Clinical Reasoning in Image Guided Radiotherapy: A Multimethod Study

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ABSTRACT

Introduction

3D Image Guided Radiotherapy (IGRT) using cone beam computer tomography has been implemented into the UK over the last decade. There is evidence to suggest that the training of therapeutic radiographers and the development of departmental processes may not have kept pace with the implementation. A literature review highlighted a paucity of evidence relating to how therapeutic radiographers make clinical decisions during image interpretation in the IGRT processes.

Purpose

The study aimed to investigate the types of decision-making processes used by therapeutic radiographers during image interpretation in IGRT. In addition, the study aimed to investigate the factors that impact on the decision-making processes of therapeutic radiographers during IGRT.

Method

A multimethod research design was adopted that utilised a think-aloud observational method with follow-up interviews. Thirteen participants were observed and interviewed across three United Kingdom (UK) radiotherapy centres. Participants were observed reviewing and making clinical decisions in a simulated environment using clinical scenarios developed in partnership with each centre's Clinical Imaging Lead. Protocol analysis was used to analyse the observational data. Thematic analysis was used to analyse the interview data. Member checking was carried out using an online presentation and questionnaire, along with periodic peer debriefing by the supervisory team. Findings from the observations and semi-structured interviews were then combined using a triangulation protocol.

Results

Therapeutic radiographers were observed using one of three decision-making processes. These assume the titles *simple linear process, linear repeating process* and *intuitive process.* Participants were found to prioritise the target volume to be treated over the organs at risk. There were notably mixed opinions on the impact of overall therapeutic radiographer experience on decision-making. The findings of the study align with general principles of expert performance, which claims that expertise is only improved by seeking out particular kinds of experience and carrying out deliberate practice in this specific task or specific area of practice.

A descriptive module was developed to demonstrate the factors that impact on decision-making. The centre structure, training and the wider involvement of the multidisciplinary team were all found to be key factors that impacted on the decision-making process during IGRT. Staffing levels and communication patterns between the multidisciplinary team were found to be highly variable across the three centres. Greater communication and involvement of the multidisciplinary team was found to improve therapeutic radiographers' confidence in making clinical decisions.

Issues in relation to pre-registration training were highlighted, with a consensus that recent graduates do not always demonstrate the skills and experience required to make clinical decisions. A lack of education in relation to clinical decision-making was highlighted at both pre-registration and post-qualification levels. A conceptual model to improve clinical decision-making in image interpretation during IGRT was developed and is presented in the thesis.

Conclusion

This research has provided new and original insight into the decision-making processes of therapeutic radiographers. It has demonstrated that therapeutic radiographers utilise complex processes during image interpretation in IGRT. It has shown that numerous factors affect the decisions that therapeutic radiographers routinely make, and that with improvements in education and radiotherapy centre infrastructure, therapeutic radiographers can be better placed to make safer, more effective decisions during the IGRT process.

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LIST OF ABBREVIATIONS

AA	Assertional Analysis
AHP	Allied Health Professional
ART	Adaptive Radiotherapy
CBCT	Cone Beam Computer Tomography
CT	Computer Tomography
CTV	Clinical Target Volume
GTV	Gross Target Volume
HCPC	Health and Care Professions Council
IGRT	Image Guided Radiotherapy
ITP	Information Processing Theory
KV	Kilo Voltage
LINAC	Linear accelerator
LTM	Long Term Memory
MDT	Multidisciplinary Team
MRI	Magnetic Resonance Imaging
MV	Mega Voltage
NTCP	Normal Tissue Complication Probability
OAR	Organs at Risk
PET	Positron Emission Tomography

PTV	Planning Target Volume
RPA	Referring Phrase Analysis
SA	Script Analysis
TR	therapeutic radiographer
TCP	Tumour Control Probability
US	Ultrasound
WM	Working Memory

CANDIDATE STATEMENT

I certify that this thesis is my own work and confirm that the work undertaken towards the above named Thesis has been conducted in accordance with the Sheffield Hallam University's Principles of Integrity in Research and the Sheffield Hallam University's Research Ethics Policy.

Signed: Dated: 06/09/2017

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CHAPTER 1: INTRODUCTION

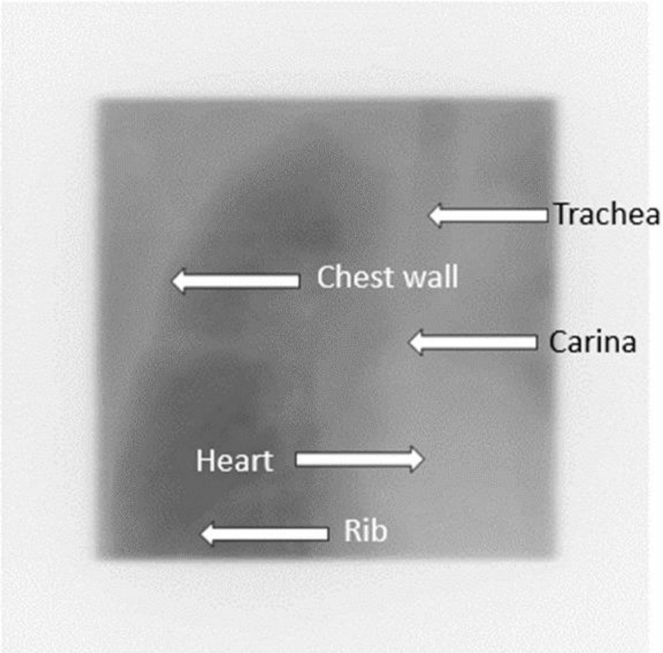
The first chapter of this thesis will provide essential background and context to the programme of study. It will commence with a brief discussion on the current use of Image Guided Radiotherapy (IGRT), with a focus on implementation and education. The final section of the chapter will highlight the gaps in the evidence base in relation to IGRT and a summary of the programme of study will be discussed.

1.1 Image Guided Radiotherapy

Since the 1980s, IGRT has been used in a number of different forms to aid treatment accuracy (McNair, Elsworthy, Dean, & Beardmore, 2014). During this process, TRs take a set of x-ray images that are evaluated to determine if the planned treatment will deliver the intended doses to the tumour while minimising dose to the surrounding healthy tissues.

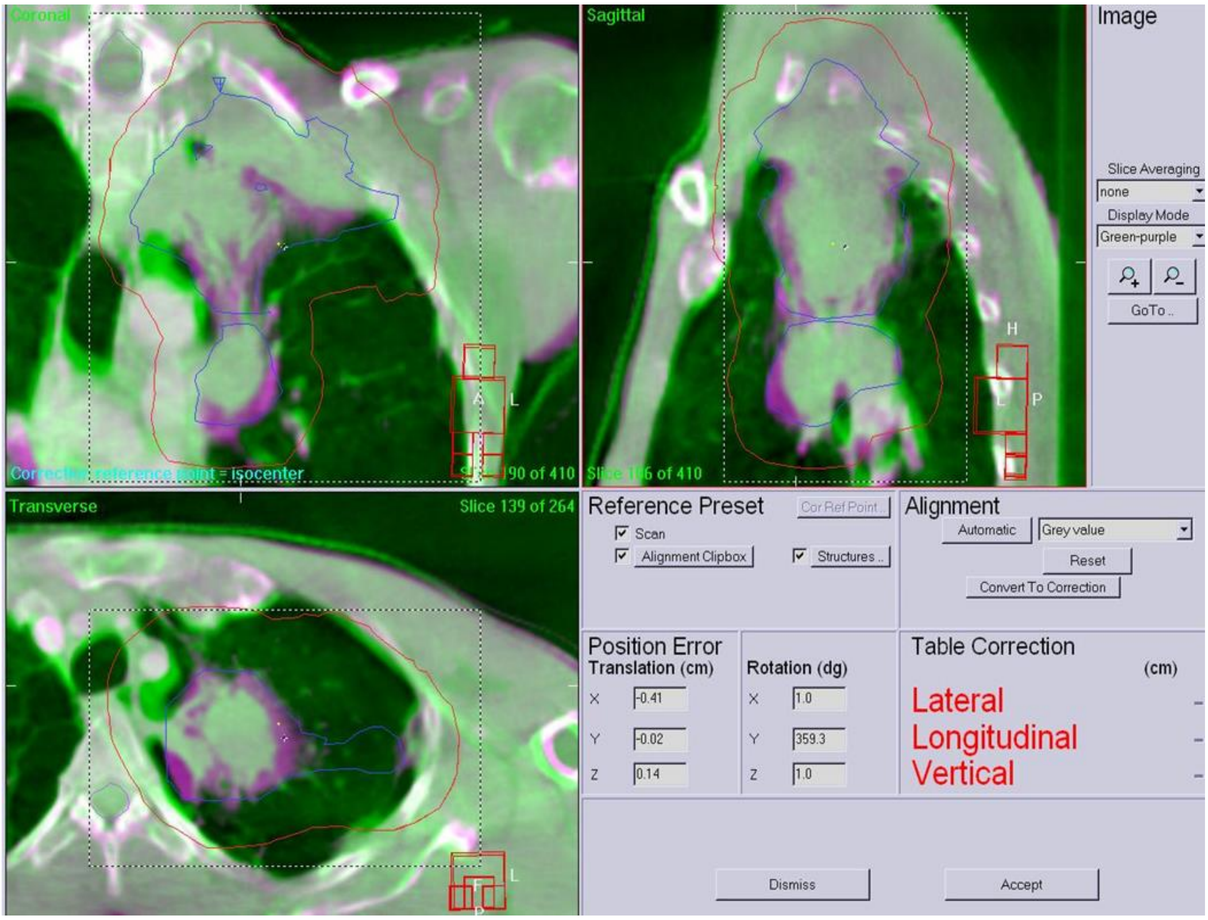
This process was traditionally reliant on low quality, 2D images using short exposure Mega Voltage (MV) x-rays from the standard Linac beam. As Figure 1.0 highlights, the information visible on these images is limited and, in most cases, only allows TRs to visualise bony anatomy and some soft tissue anatomy, using this as surrogate for the position of the tumour. These 2D images can be enhanced with a Linac upgrade, allowing the Linac to deliver a separate Kilo Voltage (KV) beam, which produces images with greater soft-tissue differentiation. Using this information TRs can assess if the treatment field is in the correct position (in relation to the visible anatomy) and determine if a treatment correction is needed. In most cases, this involves altering the position of the patient relative to the direction and position of the treatment beam(s).

FIGURE 1.0 2D VERIFICATION IMAGE (NATIONAL RADIOTHERAPY IMPLEMENTATION GROUP, 2012 WITH PERMISSION)



In recent years, centres have started phasing out 2D technology for many tumour types and replacing it with high quality KV 3D-Cone Beam Computer Tomography (CBCT) (McNair, Elsworthy and Dean et al. 2014) and this is now routine practice in the majority of centres across the UK. As Figure 1.1 highlights, the information displayed in these images is notably different to that of the 2-D image. Using this technology, TRs are able to visualise soft tissue, fluid and often the actual tumour. The CBCT software allows the TRs to overlay the CT images acquired at the pre-treatment phase with those acquired on the day of treatment (often referred to as “matching the images”). By doing this they can compare the differences between the two images and make a clinical decision about the suitability of the patient’s internal and external set-up in relation to the planned treatment. In this example, the tumour and nodal regions have reduced in size due to treatment response. The positional error also indicates that the patient has changed position relative to the treatment beams. This additional information has the potential to improve the treatment and improve patient outcomes (Zelefsky, Kollmeier, Cox et al. 2012; Shumway et al., 2011; Nguyen et al., 2011). However, these benefits can only be realised if the TRs have the skills and experience to interpret the images and make effective clinical decisions (Dean & Routsis, 2010).

FIGURE 1.1 CBCT IMAGE OF A THORAX (SHEFFIELD HALLAM UNIVERSITY, 2017 WITH PERMISSION). THE PINK IMAGE IS THE CT IMAGE ACQUIRED DURING PRE-TREATMENT AND THE GREEN IMAGE IS THE CBCT IMAGE ACQUIRED ON THE 15TH FRACTION OF TREATMENT.



1.2 The national Image Guided Radiotherapy picture

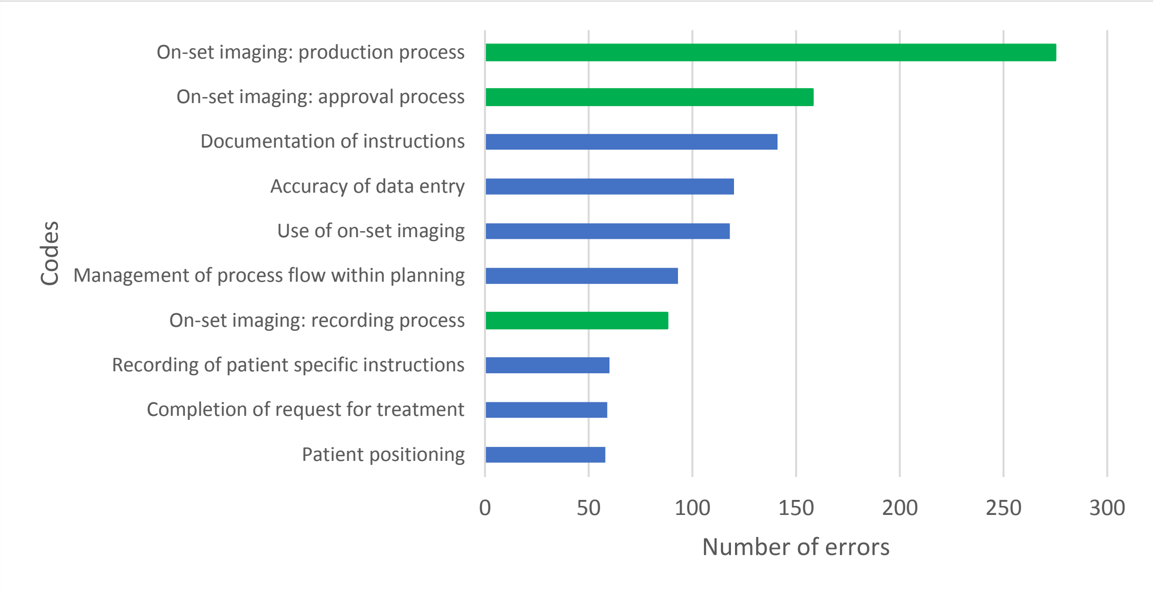
The National Radiotherapy Implementation Group (2012 p.5) Implementation report states that "*Every patient should have a form of IGRT as part of his or her radiotherapy treatment episode"* and that the most advanced version of this; "*4D adaptive radiotherapy (4D-ART) should become the standard of care"* (National Radiotherapy Implementation Group, 2012, p. 8).

However, the national rollout has been problematic for some radiotherapy centres. The Cancer Plan (National Health Service, 2000, p. 20) found that *"There are widespread geographical inequalities in the quality and type of treatment patients receive, because of shortages of specialist staff, fragmentation of care, inadequate access to surgical facilities, a postcode lottery on prescribing and insufficient radiotherapy facilities*".

In 2012, funding from the Radiotherapy Innovation Fund made a significant difference to equipment capabilities in many centres across the UK. Of the £23 million available, a significant proportion (17%) was spent on IGRT equipment. Although this fund was welcomed enthusiastically by the profession, this meant that at a national level, IGRT was implemented relatively quickly. Evidence suggests that staff training and development have not kept pace with the fast implementation. Reporting on their IGRT Clinical Support Programme, The Society and College of Radiographers (2013) highlighted that only 16 (32%) of the 50 centres they visited had satisfactory IGRT training programmes in place; 15 had no training package at all. The study did however highlight that 91% (43/47) of centres had sent members of staff on either nationally or internationally accredited IGRT courses. It should be noted that due to the substantial costs of these courses it is common practice to only send one or two members of staff. With some centres employing over 100 radiographers, it is easy to see how dissemination can be problematic, particularly when some members of staff will have qualified prior to the routine teaching of 3D anatomy and 3D image interpretation.

Some of these concerns are supported by Public Health England's reporting of errors, which has consistently highlighted issues around on-set imaging (IGRT) since 2012. Their latest report on errors between December 2016 to March 2017 (n = 2466) are summarised in Figure 1.2 (Public Health England, 2017). The bars in green relate to the different aspects of the IGRT process and it is evident that they make up a sizable proportion of the errors. It should be highlighted that errors are coded from 1-5 in relation to their severity and impact, and the largest percentage of errors fall under the Level 1: *non-conformance* (38%) and Level 2: *near miss* categories (25%).

FIGURE 1.2 RADIOTHERAPY ERRORS BY CODE (PUBLIC HEALTH ENGLAND, 2017 WITH PERMISSION).



1.3 Clinical reasoning

There is a growing evidence base supporting the premise that when sufficient training is given to TRs, they can make clinical decisions similar to those of their medical colleagues. McNair et al. (2015) demonstrated that following a tailored training programme, a 91% (126/139) concordance rate was achieved across the radiographer and medical teams when reviewing *plan of the day* images of patients undergoing treatment for bladder cancer. In a similar study involving 20 patients undergoing Stereotactic Ablative Radiotherapy (SABR) to the lung, Hudson et al. (2015) investigated the clinical decisions made by clinical oncologists and TRs, and also found an overall agreement of 91%, with small interobserver variations between TRs: The mean (range) of X, Y and Z was; X = 0·10 (−1·02 to 0·91) Y = −0·12 (−1·61 to 1·4) and Z = 0·22 (−0·37 to 1·48). Similar findings have been published in diagnostic radiology, with several studies highlighting the ability of diagnostic radiographers to carry out reporting in cases of suspected lung cancer (Bajre et al., 2017; Donovan, Manning, & Crawford, 2008) and breast cancer (Moran & Warren-Forward, 2016b).

What is not clear from these studies are the clinical reasoning processes and techniques used by the TRs and medical teams to reach their decisions. There is also a lack of understanding of the factors that impact on these clinical decisions. These studies clearly highlight the abilities of small groups of TRs to make accurate clinical decisions during IGRT, but these skills can only be realised and implemented on a national level if these processes are investigated and then implemented into the wider workforce.

When comparing the undergraduate syllabus of TRs and other Allied Health Professionals (AHPs), nurses and medical students (Banning, 2008; Croskerry, Singhal, & Mamede, 2013; Delany & Golding, 2014), it is evident that clinical reasoning is an integral part of their syllabi, both in terms of theory and application. Simulation is also commonly used to support the syllabus as it gives students an opportunity to develop their skills in a safe and controlled environment (Stephenson, 2015; Jensen, 2013; Botezatu et al., 2010). TR students are exposed to clinical decisions on a daily basis when on placements and there is limited evidence to suggest that some centres are using the Virtual Environment for Radiotherapy Training (VERT) system to support student training (James & Dumbleton, 2013). However, it is not clear how VERT is used and there is a paucity of evidence showing that fundamental clinical reasoning theory and techniques are taught during either pre-registration or post-registration training.

1.4 Rationale for the current study

In summary, Chapter 1 has documented the development of imaging technology for radiotherapy, and the challenges for radiographer role development in this area. It has been highlighted that clinical reasoning and clinical decision-making are now requirements for the TR reviewing on-treatment images and that educational shortfalls exist in some areas in relation to these.

The purpose of this Doctor of Professional Studies (DProf) thesis is to investigate the clinical decision-making processes used by TRs when using Image Guided Radiotherapy. Chapter 2 will review the existing literature on clinical decision-making including theory and practical research relevant to image interpretation.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to examine the current evidence base in relation to clinical reasoning. The chapter will commence with a description of the search strategy. This will lead to an overview of the underpinning theory of human decision-making, leading to a critical examination of the three most frequently cited models of clinical reasoning: *Hypothetico-deductive reasoning, dual process theory* and *cognitive continuum theory.* This will be followed by a critical review of the literature relating to profession-specific models of clinical reasoning in nursing and the Allied Health Professions, including the concepts and factors that affect how these professional groups make clinical decisions. Where possible, links will be made between these models and the IGRT process, with consideration as to how these might influence the clinical decisions made by TRs. The chapter concludes with an overview of the main findings, and an outline of the stud aims and research questions.

2.2 SEARCH STRATEGY

Medline, PubMed, Science Direct, CINAHL, PsycINFO and Google Scholar were used for the primary searches using a pearl growing technique (Booth, 2008). Pearl growing involves starting with a very precise search to find one key relevant citation. Index and free text terms are then highlighted in the relevant citation. Any new terms are added to the initial search strategy and this continues until all relevant terms are identified and included in the final strategy. These search terms were combined using Boolean operators and are shown in Table 2.0. Truncation and wild cards were used to strengthen the search. Additional searching was carried out on the websites of the Royal College of Radiologists, the Society and College of Radiographers and the Royal College of Nursing for grey literature. The British Library Electronic Theses Online Service was also searched for doctoral theses.

The abstracts and titles of all references were reviewed and relevant articles were imported into Mendeley (www.mendeley.com) referencing management software. Studies were assessed for quality and risk of bias using the relevant Scottish Intercollegiate Guidelines Network (SIGN) checklists (Scottish Intercollegiate Guidelines Network, 2015).

TABLE 2.0 LITERATURE SEARCH TERMS

Facet	Combined Terms
Clinical Reasoning	decision?making, clinical?reasoning, models, judgement, theory, image, interpret*
Profession	rad*, nurs*, medic*, physio*, allied health, midwi*

Following a scoping literature search, the inclusion and exclusion criteria in Table 2.1 were developed and used in the final search. Search alerts were set-up for each of the databases to ensure any newly published articles were included during the remaining project timeline.

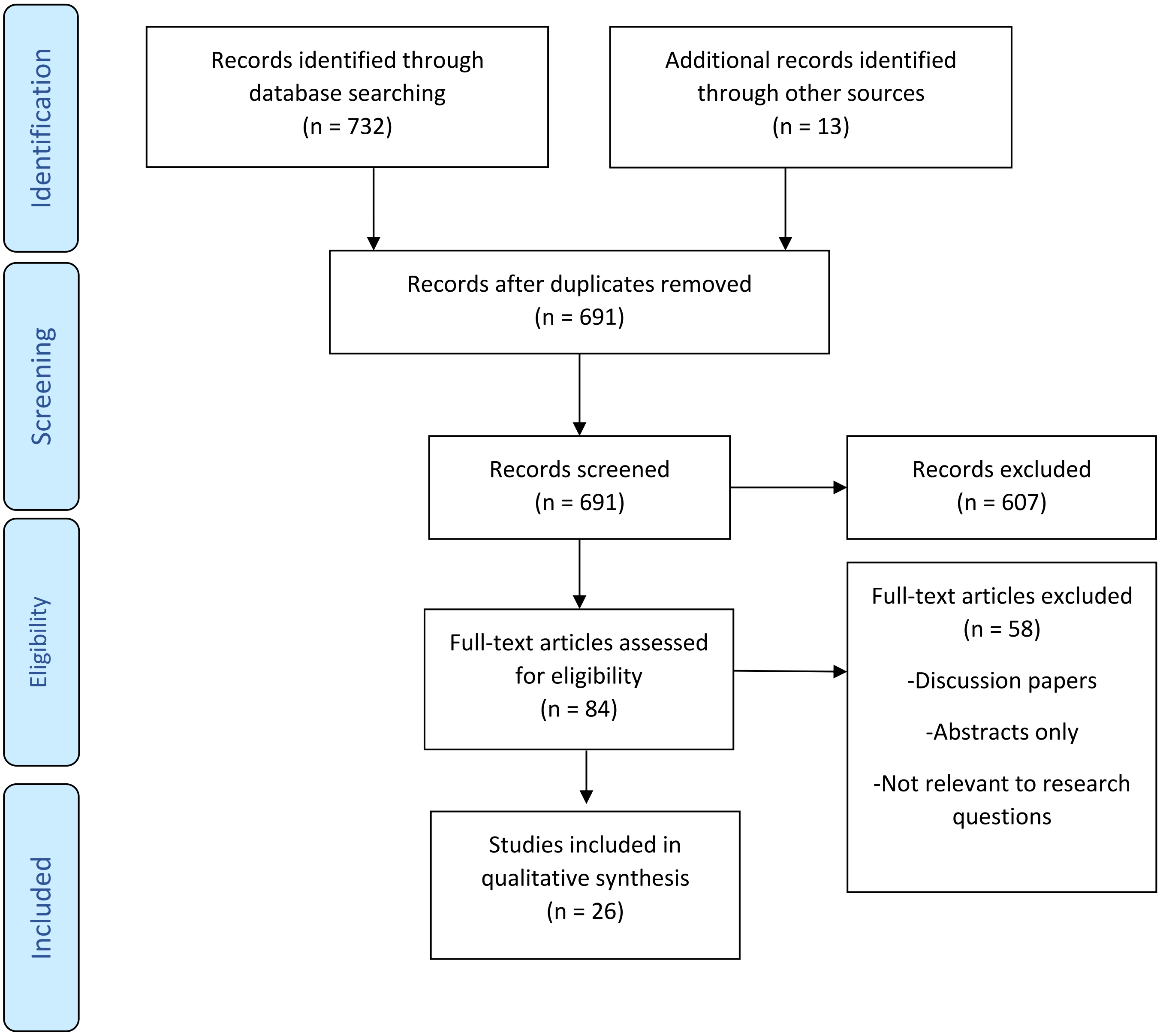
TABLE 2.1 LITERATURE REVIEW INCLUSION AND EXCLUSION CRITERIA

Research/ Study Type	
	Exclude
Randomised controlled trials (RCTs), Cohort studies, Systematic literature reviews, Observational studies, Case studies, Meta-analyses.	Discussion papers and opinion pieces where no recognised methodology has been followed.
Language	
Include	**Exclude**
Published in the English language only to avoid translation issues.	Articles not published in English. It is acknowledged that the exclusion of none English publications could introduce some elements of bias into the review.
Publication status	
Include	**Exclude**
Full papers in peer-reviewed Journals, Reports, Book chapters, Theses.	Interim results be excluded due to difficulty verifying the final results and outcomes. Authors to be contacted to identify if a full report is available or to obtain further results if deemed to be relevant.
Date Range	
Include	**Exclude**
It is acknowledged that some of the seminal texts in relation the clinical decision-making were published in the 1960's onwards. These will be read to inform the wider discussion. The scoping search highlighted the emergence of a number of studies in the early 2000's that are well-cited in the more recent evidence base. 3D CBCT imaging was also seen to be introduced into routine UK practice in the early 2000's (Verellen, Ridder, & Storme, 2008). A date range 2000-2017 was therefore deemed to be appropriate for the systematic review.	Studies published before 2000

Relevance	
Include	**Exclude**
Studies that specifically investigated the processes used during clinical decision-making. These can be carried out in the natural or simulated environment. Studies that specifically investigated image interpretation during diagnostic review and reporting. Seminal texts related to general decision- making theory to be read to inform the wider discussion.	Decision-making studies unrelated to the clinical setting.
Ethics	
Include	**Exclude**
Studies where ethical approval has been sought and granted where relevant.	Studies where consideration of ethical approval is not evident.

The search process is shown in Figure 2.0 using a PRISMA flow diagram (Moher, Liberati, Tetzlaff, & Altman, 2009). The search identified 82 articles that met the search criteria. The majority of articles were discussion papers and non-systematic literature reviews (n=58). These articles were used to form some of the underpinning theoretical descriptions in the chapter, but did not meet the minimum requirements of the relevant SIGN quality checklist. The remaining 24 articles were case studies that typically investigated clinical reasoning in a specific setting and these underwent full review. Despite being outside of the inclusion criteria on the basis of date, Fonteyn and Grobe (1992) was identified as a seminal article during the review process and so was included for full review. An overview of the articles that underwent full review are shown in Appendix 1.

FIGURE 2.0 PRISMA FLOW DIAGRAM OF LITERATURE SEARCH (MOHER, LIBERATI, TETZLAFF, & ALTMAN, 2009).



2.3 INTRODUCTION TO CLINICAL REASONING

How humans make decisions has been a popular area of study and discussion in both the academic community and in society at large. The importance of this work is reflected in the award of Nobel prizes to Herbert Simon in 1978 and Daniel Kahneman in 2002 for their ground breaking work in the 1960's and 1970's on decision-making (Carl Thompson, Aitken, Doran, & Dowding, 2013). Daniel Kahneman's work was further popularised in the book charts with his bestselling book "Thinking fast and slow" which has sold over 1 million copies worldwide (Kahneman, 2011). Much of their work has formed the basis for modern theories and concepts of decision-making and ultimately leading to the field of study known as clinical reasoning.

The terms *clinical decision-making*, *clinical judgement, problem solving* and *clinical reasoning* are often used interchangeably and a number of authors have sought to define these terms.

Jones (1992, p.876) defined clinical reasoning as:

> *"The cognitive thought processes, or thinking used in the evaluation and management of a patient."*

Other authors such as Simmons (2003 p.1152) have sought to include the complexity of the decision-making process in their definitions:

> *"A complex cognitive process that uses formal and informal thinking strategies to gather and analyse patient information, evaluate the significance and weigh alternatives."*

A focus on decision-making in the clinical environment started with early pioneers such as Hammond, Kelly, Schneider, and Vancini (1966), and since then a number of scholars have used a wide range of qualitative, and in some cases quantitative methods, to investigate and create theories of how clinicians make decisions (Koehler & Harvey, 2008; Alderson, 1998). A large range of theories exist, which are often related to the profession or environment being investigated, but they can be broadly broken down into two categories: *normative theories* and *descriptive theories.*

Normative theories seek to describe how optimal decisions should be made (Koehler & Harvey, 2008) such as “How should radiographers decide if an anatomical change is significant during IGRT?” Conversely, descriptive theories seek to describe how decisions are actually made (Koehler & Harvey, 2008) and seek to explain processes such as “How does a radiographer decide if an anatomical change is significant?”

Normative theories traditionally made primary use of decision trees or algorithms such as Bayes’ theorem (Patton, 2010; Stempsey, 2009). This is a mathematical formula that allows the investigator to calculate conditional probabilities, using prior knowledge to generate a probability. An example of this may be the prevalence of a particular disease in a certain population. Bayesian statistics can also be used to calculate the probability that a patient has a given disease based on the results of a positive test and is widely used in epidemiological and clinical studies (Croskerry & Nimmo, 2011; Gegenfurtner & Seppänen, 2013; Jefford, Fahy, & Sundon, 2011). Clearly, this purely quantitative approach has its limitations when considering the complexities of decisions in the clinical environment, many of which are not purely based on the outcome of a blood or urine test.

The difficulties involved in applying these normative theories to everyday clinical decision-making means they are rarely used in reality and so the focus of more recent research has aimed to investigate how individuals actually make decisions in practice (descriptive theories) (Gruppen, 2017; Stempsey, 2009) which is largely based on theories generated in the psychology evidence-base rather than from that of mathematics or logic (Stempsey, 2009).

As discussed in Chapter 1, the IGRT process is complex and decisions are often subjective and multi-faceted where decisions are not based on a binary result. It is therefore acceptable to assume that normative models are unlikely to provide any detailed insight into radiographer decision-making and therefore the remainder of this chapter will focus on descriptive theories.

2.4 THEORIES OF CLINICAL REASONING

2.4.1 Introduction to the theories of clinical reasoning

Clinical reasoning is particularly well researched in medicine (Thackray & Roberts, 2017) with much of the research focusing around diagnostic errors, which continues to be an area of concern (Pinnock & Welch 2014; Graber, Franklin, & Gordon, 2005; Reyna, 2004). There are over 10,000 known diagnoses in existence in the medical literature (Croskerry, 2009b) and autopsy findings have consistently shown a 20% to 40% discrepancy between these and the antemortem diagnosis (Graber, 2005).

The evidence base for clinical reasoning is supported by a wide range of methods and methodologies that will be described and evaluated in greater detail in Chapter 3. The use of observational methods has been key to the development of understanding in this field of study. Observations may occur in the environment being studied such as a ward or clinic room (Thackray & Roberts, 2017; Chaboyer et al., 2008; Mitchell & Unsworth, 2005). Where this is not appropriate, other researchers have used simulation based exercises, some use paper based scenarios (Pirret, Neville, & La, 2015; Mancini et al., 2007) and others have used simulations of a higher fidelity using actors or virtual patients (Forsberg, Ziegert, Hult, & Fors, 2014). A common approach to acquiring data during observation studies is the method of *think aloud*, which involves participants verbalising their thought processes while they carry out a task. This verbal data can then be transcribed and analysed (Lee et al., 2016; Thompson, Spilsbury, Dowding, Pattenden, & Brownlow, 2008; Charters, 2003). A number of authors have used traditional observational techniques, which involves observing participants in practice and making concurrent notes on what is observed (Dowding, Spilsbury, Thomson, Brownlow, & Pattenden, 2008; Mitchell & Unsworth, 2005).

Other methods involve the use of interviews and/or focus groups, whereby participants are commonly asked to reflect on their decision-making processes (Langridge, Roberts, & Pope, 2015). In a limited number of studies, questionnaires have also been used (Bjork & Hamilton, 2011). The analysis of the data in these studies is varied and involves the use of thematic analysis, protocol analysis and framework analysis representing the majority of the studies (Goldberg & Shorten, 2014; Ryley & Middleton, 2015; Simmons, Lanuza, Fonteyn, Hicks, & Holm, 2003).

The literature search presented in Appendix 1 was unable to find any literature that specifically discussed clinical reasoning in radiotherapy beyond the development of the protocols previously discussed in Chapter 1.

In the only study to look at clinical-decision making processes in radiographers, Prime and Le Masurier (2000) used a think aloud method to investigate how 56 diagnostic radiographers over 7 clinical centres made decisions in clinical situations. They developed three clinical scenarios that they believed to be representative of the diagnostic radiographers working practices.

The cases were scripted and then acted out by actors representing both the clients and the radiographers. The radiographers were then asked to watch the video and verbalise their thoughts as they watched the scenarios.

The recordings were transcribed and then coded into one of five coding categories.

- 1. Subject describes the scene and does not engage with the scenario.
- 2. Observations on the patient's history and presentation.
- 3. Observations based on practical knowledge of radiography.
- 4. Observations based on clinical knowledge drawn from experience or wider reading.
- 5. Observations of the actors in the videotape.

The qualitative element of the analysis found that categories 3 and 5 were the most prominent, with 216 and 115 phrases coded to them. This was followed by category 4 (83), category 1 (50) and category 2 (14).

Although the researchers claim to have mapped the thought processes of the participants, they did not attempt to link the categories together in terms of patterns or relationships. Similarly, they did not attempt to evaluate them against other known decision-making models or wider theories in clinical reasoning, which may have yielded different results. It could also be argued that observing another individual carry out a task may not actually represent how they would make clinical decisions and this was shown by the large number of quotes in category 5 which included:

> *'He's doing a lateral first which I wouldn't do, it's just a waste of time.'*
>
> *'He talks a lot, get on with the job, get on with it, get on with it, there's patients waiting outside.'*

Some interesting comments were, however, made in relation to general perceptions of clinical reasoning in diagnostic radiography. The researchers found that the participants had good background knowledge around medical conditions and linked this to imaging requirements. They also reported a clear practical element to clinical reasoning, but the findings were of a general nature rather than actual cognitive mapping.

The study therefore provided some interesting background information, but the findings do not address any of the research questions in the current study.

Four other studies (Wright & Reeves, 2017; Moran & Warren-Forward, 2016; Lockwood, Piper, & Pittock, 2014; Manning et al., 2006) were highlighted in the literature search that investigated clinical decision-making to varying degrees in diagnostic radiographers. All of the studies except for Manning et al. (2006) focussed on the ability of radiographers to make accurate decisions and did not seek to investigate the decision-making processes used. Manning et al. (2006) used eye tracking software to investigate how radiographers and radiologists review chest x-rays for suspicious nodules. Although this study is in a different setting to the current study and the image review is carried out for different purposes, this study does provide an insight into the different visual patterns novice and expert reviewers use (Section 2.4.4) during image interpretation.

Also of interest to the current study is a publication by Azevedo, Faremo and Lajoie (2010). They synthesise the findings of two unpublished parallel studies (Azevedo, 1997; Faremo, 1997) that investigated the decision-making processes and error rates of radiologists during mammography investigations. The finding of Azevedo (1997) are of particular interest as the study focussed on the cognitive processes during image review.

36 participants from one radiology department with varying degrees of experience ranging from consultant radiologist 32 medical students and interns. Participants are asked to review 10 clinical cases of varying complexity whilst thinking aloud. The verbalisations were recorded and transcribed verbatim for analysis.

A coding scheme was create using three broad headings; knowledge states, problem-solving operators and control processes. These are described in Table 2.2.

TABLE 2.2 CODING SCHEME USED BY AZEVEDO (1997). (ADAPTED WITH PERMISSION)

Code	Description
Knowledge states	Radiological observations, radiological findings and diagnosis.
Problem-solving	Problem-solving operators are used to generate or instantiate states of radiological knowledge (1) reading a clinical history, (2) placing a set of mammograms on a view-box and identifying individual mammograms in the set, (3) visually inspecting each of the mammograms, (4) identifying mammographic findings and observations, (5) characterizing mammographic findings and observations, (6) providing a definitive diagnosis or a set of differential diagnoses, and (7) specifying subsequent examinations.
Operators and control processes	Control processes included goals (the use of the future tense to indicate an intended action), diagnostic planning (the planning of subsequent examinations and their possible interpretations), and meta-reasoning (a participant conducts a self-evaluation of the quality of the evolving diagnostic strategy)

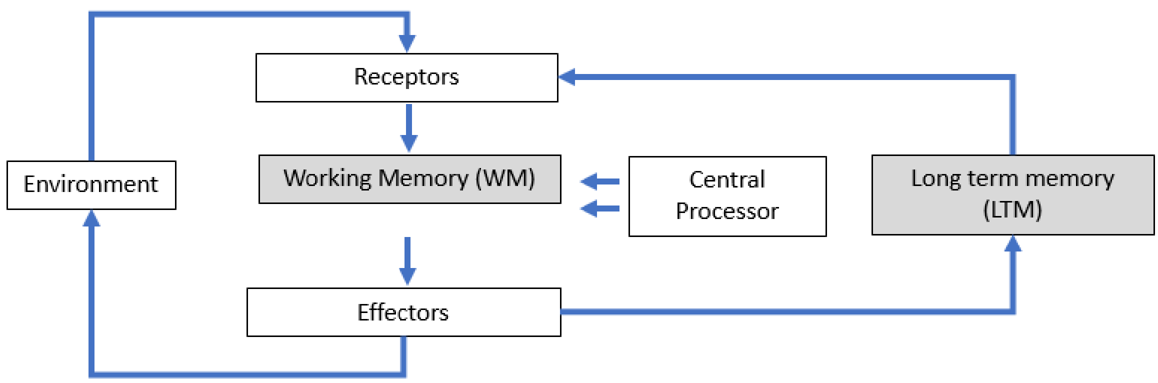
Azevedo (1997) found that these processes are used each time a practitioner interprets an image and describes this as a model. Azevedo (1997) states that the model can be used in linear way or interactively, but does not explain any distinctions between the two, nor is there any discussion on when the variations of the models are used.

Despite revealing a paucity of literature on clinical reasoning in radiotherapy, the review did highlight a significant number of articles related to clinical reasoning in nursing and to a lesser degree the Allied Health Professionals (physiotherapy and occupational therapy). These studies provide a useful insight into the design of research within the field of decision-making in healthcare and will be discussed of the IGRT setting.

2.4.2 Information processing theory

Information processing theory (IPT) has been the theoretical and methodological framework that has been used in decision-making research since its conception in the 1970s. It underpins the use of the think aloud method and is widely accepted as the model that best represents the function of the human brain (Ericsson & Simon, 1993)

FIGURE 2.1 THE MODEL OF INFORMATION PROCESSING. (ADAPTED FROM JONES, 1989 WITH PERMISSION)



IPT assumes that information is processed serially (Anselme, 2010; Koehler & Harvey, 2008). During the decision-making process, cues or information are received as input data from both motor and sensory sources (receptors) and processed in the working memory (WM) (sometimes referred to as the Short Term Memory or STM. The WM has a small working capacity and is very fast, but has a limited capacity to handle incoming information. In contrast, the LTM has a very large capacity to handle information, and relatively permanent storage ability, but is slower than the WM. Data is collected serially in the WM to represent a problem, but needs to be combined into four to seven chunks to overcome its small working capacity. The chunks are replaced in the attention span as new incoming stimuli are perceived and they are controlled by a central processor (Newell and Simon, 1972). Knowledge stored in the LTM can be unlocked or accessed by stimuli such as cues coming into the WM, which are used to aid WM processing (Thompson, 1999).

2.4.3 Intuitive and analytical thought

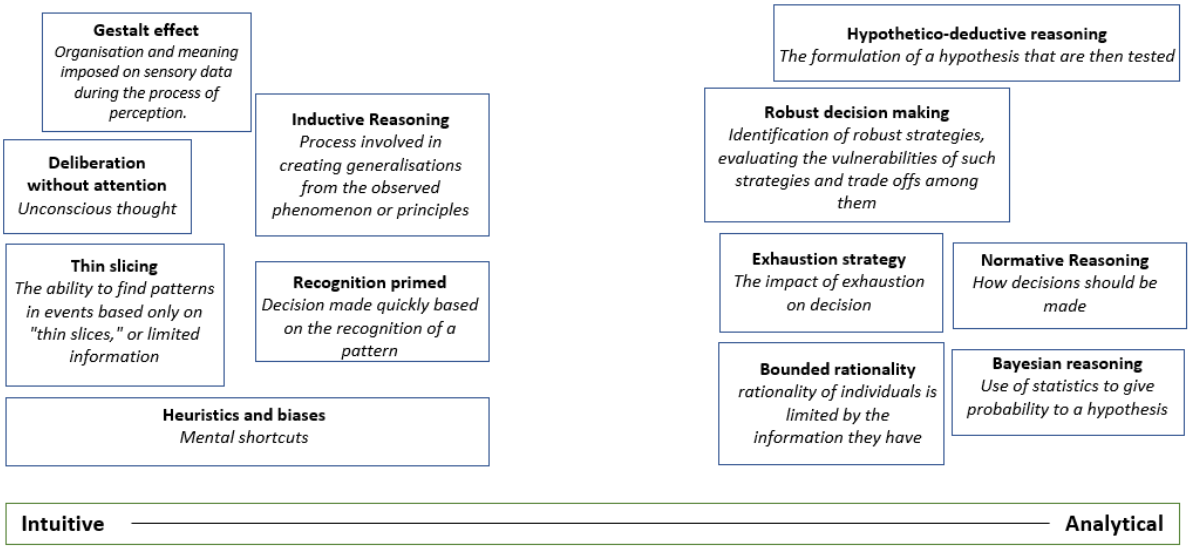
Despite the large number of models that have been proposed in the last four decades, there is little, if any consensus about one single model that meets the requirements of clinical reasoning for all individuals, in all situations and environments (Banning, 2008; Stempsey, 2009). There are however a number of similarities across the models and fundamental to all of them is the dichotomy between intuitive thought and analytical thought, as well as the spectrum or continuum that exists between (Dhami & Thomson, 2012; Hamm, 1988).

Intuition has been described as *'understanding without a rationale'* (Benner & Tanner, 1987, p.23) or 'im*mediate knowing of something without the conscious use of reason'* (Schraeder & Fischer, 1987, p.45). Intuitive thought *'involves rapid, unconscious data processing that combines the available information by 'averaging' it, has low consistency and is moderately accurate'* (Hamm 1988, p. 81). It is more likely to occur under conditions of uncertainty (Hall, 2002), and has also been linked to expertise (Crebbin, Beasley, & Watters, 2013; Ericsson, 2004; Hamm, 1988; Mitchell & Unsworth, 2005).

In contrast, analytical thought *'is carried out slowly, consciously and consistently'. Analytic thought is normally accurate but can occasionally lead to large and systematic errors'* (Hamm 1988, p .81). Analytical models assume that the decision makers' thought processes follow rational logic and these can be studied until a decision has been made (Banning, 2008).

Croskerry (2009b) summarises the facets of these two thought processes (Figure 2.2) and proposes a range of concepts and potential models that will be investigated further throughout this chapter.

FIGURE 2.2: APPROACHES TO DECISION-MAKING (ADAPTED FROM CROSKERRY (2009) WITH PERMISSION. DEFINITIONS FROM VANDENBOS (2015) AND DAVEY (2005)).



2.4.4 The impact of experience on intuition and analytical thought

Experience has been shown to impact significantly on the processes used in a clinical situation, with a particular impact being shown on the use of intuitive or analytical thought during a decision-making task (Thackray & Roberts, 2017; Banning, 2008; Jones, 1992).

Before considering the impact of experience, it is Important to consider what is meant by experience. The principal literature in healthcare around expertise comes from nursing and is largely based on the seminal work by Benner (1984). Her work provided a foundation for understanding skill levels in nursing practice and was largely linked to years of experience. The expert nurse was identified as having a greater understanding of clinical situations, recognizing patterns of patient responses, using intuition to make clinical judgements. In her early work, she described the following five skill categories of practice: *novice, advanced beginner, competent, proficient,* and *expert nurse*. Using this model, individuals can be categorised according to reasoning skills and reliance on theoretical, intuitive, and experiential knowledge. Benner's theory of intuition and expertise is grounded in the work of Dreyfus and Dreyfus (1986) who developed a model of skill acquisition for airline pilots' performances in emergency situations. In this model, Dreyfus and Dreyfus propose a transition between five stages of skill, from *Novice* to *expert* (Table 2.3) The model has four elements to it as follows (Dreyfus, 2004):

Components: This refers to the elements of the situation that the learner can perceive. These can be context free and related to the specific situation or skill needed in that specific situation.

Perspective: As the learner begins to be able to recognise almost innumerable components, he or she must choose which one to focus on. He or she is then taking a perspective of the situation.

Decision: The learner is making a decision on how to act in the situation he or she is in. This can be based on analytical or intuitive thought processes.

Commitment: This describes the degree to which the learner is immersed in the situation when it comes to understanding, deciding, and the outcome of the situation.

TABLE 2.3 DREFUS' MODEL OF SKILL ACQUISITION. (ADAPTED FROM DREYFUS (2004) WITH PERMISSION)

Skill Level	Components	Perspective	Decision	Commitment
1. Novice	Context free	None	Analytic	Detached
2. Advanced beginner	Context free and situational	None	Analytic	Detached
3. Competent	Context free and situational	Chosen	Analytic	Detached understanding and deciding; involved outcome
4. Proficient	Context free and situational	Experienced	Analytic	Involved understanding; detached deciding
5. Expert	Context free and situational	Experienced	Intuitive	Involved

Intuitive and analytical thought play a large role in this model and, using a chess player as an example, they claim that:

> *"…expert chess players can play at the rate of 5 to 10 seconds a move and even faster without any serious degradation in performance. At this speed, they must depend almost entirely on intuition and hardly at all on analysis and comparison of alternatives. "* (Dreyfus, 2004 p.180)

Ericsson, Whyte, and Ward (2007) approached the impact of experience in a different way to the traditional texts of Benner and Tanner (1987) and Dreyfus, Dreyfus, and Zadeh (1987). Citing earlier work (Ericsson, 2006), they argued that individuals improve their performance during training and initial experience until they have reached an acceptable level of performance. Beyond this experience, performance may plateau, and experience becomes a poor predictor of outcome. Ericsson and colleagues approached the domain of experience differently to many other authors, and focus around a concept they have called 'expert performance'

Ericsson argued that performance can only be improved by seeking out particular kinds of experience, namely, deliberate practice—activities which are designed by a teacher, with the sole purpose of effectively improving specific aspects of an individual's performance. Key to this is the offering of opportunities to reach performance goals with repetition, immediate feedback, and time for reflection and problem solving.

Although published earlier than Ericsson (2006), Patel and Groen (1991) argued similar concepts, but didn't go as far as Ericsson (2006) and argued that expertise should be considered along the dual continuum of both generic and specialised knowledge. They define a *novice* as an individual who has the prerequisite knowledge assumed by a specific domain, a *sub-expert* as an individual with generic knowledge, but inadequate specialised knowledge of the domain. In their model, an *expert* is categorised by an individual's specialised knowledge of the domain. These concepts are supported by Jasper (1994), who acknowledged that an expert must possess a specialised body of knowledge or skill and extensive experience in a field of practice. It has also been shown that experts are faster than novices at performing the skills of their domain and solve problems quickly with little error (Hoffman, Aitken, & Duffield, 2009). Adding to this, Jasper (1994) states that the expert will also have highly developed levels of pattern recognition and have their expertise acknowledged by others.

The concept of domain specific knowledge and skills is of particular relevance in IGRT, as radiographers may possess a wealth of experience in radiotherapy treatment delivery but may have limited IGRT experience. Equally, they may have gained a significant amount of experience reviewing one specific or a small number of anatomical sites, but may lack the skills and knowledge in more complex areas such as head and neck or paediatric cancers.

For these reasons, studies by Gegenfurtner and Seppänen (2013) and Manning et al. (2006) are of particular interest. Gegenfurtner and Seppänen (2013) sought to investigate the transfer of domain-general skills, the transfer of domain-specific skills and the transfer of domain-specific skills in context. Nine participants with varying expertise in CT, PET and PET/CT imaging were asked to review a series of clinical cases under three task conditions. The first was a familiar task, in which the participants were considered experts. The second was a semi-familiar task and the third an unfamiliar task, in which the participants were deemed to be novices. They developed three hypotheses and tested them around the following concepts:

- The transfer of domain-general skills: PET expert would be able to interpret both CT and PET/CT with high accuracy
- The transfer of domain-specific skills: CT expert would be able to interpret PET/CT with high accuracy, but not PET.
- The transfer of domain specific skills in context: PET expert would be able to diagnose PET scans with high accuracy, but not CT or PET/CT scans.

The results of the study are summarised in Table 2.4.

TABLE 2.4 RESULTS OF GEGENFURTNER AND SEPPÄNEN (2013). (REPRODUCED WITH PERMISSION).

Measure	Result
Diagnostic performance	Accuracy did transfer to the semi-familiar task Sensitivity* didn't transfer to any of the tasks Specificity~ did transfer to the semi-familiar task
Time on task	Time-on-task did transfer to both tasks
Eye movements	Number of fixations on task-relevant information did transfer to both tasks Number of fixations on task-redundant information did transfer to both tasks Fixation duration on task-relevant information didn't transfer to any of the tasks
Think aloud protocols	Verbalisations on technology did transfer to both tasks Verbalisations of cognitive activity (selecting, organizing, and integrating information) did transfer to both tasks Verbalisations of meta-cognitive activity (heuristic, control, and learning strategies) did transfer to both tasks Verbalisations of solutions did transfer to both tasks
***Sensitivity* reflects the number of true positives divided by the sum of true positives and false negatives. ~*Specificity* reflects the number of true negatives divided by the sum of false positives and true negatives.	

The results demonstrate that that there is some level of skill transfer when an individual is presented with a semi-familiar task. It is interesting to see that overall, diagnostic accuracy did transfer across, but related to this was the finding that only specificity was transferred and not sensitivity of the results. Although not well discussed in the paper, it is likely that this is connected to the use of PET and may not be as significant in other imaging modalities such as MRI and CT. The method by which a PET scanner produces images means it is often quoted as having a high false-positive rate. Image production is based on the metabolic activity, and distinguishing between metabolically active normal cells and malignant cells can be difficult (Wedman et al., 2013).

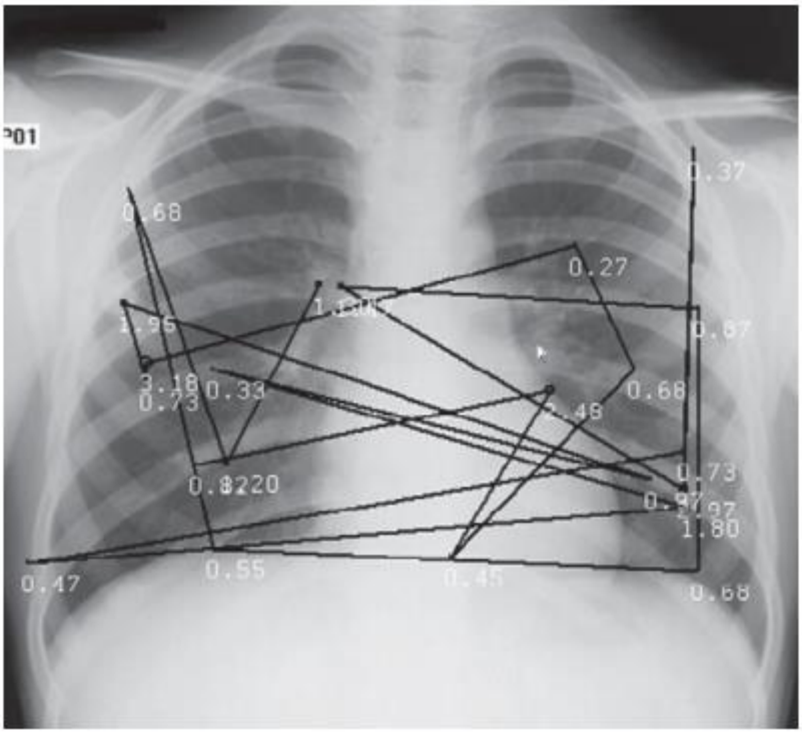
It is also interesting to note that the number of fixations also transferred across, suggesting that the participants used a similar eye pattern when reviewing the images, but the lack of expertise may not necessarily have led them to focus on the key information in the image.

However, it is difficult to draw any conclusions about the impact on level of experience, as the authors do not discuss the participants in any detail. They do not state the professional identity of the participants. It is likely that they were radiologists, but images taken in nuclear medicine may be interpreted by other professional groups in the UK. The mean experience of the participants was relatively high at 11.56 years, but this was linked to a high SD at 6.67 years. Similarly, the mean number of years since specialist training was quite high at 8.71 years (SD 7.49 years).

In a similar study, investigating the impact on experience in chest reporting in radiologists and radiographers using eye tracking software, Manning et al. (2006) found that experience impacted on the patterns of scanning, performance and the speed at which decisions were made. The population in the study were experienced radiologists (n=8), radiographers who were enrolled on a postgraduate programme of training in chest interpretation (n=5) and novice radiography students newly enrolled on an undergraduate programme in radiography (n=8).

The results found that experience reviewers tended to using a sweeping action when reviewing images and fixated on fewer zones during this sweep. Figure 2.3 is a superposition representing the focus positions of a radiologist during the image review process. It can be seen than their point of focus only stops on a small number of locations, with large sections of the lung receiving little or no attention.

FIGURE 2.3 EYE TRACKING OF EXPERIENCED RADIOLOGISTS DURING REVIEW. (MANNING ET AL. (2006) WITH PERMISSION).



The number of fixations varied with experience. The combined group of novices plus radiographers before training made a larger number of fixations per film than the trained experts (p=0.017) and the postgraduate radiographers reduced significantly their fixation number per film after their training (p=0.041). Additionally, the radiologists and trained radiographers spent significantly less time per film (p=0.02) than the pre-training and novice groups to arrive at their decisions.

