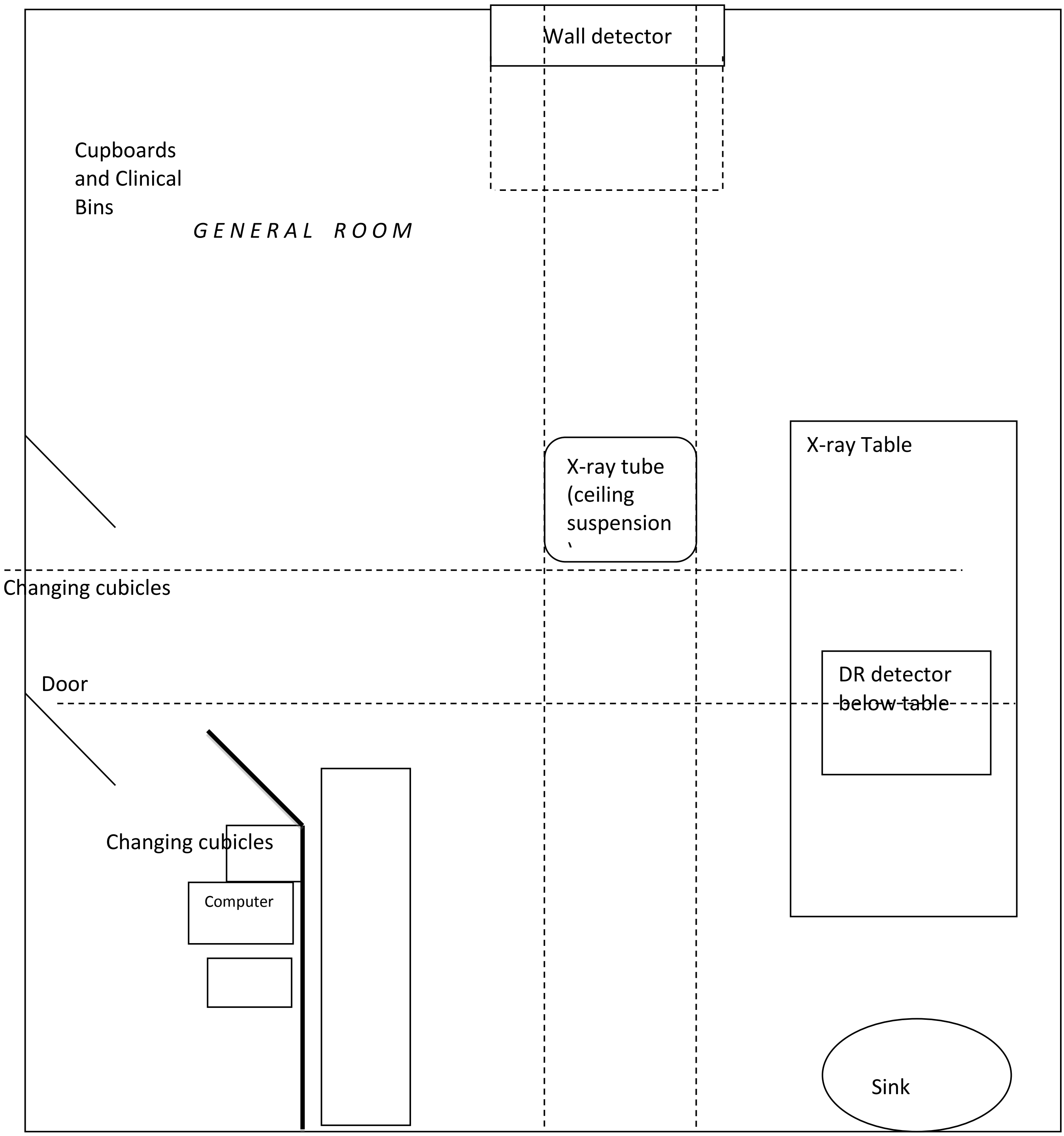
Date:

Operator: Student | AP | Rad Exp: | 1 2 3 |± 5 yrs |6-10 yrs| 10≥

Patient ID: ________________

Exam: _______________________

View One	View Two
Projection: AP | DP | PA | LAT | OBL Focus: Fine | Broad Manual Exposure: Y/N AEC: Y/N Chamber: ________________ Pre-set exposure: _________ kVp ____________ mAs X-ray exposure: _________ kVp _______ mA(s) / _______s FFD: __________ EI: _________ DAP: _________ cGycm^2 Field Size: _________	Projection: AP | DP | PA | LAT | OBL Focus: Fine | Broad Manual Exposure: Y/N AEC: Y/N Chamber: ________________ Pre-set exposure: _________ kVp ____________ mAs X-ray exposure: _________ kVp _______ mA(s) / _______s FFD: __________ EI: _________ DAP: _________ cGycm^2 Field Size: _________


Wall detector
Cupboards and Clinical Bins
GENERAL ROOM
X-ray Table
X-ray tube (ceiling suspension
Changing cubicles
Door
DR detector below table
Changing cubicles
Computer
Sink

Appendix 10: Scanned copy altered data collection

Example....
E10101010
4
10
Rad
S+

[redacted]

bservations actually sitting
around ~~not~~ waiting for examinations
to turn up. Monitor had broken,
engineer ~~replace~~ is replacing it, room
had already swapped monitors with
another screen. No ID badge,
engineer ask who I was, new staff
in department, having to renegotiate
with new staff, explain who I am,
access is constant (negotiating ongoing),
people not knowing who I am, [illegible]
[illegible] protective sign 'Stop!!! Think!!!
are you using the correct sized lead
[illegible]? The kVp, mAs, EI,
& dGycm² is all recorded on
the system which means that I
only need to get the field size

4129610589,
explained electronic markers, annotations

Appendix 11: Observational transcription

Date: 12/07/12

Method: Observation

Time: 09:00-17:00

Site: Site B

Their attire was strictly clinical with their white tunics black trousers. I began by observing just the one DR room, I began by taking notes on A4 noted paper, I am finding extremely difficult to stand up and ensure that I took down all of the information required for each radiological examination observed in practice. The complexity behind this lays with the workload the radiographers have to content, thus following the speed in which examinations need to be done. For example in a department which had three radiographic rooms available for X-ray examinations, only two were operational. A chest examination observed took over one minute to complete from the patient entering the X-ray room to the patient exiting the X-ray room. Although my intention was to participate as only an observer in the X-ray room, this proved extremely difficult within the time observed. There were occasions whereby I have to chaperone patients, assist with moving trolleys and chairs as the practitioners were on occasions finding it difficult to move. One occasion occurred whereby my presence as a research not only aided the practitioner as I had to intervene. Upon observation a patient fell off a chair whilst sitting and in reaction the radiographer rushed to the patients aid and I simply followed behind her, together we were both able to safely and appropriately move the patient back in the position necessary for the operator to take the radiograph. The operator ensured that the appropriate paperwork was carried out during this matter. As time went on throughout the observations the staff would ask me send their images to the PACS system once they had been checked by the operator. This occurred only a few times as the operators on occasion would forget to send their images upon accepting them and would ask me to send them. I felt that it was ok for me to do this, as the operator they had accepted the image and I was just conforming to their wishes. I found that during my time on this first observation that I had to make the right impression. I ensured that I helped out when I could as the operators did work on their own the majority of the time. And with regards to the patient falling the operator did say that 'I'm glad you were here'… I felt that without aiding the staff I would have built up unnecessary tension between the staff and myself which may have hindered follow-up relationships in the future in such observational and interview work. Again within this role I was not just sending images to PACS by I would also be asked if I would bring up the 'work list', check a patients attendance to the department, as I would be near the computer where this was normally done. As I was familiar with the set up I was able to correct wrongly booked patients, which I felt allowed me to become part of the team, culture and ultimately and insider.

As I observed I place myself behind the protective lead screen, on occasions I would come out of this position to aid the operator with a trolley or in the matter whereby a patient fell from his chair. As I aimed blend in with the staff I ensured that joined the staff on their coffee breaks, this allowed me to talk about the general issues with various members of staff, if also helped me being not being stereotyped as just a researcher. I was also thanked on occasions with help I had shown and given during the observations from various members of staff. There are other instances whereby I would suggest/aid the operators, for example the digital equipment would have to be on the correct setting for the operator in order for it to work effectively for the patient. If these settings are missed then either poor image quality may be produced. Therefore as I was familiar with this technology I knew when certain settings were set up correct, for example the erect detector being selected for a patient who is on the table couch. Or where there was a grid in a DR equipment it was not supposed to be, I would therefore highlight this error to the operator as they would be standing in the room with the patient and would not be able to see such information. I felt that my assistance in this matter allowed the examination and relationship between the informant and the research to run smoothly. This also recognised that this happen on several occasions whereby the incorrect detector was selected and or where the grid would need removing or placing in.

The environment

Radiographers would use the 'viewing area' to process their patients data ensuring it had arrived to the PACS system. In the 'viewing area' the cassette radiography (CR) processing took place and was often used when DR was either unavailable or not preferred for a specific examination. One radiographer did mention that they preferred the CR system and would use this over their DR systems. Outside the X-ray rooms displayed the radiation notices on entrance to the room 'X-ray controlled area', 'no entry' and no unauthorized access, with the local rules adjacent to this. Similarly outside the DR room light boxes stating 'controlled area' in a constant yellow light and 'do not enter' in a red light (when an X-ray exposure is occurring in the room). However on another X-ray room (the CR room) the yellow light box outside of the room did not stated 'controlled area' but stated 'room in use' and again 'do not enter' in red.

The DR room in question was large, approximately 6 meters by 9 meters the walls were painted yellow and it was a dark environment, dark in order for the radiographers to see the collimation light. Within the room it processes all of the clinical facilities to undertake all radiographer examinations, patient types and patient history, including hand washing/cleaning facilities, appropriate disposal of clinical and/or general waste bins. Within the room there were no windows and the floor was grey. Outside of the room illustrated three changing rooms connected to the room which would allow them as members of the public enter the changing room through one door and then through another door (within the X-ray room) the 'patient' would emerge. This environment provided the patient with a little more dignity as the patient once changed into the hospital gown did not have to wait back in the waiting room with the remaining patients. Similarly one the patients X-ray examination was finished they would enter into their personal changing room and redress into their normal attire and then leave the changing cubicle once appropriately dressed. On entrance to the DR room signs illustrated the dangers and highlighted the authority as ionising radiation was in use.

To the patient the X-ray room would be unlike any other hospital ward or clinical, with alien looking technology situated in a cold and dark room. It appeared that maybe there was an element of 'performance' associated with this environment. Whereby the operator controls the performance, patient must do what they say, whereby the patient must remain still in that position for several seconds before the X-ray is taken. During this time the patient is left in the room and the performer (the operator) leaves the patient behind a protective lead screen whereby the X-ray is performed. At the speed of light this process is now complete and may or may not require further imaging.

Within the DR room, there is an array of technical information, suggesting the optimum exposures for particular examinations aiding to provide the operator with an exposure adequate for the radiological examination being undertake. Following this there is a document illustrating the diagnostic reference levels for particular examinations, thus highlighting the need to keep within these levels. Notices such as 'Are you using the correct lead protection?' were clearly demonstrated behind the lead screen. All of these notices aim to aid the operators and thus ultimately the patients. Not only were there clinical devices in the DR but also a set of ladders in the corner. And although this was a fully operational DR room it also allowed for cassette radiography as a computing device was mounted on the protective screen. Note that the DR system was fixed, and it did not have removable detectors, the detectors were fixed in the table and in the wall stand. The environment presents other sensory stimuli, such as a smell of burning, it was clarified that this was not from the equipment or room but from the neighbouring corridors and was present in the viewing room and other corridors alike. The temperature in the room was aimed to remain at a set temperature through air conditioning was fully active, similarly this present an acceptable level of noise in the room.

As a male I was required on occasions to leave the X-ray room, the operators would on occasion suggest that I leave if the patient required to remove items such as a bra, I was however invited back into the room once the bra had been removed to further observe the examination taking place.

I got the impression that the clinical X-ray room was the performance area and yet the viewing room was the place to discuss other matters, it was apparent for example that the staff would happily discuss matters regarding the equipment outside the X-ray room and in the clinical area. In this environment the 'processing room' was several meters away from any clinical area. There appeared to be a clear divide between the performance in the clinical room and the performance in the viewing room. Within the 'processing room' the coordinating radiographer would delegate work load and deal with the day-to-day requests or concerns via telephone or face to face with other members of staff. The radiographer would performed X-rays during the day therefore there role was demanding. They would be mainly resident in the viewing room and appeared to be there during the observations. Within the viewing room it was clear to see the notices and safety equipment such as the COSHH, emergency eye washing bottles, first aid and good practice for hand hygiene, and good practices for maintaining a good working clinical environment. White boards would highlight where other radiographers were (either on a portable or in a theatre). It would highlight current faults logged with specific radiography equipment or general issues within the department. Within the processing room computers were readily available for processing patient data, creating compact discs for others. There was the ability to still print X-ray films in the likelihood of a PACS system failure. The processing area provided educational facilities for the student radiographers to perform paperwork associated with their academic portfolios. The processing room itself has no secure access; accessible from the corridor where patients and the general public alike can observe. The area itself is considerably large when compared to other viewing rooms. Above the coordinator the CCTV was illustrated and this allowed staff members to view all aspects of the waiting room and corridors in the surrounding areas.

The waiting room was big and provides large cushioned chairs for the patients waiting for their X-rays. Within this waiting room other patients on other modes of transport were apparent including those in wheelchairs, A&E trolleys and hospital beds. The patient types varied from children, adolescents, adults and the elderly each with their clinical concern. A child's play area provided stimulus for infants. Within this area the visible aspects were the danger signs behind cupboard doors warning of electrocution, signs warning individuals not to use their mobile phones within the department.

The equipment

Throughout the three-hour observations of the Philips DR equipment a technical fault occurred with different operators of the equipment, it is a known fault with one of the sensors because although the machine was 'locked' into position for a radiographic examination to take place, the computer system did not recoginse it was 'locked in' and therefore it would not expose. When it recognised that the device was locked in a green circular light appeared on the exposure console, which deemed it necessary for it to expose. The issue highlighted by the members of staff was that this was completely random, on occasions they would have patients on the X-ray table, standing for Chest X-rays and then the equipment would not allow them to expose even though the equipment was set up and would allow them to exposure 10 seconds earlier. This was not the first time with this fault and was logged first thing in the morning and the radiographers had organsied for an engineer to come in immediately to fix the issue. This 'green light issue' which it became to be known would occur during most of the radiological examinations examined throughout the 3 hour observational block.

It was observed that on the whole, radiographers would not alter the preset kVp and mAs settings. It was mentioned several times by the radiographers, including a senior radiographer that 'someone preferred the images in the other room, although the doses are much higher'… This comparison was made with another DR room, a piece of Carestream DR equipment. However it was mentioned in the viewing area that the does appeared much higher in the other DR room when compared to the Philips room. This was mentioned informally by several radiographers to whom have worked with the equipment.

It was commonly recognised that operators would not place markers on the detectors and would use the markers on the DR system, thus placing them on post radiation exposure. Similarly it was noted that operators do 'crop the image' post exposure,

One obstacle the staff recognised with the DR system was that on certain examinations the equipment was not as flexible as they would have liked. For example the equipment would only expose when ‘locked in’ a certain position. Therefore if you move the equipment out of this position it would not let the operator expose, therefore the operators had to move the patient into position on the upright detector, which took longer to do.

An aspect of the DR equipment can allow it to be controlled by a remote control if required, however I did not observe any operators doing this. Once the equipment is ‘locked’ into position the operator may stay with the patient on the erect detector and move the detector, this will in turn move the X-ray tube, this practice allows the operator to be with the patient at all times and not have to move both wall detector and X-ray tube into position. We talked about the performance from the staff however what about a performance from the equipment, this equipment is essential to patients care, however it is was often talked to as it if had a personality, whereby it would not comply with what the operator wanted it to do and would therefore not be ‘playing ball’. This is not only a performance for the patient but for the radiographers and others within the department.

<u>The staff</u>

Throughout the observations I observed several operators, both assistant practitioners and practitioners. One AP had over 5 years’ experience and some of the radiographers had between 2 and 10 years’ experience. What was highlighted was that because I also practice as a radiographer on occasion’s radiographers would ask my opinion regarding a certain technique, for example an ‘AP skull’ as these are regarded as uncommon techniques to perform, which proved problematic for the junior radiographer. Throughout the observations it was recognised that all operators generate sound rapor with the patients and many were thanked as patients left the X-ray rooms. Patients often asked questions regarding their care and/or results and the operators would ensure that the correct information was given at all times answering the patients concerns.