Both studies provide an interesting insight into some of the methods adopted by clinicians during diagnostic image review and interpretation. It is therefore likely that some of the findings will be transferable to image interpretation in the radiotherapy process, but it must be acknowledged that the aims of the participants in these studies is different to those of the TR during image interpretation in radiotherapy verification. The participants in Gegenfurtner and Seppänen (2013) and Manning et al. (2006) were focusing on the identification and diagnosis of abnormalities with high levels of sensitivity, specificity and accuracy. TRs in the IGRT process will assess the images for tumour change, but with a greater focus on how any anatomical changes will impact on the accuracy of the planned radiotherapy treatment.

In nursing, it has been demonstrated that the number of cues (information) collected and used in the decision-making process is influenced by experience. A study by Thompson and Dowding (2003) using a think aloud method on eight intensive care nurses found that expert participants used a greater variety of cues when making clinical decisions. They reported the use of 89 different cues by expert nurses as opposed to only 49 different cues in novice participants. Experienced nurses were also seen to put the cues in context of the bigger picture of the situation rationalising their importance.

Numerous limitations were however highlighted in this study, the most significant being the authors' categorisation of experience. The authors categorised participants as experienced if they had more than three years specialist experience (mean 3.2, max 3.5), and inexperienced if they had less than one years' experience. This classification as being expert is quite low on initial review, but turnover of staff may mean that this does represent an experienced member of staff in this environment.

In a novel study using head mounted cameras on occupational therapists in a community setting, Mitchell and Unsworth (2005) used a framework to code decision-making processes to either *procedural reasoning* (type of thinking where assessments are selected, problems are defined, goals are set and treatment is planned), *interactive reasoning* (guides communication with the client in the immediate face-to-face situation, where the therapist wants to understand the client as a person in order to individualise the approach) or *conditional reasoning* (clinical thinking that involves wider social, cultural and temporal considerations.)

Their analysis demonstrated a large difference in the use of procedural reasoning and conditional reasoning across the study population (n=10). They found that novices spent a much greater amount of time using procedural reasoning alone (mean novices = 70.3% vs experts = 47.2%). Conversely, the experts were seen to use more conditional reasoning than the novices (experts = 6.3% vs novices = 2.2%). The qualitative results in this study also demonstrated that the experts used a free-flowing conversational approach when reasoning during home visits, whereas the novices used paperwork and other external resources to guide discussion and felt less at ease when discussing difficult subjects. The approach of using novel technology should be commended, but this must be balanced against the limitations of the technique that is partially acknowledged by the authors. It is not clear how big the headcams are, but it is difficult to imagine that the wearing of this technology would not impact on the interactions between the participants and the patients. The authors note that "*The participants were initially self-conscious of their appearance since they had a camera strapped to their forehead and the backpack got in the way when they attempted to sit in chairs or step sideways into shower recesses."* This suggests that the technology is quite cumbersome, and little attention is made to how this may impact on the patients' comfort and confidence.

As radiotherapy is a protocol driven profession, these results are of interest and suggest that novices are more reliant on the use of procedures and guidance in a written protocol than an expert would be. These results must be read with some caution in relation to the role of protocols, as the results don't necessarily mean the experienced participants didn't use the protocols. An expert is likely to have used the protocols many times and depending on the complexity of them, it is feasible to suggest that they may have memorised them. These comments are reinforced by O'Cathain, Sampson, Munro, and Thomas (2004) who found that nurses internalised guidelines through frequent use, making them part of their own knowledge. It must also be acknowledged that the use of head cameras on the occupational therapists may well have impacted on their decision-making and made them more conscious of what they were doing. It is plausible to suggest that this would have more impact on a junior member of staff than it would an experienced member of staff and thus may introduce some bias.

2.4.5 Heuristics

The use of heuristics are intrinsically linked to experience and intuition (Elstein, 1999; Moustakas, 1990; O'Neill, 1995). Heuristics are essentially cognitive processes with a trade-off between effort and accuracy. In using heuristics the decision-maker ignores part of the information, with the goal of making decisions more quickly and frugally than would have occurred using a more complex process (Gigerenzer and Gaissmaier, 2011; Moustakas, 1990; Shah and Oppenheimer, 2008). Some of the heuristics used will be hard-wired into an individual's mindset and may be based on tendencies to copy the behaviour of senior or admired individuals in a group (Greenwood, Sullivan, Spence, & McDonald, 2000). Similarly, an individual may use heuristics acquired from the trend in a group (Cioffi, 1998; Patel, Kaufman, & Arocha, 2002) or may be learned depending upon the social, cultural, or environmental context (Croskerry, 2009a). Although authors have shown that clinicians of all experience use heuristics regularly during a decision-making task, the use of heuristics is particularly dominant in experienced clinicians (Fonteyn & Grobe, 1992; Fonteyn & Fisher, 1995; Cioffi, 1998, Simmons, 2003).

The heuristics used may be specific to an individual, however common heuristics are seen in certain settings and within professional groups. Observing 15 experienced nurses in five adult medical surgical units, Simmons, Lanuza, Fonteyn, Hicks, and Holm(2003) observed 15 heuristics, 11 of which were re-occurring in the study population (n=15) (Table 2.5).

TABLE 2.5 COMMONLY SEEN HEURISTICS (SIMMONS, LANUZA, FONTEYN, HICKS, and HOLM, 2003 WITH PERMISSION)

Heuristic	Definition
Drawing conclusions	Stating an opinion, making an inference, or reaching a decision about assessment information
Enumerating a list	Listing pieces of information consecutively; grouping information together for interpretation
Forming relationships	Connecting information together to show an association or indicate understanding of the meaning
Judging the value	Determining the significance, worth or importance of information
Providing explanations	Stating the reason behind one's actions, beliefs or comments
Recognising a pattern	Identifying similarities of present information to previous situations and recalling something familiar from the past
Searching for information	Questioning the absence of information, looking for missing information, and acknowledging the importance of information that was not obtained
Setting priorities	Ranking nursing actions or patient problems according to their importance
Stating a practice rule	Verbalizing adherence to established policies and procedures and asserting what was usually followed in clinical practice
Stating a proposition	Using an if-then rule of logic to explain the relationship between pieces of information
Summing up	Reaching the end of a reasoning task and verbalising its completion

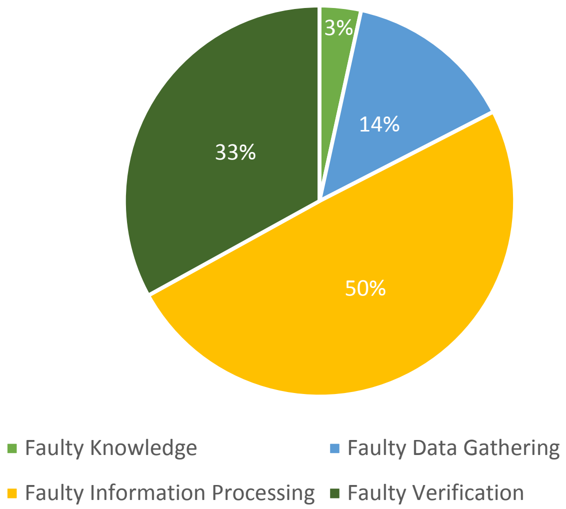
The most frequently used heuristic was pattern recognition, which has been shown to be the dominant heuristic in similar studies (Fonteyn & Grobe, 1992; Fonteyn & Fisher, 1995; Forsberg et al., 2014; Tanner, Padrick, Westfall, & Putzier, 1987). The authors suggest that as a nurse gains clinical experience through practice, they accumulate a bank of knowledge they consider to have critical links to certain outcomes. As these experiences are repeated, nurses mentally skipped steps and reached conclusions that have worked before. As outcomes became reinforced, fewer cues are needed to reach a conclusion (Simmons et al., 2003).

Pattern recognition is likely to be of relevance in the field of image analysis for radiotherapy and is widely accepted as a cognitive process used across many healthcare roles (Barrows & Feltovitch, 1987; Doody & McAteer, 2002; Thackray & Roberts, 2017). Interestingly, it has also been an area of interest outside of the clinical setting. Chess experts are regularly cited in the psychology literature and have been shown to recognise patterns reflecting areas of strategic strength and vulnerability. Chase and Simon (1973) demonstrated that a chess expert can replicate a chessboard when viewed for only 5 seconds. The ability to do this is, however, dramatically affected when pieces are randomly arranged on the board rather than being part of a tactical game. This demonstrates that the chess master has skills in pattern recognition of chess positions and plays, rather than physically remembering the position of each individual piece on the board.

As a radiographer's experience increases in radiotherapy image analysis, they will review large numbers of patients all with similar anatomy and re-occurring physiological changes such as weight loss and tumour change. It is therefore reasonable to suggest that pattern recognition may well play a role in radiographers decision-making processes.

Despite the tendency to subconsciously use heuristics in routine practice, the use of them brings with it a host of intrinsic biases and even irrationality that may ultimately lead to error (Elstein, 1999; Patel, Kaufman, and Arocha, 2002; Jefford, Fahy, and Sundin, 2011). This was well illustrated in the work carried out by Graber et al. (2005), who analysed 100 suspected diagnostic errors. They discovered that there was an average of 5.9 cognitive errors per case and grouped them into one of four categories which are presented in Figure 2.4.

FIGURE 2.4 DIAGNOSTIC ERRORS BY CATEGORY (ADAPTED FROM GRABER ET AL. (2005))



Fifty percent of the errors were linked to faulty information processing, which in part is related to the use of inappropriate heuristics. It is also conceivable that some of the errors assigned to the Faulty Verification (or lack of it), may be related to the use of heuristics. This data is based on patient records and "Fact Finding" activities from five centres, providing a wide scope of practice. The review of the information was carried out using a validated root-analysis tool (Henriksen & Kaplan, 2003), but the variation in fact finding activities and the likely variation in note keeping in the patient records must be considered when reviewing that data. However, even with some margin for error, it is clear that faulty information processes are significant in diagnostic errors.

Many of the biases cited in the literature in relation to correct diagnosis in clinical reasoning are likely to have little influence on decision-making in radiotherapy image analysis. Common biases seen during a patient consultation are factors such as gender, race, ethnicity, obesity and social class (Hall, 2002; Croskerry, 2009a). An example of this would be not offering a patient a treatment because they are deemed to be too old, or making an incorrect diagnosis as the condition is not common in a certain age category or ethnic group. Of more relevance are the common biases cited by Norman (2009) shown in Table 2.6. Two biases that are directly related to the IGRT process are *availability bias* and *confirmation bias.* Due to the nature of IGRT in practice, radiographers on a normal shift may routinely review images of patients with very similar pathology consecutively, with an emphasis on speed, and possibly in a pressured environment. This may expose their decision-making processes to bias.

TABLE 2.6 COMMON BIASES SEEN DURING CLINICAL REASONING. ADAPTED FROM (NORMAN, 2009)

Bias	Description
Availability	Tendency to judge diagnoses as more likely if they are more easily retrievable from memory.
Base rate neglect	Tendency to ignore the true rate of disease, and pursue rare but more exotic diagnoses.
Representativeness	Tendency to be guided by prototypical features of disease without appropriate consideration of base rates of disease and the tendency to miss atypical variants.
Confirmation bias	Tendency to seek data to confirm, not refute the hypothesis. Premature closure Tendency to stop too soon without appropriate consideration of alternative possibilities

The discussion of heuristics thus far has been of a negative nature, but this is not always the case. The benefits of heuristics must also be clearly emphasised. In the appropriate setting the value of their use must not be underestimated as they can produce accurate and efficient decisions (Thackray and Roberts, 2017; Croskerry, 2009; Langridge, Roberts, and Pope, 2015). It must also be acknowledged that they are not necessarily sloppy shortcuts to be avoided, but are instead efficient strategies to overcome limitations of memory (Norman, 2009).

2.5 MODELS OF CLINICAL REASONING

Emerging from the complex processes in the field of clinical reasoning, a number of models have been proposed, debated and to some degree accepted within the academic community. The following section will highlight the three most prevalent models within the evidence base: *hypothetico-deductive reasoning*, *dual process theory* and *cognitive continuum theory*. Building on this, the final part of this chapter will discuss profession specific models of clinical reasoning, which focus on concepts and processes used within the specific field of practice. Links will be made to the radiotherapy profession, which will ultimately lead to the generation of the research questions.

2.5.1 Hypothetico-deductive reasoning

Hypothetico-deductive reasoning was one of the earliest descriptive models (and possibly the most enduring) (Langridge et al., 2015). It is based on analysis by Elstein, Shulman, and Sprafka's (1978) analysis of novice and expert doctors, and has its roots in 17th-century French philosophy (Jefford et al., 2011). It is often described as the standard research method of empirical science, whereby hypotheses are formulated and tested through controlled experiments (Jefford et al., 2011; M. A. Jones, 1992). Those hypotheses that are falsified in the experiment are rejected and may be replaced by new ones (Colman, 2015) to answer the research question.

In the context of clinical reasoning, the model is based around the assumptions that clinicians generate several clinical hypotheses in the few minutes of a consultation, then collect data by questioning their patients in an attempt to support or reject these hypotheses (Elstein et al., 1978). The number of hypotheses may vary significantly, but are likely to be in the region of 5–7 diagnostic hypotheses (Burns, 2004).

Banning (2008 p.189), describes the model in a typical clinical setting using a nurse as an example:

> *"Cue recognition starts with the initial encounter with the patient, which is quickly followed by hypothesis generation. The nurse will develop a tentative hypothesis based on their initial assessment. The cue interpretation stage involves an interpretation of the cues that were initially generated and will be used to confirm or reject the original hypothesis. The final stage involves the evaluation of all the cues collected and the decision-maker will weigh up the relative merits, advantages and disadvantages of each of them before deciding to accept or reject the original hypothesis."*

It has been argued that one of the benefits of this model is the attempt to ensure that diagnostic and treatment decisions are based on logical thinking and not a rule of thumb or simple pattern recognition. It is therefore heavily reliant on biophysical facts including those that can be measured, quantified and consensually agreed (Jefford et al., 2011). However, it can be assumed that this statement would be refuted by Coderre et al. (2003) who argued that the process of generating multiple hypotheses can itself be seen as heuristic and thus subject to the biases and limitations that were discussed in the previous section. Groen and Patel (1985) take this conclusion further and argued that the use of hypothetical deductive reasoning in non-complex situations is nothing more than pattern recognition.

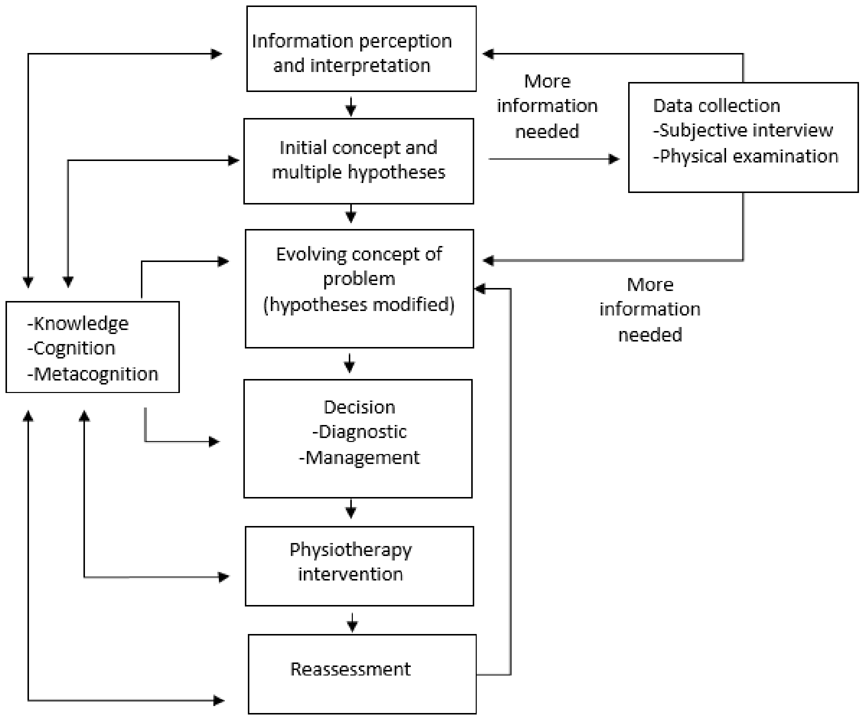
Investigating accuracy of diagnosis in the gastrointestinal setting, Coderre et al. (2003) found that the single best predictor of diagnostic success was the identification of the correct diagnosis as a hypothesis early in the encounter. Using paper-based scenarios and the think aloud technique, they compared the clinical reasoning processes of experienced clinicians and final year students. The results demonstrated that the experienced clinicians verbalised the correct hypothesis within roughly 6 minutes into the clinical encounter, whereas it took on average closer to 10 minutes for student clinicians, demonstrating an increase in the speed of hypothesis generation with experience and possibly links to pattern recognition. Of the 54 physicians who arrived at the correct diagnosis, 52 (96%) had it as an initial hypothesis; of the 7 who missed the diagnosis, 6 (85%) never mentioned it in the encounter. Reviewing the description of the model, these findings are not surprising.

Despite being widely accepted in the academic community, a number of authors have criticised the model for being too general (Howe, Holmes, & Elstein, 1984; Neufeld, Norman, Barrows, & Feightner, 1981; Norman, 2005) and not supported by research within cognitive psychology (Groen & Patel, 1985). The largest flaw in the model in terms of accuracy is the reliance on early correct hypotheses detection. If the correct decision is not identified early as one of the options or incorrect probabilities attached to the hypothesis then this will ultimately lead to an incorrect decision (Banning, 2007; Buckingham & Adams, 2000). The model also heavily relies on the assumption that the knowledge available is accurate at the time of the decision-making (Harbison, 1991). This may be appropriate when carrying out diagnostic tests in a clinic environment, but may not be appropriate in other settings (Kuipers & Kassirer, 1988; Orme & Maggs, 1993) such as a community setting. This may also be true in an IGRT scenario where the information available may be limited due to image artefacts, poor quality or technology limitations.

The model has been linked to clinical reasoning in nursing, midwifery and physiotherapy. When researching clinical reasoning in the second stage of labour, Jefford and Fahy (2015) didn't specifically refer to the term hypothetico-deductive reasoning, but concluded the most prominent processes used by the midwives involved the generating and testing of hypotheses. Similar findings were published by Thackray and Roberts (2017) who investigated clinical reasoning in cardiac physiotherapy using think aloud with post observation interviews. They highlighted a similar process to hypothetico-deductive reasoning, whereby eight key processes were identified: i*nterpreting, recognising, matching, discriminating, relating, inferring, synthesising* and *predicting.*

A modified version of the hypothetico-deductive model was presented by Jones (1992) who proposed five categories of hypotheses *(1) source of the symptoms or dysfunction (2) contributing factors, (3) precautions and contraindications to physical examination and treatment, (4) management, and (5) prognosis*. (Figure 2.5). The key differences between this and the traditional model is a focus on management and prognosis. Both are key factors in the IGRT process as the focus of the decisions made relates to the management of the disease rather than diagnosis, and whether any treatment adaption should be made. The patient's prognosis may also play a large role in determining the most appropriate decision in a given scenario as the complexity of the treatment and treatment intent could vary significantly based on this.

FIGURE 2.5 ADAPTED MODEL OF HYPOTHETICO-DEDUCTIVE REASONING IN PHYSIOTHERAPY (JONES, 1992 WITH PERMISSION).



2.5.2 Dual process theory

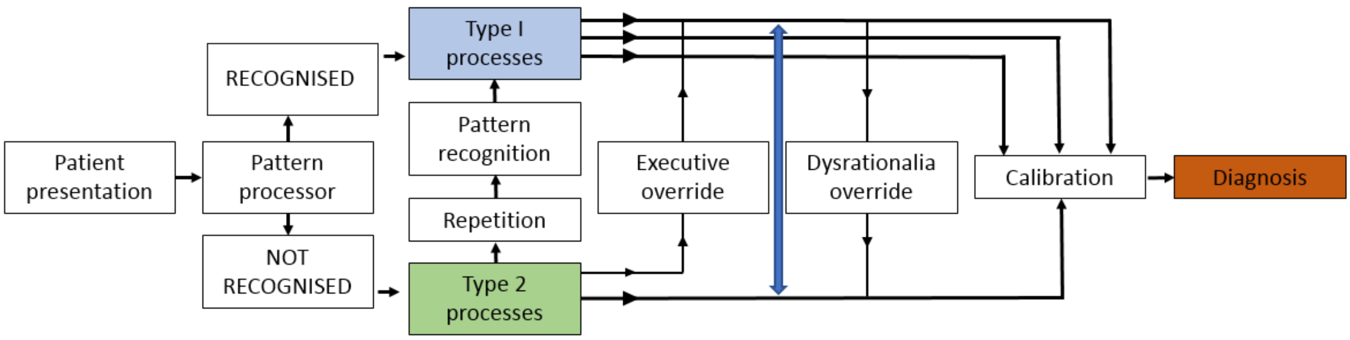
Claimed to be the most reliable model for human decision-making (Croskerry, 2009b; De Neys, 2006; Djulbegovic, Hozo, Beckstead, Tsalatsanis, & Pauker, 2012; Reyna, 2004), the dual process theory stems from the seminal work by Kahneman (2011) and assumes that cognitive processes are governed by two systems.

- System 1 is an intuitive, automatic, fast, narrative, experiential and effect based system (Djulbegovic et al., 2012) and is unavailable to introspection. It is commonly associated with rapid recognition and categorisation of objects such as a chair or a tiger in everyday life (Norman, 2009). It is believed to be independent of the working short-term memory, so is unencumbered by the series capacity limitations of the working memory (Evans, 2008).

- System 2 in contrast is analytical, slow, verbal, deliberate and logical (Croskerry & Nimmo, 2011), and places heavy loads on working memory, making it energy intensive (Norman, 2009)

The process has most frequently been investigated in the medical setting (Jefford et al., 2011) and is typically described using a patient diagnosis as an example, but it has been shown to be used by other medical professionals in nursing and midwifery (Djulbegovic et al., 2012; Jefford et al., 2011). The process ultimately involves pattern recognition to determine whether a Type I or Type 2 process should be used. The full model can be seen in Figure 2.6.

FIGURE 2.6 THE DUAL PROCESS THEORY (CROSKERRY & NIMMO, 2011 REPRODUCED WITH PERMISSION)



The model flows from left to right, starting with a patient presenting with signs and symptoms. If the clinician recognises this presentation it is likely that the intuitive mode (Type 1 process) will engage and a fast decision will be made (Croskerry, 2009b; Norman, 2009). If the presentation isn't recognised, the analytic mode (Type 2) will be engaged and a slower, more systematic process will be used to determine the diagnosis (Croskerry, 2009b; Norman, 2009).

Croskerry and Nimmo (2011 p.157) highlight six operating characteristics of the model:

1. Repeated exposure to similar presentations will eventually result in a pattern being recognised and a default shift to intuitive mode will occur. Essentially, the likelihood of this happening increases as expertise develops.
2. The analytic mode can be overridden by the intuitive mode. This is described as executive overriding the model and essentially occurs if the analytical mode thinks that the intuitive mode might be mistaken (metacognition).
3. The intuitive mode can override analytical mode, resulting in an irrational act (Dysrationalia mode).
4. The large blue arrow highlights the dynamic nature of the model and may result in a toggle between modes during the decision-making process. This may occur if an initial intuition is overridden by the analytical mode, but a second intuition results in a toggle again.
5. There is a general tendency to default to the intuitive mode whenever possible. This results in the sparing of cognitive effort and is referred to as "the cognitive miser function"
6. Calibration occurs by repeated exposure to similar scenarios whereby the clinician links the decision made to the patient outcome.

Despite using less mental effort and providing a quicker decision, Type I decisions are associated with increased errors, vulnerability to bias, low reliability and are context specific. In contrast, Type 2 decisions use more mental effort and provide a slower decision, but are associated with higher mental awareness. This in turn leads to lower vulnerability to bias, higher scientific rigour with decisions being more likely to be deliberate and rule-based (Croskerry, 2009b; De Neys, 2006; Djulbegovic, Hozo, Beckstead, Tsalatsanis, & Pauker, 2012).

The emphasis of error reduction on this model is of interest with the literature often supporting the theory that decisions repeatedly managed with Type 2 processing should become relatively error-free (Croskerry & Nimmo 2011).

Croskerry (2009b) uses the example of driving a car to demonstrate how the two modes interact over time. The continuous decision-making required to drive a car is established through Type 2 processing but repeated exposure to the same decisions will eventually relegate these decisions to a Type 1 process. For experienced drivers, the task of driving to a familiar location such as work is done on an almost automatic level. This will remain the case until the driver is challenged by performance limiting factors such as fatigue, sleep deprivation, or by conditions that may not have been met fully in the Type 2 acquisition.

The use of these two systems independently may be an oversimplification of the model. Croskerry and Nimmo (2011) acknowledge this and refer to a toggle in their description above of the model whereby an individual may switch between modes during a decision-making task. This concept is taken further by Hammond (2000) who describes a process whereby a continuous oscillation between the two modes may occur, so in some circumstances a blend of the two processes may occur rather than the use of a process exclusively.

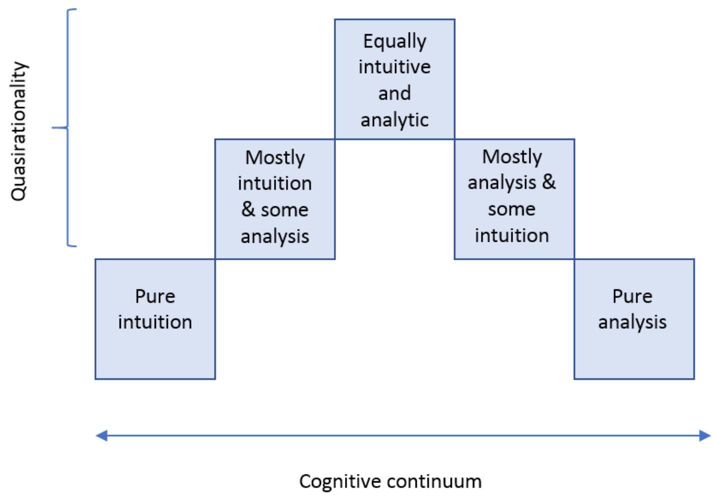
As with previous descriptions of decision-making processes, heuristics can also bias reasoning in this model (De Neys, 2006) with some situations requiring a more elaborate and analytic approach than first adopted. This may lead to a conflict in the two systems and cue different responses (Djulbegovic, Hozo, Beckstead, Tsalatsanis, & Pauker, 2012; Croskerry, 2009b) . In these cases, the analytic system will need to override the belief-based response generated by the heuristic system (Stanovich &West, 2000) which is indicated by the override arrows in the model.

Individuals must also acknowledge they spend most of their time in intuitive mode. In order to make an effective decision using this model the individual must use the correct mode in the correct situation and be conscious of bias towards certain decisions (Djulbegovic et al., 2012; Croskerry, 2009b). A number of strategies have been suggested to aid this and include the development of insight and awareness through education, the use of simulation, the minimisation of time pressures and the delivery of feedback (Croskerry & Nimmo, 2011).

2.5.3 Cognitive continuum theory

As in the dual process theory, cognitive continuum theory has intuitive and analytical thought at its core, but conceptualises them differently. Proposed by Hammond et al. (1966) and then further developed by Hamm (1988) this theory identifies the modes of cognition that lie in between intuition and analysis, describing them as *quasirationality* (Dhami & Thomson, 2012) (Figure 2.6). Proponents of the model argued that the likelihood of any task to require pure intuition or pure analysis is rare (Dhami & Thomson, 2012; Dunwoody, Haarbaue & Mahan 2000; Førde, 1998) and in reality an individual may use modes of cognition that slide up and down the continuum during a decision-making process (Offredy, Kendall, & Goodman, 2008; Thackray & Roberts, 2017). The movement along the continuum is stimulated by the success or failure of the task at any point in time; success in the task inhibits movement, whereas failure stimulates movement (Doherty & Kurz, 1999). In this sense, the model is similar on a simple level to Hammond's (2000) description of the dual process theory when the decision maker oscillates from mode 1 to mode 2 to create a blend of the two modes. This description however, still views the modes as two distinct concepts, whereas the cognitive continuum theory describes the concepts on a scale. (Dhami & Thomson, 2012).

FIGURE 2.7 THE COGNITIVE CONTINUUM THEORY (DHAMI & THOMSON, 2012 REPRODUCED WITH PERMISSION)



Using a mode towards the pure intuition end of the continuum is most efficient in situations where an individual is faced with a lot of interrelated visual information and time is limited. An example of this type of decision situation would be a rapidly deteriorating patient, who 'looks' sick, where the nurse has to respond and act quickly. If the nurse tried to use a more analytical mode by using a protocol book or guidelines they are more likely to have a negative outcome (Dowding, Spilsbury, Thomson, Brownlow, & Pattenden, 2008)

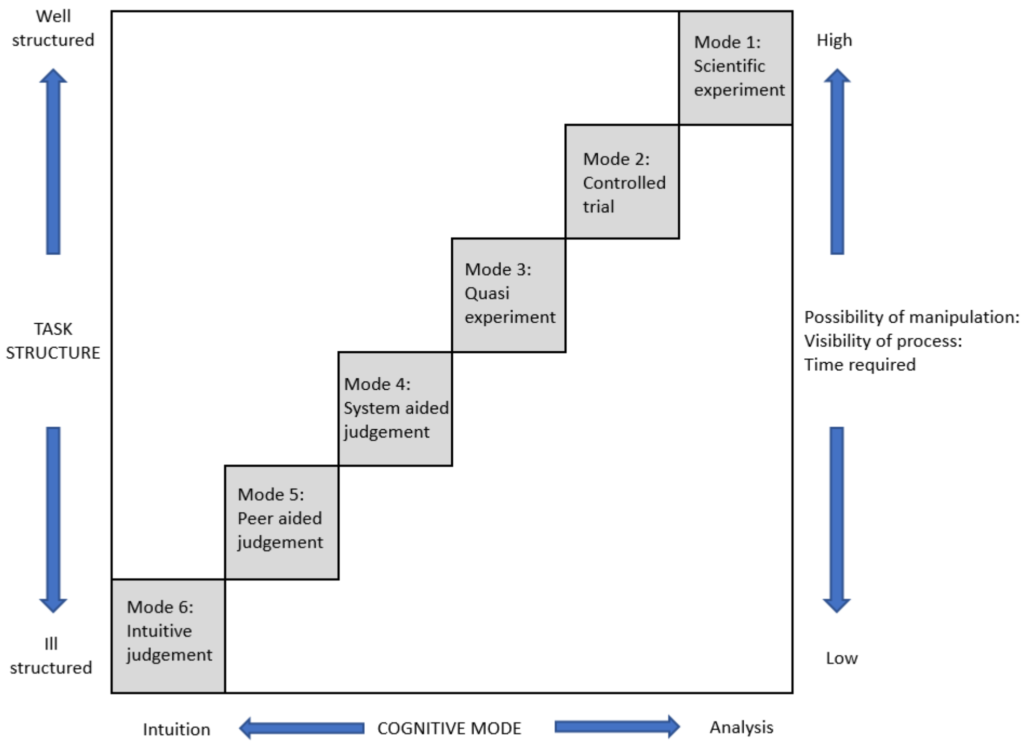
Conversely, using a mode towards the analytical end of the continuum would be more appropriate for situations where an individual has more detailed, structured information and time is available to use it. An example of this type of decision scenario would be a patient attending for management of their asthma, where the nurse can use a limited number of information cues (Dowding, Spilsbury, Thomson, Brownlow, & Pattenden, 2008).

A similar set of routine scenarios could be put into an IGRT context, when considering online and offline imaging. If a radiographer was reviewing an online image of a patient that was unwell, where taking time to make a decision could impact on the tumour position, making that decision using largely intuitive thought would be most appropriate. Reviewing an image off-line where the radiographer can take their time, refer to protocols and seek advice from colleagues is a very different situation and environment and if necessary using a mode towards the analytical end of the continuum may be more appropriate. That said, it is likely that intuition would still play a role in such decisions and so this scenario may cause more of a movement up and down the continuum than the online scenario.

In describing the cognitive continuum theory, Hamm (1988) also proposes that tasks can be ordered in a task continuum of six modes (Figure 2.8) depending on the structure of the task and whether it is more likely to induce an intuition based decision or an analysis based decision.

Each mode is related to an accompanying level of knowledge based on a variety of situations. For example, *Mode 1* would use highly analytical judgement that is based on a scientific experiment normally carried out in a controlled environment such as a laboratory. Such forms of knowledge are rarely available during IGRT and are unlikely to play a part in this process. However, decisions may be made in *Mode 2* based on a moderately strong analytical judgement from controlled trials. Although limited in IGRT, there is a growing evidence base to support certain common decisions and many protocols are now evidence based. When considering modes towards the intuition end of the continuum, *Mode 5* is potentially very relevant to the IGRT setting as there may be a lack of robust evidence available at the time of the decision and the individual involve peers in the decision-making process. In *Mode 6*, decisions are made using weak quasirational intuitive judgements where opinion may be purely based on an individual's experiences or interpretations. This again could be linked to an IGRT scenario, particularly if the case is complex and the reviewer is an experienced radiographer.

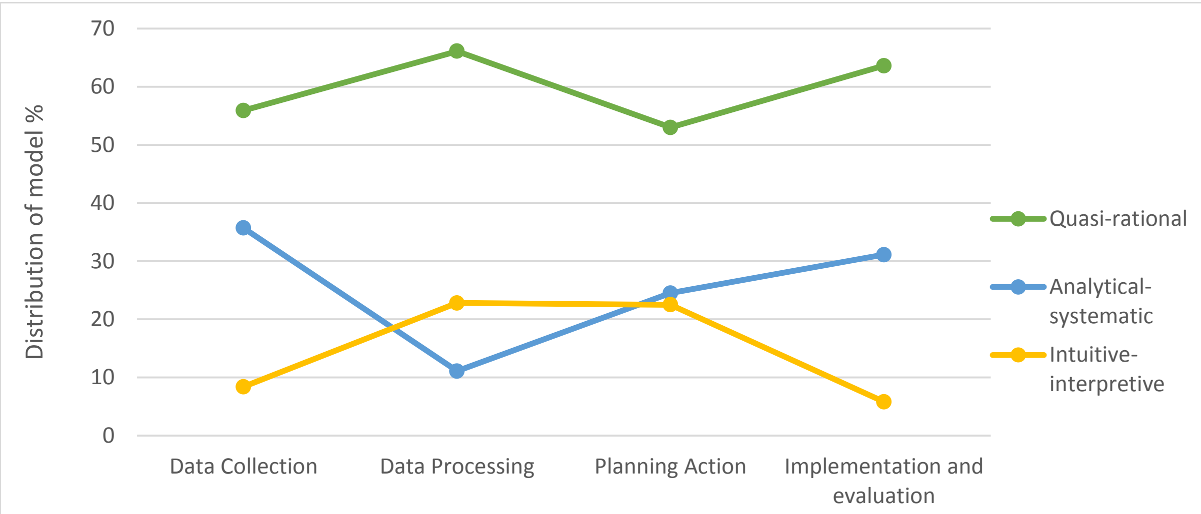
FIGURE 2.8. THE SIX MODES OF ENQUIRY (HAMM, 1988) (REPRODUCED WITH PERMISSION)



In a large study involving 2,095 nurses, Bjork and Hamilton (2011) investigated the use of cognitive continuum theory. A Likert scale questionnaire-based method was used, with the respondents being instructed to answer the questionnaire with an elective patient in mind. The authors suggest that the use of an elective case rather than a chronic one, would prompt nurses to think of their decision-making with the same type of judgment tasks in mind and thus allow for comparison across hospitals and units. Using a shortened version of a previously validated questionnaire, they used a framework to analyse the results over four phases of the task: *Data collection, data processing, planning action* and *implementation and evaluation.*

The results are summarised in Figure 2.9 and clearly demonstrate that quasirational thought was the most prominent process used across all four phases of the task. Analytical thought was also noticeably higher at either end of the task compared to intuitive thought. On further analysis, they found that years in present job is significantly associated with intuitive-interpretive thought, followed by further education, male gender, higher age, and surgical field of practice. This is in line with both Benner's and Dreyfus' models previously discussed. However, the results conflict slightly with Lauri, Salanterä and Chalmers (2001) who also used a questionnaire-based method. They reported that education was the highest predictor of the use of intuitive thought, with age also being a significant factor. Meaningful comparison of the two studies is difficult, due to the use of different questionnaires, but what can be concluded is that education plays a significant role in the types of decision-making used.

FIGURE 2.9 QUASIRATIONALITY AT DIFFERENT STAGES OF THE DECISION TASK (BJORK & HAMILTON, 2011. REPRODUCED WITH PERMISSION)



The use of questionnaires in clinical reasoning research may bring with it numerous limitations and biases that must be acknowledged. Asking individuals to self-report how they make decisions rather than observing them making those decisions has been shown to be unreliable (van Someren, Barnard, & Sandberg, 1994) as participants may carry out post-processing (Banning, 2008; Todhunter, 2015). This process is often subconscious and involves reflecting and rationalising their thoughts after they occur, potentially leading to a biased report of how they should have made the decision rather than how they actually made it (Banning, 2008; Todhunter, 2015).

Although only making a tenuous link to cognitive continuum theory in the article, Dowding et al. (2009) observed six nurses (three with more than three years' experience and three with less than one years' experience) over a series of patient interactions concerned with the titration of heart medication. The authors proposed that drug titration would involve a mixture of intuition and analysis inducing features (such as the use of guidelines) and suggested this would fit well with quasirationality. The decision strategies actually used by nurses for medication titration appeared to rely on a mixture of 'informal' guidelines and an experimental 'try it and see' approach to making decisions, which were considered to be at the analytical end of the continuum. They rarely reported observing intuitive thought and concluded that the participants may not be using optimum processes in practice.

2.5.4 Profession specific models

In addition to the theoretical models previously described, a number of profession specific models and concepts have been proposed, which focus specifically on the tasks carried out by different professional groups. Examining these models is beneficial as it may be possible to make links to IGRT that may inform the method and potential coding strategies for the current study.

As previously discussed in Section 2.4.1, a common approach used when investigating decision-making processes is the think aloud method, which involves the participants verbalising their thought processes during a task. Varying strategies have been implemented to analyse this data including protocol analysis (Göransson, Ehrenberg, Ehnfors, & Fonteyn, 2007; Kuiper, Murdock, & Grant, 2010; Simmons et al., 2003), framework analysis (Thackray & Roberts, 2017) and thematic analysis (Forsberg, Ziegert, Hult, & Fors, 2014; Lee et al., 2016; Tiffen, Corbridge, & Slimmer, 2014; (Prime & Le Masurier, 2000) in order to look for general themes and concepts.

Arguably, a more descriptive method of analysis is protocol analysis, which was first described by Fonteyn and Grobe (1992) when investigating clinical reasoning in expert nurses. This method has subsequently been used in a wide variety of settings in nursing (Göransson et al., 2007; Kuiper et al., 2010; Simmons et al., 2003). This method will be explained and evaluated in more detail in Chapter 3, but essentially involves a three-stage process of analysis (Fonteyn & Grobe, 1992).

1. Referring phrase analysis (RPA)- identification of phrases and concepts commonly used in the decision-making process
2. Assertional analysis (AA)- identification of relationships between these concepts
3. Script analysis- (SA) overall explanation of the process

Table 2.7 gives an overview of four studies in nursing with varying aims that implemented this method and includes the seminal paper by Fonteyn and Grobe (1992).

Reviewing this information, it is clear that even within a single professional group, the discourse used in clinical reasoning (RPA) is very specific to the setting and the decision tasks being carried out, which highlights the importance of understanding clinical reasoning across different settings. The large range in the number of RPA codes across the studies is also evident and may be linked to complexity or information utilised in each of the settings.

TABLE 2.7 SUMMARY OF RESULTS FROM THE FOUR STUDIES USING PROTOCOL ANALYSIS

Author	Aim	RPA	AA	SA
M. E. Fonteyn and Grobe (1992)	How do expert nurses reason when planning care and making clinical decisions for a patient who is at risk, and whose outcome is uncertain?	20 in total. Not all reported. Most common: action, amount, problem, sign, time, treatment, and value.	Indicative, causal, connotational.	Study, conclude, choose, and explain
Greenwood, Sullivan, Spence and McDonald (2000)	Investigate how nursing subculture factors manifest in clinical reasoning in a neonatal intensive care department	15 in total: Status (3 variants), temperature, blood test, psychosocial, fluids, wounds, medication, general appearance, position, age, errors	Indicative, causal	Plan, rationale, interpretation, diagnosis, plan
Johnsen, Slettebø and Fossum (2016)	To describe the cognitive processes and thinking strategies used by recently graduated registered nurses while caring for patients in home healthcare clinical practice.	41 in total. Most common: Action, patient, verification and confirmation.	Causal, Declarative, Evaluative, Indicative, Preventative	Assume, conclude, confirm, control, correct, describe, encourage, explain, gather information, judge, plan, shared decision, verify
(Simmons et al., 2003)	This qualitative descriptive study explored the cognitive strategies used by experienced nurses as they considered assessment findings of assigned patients.	Amount; care provider; condition; day, time, and date; device; diagnosis; event; family; frequency; location; missing clinical data; patient; plan; rationale; status; test; treatment; and value.	(a) Anticipative (relationships of action and looking forward), (b) causal (relationships of cause and effect), (c) declarative (relationships of stating facts), and (d) evaluative (relationships of judging significance).	Describe, explain, plan, evaluate, and conclude.

When reviewing patterns of assertions, there is much greater overlap across the settings with indicative (relationships of significance) and causal assertions (relationships of cause and effect) appearing in all three studies. This suggests that despite using different discourse and considering different concepts and cues in their decision-making processes, patterns can be made in relation to how they link these situation specific concepts, making model generation possible.

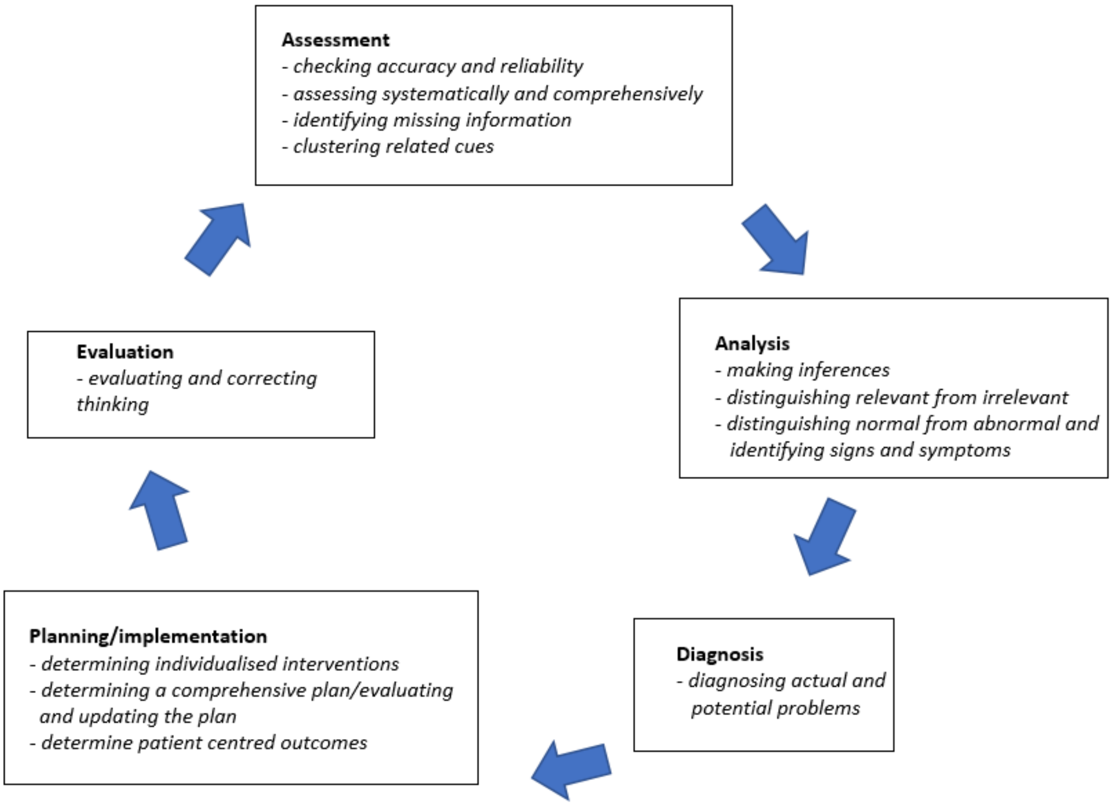
When considering an overview of the process in SA, plan, conclude and explain appear in two of the three studies, again allowing for the development of profession specific models. In all the studies, the researchers used this information to look for patterns within the populations of their studies. For example, Johnsen, Slettebø and Fossum (2016) found that the more inexperienced participants used a large number of concepts when making decisions with a greater portion of them being reactive rather than pro-active. Similarly, the study by Greenwood, Sullivan, Spence and McDonald (2000) yielded some interesting results around the use of biases by junior members of staff. One particular bias that was identified to be regularly used was in relation to "Do what senior colleagues do".

Using thematic analysis which in many cases is similar to RPA in protocol analysis, a number of authors (Forsberg, Ziegert, Hult, & Fors, 2014; Lee et al., 2016; Tiffen, Corbridge, & Slimmer, 2014; (Prime & Le Masurier, 2000) have investigated clinical reasoning in nursing and physiotherapy with similarities seen across them.

Lee et al. (2016) developed a model based on a study of Korean nurses in complex clinical situations (Figure 2.9). Although not fully described, the method involved nurses reviewing clinical scenarios and verbalising their thought processes using think aloud. The cyclical model rotates around the concepts of *assessment→ analysis → diagnosis→ planning/implementation → evaluation*. This seems like a logical process and is in line with other studies (Benner & Tanner, 1987; Forsberg et al., 2014). They reported that the majority of the time during the decision-making process was spent in the assessment phase (30-50%) and, in particular, checking accuracy and reliability. This was however measured in time, rather than the number of verbalisations, and the researchers noted that a large portion of this time was spent organising and looking at notes. Interestingly, the least used process was 'identifying patterns', which is surprising looking at the participant demographics.

The average total clinical experience was 11 years and 4 months and approximately 50% of the participants were advanced practice nurses.

FIGURE 2.10 CLINICAL REASONING MODEL BASED ON KOREAN NURSES (LEE ET AL., 2016 REPRODUCED WITH PERMISSION).

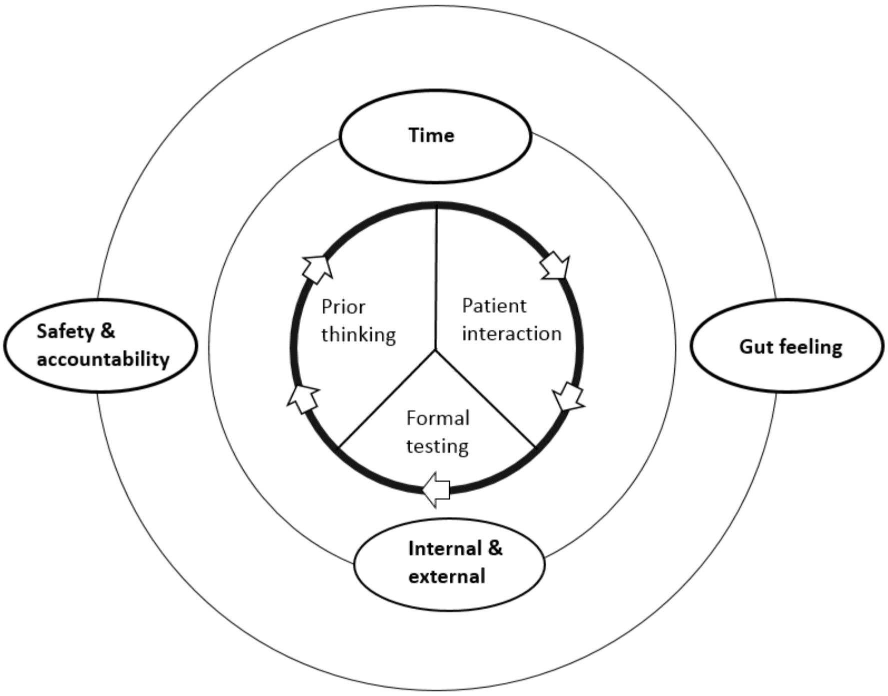


Two studies that looked to develop more complex rotational models were Langridge et al. (2015) and Thackray and Roberts (2017). Both investigated clinical reasoning in physiotherapy.

Using a two phase approach of focus groups with retrospective think aloud technique, Langridge et al. (2015) investigated how extended practice physiotherapists and non-extended practice physiotherapists made clinical decisions in relation to lower back pain in a musculoskeletal outpatient clinic. Participants were interviewed and asked to think aloud in relation to an appointment they had recently carried out with a patient.

Their final model (Figure 2.11) sought to link the cognitive processes used with the concepts that impact on them. At the centre of the model are three key themes: *prior thinking* (knowledge gained before the consultation), *patient interaction* (the clinical relationship and mutual understanding that engenders patient confidence in the clinician) and *formal testing* (the use of physical or non-physical tests that aid in the diagnosis and management of a patient.) The outer rings link to the inner rings, with an additional four themes being identified: *time, gut- feeling* (intuition), *internal and external* (external influences included indirect elements of reasoning processes such as national policy, finance constraints or NHS Trust directives; internal factors included clinician perceptions of themselves, and awareness of how others view them) and safety and accountability.

FIGURE 2.11 MODEL OF CLINICAL REASONING IN A MUSCULOSKELETAL OUTPATIENT CLINIC (LANGRIDGE ET AL., 2015 REPRODUCED WITH PERMISSION).



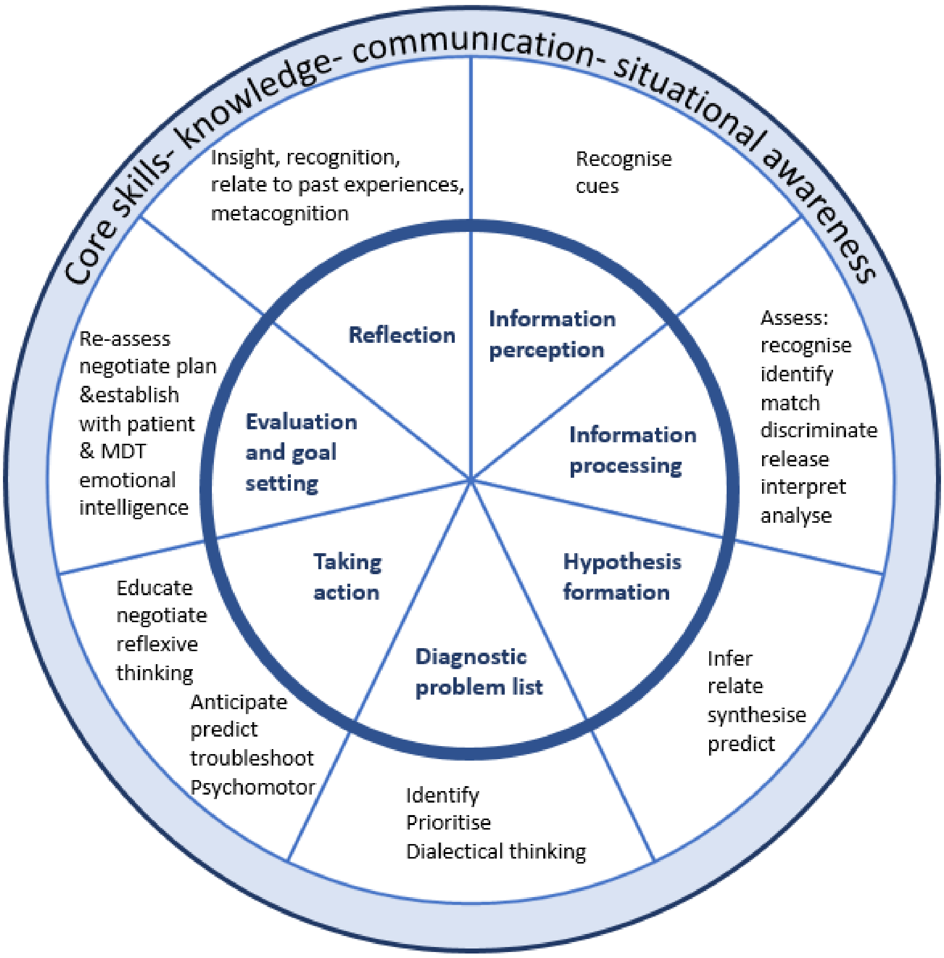
Gut-feeling (intuition) and safety and accountability were both common factors discussed by the participants and were particularly significant in the extended scope practitioners. The authors highlight that these results contrast with those from other physiotherapy related literature, which suggested that in physiotherapy the main process was pattern recognition (Stolper, Royen, & Dinant, 2010). Arguably, a gut-feeling may well be linked to pattern recognition, and separating the two may be difficult using this method. One other key area where differences were noted were in relation to experience and the use of informal testing. The experienced participants were shown to make more use of diagnostic tests such as MRI, integrating them into their routine decision-making processes.

The study does have some notable limitations in its method, which is not fully described in places. The study had two phases, one involving focus groups and the other using semi-structured interviews using think aloud. It appears different participants took part in each phase, which may be related to resource issues in the centres and therefore unavoidable. This in itself may not be problematic, but consideration of any potential impact needs to be considered. There was also no discussion of how the two phases were linked together, or if an attempt at some form of triangulation was made. The authors describe the second phase as retrospective think aloud, but the description of the method reads as though the participants were asked to reflect on a case they had recently seen rather than verbalise specific cognitive processes. Regardless of the title given to the method, the biases previously discussed in relation to retrospective descriptions must be considered.

Arguably, a more robust method was used by Thackray and Roberts (2017). Using a simulated environment of virtual patients, they investigated clinical reasoning in cardiovascular physiotherapists. They initially developed a nine step simple model of the events that were observed. In a circular model similar to Langridge et al. (2015) they reported a process of *Information perception→ information gathering→ information processing→ active gathering 2→ acute desaturation event→ response 1→ treatment→ evaluation→ plan and goal set.*

Taking these concepts further, they developed a more detailed conceptual model that can be seen in Figure 2.12. Making clear links to the hypothetico-deductive model, the authors highlight the importance of developing hypotheses and testing them through further information gathering and evaluation. What is of interest in this model, are the two outer rings which link the processes to concepts as well as the required underpinning skills. This model clearly highlights the complex, iterative and dynamic nature of decision-making in a clinical environment.

FIGURE 2.12 MODEL OF CLINICAL REASONING IN CARDIOVASCULAR PHYSIOTHERAPY (THACKRAY & ROBERTS, 2017 REPRODUCED WITH PERMISSION)



2.5.5 Key research problems and justification for this research

A review of the literature has highlighted a number of issues that underpin and justify this doctoral research. These are summarised as:

2.5.5.1 The impact of environment and task on decision-making models

The review has highlighted a large evidence base of research relating to how humans make decisions. Within the evidence base, there are a number of accepted models that describe how decisions are made in a variety of settings, including the clinical environment. There is however little, if any agreement on a model that describes how decisions are made in all settings (Banning, 2008; Stempsey, 2009).