One staff did ask questions regarding the X-ray form she had and whether the patient should be given it back for them to take to A&E, she was unaware of the

processed because she normally works at another site, therefore unfamiliar with the process. She asked for my opinion however I was unable to help her on this occasion as I was also unaware of the process, as I had never worked at the site.
After one X-ray of a patient an operator had come up to me and confirmed that a patient had seemed quite 'offish' with her. She said that she had identified as soon as the examination has taken place. She asked whether I felt the same and I did agree that I felt the patient was 'offish' with the radiographer. This patient had attended for a thumb and follow-up scaphoid X-rays and the examination took no longer than 5 minutes to complete. What was observed was that we healthcare professionals the operators had an immediate opinion of that patient.

During one examination I was asked by the radiographer 'are we passing for you', I simply replied, 'of course' and smiled. This was the first glimpse into where there may be hostility within the observational aspect of this study.

Techniques

Interestingly the AP shoulder projection was set up to use the AEC central chamber, however when the operator (a practitioner of more than 10 years' experience) did not center over the central chamber and exposed the patient. While observing the radiographers in the working environment, I had witnessed good practice, in the fast paced environment radiographers produced images of diagnostic quality which were acceptable for submission to the PACS system, ready to be interested by the refer and/or reported on also. On a whole the exposures used were generally from the preset exposures on the machines, one example for a DP foot projection was 52 kVp and 3.2 mAs, thus producing an image of diagnostic quality. There was one occasion whereby an operator reduced their kVp as the patient was much smaller than your average patient and again produced an image of diagnostic quality. Collimation was however an aspect where on occasions it would be cropped on the post processing images, therefore although initially they had collimated, they had in fact in their opinion from their image to have actually over collimated and therefore operators would 'crop' the image before it was sent to PACS. The observation of DR had identified that there was a difference in radiographic technique when compared to CR systems, for example on this observation the use of the AEC was used for an AP shoulder projection, they are able to move both X-ray tube and detector simultaneously yet only moving the detector in order to be nearer the patient. Secondly after the X-ray exposure has occurred the image is displayed on the computer system, radiographers when use tools to crop the radiographic image and place annotations onto it.

Challenges to observing DR practice

The challenges presented with observing DR for the first time was the time frame, through the radiological examinations observed a chest X-ray would have been completed in just over one minute, therefore in order to collect as much information as possible I have needed to adapt ones observing techniques and only document the vital information required. In its own sense this is the culture presented to operators in that they are able to perform radiological examinations this fast, therefore is this the norm? This intern highlights the ethnographic issues in observing radiographic practice, to this is not gradual, whereby an research may observe a doctor or nurse with a patient over a period during the course of a consultation or treatment, during a radiographic examination one patient may enter and leave the X-ray room in just over one minute, therefore capturing the essence of the digital requires ‘quick fire ethnography’ and on occasions retaining a lot of information from memory and making note when there is an opportunity to do so. Other challenges experienced included the issues in that I was required at times to assist with aspects in the room, due to my status operators would ask for me to have a look at the equipment or ask to chaperone family members, on these occasions I was difficult to take note and therefore I had to remember the situation and note much later. The other challenged experience was that because I was waiting in a DR room I had to rely on the examinations brought in by the radiographers and in a three hour observational block I did not receive a hand or wrist examination, which are of importance and what I will be using to produce laboratory data.

Appendix 12: Radiographic extremities documented

Site A – Hand examinations observed

Exam	Patient ID	Operator	Projection	Detector	Focus	Preset kVp/mAs	kVp/mAs Used	SID	FS (cm)	Crop	B/C Adjusted?	EI	Over|Acceptable|Under	DAP (cGycm2)	Comments
Hand		Rad ±5	OBL	Wall	Fine	50/2	50/2	98.0	19 x 26	No	No	200	Acceptable	1.54	None
			OBL	Wall	Fine	50/2	50/2	98.0	17 x 27	Yes	No	200	Acceptable	1.41	None
			DP	Wall	Fine	50/2	50/2	100.0	25 x 17	No	No	200	Acceptable	1.23	None
Hand	E01614766	Rad 3	DP	Wall	Fine	50/2	50/2	93.0	29 x 18	No	No	160	Acceptable	1.75	None
			OBL	Wall	Fine	50/2	50/2	93.0	28 x 19	Yes	No	160	Acceptable	1.84	None
			LAT	Wall	Fine	50/2	50/2	93.0	27 x 11	No	Yes	400	Under	1.05	None
Hand	E01364696	Rad 2	DP	Wall	Fine	50/2	50/2	100.0	19 x 27	Yes	No	160	Acceptable	1.56	None
			OBL	Wall	Fine	50/2	50/2	100.0	25 x 17	No	No	160	Acceptable	1.28	None
Hand	E917347	AP 5	DP	Wall	Fine	50/2	50/2	97.0	26 x 17	No	No	125	Over	1.91	None
			OBL	Wall	Fine	50/2	50/2	98.0	24 x 13	No	No	160	Acceptable	1.37	None
Hand (Wrist included)	E852595	Rad 1	DP	Wall	Fine	50/2	50/3.2	83.0	37 x 17	No	No	100	Over	4.30	None
			OBL	Wall	Fine	50/2	50/2	89.0	28 x 18	No	No	160	Acceptable	2.16	None
Hand	E01472097	Rad 1	DP	Wall	Fine	50/2	50/2	101.0	33 x 19	No	No	160	Acceptable	1.82	None
			OBL	Wall	Fine	50/2	50/2	101.0	26 x 18	No	No	200	Acceptable	1.40	None
Hand	E606086	Rad ±5	DP	Wall	Fine	50/2	50/2	100.0	25 x 18	No	Yes	200	Acceptable	1.35	None
			OBL	Wall	Fine	50/2	50/2	100.0	26 x 22	No	Yes	250	Acceptable	1.77	None
Hand	E900286	Rad 1	DP	Wall	Fine	50/2	50/2	102.0	26 x 18	No	No	160	Acceptable	1.82	None
			OBL	Wall	Fine	50/2	50/2	102.0	26 x 16	Yes	No	160	Acceptable	1.67	None
			LAT	Wall	Fine	50/2	50/2	101.0	24 x 11	No	No	160	Acceptable	1.27	None
Hand	E01508024	Rad 2	DP	Wall	Fine	50/2	50/2	108.0	21 x 29	No	No	200	Acceptable	2.08	None
			OBL	Wall	Fine	50/2	50/2	108.0	18 x 25	No	No	250	Acceptable	1.52	None

Site A – Wrist examinations observed

Exam	Patient ID	Operator	Projection	Detector	Focus	Preset kVp/mAs	kVp/mAs Used	SID	FS (cm)	Crop	C/B Adjusted?	EI	Under|Over|Acceptable	DAP (cGycm2)	Comments
Wrist	E950526	Rad 1	DP	Wall	Fine	57/2	52/2.5	107.0	20 x 9	No	No	200	Acceptable	0.70	None
			LAT	Wall	Fine	57/2.5	52/2.5	107.0	22 x 7	No	No	250	Acceptable	0.58	None
Wrist	E330755	Rad 5 ±	DP	Wall	Fine	57/2.5	57/2.5	106.0	11 x 21	No	No	160	Acceptable	1.06	Pb Apron-Patient Pregnant
			LAT	Wall	Fine	57/2.5	57/2.5	106.0	9 x 20	No	No	200	Acceptable	0.89	Pb Apron-Patient Pregnant
Wrist	E01407361	Rad 10+	DP	Wall	Fine	55/2	55/2	94.0	20 x 11	No	No	200	Acceptable	1.31	None
			LAT	Wall	Fine	55/2	55/2	93.0	8 x 17	No	No	400	Under	0.82	None
Wrist	E867596	Rad 6-10	DP	Wall	Fine	55/2	55/2	112.0	26 x 13	No	No	250	Acceptable	1.52	None
			LAT	Wall	Fine	55/2	55/2	113.0	29 x 11	No	No	320	Under	1.41	None
Wrist	E01352394	Rad 6-10	DP	Wall	Fine	57/2.5	57/2.5	104.0	24 x 10	No	No	125	Over	1.21	Room 1-exposures differ
			LAT	Wall	Fine	57/2.5	57/2.5	104.0	24 x 8	No	No	200	Acceptable	0.93	None
Wrist	E904501	Rad 6-10	DP	Wall	Fine	55/2	55/2	96.0	24 x 13	No	No	250	Acceptable	1.78	None
			LAT	Wall	Fine	55/2	55/2	104.0	24 x 10	No	No	400	Under	1.23	None
Wrist	E958953	AP 2	DP	Wall	Fine	55/2	55/2.0	109.0	29 x 11	No	No	250	Acceptable	1.49	None
			LAT	Wall	Fine	55/2	55/2	109.0	17 x 13	No	No	200	Acceptable	0.97	None
Wrist	E852595	Rad 1	DP	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	None
			LAT	Wall	Fine	57/2.5	60/2.5	83.0	31 x13	No	No	125	Over	3.45	None
Wrist	E913448	Rad 1	DP	Wall	Fine	57/2.5	60/3.2	100.0	29 x 17	No	No	100	Over	3.66	None
			LAT	Wall	Fine	57/2.5	60/3.2	100.0	30 x 13	No	No	125	Over	3.05	In Cast
Wrist	E904501	Rad 10	DP	Wall	Fine	55/2	57/2.5	102.0	24 x 8	No	No	320	Under	1.44	None
			LAT	Wall	Fine	55/2	60/2.0	110.0	18 x 9	No	No	320	Under	1.43	None
Wrist	E024234	Rad 10	DP	Wall	Fine	55/2	55/2	109.0	23 x 11	No	No	200	Under	1.19	None
			LAT	Wall	Fine	55/2	55/2	108.0	9 x 23	No	No	200	Acceptable	0.98	In Cast

<u>Site C – Wrist examinations observed</u>

Exam	Patient ID	Operator	Projection	Detector	Focus	Preset kVp/mAs	kVp/mAs Used	SID	FS (cm)	Crop	C/B Adjusted?	EI	Over|Acceptable|Under	DAP (cGycm2)	Comments
Wrist	41595209	Rad 6-10	DP	Wall	Fine	60/1.6	60/1.6	100.1	11 x 20	No	No	0.91	Acceptable	1.00	None
			LAT	Wall	Fine	60/2	60/2	100.1	9 x 18	No	No	0.77	Acceptable	1.10	None
Wrist	40666182	Rad 6-10	DP	Wall	Fine	60/1.6	60/1.6	91.4	12 x 23	No	No	1.12	Acceptable	1.60	None
			LAT	Wall	Fine	60/2	60/2	91.1	11 x 22	No	No	0.89	Acceptable	1.70	None
Wrist	41241423	Rad 2	DP	Wall	Fine	60/1.6	60/1.6	102.0	10 x 21	No	No	0.77	Acceptable	1.00	None
			LAT	Wall	Fine	60/2	60/2	102.1	10 x 22	No	No	0.69	Acceptable	1.10	None
Wrist	40734398	Rad 1	DP	Wall	Fine	60/1.6	60/1.6	77.2	10 x 20	No	No	1.25	Acceptable	1.70	None
			LAT	Wall	Fine	60/2	60/2	77.1	8 x 17	No	No	1.32	Over	1.30	None
Wrist	41583302	Rad 1	DP	Wall	Fine	60/1.6	60/1.6	73.4	20 x 15	No	No	1.38	Over	2.60	In Cast
			LAT	Wall	Fine	60/2	60/2	85.5	10 x 19	No	No	1.23	Acceptable	1.60	In Cast
Wrist	41077152	Rad 1	DP	Wall	Fine	60/1.6	60/1.6	90.4	13 x 20	No	No	0.71	Acceptable	1.50	In Cast
			LAT	Wall	Fine	60/2	60/2	94.2	12 x 18	No	No	0.83	Acceptable	1.50	In Cast
Wrist	40490684	Rad 3	DP	Wall	Fine	60/1.6	60/1.6	100.1	24 x 11	No	No	0.47	Acceptable	1.29	None
			LAT	Wall	Fine	60/2	60/2	100	20 x 12	No	No	0.52	Acceptable	1.41	None
Wrist	41623878	Rad 1	DP	Wall	Fine	60/1.6	60/1.6	95.2	13 x 20	No	No	0.82	Acceptable	1.37	None
			LAT	Wall	Fine	60/2	60/2	95.7	8 x 21	No	No	0.66	Acceptable	1.11	None
Wrist	41241423	Rad 2	DP	Wall	Fine	60/1.6	60/1.6	100.1	13 x 21	No	No	0.85	Acceptable	1.28	None
			LAT	Wall	Fine	60/2	60/2	100.2	12 x 24	No	No	0.74	Acceptable	1.78	None
Wrist	40916860	Rad 1	DP	Wall	Fine	60/1.6	60/1.6	100	13 x 23	No	No	0.68	Acceptable	1.42	None
			LAT	Wall	Fine	60/2	60/2	100	12 x 24	No	No	0.66	Acceptable	1.29	None
Wrist	41617407	Rad 6 - 10	DP	Wall	Fine	60/1.6	60/2	101	9 x 23	No	No	0.91	Acceptable	1.30	None
			LAT	Wall	Fine	60/2	60/2.5	101	10 x 23	No	No	0.99	Acceptable	1.60	None
Wrist	40483354	Rad 1	DP	Wall	Fine	60/1.6	60/1.6	91.0	13 x 22	No	No	0.88	Acceptable	1.68	None
			LAT	Wall	Fine	60/2	60/2	100.0	13 x 24	No	No	0.81	Acceptable	1.88	None
Wrist	41617407	Rad 6-10	DP	Wall	Fine	60/1.6	60/2	101.0	9 x 23	No	No	0.91	Acceptable	1.30	In Cast
			LAT	Wall	Fine	60/2	60/2.5	101.0	10 x 22	No	No	0.99	Acceptable	1.60	None
Wrist	40363485	Rad 1	DP	Wall	Fine	60/1.6	60/1.6	92.0	13 x 22	No	Yes	0.53	Acceptable	1.62	None
			LAT	Wall	Fine	60/2	60/2	92.0	10 x 17	No	No	0.42	Acceptable	1.21	In Cast
Wrist	41345427	Rad 2	DP	Wall	Fine	60/1.6	60/1.6	91.9	17 x 25	No	No	1.00	Acceptable	2.42	None
			LAT	Wall	Fine	60/2	60/2	94.4	9 x 24	No	No	0.71	Acceptable	1.56	None
Wrist	40687760	Rad 1	DP	Wall	Fine	60/1.6	60/1.6	101.0	8 x 23	No	No	0.90	Acceptable	0.90	None
			LAT	Wall	Fine	60/2	60/2	101.0	6 x 20	No	No	0.64	Acceptable	0.75	None
Wrist	40403684	Rad 1	DP	Wall	Fine	60/1.6	60/1.6	93	14 x 24	No	No	0.77	Acceptable	1.85	None
			LAT	Wall	Fine	60/2	60/2	96	13 x 24	No	No	0.77	Acceptable	2.04	None
Wrist	40493049	Rad 2	DP	Wall	Fine	60/1.6	60/1.6	91.2	10 x 25	No	No	0.41	Acceptable	1.50	None
			LAT	Wall	Fine	60/2	60/2	94	11 x 23	No	No	0.40	Under	1.60	None
Wrist	40949027	Rad 1	DP	Wall	Fine	60/1.6	60/1.6	100	14 x 22	No	No	0.60	Acceptable	1.48	None
			LAT	Wall	Fine	60/2	60/2	100	14 x 26	No	No	0.65	Acceptable	2.18	None
Wrist	41324676	Rad 1	DP	Wall	Fine	60/1.6	60/1.6	100	13 x 22	No	No	0.81	Acceptable	1.40	None
			LAT	Wall	Fine	60/2	60/2	100.0	12 x 22	No	No	0.79	Acceptable	1.60	None

Site C – Hand examinations observed

Exam	Patient ID	Operator	Projection	Detector	Focus	Preset kVp/mAs	kVp/mAs Used	SID	FS (cm)	Crop	C/B Adjusted?	EI	Over|Acceptable|Under	DAP (cGycm2)	Comments
Hand	41115615	Rad 3	DP	Wall	Fine	55/1.6	55/1.6	100.3	19 x 24	No	No	0.70	Acceptable	1.70	None
			OBL	Wall	Fine	55/1.6	55/1.6	100.4	18 x 24	No	No	0.67	Acceptable	1.70	None
			LAT	Wall	Fine	60/2.5	60/2.5	100.4	10 x 24	No	No	0.78	Acceptable	1.80	None
Hand	40247206	Rad 3	DP	Wall	Fine	55/1.6	55/1.6	94.7	17 x 24	No	No	0.85	Acceptable	1.80	None
			OBL	Wall	Fine	55/1.6	55/1.6	95.6	18 x 24	No	No	0.74	Acceptable	1.90	None
			LAT	Wall	Fine	60/2.5	60/2.5	95.6	10 x 26	No	No	0.79	Acceptable	2.20	None
Hand	40403137	Rad 2	DP	Wall	Fine	55/1.6	55/1.6	103.6	17 x 25	No	No	0.73	Acceptable	1.60	In Cast
			LAT	Wall	Fine	60/2.5	60/2.5	103.6	14 x 26	No	No	1.19	Acceptable	2.60	In Cast
Hand	40673027	Rad 1	DP	Wall	Fine	55/1.6	55/1.6	100.0	16 x 24	No	No	0.82	Acceptable	1.66	None
			OBL	Wall	Fine	55/1.6	55/1.6	100.0	16 x 22	No	No	0.76	Acceptable	1.43	None
			LAT	Wall	Fine	60/2.5	60/2.5	100	10 x 23	No	No	0.72	Acceptable	1.83	None
Hand	40465509	Rad 2	DP	Wall	Fine	55/1.6	55/1.6	96.3	20 x 27	No	No	0.78	Acceptable	2.26	None
			OBL	Wall	Fine	55/1.6	55/1.6	96.4	18 x 25	No	No	0.71	Acceptable	1.98	None

Appendix 13: Interview Schedule (final version)

1. Can you tell me when you first started using DR?
    a. As a Student? Probe was this a benefit and how would it compare if they did not receive training in a clinical environment?
    b. Since a Radiographer? Probe whether they think they were at a disadvantage of having to learn the DR technology ‘on the job’.
2. Can you tell me about any education that you have received in relation to DR?
    a. Probe at University?
    b. Was this appropriate for clinical use?
    c. Did the University have DR equipment?
3. Can you describe any DR training or education received within the imaging department?
    a. Probe was it appropriate?
    b. Would you have preferred more / or to been have trained in a different way, if so how?
4. What other training or education do you think would have been useful either at University or in practice?
    a. Probe such as an understanding of the detectors?
    b. An understanding regarding the algorithms?
5. How long did it take to feel confident using the DR system?
    a. Probe are there any areas which still concern you as a radiographer?
6. Can you identify areas where DR aids your clinical practice?
7. Can you identify areas where DR hinders your clinical practice?
8. How you change your radiographic technique when using DR, compared to CR?
9. How often do you rely on the exposure index during DR examinations and for you is it an accurate assessment of the image quality produced?
    a. Probe Are there occasions where you may use your own clinical judgment, regardless of the EI?
10. Do you think technology such as DR is having an affect on our radiographic profession? If so or not can you provide some examples of this?
    a. Probe for the radiography students?
    b. For healthcare professionals?
11. In our profession we have a particular set of skills to obtain an image of diagnostic quality, can you tell me what you think these skills are?
    a. Probe: How do you think others perceive our skills within our profession?
    b. How do you think this skill base affects our radiographic profession?
12. Do you think the DR technology affects the patients’ care and experiences during their X-ray examination?

   a. Probe: Does it affect the healthcare professionals relationship with their patients?

13. Do you think there are aspects of the patient, which alter our decisions in how we as radiographers obtain an image of diagnostic quality from our patient in choosing either DR or CR technology, such as a patients:
    a. Illness?
    b. Mental state - non compos mentis?
    c. Mobility?
    d. Hygiene and smell?
14. During my observations in a number of different hospitals over a number of days observing lots of different staff I have notice that:
    a. No Pb used – Question: The use of lead was rarely used when irradiating adult patients – can you tell me why you think this may be?
    b. Adjustment in brightness and contrast on X-ray images – Can you tell me what you think are the advantages and disadvantages are of being able to manipulate image contrast and brightness post exposure?
    c. Post image cropping – Question: Although the use of cropping images varies at the different sites observed, why do you think there is a tendency to crop X-ray images in practice?
    d. Altering exposure factors – Can you tell me how accurate the pre-set exposures are on the DR console? Can you give some examples when you may adjust them?
    e. Limitations of equipment and environment– How do you feel about the environment, setting and arrangement of the DR equipment and its use on specific patients compare with CR? And how do you think this could be improved for the operator?
    f. During the extremely busy periods within the imaging department do you feel that there may be a tendencies to alter ones practice in order to reduce waiting times for other patients?
        i. Probe such as using CR, whereby DR may be used?
        ii. Being able to use concentrate on using protective measures such as lead protection?
15. And Finally….Is there anything about the DR system that I haven't asked you that you think is important and would like to discuss?

<u>Thank you for your time!!!</u>

Appendix 14: Example of transcribed semi-structured interview

Respondent Mick

Researcher: Can you tell me when you first started using digital radiography?

Mick: October… Well, technically I started using it in 2010-ish, early 2010, because I used it when I was on my electives.

Researcher: So you used it as a student.

Mick: Not as a student.

Researcher: Only on the electives.

Mick: Yes, I used it for about what, two weeks?

Researcher: So mainly as a radiographer then.

Mick: Yes. Well, since I've been qualified I've been using it in Medway.

Researcher: So do you think that learning it on the job as a radiographer, you were at more of a disadvantage in that way - having to learn on the job? Would you have preferred maybe education as a student?

Mick: I think that ideally as a student, it's best to use different sorts - to use both and mix it - to use both CR and DR, so you get a more appropriate skillset when you qualify. But it's not a big thing. I wouldn't say that it's an essential thing, but it would help you if you are going into a different environment. Because I can see how, if you went into a hospital which is all DR, and you've not used DR before, how you would be at somewhat of a disadvantage compared to other people who have used it before.

Researcher: Fair enough - excellent. Can you tell me about any education that you've received in relation to DR? For example, at university?

Mick: I can't remember that much.

Researcher: How much of it was there, do you think?

Mick: There were a couple of lectures. with Christopher Geoffreys.

Researcher: Was it enough, do you think?

Mick: I think there was enough - because it was mainly surrounding the DR physics, and how they produce the images. From that respect. Because most of your technique, you learn on placement anyway. Well, when I was at university. “When I was at university…” [laughter] In regards to technique, it wasn’t taught.

Researcher: OK. So do you think then this education at university was appropriate for clinical use?

Mick: Yes. Because it gives you the background information that you need to be able to understand how to produce images. And image optimisation to a certain extent.

Researcher: OK. And what was that - can you go into that? What did they teach you - can you remember? Was it detectors?

Mick: It was to do with detectors and how the image is formed. The physics-y bit.

Researcher: Was there a lot of technique in optimisation [like] “if you did this, you’d get a better image”?

Mick: No, there wasn’t that. It was the basics of…

Researcher: The physical part of it, the image acquisition sort of thing.

Mick: It wasn’t full-on. When I was originally trained in the DR room, the applications specialist was here, so the applications specialist and the engineer were talking more about image optimisation in that respect.

Researcher: OK, good. Did the uni have DR equipment?

Mick: No. The Medway campus at the time - I don’t know if it’s changed, but at the time, it had CR.

Researcher: Can you describe any DR training or education received within the imaging department?

Mick: I had CNST? Which was done by the trainer in the room.

Researcher: OK. What's the CNST?

Mick: I'm not sure what CNST stands for, but it's essentially to say you're competent in every aspect to use that room, and to know where all the buttons are and what all of the programs do. And how to fix things if they go wrong.

Researcher: Oh right. Is that something from the applications specialist?

Mick: No, that is… I don't know if other hospitals have it, but at Medway it's your competency to say that you are competent to use a piece of equipment in regards to either producing a radiographic image, or... Even CR units have them.

Researcher: And the IIs I assume, and things like that.

Mick: IIs, yes. QI equipment's got one - all that stuff.

Researcher: OK, good. Excellent. So do you think that was appropriate?

Mick: I think if it's done properly, yes.

Researcher: So there are instances where it might be not? Some people have not even mentioned it.

Mick: No, this is the thing. People don't always get trained by people who should be training. It becomes something where "someone told me to do this", but it's not the right way. So therefore you're not necessarily getting optimal images and you're not reducing the dose to the extent that you could do, because it's just hearsay. And it's not necessarily right, because I've been in there with newly qualified members of staff and no offence to them, but they don't understand things as well. Because they've said "Oh well, Thingamajig did it this way" and you go "Well actually, that's not how you do it."

Researcher: But because they've been shown that way -

Mick: Because they've been.

Researcher: And they get an image. It might not be optimal or the right way of doing it, but they sort of get into that way of -

Mick: Yes. It's the way that they've been taught, so therefore that's the way that they follow, because they don't know -

Researcher: Any better. So that's quite a thing, isn't it really? OK.

Mick: It's to do with staffing issues and things like that.

Researcher: Yes, there's things like that, isn't there? Would you have preferred more or to have been trained in a different way within the department? And if so, how?

Mick: I think the way that I got trained was when the applications specialists were present, as well as the room trainer. I think that was quite a good level of training, really.

Researcher: It is really, isn't it?

Mick: I think I caught quite a lucky break.

Researcher: Because a lot of people obviously don't get that.

Mick: No. A lot of people don't get the applications specialist. That would tend to be the first couple of months we were using the room. And obviously a lot of people that were trained by the applications specialist have moved into specialities and things like that.

Researcher: Yes, so you sort of lose that core training don't you as such? OK. What other training or education do you think would have been useful either at university or in practice?

Mick: Well… [pause]

Researcher: Do you think maybe such as the understanding of… or you said you were sort of educated in the understanding of detectors - maybe sort of with that, and the algorithms and things? Or things that are happening behind the scenes that we don't really see?

Mick: Yes, I think that would be good to a certain extent. I mean obviously, it's a background information sort of thing. Knowing how you get to that stage, I think it is. I think it would be useful. Obviously there are a lot of other things that you have to cover in your time at university, so obviously it's not...

Researcher: That's right, yes. So is there anything you think that would be useful, or were you quite happy with the…?

Mick: Personally, I was quite happy with the way that it was put across to me.

Researcher: Good. How long did it take to feel confident using the DR system here?

Mick: Er [pause]. Confident using it? I would say just a couple of sessions, probably. Two, three sessions? A day, a day and a half?

Researcher: So quite quick then.

Mick: Well yes, I'm quite into that sort of technological frame of mind.

Researcher: It helps.

Mick: It helps if you get on alright with technology, essentially. If you're alright with computers and things like that, you're fine. Because then you understand the filters and the way that it works. Because just the way that the GE system here was set up - it's not the most user-friendly. So you have to kind of know how to work it to get -

Researcher: Round things.

Mick: To get round certain aspects of the system which aren't user-friendly, or patient-friendly.

Researcher: OK. Can you elaborate on any of that?

Mick: Yes - it's just because the way the system works, it's not always… DR generally isn't. Because CR, you adapt the plate a lot more than… the plates aren't as adaptable in the DR environment. The way that the system works in there… when I've used other DR systems, they're very adaptable in terms of angles, and it can work quite well. Very similar to the way that I would use CR. If the patient can't do that, you adapt the environment to what the patient can do. Whereas the DR room seems to find it more difficult in that adaptation sort of angles [sic]. So you have to do free cassette more, and things like that. Which aren't ideal really. It's a heavy cassette, it's got a long lead - which isn't always best.

Researcher: So do you think there's a confidence - not just for yourself, but generally - issue with that then?

Mick: With that room?

Researcher: Yes.

Mick: I think with that system, there is. Unfortunately so. I think compared to some other units that I've used previously, the GE system doesn't fill you with confidence when it gets a bit finicky.

Researcher: Yes, fair enough. Good. Are there any areas which still concern you as a radiographer? In regards to the confidence, you mentioned the moving of the stuff and the detector and things - is there anything in particular in the entire system?

Mick: I would say probably the override concerns me. The use of the override.

Researcher: The turn of the key.

Mick: The turning of the key. Because obviously where people haven't… as I referred to earlier, people not getting trained appropriately has led to an increased use of the override in the system. Which probably isn't the best way to go about producing [an image].

Researcher: It was observed quite a bit that people would do that - that people would just -

Mick: Yes, that's what I'm saying. Because if you turn the key, the collimators come out. So you have to watch your collimation, which then affects dose and things like that. And also, if you're… when you put the override on, you don't have to… you can be anywhere. You can be pointing it at a totally different place. Because the plate doesn't always follow the tube when you put the override key on. So you can expose, and it won't come out. Because someone's pressed the override key and forgotten to turn it off.

Researcher: OK. I noticed that it affects -

Mick: I suppose essentially that's a radiation issue.

Researcher: I suppose if you look at it though - if you look at it from a CR perspective, we don't have that sort of feature, do we?

Mick: No.

Researcher: We can potentially have errors of over-collimation and… so I don't know, is there a tendency to sort of protect what we're doing - trying to restrict us, do you think? Or is it a safety [issue]? Do you think it's a good intention, sort of thing?

Mick: What, why people turn the key?

Researcher: Why the key's actually there in the first place, I suppose. Because we haven't needed that, have we?

Mick: Well, it's because the system that is installed will only let you expose if you are in the 38 by 38 detector. And if all of the light beam is within that detector area. And you have to be… I think it's about 8 degrees it will let you do. So you have to have 8 degrees or less, and all the light inside the detector area for it to expose. And when people perhaps lose patience with it, they find it a lot easier to turn the key than fiddle around with the free cassette etc. So I think it's more of a patience and a training issue. Because if you were trained to bring the free cassette out essentially straight away, then you wouldn't have that issue. And it would work.

Researcher: True. OK, good. Can you identify areas where DR aids your clinical practice? Where does it help it?

Mick: [pause] say that it aids clinical practice. As in skills?

Researcher: As in anything, really.

Mick: I think the throughput of the DR room essentially, because of the positioning of it and the use of the DR room in this department, where it's outpatients only. Well, not only, but the majority of the throughput is outpatients and it's in the outpatients area. It does get a lot of throughput in a short space of time, if it's used correctly. You can easily do more patients than a CR room.

Researcher: OK, good. Can you identify any areas where DR hinders your clinical practice?

Mick: Er, in regards to this department, it can be harder to man it in a way. Because where it's out of the department, and…

Researcher: So its location, more than…?

Mick: Its location more than… DR as a whole: my experiences previous to this system, DR was a very good tool. And I think if it had the right system and it had been thought through properly in the planning stage, then it would be a very useful system to have. And I think the problem with that is now that a lot of people I believe in this hospital or in this department, where they've been at Medway for a while, and they've only had exposure to CR, that isn't the best way to go about having your first experience of DR. Because now people are like "Well, the DR room's rubbish". But DR as a whole: that's the worst DR room I've used. My [other] experiences with DR are a lot better. I know that pretty much anything we get - if we got something different - would be better.

Researcher: Yes, OK. So it hinders mainly because of your previous experiences.

Mick: It's just the way -

Researcher: The actual whole thing itself - the way it's set up -

Mick: That room I think can be a hindrance, in the way that it's set up. They way that it's been thought through and the way that it's been planned. But DR as a system and as a way of working I think is a very useful way to work, and I think it's a very efficient way to work.

Researcher: Sure, OK. How do you change your radiographic technique when using DR compared to CR?

Mick: A lot of the time in DR, like I mentioned earlier, you have to work around the system rather than work around the patient. Which tends to be more the way with CR. So in a way, you adapt - in a way, it's quite good that you get outpatients, because you get *them* to move rather than moving the plate and the equipment and stuff like that.

Researcher: The patient's moving a lot more for our benefit, really.

Mick: Yes. Rather than us moving the stuff. To get the same image - well, a slightly better image.

Researcher: Do you think that's a hindrance in itself? Do you think for not so much us, but -

Mick: I think for the patients… if you have a patient who's not particularly ambulatory, I think that could be quite a hindrance, really. Recently I had a lady, and she was quite old and we had a lot of stuff to do. And she couldn't turn, and things like that. In which case, with the way the system works in that room, it was -

Researcher: You're restricted, aren't you?