The wider evidence base supports the notions that humans make decisions using two broad methods or modes. These are typically described as intuitive and analytical modes. Disagreement is however very evident in relation to the role of these methods in the overall process and in particular how humans move from one mode to another. Three models are widely accepted in the literature: Hypothetico-Deductive Model (Elstein, Shulman & Sprafka's 1978), Cognitive Continuum Theory (Hammond et al., 1966) and The Dual Process Model (Croskerry, 2009). Cognitive Continuum Theory and The Dual Process Model describe in detail how individuals may change their cognitive mode during a task, but describe the move from one mode to another quite differently.

There is evidence to support all three models in the clinical setting, but in an attempt to better describe decision-making in specific settings or professions, a number of profession specific models have been published in both nursing and AHP (e.g. Thackray & Roberts, 2017; Lee et al., 2016; Langridge et al., 2015). All of the models cited in the review are linked to the concepts of analytical and intuitive modes to varying degrees but vary notably depending on the setting and task.

This variation in process relating to setting and task highlights the need for further investigation into decision-making during the IGRT process. The evidence presented provides a sound basis to develop IGRT specific models, and informs research design, but does not address the needs of the radiotherapy profession. By gaining an understanding of these models, radiographers will be able to make safer and more efficient decisions by understanding the strengths and limitations of how they make decisions.

2.5.5.2 Uncertainly relating to the impact of experience in decision-making

It is clear that experience impacts on human decision-making. What is less clear is how it impacts and what types of experience have the biggest effect. Grounded in the work of Dreyfus and Dreyfus

(1986), early work on decision-making and expertise in nursing by Benner (1984) linked expertise to years of practice. This resulted in the widely cited “Model of Skill Acquisition”, which describes the attributes of nurses as they progress through four stages of expertise (Benner 1984).

Despite being extensively cited in the nursing literature, this model is disputed by another seminal text published by Ericsson, Whyte, and Ward (2007) who argued that individuals improve their performance during training and initial experience until they reach an acceptable level of performance, at which point they plateau. They argued that performance can only be improved by seeking out particular kinds of experience, namely, deliberate practice in a small specific scope of practice.

There is evidence in diagnostic radiology to support the notion that expertise impacts on the reviewing processes used by radiographers and radiologist. The number of fixations made on an image and the pattern of eye motion used by the operators seems to be particularly affected by experience (Gegenfurtner & Seppänen, 2013; Littlefair, Brennan, Reed, Williams, & Pietrzyk, 2012; Manning et al., 2006). This is likely linked to the cognitive process of pattern recognition; whereby previous experiences are used to make decisions intuitively.

Due to the structure of many departments, some therapeutic radiographers may have many years of experience as a radiographer treating patients, but little experience in reviewing images as part of the IGRT process. Changes in practices and education means that many newly qualified radiographers graduate with some level of IGRT expertise and may start to review images early in their careers. If IGRT processes are to be improved and capacity increased within radiotherapy departments it is essential that these factors are better understood to allow radiotherapy mangers and educators to develop safe and efficient services.

2.5.5.3 A paucity of literature directly relating to decision-making during the IGRT process.

The literature supporting the clinical benefits of IGRT is growing and its wide-spread implantation across the UK is evident. Professional Bodies such as the Society and College of Radiographers, The Royal College or Radiologists and The Institute of Physics and Engineering in Medicine have published several influential documents relating to the implementation of equipment and protocols. These publications are supported by peer reviewed articles (e.g. McNair et al., 2015; Zelefsky, Kollmeier, Cox et al. 2012; Shumway et al., 2011; Nguyen et al., 2011) that demonstrated the ability of therapeutic radiographers to make decisions similar to those of their medical colleagues.

Evidence from Public Health England (2017) has however highlighted a number of concerns relating to errors during the image review process. As discussed in Sections 2.5.5.1 and 2.5.5.2, setting and task can impact the way individuals make decisions and the lack of any evidence relating to how therapeutic radiographers make decisions during the IGRT process is of concern.

This programme of research set out to address this gap in the evidence base, by investigating how therapeutic radiographers make decisions during the IGRT process. In addition, the study sought to determine what factors impacted on the decision-making process, so that recommendations could be made to improve practice.

2.6 RESEARCH AIMS AND QUESTIONS

2.6.1 Overarching Aim

To investigate the clinical decision-making processes used by therapeutic radiographers when carrying out Image Guided Radiotherapy.

2.6.2 Research Questions

In relation to clinical decision-making based on 3D Cone Beam CT imaging during radiotherapy:

1 - What decision-making processes do therapeutic radiographers utilise while making clinical decisions?

2 - How do therapeutic radiographers prioritise the clinical factors observed during Image Guided Radiotherapy?

3 - How does clinical experience as a therapeutic radiographer influence the decision-making process?

4 - How does experience with Image Guided Radiotherapy influence the decision-making process?

5 – Do any other factors impact on the clinical decisions made by therapeutic radiographers?

CHAPTER 3- METHODS

3.1 INTRODUCTION

This chapter will begin with an overview of the overall study design. This will be followed by a discussion on mixed method and multimethod research designs. Justifications will be made for use of a multimethod design. The chapter will then continue with a description of the pilot study and the main study, including discussion of recruitment, case study development, the method of observation and analysis, and the follow-up interviews and analysis. Ethical considerations, discussion of data validity and trial management are also presented.

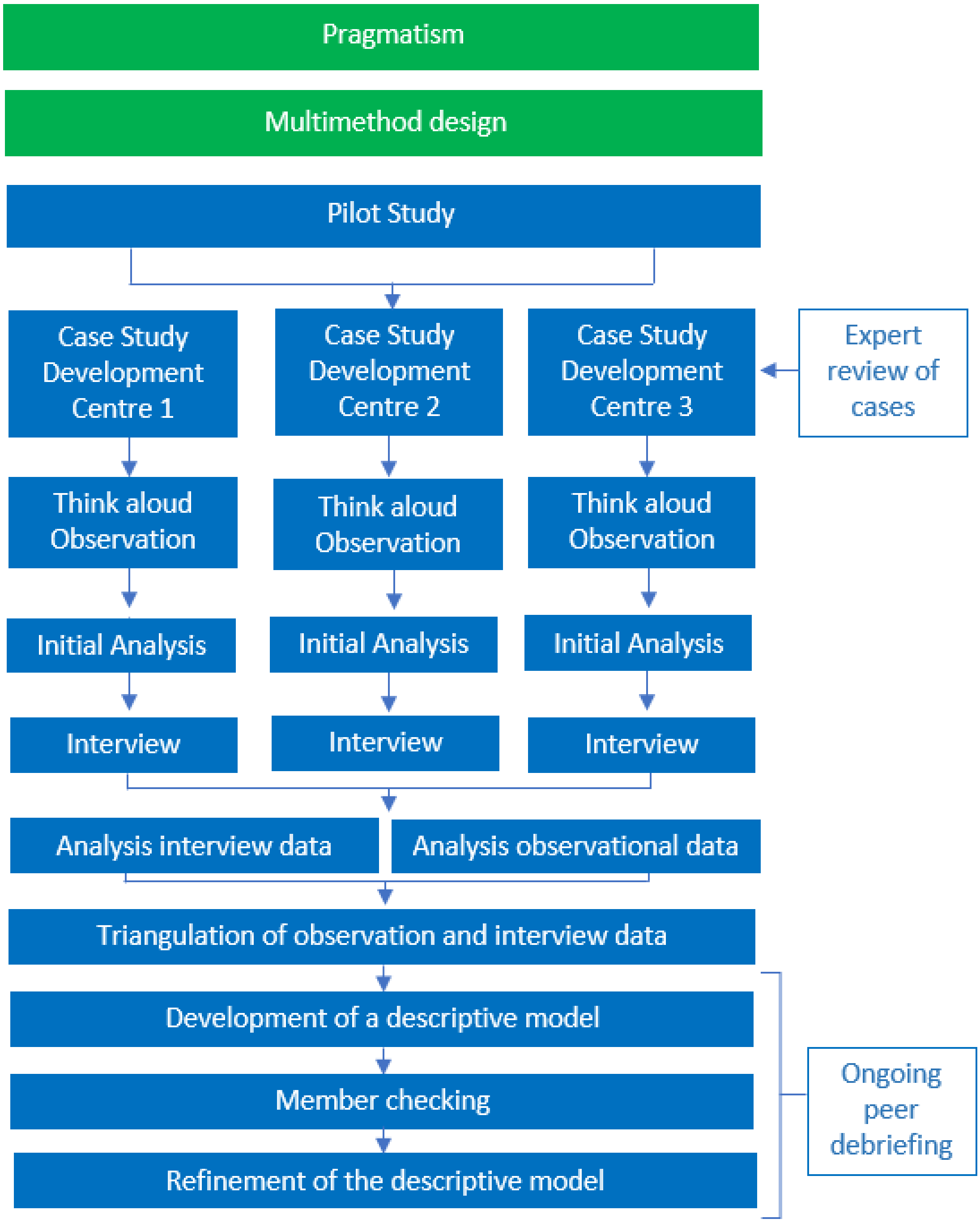
3.2 OVERALL STUDY DESIGN

The investigation of decision-making in the clinical environment is complex and previous studies have sought to use both qualitative and quantitative approaches to the area of study. Authors including Adams et al. (2017), Thackray and Roberts (2017) and Jefford and Fahy (2015) have sought to investigate participants' perceptions of their decisions, using qualitative methods such as interviews, open ended questionnaires that invite comment as well as observational methods. Conversely, a number of authors including Manning et al. (2006) and Graber et al. (2005) have used quantitative methods to investigate cognitive processes and error rates.

The research questions in this study cannot be fully answered using a single method and so lend themselves to a philosophical and methodological approach that enables the researcher to use multiple methods. Consequently, a multimethod approach (Morse, 2003) was adopted, which was informed by a philosophical standpoint of pragmatism (Crotty, 1998; Plano Clark, Creswell, & Clark, 2008).

Case scenarios were developed with radiotherapy centre imaging leads in three UK centres, covering a range of technical complexity and anatomical sites to represent a range of practice. Participants were observed reviewing the scenarios in a simulated environment and were asked to think aloud during the process. Follow-up semi structured interviews were conducted to further investigate the processes the participants used during the observations and to gain greater insight into the factors that impact on clinical decision-making during the image analysis process. All the cases were reviewed by a national IGRT expert, who defined the approach they would have taken for each scenario and to grade the complexity of each case. Protocol analysis (Fonteyn, Kuipers, & Grobe, 1993) was used to analyse the observational data. Thematic analysis (Braun & Clarke, 2008) was used to analyse the interview data. To minimise bias, member checking was carried out using an online presentation and questionnaire along with periodic peer debriefing by the supervisory team. Findings from the observations and semi structured interviews were then combined using a triangulation protocol (Farmer, Robinson, Elliott, & Eyles, 2006).

FIGURE 3.0 OVERALL STUDY DESIGN



3.3 MIXED METHOD AND MULTIMETHOD RESEARCH

The acceptance of the use of more than one method within a single study has its roots in mixed method research. Citing authors including Brewer and Hunter (1989), Fielding and Fielding (1986), and Greene and Caracelli (1989), Creswell and Plano Clark (2011) state that the origins of this movement dates back to the late 1980s. Creswell and Plano Clark (2011) consider that the evolution of mixed methods research ultimately stems from the complexity of research that is carried out in the modern world. Mixed methods research is becoming increasingly articulated and utilised within research practice, leading to its recognition as the third major research approach or research paradigm (Johnson, Onwuegbuzie, & Turner, 2007).

When considering the two traditional major paradigms, Qualitative and Quantitative, each lend themselves to a very specific type of research question and aim. Qualitative research questions are traditionally exploratory and involve theory generation, whilst quantitative research questions are confirmatory and involves theory verification (Tashakkori & Teddlie, 2003). If these broad assumptions are accepted, it is clear that in some research situations, the use of one method could limit the depth of understanding of the phenomena being investigated. By utilising a mixed methods approach, the researcher has an ability to gain an insight into theory and practice from multiple viewpoints, perspectives, positions, and standpoints (Johnson et al., 2007). Tashakkori and Teddlie (2003, p.15) argued that:

> *"a major advantage of mixed methods research is that it enables the researcher to simultaneously answer confirmatory and exploratory questions, and therefore verify and generate theory in the same study"*

When reviewing the literature on mixed methods research, there is a notable variation in the descriptions of the terminology and the theories that underpin these research strategies. Johnson et al. (2007) approach to this using a broad interpretation of the word "methods" (in mixed methods). By adopting this approach, the term can be used to address wider issues and strategies surrounding methods of data collection (e.g., questionnaires, interviews, observations), methods of research (e.g., experiments, ethnography), and related philosophical issues (e.g., ontology, epistemology, axiology).

They proposed the following definition of mixed methods research:

> *"mixed methods research is the type of research in which the researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the purposes of breadth and depth of understanding and corroboration."* (Johnson et al., 2007 p. 123)

Within this description, Johnson et al. (2007), make it clear that they do not view mixed methods simply as methods in the traditional sense (questionnaires, interviews, observations) but more as a methodology that spanned viewpoints and inferences. Using the term mixed methods in this way allows the researcher to not only describe the research process taken, but also articulate the rationale for conducting the research.

Campbell and Fiske (1959) first introduced the formal process of combining multiple research methods and in doing so introduced the concept of triangulation. In their description they refer to "multiple operationalism," in which more than one method is used as part of a validation process. By doing this they claimed that any variance could therefore be explained as the result of the underlying phenomenon or trait and not because of the method.

This concept was expanded further by Webb et al. (1999, *p. 3)*

> "*Once a proposition has been confirmed by two or more independent measurement processes, the uncertainty of its interpretation is greatly reduced. The most persuasive evidence comes through a triangulation of measurement processes. If a proposition can survive the onslaught of a series of imperfect measures, with all their irrelevant error, confidence should be placed in it. Of course, this confidence is increased by minimizing error in each instrument and by a reasonable belief in the different and divergent effects of the sources of error."*

The mixed method approach appears to provide a number of benefits for complex studies involving the collection on both qualitative and quantitative data. These potential benefits were investigated by Bryman (2008), who reviewed 232 articles that stated the use a mixed method design. The results of the study highlighted 16 potential rationales for using mixed methods research (Table 3.0).

TABLE 3.0 POTENTIAL BENEFITS OF USING MIXED METHODS RESEARCH (ADAPTED FROM BRYMAN (2008))

Rationale	Description
Triangulation	the combination of quantitative and qualitative findings in order that they may be mutually corroborated
Offset	recognition that quantitative and qualitative methods have their own strengths and weaknesses and that combining data from both allows the weaknesses to be offset against each other and the strengths drawn upon
Completeness	the notion that a more comprehensive account of the area of study can be achieved if both quantitative and qualitative research methods are employed
Process	quantitative research provides data on the 'structure' of the topic of inquiry and qualitative research provides a sense of the process
Different research questions	quantitative and qualitative methods can each answer different research questions in a study
Explanation	one method is used to help explain findings generated by the other
Unexpected results	quantitative and qualitative research can be usefully combined when one generates surprising results that can be understood by employing the other
Instrument development	qualitative research is employed to develop questionnaire or scale items so that better wording or more comprehensive closed answers can be generated
Sampling	when one approach is used to facilitate the sampling of respondents
Credibility	the notion that employing both approaches enhances the integrity of findings
Context	qualitative research can provide contextual understanding coupled with either generalisable, externally valid findings or relationships among variables discovered through a survey
Illustration	the use of qualitative data to illustrate quantitative findings. A way of adding flesh to the bones of 'dry' quantitative findings
Utility of findings	the notion that combining quantitative and qualitative data is of greater use to practitioners
Confirm and discover	using qualitative methods to generate hypotheses and using quantitative research to test them within a single project
Diversity of views	combining researchers' and participants' perspectives through quantitative and qualitative research where the quantitative approach uncovers relationships between variables and the qualitative approach reveals meanings among the participants
Enhancement	augmenting either quantitative or qualitative findings by gathering data using the alternative approach

In the review, the most commonly cited rationale for using mixed methods was *Enhancement* (73), followed by *Sampling* (31 articles), *Completeness* (31 articles) and *Triangulation* (29 articles). What is of added interest in this paper is the second part of the review. When he examined the articles in terms of practice (the process researchers actually undertook in the studies) some notable differences where highlighted.

As with the stated rationale, *enhancement* was the most common practice (121 articles), but there were some striking differences. *Triangulation* occurred in 80 articles but was used in only 29 articles as a rationale. C*ompleteness* was also much more evident in practice (67 vs 31 articles) as was *illustration* (53 vs 4 articles). In addition to this, 62 articles did not state any rationale for using a mixed method approach.

This study highlights a number of potential benefits offered by this research design in a complex setting such as that seen in the clinical environment. It does however illustrate a lack of coherence and understanding between what researchers articulate as their rationale for using mixed method research and what they actually do in practice.

3.3.1 Multimethod research

Mixed method and multimethod are often terms used interchangeably in the literature (Esteves & Pastor, 2003), but Tashakkori and Teddlie (2003) and Morse (2003) make a clear distinction between the two. Morse (2003 p.190) defined the two approaches as:

> *"**Mixed method design:** this is the incorporation of various qualitative and quantitative strategies within a single project that may have either a qualitative or quantitative theoretical drive. The imported strategies are supplemental to the major method or core method and serve to enlighten or provide clues that are followed up within the core method."*
>
> *"**Multimethod design:** this is the conduct of two or more research methods, each conducted rigorously and complete in itself, in one project. The results are then triangulated to form a comprehensive whole."*

As with mixed-method approaches, a multimethod design allows the researcher to increase the number of research strategies or methods used within a study. By doing so, the researcher is able to broaden the dimensions and hence scope of the project (Morse, 2003).

The research questions in this study closely align with a multimethod approach rather than a mixed-method approach as each of the five questions are distinct and will be answered in different phases of the study, involving the collection of both qualitative and quantitative data. To gain a full understanding of the phenomenon that is decision making in IGRT, triangulation provides an opportunity to verify and corroborate each phase of the study and so was carried out using a protocol described by Farmer et al. (2006) (See Section 4.9).

Morse (2003) emphasises the importance of acknowledging the theoretical drive of the study and as the aim of the study was to address a problem in clinical practice, a Pragmatic theoretical drive was taken using a sequential design approach.

3.3.2 Philosophical assumptions

Creswell, Plano Clark, & Clark, 2011 discuss the paradigm wars of the 1970s and 80s. These debates involved scholars arguing whether or not qualitative and quantitative data could be combined. These arguments are grounded in the concept that quantitative and qualitative data were linked with differing philosophical assumptions.

One of the outcomes of this debate was a wider acceptance of the philosophical stance of *Pragmatism.* Rescher (1995, p.710) stated:

> *"the characteristic idea of philosophical pragmatism is that efficacy in practical applications- the issue of which "works most effectively"- somehow provides a standard for the determination of truth in the case of statements, rightness in the case of actions, and value in the case of appraisals."*

This philosophical approach is now closely associated with mixed method research and Plano Clark, & Clark, 2011. p41) summarise pragmatism as having:

> *"a focus on the consequences of research, on the primary importance of the question asked rather than the methods, and on the use of multiple methods of data collection to inform the problems under the*

> *study. Thus, it is pluralistic and orientated towards "what works" and practice."*

Adding to this, Crotty (1998, p. 74) stated that:

> *"The pragmatist world is a world to be explored and made the most of, not a world to be subjected to radical criticism."*

The 'what works' approach in pragmatism, lends itself well to this study, and the focus on the research questions was appealing. The use of this approach allowed a research design to be developed that focused on the needs of each of the research questions without being closely tied or restricted by specific philosophical approach such as constructivism or positivism.

3.3.3 Reflexivity

It is acknowledged that the author could be considered to carry some of the elements of an insider researcher due to his professional and cultural knowledge of therapeutic radiography. An objective or naive standpoint could not be adopted due to the author's experience as a practitioner, educator and researcher in the field of therapeutic radiography. As the study involved the collection of qualitative data, personal biases must be acknowledged as an inevitable feature of our humanity (Nicholls, 2009) and so forms an integral part of the research process. Researchers do this by positioning themselves within the writings (Hammersley & Atkinson, 2007) in a process known as reflexivity. This essentially involves the researcher explicitly acknowledging and critically reflecting on the biases, values and experiences he or she brings to the qualitative research study (Creswell, 2013). However, in doing so the researcher must be aware of the risk of making their reflections the focus of the research, which can lead to paralysis when reporting the outcome of the study (Braun & Clarke, 2013).

During the taught phase of a Professional Doctorate, a module was completed titled "Module 5: Critical Professional Practice and Development." The assessment for the module involved the submission of a 15,000 word portfolio. The portfolio contained a substantial collection of reflective pieces relating to the author's professional history and initiated the regular completion of a research diary. Excerpts of the portfolio and diary can be seen in Appendix 2.

To address the need for the researcher to acknowledge and make public personal influences, a reflexive account was documented prior to data collection (Appendix 2) and regularly returned to during the research process. The account was written using guidance from Creswell (2013 p.216) who suggests a 2 phase approach:

> *"Part one: the researcher first talks about his or her experiences with the phenomenon being explored. This involves relying on past experiences of work, schooling, family dynamics, and so forth.*
>
> *Part two: discuss how these past experiences shape the researcher's interpretation of the phenomenon."*

The reflexive process highlighted that the author had a significant amount of experience in the field of study and therefore it is not conceivable to suggest that this brings with it a number of pre-conceived ideas around best practice during the IGRT process. The reflexive account was present in the mind of the author when carrying out the observations, interviews and during the data analysis process. During the interviews, the author was conscious not to ask leading questions that may bias any data towards his preconceptions. The use of the reflexive account during the during data analysis phase allowed the author to get as close as possible to the data and adhere closely to the beliefs described in Table 3.0.

3.4 METHODS OF DATA COLLECTION

The literature review highlighted a range of methods that have been used to investigate clinical decision-making in Nursing, the Allied Health Professions and Medicine. These include the methods commonly seen in other qualitative studies such as questionnaires (Bjork & Hamilton, 2011), interviews and focus groups (Adams, Goyder, Heneghan, Brand, & Ajjawi, 2017; Jefford & Fahy, 2015; Langridge et al., 2015). However, these methods are associated with limitations in this field of research, as they typically rely on the participants retrospectively thinking back to situations and trying to remember how they made decisions. Questions such as “How did you solve the problems?”, “What law of physics did you use?” or “Did you break the problem down in to sub goals?” may be used. On one level using questions like this may raise concerns around bias, but equally, it may simply be difficult for the participant to remember what they did, especially if some time has passed after completion of the task. Even if the time span between the task and the data collection was short, it has been shown that humans are inclined to reconstruct events as more structured than they were originally and their memory can be guided (and changed) by the knowledge of the result (van Someren et al., 1994). Similarly, if the participants behaviour was rather irrational, they may not wish to remember it like that and may interpret this situation differently to the reality. These conscious and subconscious concepts are widely acknowledged in the psychological evidence base and are known as post-hoc rationalisations (Peute, de Keizer, & Jaspers, 2015; van Someren, et al. 1994).

These methods were quickly dismissed and attention turned to observational methods which do not constrain the subjects’ behaviour in the same ways. Dowding et al. (2009) and Mitchell and Unsworth (2005) used what may be described as traditional observational techniques, whereby the researcher positions themselves so that they can observe what is going on without interacting with the participants. Both studies yielded some interesting results, but relied heavily on the researchers interpreting what they observed and with what was likely long periods of silence, it is difficult to imagine that this would not lead to limited interpretations.

The most commonly seen method, and the one used in the study was the method of *think aloud* observations, followed by semi-structured interviews. (Thackray & Roberts, 2017; Johnsen, Slettebø, & Fossum, 2016; Lee et al., 2016; Lundgrén-Laine, 2015; Pirret, Neville, & La, 2015; Gegenfurtner & Seppänen, 2013; Hoffman, Aitken, & Duffield, 2009; Funkesson, Anbäcken, & Ek, 2007; Simmons, Lanuza, Fonteyn, Hicks, & Holm, 2003; Prime & Le Masurier, 2000; Greenwood, Sullivan, Spence, & McDonald, 2000; Fonteyn & Grobe, 1992).

3.4.1 The think aloud method

The think aloud method has its roots in early introspection studies by authors such as Titchener (1929) and revolves around the assumption "*that one can observe events that take place in consciousness, more or less as one can observe events in the outside world*" (van Someren et al., 1994 p.29). The method now recognised as the think aloud method was used from the 1940s onwards (Duncker, 1945; de Groot, 1965), but it saw its greatest developments in the seminal work of Newell and Simon (1972) who used think aloud protocols in combination with computer models of problem- solving processes. From this work emerged the information procession model, previously discussed in Section 2.4.2.

The think aloud method essentially involves participants verbalising whatever thoughts enter their mind while performing a task. During the task, there should be no interruptions or suggestive prompts from the researcher, which allows the participant to focus purely on the task at hand. In doing this Ericsson and Simon (1993) claim that thinking out loud does not interfere with the task performance and the verbalisations represent the contents of the working memory at that time. The method of think aloud also assumes the verbalisation is subordinate to, and passively dependent on the task being completed.

The underpinning theory of this method assumes three key principles (Banning 2008 p.11):

1) *that human cognition is an information processing process*
2) *cognitive processes can be acknowledged through discourse*
3) *thinking aloud provides an indication of current and concentrated information*

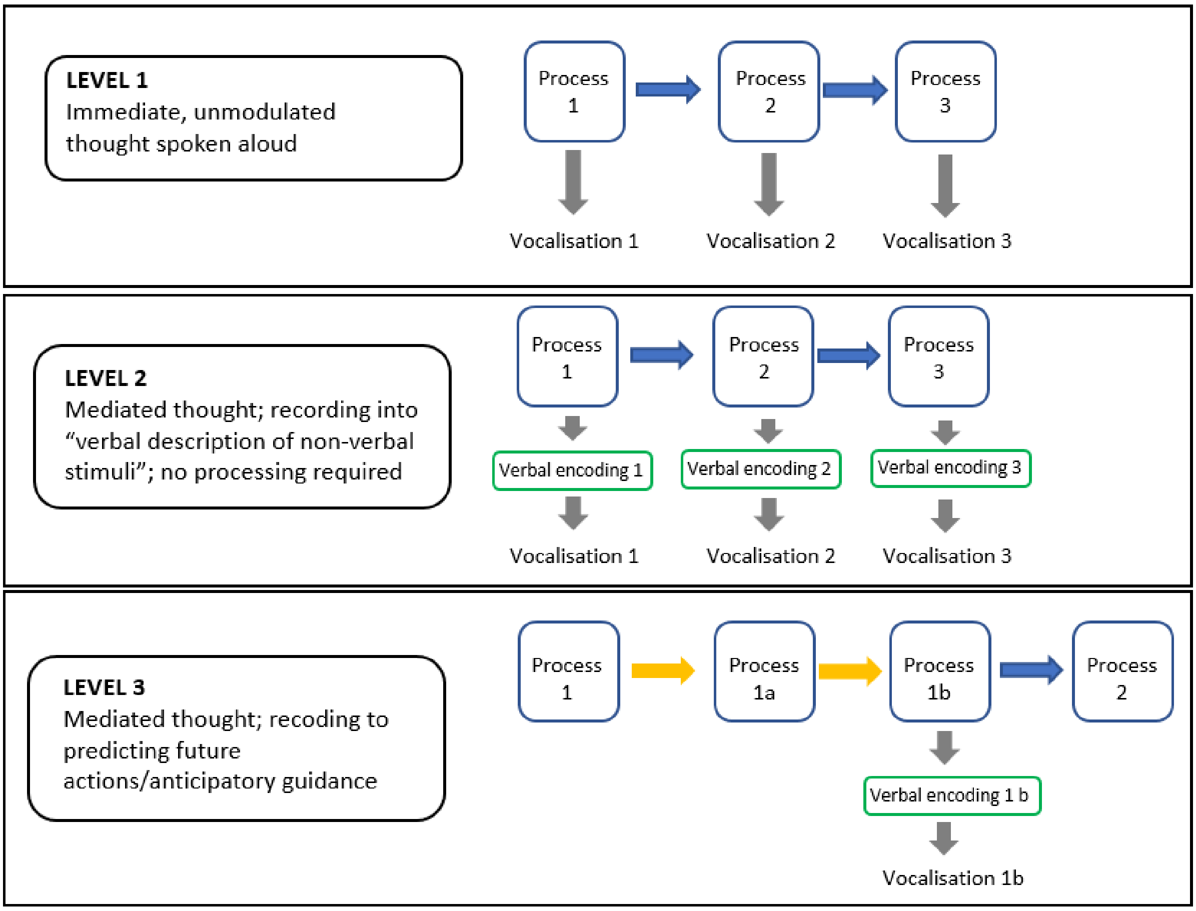
If these concepts are accepted, recording the verbalisations and carefully transcribing them verbatim will produce hard data in the form of a *verbal protocol*. These protocols can then be analysed to obtain a model of the cognitive processes that took place, or to test the validity of a model that is derived from a psychological theory (van Someren et al., 1994). It is also worth noting that Ericsson and Simon (1980) make clear distinctions between retrospective think aloud (typically interviews or debriefs) and concurrent think aloud which was the method used in the study.

Not all verbalisations are of equal interest when considering the transcribed data. Ericsson and Simon (1980) categorise the verbal data into three levels of verbalisation related to the verbal coding that occurs (Figure 3.1). In Level 1 and Level 2 verbalisations, the sequence of processed information remains intact and no additional information is heeded. Conversely, Level 3 verbalisation requires attention to additional information and hence changes the sequence of heeded information making it unreliable (Table 3.1). In line with the reviewed studies using this method, the method excluded all third-level verbalisations, meaning that only immediate decisions made using working memory were included in the analysis (Lundgrén-Laine et al., 2011).

TABLE 3.1 THREE LEVELS OF VERBALISATION (BURBACH, BARNASON, & THOMPSON, 2015. REPRODUCED WITH PERMISSION)

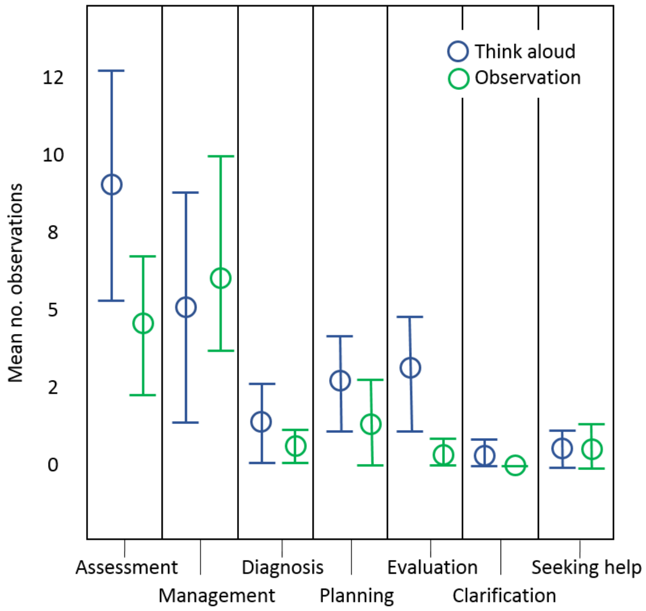
Level	Description
Level 1	Immediate, unmodulated thought spoken aloud, e.g. “Heart rate is 112.”
Level 2	Mediated thought; recoding into “verbal descriptions of non-verbal stimuli”; no reprocessing required, e.g. “Patient has tachycardia.”
Level 3	Mediated thought; recodes into predicting future actions/ anticipatory guidance, e.g. “Intravenous fluids are needed to improve fluid balance and return the heart rate to normal range.”

FIGURE 3.1 THE THREE LEVELS OF VERBAL DATA (MODIFIED FROM BURBACH, BARNASON, & THOMPSON, 2015 AND ERICSSON & SIMON, 1993)



A study by Aitken, Marshall, Elliott and McKinley (2011) was the only study found comparing traditional observation methods with the think aloud approach in a clinical setting. Observing nurses in a ward setting, the authors reported that the think aloud method led to 79 more decisions being identified than in the non- think aloud observation arm. This is an increase of 61% from the total of 130 decisions identified using the observation approach (Figure 3.1). Looking at the results, clearly some decision processes were captured much better using the think aloud method and the authors advocate its use and benefits in the paper. However, the small number of participants and the overlapping error bars (Figure 3.2) do need to be considered when evaluating the results and it would not be appropriate to justify the use of this method using this paper alone.

FIGURE 3.2 RESULTS FROM AITKEN, MARSHALL, ELLIOTT and MCKINLEY (2011). (REPRODUCED WITH PERMISSION)



3.4.2 Strengths and Weaknesses of the think aloud approach

Several authors have investigated whether the act of verbalisation has any impact on the decision-making process or task outcome. Henry, LeBreck and Holzemer (1989) recruited 60 nurses to take part in a computerised clinical simulation that required them to make clinical decisions on paediatric oncology cases. The results showed that verbalisation did not impact on the decisions made (p=<0.05). In contrast to these results, van den Haak, De Jong and Jan Schellens (2003) highlight some concerns in their seven-task software usability study involving 40 undergraduate participants. When comparing the think aloud and the non-think aloud arms, the study illustrated a negative impact on the number of tasks completed in the think aloud arm (p=<0.05). There was however, no impact on the time to complete each task individually (p=>0.05). It is notable that only 40% of the students completed the tasks set by the researchers, which brings into question the complexity of the tasks and the participants' ability to complete them. In contrast to the quantitative data in the study, experience questionnaires handed out to participants after the tasks highlighted that participants did not feel that verbalisation impacted significantly on their performance, nor did they find it unpleasant or unnatural.

As with any observational technique, participants may alter their behaviour due to Hawthorn effects that may be linked to feeling shameful about low levels of performance. Participants may also work harder when others observe them and so there may be some small deviation from natural practice (Merrett, 2006). However, some of these limitations may be mitigated by the researcher gaining the trust of the participants before the observation (Spano, 2006). These concerns were addressed by the researcher in this study, who spent a significant amount of time discussing the process of data collection, and highlighting that the study was in no way a test or assessment and that results would not be fed back to the participants peers or superiors, unless deemed grossly negligent. In addition to this, the participants would not be asked to do anything that was outside of their normal scope of practice (Charters, 2003).

3.4.3 Considerations when conducting think aloud studies

3.4.3.1 Participants

Think aloud studies are interested in gaining rich and in-depth understanding of the cognitive processes used during decision-making tasks and so typically involve small numbers of participants (van Someren et al., 1994). Participants should be voluntary, capable, and competent in thinking aloud (Lundgrén-Laine & Salanterä, 2010).

When recruiting participants for think aloud studies, researchers must consider some of the issues raised in relation to this method when involving experts as participants. It is widely accepted that they are often able to perform a task as routine and at high speed, but are unable to verbalise their thoughts during this process (Charters, 2003; van Someren et al., 1994). When this is the case, the resulting verbal protocols are likely to be incomplete (Ericsson & Simon, 1980; Kuipers & Kassirer, 1988). Charters (2003) does however note that these limitations can largely be overcome by using post-observation interviews.

3.4.3.2 Simulation

Simulation has been used in a wide range of settings in the teaching of clinical reasoning and decision-making. It allows students and practitioners to develop their skills and build confidence in a safe environment (Botezatu et al., 2010; Forsberg et al., 2014). Similarly, simulations have been used widely during the think aloud studies (Goon et al., 2014; Thackray & Roberts, 2017b; Carl Thompson, Aitken, Marshall, Elliott, & McKinley, 2011).

Some authors, including Hoffman et al. (2009) and Johansson et al. (2009), have argued that the only real way to investigate clinical reasoning is to observe participants in the real world, whilst others have argued that simulations oversimplify what would actually happen in the clinical environment (Bucknall, 2003). This may be the case in some studies where simple methods such as vignettes have been used rather than the researchers attempting to recreate a high-fidelity simulation (Forsberg et al., 2014). The impact of the different methods was demonstrated in a study by Yang (2009), who found significant differences in judgement in a study involving both written and physical simulations with nursing staff. She concluded that written cases inflate judgement performance and that high-fidelity simulations offer a superior approach to replicating decisions that would be made in the real world. These findings are supported by Jensen (2013), Bryans (2004) and Corcoran-Perry, Narayan and Cochrane (1999) who found only modest variation between the decision-making processes used in a simulated environment and those in the real-world environment .

The major benefit of using a simulated environment is the ability of the researcher to design a scenario and then repeat it in a consistent and controlled manner for a number of different participants (Thackray & Roberts, 2017a). This would not be possible in a natural environment as it is unlikely that a number of participants would encounter the same patients in the same scenarios, thus making comparisons of patient outcome and clinical performance difficult (Ericsson, Whyte, & Ward, 2007).

The ethical limitations of think aloud study in the natural environment must also be considered. Literature using this method often discuss the impact of thinking aloud on the participants (Mitchell & Unsworth, 2005), but one must also consider the impact of this on the patient. It is naive to suggest that some patients would not find the concept of their practitioner verbalising their thought processes very uncomfortable and may even feel that it compromises their care. Using simulations allows the use of retrospective anonymised data, thus avoiding any ethical complications.

3.4.3.3 Prompting

Ideally, participants in a think aloud study should not need any coaching and should verbalise their thought processes spontaneously (Charters, 2003). Prompting introduces additional cues in the participants working memory. This may lead to retrieval of spurious information from their long term memory which may push current information out of working memory, disrupting the normal process (van Someren et al., 1994). Ericsson and Simon (1993) recommend that researchers give reminders to the participants to keep on talking but do not engage in any other communication as asking specific questions in the form of prompting or probing may run the risk of leading the participant and so distort the thought processes.

Burbach et al. (2015) argued that any interruption of the speaker, including prompting may influence data validity. They advise that any questions or requests for clarification should be occur after the think aloud collection has been completed. This approach was also adopted by Thackray and Roberts (2017a) who did not prompt the participants in any way. These strict guidelines are in contrast to the findings of Fonteyn and Fisher (1995) and Norris (1990) who both report that such prompts have little or no effect on ongoing cognitive processes, and that thinking aloud has not been shown to alter critical thinking.

Some form of prompting was found to be the norm in all the studies reviewed other than those mentioned above. Lundgrén-Laine and Salanterä's (2010) method was typical of the wider evidence-base. They reminded participants to keep on talking by saying the phrases *"Please, keep on talking", "What are you thinking?"* or "*What are you doing?"* when there were silences for more than 60 seconds. Other methods such as using a flash card with "KEEP TALKING" have also been implemented (Hendry, 2001).

The decision was therefore taken to use an approach that had minimum impact on the participant and to use prompting only when necessary. The evidence suggests the impact of minimal prompting is of little concern, and the lack of data from silence would be more problematic. It was therefore decided to take a pragmatic approach and use phrases similar to those of Lundgrén-Laine and Salanterä (2010) when necessary.

3.4.3.4 Warm up

Few studies report participants having difficulty verbalising, and even those participants that do, often settle into the exercise after a very short period of time (Aitken et al., 2011). It is however, implausible to suggest that all individuals would feel comfortable carrying out this task. Van Someren et al. (1994) advocated the use of a short practice session prior to commencing the think aloud exercise. These activities can be quite simple, but provide the participant who might not have been familiar with talking out loud with an opportunity to practice articulating their thoughts without filtering (Koro-Ljungberg, Douglas, McNeill, Therriault, & Malcolm, 2012). The use of these exercises can also be used by the researcher to highlight any participants that may not be suitable for the study.

The study by Lundgrén-Laine (2015) was the only one highlighted in the literature review that stated that they consciously did not carry out any kind of warmup exercises. They do not discuss why, but it is plausible that this was due to time restrictions. Instead of a warmup exercise, participants were asked to consider an orientation session, and they were provided with an example related to the think aloud process.

The added time for warm up seemed of little significance, so participants were asked to carry out a simple warmup exercise similar to those suggested by van Someren et al. (1994) (Figure 3.3).

FIGURE 3.3 WARM UP EXERCISE

- Sally has 6 sweets, James has 10, how many more sweets does James have than Sally?
- Jacob’s birthday is on a Tuesday, Paul’s is 5 days later, what day is Paul’s birthday?
- 5 x _ = 30
- 6- _ = 5
- How many windows are in your house?
- List 10 animals

3.4.3.5 Follow-up Interview

Previous studies have shown that verbalisations can be mixed in terms of quantity and quality so follow-up interviews or participant debriefings are commonplace. They provide a number of benefits and enable the researcher to enhance the data collection process by filling in gaps in the think aloud protocol (Hoffman et al., 2009), as well as enhancing understanding and adding context (Thackray & Roberts, 2017a). Due to the large radiotherapy vocabulary and the use of local terms for equipment and treatment processes they provided an opportunity to clarify terms or colloquialisms. Their implementation is also supported by the Ericsson and Simon (1980) original framework. Using the phrase *retrospective think aloud,* they highlighted that *concurrent think aloud* data from working memory may not always be complete, as a number of thought processes may not be held long enough in the working memory to be expressed verbally.

It is common practice to hold the interviews as close to the time of the observation as possible (Aitken et al., 2011). This will clearly aid the participants in remembering the events during the observation. Memory recall in the interviews can also be supported by reviewing the observed data prior to commencing questioning.

Before the researcher can conduct the interview, they must review the observed data and carry out some level of interpretation in order to guide the interview. For this to happen, it is normal for the data to be transcribed so sufficient time must be left between observation and interview to allow these processes to occur (Koro-Ljungberg et al., 2012).

Interviews are one of the most common methods of qualitative data collection (Briggs, 1986). Braun and Clarke (2013 p.77) define interviewing as

> *"Professional conversation, with the goal of getting a participant to talk about their experiences and perspectives, and to capture their language and concepts, in relation to a topic that you have determined."*

As the aim of the interviews was to expand on the data collected in the observations, a semi-structured approach was adopted, which involved the researcher preparing an interview guide for the interview. This was used to guide the discussion, but deviation away from the precise wording often occurred.

The interviews were conducted using the assumptions listed in Table 3.2.

TABLE 3.2 INTERVIEW PRINCIPLES (ADAPTED FROM CLARKE AND BRAUN, 2013, P.79)

Interview principles
Interviewers, like participants, are individuals with their own particular interview style; question wording and the order in which questions are asked varies according to the personal style of the interviewer and the responses of the participant.
An interview guide is prepared in advance, but the ideal qualitative interview is flexible and responsive to the participant; good interviewers follow up on unanticipated issues and ask spontaneous and unplanned questions.
Open-ended questions are preferred to encourage participants to provide in-depth and detailed responses and to discuss what is important to them. The goal of an interview is to capture the range and diversity of participants responses, in their own words.
The interviewer plays an active role in the interview, co-constructing meaning with the participant. It is neither possible nor desirable to attempt to minimise the interviewer's role. The interviewer should reflect on how their practice and values may have shaped the data produced.

It has been argued that it is important to match the major social characteristics between participants and interviewers (Sawyer et al., 1995). It is clear that this would be of particular relevance in circumstances where social, religious or cultural sensitivities exist as it may influence a participant's willingness to participate in the study or comfort giving open responses. This was not perceived to be a problem during the interviews due to the nature of the questions being asked and the environment that the study was conducted in. It was however acknowledged that some power asymmetry may occur in the interviews (Kvale, 2015; Creswell, 2013), but the relaxed interviewing technique of the researcher and the collaborative approach to the questions will have aided in alleviation of this.

Prior to the interviews, the participants were given the opportunity to watch their filmed observations and this worked well as a prompt for questions. The second part of the interview was more structured and similar for each participant as the focus was on more general aspects of IGRT process and education. This approach was tested and refined during the pilot phases of the study and the final protocol can be seen in Appendix 3.

3.5 DATA ANALYSIS

As highlighted in the literature review, a number of different approaches have been taken to analyse both the observational data and the interview data. The decision was taken to analyse the observational data using the widely cited method of protocol analysis, first proposed by Kuipers and Kassirer (1988) and further developed by Fonteyn and Grobe (1992). The interview phase of the study was analysed using thematic analysis as described by Braun and Clarke (2013) and Braun and Clarke (2008).

The observational and interview data were then triangulated using a two-step process of *sorting* and *convergence coding* (Farmer et al., 2006).

Sections 3.5.1 to 3.5.2 will discuss these methods in detail along with the rationale for their selection.

3.5.1 Analysis of observational data

Various methods of analysis have been carried out on think aloud data including methods commonly seen in the analysis of interviews and focus groups, such as thematic or framework analysis (Thackray & Roberts, 2017b; Dowding et al., 2009; Langridge et al., 2015). Although the authors using these methods cite interesting results, it was felt that these methods did not investigate the cognitive processes thoroughly and only sought to gain a general insight into the overall process adopted.

The research questions in this study sought to gain an in depth understanding of the cognitive processes used and so *protocol analysis* is widely accepted as the method of choice when this is the aim (Johnsen, Slettebø, & Fossum, 2016; Ericsson & Simon, 1993; Hoffman, Aitken, & Duffield, 2009). Built on the early work by Ericsson and Simon (1980), it was first proposed by Kuipers and Kassirer (1988) and further developed by Fonteyn and Grobe (1992). Cited in over 290 studies (Google Scholar), it has been widely used in a range of clinical studies (Funkesson, Anbäcken, & Ek, 2007; Greenwood et al., 2000; Hoffman et al., 2009; Johnsen et al., 2016; Lundgrén-Laine & Salanterä, 2010; Simmons et al., 2003) and involves 3 distinct phases: *referring phrase analysis* (RPA), *assertional analysis* (AA) and *script* analysis (SA) (Table 3.3).

TABLE 3.3 DEFINITIONS OF THE 3 PHASES OF PROTOCOL ANALYSIS (ADAPTED FROM KUIPERS & KASSIRER, 1988)

Phase	Description
Referring phrase analysis (RPA)	Identifies the set of referring noun phrases in a protocol excerpt and defines a small natural universe of underlying conceptual objects which can be the referents of those phrases. This universe constitutes an ontology for the domain being discussed.
Assertional analysis (AA)	Identifies the set of assertions being made in the excerpt about the objects identified by referring phrase analysis. A set of relations on objects and connectives and operators on sentences are then defined to express the content of the assertions. This constitutes an epistemology for the domain being discussed.
Script analysis (SA)	Identifies the overall structure of the reasoning process, argument, or explanation being given in the excerpt. The analysis is intended to reveal the goal structure of the problem-solving process or the explanation

3.5.2 Analysis of interviews

The flexibility offered by thematic analysis to identify patterns across the whole data set was felt to be of importance to this study and so was adopted. Versions of thematic analysis were considered; these included that proposed by (Braun & Clarke, 2013) and Framework Analysis articulated by Richie and Spencer (2002). These approaches have been widely used in qualitative research, so it was important to evaluate which would be the most appropriate.

When investigating the approaches that fall under the broad method of thematic analysis, it's clear that the terms content analysis, qualitative content analysis and thematic analysis have been used interchangeably. One variation of this approach that has grown in popularity in health and policy research is framework analysis (Ritchie & Spencer, 2002). As with other thematic or content analysis approaches, the researcher initially familiarises themselves with the data before coding the data in relation to themes or concepts. Unique to this approach is the process of *charting* or summarising the coded data into a framework matrix to look for patterns (Gale et al., 2013) This approach can be used inductively and deductively and is particularly beneficial when trying to summarise large volumes of data. This approach could arguably have been used in the study, but concerns relating to the potential loss of meaning or feel of the data in the charting stage (Gale et al., 2013; Srivastava & Thomson, 2009) meant that other approaches were investigated.

With over 32,000 citations in the academic literature (Google Scholar) Braun and Clarkes (2008) description of thematic analysis is widely accepted in the academic community and was used to guide the analysis of the interview phase.

Braun and Clarke (2008 p.79) describe the method as

> *"a method for identifying, analysing and reporting patterns (themes) within data. It minimally organises and describes your data set in (rich) detail."*

In contrast to other methods of analysis, thematic analysis is not wedded to any pre-existing theoretical framework and therefore fits well with the Pragmatic underpinnings of this study. The method involves a flexible and organic approach to coding which should evolve throughout the process of analysis. It also sees the process of coding as an active and reflexive process and so does not advocate the use of calculation of interrater reliability scores (Braun & Clarke, 2013).

The method revolves around a pragmatic six step process (Figure 3.4).

TABLE 3.4 THEMATIC ANALYSIS PROCESS (ADAPTED FROM (BRAUN & CLARKE, 2008)

Steps	Description
1. Familiarise yourself with your data	Transcribing data, reading and rereading the data, noting down initial ideas.
2. Generating initial codes	Coding interesting features of the data in a systematic fashion across the entire dataset, collating data relevant to each code.
3. Searching for themes	Collating coding to potential themes, gathering all data relevant to each potential theme.
4. Reviewing themes	Checking if the themes work in relation to the coded extracts (level I) and the entire dataset (level II), generating the thematic map of the analysis.
5. Defining and naming themes	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names to each theme.
6. Producing the report	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back to the initial analysis, the research question and the literature, producing a scholarly report of the analysis.

Braun and Clarke (2008) describe a theme as a group of codes that represent something important about the data or represent some level of pattern. They advocate a flexible approach to this, highlighting that themes can be updated and reorganised throughout the analysis process using an inductive approach.

3.5.3 Ethical considerations

Ethical approval was sought and gained from Sheffield Hallam University's Faculty of Health and Wellbeing Research Ethics Committee (Reference 2013/HWB/HSC/DPS/11). This was followed by individual applications to each of the NHS Trusts, all of which were granted without amendments (Appendix 4).

The researcher discussed the project aims and methods individually with each of the participants and they were each given an information sheet (Appendix 5) detailing in writing what had been discussed. Written consent (Appendix 6) was obtained following discussion with the participants and after they had time to ask questions about the study. It was made clear that involvement in the project was entirely voluntary and that they could withdraw at any time in the process. This included during the observations and interviews itself, as well as at any time after the data collection. It was acknowledged that some participants may view the observation as a test and so the researcher assured them of confidentiality and anonymity of the data that would be collected and highlighted the fact that their faces would not be visible on the video recordings. Participants were told that they needed to be aware that any observations or opinions deemed to put patients at risk would be reported to the relevant person in their Centre.

The research process was felt to be of low risk to participants, but it was recognised that some participants may get anxious or feel uncomfortable during the observational interview and if this was to occur, the observation or interview would be stopped immediately.

Participants were debriefed following the observation and interview to ensure they were not affected by the project and happy to return to work.

All patient data in the study was anonymised by the imaging leads in each of the sites prior to commencing the observations. This meant neither the researcher nor the participants had any knowledge of the patients whose images were used. In choosing the case studies, patients with rare malignancies or recognisable anatomy were excluded from the study to ensure complete patient anonymity.

All study data was encrypted and stored in line with Sheffield Hallam University's data management policy (Sheffield Hallam University 2017).

3.6 PILOT STUDY

As the researcher was a novice in both the think aloud method and semi-structured interviews, pilot testing was an essential part of the research process. In general, pilot testing allows the researcher to test the equipment and refine the data collection plan, in addition to developing the questions that would be asked in the interview phase (Creswell, 2013; Yin, 2013). To ensure this was completed thoroughly a two-stage approach was adopted.

3.6.1 Stage 1 Pilot study

Stage 1 was carried out with a member of the radiotherapy team at Sheffield Hallam University using a laptop and the audio-visual equipment that was planned to be used in the main study.

This first test proved invaluable and lessons were learned that could be taken forward to the next stage of testing (Table 3.5). The biggest change was in relation to the use of remote access connection to Sheffield Hallam University. The initial project plan was to access the IGRT software at Sheffield Hallam University (SHU) using a remote 4G connection, thus allowing all participants to see the same case studies.

However, on testing this connection using a fast broadband connection it quickly became obvious that the remote access was not quick enough for the complex IGRT software. The images produced were very jumpy and were far from what would be typical in a clinical environment. This was a real concern as the premise of the observations is for the participants to make decisions as they would in the clinical environment. Having a slow and broken connection would cause them to make decisions differently to how they would normally, introducing error into the data. This would significantly impact on the validity of the data and thus any conclusions that that could be drawn. A decision was therefore taken to move away from this method and to use the participating centres' software and terminals.

Despite these limitations, the observation that followed went well and the participant appeared to be comfortable and his verbalisations flowed smoothly without any real gaps. The participant used in the pilot study is known to the researcher as a confident individual who is clearly comfortable making clinical decisions using imaging software and this might not have been the case for all participants.

A short 20 minute follow-up interview was conducted after the observation, which gave an opportunity to review and develop the interviewing technique as well as testing the use of the concurrent notes that were taken to inform the semi-structured nature of the interview.

TABLE 3.5 OUTCOME OF PHASE 1 PILOT TEST

Aim	**Outcome**
Allow the researcher to get a feel for the methods involved	Both the observation and interview went well. The observation highlighted the speed at which the researcher needs to make concurrent notes and the need to investigate the use of shorthand when doing so.
Begin the development of a data collection protocol	The participant fed back that they felt comfortable during the data collection and a discussion took place in relation to what information they would like to receive if they were participant in the main study. These discussions part-informed the participant information sheet and the brief that was given to the participants prior to each observation session.
Test the quality of the audio-visual equipment	The audio-visual equipment performed very well and the quality was more than adequate for the purposes of the study.
Test the connection to Sheffield Hallam University.	The connection was slow and broken, making this an unfeasible method in the main study.

3.6.2 Stage 2 Pilot study

Based on the findings of the Stage 1 pilot, a full test of the equipment and analysis was carried out in the radiotherapy planning and imaging suite at Sheffield Hallam University with an experienced member of clinical staff who was also known to the researcher. An anonymised patient from the university's patient database was used. The observation was carried out under the conditions planned for the main study, whereby the researcher delivered a brief, carried out the warm up exercises and a full observation and interview.

The Stage 2 pilot was successful and allowed the finalisation of the research protocol and consent process.

3.7 MAIN STUDY

Following discussions with the project supervisory team, three UK radiotherapy centres were identified ranging in size (number of Linacs) and experience of CBCT imaging. Initial contact via email was made with the radiotherapy managers in April 2015 and meetings were held with the imaging leads in April and May to discuss the aims of the study and the planned methodology and method. All three centres agreed to participate in the study and local ethical approval was sought and approved in the subsequent few months (Appendix 4).

3.7.1 Recruitment

Local recruitment was carried out by the relevant imaging leads in each centre, with the support of promotional materials (Appendix 7) produced by the researcher. The aim was to recruit between three and five participants from each centre, with a focus on recruiting participants with a range of experiences. It was foreseen that recruitment may have been difficult due to potential participants viewing the project as a test or assessment, so the researcher spent a significant amount of time developing relationships with the relevant imaging leads to demonstrate that this was not the case.

Following local ethical approval, recruitment went very smoothly and participants actively came forward in all three centres. Section 4.2 describes the participants in more detail, but in summary, five participants were recruited in case centre one, four in case centre two and three in case centre three.