Mick: It was restricted for her. If she'd gone to the CR room, maybe perhaps she would have had a better patient experience.

Researcher: OK. Do you think she would have done?

Mick: I think perhaps yes, because… Probably. I think so. Obviously, I treated her the same way and that, but perhaps in terms of time spent in the room, then I think perhaps she would have spent less time unfortunately, in the CR room.

Researcher: Because of the DR equipment. OK. How often do you rely on the exposure index during DR examinations and for you, is it an accurate assessment of the image quality produced?

Mick: I think usually it's quite reliable in that DR room. It's hard in a way, because obviously it goes back to how I was taught and that. I'm much more accustomed to the Kodak and the Fuji exposure indexes for the CR units. So I'm used to saying between -

Researcher: 1900 and unclear

Mick: Yes, around 1900. And whatever it is on the Fuji system - I can't remember. Whereas I'm not used to that exposure index to kind of place the equality. But it seems to be quite consistent in terms of body parts, when I've obviously observed it.

Researcher: And so is it a good aid for you in a sense?

Mick: Yes. You can look at it and say "That compares to what I've seen in the past". Because when I had my training, I don't remember the applications specialist saying "This is what it should be". In terms of consistency, it seems fairly consistent.

Researcher: So are there occasions where you may use your own clinical judgement, regardless of the exposure index - if it's, say, under-exposed? Or are you more on the edge of well actually, it should be within that range of exposure index for it to be diagnostic?

Mick: I think you can tell, really, when an image is of diagnostic quality.

Researcher: Irrespective of the exposure index?

Mick: I think in some cases, yes. Because I know this is off topic, but when I've used CR, and you say that it should roughly be on the Kodak system - around 1900. You look at it, and you say "Well, that's not really diagnostic for what they're looking for." And sometimes you'll get something which is by definition over the exposure index - so like, 2300 or 2400, something like that. And it will give you a much better, more diagnostic image for what they're looking for. So I think sometimes it does come down to clinical judgement, in a way.

Researcher: Because you mentioned CR exposure indexes and you know their values and things: with DR, are you quite familiar with them or is it a little bit of a grey area, sort of thing?

Mick: It is more of a grey area. Because obviously like I say, I didn't get trained using it. So I'm not 100% used to looking at it and going "<snaps fingers>, that's right!", or "That's not right". But when I'm in there, if I do a couple of body parts, then I'll be back saying "Oh, that's roughly…"

Researcher: Because it adds three boxes, doesn't it? It adds like… They're both amber if they're over or under and green if it's within the range. It's quite a nice indicator actually, isn't it?

Mick: It's quite easy.

Researcher: You don't have to know your numbers to unclear

Mick: Yes, if you're not hot on the numbers but you've got the green/amber system, so it's good in that unclear DR's got a lot more sort of recovery in it. The system can create a better image from when it's under-exposed or whatever. So sometimes it can be amber, but it's still a nice image which isn't worth repeating.

Researcher: But you do refer to the exposure index quite regularly.

Mick: Oh yes. It's there, isn't it?

Researcher: You can see it.

Mick: It's a handy tool.

Researcher: Yes, absolutely. Good stuff. So do you think then that technology such as DR is having an effect on our radiographic profession? If so (or not), can you provide some examples of this? As a whole.

Mick: As a whole, I think DR is good for the profession.

Researcher: Is it having an effect though?

Mick: I think it is. It's a different way of working. Because it's kind of moving with the times, in a way. It's a more technological area… era, even, and you have to move with the times. Everything's more computer-based now, and as a result, it's a more computer-based system. It's all linked together, it's a lot faster and that's what people tend to… These days, a lot of people want things that are fast, they want things that are efficient. And it's a fast, efficient system which is technologically relevant to the era that we live in, really. And I think there's only so much development that you can do within a CR, whereas with DR it seems to me that people are struggling. You've got DR mobile units - they're making them lighter, they're making them wireless, they're doing things like that. And it's having that sort of effect to drive the profession forward in that respect.

Researcher: OK. What do you think its effects are for DR? What do you think its effects are for radiography students, for example? I suppose it's different here in a sense because there's a lot of CR, and not so much DR.

Mick: I think in this department…

Researcher: But for DR-related - what do you think the effects may be for radiography students coming into the profession?

Mick: [pause] I think it depends, really. I think a lot of students now realise they're going into quite a technologically-based profession. I think it's quite a hard one to answer, really. In regards to the effects on them.

Researcher: Do you think it affects differently their education throughout their training?

Mick: I think so, because obviously you get trained differently because there's the wet film kind of people, who know how to use film and how to get it spot on in terms of when they develop. And then you've got the CR, and you've got the DR. I think there are three distinct ways in which people have learned. Because I learned using CR really, and the people before me were wet film. I think it will bring another kind of…

Researcher: Culture.

Mick: Yes. By learning that way - because essentially I've adapted my understanding about… But I took to it quite well. But you will have people that have essentially been brought up - not brought up, but that's how they've learned, so they will be -

Researcher: Because it's watch… how you, as a student - you watch don't you, and then you repeat.

Mick: They will be a lot more familiar with that system, so in a way, they could perhaps get better use out of it. Because they will be used to using perhaps DR only. I mean, at this department it's not quite as relevant, because you have a lot of CR. But in the future, or in DR-only or mainly-DR hospitals/departments, it will have a greater effect.

Researcher: OK, good. Do you think it's having an effect on us as healthcare professionals, the actual DR technology?

Mick: I think so, yes.

Researcher: What sort of effect have you seen, from yourself or…?

Mick: [pause] I don't really know, to be honest. I think it is having an effect in terms of… It's a different way of working, in that kind of sense. I mean, it's very technologically-based. But people these days use a lot of technology for a lot of things. So it's not really affecting that sort of… But it affects your practice and the way that you work, the way that you're able to adapt. Because perhaps in an A&E situation - because obviously our DR unit's here - we aren't in an A&E situation, but perhaps you'd use it differently so it would affect your practice differently in that way. But I wouldn't be able to comment 100%.

Researcher: No that's fine - no problem.

Mick: I think you need a flexi-room, kind of thing.

Researcher: Mmmm. One that you use for various patients on different pathways.

Mick: Yes, because you have… I know Philips do a good flex-room. The whole room is a lot more patient-friendly. So in a DR situation, when I went to the spinal centre for unclear the way that they used DR… their DR room was lovely. It doesn't affect the way that they work - they just produce nicer images. For imaging the spine, it's perfect.

Researcher: OK, good. In our profession, we use a particular set of skills to obtain an image of diagnostic quality. Can you tell me what you think these skills are?

Mick: To obtain the image, it's your technique, your exposure and patient interaction. Because if your communication's good with them, then they understand what you want from them and they understand what they've got to do to get the best image to help them get better. And if you know your exposure and your equipment to produce the best image in terms of diagnostic quality… yes, and your technique - if you've got technique that's good, then you will produce the images that need to be produced for the patient to go down the right pathway with the… ALOR? ALARA? The least dose for efficient treatment.

Researcher: OK. How do you think others perceive our skills within our profession?

Mick: Within the profession?

Researcher: Yes.

Mick: What, as in more specialist radiography or are you looking at general radiographers? Or CR radiographers?

Researcher: Maybe a bit of everything, really. Different modalities looking on general, or what they may perceive -

Mick: I think everyone is quite on the same page, really. Because everyone generally speaking kind of starts in a general environment. So even if you go to a specialist modality or you become a manager or whatever, you've got that background where you have worked in general for some period of time, no matter how short or long it's been. So they have an understanding, and I know that for instance people that have never used DR would be quite daunted by the use or however [sic]. But I think generally, there's a good perception. Is that OK?

Researcher: Yes, sure. How do you think that the skill base that you mentioned a bit earlier affects our radiographic profession?

Mick: What was I saying about the skill base earlier?

Researcher: You said about communication, exposures and unclear

Mick: Oh right, yes. Sorry.

Researcher: That's alright. So how do you think that affects our profession - does it really affect our profession, in a way?

Mick: I think it does. This is going to sound mean, but you have good radiographers and you have bad radiographers. You have radiographers who are very good with patients, and you have people that tend to have their areas where they excel, and you have people that are very good with other people - they're very… they're a people person. They're very good at communicating and getting the best of what they need from patients, perhaps in the situation of a paediatric patient. They're the people that can get the best from paediatric patients - they get them to keep still when required and do things like that. And you have other people that are perhaps better at kind of actually looking at exposures and looking at images, and things like that. You have areas which people excel in.

Researcher: Yes, there are different areas, aren't there? OK.

Mick: And some people are very good

Researcher: Yes [laughs]. Do you think that DR technology affects the patient's care and experiences during their X-ray examinations?

Mick: I think in this department it does, yes. I think a lot of outpatients now, especially with the way the department currently works, can be… say for instance if the DR room is down for whatever reason, if it's broken or if there's not enough staffing levels… whatever the reason may be, the knock-on effect in terms of… or even if you sent the DR patients to the main waiting area to have their X-rays done in the CR rooms, I think the experience… because from my experiences, when I've X-rayed patients these days, they are like "that's fast compared to…" because they come from outpatients, they sit there, you go talk to them and you get them in as soon as you're able. And it's not often you have a long wait. And they're still in the outpatients area to get seen by the consultant. So the actual transition through the patient pathway in terms of outpatients in general - maybe not perhaps physio or whatever but further down the line - but in terms of just X-raying outpatients, the interaction in that time there in hospital on that occasion is very good, I think.

Researcher: OK, good. Do you think it actually affects the healthcare professional's relationships with their patients, this DR technology? *Your* relationship with the patient.

Mick: I think in that split second, it probably does. Because obviously, if people wait longer, they get more irritable. So if someone's got a long wait, then perhaps not. I know that obviously if you're in hospital, you're probably not very well. So therefore you're not going to be in the best of moods most of the time. Fair enough. But having the experience where it's essentially streamlined, so you're getting your treatment as fast as it can go, nearly… that gives them a lot better relationship. Because they see you as facilitating them getting better as soon as possible, rather than being the person that they're kind of irritated at because they've been waiting for however long.

Researcher: So technology is helping that relationship between healthcare professionals and patients.

Mick: I think technology is, yes. I mean obviously in some respects, where you're getting them to move around more, they might associate you with perhaps being more mean, in a way. I know you do get them to move normally, but sometimes you can adapt the equipment for that little bit of angle to produce the same image. Whereas in the DR room, you're very much focused on getting that image by in a way, getting them to help you rather than you help them.

Researcher: Yes, I see what you mean.

Mick: So in a way, some people might think you're more mean or subconsciously they're associating you with more pain, perhaps. Because of the fact that you're getting them to move, when they don't -

Researcher: Necessarily need to, if it -

Mick: If it was in a different environment. If it was in a CR environment, you would perhaps do it slightly differently. Your practice.

Researcher: So it's sort of a bit of both, really. It's quite hard to answer.

Mick: I think consciously, yes. But subconsciously, maybe not.

Researcher: Yes. OK. Do you think there are aspects of the patient which alter our decisions in how we as radiographers obtain an image of diagnostic quality from our patient, in choosing either DR or CR technology? Such as a patient's illness, for example. Do you want me to repeat that?

Mick: Yes [laughs]

Researcher: Do you think there are aspects of the patient which alter our decisions in how we as radiographers obtain an image of diagnostic quality from our patient, in choosing either DR or CR technology? Such as a patient's… do you know what I mean by that? A patient comes in the room, and depending on whether they have a certain illness, you might go "Oh actually, we might need to do…"

Mick: Actually, I think there probably is. Because well, I dunno. Because you would say that some people, like I was saying earlier… some illnesses make people less ambulant, kind of thing. So they're less able to help you in a way, which we've already kind of touched on. In the DR room, you need people to help you, rather than you help them more. So you would say probably that less ambulant people would be better off with CR. But then again, you'd say things like… I know you can have CR units for it, but we don't have a CR long leg unit. So therefore, if people are going to have things like osteotomies and things like that, the doctor will refer them for something where they need to take a leg length measurement. That currently here is only available in the DR room. So therefore that unclear if you want to say, or that problem that they're going to get fixed they need to have done in the DR room. So I think… yes.

Researcher: So it does.

Mick: Yes. [laughter] That's it, yes.

Researcher: What about a patient's mental state? Like if a patient's non compos mentis for example and they come there on a trolley - do you think there may…? It's different here, because the DR room is out in the outpatients. But imagining your other experiences that you've witnessed, do you find that there is a tendency to use a certain technology rather than the other, depending on a person's mental state?

Mick: I think… obviously, when I've been out and about, I haven't seen an A&E unit where you've had a choice. You haven't had a choice between CR and DR.

Researcher: Oh really?

Mick: Yes. When I've been to places, they've either had all DR in the A&E, or all CR in the A&E. There hasn't been a mixture in the actual… for A&E patients, or perhaps in-patients. So I dunno, I think in a way, where I've previously said about the adaptability of CR, but then again it might be my learning experiences, where I haven't learned properly how to adapt with DR units. But I think that CR will probably give you that level of adaptability to not produce perhaps an optimal image in a difficult situation, but produce the best obtainable image as well.

Researcher: OK. So do you think it even comes down to the patient themselves in their hygiene and things like that? Does it come down to their personal state and things? Is that something where we make a decision based on that, do you think?

Mick: I think you could make a decision based on that - I can see how you would look at someone and say "well, I think that CR or DR would be more suited to what we're looking at on your person."

Researcher: Yes. OK. Excellent, thanks. Er… sort of lost it [laughter]

Mick: *Sort* of lost it?

Researcher: 1, 2, 3, 4… 6 questions. unclear So, during my observations in a number of different hospitals over a number of different days observing lots of different staff, I've noticed - and I've done it not only here, but at three sites in East Kent Trusts - I've noticed that lead is hardly or very rarely used. So the use of lead is very rare… just when irradiating adult patients unclear paediatric patients. Can you tell me why you think this may be?

Mick: It depends how people train. If you're trained in a way where people always put lead on people's laps… because I've experienced in my learning different radiographers working in different ways. And some radiographers, they will always cover… like if you're doing a finger, they will always put a lap belt on the person's lap when they're having their X-ray done. And that is just how they work. It's how they've always worked and that is it. Whereas there are other people who do not do that. Because they believe - and I can see the point from both ways - but they believe that if they've got collimation, fair enough there's scatter, but that scatter is not going to go far, in a way. You've got your inverse square rule and all that, which is preventing that from being what they consider an issue for the patient.

Researcher: Do you think it's an individual thing?

Mick: I think it is an individual thing - I think it's how you've been trained and then perhaps your research after you've qualified. Because I'm not sure about generally, but there are people that…on pregnant ladies, they will say that you do not cone because it can produce an internal scatter effect. What am I talking about - do not cone - do not put lead on, because of the internal scatter effect. So therefore it's causing more harm to the foetus in terms of your trapping X-rays coming back out, if they're high energy. To shoot back out the other way, rather than… so it's the kind of argument they use in nuclear Medway : "it'll go straight through you - don't worry about it". Whereas other people are saying "Well, you're going to stick it on because it will stop it going through in the first place." But then again, you could say that by putting that lead on, you're just slowing it down so it's more likely to stop on the way through. Or interact.

Researcher: Yes. OK. So it's quite individual, isn't it?

Mick: It is very individual.

Researcher: Er, there was a question I was going to ask unclear actually. It's escaped [laughter]

Mick: Lead? Babies?

Researcher: No, it was more…

Mick: Individual training? Learning? Research?

Researcher: [laughs] It was something like that. Talking about the lead: you were saying about the protection with lead, and how it's individual, and then the risk… It was more to do with the risk perception. I'm going to have to forget about it. No worries. Thank you for that, anyway. Er, adjustment of brightness and contrast on X-ray images: So this is still on the observations that

I've done: can you tell me what you think about the advantages and disadvantages of being able to manipulate image contrast and brightness post-exposure?

Mick: Pros and cons?

Researcher: Advantages and disadvantages, yes.