It was felt that the sample in each of the case centres was adequate, however the range and experience was limited and despite attempts by the local imaging leads, no inexperienced (less than two years of experience) members of staff were willing to take part. This is acknowledged as a limitation in the study, but was not surprising as it is understandable that inexperienced members of staff may feel intimidated or anxious about taking part in a study of this nature.

3.7.2 Patient scenario development

The researcher visited each centre on more than one occasion to develop the scenarios to be used in the observation stage of the study. To increase the ability of comparison from centre to centre, attempts were made to have similar patient case scenarios in each of the three centres. The experience of the participants involved also played a role in the development of the case studies. For example, two of the participants had no experience of reviewing paediatric patients and so asking them to do that in the study would reduce fidelity and consequently the validity of any results gained from the data. It was therefore decided to use images of patients with pelvic cancer, lung cancer and head and neck cancer. The use of these three specific disease sites also produced a range of complexity in the scenarios as pelvic treatments are often less complex than lung or head and neck treatments. The imaging lead also checked that the participants had not previously reviewed the case studies being used. The involvement of the local imaging lead also reduced any bias in patient selection on the part of the researcher, as the imaging lead was asked to source images of patients that may be classed as a routine treatment in their centres.

To increase the fidelity of the scenarios, anonymised versions of all routine paperwork, such as treatment plans and set up sheets were also created for the observation stage of the study.

An overview of each case can be seen in Appendix 8.

3.7.3 Expert Panel

Following discussions with radiotherapy colleagues and a review of the literature, a nationally recognised IGRT expert was identified and approached to act as an independent reviewer. Following a discussion on the requirement of the role, the expert agreed to independently reviewed a video recording of each of the cases. Based on their experience, the expert used factors such as dose and fractionation, size and location of tumour relative to organs at risk and any other relevant clinical factors to allocate each of the cases a complexity rating between one and five. The expert also commented on how they would manage the patient based on the images and what factors impacted on their decisions.

The expert agreed that the cases provided the study with a wide range of scenarios which represented current clinical practice in the UK.

3.7.4 Observational stage of the study

Based on the pilot studies and the guidance in the literature, each of the scenarios was set up similarly to that depicted in Figure 3.4. In centres one and three, terminals were used in the centre's training rooms. In centre two, a terminal was used in the linac control area that was not in use at the time. The participant was asked to sit as they would do normally in front of a terminal screen and a high definition voice recorder was placed in front of them. A high definition video recorder was placed on a tripod behind each of the participants ensuring that the frame of the images only captured the screen and not the face of the participant.

Prior to the commencement of each observation, consent was checked and participants were given an opportunity to withdraw from the study if they wished to do so.

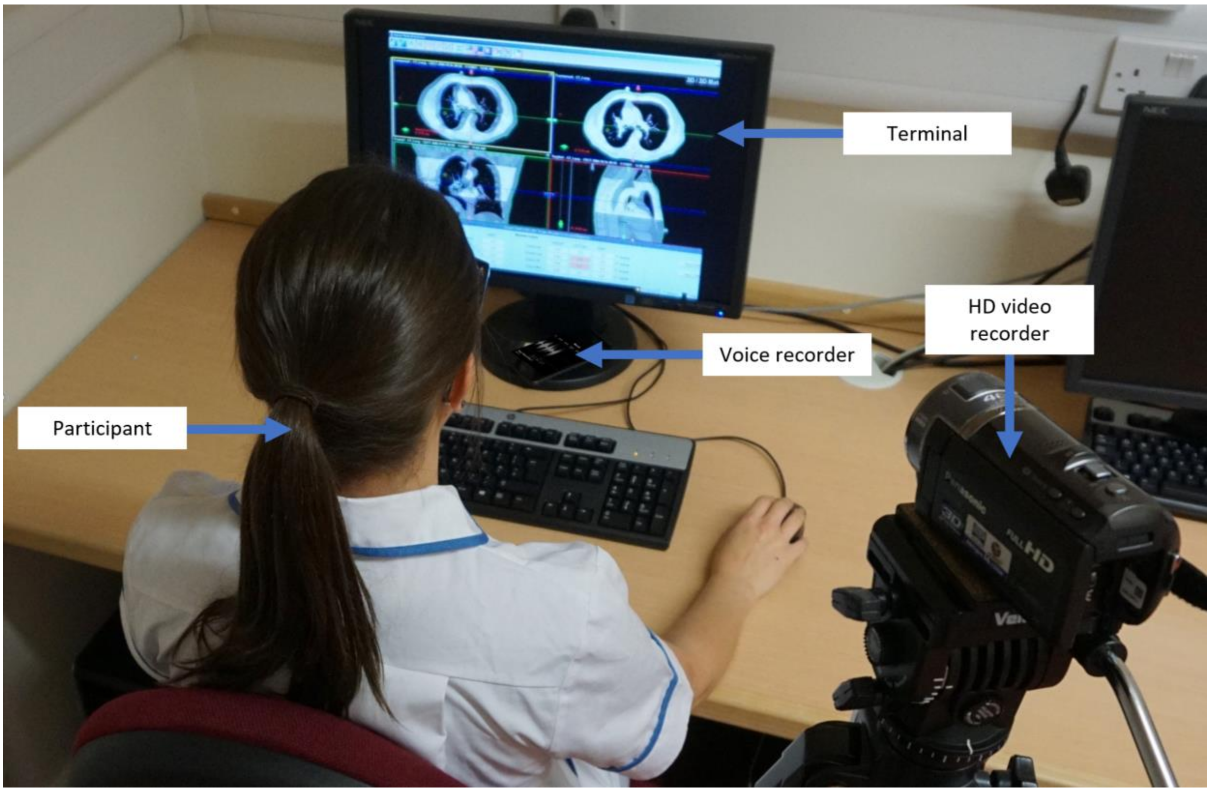
Following the testing of the audio-visual equipment, participants were invited to carry out the warm up exercises. All but one of the participants (Pseudo name Fathima) agreed to carry out the warm up exercises, however Fathima felt that there was not sufficient time for this to occur and wished to proceed straight on to the case studies.

None of the participants were observed to have any difficulties during the warmup exercises, so after a final check that they were comfortable and happy to continue, the simulation began. The researcher was conscious of not guiding the participants in any way, so simply asked them to continue as they would do in the clinical environment and to verbalise any thoughts that came into their heads.

Most of the participants verbalised their thought processes comfortably and with little effort, however short prompts using the terms “keep talking” or “what are you thinking” were used during each simulation. The researcher consciously kept these to a minimum, and only spoke when it was apparent the participant had stopped verbalising thought processes.

The researcher positioned himself out of view behind the participant, but in a position where he could see the screen. The researcher took concurrent notes throughout each verbalisation and attempted to note down anything of interest. This included any non-verbal cues as well as any concepts or ideas that required further investigation at interview.

FIGURE 3.4 OBSERVATION SET UP



Following the observation, the data was anonymised and the audio recording uploaded for professional transcription. It was important that the audio recordings were transcribed verbatim including all pauses and utterances.

Transcripts were generally returned within 48 hours and the researcher carefully listened to the audio recordings at the same time as reviewing the transcripts for any inaccuracies. On the whole, the transcripts were very accurate, and only minor corrections were made for acronyms and technical terms.

Once the accuracy of the transcript was verified, the researcher added any relevant information obtained from the concurrent notes, identified by an *(obs)* annotation on the transcript. Two examples of this from Sara's transcript are shown in Figure 3.5. In the first an annotation was made in relation to the use of written prompts to aid her decisions. In the second, the researcher wanted to remind himself of something he saw on the case study image.

FIGURE 3.5 ANNOTATED TRANSCRIPT

…Eight, nine and there's a 5mm tolerance for the gynae patient

(obs use prompt)

It's loading up day one, in a second…

…Looks like there's something a bit different here ***(obs tissue change a mass outside PTV),*** so that would probably get the PI rad around as well just to have a quick look at that….

Initial analysis of the observation data was carried out with the aim of generating broad ideas and themes for further investigation at interview.

3.7.5 Interview process

In centres one and two, interviews were conducted approximately one to 2 weeks following the observation, allowing the researcher to carry out the steps discussed above and create some specific questions relevant to each participant's observations. Due to resource and time issues at centre three, it was felt that this was not appropriate and so following the observations, the researcher spent two hours reviewing the observation data in order to create questions to guide the interview. It is acknowledged that this situation was not ideal, but in order to maintain a good relationship with the host centre it was felt that this was an acceptable compromise to make and would not impact significantly on the interview. These were the last set of interviews that were conducted, so by this point the researcher had gained considerable experience at conducting these interviews and felt confident that this would not impact negatively on the data.

As with the observational data, the interview audio recordings were anonymised and uploaded for professional transcription.

Overall, the interviews were carried out as planned (Section 3.4.1.2) and were without incident. A conversational approach was adopted with the participants, which seemed to generate rapport between the researcher and participant quickly. This aided the flow of conversation and the answering of questions.

As with any research in the real world, a small number of minor limitations were encountered throughout the process. The interview with Tom was conducted in his lunch hour and David's interview was conducted in between meetings, so the time pressures meant these interviews felt a little rushed at times. Factors such as this are unavoidable and were not viewed as overly problematic.

Several of the participants were known to the researcher in a professional context and so the researcher was very conscious of the influence this may have and in terms of them feeling obliged to participate or feeling that they could not talk freely. In reality, none of the participants seemed to "hold back" in the interview and the existing relationship may well have helped them to feel relaxed as some level of trust was already subconsciously there.

3.7.6 Analysis of data

All the transcripts were imported into the qualitative analysis software Quirkos 1.4 (Quirkos Ltd) for analysis.

Full analysis of the observational data was carried out using the three-step process by Fonteyn and Grobe (1992). Following the coding of RPA for eight patients, the number of codes exceeded 70, so a review of the coding was conducted and discussed with the supervisory team. This led to the merging of several codes ultimately reducing the overall number to a more manageable number. Several themes clearly emerged from the data and the whole process went smoothly and relatively quickly.

The process of AA was found to be a little more complex and the researcher sought the advice of Ruth-Anne Kuiper (Kuiper, 2010; Kuiper, 2003; Fonteyn et al., 1993), who kindly offered to answer any questions and sent examples of raw coded data to the researcher to explain the concepts. Following these discussions, numerous clear assertions were made in the data which ultimately proved useful in the development of the final descriptive model.

The final process, SA, was also completed without complication, revealing some exciting and interesting patterns. The codes were colour-coded and imported into Microsoft Excel 2010 (Microsoft Corporation) using a similar process to Adderley (2013) which provides the researcher and reader with a visually easy method to view patterns in the decision-making processes.

The analysis of the interview data was completed as planned. The process was partially aided by the pragmatic approach of Braun and Clarke and the structure of their well written publications (Braun & Clarke, 2008; Braun & Clarke, 2013).

3.8 TRUSTWORTHYNESS OF THE ANALYSIS

Many perspectives exist relating to the importance of validation in qualitative research and its relative value (Creswell, 2013). Traditionally, authors sought to find terms linked to quantitative equivalents (LeCompte & Goetz, 1982), which has been criticised for trying to facilitate the acceptance of quantitative research in a qualitative world by using positivist terminology (Ely, 1991). Denzin and Lincoln (2011) highlight the importance of *"trustworthiness"* in a study by assessing *credibility, authenticity, transferability, dependability, confirmability* and *credibility.*

Braun & Clarke (2013) agree with the position of not attempting to assess a qualitative study using quantitative paradigms. They state that terms such as *"reliability"* are of little concern in qualitative studies, as good qualitative researchers acknowledge that they inevitably influence the research process and so repeating the study with different researchers would yield different results. They also dispute the use of inter-rater variability calculations using techniques such as Cohen's Kappa analysis because of the objective nature of the coding process and the impact of the individual researcher on this.

Following discussions with the supervisory team, the trustworthiness of the data was evaluated using peer debriefing and member checking, both of which are recognised methods of assessment (Braun & Clarke, 2013)

3.8.1 Peer debriefing

Lincoln and Guba (1985 p308) define peer debriefing as a *"process of exposing oneself to a disinterested peer in a manner paralleling an analytic session for the purpose of exploring aspects of the inquiry that might otherwise remain only implicit within the inquirer's mind"*

Peer debriefing occurred regularly throughout the project and involved the researcher and the three members of the supervisory team. The main aspects of the process involved discussions and critiquing of:

- The methodology and methods
- The interview schedules
- Initial codes and development of final codes
- Initial themes and development of final themes
- Triangulation of the data and development of the final descriptive model

3.8.2 Member checking

Braun and Clarke (2013 p.284) cite numerous issues and practical problems in relation to member checking, including the reluctance of participants to engage, power asymmetry between researcher and participant, the potential for contradictory feedback and time to complete the process. In contrast to this, Lincoln and Guba (1985) observe that member checking is crucial to establish the credibility of the findings and may serve to alleviate the researcher's anxieties in relation to their ability to understand the experiences of the participants.

Member checking was carried out in the first part of the follow-up interview. Whilst watching the videos back, the author and participants could clarify any uncertainties in the authors initial analysis. Following the interviews, an online presentation highlighting the key findings of the study was produced and sent to the participants. Participants were invited to watch the video in their own time and complete a short online questionnaire (Appendix 9), where they had opportunity to comment freely about the findings of the study.

Participant uptake on the member checking phase of the study was lower than anticipated and despite several emails to the participants asking for input, only three participants engaged in the process and their engagement could be considered as limited. The feedback they presented was positive in all three cases and strengthened the trustworthiness of the findings, but only equated to several lines of text. This was a little disappointing at first, but not wholly unexpected as the participants had already engaged in both the observation and interview phases of the study.

3.9 Summary

Chapter 3 has highlighted a number of approaches that could have been adopted during the data collection and analysis phase. Standard observational approaches were rejected due to the lack of insight they offer and the potential risk of researcher bias. The think aloud method was critiqued and was adopted for the observational stage of the study. This method is supported by a wide evidence base highlighting the method's ability to gain an in-depth understanding of an individual's cognitive approaches during a task or decision-making process. Participants were video recorded whilst making clinical decisions on a series of pre-determined clinical scenarios. Fonteyn and Grobe (1992) protocol analysis was chosen as the method of analysis for the observational data and the use of the approach justified. Semi-structured interviews were conducted following the observational stage. These interviews acted as a form of member checking as well as allowing the author to gain a greater insight into the experiences and views of the participants. The transcribed recordings were analysed using an approach to Thematic Analysis by Braun and Clarke (2017). The analysed data from the observational and interview stages of the study were triangulated using a matrix proposed by Farmer et al. (2006).

CHAPTER 4: RESULTS

4.1 INTRODUCTION

This chapter will present the findings of both the observational phase of the study and the post-observation interviews.

Section 4.2 will present the demographics of the participants. Section 4.3 will present the protocol analysis element of the observational phase of the study. This is a three-stage process and will be presented in sections 4.3.1 to 4.3.8. Analysis of the data highlighted a large variation in practice across the three case centres, so a focus has been placed on this during the presentation of the data.

This section will commence with the results of the referring phrase analysis (RPA) in section 4.3.2. The assertional analysis (AA) assertions and referring phrase analysis (RPA) relationships are then combined and presented in section 4.3.7. Script Analysis is the final stage of protocol analysis and the four decision-making models that were identified will be presented in section 4.3.8.

Section 4.4 will present the findings of the participants' final clinical decisions for each scenario. These will be presented alongside the opinions of a national IGRT expert for the purposes of comparison.

Section 4.5 to 4.7 follows with the thematic analysis of the post-observation interviews. Two models, both providing a unique contribution to knowledge will be presented. The first is a model containing the five elements of IGRT decision-making. This will be expanded in Section 4.8.4 where a descriptive model of the factors that impact IGRT decision-making will be presented.

Section 4.8 provides a detailed account of the participants' experience of the think aloud method.

Descriptions and Screen shots of each case can be seen in Appendix 8.

4.2 PARTICIPANT DEMOGRAPHICS

The demographics of the 12 participants is shown in Table 4.0. Gender did not form part of the analysis of the data due to the imbalance of participants in each category. To maintain the anonymity of each of the participants, the chosen pseudonym for each participant is not gender specific.

TABLE 4.0 PARTICIPANT DEMOGRAPHICS

Pseudonym	Case Centre	Experience as a therapeutic radiographer (Years)	Experience with 3D-IGRT (Years)	Radiotherapy related qualifications
Tom	One	2-5	< 2	BSc (Hons)
Sara	One	>20	2-5	DCR(T), MSc, BSc (Hons)
Nicole	One	5-10	2-5	BSc (Hons)
Liz	One	>20	2-5	DCR(T), MSc
James	One	10-15	2-5	BSc (Hons)
David	Two	10-15	>5	BSc (Hons)
Lisa	Two	2-5	<2	BSc (Hons)
Hannah	Two	2-5	<2	PGDip
Adam	Two	5-10	2-5	BSc (Hons)
Fathima	Three	>20	>5	DCR(T), MSc
Rachel	Three	10-15	>5	MSc, BSc (Hons)
Ahmed	Three	15-20	>5	MSc, BSc (Hons)

The demographics of the 3 centres involved in the study is shown in Table 4.1.

TABLE 4.1 CENTRE DEMOGRAPHICS

Centre	Clinical Linacs	Linacs with CBCT capability	Approximate number of employed therapeutic radiographers
One	7	6	70
Two	10	10	100
Three	10	10	120

4.3 RESULTS OF THE OBSERVATIONAL PHASE OF THE STUDY

4.3.1 Introduction

This section presents the three-stage process used to analyse the observational phrase of the study; referring phrase analysis (RPA), assertional analysis (AA) and script analysis (SA).

4.3.2 Referring Phrase Analysis for all participants

Referring Phrase Analysis is the first stage of the protocol analysis and defines the vocabulary concepts that the participants used during the observations (Fonteyn, Kuipers, & Grobe, 1993). Twenty-five concepts were identified during the RPA stage of the analysis with some phrases being coded to more than one concept. The concepts developed in this stage of the analysis are very specific to the processes being studied. While some of them such as Experience and Knowledge of patient may have been expressed in other clinical settings, the majority of the concepts are based on interpretation of IGRT process and radiotherapy discourse. The final concepts that emerged are summarised in Table 4.2.

TABLE 4.2 DESCRIPTION OF REFERRING PHRASE ANALYSIS CONCEPTS

Concept	Phrases (overall n)	Phrases (overall %)	Description	Examples
Target Volume	118	14	Reference to Target Volumes (GTV, CTV, ITV ,PTV)	*It's dropped inferior, at the moment it still looks like it's within the PTV, it's still getting the 95%* (Nicole) *This is well within the PTV, still, if it is any tumour expansion* (James)
Image manipulation	111	13	Reference to manipulating the imaging software	*Going to put on my colour wash, which is a strange colour on this screen, so normally this would be orange and blue* (Rachel) *Just pick the first scan. Again, change the window levels to something more appropriate* (Sara)
Intermediate decisions	83	10	Process of making a decision part-way through the review	*That match however is good to spine* (Becky) *So, looking from that I can't see any significant changes* (Fathima)
Soft/Bone	69	8	Reference to bony or soft tissue anatomy	*So, I'm going to look and check that I'm happy with my bony match* (Rachel) *But other than that soft tissue, match looks good* (James)

Normal structures	63	7	Reference to structures other than Target Volumes; Includes Organs at Risk	*The chin position, that's very good* (Nicole) *I can see some of the clavicle and I can see the apex of the chest wall* (James)
Changes in anatomy	58	7	Identification of a change in patient anatomy. This includes changes to patient contour and internal structures	*So, bladder volume straightaway – it's about half of what they had at CT* (Nicole) *The patient's lost quite a considerable amount of weight* (Fathima)
Written guidance	52	6	Process of referring to written guidance; includes protocols and notes made by other colleagues	*That's under our action levels* (Lisa) *In tolerance is five mm or below* (Ahmed)
Final decision	41	5	Process of final decision	*I probably would have got her off the table* (Liz) *I'll just move it slightly left right cover to get a spine match and I'm happy with that* (Lisa)
Patient position	37	4	Reference to patient position; includes rotation and tilt	*So, I can see there when I'm looking at it, that there's some pitch rotation on the patient* (Rachel) *Pelvis is a little bit tilted at the edges* (Sara)

Automation	33	4	Reference to an automated process	*I'm just going to run the auto-match* (Hannah) *First of all, we do an auto match* (Tom)
Gross check	26	3	Process of a gross or quick check	*Just a very brief overview to make sure that I can see what I need to see* (Sara) *Just to see, quickly glance to make sure that there is no significant weight loss or where there is weight loss, if only to document where that weight loss is* (Fathima)
Setting	26	3	Process of establishing the context of the review to be carried out	*Okay, so this is a lung patient* (Tom) *We're doing a fraction 11 week image* (Lisa)
Multi-Disciplinary Team (MDT)	24	3	Reference to reliance on other team members; includes members of the wider MDT	*I would definitely get physics round to have a look and see if they plan on making any alterations* (Lisa) *So that would probably get the PI rad around as well just to have a quick look at that* (Sara)
Issues with image	22	3	Identification of issues in relation to image quality or manipulation	*It looks like we've got an artefact going through the middle there* (Fathima) *They're very fuzzy but I think that's just the quality of the scan* (Rachel)

Experience	15	2	Reference to reliance on previous experience	*But generally, the soft tissue is not as moveable in the head and neck region* (Tom) *I wouldn't expect there to be any weight loss issues* (Sara)
Compromise	14	2	A compromise was made with two or more clinical factors	*Might need to make a best fit on that* (Sara) *The match itself for the main part of the tumour areas looks quite good* (Lisa)
Double checking	8	1	Process of double checking decision	*I am just going to check the frontal view as well* (Tom) *I've got to check the other views as well* (Nicole)
Knowledge of patient	6	1	Reference to previous experience of reviewing the patient	*As I don't know this patient I need to check quite a few things before I look, review the cone beam* (Fathima) *Right, same thing again. I don't know this patient* (Fathima)
Speak to patient	6	1	Process of discussing findings with patient	*I would probably speak with the patient and ask them how they are getting on with their enema* (Ahmed) *I would speak to the patient about their drinking protocol* (Nicole)

Immobilisation	5	1	Reference to patient immobilisation	*Just have a look to see the position where they actually are in the mask to begin with* (David) *They're not immobilised in a cast, it's a very kind of Pancoasty region, but normal Pancoast protocol patients are immobilised in a cast* (Rachel)
Causes of change	4	<1	Identification of a factor that has impacted on the patient's anatomy	*Possibly struggling due to pain on swallowing* (Lisa) *It's probably a lung chemo patient* (Becky)
Dose	4	<1	Reference to the treatment dose	*It still looks like it's within the PTV, it's still getting the 95%* (Nicole) *It would be just the dose impact really to the patient* (David)
Difficulty	4	<1	Reference to level of difficulty	*But again, there's a lot of gas which will make it quite hard to assess* (Tom) *They are quite easy to look at* (Tom)

Note for future fraction	3	<1	Process of making a note for future treatments	*But we just make a note of that to keep an eye on it* (Tom) *All right, it looks like this patient has gone down to daily cone beam CTs so it would be repeated again the following day* (Fathima)
Use prompt	2	<1	Process of using a personal prompt to assist in decision-making	[observation]* *use of prompt* (Tom)

*[observation] indicates research observation

The concepts with the largest frequencies were *Target Volume* (14%), *Image Manipulation* (13%), *Intermediate decisions* (10%), *Soft/Bone Tissue* (8%), *Normal Structures* (7%), *Changes in Anatomy* (7%), *Written Guidance* (6%) and *Final Decision* (5%).

Participants referred to the target volume twice as many times as they did the normal structures. All participants regularly referred to the anatomy as soft tissue or bony anatomy (8%) rather than the anatomical name of the structure. Bony matching relates to the use of bony anatomy such as the pelvis or spine as a surrogate to determine the position of the target volume, whereas a soft match refers to the use of non-bony anatomical structures such as organs, muscle groups or the tumour to determine the position of the target volume.

Four concepts had unexpectedly low frequencies during the observations. However, overall frequency may not be indicative of importance as they were often referred to by a number of participants. Three participants (Sara, Nicole and David) referred to *dose* during the observation, but this represented less than 1% of the overall coded concepts. Four participants said they would *Speak to the patient* (Tom, Nicole, James and Ahmed). Although nine participants referred to *the MDT*, this only represented 3% of the phrases used. Six participants referred to the *need to compromise*, representing 2% of the phrases used.

4.3.3 Inter-Centre Referring phrase analysis

There was a variation in the frequency in which the concepts identified in the Referring phrase analysis occurred across the case centres. These are shown in Figures 4.1 and 4.2.

FIGURE 4.1 RPA SUMMARY CATEGORISED BY CASE CENTRE

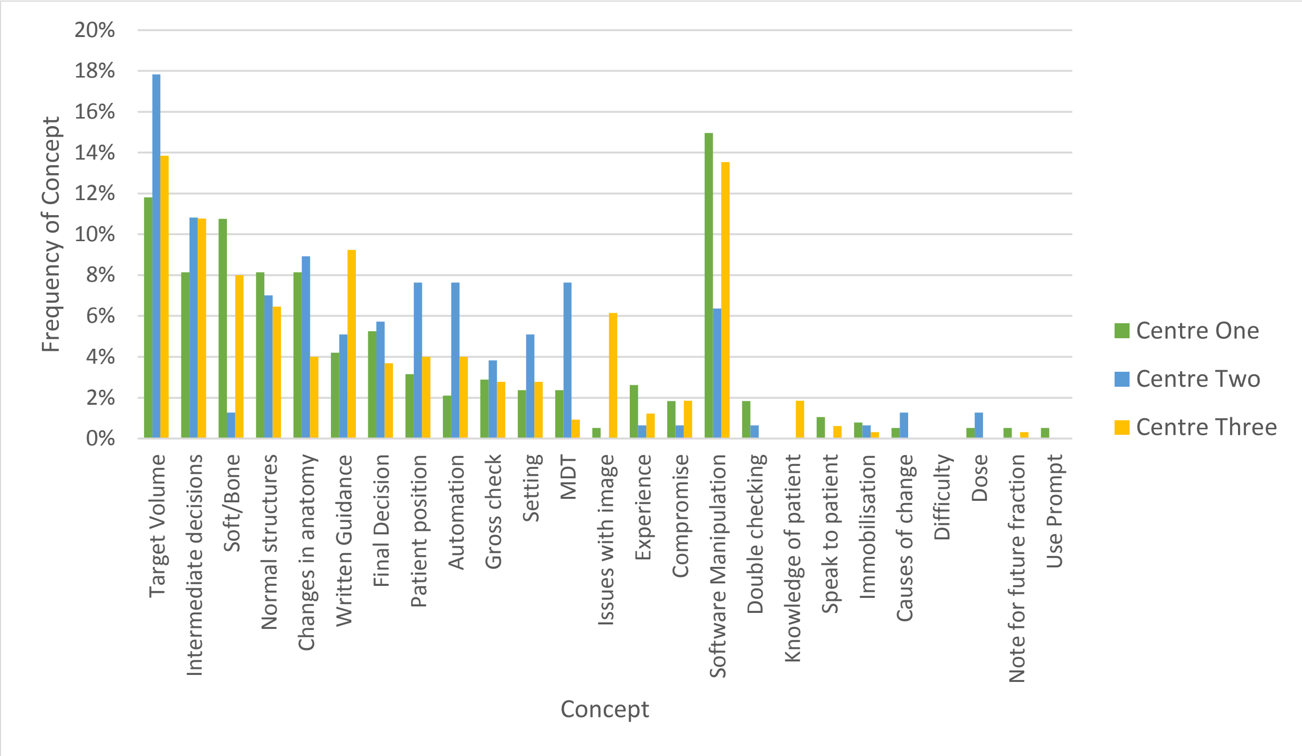
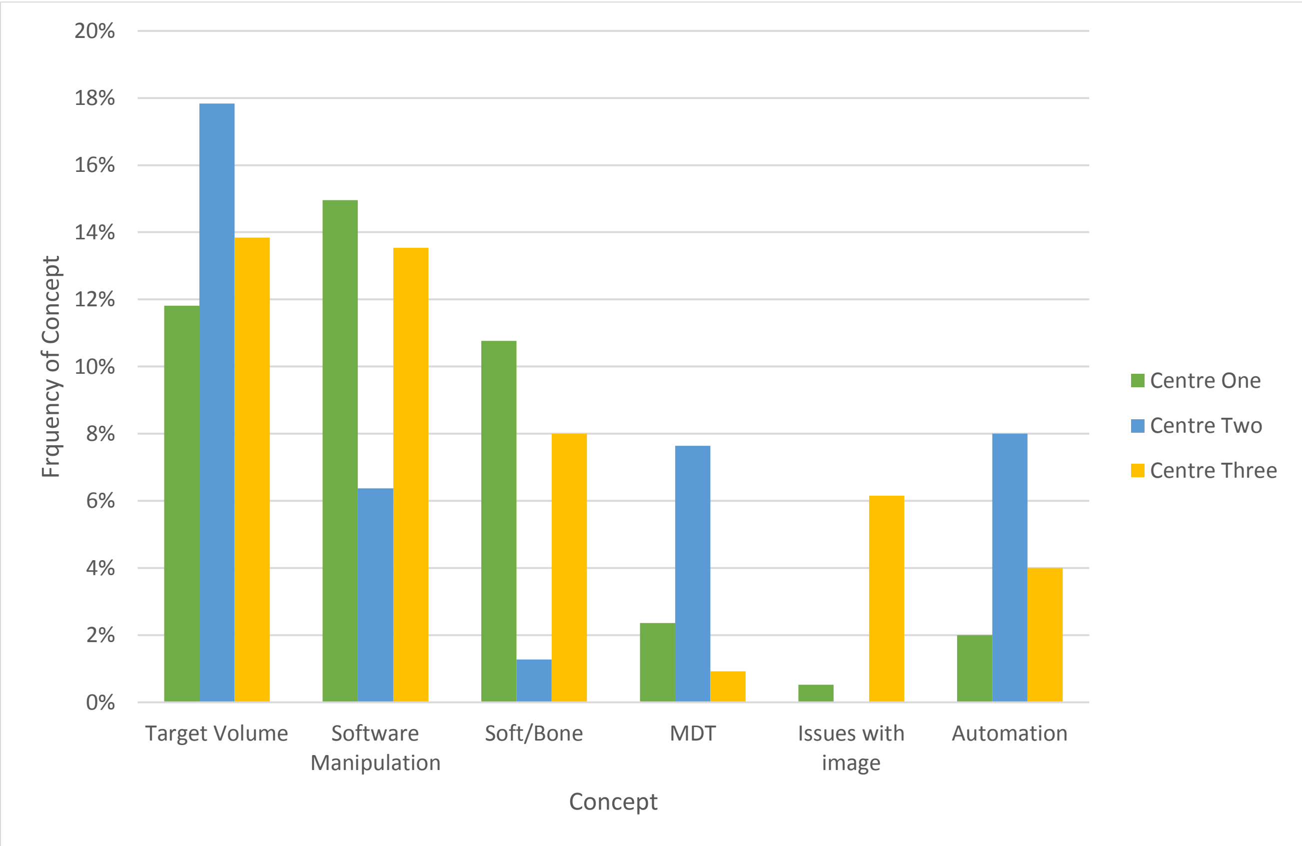


FIGURE 4.2 KEY DIFFERENCES IN CODED CONCEPTS CATEGORISED BY CASE CENTRE



The mean frequency of the concept *Target Volume* was 15% across all centres, but ranged from 12% in centre one to 18% in centre two. The concept of *Software Manipulation* had a mean frequency of 13% across all participants, but was only observed 6% of the time in centre two. Centre two is the only centre to use Elekta Software, with the other two using Varian. Centre two used the terms *Soft and Bony t*issue less than the other two centres (1% as opposed to 11% and 8% in centres one and three respectively). Centre two referred to the concept of *MDT* much more than the other two centres (8% as opposed to 2% and 1% in centres one and three respectively). Participants in centre three were the only ones to frequently refer to issues with *image quality* (6%), but this was in large part due to an artefact on one of the case study images. *Automation* featured in all three centres protocols, but centre two referred to it most frequently, with twice as many references (8%) as centre three (4%) and four times as many as centre one (2%).

4.3.4 Assertional analysis for all participants

Assertional analysis is the second stage of the protocol analysis and was used to identify the assertions that were used to form relationships between the concepts found in RPA (Fonteyn, Kuipers, & Grobe, 1993). The existing evidence base on think aloud was used to develop these assertions (Adderley, 2013; M. E. Fonteyn et al., 1993; Lundgrén-Laine, 2015; Simmons et al., 2003). Four assertions were highlighted during this stage of the analysis *Evaluate, Significance, Cause and Effect* and *Stating Facts*. These are summarised in Table 4.3. Not all phrases were linked with an assertion.

TABLE 4.3 DESCRIPTION OF ASSERTIONAL ANALYSIS CONCEPTS

Assertion	Phrases (Total n)	Phrases (Total %)	Description	Example
Evaluate	229	41	Evaluative relationship	*Slightly disagree with that match.* (Fathima) *Okay, so that looks quite reasonable there* (Rachel)
Significance	153	27	Relationship of Significance	*So, it's part way through their treatment and part way through what we call our mid-course* (Lisa) *And the main thing we are concerned with, with lungs is that we are in the PTV and also the GTV* (Tom)
Cause and Effect	106	19	Relationship of Cause and Effect	*This patient has got quite a lot of gas which can make it quite difficult to match* (Tom) *So, if we just clean this up a little bit just to check for gas as well [observation]* change window level* (James)
Stating Facts	77	14	Relationship of Stating Facts	*Okay, so doing an auto-match again* (David) *Right so we've got a head and neck* (Becky)

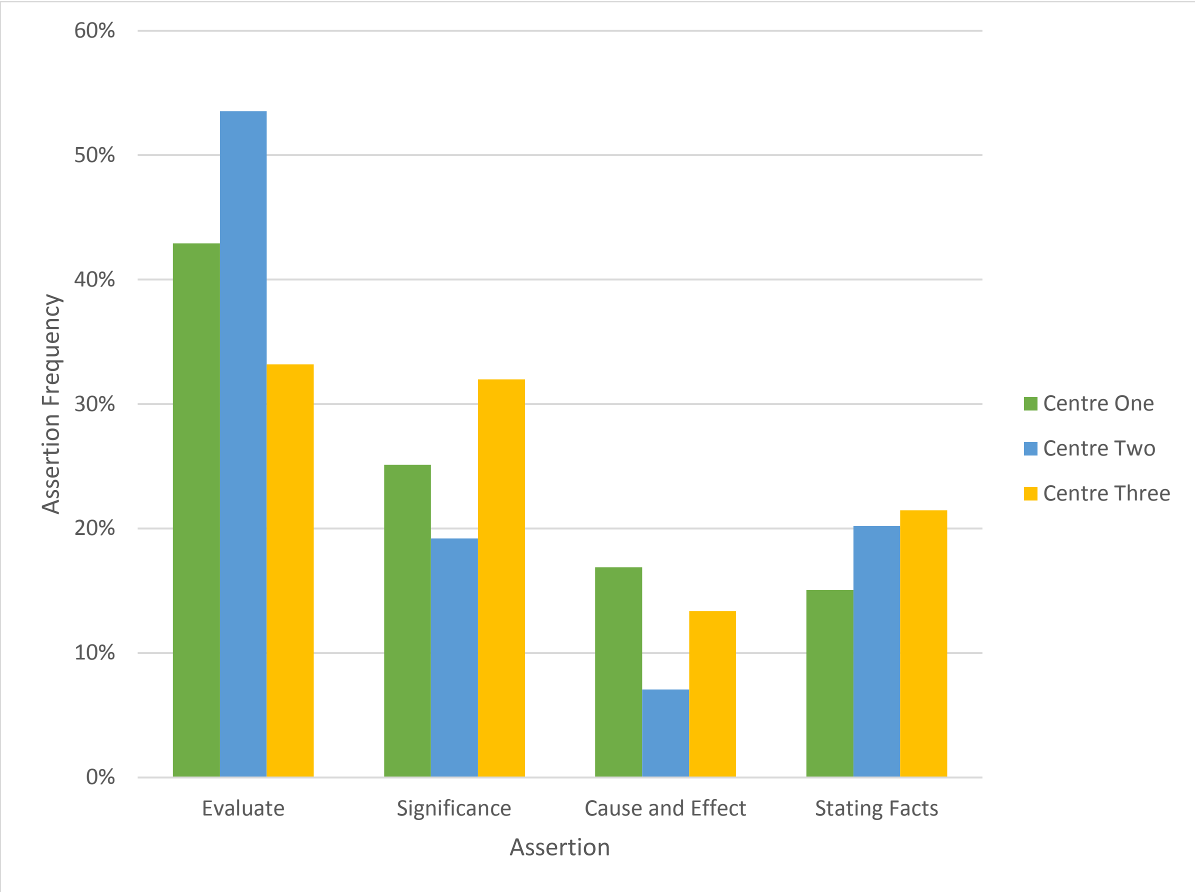
*[observation] indicates research observation

The four assertions were observed across all the participants. The most common assertion was *Evaluate* (41%), this was followed by *Significance* (27%), *Cause and Effect* (19%) and *Stating Facts* (14%).

4.3.5 Inter-Centre Assertional Analysis

Frequency variations of the four assertions were seen across the three centres. Figure 4.3 summarises these.

FIGURE 4.3 KEY DIFFERENCES IN RELATIONSHIPS CATEGORISED BY CASE CENTRE



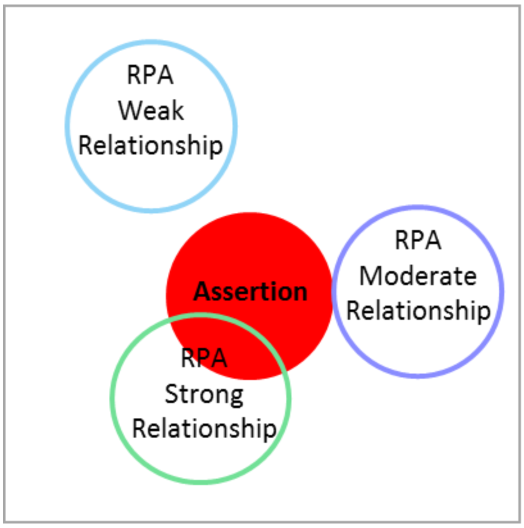
Evaluate was the most common assertion seen across all three centres, although there was a range in frequency from centre to centre. The largest difference was seen between centres two and three with a frequency of 54% and 33% respectively. A similar difference between centre two and three exists for frequency of the assertion *Significance,* although here centre two had the lowest frequency of occurrences at 19% and centre three had the highest at 32%. Participants in centre two also used the assertion *Cause and effect* less often (7%), with centre one using this assertion the most (17%). A smaller range on the use of *Stating Facts* was also seen ranging from 15% in centre one, with centres two and three being similar at 20% and 21% respectively.

4.3.6 Relationships between Referring Phrase Analysis and Assertional Analysis for all centres.

The relationship between the concepts in RPA and AA make up the epistemology of the data (Fonteyn, Kuipers, & Grobe, 1993). To determine if any relationships existed, the RPA concepts with the highest frequencies (n=8) were analysed against the all the AA assertions. It would have been possible to look for relationships across all RPA concepts and AA assertions, however, this approach would have resulted in a large number of relationships with minimal significance, so the decision was taken to focus on the relationships with the greatest impact.

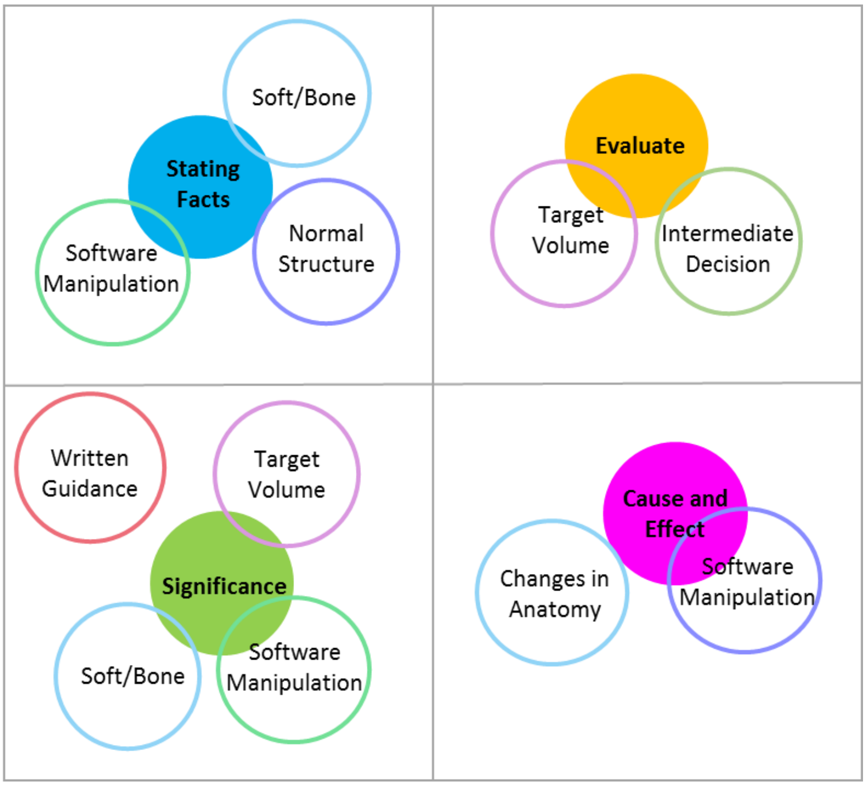
The relationships are presented in Figures 4.4 to 4.8. An explanation of the figures is presented in Figure 4.4 and the text below.

FIGURE 4.4 EXAMPLE RELATIONSHIP



The central bubble represents the AA assertion and the outer bubbles represent the RPA concepts. A larger overlap represents a stronger relationship Figure 4.4). These diagrams are re-produced from the reports generated by Quirkos by analysing the overlap of codes on a section of text. The analysis does not generate a numerical value, so is purely based on a visual interpretation. An example of the Quirkos report can be seen in Appendix 11.

FIGURE 4.5 RELATIONSHIPS BETWEEN RPA AND AA FOR ALL PARTICIPANTS



Realtionships were seen between *Stating Facts* (AA) and *Software Manipulation* and *Normal Structures* (RPA), with the strongest relationship seen in *Software Manipulation.*

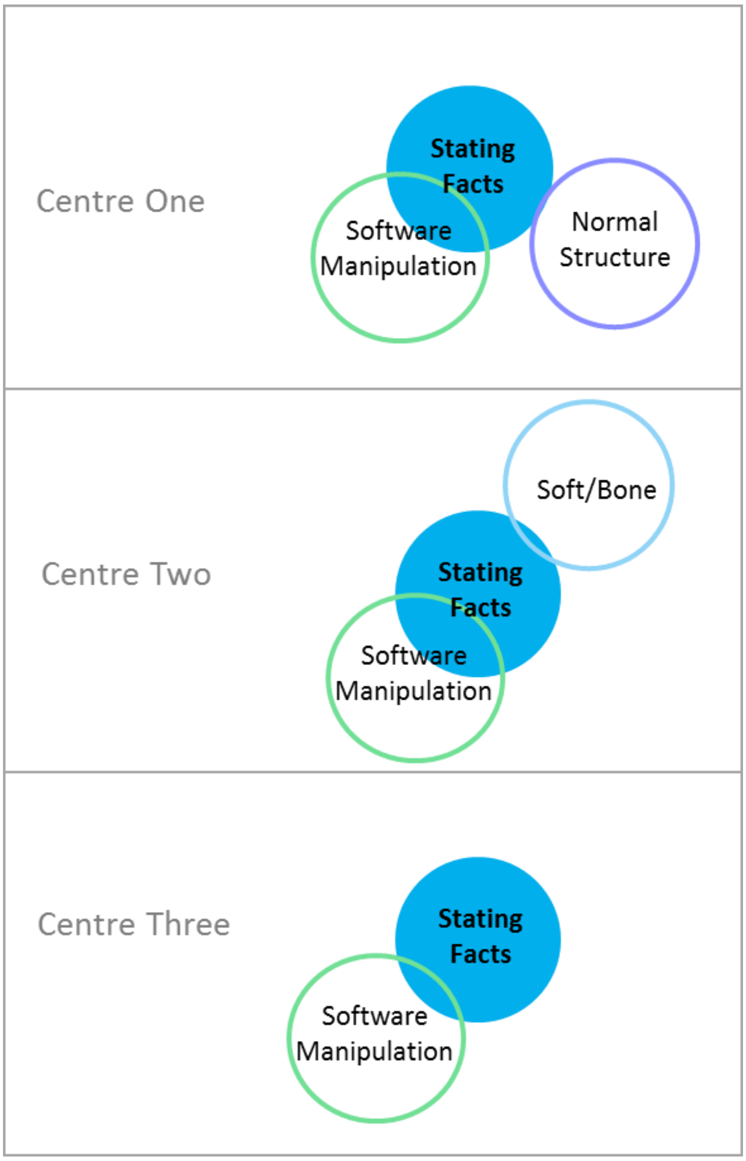
Four RPA concepts (*Written Guidance, Target Volume, Soft/Bone Tissue* and *Software Manipulation*) demonstrated a relationship the AA *Significance. Software Manipulation* had the strongest relationship, with the remaing three having weaker relationships.

The AA *Evaluate* was shown to have a similarly strong relationship with *Target Volume* and *Intermediate Decision,* whilst the AA *Cause and Effect* had relationships with both *Changes in Anatomy* and *Software Manipulation*.

4.3.7 Relationships between Referring Phrase Analysis and Assertional Analysis for all centres.

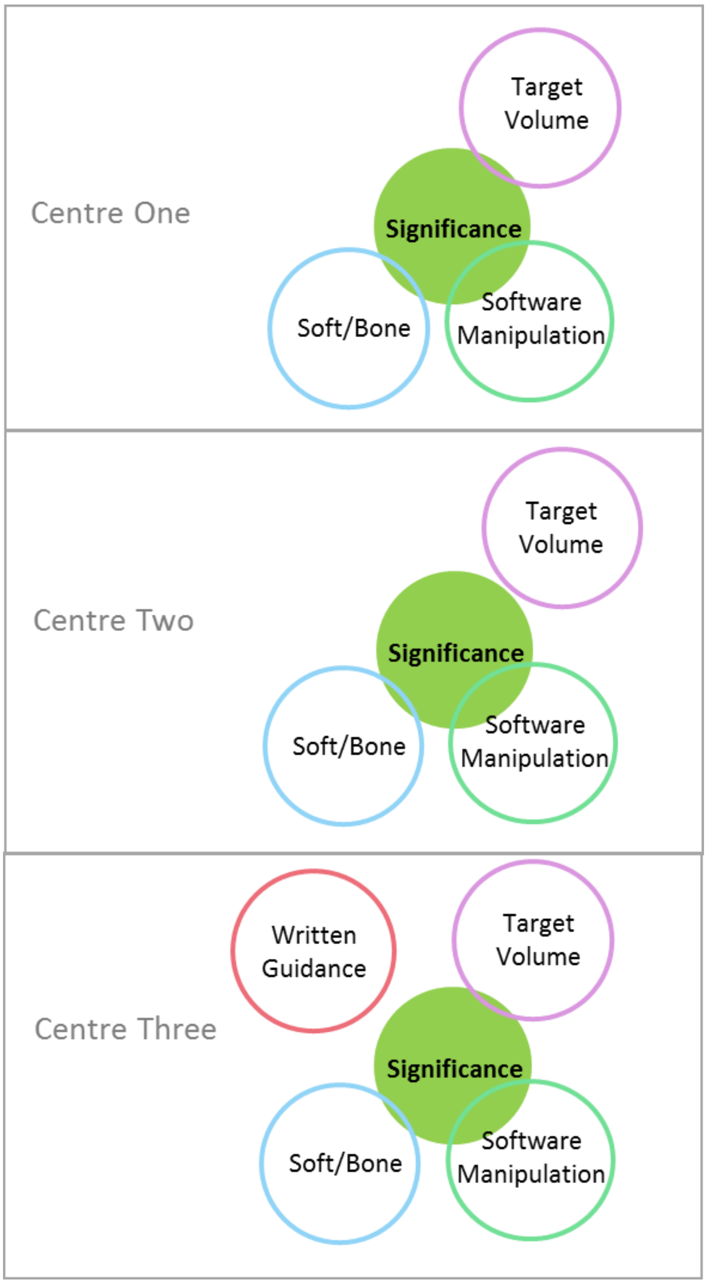
Figures 4.6 to 4.9 summarise the relationships between RPA and AA by Case Centre.

FIGURE 4.6 RELATIONSHIPS BETWEEN RPA AND THE AA RELATIONSHIP 'STATING FACTS'



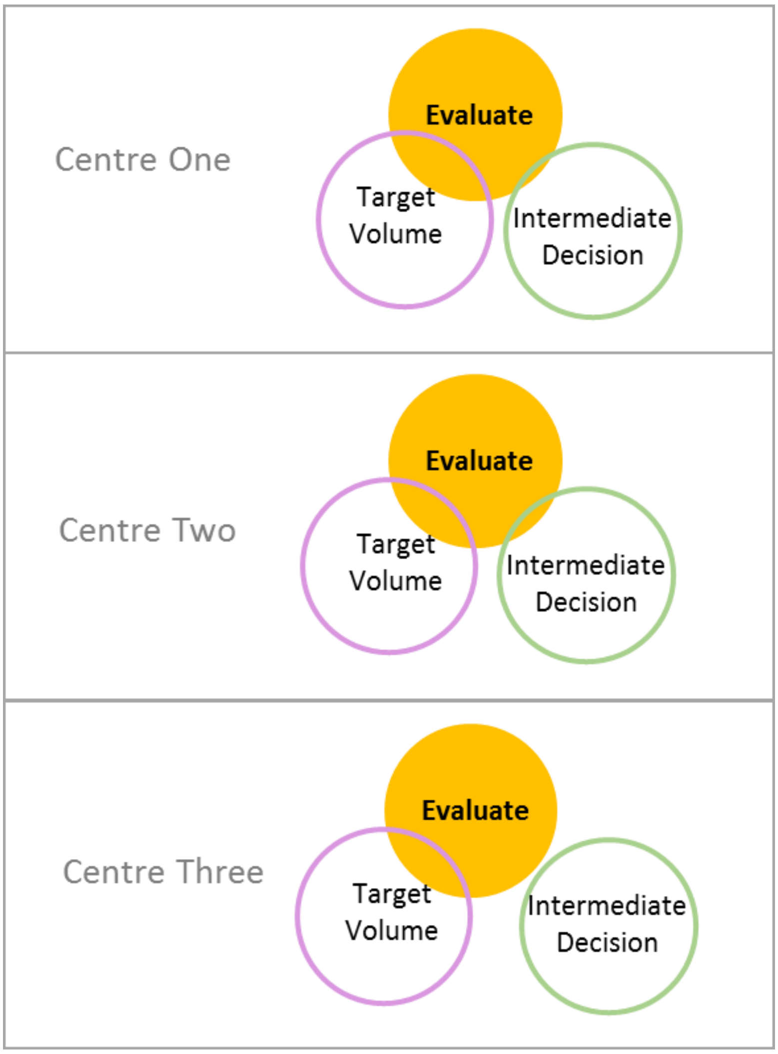
Relationships were observed with RPA concept *Software Manipulation* and the AA assertion *Stating Facts* across all three centres. Differences were seen between the relationship of *Soft/Bone* and *Normal Structure* across the three centres. As described in Section 4.2.2, these phrases may be used interchangeably and may be linked to local centre discourse as a Radiographer may refer to soft or bony anatomy as a normal structure (i.e. not a Target or Organ at Risk).

FIGURE 4.7 RELATIONSHIPS BETWEEN RPA AND THE AA RELATIONSHIP 'SIGNIFICANCE'



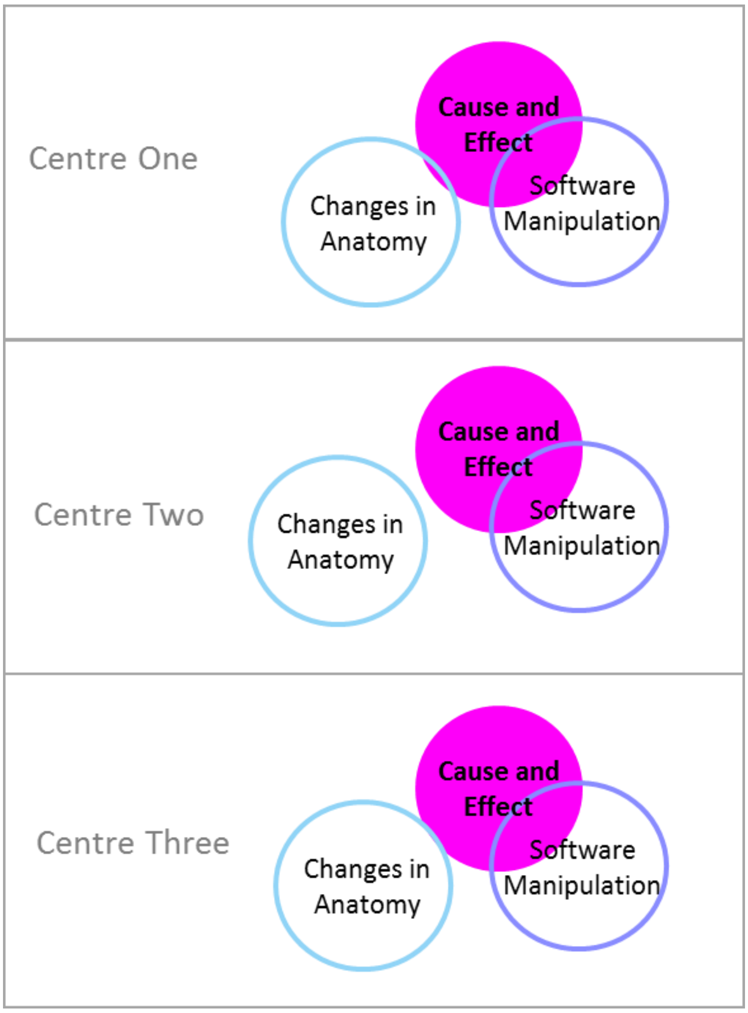
In centres one and two the RPA concept *Soft/Bone, Target Volume* and *Software Manipulation* had relationships with the AA assertion *Significance*, with *Software Manipulation* having the strongest relationship. Centre three had very similar relationships between AA and RPA concepts, but an additional RPA Concept (*Written Guidance*) was observed to have a small relationship.

FIGURE 4.8 RELATIONSHIPS BETWEEN RPA AND THE AA RELATIONSHIP 'EVALUATE'



All three centres had similar relationships between the assertion *Evaluate* (AA) and the RPA concepts *Target Volume* and *Intermediate decision.* It is interesting to note that *Normal Structures* or *OARs* did not have a relationship with this assertion. This suggests that the participants evaluated the impact of any changes on the Target Volume to a higher degree that that of the normal structures.

FIGURE 4.9 RELATIONSHIPS BETWEEN RPA AND THE AA RELATIONSHIP 'CAUSE AND EFFECT'



All three centres had similar relationships between the assertion *Cause and Effect* (AA) and the RPA concept *Software Manipulation,* with centre two having a slightly smaller relationship than the other two with *Cause and Effect* and *Changes in Anatomy*. No other relationships were observed.