Mick: Well, I think there are pros and cons because… I'm not sure if this is perhaps correct, but this is what I have been informed by the pacs person: that they say when you alter an image's contrast density; you're altering essentially the algorithm and all that. So therefore you are altering the window in the pacs - how much they can play with it once it's onto the pax system. So therefore that would be a con, because if you've messed around with it already, to produce what you believe is the optimal quality, what you believe is the optimal quality and what a referrer or someone perhaps who's reporting it wants to look at isn't necessarily the same thing. So in that respect, it could be a con because you're windowing it and then they can't window to the same extent. Whereas if you'd just left it, then they can put it to how you thought it was best, and also look at whatever they wanted to look at in the future, if they're looking at… perhaps on a chest, if they're looking and comparing them together. They might want to look at something that they might have seen there, but they can't brighten it or darken it to the same extent as that one, and perhaps it could hinder prognosis. In an advantageous way, you are obviously doing your best to produce the optimal image.

Researcher: Yes. Advantages of it?

Mick: Producing the optimum image. So what you see is the unclear So it's both, really.

Researcher: In a sense it's difficult, because you're producing something that you think is good - that's the advantage. But then actually, it could be a disadvantage later on, which we never actually see.

Mick: Yes. That's further down the line, so in your head that doesn't… but then again, it could affect care further [down] the patient pathway.

Researcher: Good, OK. Post image cropping, shuttering and all that: although the use of cropping images varies at different sites observed, why do you think there is a tendency to crop X-ray images in practice?

Mick: I think people want to make them look… this is going to sound really… but people want to make them look pretty. They want to produce a nice picture, and if they've got perhaps information they don't need, or what they see as they don't need, they will crop it off. In this department, because of where we've worked with CR, the Kodak system doesn't allow cropping. So it's not generally the done thing. But you will see some of the newer members of staff cropping their images in the DR. I can see that people would perhaps… if they didn't want everything on there, because they've done something by mistake, they might cone it off perhaps. But perhaps that might be me being slightly cynical.

Researcher: No, that's fine [laughs]. Altering exposure factors: can you tell me how accurate the pre-set exposures are on the DR console, and can you give some examples of when you may adjust them?

Mick: Er, yes [laughter]. In my use of the system, they are quite accurate. I mean a lot of the time, it does work off like an OEC unclear. And once it feels that it's got enough to produce a nice image, then it will do that. However, obviously you alter it in terms of patient size and patient unclear and stuff like that. You would alter it to an appropriate level. Or if you're using not a free cassette, but a tethered cassette. If you've got it out of the wall or table bucky, then you put it on there, and you just go by your eye essentially. Pre-sets may not perhaps be… although usually they are best for producing the diagnostic quality that is required, they might not necessarily be -

Researcher: For the individual patient.

Mick: unclear

Researcher: Of course, yes. Limitations of equipment and environment - how do you feel about the environment, setting and arrangement of the DR equipment and its use on specific patients compared with CR? You've sort of mentioned it.

Mick: Yes, where do you want me to start? [laughs]

Researcher: How do you think this could be improved for the operator?

Mick: For the operator?

Researcher: Yes. Or for the patient.

Mick: I think generally speaking, the room isn't in the best place for its use. I would say that it would be better off in the general department perhaps - in the main department. Putting in a room by itself opens lots of cans of worms in terms of lone working. And if someone was perhaps unwell - in terms of that, and the way that the system is designed here isn't perhaps the most adaptable. Because other rooms here, you can just tilt it to however much angle you want.

That doesn't work as well in there. The placing of the couch: it's not perhaps the best place they could have put it in there - it's right in the corner. It's quite hard to -

Researcher: To get to.

Mick: If you perhaps wanted to do anything unclear, then that makes it quite difficult in that respect. Lots of little things really, that make it harder to use for the operator and in turn, perhaps more time consuming for patients. And not necessarily the best patient experience they could have.

Researcher: Sure, OK. Good. During the busy periods within the imaging department (DR related), do you feel that there may be tendencies to alter one's practice in order to reduce waiting times for other patients? We spoke a little bit about the relationship between that and trying to get them through and stuff.

Mick: I think it all relates back to that kind of override, where people don' have patience, so they're more likely to turn the override key. Which isn't best practice. Because they've got five or so patients or whatever, and they want to just get it done rather than -

Researcher: They don't want to lock it in in the right way.

Mick: No.

Researcher: You think that's an issue?

Mick: I think that would be an issue, yes.

Researcher: Do you think that also that in a sense, that rushed-ness, that sort of busy period that you get: do you think that sort of prevents the concentration of using protective measures?

Mick: I think yes - it does that as well, yes. I think because there is a lap belt in there for use. So therefore if it's not being used, it's not because it's not there. It's because people… the way they're thinking, it's not on their list of priorities when perhaps it should be. They're thinking "get the patient done" rather than "give the patient the best".

Researcher: Yes, I know what you mean. There is that sort of -

Mick: Do it, rather than…

Researcher: Thinking maybe. Or maybe not thinking, but -

Mick: Not thinking.

Researcher: Exactly. Excellent. And finally: is there anything about the DR system that I haven't asked you that you think is important and would like to discuss?

Mick: Not really. No, I think it's OK.

Researcher: Yes? Excellent. Thank you for your time.

Appendix 15: Quality Assurance on Digital Equipment

X-ray Beam Alignment

Site A & C

The X-ray beam alignment was tested using the Wisconsin RMI 161A and RMI 162A's (test tool). Its suitability is sound, calibrated to test misalignment to within 0.5 cm (IPEM 2010), constructed of brass; its centimeter etchings give ruled dimensions on the radiograph (Gammex RMI 2003). The X-ray has been scanned and can be found on pages 357 and 358. Collimators tested successfully; the x-ray field fell within 1cm of the rectangular frame. Furthermore the beam alignment is optimum as the top ball (larger shadow) intercepts the first circle, approximately 1.5º away from the perpendicular and within the second circle (IPEM, 2010).

kVp[2] and Output Test

Site A

Radiation output tests were carried out using a 'Unfors ThinX RAD' to measure the radiation output. It has a dose range between 20 µGy – 999 mGy and contained a precision ion chamber with an energy response of ± 3% from 45 to 150 kVp giving it the approval of action necessary to provide adequate confidence that radiation output will perform satisfactory and safely complying with agreed standards (IRR 1999). Filtration was added to the tube in order to evaluate the kVp; a thickness of absorbing material (Aluminium 2.5mm, Z=13) was used reducing the transmission of the beam by one half, thus comparing penetrating power of X-ray beams (IPEM 2010).

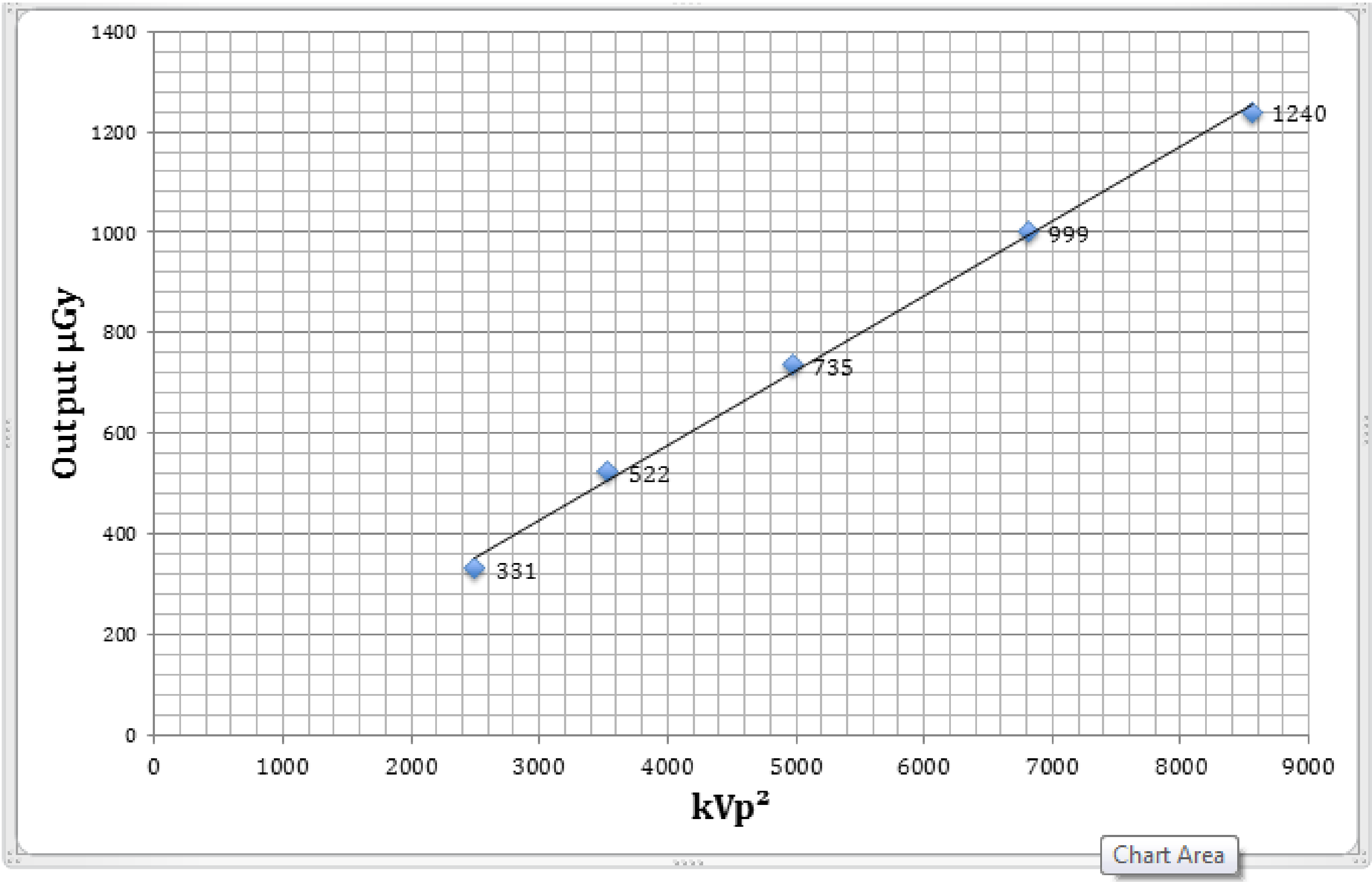
Table Eleven: kVp² Test - Site A

kVp	mAs	Output µGy (without Al)	Output µGy (with Al 2.5 mm)	Measured kVp	Measured kVp²	(DAP)	Pass / Fail
50	20	331	137	50	2500	()	Pass
60	20	522	246	59.5	3540.25	()	Pass
70	20	735	378	70.5	4970.25	()	Pass
81	20	999	559	82.5	6806.25	()	Pass
90	20	1240	720	92.5	8559.25	()	Pass

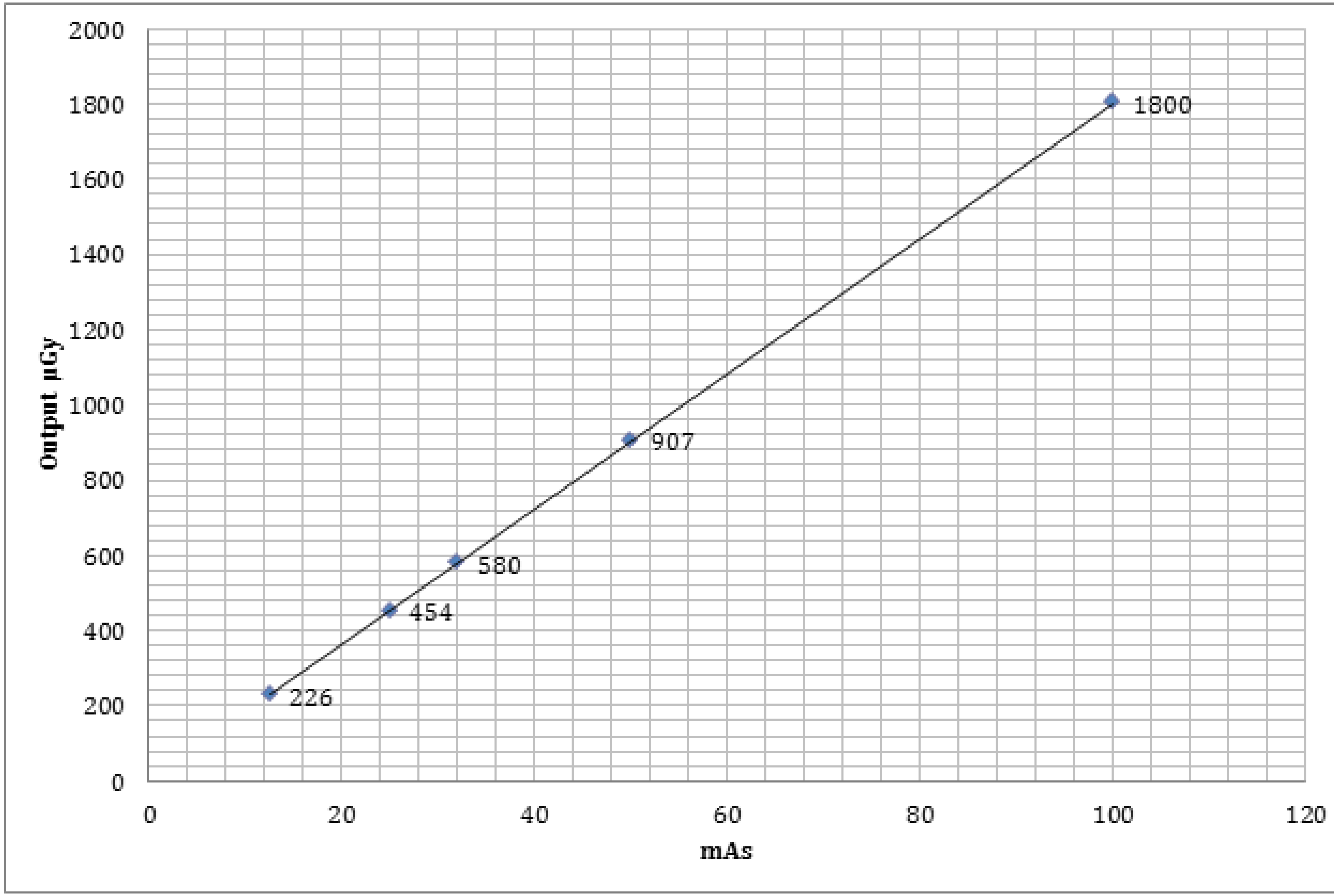
Table Twelve: Tube Output (mAs) – Site A

kVp	mAs	Output µGy
50	12.5	226
50	25	454
50	32	580
50	50	907
50	100	1800

Graph Six: kVp² Test - Site A



Graph Seven: Tube Output Test – Site A



Site C

For the output test at this research site C the '06-526 Rad Check™' tool was used to measure the radiation output. It ranges from 0.01 to 20 mGy; 0.1 to 200 mGy/min, contains a measurement area of 20.5 cm^2, a precision ion chamber, with an energy response of ± 5% from 30 to 150 kVp giving it the approval of action necessary to provide adequate confidence that radiation output will perform satisfactory and safely complying with agreed standards (IRR 1999). Both devices were suitable for QA testing complying with and IRR (1999) and IR(ME)R (2000) ensuring that the equipment is working and maintained at optimum levels and within safe limits (IPEM 2010).