4.3.8 Script Analysis

Script Analysis is the final stage of protocol analysis and provides an overall description of the reasoning processes (Fonteyn, Kuipers, & Grobe, 1993). Six processes were observed in the protocols: *Describe, Optimise Image, Evaluate, Explain, Correction* and *Treatment.* Table 4.4 summarises these concepts.

As in the AA analysis, the existing evidence base on think aloud was used to develop several of these concepts; *Describe* (Simmons et al., 2003), *Evaluate* (Simmons et al., 2003), *Explain* (Adderley, 2013). The Concepts *Treatment, Correction* and *Optimise Image* are specific to this case study and these processes were developed based on interpretation of what was observed. Participants regularly made translational corrections to the patient's position during the review process, but this was different to a decision to treat or not and these have been represented as discrete concepts. Similarly, participants frequently optimised the images they were reviewing to better inform their decisions.

TABLE 4.4 DESCRIPTION OF SCRIPT ANALYSIS CONCEPTS

Concept	Description	Example
Describe	When participants described or narrated the setting or patient	*Okay, so this is a lung patient, looking at day two image* (Tom) *So, this is head and neck mid-course* (Hannah)
Optimise Image	When participants optimised the imaging software	*Just going to change those window levels* (Sara) *Change my contrast to medium and I'm starting on the isocentre slice* (Lisa)
Evaluate	When participants evaluated the information	*Okay there doesn't seem to be any more gas or anything in there* (Nicole) *Yes, so the bladder volume looks slightly bigger, bigger than the GTV* (David)
Explain	When participants interpreted information, or provided a rationale	*I can start to look at that because although I am doing a bony match, it's not really the bony match I am totally interested in because we are interested in what soft tissues are in the target here* (Sara) *My first thoughts are to check the spine position* (David)
Correction	When participants made a correction to the treatment parameters	*I'm just going to move us slightly post for better coverage* (Lisa) *It just alters the contrast so it's a bit more clear* (Tom)
Treatment	When participants referred to the delivery of treatment	*I can obviously go ahead and treat online because it's covered by the PTV* (David) *I'd get someone to come and look at that online. To me, we can't be sure we're actually covering what we need to cover there* (Hannah)

Each transcribed phrase was coded to a process concept and mapped onto a colour-coded model (Adderley, 2013). The map can be read by working across each case from left to right and using the coloured legend to determine the order of concepts. An example process is shown in Figure 4.10

FIGURE 4.10 EXAMPLE SCRIPT ANALYSIS

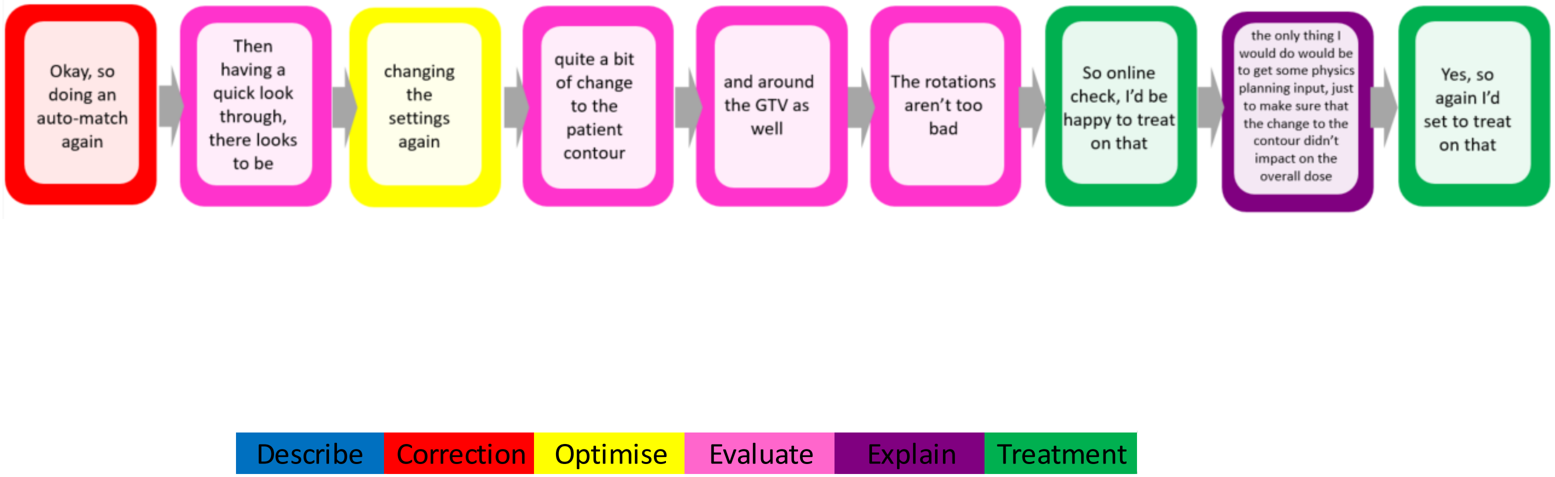
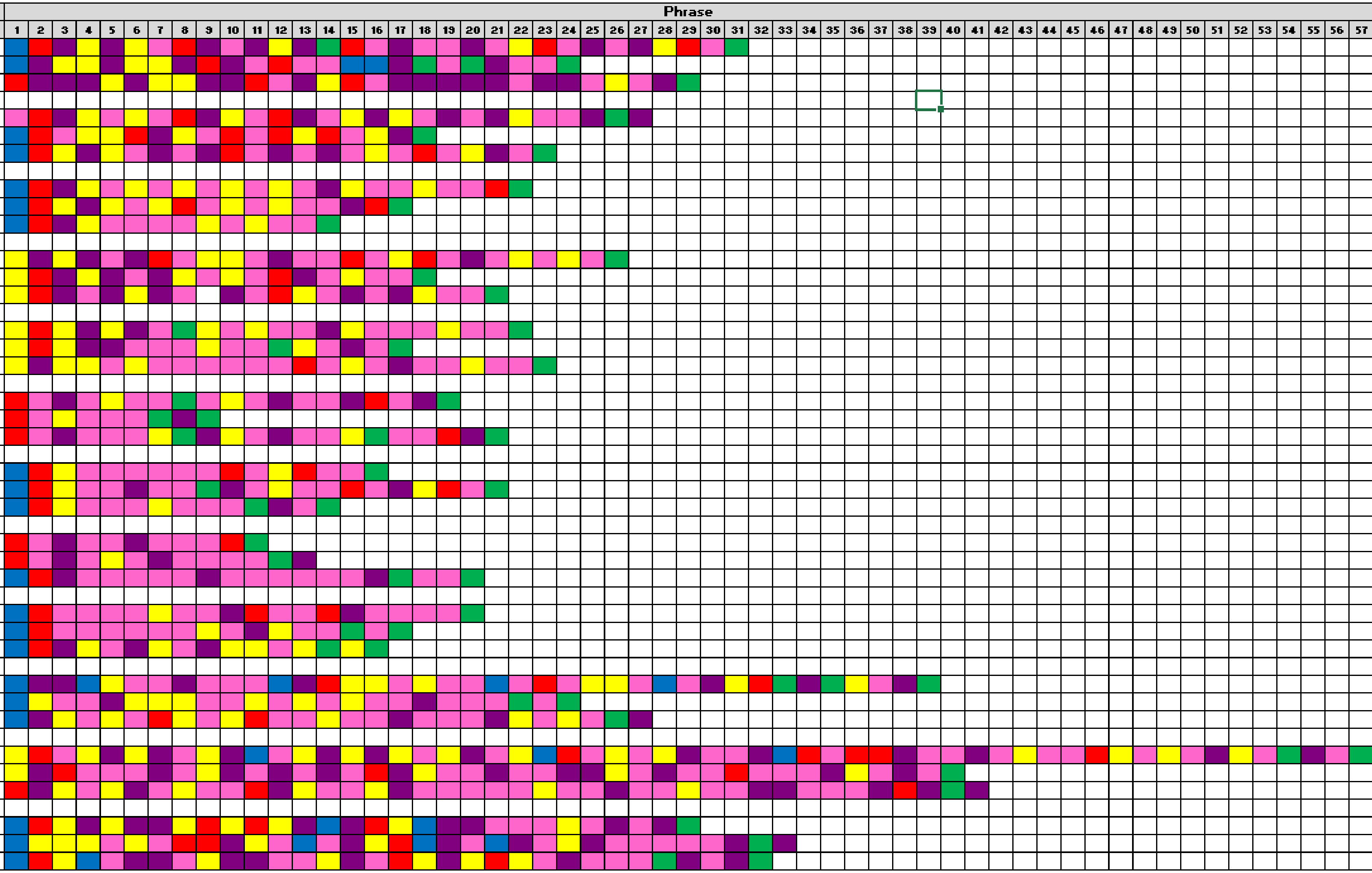


Figure 4.11 summarises all the observed cases. An example of a fully coded transcript can be seen in Appendix 12.

FIGURE 4.11 SCRIPT ANALYSIS



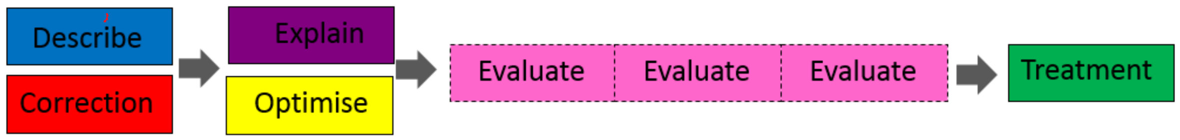
Name	Case	Comp	Total Phrases
Tom	Cervix	4	31
Tom	Lung	3	24
Tom	H&N	3	29
Sara	Cervix	4	27
Sara	Lung	3	18
Sara	H&N	3	23
Nicole	Cervix	4	22
Nicole	Lung	3	16
Nicole	H&N	3	14
Liz	Cervix	4	26
Liz	Lung	3	18
Liz	H&N	3	20
James	Cervix	4	22
James	Lung	3	17
James	H&N	3	23
David	Bladder	2	19
David	Lung	4	9
David	H&N	3	21
Lisa	Bladder	2	16
Lisa	Lung	4	21
Lisa	H&N	3	14
Hannah	Bladder	2	11
Hannah	Lung	4	13
Hannah	H&N	3	20
Adam	Bladder	2	20
Adam	Lung	4	17
Adam	H&N	3	16
Fathima	H&N	4	39
Fathima	Lung	3	24
Fathima	Bladder	3	27
Rachel	H&N	4	57
Rachel	Lung	3	40
Rachel	Bladder	3	41
Ahmed	H&N	4	29
Ahmed	Lung	3	33
Ahmed	Bladder	3	32

Describe | Correction | Optimise | Evaluate | Explain | Treatment

Several patterns emerged from the SA analysis which have been developed into three decision making processes; *simple linear, repeating linear* and *intuitive.*

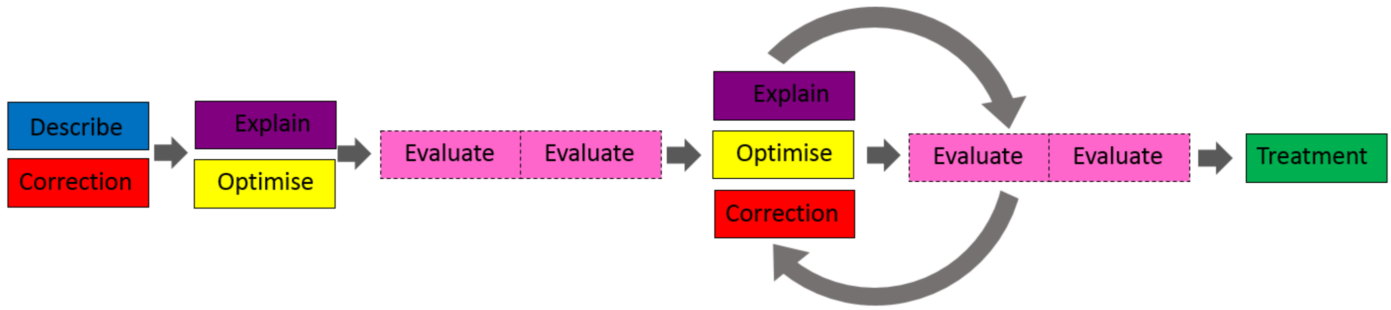
The *simple linear process* is the basis for all three decision-making processes and involves an early description and correction followed by an explanation and/or an optimisation, before a variable period of evaluation. The intention to treat or not treat is not verbalised until the end of the process.

FIGURE 4.12 SIMPLE LINEAR PROCESS



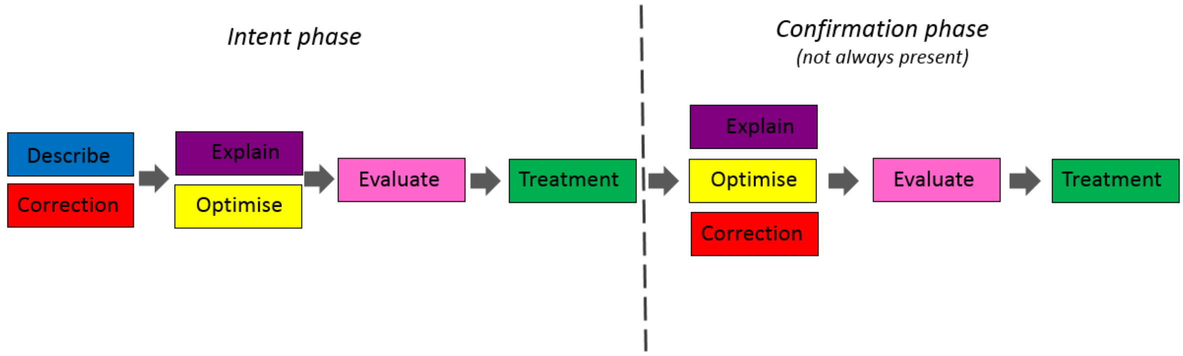
The most common process was the *repeating linear process.* Using this process, a correction was made almost immediately, followed by a period of evaluation before making further corrections. This cylindrical process continued until a decision to treat or not treat was made. This pattern was observed on 13 occasions across all participants except for James and Lisa (Figure 4.13) On most occasions, participants would explain the rationale for their decisions, but this was not always the case.

FIGURE 4.13 REPEATING LINEAR PROCESS



The *intuitive process* is defined by the an *intent phase* and a *confirmation phase.* The intuitive process was used by Tom, Nicole, James, David, Lisa and Hannah. All participants followed the intuitive phase that resulted in a quick decision to treat or not treat. On some occasions the processes ended at this point. On most occasions, the participants then spent the remainder of the process checking to see if their initial decision was appropriate (the confirmation phase).

FIGURE 4.14 INTUITIVE PROCESS



A range in the number of phrases were seen across the participants. The maximum number of phrases was 57, the minimum 9 and the mean 24. Five case studies were carried out with less than 15 phrases (Nicole, David, Lisa and Hannah). Three participants used more than 30 phrases, all practiced in centre three.

4.4 FINAL DECISIONS AND EXPERT COMMENTS

4.4.1 Introduction

This section presents the participant's final decision with those of the IGRT expert highlighting similarities and differences across the participants. It should be noted that the expert was blinded to the participants decisions. The findings are summarised in Figures 4.15 to 4.17. A green box indicates an intention to treat, a red box an intention not to treat and an orange box a borderline decision.

FIGURE 4.15 CENTRE ONE AND EXPERT FINAL DECISIONS

	Centre One		
Participant	**Cervix Case 1 Complexity 4**	**Lung Case 2 Complexity 3**	**H&N Case 3 Complexity 3**
Tom	Intention: Treat Could be improved With bladder status	Intention: Treat Change worth considering after treatment	Intention: Treat
Sara	Intention: Not Treat Get patient off and drink	Intention: Treat No mention of changes on edge of PTV	Intention: Treat Slight twist but happy to treat
Nicole	Intention: Not Treat Speak to patient prior to treatment	Intention: Not Treat Notice consolidation, but inside PTV. Out of tolerance for treatment	Intention: Treat
Liz	Intention: Not Treat	Intention: Treat No mention of changes on edge of PTV	Intention: Treat
James	Intention: Treat Bladder size is significantly less but not a disaster given the size of the PTV	Intention: Treat Some concern around change in mass, but inside PTV.	Intention: Treat
Expert	Intention: Not Treat If bowel in field don't treat. Not in this case, but the bladder significantly smaller. Borderline. Err on the side of caution	Intention: Treat Some changes in tissue around the PTV. Treat and ask medic to review after.	Intention: Treat Need to check chin and shoulder position

Case one was a patient receiving treatment for cervical cancer. There was a large difference in size between the bladder on the planning scan and on the CBCT. This caused the small bowel and other structure close to the bladder to move. Tom and James would have treated the patient, where as participants Sara, Nicole and Liz felt the changes were too significant and that the bladder would need to be fuller before treating. The Expert felt that the bowel was not an issue in this case, but due to the large difference in bladder size, she felt that the best decision would be to not treat and get the patient to fill their bladder. The Expert rated this as the most complex case at this site.

Case two was a patient receiving treatment for lung cancer. On the images, there were notable changes on the edge of the PTV. Participants Tom, Sara, Liz and James would have treated the patient. Sara and Liz did not comment on the changes on the edge of the PTV. The Expert noted these changes, but felt that it was not disease progression and that she would have treated the patient and then sought advice from the medical team before the next treatment fraction.

Case Three was a patient receiving treatment for head and neck cancer. A small rotation was evident. All participants and the Expert felt that any changes were within acceptable levels and that the patient should have been treated.

FIGURE 4.16 CENTRE TWO AND EXPERT FINAL DECISION

	Centre Two		
Participant	**Bladder** **Case 4**	**Lung** **Case 5**	**H&N** **Case 6**
	Complexity 2	**Complexity 4**	**Complexity 3**
David	Intention: Treat Very quick decision	Intention: Treat Very quick decision. Get physics to review weight loss	Intention: Not Treat Planning to review online
Lisa	Intention: Treat Very quick decision	Intention: Treat Get physics to review weight loss after treatment	Intention: Not Treat Re-set the patient up Involve planning
Hannah	Intention: Treat Very quick decision	Intention: Treat If it was VMAT get physics online	Intention: Not treat Planning to review online
Hannah	Intention: Treat Very quick decision	Intention: Treat Note changes: Get medic/ physics review after	Intention: Not treat Note changes around nodes. Get medic/physics review
Expert	Intention: Treat Straight forward	Intention: Treat Decision based on fraction Treat get physics review If it was early don't treat	Re-set the patient up Get physics review

Case Four was a patient receiving treatment for bladder cancer. There was a difference in bladder size between the planning scan and the CBCT, but all participants and the Expert felt that the case was a straight forward treat.

Case Five was a patient receiving treatment for lung cancer. There were some changes in the mediastinum and around the patient's external contour. All participants and the expert made a decision to treat. All the participants commented that they would ask the medical or physics team to review the weight change before the next fraction.

Case Six was a patient receiving treatment for head and neck cancer. There was a difference in the patient's external contour between the planning scan and the CBCT. None of the participants would have treated the patient based on this set of images. All the participants stated that they would ask the medical or physics team to review the weight and PTV changes before treating that fraction. The Expert agreed with this.

Centre two was the only centre where all the participants made the same final decision for all cases.

FIGURE 4.17 CENTRE THREE AND EXPERT FINAL DECISIONS

Centre 3			
Participant	**H&N** **Case 7**	**Lung** **Case 8**	**Bladder** **Case 9**
	Complexity 4	**Complexity 3**	**Complexity 3**
Fathima	Intention: Not Treat Get someone else to review due to weight changes	Intention: Treat Check with medic after	Intention: Not Treat Changes too large
Rachel	Intention: Treat Artefact noted	Intention: Treat Get physics to review after	Intention: Treat Changes noted
Ahmed	Intention: Treat Artefact noted	Intention: Treat Get medic to review after	Intention: Treat Speak to patient about enema
Expert	Intention: Not treat Physics to review artefact Is Spinal Cord safe? Get physics to review before treatment	Intention: Treat Get physics to review after	Intention: Treat Changes noted. Discuss with patient

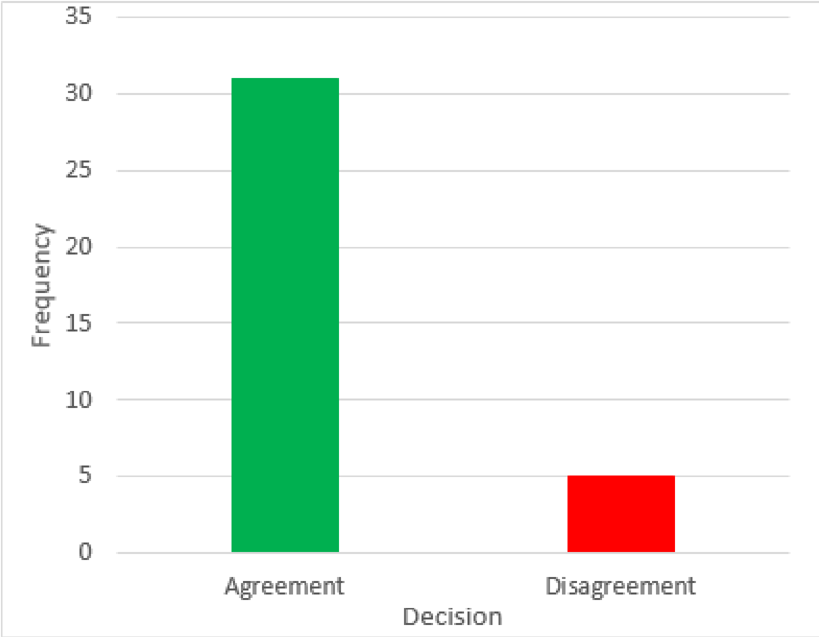
Case Seven was a patient receiving treatment for head and neck cancer. There were differences between the external contour on the planning scan and the CBCT. There was also a large artefact on the image. Fathima said that she would get a more experienced colleague to review the patient prior to making a final decision. Rachel and Ahmed made the decision to treat and noted the large artefact. The Expert felt that the dose to the Spinal Cord could be impacted by the weight loss and would have sought the advice of the physics department.

Case Eight was a patient receiving treatment for lung cancer. There was some change in and around the region of the PTV. All the participants and the Expert made the decision to treat, and would have got the medical or physics team to review it before the next fraction.

Case Nine was a patient receiving treatment for bladder cancer. There was some change in the bowel and rectum between the planning scan and the CBCT. All three participants commented on the gas in bowel and rectum. However, only Fathima felt that these changes were significant enough to prevent the patient from being treated. The Expert made a decision to treat the patient but would discuss the bowel and rectal status with the patient.

In total, the participants agreed with the expert on 31 (86%) occasions and disagreed on 5 (14%) occasions Figure 4.18.

FIGURE 4.18 FREQUENCY AGREEMENT AND DISAGREEMENT



4.4.2 Intuitive decisions

The literature highlighted the error prone nature of intuitive decisions (Pretz & Folse, 2011; Pat Croskerry, 2009b), so to address this analysis was carried out comparing the use of the intuitive process and the accuracy of the decision (Table 4.6)

The sample size in this study is insufficient to make any wider generalisations, but the table is worthy of comment as clearly shows that decision error is not linked to the intuitive process in this sample of participants. In the borderline cases, Tom and James made a different decision to the Expert, but as the Expert highlighted these as borderline cases they cannot be classed as true errors.

Non-intuitive decisions are highlighted with a grey box. Intuitive decisions are either green or yellow, with a green box indicating agreement between the participant and the expert and yellow box indicating a borderline decision, where the expert felt either a decision to treat or not treat may be appropriate.

TABLE 4.6 INTUITIVE DECISIONS

Name	Case one	Case two	Case three
Tom	Borderline	Agreement	Not intuitive
Nicole	Not intuitive	Not intuitive	Agreement
James	Borderline	Agreement	Not intuitive
David	Agreement	Agreement	Agreement
Lisa	Agreement	Agreement	Agreement
Hannah	Agreement	Agreement	Not intuitive

4.5 POST-OBSERVATION INTERVIEWS

4.5.1 Introduction

In this section, the key findings from the post-observation interviews are presented. The interviews were carried out in two stages. The first part involved a member checking stage where participants were asked to discuss the processes they followed during the image analysis process (Section 4.6). The second section involved a discussion around the factors that participants believed had an impact on their decisions and these are presented in Section 4.7.

Section 4.7 presents the findings in relation to the factors that impact on decision-making processes. Initial thematic analysis identified 36 sub-themes, which led to the development of seven main themes.

The themes observed during thematic analysis were then analysed further with the intention of developing a descriptive model of the factors that impact on the decision-making process. Sections 4.7.1 to 4.7.3 focus on the building of the descriptive model which has three themes: *The MDT, Experience* and *Training.* The final model is presented in Section 4.8.

4.6 THE DECISION-MAKING PROCESS

4.6.1 Introduction

This section presents the key themes that emerged from the member checking stage of the interview where participants watched the video recording s of their scenarios. They were asked to discuss the processes they followed during the image analysis stage of IGRT which relates to research questions 1 and 2. Five themes emerged from the analysis: *Set Sequence, Site Specific Clinical Priorities, Initial Gross Review, Decision to treat* and *Compromise.*

4.6.2 Set sequence

Most of the participants talked about following a set pattern, which always started with an automatic-match. Not everyone followed the same process, but participants seemed to have their own sequence. The comments from Hannah and James are typical of discussions from participants.

> *It's kind of a set process, so always run the auto-match first and look what the errors actually are, so his are all quite small I think and then generally just eyeball, is the contour okay, is the bony match good?* (Hannah)
>
> *I think that's probably down to the person that I was doing, who is sort of going back to my teaching and my initial experience of it……. So yes, tend to start on sagittal plane and then frontal plane after that. But it sort of varies a little bit depending on site and exactly what you are going to be looking at.* (James)
>
> *I think it's a very similar process. It is looking for the big changes first and then getting down to the finer details* (David)

4.6.3 Site specific clinical priorities

When discussing how they prioritised the clinical information on the images, a clear site-specific theme emerged. Participants discussed having set priorities for each anatomical site. In head and neck treatments where the tumour is often close to critical structures, the participants talked about the OARs being priority, whereas in images of the pelvis, the participants talked about the target volume being the priority.

> *Okay, okay. So, for head and neck for instance, your priority would be your spinal cord over your PTV coverage* (Sara)
>
> It depends on what we are treating…. we could look at a plan and think oh the dose is coming really close to the cord here (Becky)

When discussing the bladder:

> *For this one it is obviously making sure that the tumour is covered, because if that's not covered then there's no point in carrying on* (David)

4.6.4 Initial gross review

All the participants talked about carrying out a quick or gross review initially and then focusing on specific areas of interest. This typically involved quickly scrolling through the images and often all three planes (axial, sagittal and coronal)

> *I think I would always do a general overview first, a general kind of look around… Kind of look at the bigger picture then cone down to the minutiae.* (Sara)
>
> *I think it's very similar process. It is looking for the big changes first and then getting down to the finer details* (David)
>
> *You look at the images generally at first, just have a general look through, is it sensible, and then I suppose you look in more detail. So if it's a big change it's usually quite obvious from the start.* (Tom)

4.6.5 Decision to Treat

Nicole, David, Fathima and Rachel felt that they quickly made a decision about accepting treatment position and whether to allow treatment to progress.

> *I personally make a decision quite quickly*. (Nicole)
> *It is almost instant.* (David)
>
> *It's quite quickly really because you're doing an auto-match first and then you're quickly glancing through all the levels to make sure you're happy with that*. (Fathima)

> *Normally within the first few seconds, when you look at your coronal slice. Generally, I get a feel from the very beginning* (Rachel)

James made an interesting point in relation to what he thought he should do and what he actually did.

> *I think ideally, obviously you should do the full match, all the things mentioned before, you make an informed decision about it. I think realistically in your head you are forming an opinion as you are going through.* (James)

4.6.6 Compromise

The need to use clinical judgement and make compromise was also a feature of the decision-making process discussed by the participants. This was mainly apparent when talking about head and neck treatments.

> *Head and neck you wouldn't compromise on a brain stem, but say if part of the spine a bit further down, a bit further up was a bit wonky, you'd compromise that way*. (Lisa)
>
> *Yes, with head and necks particularly…. (*Hannah)
>
> *More with, probably most with the head and necks, because the head and necks are the ones that we review, rather than reviewing, we generally review at different levels* (Rachel)

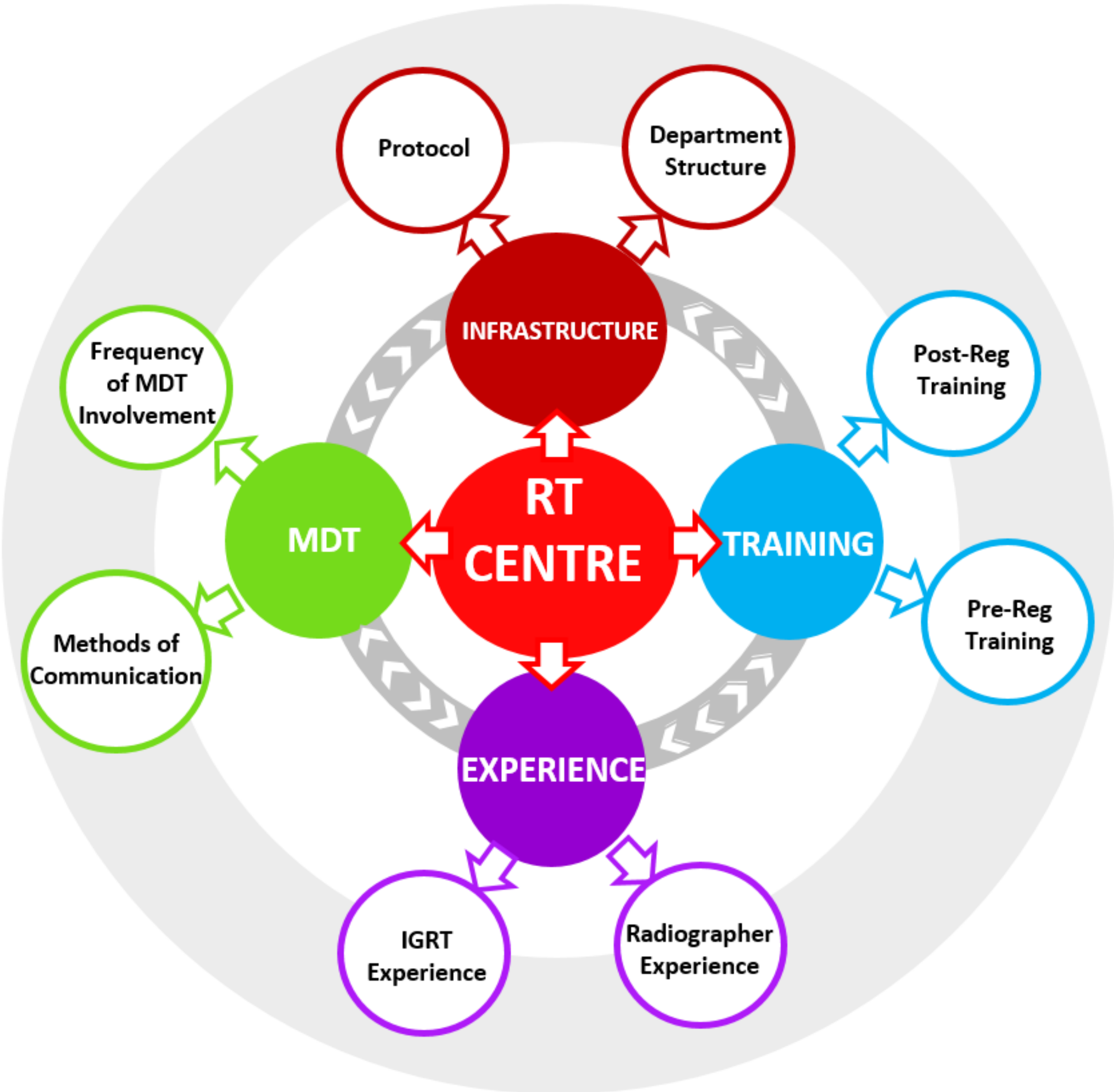
4.7 PARTICIPANTS' REFLECTIONS ON FACTORS THAT INFLUENCE THEIR DECISION-MAKING PROCESS

The following sections focus on research questions 3, 4 and 5 and describe the emerging themes and subthemes that were used to develop the final descriptive model that is presented in Figure 4.23

When carrying out the analysis, a key theme around the MDT emerged. This theme is not directly related to a specific research question, but the significance assigned to it by the participants means that it forms an essential part of the model.

Sections 4.7.1 to 4.7.3 will summarise the four main themes of the model, which are *The Multidisciplinary Team (MDT), Infrastructure, Training* and *Experience.* The sub-themes will be highlighted individually and presented in the context of their impact on the decision-making process. These are depicted in Figure 4.19.

FIGURE 4.19 THEMES AND SUB-THEMES



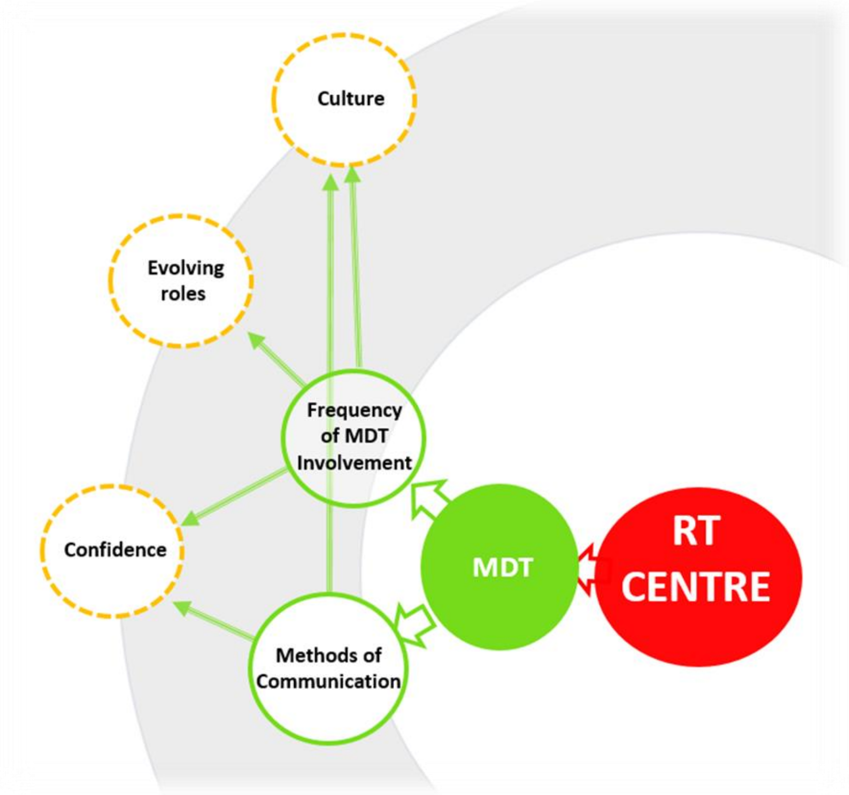
4.7.1 The Multi-Disciplinary Team

The role of the wider MDT formed a large part of the discussions in all the interviews. The function of the MDT varied significantly across the three centres as did the participants perceptions of the role of the MDT. The interactions between the MDT appear to impact on the decision-making of radiographers in several ways, as does the involvement of the MDT in the centre structure and training.

Sections 4.7.1.1 will present the two MDT sub-themes that emerged from the data, which were *Frequency of MDT Involvement* and *Methods of Communication*. Both themes were commonly discussed alongside each other, so they will be presented together in the same section to reflect the discussions in the interviews. The participants broadly discussed the MDT in terms of the medical team, the physics team and radiographer advanced practitioners/imaging radiographers, so this section is presented in the context of these three staff groups.

Section 4.7.1.2 explores the impact of the themes and sub-themes that emerged in Section 4.7.1.1, linking the differences to confidence and culture.

FIGURE 4.20 THE MULTI-DISCIPLINARY TEAM



4.7.1.1 Sub-Themes: Frequency of MDT Involvement and the methods of communication

All the participants discussed involving the physics and medical teams in the decision-making process. However, the frequency at which the wider MDT was involved and the methods of communicating and reviewing images varied across the three centres.

The participants in centre one spoke about their physics colleagues being involved in the decision-making process, but said that they do not typically come to the treatment set to review the patient.

> *But we regularly have that conversation, we regularly do it with physics as well and we'll regularly refer back to physics in terms of a plan assessment, as in if somebody has lost a load of weight or the PTV's shrunk, a massive shrink or whatever's changing the PTV coverage. We'd be asking physics to do a plan assessment, so much more than a look at the image, but what's it doing to the doses?* (Tom)

> Question: And what about the planning department or physics or, in terms of how often would they ever come and look at an image with you?
>
> *Not for a patient who's under treatment* (James)
>
> *Typically, if it's a live match we'd get our image review radiographers first, but we take the offline review images to physics and we will sit and discuss them. So, if they are involved in the process. I don't think I've ever had one for a live image. No reason why not but typically just the process here* (James)

In centre One, there were mixed views on the involvement of the medical team.

> Question: And do the doctors come down here too, into the department?
>
> *Yes, quite often if, well they do their clinics down here anyway, so we might, when they're having their clinic just take the stuff round and sit with them and look at the images and tell them what we think the problems are. Or if it's something we're really not happy with when we look at the image online, we might even get them down to have a look on the screen before we treat.* (Tom)
>
> *It depends on the setup and what we are seeing on the scan. I say a lot, all of our doctors are brilliant here, really good for communication and really happy to come down. So, if they are in the department we can just call them, email them, bleep them and they will pop down at some point, hopefully before the next fraction to review the scans with us to discuss the problems and see what is happening.* (James)

But then conversely, Sara said:

Medics don't look at images routinely.

On asking further questions it became apparent that the medical team are involved in the decision-making process regularly at this centre, but often review the images from their offices or clinic.

> *I mean it's got better because medics access to images has got better, so they can look in their offices, we can ring somebody up and say, 'can you have a look at this image' and that kind of thing and I think that's made the MDT conversation a lot better* (Tom)

All three centres have radiographers in imaging support roles, however centre one appeared to have a culture of using them more than the other centres in the routine decision-making process.

> *Also, if like with the lung one, if we think the tumour might have grown slightly, then we'll get the, first of all get the PI Rad [Portal Imaging Radiographer] to have a look* (Tom)

> *We have got an image review radiographer as well, typically superintendents but countless times I've phoned the office or gone to them and said I've got this, this is what I think, can I borrow you and try and get some more expertise into the online match* (James)

The physics and medical teams appeared to have a greater involvement in reviewing images on-set in centre two.

> *Yes, with all the patients we have, probably a couple of times a week you'll call them round and then sometimes for specific patients they will be round every day of that week because it is quite, you know quite complex, or a head and neck we tried to do something to fix their positions. They come back the next day to see if they are happy. It didn't work so then they are back the next day kind of thing. And then sometimes they come round and go, yes whatever, its fine.* (Lisa)

Centre two was the only centre to hold routine weekly site-specific meetings with the wider MDT.

The medical team also reviews patients routinely on-set.

> *Head and necks will definitely have… well physics have to agree all TC (Treatment Centre) changes with head and necks, so they come round at least twice minimum during their treatment and then if there were a lot of contour changes, particularly on the neck, the doctor would probably come round to say if they were happy with nodal coverage or not and they would be the one who would authorise a rescan* (Hannah)

The involvement of physics on the treatment set in centre three appears to be somewhere in the middle of the other two centres.

> When discussing the physics team: *They can either physically come to assess or they can pull up journal notes or they can, you can just speak to them over the phone and say 'look, this is so-and-so, this is the results, your tolerance at this level is blah, blah, blah, can we apply this?' and they'll either say yes or no and, quite often, what they might do is they might say 'yes, go ahead' or 'no' but if they say 'yes, go ahead' then they will review it prior to the fraction and you know, 'do we need to SSE' [Systematic Setup Error*]* (Fathima)

* Systematic Setup Error represents the mean error over a series of treatments. This is typically calculated with a minimum of three sets of data.

So, there's a protocol here that, there's a couple of people that you refer to first, so that everybody's not kind of going to the doctors separately. And the clinicians review lung Cone Beam CTs once a week anyway. So, for any of their patients they have a little kind of mini clinics with one of the radiographers to identify, so each person has a, like so and so has Dr whatever his name is, his clinic. And they'll sit down and look at the Cone Beam CTs for that week. (Rachel)

4.7.1.2 Impact of the MDT on the decision-making process.

The closer relationships at centre two seems to have resulted in a greater *confidence* amongst the participants in this centre. All of them commented on the benefits of having spent time discussing cases with their colleagues. Participants in centre one did not mention the MDT when discussing confidence, suggesting that the MDT has not had an impact on this.

Been reviewing now for a while so you tend to know the ones that physics will accept and the doctors will be happy with, and then just get them to come round afterwards. But still, especially with the head and necks, usually about half way through you get someone to come round to see them at least. (Lisa)

David and Adam in centre two talked about relying on physics less now than they did in the past. David had quite strong views on the use of the wider MDT and commented on a *culture* of over-reliance at times. It is worth noting that David is very experienced.

Me personally it is, I don't get them involved as much but I think as a department we rely on them a lot more. All depends on the individual really. And I've noticed that, I mentioned it before that there are other people that get MDT involved a lot more than others, just because it comes down to making a decision. I have been in other meetings as well where they said we are being called for an awful lot of things we don't need to be called for (David)

But if they are unsure then it is always easier to say I'll get someone else to make that decision. (David)

Lisa also talked about the creation of a *culture* where staff won't ask for assistance.

I think there is some staff that do get quite scared to ask for help (Lisa)

Hannah also talked around a *culture* of getting the MDT involved because it was the process rather than a need.

Sometimes you call a doctor round and not put words into their mouths but you show them what you've got and almost what needs to be done, you just need their authorisation to do things, (Hannah)

Ahmed in centre three talked about very similar experiences to David.

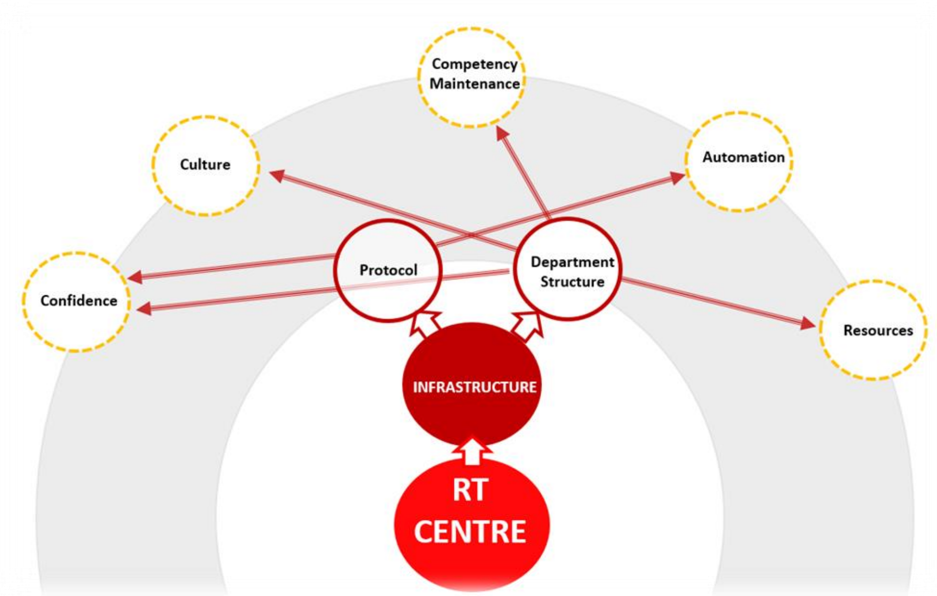
Before physics had a huge kind of role in the head and neck matching, we used to always have them there whereas now it's more rad led because we have that process. (Ahmed)

…initially people were just emailing the doctors over things that maybe weren't relevant, so to kind of filter that out they have assigned certain people to kind of check it first and then yes, get in touch with the doctor and know that's fine, so the thing is to alleviate that problem because obviously if you are a clinician and people are emailing you don't need to. (Ahmed)

4.7.2 Infrastructure

The infrastructure that underpins the IGRT service in each centre was also noticeably different across case centres. Two key themes emerged from the interviews in relation to infrastructure. These were *Protocols and Department Structure*.

FIGURE 4.21 INFRASTRUCTURE



4.7.2.1 Sub-Theme: Protocols

The role of protocols formed a significant part of the discussion with some of the participants. The participants identified the existence of set tolerances for each site and how they were used to guide radiographers during the decision-making process. The following phrases are typical of what was discussed.

> *There's a 5mm tolerance for the gynae patient* (Tom)
>
> *because your tolerances are so tight [in head and neck patients]* (Tom3)

The use of auto-matching functions is part of the imaging protocols in all the centres and formed a large part of the discussion for several participants. All the centres use the automatic-matching function as the first step in the image review process. Participants in centres two and three discussed a move to using the auto-match function as a safe or standard match to reduce variability across staff.

> *I was in one of the imaging meetings a while back and they were wanting to standardise the actual matching, because when they try and audit things and say well is this good, is this bad, then if you are relying on ten radiographers all doing their own match, they will all match in a slightly different way. whereas if you standardise it so it is all an automatic match you've got a lot better data to say that yes this is a good technique, this is a bad technique, this is the results so we can make any changes or do things from there. It is quite good in that respect but then some people do tweak it less than 3mm and some people don't so you've still got the ...* (David)
>
> *And really the automatic match is the safe match. So, if that does what you need it to do then you're not going to be changing things that are going to cause potentially unthought-of processes.* (Rachel)

The over reliance of this technique was also highlighted by a few participants and is summed up with David' comments.

> *Yes, I think it is more that way rather than the other way. I think because we are so protocol driven now it is breeding a less confident radiographer.* (David)

4.7.2.2 Sub-Theme: Department Structure

None of the three centres have Cone Beam Computerised Tomography (CBCT) on all their treatment machines and it is typical for radiographers to rotate periodically from one machine to another. It is also common for centres to have treatment machines that only treat specific disease sites, limiting the exposure of some radiographers to a smaller range of anatomical systems to review. The majority of the participants felt that this was problematic and raised issues around the maintenance of competence and confidence on some disease sites.

> *I mean there are some machines that are more site specific just because they're not dual energy, for instance. So, if you have a single energy machine you're never going to be treating patients that need a higher energy and things like that. The other limitation is the actual features that the machine has. So, you might never treat head and necks on a certain machine because it's not able to, it's old and it's not able to cope with the physics and the planning part as treatments have advanced.* (Liz)

> *But then we have a couple of machines that don't even have XVI* so if you get a rotation on there, I don't believe that's 5 months you haven't seen an Xvi scan for so that can, you know make a difference when you come back again. Haven't seen one in a while, I might call you a bit this morning, just until you feel confident again and remember everything* (Lisa)

> *And also because I am more rusty on head and necks……. Because I don't do them day in, day out, I didn't feel as confident* (Ahmed)

> *So as a radiographer you might not go on those machines for a year (*Sara)

> *Yes, because our band 7 rotations are generally 12 months. So as a band 7 you're the expert in what you're doing but actually then after 12 months you go somewhere else, treating a completely different area, and with the best will in the world, as much as you try and maintain, there's no rigid maintenance for competency.* (Ahmed)

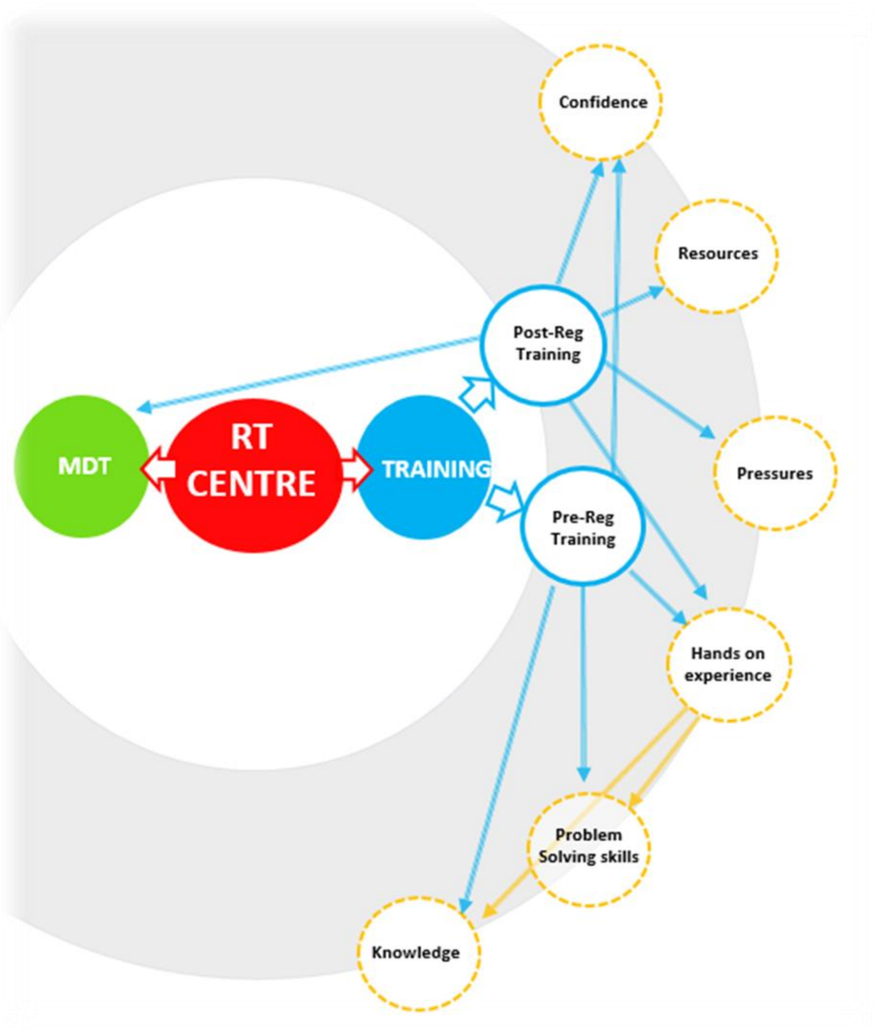
> *Lungs I probably review, one every three months or something like that, because I'm not on a machine that treats lungs. So, I occasionally get called to cover somewhere else. So, I am not as familiar as looking at lungs*. (Rachel)

*XVI is a local term used to describe the imaging software.

4.7.3 Training

The training on IGRT varied widely across the participants. Many of the participants trained as a radiographer before IGRT formed part of the pre-registration syllabus, so they were not able to discuss the impact of pre-registration training on their decision-making. Similarly, several of the participants were the first people in their centres to do IGRT and so had limited formal training. The following sections will focus on the participants' experiences and their perceptions of what makes good training and assessment. Section 4.7.3.1 will present the participants' views on pre-registration training and Section 4.7.3.2 their thoughts on post-registration training.

FIGURE 4.22 TRAINING



4.7.3.1 Sub-Theme: Pre-registration Training

Participants from all centres talked about the lack of image analysis training they received and what they perceive to be a lack of training in the current newly qualified workforce.

> *I didn't look at many CT scans as a student in Uni, so I didn't really you know have a clue. I knew anatomy and stuff but we didn't look at CT scans.* (Lisa)
>
> *I think they need to learn imaging right from the beginning because we can't do our job without imaging.* (Tom)
>
> *A lot of the newly qualified's have not looked at any images at all until they start and so I think it kind of hinders them in a way because they're not comfortable…* (Hannah)
>
> *I think quite a lot of them have asked like newly qualified staff can, you know, have a look where your sinus processes are or your pedicles and they'll go like 'oh what's that'* (Tom)

All the participants agreed on the importance of students being exposed to IGRT and image interpretation in the centre as well as part of the academic syllabus.

> *But I think it's essential because this is actually routine bread and butter work now isn't it?* (Sara)
>
> *It is just, it is no longer a weekly image and something you can get away with sort of learning as you go. It is going to be, this is part of that person's daily treatment. For me I think we need to get a lot more involved in the training.* (James)

There were however mixed views on when and how pre-registration training should be carried out.

Opinions ranged from introducing the concepts in year one:

> *I think they should be starting in year 1, to a degree because as with any aspect of training, we try and build up and develop experiences. For somebody dropping a third year that is 2 weeks off qualification and say right there's a lung CBCT, go and match it. It's like they have sort of missed out on this experience they could have had.* (James)

Through to the third year:

> *Probably don't think until the third year because I think there's a lot you need to know before you start and a lot of experience that they will have had on the machines to help them. But I do think it is good to have seen it and kind of had a play round.* (Nicole)

> *I think by the time, probably by the time they get to third year and they're very much putting everything they've learnt, they've learnt the basis of most things. They're doing a lot of practical in-department things that they're seeing day to day. I think they should really be taught at least at that stage* (Tom2)

It was widely felt that a "hands on" practical element to training was essential to enable students to develop the skills they need:

> *So, seeing it there and then, putting it into reality, whereas on paper it doesn't always marry up when you actually get into the clinical setting.* (David)

> *But that's the kind of thing that we do on a day-to-day basis and we expect that to come… I suppose it's like your driving test again, you learn the kind of basics of operating a car but the kind of real world manoeuvrabilities and what you do about an accident and that kind of thing, you do when you've passed and I think it's the same analogy with image analysis, we want people who've got sound anatomy, who can probably use the tools that… and again it's different software and things, but use some basic tools and know what to look at and have a basic understanding of the basic body sites and what factors influence them* (Sara)

> *Yes, I think a lot of it, I agree certainly can be taught in the classroom with offline images because we can always reset the images back. Say if this was the online match, this was the problem that we have then seen and you can develop a discussion about, you know all the time in the world with no pressure on you. You know versus what we are saying and we can get students to match up, match offline quite happily because you have a department, can do it at Hallam, wherever it is sort of thing*. (James)

James also made an interesting comment about the fidelity of training.

> *What you can't teach is being under pressure*

4.7.3.2 Sub-Theme: Post-registration Training

Participants were asked to discuss the training they received and their thoughts around what makes good training.

There was a consensus across the participants that experiential learning was a key element to their image analysis skills development.

> *I think that's all valuable stuff but a lot of it is kind of working with staff every day, making those decisions at the coal face, you can't simulate that can you?* (Sara)

When asked about their confidence after training Hannah, Tom and Liz said

> *I think so, because I'd already been on an XVI unit quite a lot anyway, so I was already reviewing images unofficially, with like someone next to me. So… yes. I think if you're just thrown in but without seeing many XVI scans you might not feel quite as confident but I'd already had experience in that area*. (Hannah)

> *It's quite daunting obviously at first but I think, for me anyway learning on the job is the most effective way.* (Tom)

> *I almost think the training needs to be as short as possible and safe as possible, but as short as possible to get them out there doing it and saying right, yes, this is giving them examples of what can happen.* (David)

> *Yes. But that is because I'd spent a lot of time not under pressure of having somebody look over my shoulder, to just sort of look at things and familiarise myself with the way things should be.* (Liz)

Centre two and three have workbook/scenario based training package available to staff. These are used in centre two as a method of assessment.

> *It was just case studies, just got some case studies to do, I think it was ten. And then you just got signed off, yes you can review those. So that way it is good because it is in your mind and you are not having to do it, you know do one day or one case discussion and then two weeks later* (David)

> *Like we looked through patients with you, we had piles and piles and piles of them for every area. Then we go through, fill case studies in, hand them in, they come back to us the next day with what's right and what's wrong, look through them and do the next area. So, we had to do that every afternoon for a week.* (Lisa)

The training package in centre three seemed to be less developed and utilised.

> *You could have a whole lot of different types of patients, because we have got like spreadsheets with all the different patients that we've treated for the lungs, the bladders, stomach, all different ones, so you could like get a good kind of selection of different things to do. So, I personally think that that would be the best way of training, but then obviously that's a lot of work to create those databases.* (Tom)

Tom in centre one talked about the need for such a package

> *But then I think after that, maybe it would be good to have a sort of package where you do sit down with someone who's very experienced looking at images, and just have a look at some practice ones. Maybe look at one for each site or a few and then once you're comfortable. You could even be a sort of third person looking at the image online, before you progress to just working as a two, assessing the images*. (Tom)

As someone who is involved in training, Tom felt that different staff have different requirements.

> *But I don't, we just can't really come up with a solution to get people signed up quickly and the thing is you can go through the theory, you can practise, but actually one person might only need to do X amount of logs to be really confident, and somebody else might need to do five times as many* (Tom)

> *And some people really struggle and it is quite frustrating because sometimes those people need an awful lot of time and energy to get signed off, but even when they are signed off they are not necessarily you know, well they are signed off as competent, but they would be quite limited in their competency.* (Tom)

All the participants that are involved in training spoke about the difficulties of getting staff trained with the available resources.

The Elekta set-up (centre two) does not allow staff to review images remotely and so staff have to train on the live treatment units, using the software between patients.

> *Whereas we need, I think Elekta are meant to be making it so we can start reviewing them outside of the room, just haven't done it yet. But apparently it is in the next upgrade. So that would make training easier then because you could sit and do it when you are not on set. You could do a bit of work, do that, do a bit of work but at the moment you've got to wait for a PC to be free.* (Lisa)

> *We kick anyone off during their training to treat patients and then the linacis broken so they can't use the XVI there so then they are stuck, they don't have a PC to play on.* (Lisa)

> *Now the problem with that is that a lot of the time it, you may not feel able to take yourself away from that treatment set. So,*

and it has actually taken me quite a long time to go through that process, just because you feel like you're busy and don't want to take yourself away from your colleagues, or the people that you want to sit down with, obviously have a lot of other responsibilities and aren't able to match up their time with yours. So that's the, that's difficult, yes. (Liz)

I think it can. I think it's harder now because of staffing restraints on machines. To get someone off to do the training, to do it as I, especially as I did it, there wouldn't be the time. We had much more staff when I did it. And even now just to get someone off to do the basic level is difficult (Tom).

As with the MDT theme, there was a variation in the participant's perceptions of the involvement of the wider MDT in their training and how it impacted on their development.

When talking about the medical team being involved in her development¸ Nicole said

And they give you the reasons why and that gives you a bit more confidence in what you are doing.

James (centre one) felt he would benefit from having more MDT involvement in training.

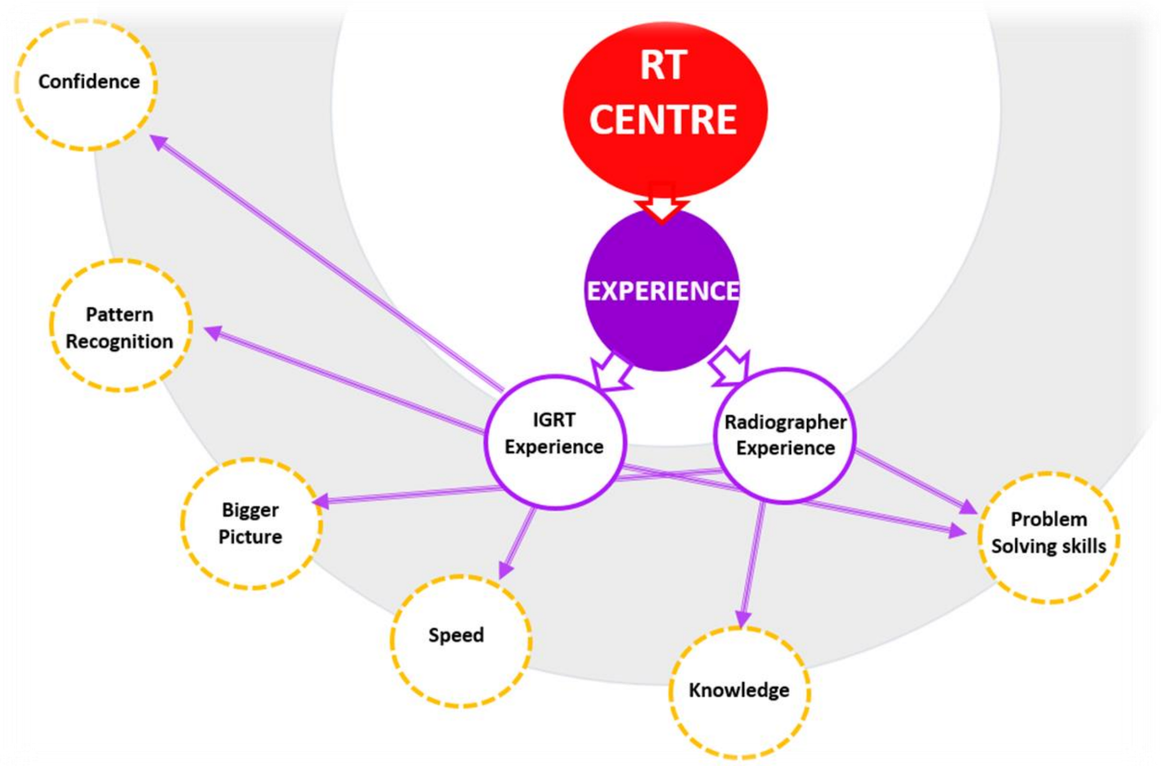
But I'd be more than happy sitting in and listening to a radiologist, a consultant, a physics person saying okay we've got this and this is how we've achieved it. Online, what you need to be looking for is a, b and c. I think there's still a lot of learning that we can get from it. (James)

Personally, I'd be interested to know what other centres did. You know like you are talking to different staff groups and obviously it is going to come out in your conclusions. But whether immediately we should be doing either something, you know whether it is meetings or sort of MDT type discussions (James)

4.7.4 Experience

Participants were asked to talk about their perceptions of how experience as a radiographer and experience specifically doing image analysis influences their decision-making practices.

FIGURE 4.23 EXPERIENCE



4.7.4.1 Sub-Theme: Experience as a radiographer

There were varying views on the impact of radiographer experience on the image analysis process. Sara. James, Lisa and Tom spoke about the importance of having experience as a radiographer before being able to do image analysis and the impact it has on their decision-making abilities.

> *I wouldn't expect a Band 5 radiographer to be making decisions on their own.* (Sara)
>
> *They could match an image and say, 'this is out of tolerance' and that's reasonably easy to do with imaging training. What's not easy to do is to say, 'well why is this happening and what do we do about it next?' that's much more about general experience.* (Sara)

As opposed to just looking at two visual images as a black and white thing. I sometimes see in radiographers who are less experienced, they don't understand the factors that could have caused those things. (Sara)

I think it was just on 2 years when I got mine and I felt like I was ready then. Then I'd probably say, probably 8 to 12 months. It is knowing what you can do to problem-solve it. So just knowledge base really. (Lisa)

because you need to know what the problems might be, if it's the shoulders. Instead of just going oh it's not right, you need to think oh I saw this one put the shoulders up once. You only learn by seeing what your Band 6s do from when you started. So as much as I thought Band 5s should be allowed to train as a level 2, I think they should have some time on set before they do actually undertake it so they have seen all the scenarios. And they can think of stuff to do themselves. (Lisa)

I think it possibly helps by bringing in aspects of that particular patient into what you're seeing on the screen. (James)

I do think a lot of experience, like of being just a general radiographer makes a big difference because you know what causes those problems, what you can do. It's one thing to be able to spot it on an image and you can have all the training in the world to be able to spot that on the image, see what's different but if you don't know how to then put that in a "what can I do", and I think a lot of that comes from being an experienced radiographer itself. (Tom)

Conversely, Liz, Fathima, Rachel, Ahmed and David felt experience as a radiographer had less influence than other attributes.

[image analysis] should be competency based rather than band based, because you do have, even though people are different levels, doesn't necessarily mean… they're either comfortable doing it or they're happy to do it. There are some radiographers that, you know, don't want to take the responsibility… that extra responsibility of making a judgement call that can be so… how should it be? (Fathima)

Presuming that all the fine details like, you understand the software and you understand the machine and all that sort of stuff is out of the way, [staff should do image analysis] almost immediately. (Liz)

During our initial training and I think that's where some of the ones who are newly qualified are much better because they are much more familiar with that. (Sara)

No, not at all. No, I think a lot of imaging people have an aptitude for. So, I think generally people can either see things and observe things or people struggle. So, I think most people

> *have a, are perfectly capable of learning to do it and I think there's people who've been qualified 20 years who just can't get their heads around it, no matter how hard they try.* (Rachel)

> *Well that's a bit of a difficult one because, just because you've got lots of years of experience as a radiographer doesn't mean that the imaging comes naturally for you.* (Ahmed)

> *But again, it comes down to individuals. Someone you can train for weeks and weeks and they still don't quite get it. Whereas someone you can just tell something, and they've got it instantly and just happy to go ahead and run with it.* (David)

4.7.4.2 Sub-Theme: Experience of Image Analysis

Unlike general radiographer experience, there was agreement across all the participants that experience of image analysis influences their current practice. Participants spoke about image analysis experience affecting *General problem solving, Pattern recognition, Speed* and *Confidence.*

Tom and Hannah felt that as they get more experienced they are able to deal with more *problems* that occur.

> *I think I'm more able to cope with problems. I think generally, my abilities probably have improved slightly, but I think I'm better at overcoming problems and knowing why problems arise and knowing who to consult if there is a problem. I suppose, you get quicker and I suppose probably more confident. (Tom)*

> *When I was first signed off I was calling physics round a lot because you're never fully happy to make that decision…. If you've seen something before, even if it was two years ago then you're much more… if you've seen it before you're much more comfortable making that decision again. (Hannah)*

Several participants including Hannah, Rachel and Sara spoke about how they think back to past experiences when making clinical decisions. The experience they have gives them the ability to link previous cases to the current case; a form of *pattern recognition*.

> *But the tumour itself, I'd be happy, the reason I'd be happy treating is because it is one that I've seen similar on previous ones.* (Hannah)

> *So, if it happens again, if I see something and think oh that looks a bit like the patient who had pneumonia. So yes, again it's a building up of experience, a knowledge of things that have happened in the past and what happened and why they are like they are.* (Rachel)

> *Yes because, you know, more… you develop that bank of knowledge about what you expect to see but also, you're more alert to things you're not expecting to see.* (Sara)

Most of the participants commented that experience increases the *speed* at which they make decisions.

> *Yes, definitely quicker. We used to book patients out for half hour treatments for cone beam. They should be in a 20-minute slot. On a routine scan we can do a cone beam and treatment in 12-14 minutes so speed has definitely improved. (James)*

> *I am a lot quicker. So, I know that I can be quick enough to check if there's glaring errors. (Lisa)*

There was also a clear link between experience and *Confidence.*

> *going back to confidence, you know, I've done a lot of cone beam scans, I've had a lot of placements so I am happy with what I am doing. (David)*

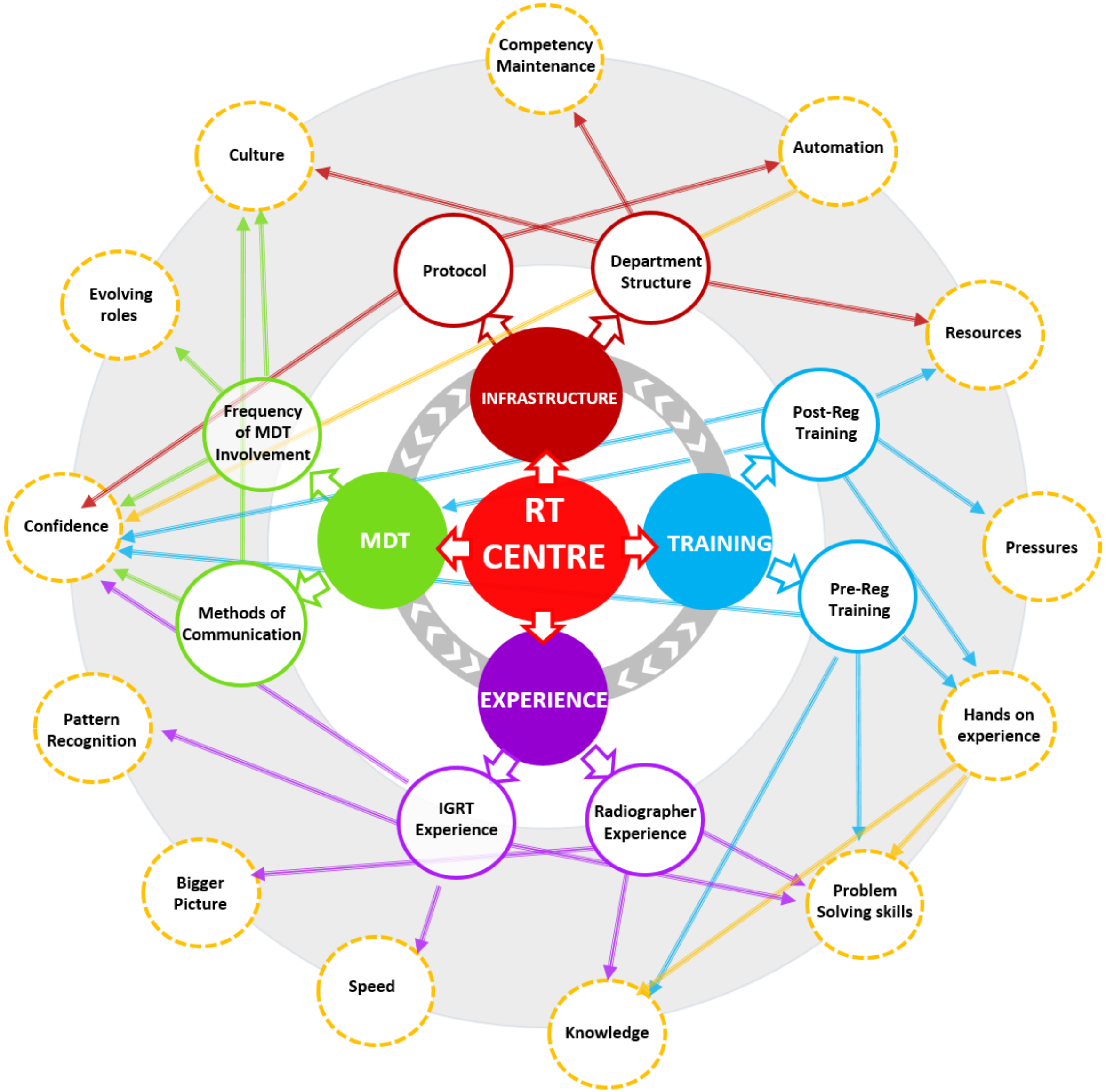
> *I used to be a bit, is this right, is this right, even though you've passed, no one is holding your hand any more so be like if I did something wrong. Whereas now I am a lot more confident in myself and that, and I am confident to say if I need physics or not as well, or confident to call somebody else. (Lisa)*

> *I have confidence in what I'm trying to achieve, I think maybe it's deviating from protocols a little bit more than anything else.* (Ahmed)

4.8 THE DESCRIPTIVE MODEL

A model of the facilitators, enablers and influencing characteristics that determine the decision-making process in the sample studied is proposed, and is based on the participants' reflective accounts of their own practice and the think aloud observational analysis (Figure 4.23). At the heart of the model is the Radiotherapy Department; this was the largest factor that influenced the decision-making process. The inner ring has four themes: *Infrastructure, Training, Experience* and *MDT*. These themes interact with each other and influence how radiographers make decisions and is represented by the inner band of arrows. The two outer rings show how the sub-themes: *Protocol, Department Structure, Post-Reg Training, Pre-Reg Training, Radiographer Experience, Image Analysis Experience, Methods of Communication* and *Frequency of MDT Involvement* interact with the 13 elements of decision-making which are: *Culture, Competency Maintenance, Automation, Resources, Pressures, Knowledge, Hands on experience, Problem Solving skills, Speed, Bigger Picture, Pattern Recognition, Confidence and Evolving roles.*

FIGURE 4.24 A DESCRIPTIVE MODEL OF THE FACTORS THAT IMPACT OF DECISION-MAKING ACROSS THE THREE CENTRES



4.8 THE THINK-ALOUD EXPERIENCE

All the participants commented on their experience of the think-aloud process. The participants had a mixed experience of the think-aloud process. Most of the participants felt that the process of recording did not impact on their decision-making.

> *I think it is, obviously teaching is a big aspect of radiotherapy as well so whether it is the scan or any other part of a technique you are quite often trying to talk things through with younger staff, sorry less experienced staff or students. So just trying to talk about what you are doing is sort of part of what we do anyway. So yes, we forget about the tape. Personally, it didn't distract me.* (David)

A number of participants across all three centres commented that thinking aloud was part of their routine clinical practice and that they were used to doing it.

> *And when I'm working with other people as well, that I'm not used to working with, I ask them to talk me through what they're doing* (Fathima)
>
> *So quite often you're working with someone who's junior or learning or isn't, yes, isn't signed off to do it. So as much as they don't have to take responsibility for what they're matching, I'll always talk, I always talk through exactly what I'm doing so that they know, can either question what I've said, that they agree or disagree, or I'm explaining to them my thought process for their future learning* (Rachel)

When asked about whether they thought the process of thinking aloud changed what they would have done in the clinical environment they all said that they didn't think it did. Tom did make the following comment though:

> *I think I would still follow the same thought processes, I'd still look out for the same things, with the PTV coverage, the weight loss and things like that. But it's just a more pressured environment, yes.*

Three participants commented that it felt a little unnatural at first, but soon forgot that they were being recorded.

> I found it a bit awkward at first, but once you got into it, it was fine and it was quite useful to sort of *make you actually think about how you do process things*. (Tom)
>
> *I think I felt fine doing the second and third one*. (Fathima)

There were a small number of comments in relation to a negative experience. These were predominantly seen in centre one.

> *I think it's something that feels uncomfortable…* (Sara)

> *I think it's something that doesn't come natural* (Nicole)

4.9 TRIANGULATION OF DATA

The guidance of Farmer et al. (2006) was used to generate a process of triangulation. Their article is based on work by The Canadian Heart Health Dissemination Project (Elliott et al., 2003). The process they advocate has two steps (Farmer et al., 2006):

1. *Sorting the* data from each of the two datasets to create a unified list that identified the key themes discussed in each dataset.
2. *Convergence coding* is then carried out whereby the findings are compared to determine the degree of convergence

The coding system uses four codes: *Agreement, Partial agreement, Silence and Dissonance* to describe how the findings of the four stages of analysis converge (Table 4.7).

TABLE 4.7 CONVERGENCE CODES (ADAPTED FROM FARMER ET AL., 2006, P.383)

Code	Description
Agreement	There is full agreement between the sets of results on both elements of comparison (e.g. meaning and prominence are the same, provincial coverage and specific examples provided are the same).
Partial agreement	There is agreement on one but not both components (e.g., the meaning or prominence of themes is the same, provincial coverage or specific examples provided are the same).
Silence	One set of results covers the theme or example, whereas the other set of results is silent on the theme or example.
Dissonance	There is disagreement between the sets of results on both elements of comparison (e.g., meaning and prominence are different; provincial coverage and specific examples provided are different).

The five themes highlighted in the results section were: 1. *Therapeutic radiographers use a set sequence, 2. Automation is a significant part of the process, 3. Image manipulation is a significant part of the process, 4. The target volume is given greater priority then the organs at risk* and *5. Radiographers use intuition during decision making.*

The first stage of the process involved placing the theme statements in the first column of the table. A column was then created for each of the stages of analysis. *Stage 1: Referring Phrase Analysis, Stage 2 Relationship between Referring Phrase Analysis* and *Assertional Analysis, Stage 3 Scrip Analysis* and *final decision* and *Stage 4 Interview.*

The triangulation process involves evaluating each of the theme statements in relation to each stage of the analysis to determine if the statement and method of analysis are in *Agreement, Partial agreement, Silence* or *Dissonance (Disagreement)* as described in Table 4.7.

To explain the process, the first theme statement *Therapeutic radiographers use a set sequence* is described in detail.

Stage 1: Referring Phrase Analysis. This stage of the analysis did not seek to investigate sequence and so there is no reference to sequence in this section of the results. The convergence code is therefore *Silence.*

Stage 2: Relationship between Referring Phrase Analysis (PRA) and Assertional Analysis (AA). During this stage of the analysis, the results demonstrated that the relationships between the RPA concepts and the AA concepts did not vary significantly from centre to centre. Although this stage of the analysis did not focus directly on the sequence of processes used by TRs, it does demonstrate consistency of broader concepts in decision-making. A convergence code of *Partial Agreement* was allocated.

Stage 3: Script Analysis (SA) and final decision. This was the stage of the analysis that focused on the decision-making process. Two prominent models were identified, a *linear process* and *linear repeating process*. These use of these two models demonstrates that TRs routinely use a set sequence when making clinical decision. A convergence code of *Agreement* was allocated.

Stage 4 Interview. During the interviews, all of the participants talked about using a set process when making decisions during the IGRT process. This was typically linked to the anatomical site that was being treated. A convergence code of *Agreement* was allocated.

The results of the triangulation process are presented in Table 4.8 and are discussed in Sections 4.9.1 to 4.9.4.

TABLE 4.8 TRIANGULATION OF DATA. BLUE ITALIC INDICATES CONVERGENCE CODING

Theme	**Stage 1** **Referring Phrase Analysis** **(RPA)**	**Stage 2** **Relationship between Referring Phrase Analysis (RPA) and Assertional Analysis (AA)**	**Stage 3** **Script Analysis (SA) and** **final decision**	**Stage 4** **Interview**
Therapeutic radiographers use a set sequence	*Silence*	Very little deviation in the relationships in the AA analysis *Partial Agreement*	A linear process and linear repeating process were very prominent. *Agreement*	All participants talked about a set process. Typically linked to the anatomical site that was being treated. *Agreement*
Automation is a significant part of the process	Automation a key concept, particularly in centre 2. *Partial Agreement* Not a key concept in centre one and limited in centre three *Dissidents*	*Silence*	Featured on all cases, typically in the first three phrases. *Agreement*	All participants stated that an auto-match was a key part of the process. *Agreement* Some discussion on improvement in consistence of decision. *Partial Agreement* Concern over de-skilling of staff. *Partial Agreement*

Image manipulation is a significant part of the process	Highest frequency concept in centres one and three. *Agreement* Lower frequency concept in in centre two. *Partial Agreement*	Strong relationship between AA *Cause-and-effect* and *Significance* and RPA *Software manipulation* *Agreement*	Low frequency of image optimisation in centre one. High incidences of optimisation in centres one and three. *Partial Agreement*	Participants discussed their preferred image settings *Partial Agreement*
The target volume is given greater priority then the organs at risk.	Target volume was higher frequency than normal structures *Agreement*	No relationship between AA *Significance* or *evaluate* and RPA *normal structures* *Agreement* Strong relationship between AA *Evaluate* and RPA *Target Volume* *Agreement* Relationship between AA *stating facts* and RPA *stating facts* (rather than *evaluate*) *Agreement*	*Silence*	Little discussion of OAR other than the spinal cord. Participants felt strongly about the importance of not overdosing the spinal cord. *Partial Agreement*

Radiographers use intuition during decision making	Gross check featured as a key RPA theme *Partial Agreement*	*Silence*	. Intuitive model used by six participants. Mixed in experience, and role. So cannot clearly be linked to experience. *Agreement* Difficult to determine what is intuition based SA *Partial Agreement* Intuitive decisions were correct *Agreement*	. There were comments about how some people pick it up quickly and others don't. *Partial Agreement* The majority of the participants felt they had a feel for the outcome of the analysis early on in the decision-making process. *Agreement* Fatima and Rachel said they used intuition but the SA analysis does not support this. *Disagreement*

4.9.1 Radiographers use a set sequence

Stage 3 analysis indicated that the linear repeating process was very prominent in the data, which supports the comments in Stage 4, with all participants commenting that they used site specific processes. The purpose of Stage 1 analysis was not related to the sequence of decision-making processes and a convergence code of silence was allocated. Similarly, Stage 2 analysis does not focus on the sequence of decision-making processes.

The triangulation of this theme is therefore partially supportive of the concept that TRs commonly use a set sequence of decision-making processes during image review.

4.9.2 Automation is a significant part of the process

Automation was evident in all cases during Stage 3 analysis. Stage 4 highlighted some disagreement across the participants. All of them discussed the role of automation and it was clearly a feature of their decision-making processes. What was not clear was the benefits automation brought to the decision-making process. When considering the frequency of automation in Phase 1, it was not a prominent theme in centres one and three. The qualitative nature of the study must however be considered when analysing these findings as frequency is not necessarily an indicator of importance.

The triangulation of this theme highlights the significance of automation in the image review process.

4.9.3 Image manipulation is a significant part of the process

Stage 1 and 2 analysis emphasised the importance of image manipulation in the decision-making process, particularly in centres one and three. Similar findings were reported after Stage 3 analysis, with participants from centres one and three being observed to manipulate the images regularly during the image review process. Image manipulation was not discussed in any detail during Stage 4 beyond the participants highlighting their preferred settings on the software.

Triangulation on image manipulation suggests that TRs regularly optimised the images they reviewed. This was particularly evident in the Varian Centres (one and three). The lack of discussion in the interviews may be related to the sub-conscious nature of this optimisation which is imbedded into their practice.

4.9.4 The target volume is given greater priority then the organs at risk

Stages 1 and 2 of the analysis showed agreement that the target volume is given greater priority than the organs at risk in terms of the frequency it is stated in the review process. Similarly, Stage 2 demonstrated that there was a strong relationship between the AA concept *Evaluate* and RPA concept *Target Volume.* There was no relationship between AA *Significance* or *Evaluate* and RPA concept *Normal Structures*. Stage 3 of the analysis focused on cognitive processes and so was not able to investigate this theme. During the interviews in Stage 4, there was little discussion on the importance of organ at risk sparing other than in the head and neck region, where the spinal cord was seen to be of high importance.

The triangulation of this theme is suggestive of the concept that more priority is given to the target volume that organs at risk in all of the observed treatment sites other than the head and neck region.

4.9.5 Radiographers use intuition during decision making

Although intuition could not be directly investigated in Stage 1 of the analysis, a *Gross Check* was a notable theme, which has some links to pattern recognition and therefore intuition. The intuitive model resulted from the Stage 3 analysis, but it should be highlighted that it was difficult to determine if a purely intuitive process was used in some cases. During Stage 4, the majority of the participants felt they had a feel for the outcome of the analysis early on in the decision-making process, so were using intuitive processes. The comments by Fatima and Rachel highlight the difficulty in determining an intuitive decision in Stage 3.

Triangulation has highlighted the role of intuition in the decision-making process during the image review process. What is interesting is the disagreement between what was observed and what the participants felt they did in certain scenarios.

CHAPTER 5: DISCUSSION

5.1 INTRODUCTION

This programme of research set out to investigate the clinical decision-making processes used by therapeutic radiographers when using Image Guided Radiotherapy.

It sought to answer the following research questions:

In relation to clinical decision-making based on 3D Cone Beam CT imaging during radiotherapy:

1 - What decision-making processes do therapeutic radiographers utilise while making clinical decisions?

2 - How do therapeutic radiographers prioritise the clinical factors observed during Image Guided Radiotherapy?

3 - How does clinical experience as a therapeutic radiographer influence the decision-making process?

4 – How does experience with Image Guided Radiotherapy influence the decision-making process?

5 – Do any other factors impact on the clinical decisions made by therapeutic radiographers?

To fully address this aim and research questions, a case study approach was adopted using think-aloud observations and follow up interviews.

5.2 THE DECISION-MAKING PROCESS

The analysed observational data was triangulated with the analysed interview data to investigate the decision-making processes used by the participants.

Several processes emerged from the analysis, the basis for all of which was the *simple linear model.* During this process, participants would make a correction and describe the situation very quickly, followed by an explanation and then optimisation. Participants would then evaluate the image before making a final decision: the time spent evaluating the image varied from participant to participant. Where the *repeating linear model* was observed, this process recurred with very little deviation in the order of the repetition. It should be noted that the data was coded in relation to phrases rather than time and so, although the two are closely linked, there was some variation in the length of phrases, varying from one or two words up to around 10. The key factor in identifying the use of the simple and repeating linear models over the *intuitive process* was that the decision to treat or not was only made at the end of the process. These were the most commonly seen processes in the observations and were observed on 13 occasions in all participants except James.

The final process observed was the *intuitive process* and this was defined by a decision to treat very early in the process. At an early stage, participants would typically state an intention to treat or not treat, with the remainder of the process being taken up by evaluation and optimisation of the image to confirm or disagree with their initial thoughts.

David and Lisa used the intuitive model in all three cases they reviewed (centre one). Tom and James (centre one) both used the intuitive model for two of the three case scenarios. Neither of them used the intuitive model while reviewing the images of the patient with head and neck cancer. This is similar to Hannah (centre one) who also used an intuitive process on two of the three cases and not on the images of the patient with head and neck cancer in her case series. In contrast, Nicole *only* used intuition on the case study of the patient with head and neck cancer. In common with other studies investigating intuition (Norman, 2009; Barrows & Feltovitch, 1987), David, Nicole, Fathima and Rachel spoke about making decisions early in the process, which can be assumed to be linked to intuition. However, when Fathima's and Rachel's SA is reviewed, neither of them were shown to make intuitive decisions and they were actually the two participants who used the largest number of phrases before mentioning a decision. These two examples highlight issues about retrospective analysis of decision-making, as the participants' recall was different to the actual process they carried out.

Intuition has traditionally been linked to experience and experience linked to expertise (Crebbin et al., 2013; Ericsson, 2004; Hamm, 1988; Mitchell & Unsworth, 2005), but this does not seem apparent in this small cohort. The experience of these four individuals was notably varied; Tom and Hannah both had 2 to 5 years of experience as radiographers and less than five years using IGRT. James and David had significantly more experience as radiographers with 10 to 15 years, James had two to five years of experience of IGRT and David had more than five. Sara, Fathima, Rachel and Ahmed were all advanced practitioners and none of them were observed to use the intuitive model. Three of them (Fathima, Rachel and Ahmed), were all advanced practitioners in centre three with significant experience and none were seen to use an intuitive process. These findings align closely with Ericsson, Whyte and Ward (2007) and will be discussed further in section 5.3.

Intuitive thought is considered to *'involve rapid, unconscious data processing that combines the available information by 'averaging' it, has low consistency and is moderately accurate'* (Hamm 1988, p. 81). As discussed in the literature review, it is linked to heuristics (Gigerenzer & Gaissmaier, 2011; O'Neill, 1995; Ramkumar et al., 2013) and is often considered to be "*error- prone"* (Croskerry & Nimmo, 2011, p. 156) and a cause of "*diagnostic error*" (Graber, Franklin, & Gordon, 2005; Elstein, 1999).

The results in the study contradict traditional views, as Table 4.5 demonstrated that errors and intuitive thought were not a feature in this cohort. Norman (2009 p.41) supported these findings and argues against the view that *"analytic reasoning is good''* and *"intuitive reasoning is bad''* and suggests that this view exists to provide satisfactory solutions to problems, taking into account the constraints of the human ability to process information. Norman (2009) argued that that heuristics are not sloppy shortcuts to be avoided, but are instead efficient strategies to overcome limitations of memory. The reliability of intuitive thought has been shown in studies outside of the clinical environment with chess players. Burns (2004) measured overall chess skill, and skill under speed conditions (blitz chess) and found that speed performance using intuition was strongly related to overall ability in the speciality.

Pattern recognition is intrinsically linked to the intuitive decision, and the theme of pattern recognition appeared to play a significant role in decision-making in many of the articles reviewed for the study (see literature review) (Thackray & Roberts, 2017b; Forsberg, Ziegert, Hult, & Fors, 2014; Simmons et al., 2003). Studies by Jefford, Fahy, Sundon and Sundin (2011) and Simmons et al. (2003) found that pattern recognition was the most commonly used heuristic in their studies of midwives and geriatric nurses. They concluded that the use of pattern recognition was linked to expertise, but the patterns that emerged in relation to the diagnosis and management of patients on a ward, or during labour are very different to those found in IGRT. Arguably, the patterns that emerge during IGRT involve fewer cues than those found in the ward environment. This is in part supported by the interviews in the study, where most of the participants spoke about the use of pattern recognition during decision-making regardless of experience. Experience clearly plays a role on some level, and this was shown during the interviews of experienced participants such as David and Fathima. They spoke about how their decisions have changed over time and how that is likely to be partly influenced by seeing lots of cases with similar parameters. However, in contrast to this, Hannah had fewer than two years of experience of IGRT and only 2 to 5 years of experience as a TR, but was one of the participants who made heuristic decisions and in fact had the shortest number of phrases of all participants (11) during one of her cases. Doing this she was clearly using pattern recognition. The potential links between experience and pattern recognition will be discussed in more detail in Section 5.4.

The SA stage of the analysis is very quantitative in nature and is purely looking at the frequency of phrases used rather than emphasising the importance placed on each phrase or phase of the decision-making process. To fully understand the process, these findings were triangulated with the other phases of the observational analysis and the interview analysis.

The concept of having a set process is supported by the interviews, which overwhelmingly highlighted the fact that the radiographers have set sequences when they review the patients. All the participants talked about having set processes when they review images: often these processes were site-specific, but all started with a) an auto-correction, followed by b) scrolling up and down the image set as a whole to get an overview, before c) scaling down to specifics. This set process is adopted by radiological colleagues who professionally have a longer history of interpreting images. The basis of radiological teaching encourages trainees to develop a systematic step-by-step checking process which starts with a review of the normal radiographic anatomy (Raby, 2015). They are also encouraged to use a systematic approach as it helps to minimise interpretive errors (Chan, 2013).

It is interesting to see how this has become embedded into radiotherapy practice and may be due to the often close links between radiotherapy and radiology departments, or may simply be because a systematic approach appears to be the most obvious approach when faced with a protocol driven task.

These set processes were seen in both the simple and repeating linear models. The use of linear models has been demonstrated in nursing settings, particularly where protocols and patient monitoring are commonplace, such as intensive care units (Lundgrén-Laine & Salanterä, 2010; Han et al., 2007) and in the diagnosis of leg ulcers (Adderley, 2013; Funkesson et al., 2007). It is unsurprising that clinical staff adopt these processes when following protocols as the decisions made are clearly going to be influenced by the content of the protocol. The repeating linear model seen in this study is more cyclical in nature and better captures the dynamic, iterative nature of clinical decision-making and similar processes are reported throughout the evidence base (Thackray & Roberts, 2017a; Lee et al., 2016; Arocha, Wang, & Patel, 2005).

As discussed in Section 2.5.2, the dual process theory has pattern recognition at its heart and offers a better explanation for the cognitive processes observed in this study. Pattern recognition is the first process that occurs prior to participants either using intuitive thought when a pattern is recognised (Type 1 processes), or analytical thought when a pattern is not recognised (Type 2 processes). This fits well with the data collected in this study, as participants appeared on the whole to go for one of two commonly seen processes; *the repeating linear process* which is Type 2 in nature or the *intuitive process* which is Type I in nature.

5.3 SOFTWARE MANIPULATION

Software manipulation was the most frequently used RPA concept in centre one (18%) and was equal to target volume in centre three (14%). Conversely, at only 6%, it was not a commonly used concept in centre two. These findings relate closely to the software used in the departments. Both centres one and three use Varian software, whereas centre two uses Elekta software. When analysing the overlap between AA and RPA, the AA concepts of *Cause-and-effect* and *Significance* demonstrated a *s*trong relationship with the RPA concept *software manipulation,* indicating the impact that image manipulation has on the process.

Software manipulation can also be seen more frequently in centres one and three in the SA analysis. This phrase featured 15 times on Rachel's case one (centre three), seven on Ahmed's case two (centre three), and represents nearly every other verbalisation in Nicole's case one (centre one). In contrast David (centre 2) only optimised the images twice in case one and twice in case two. Hannah (centre one) only optimised the image once in the whole process.

When observing the user interfaces of the two software packages, it is clear that the Varian software has many more options in terms of views and overlays. Participants can select a number of different blending modes when overlaying images. They can maximise the view of individual planes of view (Axial, coronal and sagittal), which is also possible on the Elekta software, where all three planes are visible all of the time. There may also be a link between the high frequency of the concept *automation,* which was notably higher in centre two (8% vs. 2% and 4%) and a reduction in the phrases relating to software manipulation. The link is not clear, but may suggest that centre two relies more heavily on automated settings than centres one and three.

5.4 THE IMPACT OF EXPERIENCE ON DECISION-MAKING

The descriptive model in Figure 4.23 shows that experience impacts on *problem-solving skills, speed, pattern recognition* and the ability to *see the bigger picture.*

During interviews, two specific types of experience emerged in the discussions. These were in relation to overall experience as a TR and experience of IGRT.

Views in relation to this question ranged across the departments. Sara felt the newly qualified (Band 5) TRs do not possess the skills to make autonomous decisions. Tom did not state a minimum amount of time required, but felt that general experience as a radiographer was vital, therefore image reviewers should have a significant amount of experience before reviewing images. Lisa's thoughts fell in the middle of this non-specific range, with 8 to 12 months of experience being needed. In contrast, there was overall agreement that experience of IGRT impacted on the decisions. Subthemes that came out of this were *general problem-solving, pattern recognition, speed* and *confidence.*

These findings are in line with a number of nursing studies that found little or no difference in the performance of nurses when comparing general years of experience (Dowding et al., 2009; Estabrooks et al., 2005; Aiken, Clarke, Cheung, Sloane, & Silber, 2003). Similarly, in non-medical professions such as music and sport, superior performance is linked to deliberate practice in a very specific domain rather than general experience (Ericsson, Krampe, & Tesch-Römer, 1993).

Links can be made with Ericsson's (2006) work on expert performance (performance can only be improved by seeking out particular kinds of experience, namely, deliberate practice) and the findings of research carried out in diagnostic radiology. Diagnostic radiographers are increasingly taking on roles that were traditionally carried out by radiologists who are medically trained. These are an interesting group to study due to the obvious links in image interpretation, but also due to their practice which involves repeated practice of a specific set of skills in a specific domain. Reporting radiographers have been shown to perform as well as their medical colleagues in certain settings despite significant differences in training (McLaughlin et al., 2017; Hardy at al., 2016; Moran & Warren-Forward, 2016; Manning et al., 2006). These findings may have links to the scope of practice of reporting radiographers compared to that of a radiologists. Reporting radiographers work within a well-defined scope of practice for which they have been educated, trained, assessed and deemed competent (The College of Radiographers, 2012). Although radiologists may specialise in an areas of practice, they will have a much larger scope of practice. This means that a reporting radiographer will quickly gain a significant amount of experience in a specific area of practice compared to a radiologist with similar experience who will gain experience in a wider scope of practice and thus less experience in a specific domain. If this premise is accepted, then it aligns with the work of Ericsson (2006) and supports the notion that practice in a very specific domain will allow a reporting radiographer to develop the characteristics of expert performance seen in radiologists, despite the reduced levels of overall training.

This thesis builds on these concepts, as well as drawing parallels with the evidence base. Up to 40 or 50 patients a day may be treated on a linac, which means TRs with more years of experience will have treated many patients. Using this experience, TRs can make effective decisions regarding patient set up and commonly occurring changes. They will also be able to use this experience to make decisions in more unusual situations as it is likely they will be able to make links to other similar cases that a less experienced member of the team would not. Arguably, a large proportion of decisions that are made during IGRT relate to the patient set-up and the impact of dose changes on the patient. However, a significant difference between the two scenarios is that one involves looking at the actual patient and assessing changes based on measurements in the treatment room, whereas decisions made during IGRT are based on the ability to interpret images and link them to the patient. Images on the IGRT console are viewed as a series of 2D images in three planes (axial, sagittal and coronal) and TRs must reconstruct these three planes into a 3D image in their heads prior to interpretation. They must then use their knowledge of the oncology of the site coupled with knowledge relating to the impact of any anatomical change on the delivered dose. It is clear that there are general skills related to this, but the findings of this study support the notion that this knowledge is anatomically site specific, and that the factors that impact one treatment site will be different to that of another site. This will be discussed further in Section 5.5, but TRs comments relating to feelings of not maintaining competency in certain anatomical sites and the use of intuitive decisions linked to pattern recognition support the concept that experience in a specific area of practice through repeated practice is the essential in the acquisition of expert performance. If this is the case then experience in specific image interpretation is more important than overall experience as a TR.

An added complexity in the development of expertise is the natural ability of some individuals to re-construct 3D imagery. The variation in ability of individuals to do this was highlighted in this study, particularly by David and Tom who are heavily involved in IGRT staff training. Both of them commented that experience as a TR does not necessarily link to an individual's ability to make decisions using IGRT images, and in fact both had trained TRs with many years of experience who struggled to interpret the 3D images and therefore make decisions based on the IGRT images.

The ability of individuals to reconstruct the real world using 3-D imagery has been shown to vary in Virtual Reality (VR) education (Dalgarno, Hedberg, & Harper, 2002). These findings were further explored by Appleyard (2014) who investigated the impact of using 3D VR models in anatomy education in TR students. Part of his study investigated how an individual's 3D spatial awareness prior to the commencement of the study impacted on their ability to reconstruct 3-D images. He found that prior 3D spatial awareness is positively correlated with the ability to reconstruct 3D images, highlighting the fact that some individuals are predisposed to be able to reconstruct 3-D images better than others. His findings also concluded that prior 3D spatial awareness did not influence how well individuals could improve that ability, suggesting that all TRs can improve their ability to reconstruct 3-D images regardless of prior spatial abilities. Linking this to Ericsson, Whyte and Ward (2007) one could suggest that individuals can only become experts at reviewing IGRT images by deliberately practising the review of IGRT images, and that additional general experience as a TR would have limited impact.

The limitations of this study must however be acknowledged with evaluating the findings. The observational analysis cannot be sufficiently generalised to make any firm statements on the impact of experience on process, however the ranging opinions discussed in the interviews highlight the discord that exists across centres and will ultimately impact on how departments are structured. Centre three appears to be the most proactive centre in terms of training newly qualified TRs to be competent at reviewing and making clinical decisions on IGRT images. Centre two is the largest centre and appears to be committed to upskilling their staff. They have adopted and implemented a solution suggested by The National Radiotherapy Implementation Group (2012) and have two levels of review TR. Level 2 TRs are essentially trained to carry out reviews looking for gross errors on images and make corrections if necessary based on these. This is very much protocol driven and they are not required to make decisions outside of the protocol. Level 1 TRs have a greater level of training and are typically more experienced radiographers, which allows them to review more complex cases and make decisions outside of protocol as well as offering advice where necessary to Level 1 TRs. This appears to be a sensible solution as it enables the centre to provide an IGRT service on all their IGRT enabled linacs whilst minimising the impact on training and resources.

Centre three approaches the issue from a different point of view and has a small core of experienced TRs who reviewed the centre's IGRT images. Their rationale for this appears to be that it is more important to have a small number of highly skilled staff than to have a large number of staff with limited skills.

It is clear that IGRT technology is going to become more and more routine in clinical centres and it is now becoming commonplace in some centres for two Band 5 TRs with limited experience to work together. Taking this in to consideration, it is difficult to see how centres are going to able to embrace this technology and use it to its full potential unless a significant proportion of their clinical staff are able to use and interpret the images. Achieving this is not a straight-forward process and the issues of staff training and development will be discussed further in Section 5.9.

5.5 PRIORITY OF CLINICAL FACTORS

The RPA and AA elements of the observational analysis in conjunction with the triangulated interview data provide an insight into the prioritisation of clinical factors. Initial analysis of the RPA data was carried out following guidance from the evidence base, but it quickly became evident that this stage of the analysis was very much linked to the discourse of the profession of radiotherapy. Some of the concepts used could be described as general terms and link to other professions such as *intermediate decisions, final decision, setting, compromise,* but the majority of terms are idiosyncratic to radiotherapy.

In general terms, anatomical structures can be broken down into two main categories when considering them in relation to IGRT. Target volumes are those structures that require high doses of radiation, and OARs are those where dose must be minimised as much as possible. The literature suggests (Zelefsky et al., 2012; Gupta & Narayan, 2012; Nguyen et al., 2011; The Royal College of Radiologists, Institute of Physics and Engineering in Medicine, & Society and College of Radiographers, 2008) that both categories are of vital importance in the radiotherapy and thus the IGRT process. Under-dosing of the tumour (Target Volume) or over-dosing normal structures (OARs) both have serious consequences, with the former increasing the risk of relapse and the latter causing potentially life-threatening and certainly *quality* of life threatening consequences (Marks, Ten Haken, & Martel, 2010). One of the fundamental concepts in relation to dose and radiobiology in radiotherapy is the balance between the probability of *tumour control* (TCP) and the risk of *normal tissue complications* (NTCP). This is known as the therapeutic ratio and ideally this should be maximised where possible (Crebbin et al., 2013).

In the RPA analysis in the current study, the Target Volume frequency was double that of the normal structures (14% vs. 7%). Some of this may in part be due to discourse, as some participants may refer to OARs as normal structures or soft tissue, although it is unlikely that every mention of soft tissue or normal structure was in relation to OARs, as structures such as muscle and subcutaneous tissue would not necessarily be considered as an OAR. Even when this is taken into account, the differences are still substantial. Consideration was made at the time to create a specific code called *OARs,* but this would have relied too heavily on the researcher's interpretation of whether the participant was actually considering the normal structure as a dose-limiting OAR.

When interpreting the RPA and AA data, the RPA concept *Target Volume* was shown to have a close relationship with the AA assertion *Evaluate and Significance.* Conversely, no relationship was observed between *Normal Structures* and *Evaluate or Significance.* The only relationship observed with *Normal Structures* was the assertion *Stating Facts.* This further supports the assumption of priority being given to the target volume over OARs.

During the interviews, it became clear that OARs, and in particular the dose to the spinal cord was of concern to the participants. The spinal cord seems to be of greater focus for the participants than any other OAR and was almost exclusively the only one discussed. The consequences of overdosing the spinal cord are very significant to the patient, potentially causing myelopathy which may result in paralysis (Marks et al., 2010), so it is understandable why such an emphasis would be placed on this particular structure. What is less obvious is why other OARs are not given similar attention. Over-dosing OARs outside the central nervous system still has serious consequences. For example, when considering the rectum, delivering more than 50 Gy to 50% of the organ, 60Gy to 35%, 65Gy to 25%, 70Gy to 20% or 75Gy to 15% could induce significant late rectal toxicity (Marks et al., 2010). Similarly delivering more than 20 Gy to 30% of the lung would considerably increase the likelihood of symptomatic pneumonitis (Marks et al., 2010). The only exception to this was in case one, in centre one where several participants were concerned about the dose to the small bowel, which had quite notably dropped into the treatment field. None of the participants discussed the impact of the dose, so is not clear whether judgements were based on the possible consequences of over-dosing the small bowel. Similarly, participants also talked of the need to make compromising decisions in head and neck treatments due to the spinal cord, but there was very little discussion about compromising in other treatment sites.

In the researcher's experience, the consequences of overdosing the spinal cord is something that is commonly discussed in radiotherapy discourse and is emphasised throughout the whole of radiotherapy training. In addition to this, it is quite common for disease in the head and neck to be very close to the spinal cord and the difference in dose required to treat the tumour, compared to the acceptable tolerance to the organ at risk can often be significant. In contrast, this is not always the case in some treatments. For example, treating the lung where the spinal cord may be some distance from the tumour, or the pelvis where the difference between the therapeutic dose to structures like the prostate, and the acceptable dose to OARs such as the bladder and rectum is much smaller, and so may be less of a focus.

It is difficult to come to any firm conclusions about the factors that influence this and there is a paucity of evidence on the subject in relation to imaging and IGRT. In general terms, assessing risk is always going to be part of any decision-making process (Tiffen et al., 2014) and humans are not always good at doing this (Hoffman et al., 2009; Carl Thompson et al., 2008). Influential radiotherapy reports such as those published by the National Radiotherapy Implementation Group (2012) and Korreman et al., (2010) discuss the importance of maximising Target Volume dose whilst minimising dose to OARs, but do not make any recommendations in relation to the priorities of one over the other. This may be a conscious decision, as each clinical case will have distinct clinical priorities and so generalised recommendation may not be appropriate, but additional guidance would be beneficial in this context.

It is likely that these priorities are seated in education and culture of decisions in radiotherapy rather than the technical radiotherapy literature. An example of this is found in the treatment of breast cancer. Findings relating to the importance of reducing dose to the heart during treatment (Darby et al., 2013) has made a significant impact on the method of treatment delivery for this patient group, which now commonly involves the process of patients holding their breath during treatment (Deep inspiration breath-hold) (Nguyen & Gonzalez, 2015; Wiant, Wentworth, Liu, & Sintay, 2015). This large change in practice will undoubtedly have more of an impact on the TRs awareness than the publication of literature which may not be read by all TRs.

5.6 DEPARTMENT STRUCTURE

The results of the study demonstrated that treatment centre structure had an impact on *culture* and the *maintenance of competency.*

Linked closely to training was department structure and in particular, a strong sub-theme around participants maintaining competence. This was raised in all the departments and stemmed from two main issues: firstly, not all of the linear accelerators have CBCT facilities on them and secondly, some linacs are used as site-specific machines and so may only treat a certain anatomical site. This is commonplace in the UK and is due to a perceived increase in efficiency by having teams treating the same patient groups. By using the same equipment and a similar set up for each patient, these teams may therefore increase the speed at which they can treat patients. It may also be linked to functionality in certain linacs. For example, disease in the prostate is typically treated with higher energy x-rays than disease in the head and neck region. If only a small number of linear accelerators have a high-energy facility in the department then they will typically treat patients with disease in the pelvis rather than head and neck.

Common themes that came out of the interviews were around staff only being exposed to certain patient groups and so becoming "rusty" in relation to reviewing different patient groups. It was also highlighted that if a TR is rotated on to a machine without CBCT facilities, they may not see CBCT image for a number of months. This could be as much as 12 months in centre three, which clearly raises a number of concerns around maintaining competence.

These concerns are shared in other industries such as the aviation industry, where crews routinely carry out simulations in order to practice emergencies and other situations that may occur very rarely. By doing this it enables crews to:

- *Engage in deliberate practice that includes a goal and evaluation criteria*
- *Build an extensive experience bank from diverse scenarios*
- *Obtain feedback that is accurate, diagnostic and timely*
- *Reviewing prior experiences to derive new insights and lessons from mistakes*. (Orasanu, 2010 p.169)

In their IGRT practical and technical review guidance document, The European Society of Therapeutic Radiology and Oncology (Korreman et al., 2010 p.139) highlight the need for a "*training and competency framework to ensure that the professionals are confident particularly when making on-line decisions."* Similarly, the National Radiotherapy Implementation Group guidance on the implementation of IGRT (National Radiotherapy Implementation Group, 2012 p.33) states that "*Competency for all clinical disciplines should be regularly assessed against current clinical standards which the professional bodies, i.e. RCR, SCoR and IPEM, should consider defining."* It is however not clear how widespread the competency element of this is in UK departments. Figures from the Society and College of Radiographers (2013) suggest that this is limited, with only 32% of centres surveyed having satisfactory training in place. More recent evidence is promising, with several articles being published on IGRT training. In response to concerns over competency in their Canadian department, Li, Cashell, Jaffray and Moseley (2016) created an e-learning package which the TRs in their department must complete annually in order to continue practising. The median time for completion of the package is just over 20 minutes. They have yet to complete a full evaluation of the software, but it is clear to see how such solutions may help TRs to maintain competence. A similar study by Hutton, Leadbetter, Jain and Baker (2013) created a database of images to develop competency assessment, and a training package to aid the implementation of adaptive radiotherapy in bladder patients. Their study highlighted a number of issues in the development of such a package, particularly in relation to the way current IGRT software is written and its limited functionality in relation to supporting training, as opposed to its intended purpose of reviewing live patient images. Matters are further complicated by the variation in baseline skills of qualified staff in relation to image interpretation, many of whom may not have received previous training on 3D anatomy and image interpretation. The added challenge is therefore to develop a pedagogical approach that takes account for this and individual learning styles.

Lessons can be learned from the aviation industry in relation to the development of a competency process, but unlike this industry where competency checking is routine and an accepted part of the role, the culture around such processes in radiotherapy are very different and implementation may be difficult due to TRs' concerns around the motives of these activities and a feeling of being tested. There is support in the wider evidence base for addressing competency using methods similar to Li, Cashell, Jaffray and Moseley (2016) and Hutton, Leadbetter, Jain and Baker (2013). Both simulation and e-learning has been widely used in nursing and medicine to enable clinicians to increasingly accept that they need to periodically demonstrate competency (Butler-O'Hara, Marasco and Dadiz, 2015). The use of simulations have been shown to improve communication, teamwork, and critical thinking, and, with a readily available database of previous patients, this is something that can in theory be set up with minimal technical knowledge.

Doing so is not without its challenges and for it to have maximum impact, the simulations need to be developed using a robust process that ensures all of the proposed aims can be achieved. Much of the literature around simulation focuses on creating a high fidelity environment with individuals re-enacting roles, or the utilisation of virtual patients (Botezatu et al., 2010; Jensen, 2013). Much of this is not really relevant to an IGRT simulation, although there is no reason why centres could not create scenarios where members of the MDT practised delivering complex new technologies prior to doing so on the first patient. This would work well in situations such as the implementation of stereotactic ablative radiotherapy (SABR), where it is common for TRs, medics and physicists to be present during each treatment. What is more achievable however, would be to learn from the experiences of radiotherapy centres that have implemented e-learning and simulation using retrospective patient images to create workbooks (Li, Cashell, Jaffray, & Moseley 2016; Hutton, Leadbetter, Jain, & Baker 2013) and update them regularly to ensure staff can be assessed against new cases each time. Implementing this routinely is clearly going to require commitment of resources and a change in mindset for some staff. It has however been shown to benefit the individual staff member, as an opportunity is given to receive feedback on their performance similar to clinical supervision which is seen in other areas of healthcare (Stephenson, 2015b).