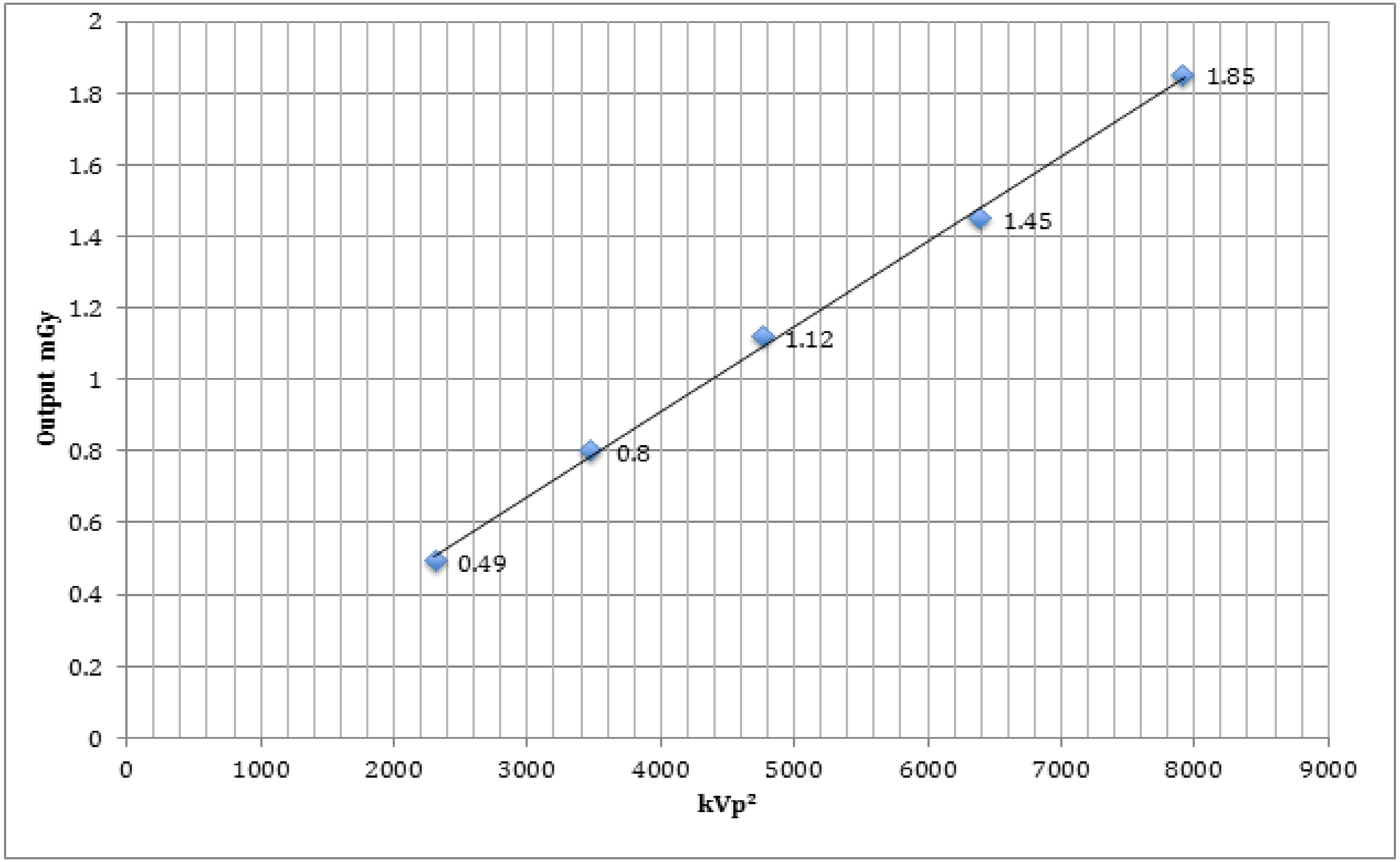
Table Thirteen: kVp^2 Test - Site C

kVp	mAs	Output mGy (without Al)	Output µGy (with Al 2.5 mm)	Measured kVp	Measured kVp^2	(DAP ($dGycm^2$))	Pass / Fail
50	20	0.49	0.12	48	2304	(0.61)	Pass
60	20	0.80	0.24	59	3481	(0.96)	Pass
70	20	1.12	0.41	69	4761	(1.37)	Pass
80	20	1.45	0.62	80	6400	(1.81)	Pass
90	20	1.85	0.87	89	7921	(2.31)	Pass

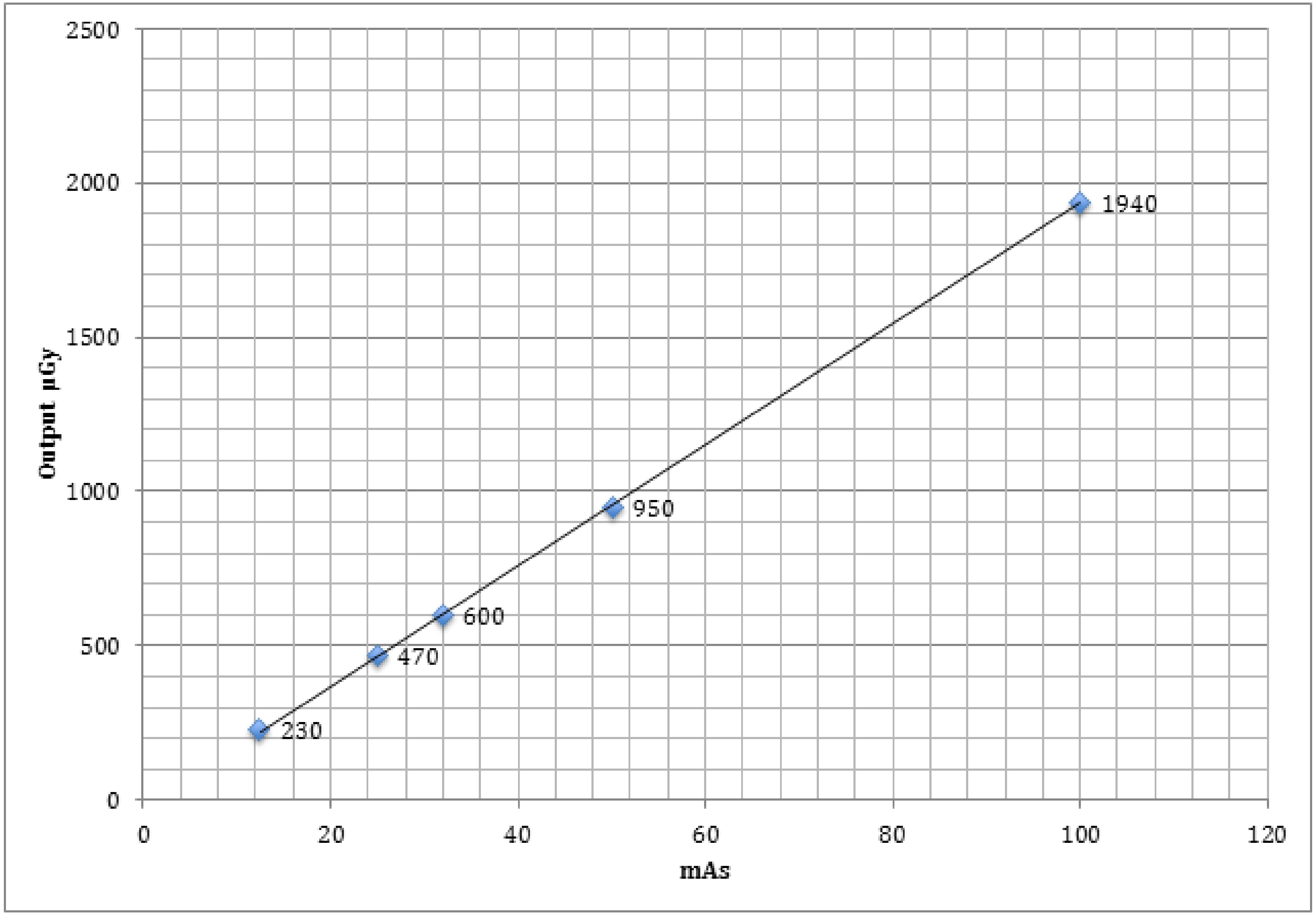
Table Fourteen: Tube Output (mAs) – Site C

kVp	mAs	Output µGy
50	12.5	230
50	25	470
50	32	600
50	50	950
50	100	1940

Graph Eight: kVp² Test - Site C

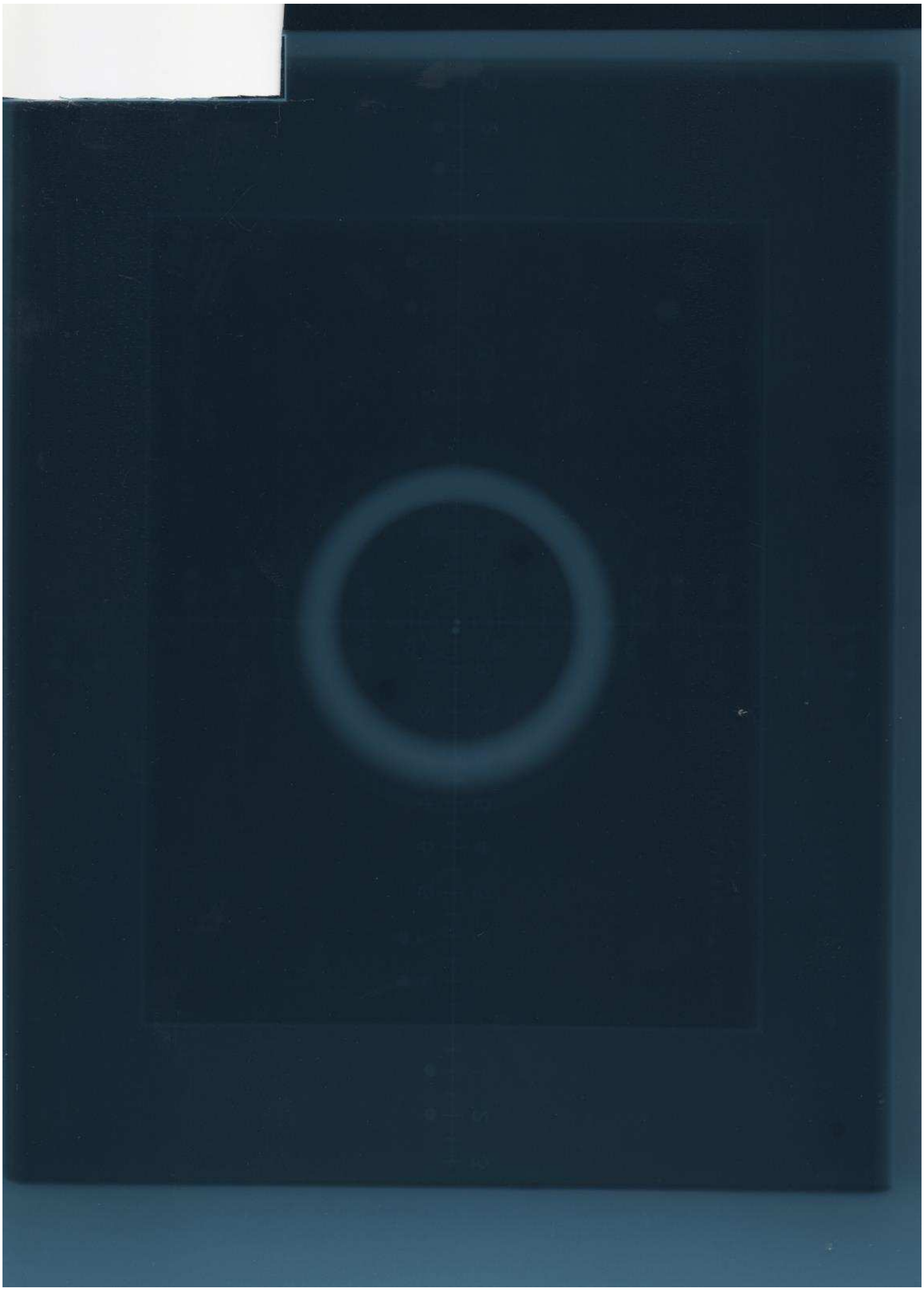


Graph Nine: Tube Output Test - Site C

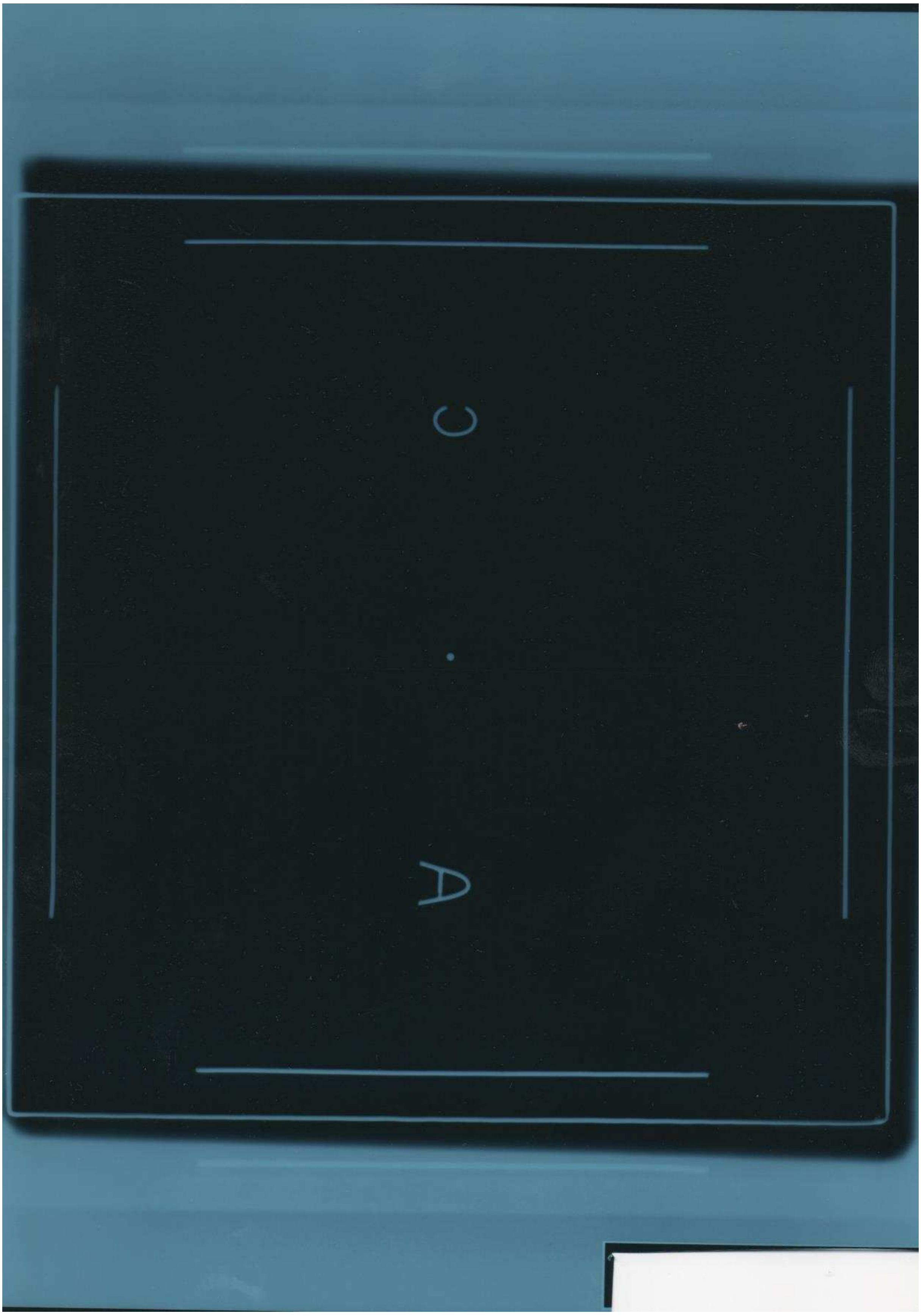


The results for tube output with kVp^2 and tube output at sites A and C demonstrate linear relationships in radiation dose output. These results met the local quality assurance specifications ensuring no change in radiation output due to ageing, drift, component failure or miscalibration (IPEM 2010). This demonstrates that the DR equipment was working within the optimum and safe parameters according to local QA protocols at the time of this research.