5.7 THE WIDER MDT

Roles within radiotherapy have changed significantly in recent years and have gone from a medical-led service to a more multidisciplinary team approach (MDT). Radiographers are routinely involved in all aspects of the radiotherapy pathway and have taken on roles traditionally fulfilled by the medical team. This includes patient review, prescription of treatments and image review. These tasks may be taken on by all levels of TRs, however there has been a gradual increase in advanced practice roles, with some radiographers now working in consultant roles (Maryann Hardy & Snaith, 2007).

When discussing the MDT in the radiotherapy setting, in addition to TRs, one can assume that it typically involves the professionals in Table 5.0.

TABLE 5.0 THE RADIOTHERAPY MULTIDISCIPLINARY TEAM

Professional	**Traditional Responsibilities**
Consultant Clinical Oncologist	Determine the appropriate treatment for patients Consent patients Contour target volumes and organ at risk Prescribe treatment Review of verification images
Specialist Registrar in Clinical Oncologist	Support the Consultant Clinical Oncologists in all of their roles
Radiologist	Support the Clinical Oncologist in determining the location and extent of disease as well as the contouring of volumes
Physicist and Dosimetrist (Physics Department)	Plan and calculate treatment plans Support clinical staff during the verification process in determining the impact of changes on the radiotherapy dose distribution
Clinical Nurse Specialist	Clinical review of patients throughout the course of treatment

Despite having low-frequency in all centres, the RPA analysis highlighted a large range in the reference to the *MDT.* Participants in centre two spoke about it much more than those in centres one and three (8% as opposed to 2% and 1% in centres one and three respectively). These findings were supported by the interview data which highlighted a variety of experiences of participants; how they worked within the team and what impact this had on the decisions they made. Although there were mixed comments from centre one, it appeared that the medical team and physics team interacted much less with the radiographers than they did in centres two and three, with the largest interactions noted in centre two. There was also a notable difference in the communication methods used across the centres. Participants in centre one commented that physics and medical teams do not review patients on-set in person, and typically look at images remotely or by speaking on the telephone. Conversely, in centres two and three TRs appear to have a much closer working relationship with both the medical and physics teams who routinely review patients on the treatment set with TRs. All the centres also had specialist review radiographers/imaging leads who appear to be well utilised, typically offering advice in complex or uncommon situations.

This variation in practice raised a number of interesting points in the interviews. There seem to be notably different cultures in centres two and three, where participants spoke about having good relationships with the wider MDT and feeling that they could contact colleagues at any time for advice. This relationship seems to create a good culture in these centres and there was a positive theme of improved confidence in the decisions TRs make knowing they have MDT input at that time, or past experiences with the MDT allow them to make decisions more confidently, as they would have discussed similar scenarios in the past with the MDT. It was also evident that a closer MDT working relationship also enables better education through sharing of experiences and knowledge.

Two opposing views became apparent when talking about the wider MDT. Some participants appeared to be very confident at making decisions, and felt that their role had evolved to the point where they did not need wider MDT input as frequently as they once did. There was some evidence that they felt they had to involve them as it was part of the process rather than because they needed the input. Conversely, there was a feeling in centres two and three that some TRs in the centre got other members of the TR team or the MDT to make decisions for them as a form of "back covering" or not wanting to take responsibility for decisions. This may ultimately impact on the relationship between the TRs and the MDT. It should however be acknowledged that the two participants in centre two with the strongest views around this are involved in training of TRs and both have signifianct IGRT expertise. Therefore, these views may not be representative of the wider TR group in this centre.

These two opposing cultures, with an apparent lack of communication in centre one between TRs and the MDT, and a closer relationship in centre two that almost verges on overreliance at times is interesting. It raises a number of issues in relation to the evolving role of TRs and determining their role within the MDT which has clearly evolved over recent years. This is something that will need addressing as the roles of TRs continue to evolve in both the TR profession and the wider MDT. For this to happen efficiently and safely, it must be acknowledged that each discipline is likely to have different areas of expertise.

This evolution is complicated further by the fact that IGRT is also a new skill set for both the medical and physics teams with minimal time allocated to it on either training programme (Institute of Physics and Engineering in Medicine, 2016; The Royal College of Radiologists, 2016). The results of the Royal College of Radiologists' survey of new consultants (Benstead et al., 2012) demonstrated that newly qualified consultants do not feel prepared for practice in modern technologies such as intensity modulated radiotherapy (IMRT) and IGRT. When asked if they felt they have "adequate opportunity during your training to develop skills in newer radiotherapy technologies e.g. IMRT, IGRT", 13% strongly disagreed and 31% disagreed. The report also highlighted the importance of shared learning, suggesting that radiographers and nurses may need to play an increasing role in teaching trainees. This is echoed by Franks and McNair (2012) who acknowledge that a multidisciplinary approach is essential for the initial implementation and maintenance of a quality of an IGRT programme. The benefits of working within an MDT rather than as an individual professional group are clear. Powell and Baldwin, (2014) demonstrated that closer MDT working improves communication and understanding between the professional groups, which can lead to service improvement (Aveling et al., 2012), as well as create opportunities for education (Powell & Baldwin, 2014), all of which ultimately lead to improved job satisfaction (Jeremy et al., 2010).

When considering the evolving role of the radiographer within the MDT, there is a growing volume of evidence in relation to advanced practice and consultant roles. On the whole, the experience of these practitioners appears to be positive (Henwood, Booth, & Miller, 2016; Roberts, 2016). However, the transition has not always been a smooth experience for practitioners, particularly in diagnostic radiography where consultant practitioners have talked about it being *"a highly emotional and intensely stressful experience*" due to a lack of role clarity (Nightingale & Hardy, 2012 p.21). There also appears to be a lack of support and in some cases active resistance from radiography colleagues toward individuals who move into these roles (Henwood et al., 2016). Other more practical issues may also be problematic, with different professionals not understanding one another's perspectives. This can be further hampered by the use of different technical language when communicating (Gillan, Wiljer, Harnett, Briggs, & Catton, 2010).

It is clear that working as part of a wider MDT has a number of benefits, both for the patient in terms of a better clinical decision being made during their management, as well as improving culture and confidence in the TR workforce. Some of the issues raised may be linked to traditional hierarchical values and cultures in the NHS (Bate, 2000), but this was not raised as a concern by any of the participants. Certainly, in centre one, the medical team's offices are geographically remote from the linacs and so it is easy to see why it is easier to communicate over the phone than face-to-face. Evidence from centre two does suggest that face-to-face conversations are much better in terms of improving relationships and sharing of knowledge and so this is undoubtedly a better way to communicate. Making this happen on a practical level is not something that can be achieved easily, particularly in radiotherapy centres such as centre one where the building is old and not designed with communication and workflow in mind.

Shared learning has been shown to be beneficial in terms of breaking down barriers and understanding the perspectives of each other's roles and responsibilities (Bate, 2000). Approaching the task of upskilling potentially large numbers of staff in a shared manner must surely be seen as the best approach. Achieving this on a practical level is clearly going to be challenging, but the increased awareness of the importance of shared learning seems to be acknowledged by the professional bodies (National Radiotherapy Implementation Group, 2012) and so there is certainly a willingness and drive for it to happen across the various professional groups.

5.8 TRAINING

It was generally accepted by the participants that their pre-registration training had been limited in relation to imaging analysis. When considering this, it is important to remember that many of the participants trained before IGRT and certainly 3-D IGRT were TR led. Several of the participants had trained prior to radiographer training becoming a degree program, training under the curriculum on a Diploma, and so there are clearly some historical considerations to be borne in mind.

When discussing recent graduates, there was an overwhelming sense that the participants felt that recent graduates do not possess the skills and expertise required to carry out IGRT. At Sheffield Hallam University, students typically spend around 50% of the time on clinical placement and so questions must be raised about the current training in HEIs and how they work in partnership with clinical centres. It was universally agreed that image interpretation should form a core element of the training and that hands-on experience is vital in the education of the students. It was felt that the fundamentals could be taught in the classroom, but in order to develop the skills students need to see real patients being treated in the clinical environment.

There was large variation in opinions about when IGRT training should be delivered, ranging from year one through to year three. The rationale for it being in year one relates to the perceived fundamental nature of IGRT as part of the role. However, those advocating a delay until the third year felt that students need to acquire a good understanding of basic radiographer skills before they can appreciate and refine the skills required for IGRT.

It seems clear that an approach using case studies is beneficial (Li et al., 2015), but developing and setting this up in an HEI is difficult for both practical reasons and the ability of academic staff to deliver this training. As previously discussed, using clinical software as a form of simulation is difficult and issues around patient anonymity and the ability to copy retrospective patient data is problematic as software is written with a focus on patient safety. Other practical problems exist in relation to negotiating the sharing of images from clinical departments with HEIs and the data protection regulations that surround this.

From a teaching perspective, academic staff do not routinely work in a clinical department and although it is likely they have a significant amount of experience in their area of interest and topics they teach, maintaining up-to-date clinical knowledge can be problematic and often relies on the published evidence base which can at times be limited in availability and be outdated (White & Kane, 2007). In addition to this, each radiotherapy department will have its own set of protocols, guidelines and be at different stages of IGRT implementation, so delivering training that meets the needs of all is challenging.

These potential issues do, however, need to be seen as challenges rather than barriers, and they are certainly not insurmountable. The closer working of HEIs and radiotherapy centres is supported by the Society and College of Radiographers (2013 p.23) who state that:

> *Radiotherapy service providers must work with local Higher Education Institutions in developing the minimum requirements to enable new radiographers to be fit for purpose as outlined in the Education and Career Framework.*

> *Volumetric image analysis and decision-making skills need to be developed during undergraduate and post graduate pre-registration programmes via a standardised IGRT curriculum.*

There is also guidance on how this may be implemented using a workbook or portfolio based approach (Society and College of Radiographers 2013 p.34).

There seems little disagreement that the methods discussed are the way forward for IGRT education, but the challenges are around the implementation and coordination of such training within HEIs and clinical centres, requiring assistance on a national level from the professional bodies.

5.9 CLINICAL REASONING EDUCATION

A review of the literature demonstrates that clinical reasoning education forms an integral part of undergraduate courses in medicine, nursing and other Allied Health Professionals (Croskerry, 2009; Thackray & Roberts, 2017b; Thompson, Cullum, McCaughan, Sheldon, & Raynor, 2004), so it is surprising to see that it does not seem to feature on the training syllabuses of TRs. Similarly notable for its absence during the interviews was the lack of any discussion around clinical reasoning education, and so it is reasonable to suggest that the radiotherapy profession is not aware of the potential benefits of increased awareness and education in this field of study.

If TRs are to develop skills in decision making, pre-registration and post-registration professional development programmes need to incorporate relevant training in to their frameworks (Banning, 2008; Thompson & Dowding, 2002). In light of the discovered link between TR decision making Dual Process Theory (Croskerry, 2009a), TRs and educators must be aware of the limitations presented in the model in order to make efficient and safe decisions.

To improve TRs decision making skills, educators both in the clinical setting and in the HEI need to raise awareness of the fallibility of the human mind and a potential over reliance on Type 1 decisions and the use of biases and heuristics.

To aid the development of such a programme, a conceptual model to improve clinical decision-making has been developed and is presented in Figure 5.0. The model contains four concentric circles or themes. At the centre is the aim of the model Improved Decisions. The second ring contains the three concepts deemed to be of importance relating to image interpretation in IGRT: *Feedback on decisions, deliberate image review practice* and *decision-making and de-biasing training.* The next ring suggests methods of implementing these concepts and the outer ring breaks the model in to pre-registration and post re-registration training.

FIGURE 5.0 A CONCEPTUAL MODEL TO IMPROVE CLINICAL DECISION-MAKING IN IMAGE INTERPRETATION DURING IGRT.

5.9.1 Feedback on decisions

5.9.1.1 Post-registration setting

Unlike other healthcare professionals, TRs do not routinely get feedback on the clinical impact of the decisions they make. In professions such as physiotherapy and some areas of nursing and medicine, clinicians are likely to see the impact of their decisions through the process of patient follow-up. Similarly, professionals working in settings such as surgical units or accident and emergency may receive immediate feedback on their decisions due to changes in patient status after a decision has been made. The importance of feedback is not a new concept and was seen as pivotal part of effective decision-making in the early work of Tversky and Kahneman (1974). The concept of using feedback is simple; it allows individuals to reflect on the decisions they have made and calibrate the processes they use in future (Croskerry, 2009b).

One way of achieving this feedback in the radiotherapy setting would be the wider involvement of TRs in the patient review process. An increasing number of TRs are involved in patient review, however in radiotherapy this is often seen as a specific role and so it is not common for the same TR to both make the decisions during image review and to review the patient during follow-up. However, there are a number of other methods that could be used to involve TRs in review. Standard practice in centre two was the routine involvement of TRs in weekly site-specific peer review MDT meetings. A recent publication by The Royal College of Radiologists (2017) highlighted the importance of peer review during the contouring of target volumes and organs at risk. Their recommendations clearly state that clinical staff should have protected time to peer review the contouring of structures and that loco-regional control and toxicity should be periodically audited. During the interviews, it was clear that TRs in centre two found these meetings beneficial and that the scope of the meetings extended beyond volume delineation and included discussions around patient set up, image review and follow-up. The impact of this type of review meeting was highlighted by Rooney et al. (2015) who audited their department's peer review process in lung cancer treatments over a 13 month period, and found that 27% of plans were modified as a consequence. This clearly highlights the potential benefit for widespread implementation of peer review involving TRs, and departments should look to implement this at the earliest opportunity.

Another common process that occurs in other health professions is clinical supervision (White, 2017; Schell & Schell, 2008; Sellars, 2004). There are many definitions of clinical supervision, but common to all is the intention to improve quality, standards or accountability (Bond, 2010). Engaging in clinical supervision also allows an individual to reflect on their experience in practice and develop professional knowledge and skills whilst developing self-awareness (Lynch, 2008; Sloan, 2006). Bond (2010) highlighted the importance of the supervisee seeing the experience as empowering rather than controlling, suggesting that a better name for the process could be *coaching* rather than *supervising,* which elicits connotations of control.

There are clearly a number of barriers that must be overcome in order to introduce routine clinical supervision or coaching. Bush (2005) highlighted concerns similar to Bond (2010), suggesting that the term *supervision* can be seen as a form of organisational surveillance. Such views are likely to be seen by individuals during the early implementation of such processes, but it has been shown that some of these concerns can be overcome with simple solutions such as allowing the supervisee the choice of supervisors, maintenance of confidentiality and reassurance that there will be no repercussions unless there is evidence that staff or patients may be at risk (Cole, 2002).

In a busy radiotherapy department, where resources are commonly stretched, perhaps the biggest challenge is creating time for staff to engage in such a process. To overcome this, organisations must see the benefits of the supervision process (Clifton, 2002) and support it with the required resources. To be meaningful, the process should be conducted at least four time a year (Grol, 1994) and could involve the supervisee bringing a clinical case that they wish to discuss in more detail. Another method could be the adoption of a *case of the month* whereby complex cases are highlighted by an appropriate person in the department and individuals are given the opportunity to discuss how they would have managed that particular case. This method can also be done as a group activity, whereby a small group of individuals evaluate the possible management options in a given situation.

The evidence base and the results of this study clearly indicate the need for some form of peer review process for image review and departments are encouraged to discuss what method of implementation would best suit them and their clinical staff.

5.9.1.2 Pre-registration setting

Assessment and feedback are key components of any well-developed pre-registration pedagogy and so incorporating them into education around image interpretation should be a straightforward process for HEIs. In the HEI setting this concept is intrinsically linked to deliberate image review practice (Section 5.9.2). Carrying out deliberate practice without regular constructive feedback will limit an individual's ability to apply skills to their own development. Academic and clinical staff should take regular opportunities during educational sessions to feedback on the decisions made by the trainee TRs. This could be in the form of written or verbal feedback following the session, but to be most effective, it should ideally be carried out during the session, as immediate feedback has been shown to have a greater impact (Croskerry & Nimmo, 2011). This should ideally be done on a one-to-one basis, but this may be problematic with the resources available and so group feedback may be a more appropriate method to use.

5.9.2 Deliberate image review practice

5.9.2.1 Post-registration setting

Section 5.4 discussed how expert performance can only be achieved through deliberate practice in a specific domain. The interviews highlighted staff concerns over maintaining competency due to departmental structures and lack of rotations around the department.

Departments are therefore encouraged to evaluate their staffing of clinical areas and whether they can create opportunities for staff to rotate. The fact that this does not appear to happen routinely in the centres in this study may be a consequence of a potential conflict between rotas that give the greatest efficiency in terms of patient throughput, versus rotas that give the greatest opportunity to improve staff competency, at a cost of some reduction in efficiency. When reviewing their policies on rotas, managers should consider the rotation of senior staff as well as more junior colleagues. The participants in this study that commented on feeling de-skilled in certain areas were in fact senior members of the team. Traditionally, junior staff in radiotherapy departments rotate more frequently than senior staff, who often specialise in a certain area or take on additional responsibilities such as “Team Leader” roles on a Linac.

One solution to addressing resource issues may be an increased use of simulation. Images acquired during the radiotherapy process need to be retained for a minimum of eight years (The Royal College of Radiologists, 2008), thus providing radiotherapy departments with a large database of images which are typically used in training. It is usual therefore for departments to have the technical ability to anonymise and present images that could also be used for competence based training.

Lessons on simulation-based competency frameworks can be taken from other professions, including nursing (Hagler & Wilson, 2013; Schreiber, Foran-Lee, & Ross, 2010) and surgery (Raison et al., 2017; Lodge & Grantcharov, 2011; Paisley, Baldwin, & Paterson-Brown, 2001), where they are used widely. However, of particular relevance is the use of simulation based training in radiology.

Discussing the importance of acquiring expertise through task repetition in radiology, Klein and Neal (2016) highlighted the benefits, including the ability to provide personal feedback and the capability of tailoring specific simulation tasks to each clinician. Several studies in radiology involving both trainee and consultant radiologists have demonstrated significant improvement in performance and accuracy (Mendiratta-Lala, Williams, de Quadros, Bonnett, & Mendiratta, 2017; Berry, Reznick, Lystig, & Lönn, 2008; Berry, Lystig, Reznick, & Lönn, 2006). These activities could be linked to a clinical supervision activity or linked to the peer review process discussed in Section 5.9.1.1.

5.9.2.2 Pre-registration setting

Following an initial introduction to image interpretation and the IGRT process, the pedagogy of pre-registration education focuses heavily on exposure to varying IGRT scenarios. The evidence clearly highlights the importance of repeated practice in the acquisition of clinical skills and ultimately the journey to expert performance (Thackray & Roberts, 2017; Pinnock & Welch, 2014; Gegenfurtner & Seppänen, 2013; Thompson et al., 2008; White & Mckay, 2004; Patel, Kaufman, & Arocha, 2002). As discussed in section 5.9.2.1, this can effectively be achieved using a simulated environment. Trainees should be exposed to these scenarios early in their education, with the scenarios increasing in complexity as their experience and confidence builds. It is however important not to forget that trainees need to experience the management of patients on placement in real clinical environments. Clinical departments and HEIs therefore need to work more closely to ensure these requirements are met, with considerations being made as to how image interpretation and clinical decision-making can be linked to clinical competencies whilst on placement.

5.9.3 Decision-making and de-biasing training

The interviews carried out in this study, underpinned by the literature review, highlighted a notable lack of education around clinical decision-making and de-biasing in the radiotherapy profession. The only way this can be overcome is with the introduction of such training in both the pre-registration and post-registration curricula, and for clinical staff currently working in the radiotherapy centres in the UK.

The content of the curricula for both groups are very similar and of equal importance, however the method of delivery may need to vary. The findings of the literature review from this study could be used as the basis of such a curriculum and should include:

- An introduction to the theories of clinical reasoning
- Development of an understanding of the differences between intuitive and analytical thought
- The various published models explaining human decision-making, with a particular emphasis on dual process theory.
- The impact of heuristics on decision-making
- Commonly seen biases in the clinical and radiotherapy setting
- Methods of overcoming bias
- What it means to be an expert and how this status is achieved

HEIs should be encouraged to routinely include clinical decision-making and de-biasing training in the curriculum. Ideally, this should be integrated across the whole of the course, increasing in complexity over the duration. A mixture of taught, seminar and simulation sessions should be used. The use of clinical scenarios is encouraged as it is an easy way for academic staff to demonstrate how biases and heuristics may be caused and how this may lead to inefficient decisions.

Clinical departments should look to educate their staff using a similar, although more likely condensed curriculum. It is unlikely that clinical staff could be released to undergo long courses of clinical decision-making, however individual departments or professional bodies such as the Society and College of Radiographers could look to develop online materials involving clinical scenarios, using a similar approach as discussed above.

5.10 THE FUTURE OF IGRT DECISION-MAKING

Automation which, despite only representing 4% of the coded phrases in the RPA analysis, was a significant area for discussion in the interviews. In the IGRT process, this essentially involves the software carrying out an "auto-match" using an algorithm and this was done by all participants in the first three verbalisations of SA. Staff can select certain parameters for it to focus on, for example the tumour or the bony anatomy, by drawing a box around it. Ultimately, however, the software makes a best guess at the match and then the TR can choose to accept the result or refine it. In phantom studies, the software has been shown to be reproducibly accurate within 1.8mm and 0.4^{o} (Sharma, Dongre, Mhatre, & Heigrujam, 2012). There were some perceived benefits of automation, with participants in both centres two and three speaking about it providing safe, reproducible decisions that removed the subjectivity introduced when TRs make decisions. David in particular felt strongly about its benefits, but acknowledged that routine use risked de-skilling of staff. These concerns are not without justification as evidence suggests that an increased use of automation does diminish the skill of staff, and impacts on motivation and satisfaction (Milkman & Pullman, 1991; Kelley, 1989).

A review of the literature in radiology highlights the significant role pattern recognition plays in the diagnosis of conditions. This has ultimately led to an increased use of software which is able to machine learn, enabling it to recognise patterns on diagnostic images and make clinical decisions based on these. These include the ability to make decisions in mammography, Computer Tomography colonography, Computer Tomography lung nodule, brain function or activity analysis and neurological disease diagnosis from Functional Magnetic Resonance images (Wang & Summers, 2012). The use of this technology has become so accurate and widespread in use, that some authors are claiming it is one of the largest threats to the profession of the radiologist (Chockley & Emanuel, 2016). Although still in its infancy in terms of accuracy, automated contouring of anatomical structures during the treatment planning process is becoming routine practice (Pekar, McNutt, &

Kaus, 2004). Planning systems using machine learning have also been shown to be able to plan clinically acceptable plans in the prostate (Kubo et al., 2017) , the head and neck region (Fogliata et al., 2017) and in the thorax (Fogliata et al., 2015) with minimal human intervention. Although carrying out automated matches on phantom studies is very different to planning a patient, it is difficult to imagine how automation will not play an increasingly significant role in the process of IGRT. The question must therefore be asked whether the future of IGRT decision-making lies in a completely new skill set; the interaction between human and machine.

5.11 STRENGTHS AND WEAKNESSES OF THE RESEARCH DESIGN

A review of the research process highlighted a range of strengths and weaknesses in the research design that will be used to inform future studies.

5.11.1 Recruitment

Participants were recruited from three UK centres allowing for inter-centre comparison across the data. Although the aim of the study was not to achieve generalisable results that represented the whole of the UK, the three centres varied notably in size and experience of using IGRT, which provided a real insight into the range of UK practice.

The differences were particularly evident in relation to how teams in the wider MDT communicate with each other and has provided an opportunity to make recommendations in relation to this. Other noteworthy difference relating to practice were in linked to the structure of the department and the experience TRs are expected to have prior to being involved in the IGRT process.

Research questions three and four both related to the impact of experience on the decision-making process and so ideally a wider spread of experience in the study population would have been desirable. The population in the study had a slant towards the more experienced end of the spectrum and this was likely due to less-experienced members of staff having greater anxieties about involvement.

Although only a small variation, it would have been desirable to have equal numbers of participants across all three centres, which would have increased the overall number of participants in the study. Despite this variation, it was felt that the number of participants in each centre allowed the researcher to investigate practices in each of the centres fully. The researcher’s approach to interviewing allowed for a full and honest discussion with the participants, which in most cases was not time restricted. These extensive conversations allowed the researcher to get a real feel for the departments and the concerns of the participants.

This will be addressed in future work by spending more time in departments prior to the study commencing. This will give the researcher a greater opportunity to explain the rationale for the study, the underpinning ethics of the study and the potential benefits of participant involvement.

5.11.2 The think aloud method

The evidence supports the use of the think aloud method and there is widespread acceptance that the process has little if any impact on a participant's ability to complete a task decision-making process.

It was however noted that some participants verbalised easier than others, with some participants requiring multiple prompts during the observation. This variation is consistent with other similar studies and so is not a concern, but raises the question of whether some participants could have been better prepared prior to the study commencing. These concerns were noted in the researcher's diary at the time and was particularly felt in centre one. This may have been due to the researcher's inexperience of the method early in the study. The researcher commented in his reflective diary that "On reflection, I could have been more assertive about my requirements" prior to the first set of data collection. These reflections were acted on in subsequent sessions and data collection was notably smoother as the study progressed.

5.11.3 Member checking and peer review

The member checking phase of the study was thorough and was felt to be more extensive than that discussed in the wider literature. This was carried out by giving the participants an opportunity to watch back a recording of their observation prior to the follow-up interview. In addition to this, at the end of the study a screencast of the final analysis was shared allowing for further comment.

The participants commented that the opportunity to watch their observations back prior to the interview, was particularly useful as well as allowing the researcher to discuss their interpretations and clarify any local terms or practices. Reviewing the observations can also be seen as an educational opportunity for the participants and several commented that they had never had an opportunity to really think or reflect on how they make decisions.

Peer review was also very beneficial during the analysis phase of the study and the researcher was lucky enough to have a number of viewpoints from supervisors with different professional backgrounds. This provided him with a balanced and varied “sounding board” during theory generation and subsequent analysis, which resulted in a number of changes during the coding phase of the analysis.

5.11.4 Eye tracking software

Several studies cited in the literature review that investigated decision-making in radiology used eye tracking software to record where the participants were looking during study task. This yielded some interesting results in those studies and may have been of benefit in this study. The use of the technology was briefly investigated during the design phase, but it was decided that lack of availability of the hardware made the use of it unfeasible.

It would be desirable to use this technology in any future studies and the researcher will investigate the possibility of collaborative project with an institution that has the technology available.

CHAPTER 6: CONCLUSION

6.1 INTRODUCTION

This Doctoral programme of research aimed to investigate the clinical decision-making processes used by therapeutic radiographers when carrying out Image Guided Radiotherapy.

The justification for the study was the lack of evidence in relation to clinical decision-making in radiotherapy and in the Image Guided Radiotherapy process. Further justification was seen in the number of errors that are associated with the Image Guided Radiotherapy process, which in part was linked to a lack of understanding of the processes involved.

A think-aloud study using a multimethod approach was adopted, comprising of observations and follow up interviews at three UK radiotherapy centres.

This research has made an original contribution to knowledge by:

- Demonstrating that therapeutic radiographers use one of three models; *simple linear, linear repeating* or *intuitive.*
- Demonstrating that therapeutic radiographers prioritise target volumes accuracy over changes in organs at risk.
- Developing a descriptive model of the factors that impact on the clinical decisions therapeutic radiographers make during image guided radiotherapy.
- Developing a conceptual model to improve clinical decision-making in image interpretation during IGRT.

This final chapter will summarise the main findings in relation to the study's research questions. The significance of these findings will then be outlined along with recommendations for practice. Future research opportunities will be proposed.

6.2 SUMMARY OF FINDINGS

6.2.1 Research Questions

In relation to clinical decision-making based on 3D Cone Beam CT imaging during radiotherapy:

RQ1: What decision-making processes do therapeutic radiographers utilise while making clinical decisions?

Participants were observed using one of three decision-making processes. These assumed the titles *simple linear process, linear repeating process* and *intuitive process.* The processes are supported by the literature and in particular the work of Croskerry (2009) and his work on the dual process theory of decision-making. The models proposed in this study take the discussion beyond Type 1 and Type 2 decisions described in the dual process. In particular, the *linear repeating model* highlights the complex nature of image interpretation and its links to decision- making process in IGRT.

RQ2: How do therapeutic radiographers prioritise the clinical factors observed during Image Guided Radiotherapy?

The results of the observational stage of the study triangulated with the interview data showed that in all cases other than the head and neck region, participants prioritised the target volume to be treated over the organs at risk. This goes against published research evidence, that highlights the importance and the consequences of delivering an inappropriate dose to both the target volume and the organs at risk. This is therefore an important discovery requiring attention in training modules.

RQ3: How does clinical experience as a therapeutic radiographer influence the decision-making process?

There were notably mixed opinions on the impact of overall therapeutic radiographer experience, but the overall findings of the study align with Ericsson (2006) general principles of expert performance, which claims that expertise is only improved by seeking out particular kinds of experience, namely, deliberate practice, with the sole purpose of effectively improving specific aspects of an individual's performance, i.e. practice in image interpretation and decision-making. Another important finding was in relation to an individual's predisposed ability to visualise and reconstruct images with multiple 2-D planes, into a 3-D image that can be related to the patient. It became apparent that some therapeutic radiographers are able to master the art of Image Guided Radiotherapy very quickly whilst others find it more difficult.

RQ 4: How does experience with Image Guided Radiotherapy influence the decision-making process?

Results from the interviews clearly found that specific experience of Image Guided Radiotherapy affected the decision-making process by improving confidence and speed. This was linked to pattern recognition and as with research question three is supported by the literature of Ericsson (2006) .

RQ: Do any other factors impact on the clinical decisions made by therapeutic radiographers?

The centre infrastructure, training and the wider involvement of the multidisciplinary team were all found to be key factors that impact on the decision-making process during IGRT. A range of structures in terms of staffing levels and communication between the multidisciplinary team were found to exist in the three centres. Improved communication and involvement of the multidisciplinary team was found to enhance therapeutic radiographers' confidence in making clinical decisions.

Issues in relation to pre-registration training was highlighted, with a consensus that current graduates do not currently possess the skills and experience to make clinical decisions early in their careers. Similar concerns were also highlighted around staff maintaining competency in all treatment sites.

To address these concerns, this study proposes a conceptual model to improve clinical decision-making in image interpretation during IGRT. The model has three facets relating to pre-registration and Post-registration training which are *feedback on decisions, deliberate image review practice* and *decision-making and de-biasing training.*

6.3 RECOMMENDATIONS FOR PRACTICE

The findings of the study support recommendations in four key areas.

6.3.1 Feedback on decisions

The evidence base strongly supports the notion that regular feedback improves decisions and reduces errors. There is a notable difference between the feedback TRs receive on their decisions during the IGRT process compared to the feedback received by other professions in AHP, nursing and medicine, where clinical supervision is routinely carried out. The study highlighted evidence that a small number of TRs are involved in patient review meetings, but this was limited to one centre and a small number of TRs.

Recommendation: Radiotherapy managers should look to implement routine clinical supervision across all grades of staff working clinically. Training should be developed and rolled out for supervisors and supervisees to allow them to benefit as much as possible from the process. Consideration should also be given to the involvement of TRs in wider MDT meetings.

6.3.2 Communication within the wider MDT

There was a notable difference between the centres in relation to how TRs communicated with and problem solved with the wider radiotherapy MDT.

TRs in centres where the MDT meet face-to-face on the treatment set to review images and problem solve together commented extensively on the benefits this brings. In particular, TRs felt that the face-to-face nature of discussions improved relationships, understanding and confidence as well as providing an opportunity for shared learning.

Recommendation: Where possible, staff should review patient images face-to-face, preferably on the treatment unit. This will promote a full discussion on the issues raised and provide an opportunity for shared learning.

6.3.3 Deliberate review practice

The study supports the wider evidence base on expert performance, and the positive impact of regular, deliberate practice. Participants in all centres commented that they felt de-skilled in certain aspects of image review during IGRT due to the structure and rotas within radiotherapy departments.

Recommendation: It is acknowledged that the current financial climate in radiotherapy departments may restrict the ability of managers to significantly alter departmental structures and rotas. However, small changes may yield large benefits and so consideration should be given to allow TRs to review images across a range of anatomical site where possible. Opportunities for staff to carry out deliberate practice in a simulated environment should be created and encouraged, which should be facilitated alongside clinical supervision.

6.3.4 Decision-making and de-bias training

The study highlighted a lack of knowledge and education relating to specific decision-making and de-bias training at all levels. The study revealed a greater emphasis on such training in other AHP, nursing and medical course, both at pre-registration and post-registration stages. The evidence base clearly demonstrates the benefits of this type of training and it has been shown to improve decisions and reduce errors.

Recommendation: Decision-making and de-bias training should be integrated into TR training at both at pre-registration and post-registration stages. HEI’s should work with radiotherapy departments to develop resources and share practice.

6.4 Future research

The current study has highlighted a number of avenues for future research, but the conclusions suggest priorities should be placed on specifically investigating impact of experience on decision-making using a larger cohort, with a focus purely on the final decisions made. Doing this will enable centres to better plan the resources required to carry out routine Image Guided Radiotherapy and determine at what level of experience radiographers should commence Image Guided Radiotherapy image review.

A programme of clinical decision-making education should be developed and integrated into the curriculum at both pre-registration and post-registration CPD training. The growing evidence base around this should be utilised. It is essential that such training covers the fundamental theory of decision-making and biases as well as the limitations of Type 1 and Type 2 decision-making processes. This training should be supported with routine peer review and debriefing following Image Guided Radiotherapy decisions, thus allowing individuals to further develop their skills in this area.

6.4 Conclusion and original contribution to knowledge

In conclusion, this thesis has provided new and original insight in the decision-making processes of therapeutic radiographers. The study has developed three process models to explain these processes with the titles *simple linear process, linear repeating simple linear process* and the *intuitive simple linear process.* The study has highlighted that therapeutic radiographers commonly prioritise target volumes accuracy over changes in organs at risk. Two models were developed unique to image interpretation in the Image Guided Radiotherapy process. The first is a descriptive model of the factors that impact on the clinical decisions therapeutic radiographers make during image guided radiotherapy. The second is a conceptual model to improve clinical decision-making in image interpretation during IGRT. Professional bodies, clinical departments and Higher Education

Institutions are encouraged to use the models to improve education and infrastructure in the support of more effective clinical decisions.

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APPENDIX 1 SUMMARY OF ARTICLES

Author	Profession	Method	Key findings and conclusions	Appraisal	Relevance to current study	SIGN Rating*
Goyder et al. (2017)	Medicine	Qualitative study. Semi-Structured interviews or focus group with junior doctors (n=20). Grounded theory used to inform analysis	Authors developed a model of three phases: case framing, evolving clinical reasoning (including heuristics**), management and ongoing uncertainty (referral to senior colleagues).	Some participants were interviewed, whilst others were involved in focus groups. The retrospective nature of these methods may be open to bias as it involves the participants reflecting on how they think they make decisions.	Interesting discussion on heuristics** and the referral of decisions to senior colleagues. However, the setting of this research may provide limited explanation of how TRs make decisions during IGRT.	+
Thackray and Roberts (2017)	Physiotherapy	Qualitative study. Authors observed physiotherapists (n=9) making decisions in a simulated environment using manikins. Retrospective think aloud and follow up interview method were used. Data was analysed using thematic analysis.	Authors reported a model similar to hypothetico deductive reasoning, but more closely linked to dual process theory. They developed a seven stage process: recognition, matching, discriminating, relating, inferring, synthesising and prediction.	Participants had the option to call a colleague into the scenario, which is akin to clinical practice. The use of retrospective think aloud may introduce bias.	The model presented may have some links to IGRT. Setting limitations as in Goyder et al. (2017)	++

Wright andReeves (2017)	Diagnostic Radiography	Quantitative study. Using a range of bony anatomy sites, the image interpretation performance of one cohort of student radiographers (n=23) was measured in a longitudinal study. Time scale was from enrolment in the first week of university education and then again prior to graduation. The receiver operator characteristic (ROC) was calculated with the JROCFIT web based calculator was used.	There was a positive shift in graduate mean accuracy (+16%) was driven by increases in specificity (+27%) rather than sensitivity (+5%). No statistically significant differences (ANOVA) could be found between age group, gender and previous education however trends were identified.	A well-designed study for purposed of research questions. Study had a high drop off rate in participants (n=13)	The study demonstrated that trained Diagnostic Radiographers have better diagnostic accuracy than novice Radiographers. The study did not to seek to investigate decision making processes.	++
Johnsen, Slettebø, and Fossum (2016)	Nursing	Qualitative study. Authors observed graduate nurses (n=8) (less than one years experience) using a think aloud study. Data was analysed using protocol analysis: RPA, AA, SA***.	High number of concepts in each of the three phases of analysis. RPA, only listed four most common: action, patient, verification, and confirmation. AA: causal, declarative, evaluative, indicative, and preventative. SA: Assume, Conclude,	Use of think aloud in difficult clinical setting. Two participants acknowledged that they filtered information in front of the patients.	Interesting insight into the decision-making processes of novice clinicians. Setting limitations as in Goyder et al. (2017).	+

			Confirm, Control, Encourage, Explain, Gather information, Judge, Personal engagement, Plan, Participants use more reactive decision-making. Probably due to lack of experience			
Lee et al. (2016)	Nursing	Qualitative study. Authors observed nurses (n=11) using a think aloud method. Data was analysed using thematic analysis	Developed a circular descriptive model: assessment-analysis-diagnosis-planning-evaluation.	Good simple model of decision-making. Researchers do not discuss if this model is appropriate in all cases/scenarios. The two researchers couldn't agree some of the codes so got third Authors to assist	The development of a profession specific model is of interest. Setting limitations as in Goyder et al. (2017).	+
Jefford and Fahy (2015)	Midwives	Qualitative study. Interviewed midwives (n=26) about decision-making in second stage labour. Coded using a feminist, Interpretive approach	The results demonstrated the use of processes similar to hypothetico deductive reasoning (do not specifically refer to the model) Pattern recognition shown to be a frequently used bias	The authors highlight the lack of knowledge on decision-making in midwifery, but use a pre-established framework to analyse the data in nursing. May have been better to use an inductive approach to coding. The use of interviews as sole method of investigation has been shown to increase risk of bias.	Interesting discussion on pattern recognition, which may have links to decision-making in IGRT. Setting limitations as in Goyder et al. (2017).	+

Langridge, Roberts and Pope (2015)	Physiotherapy	Qualitative study using grounded theory. Authors used focus group, semi structured interviews and retrospective think aloud to investigate the decision-making processes used by extended scope and non-extended scope physiotherapists (n=6)	Found that the models for both groups are very similar with three key themes. Patient interaction and formal testing. One area where difference was noted was informal testing, with the experienced members of staff making more use of diagnostic tests such as MRI, using these to make clinical decisions. Gut feeling was found to be a key concept	The study used three methods of data collection and it appears different participants were involved in the different methods. There is very little discussion about how the different methods were triangulated. One of the methods was described as retrospective think aloud, but read as semi-structured interviews/reflections.	Interesting discussion on the impact of experience on decision-making. Setting limitations as in Goyder et al. (2017)	+
Moran andWarren-Forward (2016)	Diagnostic Radiography	Two thousand mammograms were reviewed by experienced Radiographers (n=6) at biennial re-screen. Analysis of the results included validation of normal results by negative follow-up screens and new cancers at biennial review; there is also analysis on the types of lesions detected and missed.	Diagnostic accuracy ranged from 91 to 98%. The missed cancers by the radiographers totalled 21; of these, there were 3 calcifications, 3 mass lesions, 9 non-specific densities and 6 stellate lesions, but there was excellent perception (100%) of architectural distortion.	A generally well-designed study for purposed of research questions. There was some discussion on the decisions of Radiologists, but it was not clear from the method what their exact involvement was.	The study highlighted the abilities of Diagnostic Radiographers to detected abnormalities in mammograms, but did not seek to investigate decision making processes.	++

Pirret, Neville, and La (2015)	Nursing and medicine	Qualitative study. Authors observed nurses (n=30) and doctors (n=16) using a think aloud method to investigate diagnosis of case studies. Data was analysed using thematic analysis	61.9% of doctors identified the correct diagnoses, compared to 54.7% in the nursing group (not statistically different)	A strength in the study was the use of a Delphi study to determine correct diagnosis. There was bias in the recruitment with twice as many nurses as medics.	The study demonstrates that non-medics can make same decisions as medics, which may be of relevance in the multi-disciplinary IGRT process. Setting limitations as in Goyder et al. (2017).	+
Forsberg, Ziegert, Hult, and Fors (2014)	Nursing	Qualitative study. Researcher observed how nurses (n=30) made clinical decisions using a virtual patient. A think aloud method was used which was analysed using content analysis	Three categories were identified in the analysis: hypothesis orientation, high specific competence and experience. Intuitive processes were found to be the predominant process.	A well designed study using novel technology.	Good insight into impact of experience on decision-making processes. Setting limitations as in Goyder et al. (2017).	++
Lockwood, Piper, and Pittock (2014)	Diagnostic Radiography	Quantitative study. Diagnostic Radiographers (n=24) who had recently completed a postgraduate course in CT head and neck interpretation were asked to report on a series of cases (total n=600).	When compared to radiologist reports, The mean sensitivity rate of 99%, specificity 95% and agreement concordance rates of 90%.	A well-designed study for purposed of research questions	The study highlighted the abilities of Diagnostic Radiographers to detected abnormalities in in head and neck CT images, but did not seek to investigate decision making processes.	+++

Gegenfurtner and Seppänen (2013)	Radiology	Mixed study approach. Participants (n=9) were asked to review a series of cases using CT, PET and PET/CT. Participants were deemed to be experts in only one of the modalities. A think aloud study was used alongside eye tracking technology.	Study investigated the transfer of expertise in medical imaging. Four dimensions were seen to impact on the analysis. (1) a technology dimension, which reflected verbalizations of interacting with and commenting on the visualization tool; (2) a dimension of cognitive comprehension, which reflected verbalizations of selecting data, organizing data, and integrating data with long-term memory (3) a dimension of metacognitive comprehension, which reflected verbalizations of using heuristic**, control, or learning strategies; and (4) a solution dimension, which reflected verbalizations of correct or incorrect problem solutions	A well-designed study using tracking software. The authors do not state which professional group was involved in the study, but it is presumed that they were radiologists. Large standard deviations in experience which is not discussed. Surprising to read that a PET reviewer would not be familiar with PET/CT.	The results may have some links to IGRT due to the imaging nature of the study. However, the decisions being made were related to diagnosis of disease and so do not answer any of the questions in the current study.	++

Littlefair, Brennan, Reed, Williams, andPietrzyk (2012)	Radiology	Quantitative study. Participants (n=7), used eye tracking software along with the think aloud method whilst reviewing one set radiographic images (30). The process was repeated without using the think aloud method. The diagnostic accuracy and decision times were compared.	No significant difference was seen between the two arms of the study in either time to decision or diagnostic accuracy.	Participants were told that they were looking for either one nodule or none. They were told to ignore any other pathology. Doing so reduces the fidelity of the simulation.	It is likely that the method caused participants to deviate away from routine clinical practice. The results confirm the findings of previous authors in relation to the impact of think aloud.	++
Bjork and Hamilton (2011)	Nursing	Quantitative study. A shortened version of a validated study (24 item questionnaire) was sent to Norwegian nurses across 4 centres. n=2000.	Explored the cognitive processes used by Norwegian nurses. Quasirationality was found to be the most common approach (72%) followed by analytical (22%) and intuitive (6%).	Large population, but questions must be asked about the reliability of a questionnaire based approach in decision-making studies. 75 questionnaires were returned with more than 40% of answers missing and were not included in the study. Authors chose to use a shortened version of a validated scale, with little justification.	Useful discussion on the various cognitive process. Setting limitations as in Goyder et al. (2017).	+

Azevedo, Faremo, and Lajoie, (2010)	Radiology	Mixed methods study. Investigated problem-solving strategies during mammogram interpretation.	Three codes generated: *Knowledge states, Radiological observations, radiological findings and diagnosis*. Problem-solving operators are used to generate or instantiate states of radiological knowledge (1) reading a clinical history, (2) placing a set of mammograms on a view-box and identifying individual mammograms in the set, (3) visually inspecting each of the mammograms, (4) identifying mammographic findings and observations, (5) characterizing mammographic findings and observations, (6) providing a definitive diagnosis or a set of differential diagnoses, and (7) specifying	The study attempted to pull together to unpublished theses from different authors into one publication. It appears that the parallel studies used the same participants and case studies making a comparison achievable to some degree.	The development of the cognitive coding system can be used to partly inform the development of the coding system in the current study. However, the description around the final model proposed was very limited and so it is difficult to put in the context of radiotherapy.	+

			subsequent examinations (if Operators and control processes Control processes included goals (the use of the future tense to indicate an intended action), diagnostic planning (the planning of subsequent examinations and their possible interpretations), and meta-reasoning (a participant conducts a self-evaluation of the quality of the evolving diagnostic strategy)			
Lundgrén-Laine (2010)	Nursing	Qualitative study. Authors observed nurses (n=20) in an intensive care unit using a think aloud method. Data was analysed using protocol analysis: RPA, AA, SA***.	Analysis focused around clinical tasks and information needs and coded into 13 categories: admission, special treatments, material resources, adverse events, human resources, administrative data, know-how of personnel, patient information and vital signs, medication,	Coding revolved around activities rather than cognitive thought processes. Good demonstration of how think aloud can be used for alternative results. Good discussion around method and limitations of it	Useful in study design. Setting limitations as in Goyder et al. (2017).	++

			laboratory tests, radiology and imaging, diagnosis, and discharge.			
Dowding et al. (2009)	Nursing	Qualitative study. Authors observed interactions between patients and nurse specialists (n=6). Nurses were also interviewed (n=12) about how they make decisions. The data was analysed using thematic analysis with pre-determined codes derived from a pilot study.	Results demonstrated a similarity to cognitive continuum theory. Authors commented on large use of protocols which limited the use of intuitive processes.	Observations were used to evaluate decision-making processes. The method could have been improved by using a think aloud method. Despite being derived from a pilot study, the use of predetermined codes may have limited the analysis. They categorised participants as experienced if they had more than three years specialist experience (mean 3.2, max 3.5) and in-experienced if they had less than one years' experience. This is quite low	The heavy use of protocols by participants are of interest in the current study. Setting limitations as in Goyder et al. (2017).	+

Hoffman, Aitken, and Duffield (2009)	Nursing	Qualitative study. Authors observed nurses (n=8) (expert and novice) using a think aloud study. Data was analysed using protocol analysis: RPA, AA, SA***.	Demonstrated differences in expert nurses and novice nurses particularly around number of cues collected and proactive behaviour of expert nurses as opposed to novice nurses	Used the method to look at tasks rather than decision-making processes. Didn't link the study to existing decision-making models.	Setting limitations as in Goyder et al. (2017).	+
Funkesson, Anbäcken and Ek (2007)	Nursing	Qualitative study. Authors observed nurses (n=11) during planning tasks using a think aloud study. Data was analysed using protocol analysis: RPA, AA, SA***.	Analysis found the following concepts. RPA: The six most frequently used where sign, valuation, general action, nursing action, paramedic action and goal. AA implicational, significative, causal. SA Communication, Breathing /circulation, Nutrition, Elimination Skin, Activity, Wellbeing, Nursing care, Management. The results demonstrated that decision processes are very much linked to the environment and the profession	A well designed study.	Good description around the think aloud method. Setting limitations as in Goyder et al. (2017)..	++

Manning et al. (2006)	Diagnostic Radiography	Quantitative Study. Eight experienced radiologists, 5 experienced radiographers before and after six months training in chest image interpretation, and 8 undergraduate radiography students were asked to detection and localise significant pulmonary nodules in postero-anterior views of the chest. One hundred and twenty digitised chest images were used. Eye tracking was carried out to investigate differences in visual search strategies between observers. Detection	Performance measures showed the experienced group of radiologists plus radiographers after training were better at the task than the remainder (t-test p=0.046). Differences were shown in the eye-tracking parameters between the groups: saccadic amplitude (ANOVA p=0.00047), number of fixations before and after training (t-test p=0.041), and scrutiny time per decision and per film for the experienced versus the inexperienced observers (t-test p=0.02). Visual coverage reduced with increasing level of experience but this result did not reach significance.	A generally well designed study. Good use of eye tracking technologies that were evaluated well. The use of complete novices in the study could be questioned. They made up a significant proportion of the population and would clearly performance less well that trained staff.	Useful insight into the impact of experience on speed and accuracy of image review. The study did not seek to investigate the decision-making processes used.	++

Graber et al. (2005)	Medicine	Quantitative study. (n=100) cases of diagnostic error were reviewed using patient records and fact-finding methods. Analysed using root cause checklist developed by the Veterans Health Administration	Errors categorised into: Faulty knowledge (3%), faulty data gathering (14%), faulty processing (50%), faulty verification (33%)	The review of the information was carried out using a validated root-analysis tool, but the variation in fact-finding activities and the likely variation in note keeping in the patient records must be considered when reviewing that data	Highlights the prevalence of faulty processing and verification in the decision-making process. Setting limitations as in Goyder et al. (2017).	+
Mitchell and Unsworth (2005)	Occupational Therapy	Qualitative study. Authors used head cameras to observe occupational therapists (n=10) in a community health setting. Analysed using pre-determined codes from previous research	Coded into five categories: Procedural, Interactive, Conditional, Procedural-Interactive, Procedural-Conditional, Interactive-Conditional. Novices used procedural reasoning much more than experts. Experts used more conditional reasoning than the novices.	Interesting use of headcams, but must consider how this impacted on the interactions with patients (both participants and patients)	Setting limitations as in Goyder et al. (2017).	+
Simmons et al. (2003)	Nursing	Qualitative study. Authors observed experienced nurses (n=15) on a ward using a think aloud method. Data was analysed using protocol analysis:	Analysis found the following concepts. RPA: amount, care provider, condition, day, time, and date, device, diagnosis, event, family, frequency, location,	A well-designed study using simulation methods. Good discussion on the use of think aloud and the implication of the results on education.	Interesting discussion on heuristics; some of which may be relevant to IGRT. Setting limitations as in Goyder et al. (2017).	++

		RPA, AA, SA***.	missing clinical data, patient, plan, rationale, status, test, treatment, and value. AA: anticipative (relationships of action and looking forward), causal (relationships of cause and effect), declarative (relationships of stating facts), and evaluative (relationships of judging significance). SA: describe, explain, plan, evaluate, and conclude. Highlighted large use of heuristics** (15 commonly occurred). The most prominent was pattern recognition.			
Greenwood (2000)	Nursing	Qualitative study. Authors asked nurses (n=4) in neonatal intensive care to retrospectively think aloud. This was followed by interviews. Data was analysed using protocol analysis:	Analysis found the following concepts. RPA 15 in total: Status (3 variants), temperature, blood test, psychosocial, fluids, wounds, medication, general appearance, position, age, errors. AA:	Used retrospective think aloud with has been shown to have a greater risk of bias. The Authors prompted the participant from her observation notes, which may further increase risk of bias.	Issues around bias may have links to IGRT. Setting limitations as in Goyder et al. (2017).	+

		RPA, AA, SA***.	Indicative, causal SA: Plan, rationale, interpretation, diagnosis, plan. Several participants commented that they "Did what senior colleagues did"			
Prime and Le Masurier (2000)	Diagnostic radiography	Qualitative study. Authors developed three scenarios which were then acted out by actors (both radiographers and client). Participants (n=56) used think aloud to verbalise their thoughts when watching cases back. Analysis was carried out using a predetermined coding system.	Researchers coded the data into five categories: 1. Subject describes the scene and does not engage with the scenario. 2. Observations on the patient's history and presentation. 3. Observations based on practical knowledge of radiography. 4. Observations based on clinical knowledge drawn from experience or wider reading. 5. Observations of the actors in the videotape. Categories 3 and 5 were the most prominent.	A strength of the study was a large population. The findings also provide a good insight into some of the factors that radiographers consider when making decisions. The method had limited analysis on actual processes as it was not based on the participants' thought processes. The results didn't really report on the thought processes, but gave more of a general overview of things that radiographers think about when making decisions.	The only study using the Think Aloud Method involving Radiographers. Although Diagnostic Radiographers, findings may be of relevance in the current study.	+

Fonteyn and Grobe (1992)	Nursing	Qualitative study. Authors observed nurses (n=10) on a ward using a think aloud study. Data was analysed using protocol analysis: RPA, AA, SA***.	Analysis found the following concepts: RPA 20 in total. Not all reported. Most common: action, amount, problem, sign, time, treatment, and value. Indicative, causal, connotational. RPA: study, conclude, choose, and explain. Pattern recognition and forward reasoning were common heuristics**.	One of the seminal papers quoted by many authors in relation to think aloud and protocol analysis.	Useful discussion of the use of think aloud and protocol analysis. Setting limitations as in Goyder et al. (2017).	++

* SIGN ratings: High quality (++), Acceptable (+), Low quality (-)

**Heuristics are mental short-cuts (Section 2.4.5)

*** Method developed by Fonteyn andGrobe (1992). Referring Phrase Analysis (RPA), Assertional Analysis (AA), Script Analysis (SA). See section 3.4.1 for further explanation.

APPENDIX 2 REFLEXIVE ACCOUNT

This section is something that doesn't come naturally to me, but a review of the literature in Section 3.3.3 highlights the importance of it and I have tried to acknowledge these concepts throughout my data collection, analysis and write-up. Based on the recommendations of Creswell (2013) the following reflexive account will be broken down into two sections. In part one, I will explore my experiences within radiotherapy and image guided radiotherapy. This will be followed by part two, which will discuss how these past experiences shape my interpretation in the current study.

Part one

As a starting point for this section, I reviewed my curriculum vitae. On doing this, a number of key themes can be seen. Until commencing this period of study, I had not really engaged with any qualitative research and knew very little of its existence. My undergraduate degree was in forensic science and was largely a lab-based course, with the majority of the assignments and exams based around quantifiable measurements and how you can draw conclusions from these.

On completing this course, I commenced the PgDip in Radiotherapy and Oncology at Sheffield Hallam University. From the outset, my interest was very much around the technical side of the course and this is where my strengths lay during assessment. This is not to say that I did not get a lot of job satisfaction from working with patients and do my utmost to try and ensure their experiences and care were the best possible whilst undergoing radiotherapy treatment. I was however quick to acknowledge that my interest really revolved around the imaging and treatment planning and I felt that this is where I had the most to offer.

On graduating from Sheffield Hallam, I took up a post at a large cancer centre as a therapeutic radiographer. I would like to think I was very proactive and was one of only a couple of radiographers that were involved in audits and research at such a junior level. Within quite a short period of time, a position was advertised as a dosimetrist and I immediately recognised this as an exciting opportunity. I arranged to spend some time in the physics department on my days off which solidified my initial thoughts that this is where my future lay.

I was lucky enough to work in the centre when the use of IGRT became a real area of priority within the radiotherapy profession. My centre was very proactive in this, and this exposed me to a lot of IGRT review on a daily basis. My confidence in making decisions grew quickly, and this was mainly due to the support and mentorship from an excellent manager who was very good at sharing his knowledge and experience whilst giving me space to make decisions and sometimes mistakes.