Site A – X-ray alignment and collimation test



Site C – X-ray alignment and collimation test



Appendix 16: Qualitative categories and themes

Overarching categories with themes

Learning	Radiographer challenges
Students (learned behaviour) Lack of clinical training (radiographers) Lack of theoretical understanding (radiographers & students) Hidden curriculum (students) Exposure index Little confidence using DR	'Is the imaged flipped'? Performing the diagnosis - problematic Operator error / near misses Workload / time pressures Deskilling Laziness Patient satisfaction with DR
Ionising radiation	**Patient care delivery**
Hidden radiography Lack of understanding to optimize doses Cropping / shuttering Little lead protection Exposure factors	Depersonalization Technology-focused Increased pain/discomfort with DR Quick repeats

Linking themes between categories

Learning	**Radiographer Challenges**
Students (learned behaviour)	Performing the diagnosis - problematic
Clinical and cascaded training	Operator error / near misses
Lack of theoretical understanding (radiographers & students)	Workload / time pressures
Hidden curriculum (students)	Deskilling
Exposure index	Laziness
Little confidence using DR	
Ionising Radiation	**Patient care delivery**
Hidden radiography	Depersonalization
Lack of understanding to optimize doses	Technology-focused
Cropping / shuttering	Increased pain/discomfort with DR
Little lead protection	Quick repeats
Exposure factors	Patient satisfaction with DR
Radiation incidents	
Dose creep	

Appendix 17: X-ray experiment results

Research Site	Body Part	X-ray Label	Projection	kVp	mAs	SID (cm)	Field Size (cm)	EI	Under|Over|Acceptable	DAP dGycm2
A	Hand	1a	DP	50	2	80	Small 19 x 17	125	Over	0.204
A	Hand	b	DP	50	2	80	Small 19 x 17	125	Over	0.205
A	Hand	c	DP	50	2	80	Small 19 x 17	125	Over	0.204
A	Hand	2a	DP	50	2	80	Medium 26 x 23	100	Over	0.376
A	Hand	b	DP	50	2	80	Medium 26 x 23	100	Over	0.376
A	Hand	c	DP	50	2	80	Medium 26 x 23	100	Over	0.374
A	Hand	3a	DP	50	2	80	Large 33 x 29	100	Over	0.611
A	Hand	b	DP	50	2	80	Large 33 x 29	100	Over	0.611
A	Hand	c	DP	50	2	80	Large 33 x 29	100	Over	0.614
A	Hand	4a	DP	50	2	85	Small 19 x 17	125	Over	0.179
A	Hand	b	DP	50	2	85	Small 19 x 17	125	Over	0.179
A	Hand	c	DP	50	2	85	Small 19 x 17	125	Over	0.180
A	Hand	5a	DP	50	2	85	Medium 26 x 23	125	Over	0.342
A	Hand	b	DP	50	2	85	Medium 26 x 23	125	Over	0.342
A	Hand	c	DP	50	2	85	Medium 26 x 23	125	Over	0.342
A	Hand	6a	DP	50	2	85	Large 33 x 29	125	Over	0.546
A	Hand	b	DP	50	2	85	Large 33 x 29	125	Over	0.546
A	Hand	c	DP	50	2	85	Large 33 x 29	125	Over	0.546
A	Hand	7a	DP	50	2	90	Small 19 x 17	160	Acceptable	0.165
A	Hand	b	DP	50	2	90	Small 19 x 17	160	Acceptable	0.164
A	Hand	c	DP	50	2	90	Small 19 x 17	160	Acceptable	0.165
A	Hand	8a	DP	50	2	90	Medium 26 x 23	125	Over	0.305
A	Hand	b	DP	50	2	90	Medium 26 x 23	125	Over	0.299

A	Hand	c	DP	50	2	90	Medium 26 x 23	125	Over	0.299
A	Hand	9a	DP	50	2	90	Large 33 x 29	125	Over	0.484
A	Hand	b	DP	50	2	90	Large 33 x 29	125	Over	0.484
A	Hand	c	DP	50	2	90	Large 33 x 29	125	Over	0.484
A	Hand	10a	DP	50	2	95	Small 19 x 17	160	Acceptable	0.142
A	Hand	b	DP	50	2	95	Small 19 x 17	160	Acceptable	0.142
A	Hand	c	DP	50	2	95	Small 19 x 17	160	Acceptable	0.142
A	Hand	11a	DP	50	2	95	Medium 26 x 23	160	Acceptable	0.272
A	Hand	b	DP	50	2	95	Medium 26 x 23	160	Acceptable	0.271
A	Hand	c	DP	50	2	95	Medium 26 x 23	160	Acceptable	0.272
A	Hand	12a	DP	50	2	95	Large 33 x 29	160	Acceptable	0.429
A	Hand	b	DP	50	2	95	Large 33 x 29	160	Acceptable	0.429
A	Hand	c	DP	50	2	95	Large 33 x 29	160	Acceptable	0.429
A	Hand	13a	DP	50	2	100	Small 19 x 17	200	Acceptable	0.131
A	Hand	b	DP	50	2	100	Small 19 x 17	200	Acceptable	0.131
A	Hand	c	DP	50	2	100	Small 19 x 17	200	Acceptable	0.131
A	Hand	14a	DP	50	2	100	Medium 26 x 23	160	Acceptable	0.242
A	Hand	b	DP	50	2	100	Medium 26 x 23	160	Acceptable	0.241
A	Hand	c	DP	50	2	100	Medium 26 x 23	160	Acceptable	0.243
A	Hand	15a	DP	50	2	100	Large 33 x 29	160	Acceptable	0.388
A	Hand	b	DP	50	2	100	Large 33 x 29	160	Acceptable	0.390
A	Hand	c	DP	50	2	100	Large 33 x 29	160	Acceptable	0.388
A	Hand	16a	DP	50	2	105	Small 19 x 17	200	Acceptable	0.121
A	Hand	b	DP	50	2	105	Small 19 x 17	200	Acceptable	0.120

A	Hand	c	DP	50	2	105	Small 19 x 17	200	Acceptable	0.121
A	Hand	17a	DP	50	2	105	Medium 26 x 23	200	Acceptable	0.222
A	Hand	b	DP	50	2	105	Medium 26 x 23	200	Acceptable	0.222
A	Hand	c	DP	50	2	105	Medium 26 x 23	200	Acceptable	0.221
A	Hand	18a	DP	50	2	105	Large 33 x 29	160	Acceptable	0.356
A	Hand	b	DP	50	2	105	Large 33 x 29	160	Acceptable	0.356
A	Hand	c	DP	50	2	105	Large 33 x 29	160	Acceptable	0.363
A	Hand	19a	DP	50	2	110	Small 19 x 17	250	Acceptable	0.107
A	Hand	b	DP	50	2	110	Small 19 x 17	250	Acceptable	0.108
A	Hand	c	DP	50	2	110	Small 19 x 17	250	Acceptable	0.108
A	Hand	20a	DP	50	2	110	Medium 26 x 23	200	Acceptable	0.202
A	Hand	b	DP	50	2	110	Medium 26 x 23	200	Acceptable	0.202
A	Hand	c	DP	50	2	110	Medium 26 x 23	200	Acceptable	0.202
A	Hand	21a	DP	50	2	110	Large 33 x 29	200	Acceptable	0.322
A	Hand	b	DP	50	2	110	Large 33 x 29	200	Acceptable	0.323
A	Hand	c	DP	50	2	110	Large 33 x 29	200	Acceptable	0.322
A	Hand	1a	OBL	50	2	80	Small 17 x 13	200	Acceptable	0.144
A	Hand	b	OBL	50	2	80	Small 17 x 13	200	Acceptable	0.144
A	Hand	c	OBL	50	2	80	Small 17 x 13	200	Acceptable	0.143
A	Hand	2a	OBL	50	2	80	Medium 22 x 20	160	Acceptable	0.281
A	Hand	b	OBL	50	2	80	Medium 22 x 20	160	Acceptable	0.281
A	Hand	c	OBL	50	2	80	Medium 22 x 20	160	Acceptable	0.281
A	Hand	3a	OBL	50	2	80	Large 28 x 27	125	Over	0.487
A	Hand	b	OBL	50	2	80	Large 28 x 27	125	Over	0.485

A	Hand	c	OBL	50	2	80	Large 28 x 27	125	Over	0.485
A	Hand	4a	OBL	50	2	85	Small 17 x 13	200	Acceptable	0.125
A	Hand	b	OBL	50	2	85	Small 17 x 13	200	Acceptable	0.126
A	Hand	c	OBL	50	2	85	Small 17 x 13	200	Acceptable	0.126
A	Hand	5a	OBL	50	2	85	Medium 22 x 20	160	Acceptable	0.254
A	Hand	b	OBL	50	2	85	Medium 22 x 20	160	Acceptable	0.254
A	Hand	c	OBL	50	2	85	Medium 22 x 20	160	Acceptable	0.255
A	Hand	6a	OBL	50	2	85	Large 28 x 27	160	Acceptable	0.430
A	Hand	b	OBL	50	2	85	Large 28 x 27	160	Acceptable	0.430
A	Hand	c	OBL	50	2	85	Large 28 x 27	160	Acceptable	0.430
A	Hand	7a	OBL	50	2	90	Small 17 x 13	250	Acceptable	0.112
A	Hand	b	OBL	50	2	90	Small 17 x 13	250	Acceptable	0.113
A	Hand	c	OBL	50	2	90	Small 17 x 13	250	Acceptable	0.112
A	Hand	8a	OBL	50	2	90	Medium 22 x 20	200	Acceptable	0.222
A	Hand	b	OBL	50	2	90	Medium 22 x 20	200	Acceptable	0.221
A	Hand	c	OBL	50	2	90	Medium 22 x 20	200	Acceptable	0.221
A	Hand	9a	OBL	50	2	90	Large 28 x 27	160	Acceptable	0.391
A	Hand	b	OBL	50	2	90	Large 28 x 27	160	Acceptable	0.391
A	Hand	c	OBL	50	2	90	Large 28 x 27	160	Acceptable	0.389
A	Hand	10a	OBL	50	2	95	Small 17 x 13	250	Acceptable	0.100
A	Hand	b	OBL	50	2	95	Small 17 x 13	250	Acceptable	0.100
A	Hand	c	OBL	50	2	95	Small 17 x 13	250	Acceptable	0.100
A	Hand	11a	OBL	50	2	95	Medium 22 x 20	200	Acceptable	0.200
A	Hand	b	OBL	50	2	95	Medium 22 x 20	200	Acceptable	0.199

A	Hand	c	OBL	50	2	95	Medium 22 x 20	200	Acceptable	0.199
A	Hand	12a	OBL	50	2	95	Large 28 x 27	200	Acceptable	0.351
A	Hand	b	OBL	50	2	95	Large 28 x 27	200	Acceptable	0.352
A	Hand	c	OBL	50	2	95	Large 28 x 27	200	Acceptable	0.351
A	Hand	13a	OBL	50	2	100	Small 17 x 13	250	Acceptable	0.093
A	Hand	b	OBL	50	2	100	Small 17 x 13	250	Acceptable	0.094
A	Hand	c	OBL	50	2	100	Small 17 x 13	250	Acceptable	0.094
A	Hand	14a	OBL	50	2	100	Medium 22 x 20	250	Acceptable	0.182
A	Hand	b	OBL	50	2	100	Medium 22 x 20	250	Acceptable	0.182
A	Hand	c	OBL	50	2	100	Medium 22 x 20	250	Acceptable	0.183
A	Hand	15a	OBL	50	2	100	Large 28 x 27	200	Acceptable	0.309
A	Hand	b	OBL	50	2	100	Large 28 x 27	200	Acceptable	0.310
A	Hand	c	OBL	50	2	100	Large 28 x 27	200	Acceptable	0.309
A	Hand	16a	OBL	50	2	105	Small 17 x 13	320	Under	0.081
A	Hand	b	OBL	50	2	105	Small 17 x 13	320	Under	0.081
A	Hand	c	OBL	50	2	105	Small 17 x 13	320	Under	0.081
A	Hand	17a	OBL	50	2	105	Medium 22 x 20	250	Acceptable	0.163
A	Hand	b	OBL	50	2	105	Medium 22 x 20	250	Acceptable	0.162
A	Hand	c	OBL	50	2	105	Medium 22 x 20	250	Acceptable	0.163
A	Hand	18a	OBL	50	2	105	Large 28 x 27	200	Acceptable	0.284
A	Hand	b	OBL	50	2	105	Large 28 x 27	200	Acceptable	0.284
A	Hand	c	OBL	50	2	105	Large 28 x 27	200	Acceptable	0.285
A	Hand	19a	OBL	50	2	110	Small 17 x 13	320	Under	0.077
A	Hand	b	OBL	50	2	110	Small 17 x 13	320	Under	0.077

A	Hand	c	OBL	50	2	110	Small 17 x 13	320	Under	0.077
A	Hand	20a	OBL	50	2	110	Medium 22 x 20	320	Under	0.150
A	Hand	b	OBL	50	2	110	Medium 22 x 20	320	Under	0.150
A	Hand	c	OBL	50	2	110	Medium 22 x 20	320	Under	0.150
A	Hand	21a	OBL	50	2	110	Large 28 x 27	250	Acceptable	0.261
A	Hand	b	OBL	50	2	110	Large 28 x 27	250	Acceptable	0.260
A	Hand	c	OBL	50	2	110	Large 28 x 27	250	Acceptable	0.260
C	Wrist	1a	DP	60	1.6	75	Small 8 x 11	0.97	Acceptable	0.070
C	Wrist	b	DP	60	1.6	75	Small 8 x 11	0.97	Acceptable	0.070
C	Wrist	c	DP	60	1.6	75	Small 8 x 11	0.97	Acceptable	0.070
C	Wrist	2a	DP	60	1.6	75	Medium 16 x 18	1.39	Over	0.239
C	Wrist	b	DP	60	1.6	75	Medium 16 x 18	1.39	Over	0.237
C	Wrist	c	DP	60	1.6	75	Medium 16 x 18	1.38	Over	0.238
C	Wrist	3a	DP	60	1.6	75	Large 24 x 25	1.60	Over	0.514
C	Wrist	b	DP	60	1.6	75	Large 24 x 25	1.60	Over	0.511
C	Wrist	c	DP	60	1.6	75	Large 24 x 25	1.59	Over	0.510
C	Wrist	4a	DP	60	1.6	80	Small 8 x 11	0.88	Acceptable	0.062
C	Wrist	b	DP	60	1.6	80	Small 8 x 11	0.87	Acceptable	0.062
C	Wrist	c	DP	60	1.6	80	Small 8 x 11	0.87	Acceptable	0.062
C	Wrist	5a	DP	60	1.6	80	Medium 16 x 18	1.24	Acceptable	0.209
C	Wrist	b	DP	60	1.6	80	Medium 16 x 18	1.23	Acceptable	0.209
C	Wrist	c	DP	60	1.6	80	Medium 16 x 18	1.23	Acceptable	0.209
C	Wrist	6a	DP	60	1.6	80	Large 24 x 25	1.42	Over	0.447
C	Wrist	b	DP	60	1.6	80	Large 24 x 25	1.42	Over	0.446

C	Wrist	c	DP	60	1.6	80	Large 24 x 25	1.41	Over	0.443
C	Wrist	7a	DP	60	1.6	85.2	Small 8 x 11	0.77	Acceptable	0.054
C	Wrist	b	DP	60	1.6	85.2	Small 8 x 11	0.77	Acceptable	0.054
C	Wrist	c	DP	60	1.6	85.2	Small 8 x 11	0.77	Acceptable	0.054
C	Wrist	8a	DP	60	1.6	85.2	Medium 16 x 18	1.09	Acceptable	0.183
C	Wrist	b	DP	60	1.6	85.2	Medium 16 x 18	1.09	Acceptable	0.183
C	Wrist	c	DP	60	1.6	85.2	Medium 16 x 18	1.09	Acceptable	0.183
C	Wrist	9a	DP	60	1.6	85.2	Large 24 x 25	1.25	Over	0.390
C	Wrist	b	DP	60	1.6	85.2	Large 24 x 25	1.26	Over	0.392
C	Wrist	c	DP	60	1.6	85.2	Large 24 x 25	1.26	Over	0.392
C	Wrist	10a	DP	60	1.6	90	Small 8 x 11	0.69	Acceptable	0.049
C	Wrist	b	DP	60	1.6	90	Small 8 x 11	0.69	Acceptable	0.049
C	Wrist	c	DP	60	1.6	90	Small 8 x 11	0.69	Acceptable	0.049
C	Wrist	11a	DP	60	1.6	90	Medium 16 x 18	0.97	Acceptable	0.163
C	Wrist	b	DP	60	1.6	90	Medium 16 x 18	0.98	Acceptable	0.164
C	Wrist	c	DP	60	1.6	90	Medium 16 x 18	0.99	Acceptable	0.166
C	Wrist	12a	DP	60	1.6	90	Large 24 x 25	1.13	Acceptable	0.348
C	Wrist	b	DP	60	1.6	90	Large 24 x 25	1.14	Acceptable	0.352
C	Wrist	c	DP	60	1.6	90	Large 24 x 25	1.14	Acceptable	0.352
C	Wrist	13a	DP	60	1.6	94.9	Small 8 x 11	0.62	Acceptable	0.043
C	Wrist	b	DP	60	1.6	94.9	Small 8 x 11	0.61	Acceptable	0.043
C	Wrist	c	DP	60	1.6	94.9	Small 8 x 11	0.61	Acceptable	0.043
C	Wrist	14a	DP	60	1.6	94.9	Medium 16 x 18	0.88	Acceptable	0.146
C	Wrist	b	DP	60	1.6	94.9	Medium 16 x 18	0.88	Acceptable	0.147

C	Wrist	c	DP	60	1.6	94.9	Medium 16 x 18	0.89	Acceptable	0.147
C	Wrist	15a	DP	60	1.6	94.9	Large 24 x 25	1.02	Acceptable	0.310
C	Wrist	b	DP	60	1.6	94.9	Large 24 x 25	1.02	Acceptable	0.311
C	Wrist	c	DP	60	1.6	94.9	Large 24 x 25	1.03	Acceptable	0.314
C	Wrist	16a	DP	60	1.6	100.1	Small 8 x 11	0.56	Acceptable	0.039
C	Wrist	b	DP	60	1.6	100.1	Small 8 x 11	0.56	Acceptable	0.039
C	Wrist	c	DP	60	1.6	100.1	Small 8 x 11	0.56	Acceptable	0.039
C	Wrist	17a	DP	60	1.6	100.1	Medium 16 x 18	0.81	Acceptable	0.132
C	Wrist	b	DP	60	1.6	100.1	Medium 16 x 18	0.80	Acceptable	0.132
C	Wrist	c	DP	60	1.6	100.1	Medium 16 x 18	0.81	Acceptable	0.133
C	Wrist	18a	DP	60	1.6	100.1	Large 24 x 25	0.93	Acceptable	0.284
C	Wrist	b	DP	60	1.6	100.1	Large 24 x 25	0.94	Acceptable	0.286
C	Wrist	c	DP	60	1.6	100.1	Large 24 x 25	0.93	Acceptable	0.282
C	Wrist	19a	DP	60	1.6	105.1	Small 8 x 11	0.51	Acceptable	0.035
C	Wrist	b	DP	60	1.6	105.1	Small 8 x 11	0.51	Acceptable	0.035
C	Wrist	c	DP	60	1.6	105.1	Small 8 x 11	0.51	Acceptable	0.035
C	Wrist	20a	DP	60	1.6	105.1	Medium 16 x 18	0.74	Acceptable	0.121
C	Wrist	b	DP	60	1.6	105.1	Medium 16 x 18	0.73	Acceptable	0.119
C	Wrist	c	DP	60	1.6	105.1	Medium 16 x 18	0.74	Acceptable	0.120
C	Wrist	21a	DP	60	1.6	105.1	Large 24 x 25	0.84	Acceptable	0.254
C	Wrist	b	DP	60	1.6	105.1	Large 24 x 25	0.84	Acceptable	0.254
C	Wrist	c	DP	60	1.6	105.1	Large 24 x 25	0.85	Acceptable	0.257
C	Wrist	1a	LAT	60	2	74.9	Small 8 x 11	1.26	Over	0.088
C	Wrist	b	LAT	60	2	74.9	Small 8 x 11	1.27	Over	0.088

C	Wrist	c	LAT	60	2	74.9	Small 8 x 11	1.27	Over	0.088
C	Wrist	2a	LAT	60	2	74.9	Medium 13 x 19	1.47	Over	0.255
C	Wrist	b	LAT	60	2	74.9	Medium 13 x 19	1.46	Over	0.255
C	Wrist	c	LAT	60	2	74.9	Medium 13 x 19	1.45	Over	0.255
C	Wrist	3a	LAT	60	2	74.9	Large 20 x 26	1.44	Over	0.550
C	Wrist	b	LAT	60	2	74.9	Large 20 x 26	1.45	Over	0.550
C	Wrist	c	LAT	60	2	74.9	Large 20 x 26	1.45	Over	0.551
C	Wrist	4a	LAT	60	2	80	Small 8 x 11	1.10	Acceptable	0.077
C	Wrist	b	LAT	60	2	80	Small 8 x 11	1.12	Acceptable	0.078
C	Wrist	c	LAT	60	2	80	Small 8 x 11	1.11	Acceptable	0.078
C	Wrist	5a	LAT	60	2	80	Medium 13 x 19	1.28	Over	0.224
C	Wrist	b	LAT	60	2	80	Medium 13 x 19	1.29	Over	0.224
C	Wrist	c	LAT	60	2	80	Medium 13 x 19	1.30	Over	0.225
C	Wrist	6a	LAT	60	2	80	Large 20 x 26	1.29	Over	0.484
C	Wrist	b	LAT	60	2	80	Large 20 x 26	1.28	Over	0.483
C	Wrist	c	LAT	60	2	80	Large 20 x 26	1.30	Over	0.486
C	Wrist	7a	LAT	60	2	84.9	Small 8 x 11	1.00	Acceptable	0.069
C	Wrist	b	LAT	60	2	84.9	Small 8 x 11	1.00	Acceptable	0.069
C	Wrist	c	LAT	60	2	84.9	Small 8 x 11	1.00	Acceptable	0.165
C	Wrist	8a	LAT	60	2	84.9	Medium 13 x 19	1.15	Acceptable	0.199
C	Wrist	b	LAT	60	2	84.9	Medium 13 x 19	1.14	Acceptable	0.197
C	Wrist	c	LAT	60	2	84.9	Medium 13 x 19	1.14	Acceptable	0.198
C	Wrist	9a	LAT	60	2	84.9	Large 20 x 26	1.15	Acceptable	0.432
C	Wrist	b	LAT	60	2	84.9	Large 20 x 26	1.15	Acceptable	0.427

C	Wrist	c	LAT	60	2	84.9	Large 20 x 26	1.15	Acceptable	0.430
C	Wrist	10a	LAT	60	2	89.9	Small 8 x 11	0.90	Acceptable	0.060
C	Wrist	b	LAT	60	2	89.9	Small 8 x 11	0.91	Acceptable	0.061
C	Wrist	c	LAT	60	2	89.9	Small 8 x 11	0.90	Acceptable	0.061
C	Wrist	11a	LAT	60	2	89.9	Medium 13 x 19	1.02	Acceptable	0.175
C	Wrist	b	LAT	60	2	89.9	Medium 13 x 19	1.02	Acceptable	0.176
C	Wrist	c	LAT	60	2	89.9	Medium 13 x 19	1.03	Acceptable	0.176
C	Wrist	12a	LAT	60	2	89.9	Large 20 x 26	1.01	Acceptable	0.379
C	Wrist	b	LAT	60	2	89.9	Large 20 x 26	1.02	Acceptable	0.379
C	Wrist	c	LAT	60	2	89.9	Large 20 x 26	1.01	Acceptable	0.376
C	Wrist	13a	LAT	60	2	94.9	Small 8 x 11	0.81	Acceptable	0.054
C	Wrist	b	LAT	60	2	94.9	Small 8 x 11	0.83	Acceptable	0.055
C	Wrist	c	LAT	60	2	94.9	Small 8 x 11	0.81	Acceptable	0.054
C	Wrist	14a	LAT	60	2	94.9	Medium 13 x 19	0.93	Acceptable	0.157
C	Wrist	b	LAT	60	2	94.9	Medium 13 x 19	0.94	Acceptable	0.158
C	Wrist	c	LAT	60	2	94.9	Medium 13 x 19	0.93	Acceptable	0.156
C	Wrist	15a	LAT	60	2	94.9	Large 20 x 26	0.92	Acceptable	0.338
C	Wrist	b	LAT	60	2	94.9	Large 20 x 26	0.91	Acceptable	0.337
C	Wrist	c	LAT	60	2	94.9	Large 20 x 26	0.91	Acceptable	0.336
C	Wrist	16a	LAT	60	2	100.1	Small 8 x 11	0.73	Acceptable	0.049
C	Wrist	b	LAT	60	2	100.1	Small 8 x 11	0.74	Acceptable	0.049
C	Wrist	c	LAT	60	2	100.1	Small 8 x 11	0.74	Acceptable	0.049
C	Wrist	17a	LAT	60	2	100.1	Medium 13 x 19	0.82	Acceptable	0.140
C	Wrist	b	LAT	60	2	100.1	Medium 13 x 19	0.82	Acceptable	0.140

C	Wrist	c	LAT	60	2	100.1	Medium 13 x 19	0.84	Acceptable	0.144
C	Wrist	18a	LAT	60	2	100.1	Large 20 x 26	0.81	Acceptable	0.302
C	Wrist	b	LAT	60	2	100.1	Large 20 x 26	0.82	Acceptable	0.304
C	Wrist	c	LAT	60	2	100.1	Large 20 x 26	0.82	Acceptable	0.306
C	Wrist	19a	LAT	60	2	105	Small 8 x 11	0.67	Acceptable	0.044
C	Wrist	b	LAT	60	2	105	Small 8 x 11	0.65	Acceptable	0.045
C	Wrist	c	LAT	60	2	105	Small 8 x 11	0.67	Acceptable	0.045
C	Wrist	20a	LAT	60	2	105	Medium 13 x 19	0.74	Acceptable	0.127
C	Wrist	b	LAT	60	2	105	Medium 13 x 19	0.76	Acceptable	0.128
C	Wrist	c	LAT	60	2	105	Medium 13 x 19	0.76	Acceptable	0.128
C	Wrist	21a	LAT	60	2	105	Large 20 x 26	0.74	Acceptable	0.274
C	Wrist	b	LAT	60	2	105	Large 20 x 26	0.75	Acceptable	0.275
C	Wrist	c	LAT	60	2	105	Large 20 x 26	0.75	Acceptable	0.275

Appendix 18: SPSS output data

Hand Site A

Descriptive Statistics[a]

	Mean	Std. Deviation	N
DAP dGycm2 A	.258121	.1349754	42
SIDRECODEDAGAIN	5.0000	2.02424	42
Field Size Recoded New	10.6667	6.33868	42

a. Body Part = Hand

Correlations[a]

		DAP dGycm2 A	SIDRECODE DAGAIN	Field Size Recoded New
Pearson Correlation	DAP dGycm2 A	1.000	-.410	.886
	SIDRECODEDAGAIN	-.410	1.000	.000
	Field Size Recoded New	.886	.000	1.000
Sig. (1-tailed)	DAP dGycm2 A	.	.004	.000
	SIDRECODEDAGAIN	.004	.	.500
	Field Size Recoded New	.000	.500	.
N	DAP dGycm2 A	42	42	42
	SIDRECODEDAGAIN	42	42	42
	Field Size Recoded New	42	42	42

a. Body Part = Hand

Variables Entered/Removed[b,c]

Model	Variables Entered	Variables Removed	Method
1	Field Size Recoded New, SIDRECODE DAGAIN[a]	.	Enter

a. All requested variables entered.
b. Body Part = Hand
c. Dependent Variable: DAP dGycm2 A

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.976[a]	.953	.950	.0301204	.953	392.163	2	39	.000

a. Predictors: (Constant), Field Size Recoded New, SIDRECODEDAGAIN
b. Body Part = Hand

ANOVA[b,c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.712	2	.356	392.163	.000[a]
	Residual	.035	39	.001		
	Total	.747	41			

a. Predictors: (Constant), Field Size Recoded New, SIDRECODEDAGAIN
b. Body Part = Hand
c. Dependent Variable: DAP dGycm2 A

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	.193	.015		13.066	.000			
	SIDRECODEDAGAIN	-.027	.002	-.410	-11.754	.000	-.410	-.883	-.410
	Field Size Recoded New	.019	.001	.886	25.420	.000	.886	.971	.886

a. Body Part = Hand
b. Dependent Variable: DAP dGycm2 A

Wrist - Site C

Descriptive Statistics[a]

	Mean	Std. Deviation	N
DAP dGycm2 A	.204024	.1469806	42
SIDRECODEDAGAIN	4.0000	2.02424	42
Field Size Recoded New	5.6667	5.08305	42

a. Body Part = Wrist

Correlations[a]

		DAP dGycm2 A	SIDRECODED AGAIN	Field Size Recoded New
Pearson Correlation	DAP dGycm2 A	1.000	-.326	.876
	SIDRECODEDAGAIN	-.326	1.000	.000
	Field Size Recoded New	.876	.000	1.000
Sig. (1-tailed)	DAP dGycm2 A	.	.018	.000
	SIDRECODEDAGAIN	.018	.	.500
	Field Size Recoded New	.000	.500	.
N	DAP dGycm2 A	42	42	42
	SIDRECODEDAGAIN	42	42	42
	Field Size Recoded New	42	42	42

a. Body Part = Wrist

Variables Entered/Removed[b,c]

Model	Variables Entered	Variables Removed	Method
1	Field Size Recoded New, SIDRECODED AGAIN	.	Enter

a. All requested variables entered.
b. Body Part = Wrist
c. Dependent Variable: DAP dGycm2 A

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.935[a]	.874	.868	.0534284	.874	135.642	2	39	.000

a. Predictors: (Constant), Field Size Recoded New, SIDRECODEDAGAIN
b. Body Part = Wrist

ANOVA[b,c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.774	2	.387	135.642	.000[a]
	Residual	.111	39	.003		
	Total	.886	41			

a. Predictors: (Constant), Field Size Recoded New, SIDRECODEDAGAIN
b. Body Part = Wrist
c. Dependent Variable: DAP dGycm2 A

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	.155	.021		7.511	.000			
	SIDRECODEDAGAIN	-.024	.004	-.326	-5.741	.000	-.326	-.677	-.326
	Field Size Recoded New	.025	.002	.876	15.438	.000	.876	.927	.876

a. Body Part = Wrist
b. Dependent Variable: DAP dGycm2 A

DAP and EI Correlation – Hand - Site A

Correlations[a]

		Exposure Index A	DAP dGycm2 A
Exposure Index A	Pearson Correlation	1	-.694**
	Sig. (2-tailed)		.000
	N	42	42
DAP dGycm2 A	Pearson Correlation	-.694**	1
	Sig. (2-tailed)	.000	
	N	42	42

**. Correlation is significant at the 0.01 level (2-tailed).
a. Body Part = Hand

DAP and EI Correlation – Wrist – Site C

Correlations[a]

		DAP dGycm2 A	Exposure Index A
DAP dGycm2 A	Pearson Correlation	1	.689**
	Sig. (2-tailed)		.000
	N	42	42
Exposure Index A	Pearson Correlation	.689**	1
	Sig. (2-tailed)	.000	
	N	42	42

**. Correlation is significant at the 0.01 level (2-tailed).
a. Body Part = Wrist

Appendix 19: Variation in Wrist Examinations at Site A

Exam	Operator	Projection	Focus	Preset kVp/mAs	kVp/mAs Used	SID	Collimation (cm)	EI	Under|Over|Acceptable	DAP (cGycm2)
Wrist	Rad 1	DP	Fine	57/2	52/2.5	107.0	20 x 9	200	Acceptable	0.70
		LAT	Fine	57/2.5	52/2.5	107.0	22 x 7	250	Acceptable	0.58
Wrist	Rad 5 ±	DP	Fine	57/2.5	57/2.5	106.0	11 x 21	160	Acceptable	1.06
		LAT	Fine	57/2.5	57/2.5	106.0	9 x 20	200	Acceptable	0.89
Wrist	Rad 10+	DP	Fine	55/2	55/2	94.0	20 x 11	200	Acceptable	1.31
		LAT	Fine	55/2	55/2	93.0	8 x 17	400	Under	0.82
Wrist	Rad 6-10	DP	Fine	55/2	55/2	112.0	26 x 13	250	Acceptable	1.52
		LAT	Fine	55/2	55/2	113.0	29 x 11	320	Under	1.41
Wrist	Rad 6-10	DP	Fine	57/2.5	57/2.5	104.0	24 x 10	125	Over	1.21
		LAT	Fine	57/2.5	57/2.5	104.0	24 x 8	200	Acceptable	0.93
Wrist	Rad 6-10	DP	Fine	55/2	55/2	96.0	24 x 13	250	Acceptable	1.78
		LAT	Fine	55/2	55/2	104.0	24 x 10	400	Under	1.23
Wrist	AP 2	DP	Fine	55/2	55/2	109.0	29 x 11	250	Acceptable	1.49
		LAT	Fine	55/2	55/2	109.0	17 x 13	200	Acceptable	0.97
Wrist	Rad 1	DP	Fine	57/2.5	60/3.2	100.0	29 x 17	100	Over	3.66
		LAT	Fine	57/2.5	60/3.2	100.0	30 x 13	125	Over	3.05
Wrist	Rad 10	DP	Fine	55/2	57/2.5	102.0	24 x 8	320	Under	1.44
		LAT	Fine	55/2	60/2	110.0	18 x 9	320	Under	1.43
Wrist	Rad 10	DP	Fine	55/2	55/2	109.0	23 x 11	200	Under	1.19
		LAT	Fine	55/2	55/2	108.0	9 x 23	200	Acceptable	0.98