Relationships were sometimes stretched between the radiotherapy and the physics department at a management level and this filtered down to those of us working on the shop floor. In addition to this, the protocols at the time were also quite restrictive for the radiographers and it felt at times that my opinion was only asked to “back cover” or “tick a box”. On a positive note, this meant I was exposed to lots of interesting and complex cases and I gained a huge amount of job satisfaction from being involved.

After working in the planning department for a year or so, I was supported to undertake an MSc in radiotherapy treatment planning. This fitted really well with my role in the Department and allowed me to undertake independent study, which ultimately led to my dissertation around IMRT planning in Ewing’s Sarcoma.

In my last year working in the NHS, I became involved in teaching the specialist registrars in my department as part of their fellowship training. I really enjoyed doing this and this led me to investigate teaching elsewhere. I was lucky enough to be given the opportunity to do some guest lecturing at Sheffield Hallam, which ultimately led to me taking up a full-time post. This wasn’t a decision I took lightly as I really enjoyed my job in the NHS and gained a huge amount of job satisfaction. I did, however, acknowledge the limits in terms of career progression at the time and this in part led me to take the path into academia from which I haven’t looked back.

In my five years at the University I have been heavily involved in the technical side of both undergraduate and postgraduate courses. My area of interest has continued to be around imaging and treatment planning and with the support of two colleagues I have increased the focus of IGRT on the undergraduate syllabus quite significantly. I do however feel that it still isn't represented enough on the syllabus and that there is scope to embed it into the syllabus more. This is something I hope that we will be discussing during the next revalidation to try and reach a consensus.

Part two

In writing this reflexive account, there are two areas in my history which I feel are particularly relevant to the current study. These are my lack of experience in qualitative research and my strong opinions around IGRT decision-making and teaching.

I had to spend a lot of time reading and seeking the advice of colleagues and my supervisors before commencing my final project. Despite this, I acknowledge that I was very much a novice at the beginning, and it felt like an incredibly steep learning curve that involved a new language that I was not familiar with. This lack of knowledge was very evident in my pilot study, which proved to be invaluable in my development. My skills as a qualitative researcher definitely improved after my first couple of observations and interviews, and I felt able to sit back and let the participants guide conversation on what they felt was important.

I do feel that my experience in IGRT decision-making and teaching had the largest potential to bias my findings, and I have worked hard to constantly bear this in mind throughout the data collection and analysis. Through doing this, I genuinely feel that my research represents the voices of my participants and not my own views. One example of where this comes through my research is around perceptions of when radiographers should start reviewing images. My views have always been that radiographers should be carrying out this role as soon as they start working as a radiographer. This was the view of some of the radiographers in my study, however a number of them felt that radiographers should have some base experience in general radiotherapy treatment delivery before they are given the responsibilities involved in IGRT. I believe I have created a balanced discussion around this in both my results and discussion sections.

I was also conscious that my experience in the NHS is purely based on the experiences in one clinical centre. It is quite widely accepted that a range of practices exist within a radiotherapy department in terms of protocols and how members of the multidisciplinary team worked together. I was lucky enough to work ina department where these links were very strong most of the time, but anecdotally I know that this is not always the case in other centres. As with my opinions around radiographer experience, I was careful not to portray my views around best practice, but again voiced the views of my participants.

Summary

Despite being a little cynical at first, I have found this opportunity to be reflexive a very useful process and I am confident that it has allowed me to position myself within my study and consider how I may impact on the analysis and ultimately the conclusions this study comes to.

Excerpts of Portfolio

Below are links and screenshots of two excerpts of the reflective portfolio completed as part of the taught element of the Doctorate in Professional Studies.

Reflection on first data collection:

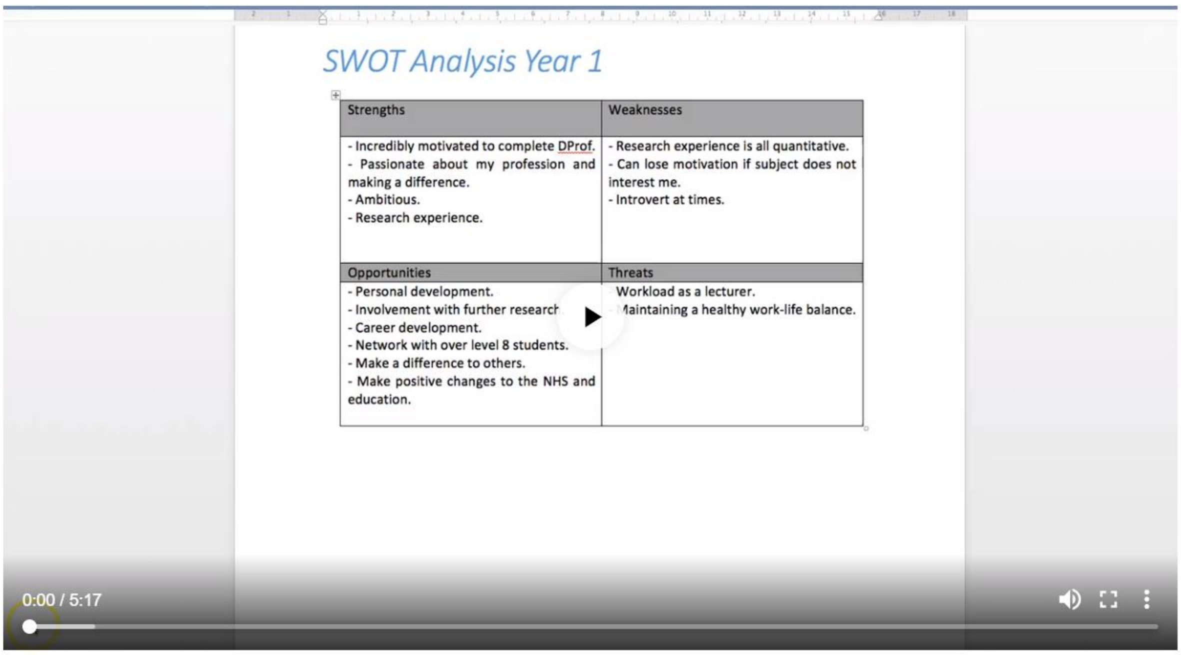
https://atlas.pebblepad.co.uk/atlas/hallam/Viewer/Submission/ViewV5/3572/341706/0/yRr9jH8pWz85gnMZG5m3GdsHnZ

FIGURE A2.0 SCREENSHOT OF REFLECTION ON FIRST DATA COLLECTION

Reflection on swot analysis:

https://atlas.pebblepad.co.uk/atlas/hallam/Viewer/Submission/ViewV5/3572/341706/0/yRr9jH8pWz85g54w5ZMkWWd7gw

FIGURE A2.1 SCREENSHOT OF REFLECTION ON FIRST SWOT ANALYSIS



SWOT Analysis Year 1

Strengths	Weaknesses
- Incredibly motivated to complete DProf. - Passionate about my profession and making a difference. - Ambitious. - Research experience.	- Research experience is all quantitative. - Can lose motivation if subject does not interest me. - Introvert at times.
Opportunities	**Threats**
- Personal development. - Involvement with further research - Career development. - Network with over level 8 students. - Make a difference to others. - Make positive changes to the NHS and education.	- Workload as a lecturer. - Maintaining a healthy work-life balance.

APPENDIX 3 INTERVIEW PROTOCOL

Introduction

- Welcome participant and thank them for meeting for a second time
- Explain that some initial analysis has been conducted and I'd like to ask some questions in relation to it as well as some more general questions about the IGRT process.
- Explain that it will be recorded and transcribed
- Emphasise that they will remain anonymous in the analysis and thesis unless they say something that is deemed to be grossly negligent or a risk to patients.
- Ask if they have any questions and ask if they are happy to continue

Part One

- Watch the observations back and use key events as a prompt for questions.
- This phase may be very different for each participant dependant on the observation.

Part Two

Questions will be open-ended and may be guided by what was discussed in section one. Areas to be covered are:

- Are processes different for
    - Different anatomical sites?
    - Online and offline
- How does time impact on decisions?
- How are other members of the radiotherapy team and MDT involved in decision-making?
- How does their involvement impact on the decisions made?
- Discuss participant's thoughts of the impact of radiographer experience as a whole and with IGRT
- Discuss participant's thoughts on when radiographers should start carrying out IGRT
- How is training conducted in the participant's department?
- Discuss participant's thoughts on the training they received?

- Discuss participant’s thoughts on pre-registration training and what their role should be within it?

Round up

- Ask if there’s anything else they would like to add
- Explain what will happen to this data
- Ask if they would be happy to participate in member checking
- Thank them for their help

APPENDIX 4 ETHICAL APPROVALS

Approval from Sheffield Hallam University

centre for
health and social care
research

24032015

RE: 2013/HWB/HSC/DPS/11

Dear Mark COLLINS

This letter relates to your research proposal

Clinical reasoning in image-guided radiotherapy

This proposal was submitted to the Faculty Research Ethics Committee for ethics and scientific review. It has been reviewed by two independent reviewers and has been passed as satisfactory. The comments of the reviewers are enclosed. You will need to ensure you have all other necessary permission in place before proceeding, for example, from the Research Governance office of any sites outside the University where your research will take place. This letter can be used as evidence that the proposal has been reviewed ethically and scientifically within Sheffield Hallam University.

Good luck with your project.

Peter Allmark

Peter Allmark
Chair Faculty Research Ethics Committee
Faculty of Health and Well-being
Sheffield Hallam University
32 Collegiate Crescent
S10 2BP

0114 225 5727
p.allmark@shu.ac.uk

Centre for Health and Social Care Research
Faculty of Health and Wellbeing   Montgomery House   32 Collegiate Crescent   Sheffield, S10 2BP   UK
Telephone +44 (0) 114 225 5854   Fax +44 (0) 114 225 4377
Email: chscr@shu.ac.uk   www.shu.ac.uk/chscr
Executive Dean of Faculty Professor Rhiannon Billingsley

Sheffield Hallam University

Letters of access for participating centres (information redacted to maintain anonymity)

[redacted]

Dear [redacted]

[redacted]

NIHR CSP Ref: 18942

SHUREC Ref: N/A

2013/HWB/HSC/DPS/11

Title: Clinical Reasoning in Image Guided Radiotherapy: An Observational Study.

Sponsor: [redacted]

Chief Investigator: Mark Lee Collins, Sheffield Hallam

I am pleased to confirm that [redacted] has reviewed the above study and agrees that it has approval to commence at [redacted]

The following documents have been reviewed:

– Sheffield Hallam University Research Ethics Approval	24 Mar 15
– Study Proposal	Unversioned, undated
– Honorary Contract	Mark Lee Collins, Expires 31 Nov 15
– GCP Certificate	Mark Lee Collins, 27 Apr 15

Please ensure that the study is run in accordance with The Data Protection Act 1998, NHS Confidentiality Code of Practice, Caldicott Principles, The Human Tissue Act 2004, Good Clinical Practice and the NHS Research Governance Framework for Health and Social Care, Second Edition April 2005.

Yours sincerely

[redacted]

Director of R&D, [redacted]

[redacted]

NHS

[redacted]

12/05/2015

Research & Innovation

[redacted]

Mark L Collins
Clinical Services Manager
Sheffield Hallam University
F423 Robert Winston building
Collegiate Crescent Campus
Sheffield
S10 2BP

Dear Mark L Collins

Re: NHS Permission at [redacted] Clinical Reasoning in Image Guided Radiotherapy: An Observational [redacted] R&I Number: RD15/158: REC: GT/RDSC

I confirm that *NHS Permission for research* has been granted for this project at [redacted] NHS Permission is granted based on the information provided in the documents listed below. All amendments (including changes to the research team) must be submitted in accordance with guidance in IRAS. Any change to the status of the project must be notified to the R&I Department.

The study must be conducted in accordance with the *Research Governance Framework for Health and Social Care*, ICH GCP (if applicable), the terms of the Research Ethics Committee favourable opinion (if applicable) and NHS Trust policies and procedures (see [redacted] including the requirements for research governance and clinical trials performance management listed in appendix 1 and 2 . NHS permission may be withdrawn if the above criteria are not met including the requirements for clinical trials performance

[redacted] participates in the NHS risk pooling scheme administered by the NHS Litigation Authority ""Clinical Negligence Scheme for NHS Trusts"" for: (i) medical professional and/or medical malpractice liability; and (ii) general liability. NHS Indemnity for negligent harm is extended to researchers with an employment contract (substantive or honorary) with the Trust. The Trust only accepts liability for research activity with NHS Permission

The Trust therefore accepts liability for the above research project and extends indemnity for negligent harm. Should there be any changes to the research team please ensure that you inform the R&I Department and that s/he obtains an appropriate contract, or letter of access, with the Trust if required.

Yours sincerely

[redacted]

Associate Director of R&I

[redacted] NHS

[redacted]

Date: 05/07/2015

Dear Mr Collins

Letter of access for research

This letter confirms your right of access to conduct research for the purposes of the audit proposal as outlined in your email application, through [redacted] NHS Foundation Trust for the purpose and on the terms and conditions set out below. This right of access commences on 06/07/2015 and ends on 06/07/2016 unless terminated earlier in accordance with the clauses below.

You have a right of access to conduct such research as confirmed in writing in the letter of permission for research from this NHS organisation. Please note that you cannot start the research until the Principal Investigator for the research project has received a letter from us giving permission to conduct the project.

The information supplied about your role in research at [redacted] has been reviewed and you do not require an honorary research contract with this NHS organisation. We are satisfied that such pre-engagement checks as we consider necessary have been carried out.

You are considered to be a legal visitor to [redacted] Trust premises. You are not entitled to any form of payment or access to other benefits provided by this NHS organisation to employees and this letter does not give rise to any other relationship between you and this NHS organisation, in particular that of an employee.

While undertaking research through [redacted] Trust you will remain accountable to your employer Sheffield Hallam University but you are required to follow the reasonable instructions of [redacted] NHS organisation or those given on their behalf in relation to the terms of this right of access.

Where any third party claim is made, whether or not legal proceedings are issued, arising out of or in connection with your right of access, you are required to co-operate fully with any investigation by this NHS organisation in connection with any such claim and to give all such assistance as may reasonably be required regarding the conduct of any legal proceedings.

You must act in accordance with [redacted] Trust policies and procedures, which are available to you upon request, and the Research Governance Framework.

You are required to co-operate with [redacted] Trust in discharging its duties under the Health and Safety at Work etc Act 1974 and other health and safety legislation and to take reasonable care for the health and safety of yourself and others while on [redacted] Trust premises. You must observe the same standards of care and propriety in dealing with patients, staff, visitors, equipment and premises as is expected of any other contract holder and you must act appropriately, responsibly and professionally at all times.

You are required to ensure that all information regarding patients or staff remains secure and *strictly confidential* at all times. You must ensure that you understand and comply with the requirements of the NHS Confidentiality Code of Practice (http://www.dh.gov.uk/assetRoot/04/06/92/54/04069254.pdf) and the Data Protection Act 1998. Furthermore you should be aware that under the Act, unauthorised disclosure of information is an offence and such disclosures may lead to prosecution.

You should ensure that, where you are issued with an identity or security card, a bleep number, email or library account, keys or protective clothing, these are returned upon termination of this arrangement. Please also ensure that while on the premises you wear your ID badge at all times, or are able to prove your identity if challenged. Please note that this NHS organisation accepts no responsibility for damage to or loss of personal property.

We may terminate your right to attend at any time either by giving seven days' written notice to you or immediately without any notice if you are in breach of any of the terms or conditions described in this letter or if you commit any act that we reasonably consider to amount to serious misconduct or to be disruptive and/or prejudicial to the interests and/or business of this NHS organisation or if you are convicted of any criminal offence. Your substantive employer is responsible for your conduct during this research project and may in the circumstances described above instigate disciplinary action against you.

[redacted] Trust will not indemnify you against any liability incurred as a result of any breach of confidentiality or breach of the Data Protection Act 1998. Any breach of the Data Protection Act 1998 may result in legal action against you and/or your substantive employer.

If your current role or involvement in research changes, or any of the information provided in your Research Passport changes, you must inform your employer through their normal procedures. You must also inform your nominated manager in this NHS organisation.

Yours sincerely

[redacted]

Research Manager, [redacted] Trust

cc: [redacted] Trust
Trust
Trust
HR Partner, Sheffield Hallam University

NHS
National Institute for Health Research
Clinical Research Network

Certificate of Completion

Mark Collins

has completed

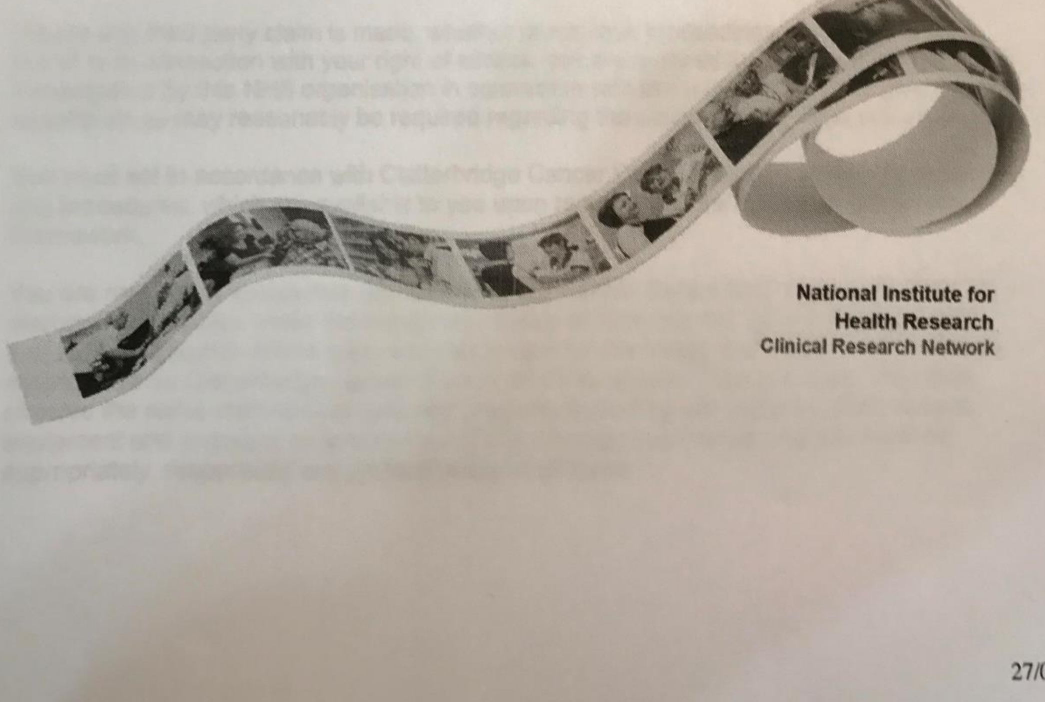
Introduction to Good Clinical Practice (GCP) e-learning course

A practical guide to ethical and scientific quality standards in clinical research

on 27/04/2015

Modules completed

Introduction to Research in the NHS
Good Clinical Practice and Standards in Research
Study Set-up and Responsibilities
The Process of Informed Consent
Data Collection and Documentation
Safety Reporting
Summary



National Institute for Health Research
Clinical Research Network

APPENDIX 5 PARTICIPANT INFORMATION SHEET

Participant information sheet

Study title:	Clinical reasoning in Image Guided Radiotherapy: An observational study
Chief investigator	Mark Collins
Telephone number	0114 225 6524

Study Sponsor: Sheffield Hallam University

We would like to invite you to take part in our research study. Before you decide we would like you to understand why the research is being done and what it would involve for you. Talk to others about the study if you wish. Ask us if there is anything that is not clear.

Participant name:

1. What is the purpose of this study?

The purpose of this study is to gain an understanding of the clinical reasoning processes used by therapeutic radiographers when using 3D- Cone Beam CT (3D-CBCT).

2. Why have I been invited?

We are inviting members of the radiotherapy community with varying levels of 3D-CBCT experience to take part in the study. We would very much appreciate your consideration of becoming a participant.

3. Do I have to take part?

Your decision to take part in this study is entirely voluntary. You may refuse to participate or you can withdraw from the study at any time.

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

If you are interested in participating in the study, all you have to do is to email the researcher listed at the end of this information leaflet. You will then be contacted and

given an opportunity to ask questions about the study. You will be given plenty of time to decide whether you would like to take part or not.

The study will be using a method known as a think aloud Observation. You will be asked to review three patients on a verification terminal as you would in clinical practice. You will be asked to verbalise your thought processes as you review the patients. The terminal screen will be video recorded along with your verbalisations.

The observation will be followed up two weeks later with a short interview of 30-45 minutes . The researcher will use this interview to clarify their interpretations of what they observed and gain a better understanding of the processes you used.

The researcher will also seek to gain an understanding of how your training and experience impacts how you make clinical decisions.

The aim of the study is not to make judgement on your IGRT skills and you are not being tested in any way. All of the data collected in the observation and interview will remain anonymous and individual findings will not be reported back to anyone in your department.

Following the observation and interview the researcher will carry out a de-brief, where you will be given the opportunity to discuss the experience and clarify any questions or concerns you have about the study.

5. Expenses and payments

You will not be paid for taking part in this study.

6. What will I have to do?

The observation and interview will take about one hour. You may also be contacted at a later date should the researcher have any queries.

7. What are the possible disadvantages and risks of taking part?

There are no risks to taking part in this study. There may be some inconvenience since you will be giving up time to take part.

8. What are the possible benefits of taking part?

There are no specific intended benefits. However, you will contributing to research and education of the radiotherapy community. A digital badge will be issued by SHU to each participated to acknowledge the skills demonstrated in the observation. You may also find that participating in the study is both enjoyable and rewarding.

9. What if there is a problem or I want to complain?

If you have any queries or questions please contact: Mark Collins, Principal Investigator. Contact details m.l.collins@shu.ac.uk; 0114 225 6524

10. Will my taking part in this study be kept confidential?

All of the recordings will be anonymised and will not been seen by anyone outside of the research team.

The documents relating to the administration of this research, such as the consent form you sign to take part will be kept in a project file. This is locked away securely. The file might be checked by people in authority who want to make sure that researchers are

following the correct procedures. These people will not pass on your details to anyone else. These documents will be destroyed seven years after the end of the study.

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

The results of this study will form the basis of a thesis for a Doctorate of Professional Studies. It is also the intention of the researcher to publish the results of this study in a peer-reviewed journal.

The final manuscript will also be published on the Sheffield Hallam University Research Archive (SHURA) which is an open access repository containing scholarly outputs and publications written by researchers at Sheffield Hallam University.

14. Who is sponsoring the study?

The sponsor of the study has the duty to ensure that it runs properly and that it is insured. In this study, the sponsor is Sheffield Hallam University.

15. Who has reviewed this study?

All research based at Sheffield Hallam University is looked at by a group of people called a Research Ethics Committee. This Committee is run by Sheffield Hallam University but its members are not connected to the research they examine. The Research Ethics Committee has reviewed this study and given a favourable opinion

APPENDIX 6 PARTICIPANT CONSENT FORM

Participant consent form

Study title:	Clinical reasoning in Image Guided Radiotherapy: An observational study
Chief investigator	Mark Collins
Telephone number	0114 225 6524

Participant name	

	Please read the following statements and put your initials in the box to show that you have read and understood them and that you agree with them	**Please initial each box**
1	**I confirm that I have read and understood the information sheet dated for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.**	

2	**I understand that my involvement in this study is voluntary and that I am free to withdraw at any time, without giving any reason and without the progress on my educational course being affected.**	
3	**I understand that responsible individuals from the Sponsor and the Research Ethics Committee may look at data collected during the study, where it is relevant to this research. I give permission for these individuals to have access to this data.**	
4	**I agree to take part in this study**	

To be filled in by the participant

I agree to take part in the above study

Your name

Signature

Date

To be filled in by the person obtaining consent

I confirm that I have explained the nature, purposes and possible effects of this research study to the person whose name is printed above.

Name of investigator

Signature

Date

Filing instructions

1 copy to the participant

1 original in the Project or Site file

Version 1.0

APPENDIX 7 PROMOTIONAL MATERIAL

Version 1.0

APPENDIX 8 CASE STUDIES

This section will present each of the case studies developed in collaboration with the imaging lead of the respective departments. A brief description of each case will be given as well as supporting images and the rating given by the National IGRT expert.

Case one- Patient with cervical cancer

Complexity rating four

Case one involved images of a patient diagnosed with cervical cancer. Multiple target volumes were contoured on the study set including a gross target volume (GTV) two clinical target volumes (CTV) and a planning target volume (PTV). The bladder and rectum were both contoured and defined as organs at risk (OAR). The most clinically significant difference highlighted by the expert between the verification scan and the treatment scan was the size of the bladder, which was significantly smaller in the verification scan.

FIGURE A8.0 SAGITTAL IMAGE IN MOVING WINDOW VIEW (VARIAN MEDICAL SYSTEMS)

FIGURE A8.1 AXIAL IMAGE IN MOVING WINDOW VIEW (VARIAN MEDICAL SYSTEMS)

Case Two- Patient with lung cancer

Complexity rating three

Case two involved images of a patient with a large mediastinal lung tumour. The study set had a single GTV, CTV and PTV. The spinal cord was contoured as an OAR. The national expert commented on the changes around the PTV which may have been disease extension or consolidation.

FIGURE A8.2 CORONAL IMAGE IN MOVING WINDOW VIEW (VARIAN MEDICAL SYSTEMS)

FIGURE A8.3 CORONAL IMAGE IN MOVING WINDOW VIEW (VARIAN MEDICAL SYSTEMS)

Case Three- Patient with head and neck cancer

Complexity rating three

Case three involved images of a patient with head and neck cancer, with the primary disease situated in the larynx. One G TV, three CTVs and three PTVs were contoured. The spinal cord, brain stem, parotid and mandible were contoured as OARs. The only feature of clinical concern raised by the national expert was a slight change in chin and shoulder position.

FIGURE A8.4 SAGITTAL IMAGE IN MOVING WINDOW VIEW (VARIAN MEDICAL SYSTEMS)

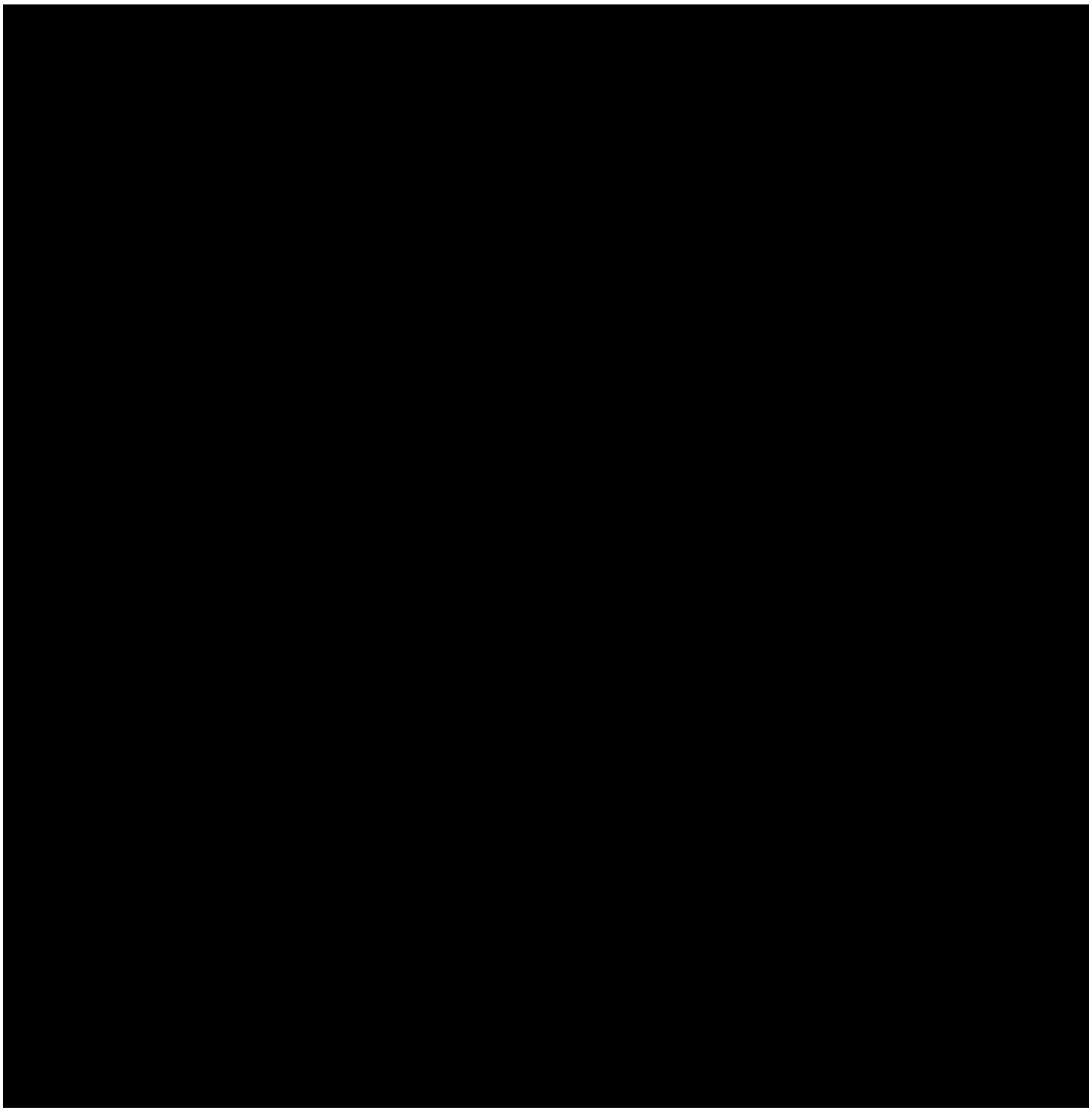
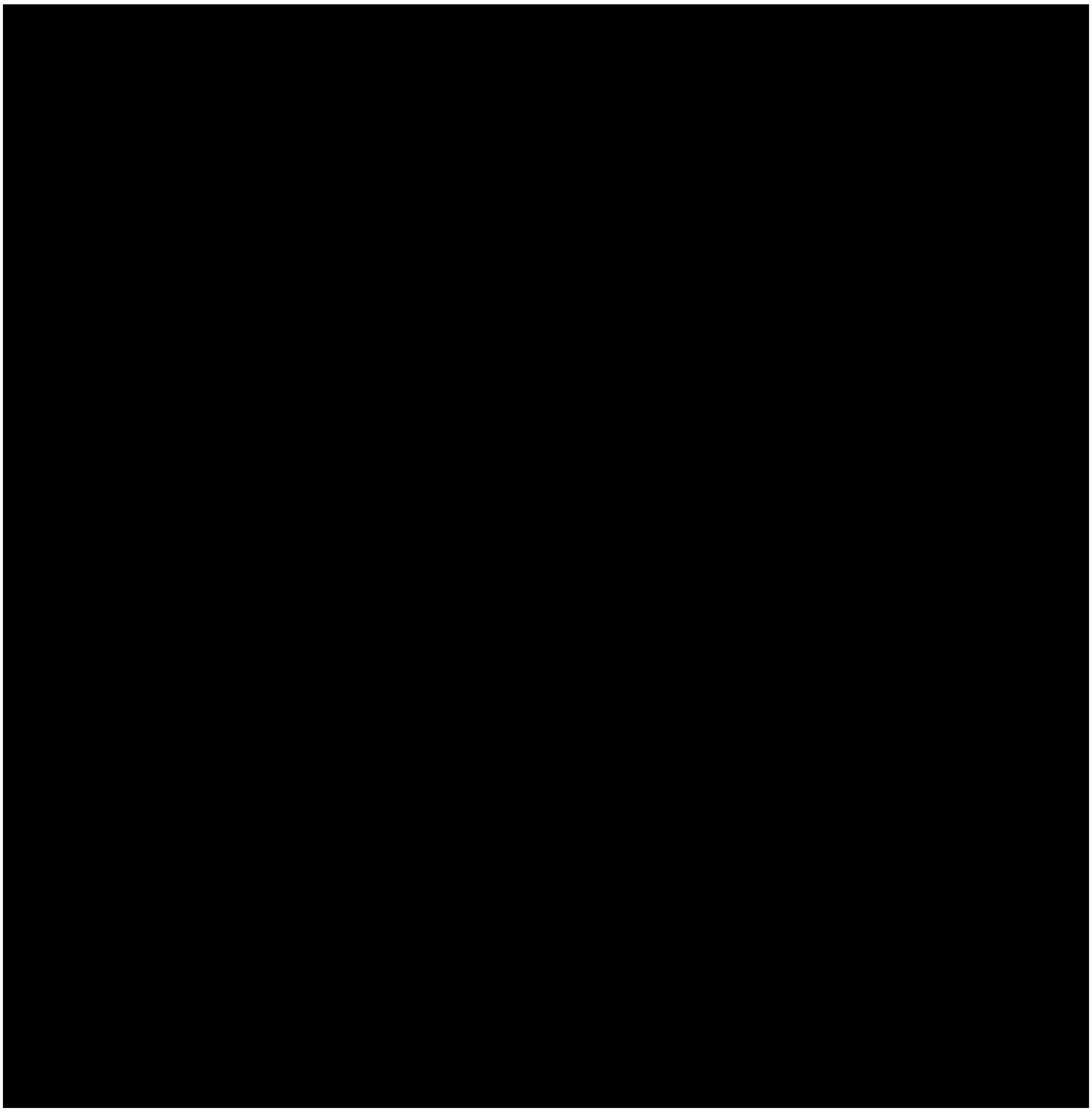


FIGURE A8.5 AXIAL IMAGE IN MOVING WINDOW VIEW (VARIAN MEDICAL SYSTEMS)



Case Four- Patient with bladder cancer

Complexity rating two

Case four involved images of a patient with prostate cancer No GTV, one CTV and one PTV were contoured. The rectum was contoured as OARs. Despite a small change in bladder size, no areas of concern were raised by the national expert.

FIGURE A8.6 CORONAL IMAGE OF VERIFICATION VIEW (ELEKTA)

[redacted]

FIGURE A8.7 AXIAL IMAGE OF VERIFICATION VIEW (ELEKTA)

[redacted]

Case Five- Patient with lung cancer

Complexity rating four

Case five involved images of a patient with a large mediastinal lung tumour. The study set had a single GTV, CTV and PTV . The spinal cord was contoured as an OAR. The national expert commented on the weight loss of the patient and felt it may be a significance.

FIGURE A8.8 CORONAL IMAGE IN OVERLAY VIEW. THE PINK IMAGE IS THE VERIFICATION SCAN AND THE GREEN THE PLANNING SCAN (ELEKTA)

FIGURE A8.9 AXIAL IMAGE IN OVERLAY VIEW. THE PINK IMAGE IS THE VERIFICATION SCAN AND THE GREEN THE PLANNING SCAN (ELEKTA)

Case six- Patient with head and neck cancer

Complexity rating three

Case six involved images of a patient with head and neck cancer. The study set had a single GTV, three CTVs and three PTVs . The spinal cord, brain stem, parotid and mandible were contoured as OARs. The only feature of clinical concern raised by the national expert was the change in shoulder position and thus the position of the lower neck nodes.

FIGURE A8.10 CORONAL IMAGE IN OVERLAY VIEW. THE PINK IMAGE IS THE VERIFICATION SCAN AND THE GREEN THE PLANNING SCAN (ELEKTA)

FIGURE A8.11 AXIAL IMAGE IN OVERLAY VIEW. THE PINK IMAGE IS THE VERIFICATION SCAN AND THE GREEN THE PLANNING SCAN (ELEKTA)

Case seven- Patient with head and neck cancer

Complexity rating four

Case seven involved images of a patient with head and neck cancer with the primary tumour in the base of the tongue. The study set had a single GTV, three CTVs and three PTVs . The spinal cord, brain stem, parotid and mandible were contoured as OARs. The only feature of clinical concern raised by the national expert was the weight loss that may be of significance.

FIGURE A8.12 SAGITTAL IMAGE IN SPLIT WINDOW VIEW (VARIAN MEDICAL SYSTEMS)

FIGURE A8.13 AXIAL IMAGE IN SPLIT WINDOW VIEW (VARIAN MEDICAL SYSTEMS)

Case eight- Patient with lung cancer

Complexity rating three

Case eight involved images of a patient with a large upper lobe lung tumour. The study set had a single GTV, CTV and PTV . The spinal cord was contoured as an OAR. The national expert felt the changes seen around the PTV may have been of clinical significance.

FIGURE A8.13 AXIAL IMAGE IN SPLIT WINDOW VIEW (VARIAN MEDICAL SYSTEMS)

FIGURE A8.14 CORONAL IMAGE IN SPLIT WINDOW VIEW (VARIAN MEDICAL SYSTEMS)

Case nine- Patient with bladder cancer

Complexity rating three

Case nine involved images of a patient with prostate cancer No GTV, one CTV and one PTV were contoured. The rectum and bowel bag were contoured as OARs. The national expert commented on the changes in bowel gas and felt they may be of clinical significance.

FIGURE A8.14 SAGITTAL IMAGE IN SPLIT WINDOW VIEW (VARIAN MEDICAL SYSTEMS)

FIGURE A.16AL IMAGE IN SPLIT WINDOW VIEW (VARIAN MEDICAL SYSTEMS)

[redacted]

FIGURE A8.15 AXIAL IMAGE IN SPLIT WINDOW VIEW (VARIAN MEDICAL SYSTEMS)

APPENDIX 9 MEMBER CHECKING QUESTIONNAIRE

Clinical Reasoning in Image Guided Radiotherapy: A Qualitative Investigation of Therapeutic Radiographers.

Please use this form to share your thoughts on the data that I have presented. You may wish to comment on whether you feel the data accurately reflects practice or if I've missed anything. All of your replies will be kept in the strictest confidence.

Name

Your answer

Centre

Your answer

Contact email adress

Your answer

Please share your thoughts below, using whatever format you find easiet.

Your answer

SUBMIT

Never submit passwords through Google Forms.

APPENDIX 10 SAMPLE RPA AND AA

M: Okay, so I'm just going to do an auto-match

So what our protocol online is to do is that we would review to see that everything was okay, as long as it's been covered then it can go ahead and treat

I'm just having a look through here, I'm just going to change the contrast to make the bladder a bit more visible (obs scrolling axial)

Yes, so the bladder volume looks slightly bigger, bigger than the GTV, so I can obviously go ahead and treat online because it's covered by the PTV

The bowels again, I've had a look at those to make sure nothing was obviously making a change (obs sagittal view)

Just flicking between the two, between the reference and the localisation

That's looks okay, you can just see the slight difference, so if I was reviewing it offline then I would want to make sure that we optimised our GTV coverage so, I've just done that wrong

There we go, so when you click on the correction button it takes away the rotation, anyway the rotations doesn't seem too bad, so just changing the sup inf and the ant post position

The protocol is that we don't make corrections or changes greater than 3 mmm to what we do on the auto-match, unless you think is compromising coverage So I would say that that's the better match

(obs scolling through all planes)

This would then be, because I've changed it more than 3 mm, then the next fraction it wouldn't be reviewable by a Level 1 radiographer, so it would have to be a Level 2 online to accept the correction

Lung

M: Okay, so doing an auto-match again

Then having a quick look through, there looks to be, changing the settings again, quite a bit of change to the patient contour and around the GTV as well

The rotations aren't too bad, set those

So online check, I'd be happy to treat on that because nothing is going to stop us from treating, the only thing I would do would be to get some physics planning input, just to make sure that the change to the contour didn't impact on the overall dose

Yes, so again I'd set to treat on that

227: 1 stating f...	1 stating fact by Mark Collins
228: 2 Signific...	2 Significance by Mark Collins
230: 4 Cause a...	4 Cause and Effect by Mark
225: Software...	Software Manipulation by Mark
11: Target Vol...	Target Volume by Mark Collins
229: 3 Evaluate	3 Evaluate by Mark Collins
27: Intermedia...	Intermediate decisions by Mark
229: 3 Evaluate	3 Evaluate by Mark Collins
222: Changes i...	Changes in anatomy by Mark
229: 3 Evaluate	3 Evaluate by Mark Collins
229: 3 Evaluate	3 Evaluate by Mark Collins
225: Software...	Software Manipulation by Mark
11: Target Vol...	Target Volume by Mark Collins
27: Intermedia...	Intermediate decisions by Mark
229: 3 Evaluate	3 Evaluate by Mark Collins
227: 1 stating f...	1 stating fact by Mark Collins
210: Patient p...	Patient position by Mark Collins
228: 2 Signific...	2 Significance by Mark Collins
226: Written G...	Written Guidance by Mark
219: Final Deci...	Final Decision by Mark Collins
19: MDT	MDT by Mark Collins
229: 3 Evaluate	3 Evaluate by Mark Collins
227: 1 stating f...	1 stating fact by Mark Collins
11: Target Vol...	Target Volume by Mark Collins
229: 3 Evaluate	3 Evaluate by Mark Collins
229: 3 Evaluate	3 Evaluate by Mark Collins
210: Patient p...	Patient position by Mark Collins
229: 3 Evaluate	3 Evaluate by Mark Collins
219: Final Deci...	Final Decision by Mark Collins
19: MDT	MDT by Mark Collins

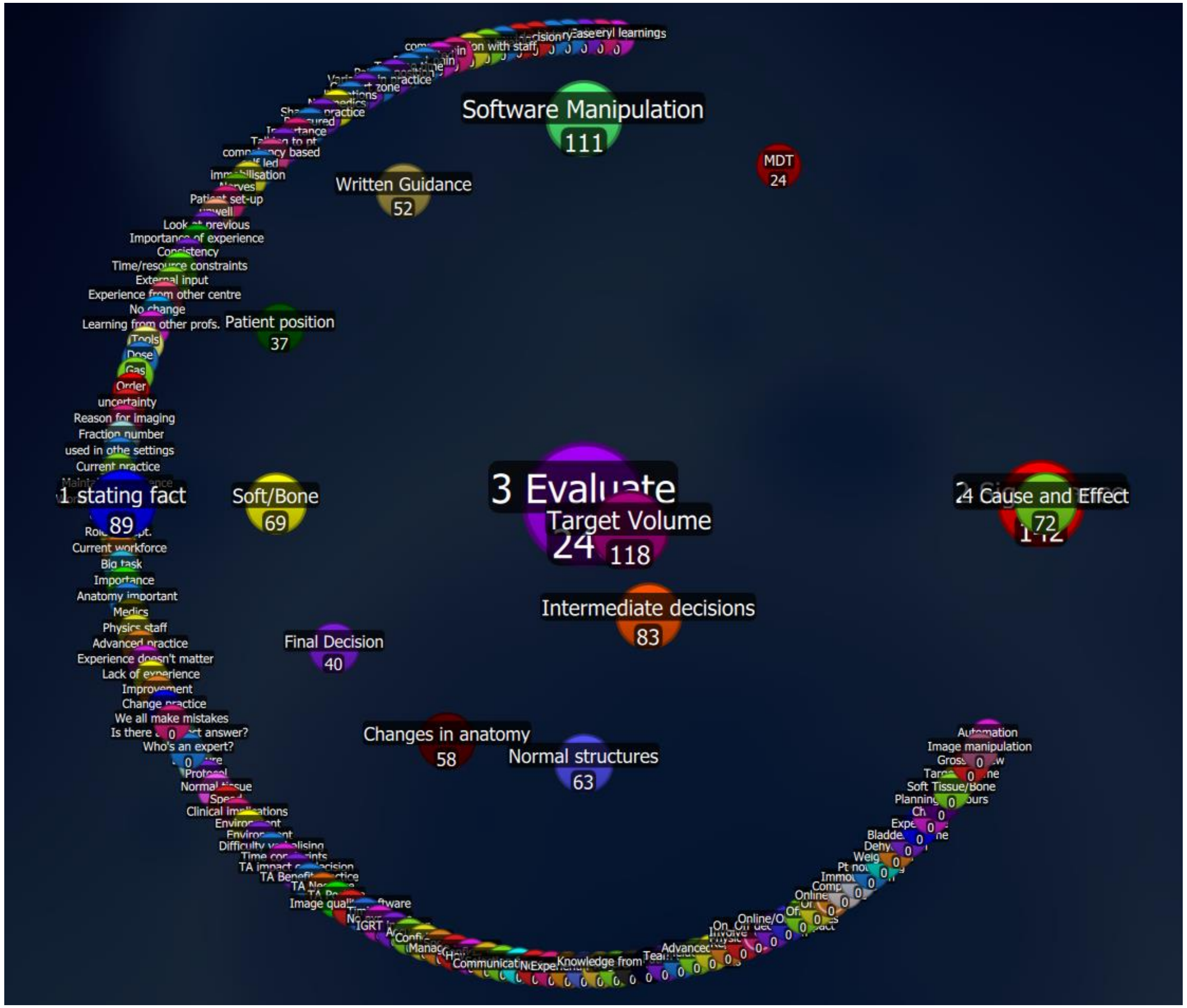
H&N

M: Okay so going just on the auto-match, my first thoughts are to check the spine position
So rotations are minimal, I'm happy with that
The actual translations are good
Just scrolling through them, having a look through, checking the contour
Looks to have been some weight loss, that's something I'd get checked out with physics planning, to make sure that the impact on the dose isn't too great then also making sure they are able to eat okay, because I looked at it and they'd lost quite a lot of weight, quite a large change down here, so making sure if they've got dieticians appointments and are able to manage feeding
So I'll have a look at the main problematic area which is down here (obs around lowe neck nodes)
There is a large difference on this, this is something I would possibly even get the planning round to review online to get their input onto it
I'd say that it would appear that we are treating most of what we want to treat, it would be just the dose impact really to the patient
Sometimes also just have a look to see the position where they actually are in the mask to begin with and they've set up so that they're very, they're in a very good position from the start, check that there's no difference between the two images

Q: Next up, thank you

227: 1 stating f...	1 stating fact by Mark Collins
228: 2 Signific...	2 Significance by Mark Collins
16: Normal str...	Normal structures by Mark
210: Patient p...	Patient position by Mark Collins
229: 3 Evaluate	3 Evaluate by Mark Collins
225: Software...	Software Manipulation by Mark
229: 3 Evaluate	3 Evaluate by Mark Collins
222: Changes i...	Changes in anatomy by Mark
19: MDT	MDT by Mark Collins
229: 3 Evaluate	3 Evaluate by Mark Collins
11: Target Vol...	Target Volume by Mark Collins
229: 3 Evaluate	3 Evaluate by Mark Collins
19: MDT	MDT by Mark Collins
11: Target Vol...	Target Volume by Mark Collins
229: 3 Evaluate	3 Evaluate by Mark Collins
229: 3 Evaluate	3 Evaluate by Mark Collins

APPENDIX 11 RPA AND AA OVERLAY



APPENDIX 12 EXAMPLE SA CODING

BLADDER

M: Okay, so I'm just going to do an auto-match

So what our protocol online is to do is that we would review to see that everything was okay, as long as it's been covered then it can go ahead and treat

I'm just having a look through here, I'm just going to change the contrast to make the bladder a bit more visible (obs scrolling axial)

Yes, so the bladder volume looks slightly bigger, bigger than the GTV, so I can obviously go ahead and treat online because it's covered by the PTV

The bowels again, I've had a look at those to make sure nothing was obviously making a change (obs sagittal view)

Just flicking between the two, between the reference and the localisation

That's looks okay, you can just see the slight difference, so if I was reviewing it offline then I would want to make sure that we optimised our GTV coverage so, I've just done that wrong

There we go, so when you click on the correction button it takes away the rotation, anyway the rotations doesn't seem too bad, so just changing the sup inf and the ant post position

The protocol is that we don't make corrections or changes greater than 3 mmm to what we do on the auto-match, unless you think is compromising coverage So I would say that that's the better match

(obs scolling through all planes)

This would then be, because I've changed it more than 3 mm, then the next fraction it wouldn't be reviewable by a Level 1 radiographer, so it would have to be a Level 2 online to accept the correction

LUNG

M: Okay, so doing an auto-match again

Then having a quick look through, there looks to be, changing the settings again, quite a bit of change to the patient contour and around the GTV as well

The rotations aren't too bad, set those

So online check, I'd be happy to treat on that because nothing is going to stop us from treating, the only thing I would do would be to get some physics planning input, just to make sure that the change to the contour didn't impact on the overall dose

Yes, so again I'd set to treat on that

2: 2 Optimise i...	2 Optimise image by Mark Collins
7: 5 Explain	5 Explain by Mark Collins
2: 2 Optimise i...	2 Optimise image by Mark Collins
3: 3 Evaluate w...	3 Evaluate what looking at and if goo
4: 6 Choose	6 Choose by Mark Collins
3: 3 Evaluate w...	3 Evaluate what looking at and if goo
2: 2 Optimise i...	2 Optimise image by Mark Collins
2: 2 Optimise i...	2 Optimise image by Mark Collins
7: 5 Explain	5 Explain by Mark Collins
2: 2 Optimise i...	2 Optimise image by Mark Collins
7: 5 Explain	5 Explain by Mark Collins
7: 5 Explain	5 Explain by Mark Collins
2: 2 Optimise i...	2 Optimise image by Mark Collins
4: 6 Choose	6 Choose by Mark Collins
2: 2 Optimise i...	2 Optimise image by Mark Collins
3: 3 Evaluate w...	3 Evaluate what looking at and if goo
3: 3 Evaluate w...	3 Evaluate what looking at and if goo
4: 6 Choose	6 Choose by Mark Collins
7: 5 Explain	5 Explain by Mark Collins

H&N

M: Okay so going just on the auto-match, my first thoughts are to check the spine position
So rotations are minimal, I'm happy with that
The actual translations are good
Just scrolling through them, having a look through, checking the contour
Looks to have been some weight loss, that's something I'd get checked out with physics planning, to make sure that the impact on the dose isn't too great then also making sure they are able to eat okay, because I looked at it and they'd lost quite a lot of weight, quite a large change down here, so making sure if they've got dieticians appointments and are able to manage feeding
So I'll have a look at the main problematic area which is down here (obs around lowe neck nodes)
There is a large difference on this, this is something I would possibly even get the planning round to review online to get their input onto it
I'd say that it would appear that we are treating most of what we want to treat, it would be just the dose impact really to the patient
Sometimes also just have a look to see the position where they actually are in the mask to begin with and they've set up so that they're very, they're in a very good position from the start, check that there's no difference between the two images

2: 2 Optimise image
2 Optimise image by Mark Collins

7: 5 Explain
5 Explain by Mark Collins

3: 3 Evaluate what looking at and if good
3 Evaluate what looking at and if good by Mark

3: 3 Evaluate what looking at and if good
3 Evaluate what looking at and if good by Mark

2: 2 Optimise image
2 Optimise image by Mark Collins

3: 3 Evaluate what looking at and if good
3 Evaluate what looking at and if good by Mark

7: 5 Explain
5 Explain by Mark Collins

7: 5 Explain
5 Explain by Mark Collins

3: 3 Evaluate what looking at and if good
3 Evaluate what looking at and if good by Mark

4: 6 Choose
6 Choose by Mark Collins

3: 3 Evaluate what looking at and if good
3 Evaluate what looking at and if good by Mark

7: 5 Explain
5 Explain by Mark Collins

7: 5 Explain
5 Explain by Mark Collins

APPENDIX 13 EXAMPLE INTERVIEW TRANSCRIPT

Q So this is Participant 7, so thanks again for doing this. We've just watched the videos just to refresh our memories on the 3 patients that you looked at. So the first thing I wanted to ask you about of it's okay, before we start talking about IGRT was, the experience of doing, taking part in this study, so I use this method called think Aloud and it has never really been used before, well it's never been used before in radiotherapy. So I am interested to hear your thoughts in terms of how you felt doing it?

M I do it anyway, I do it but when, certainly when anybody asks me. It's generally the level ones that say can you just talk me through what you're doing.

Q Right, okay.

M And I like to do that anyway.

Q Okay.

M And I like to show the students what to do so that anybody that's interested, I just talk them through my method of doing things. I pretty much go through the same process every time, just say it out loud when anybody's interested.

Q Okay, and do you think it changes your, by verbalising do you think it changes your decision-making?

M I think it solidifies it, if that's the right word. It reaffirms.

Q Okay, so it almost allows you to rationalise even more?
0:01:33
M Yes, I think it's a useful thing to do., I certainly like to teach people stuff anyway so, and I think that was, it's a good thing to do so that if anybody was thinking what's he doing, or if somebody of equal experience was sat next to me and said hang on what do you mean by that, why are you doing that, because I wouldn't do that. Then it is quite useful to do. So that everybody knows what you're doing when you're doing it.

Q Yes, and the fact that I was stood over you with a video camera, did that interfere with any, the way that you were kind of looking at the patients and reviewing them?

M I think there's obviously, this is going down on record, so that aspect of it. But if you're confident in what you do anyway then it shouldn't really affect you. There was that little doubt in the back of your mind that ...

Q Yes, okay.

M I am quite comfortable in what decisions I make now. I've been doing it for so long.

Q So long, yes, okay cool, that's really good. Thanks for that. so in terms of looking at the

143: used in othe settings
used in other settings by Mark Collins

143: used in othe settings
used in other settings by Mark Collins

96: TA impact on decision
TA impact on decision by Mark Collins

143: used in othe settings
used in other settings by Mark Collins

95: TA Benefit practice
TA Benefit practice by Mark Collins

94: TA Negative
TA Negative by Mark Collins

86: Confidence
Confidence by Mark Collins

patients, I am just going to pause this a second while I plug the laptop in. [Pause] So if we start to have a think about the patients that were reviewed, so there was the three patients, the bladder patient, the lung patient and the head and neck patient. If I just bring up the first patient, I'll just turn the sound down. So do you mind just talking me through kind of the process that you go through when you look at this and actually what is going through your head in terms of what your priorities are and what you're focusing on?

M Well the main thing is, the standard is just to do an auto match anyway so that's the first button that you hit which is trained into people. Then you just assess what that match is like really. And then the main, obviously thing is to look at coverage of the tumor, the volume of interest. Making sure that that's covered and then you start looking at other organs at risk. So with this one it is quite straightforward. Looking at whether the bladder is, the volume is the same. If obviously if it was something which is changeable so that they look as though they haven't completed voided, you could say right let's get them off the bed. This one, it does look like it's changed slightly but ... if I can see, it does look like it has, it is covered so it is just a judgement call whether you actually change that, whether you manipulate the auto match to cover better. Or whether you just accept that you're covering, it's been covered by the same dose so go with it.

Q So for instance on this here, you just pointed out there - so when you say you are interested in covering, is it the PTV that you are, I mean it's where that, so the bladder is coming out there.

M Yes.

Q What, at what point does that become unacceptable?

0:05:00
M When the bladder isn't within the PTV.

Q The PTV, okay, yes.

M I suppose the, if it is scrimpy then it's obviously chance for the patient to move, you are not quite sure whether the volume is completely covered by the 95%. Then you could say well I'll just manipulate it slightly so that it is covering better. But you know as long as it is covered by the PTV, in theory it should be covered.

Q Okay, and the one thing I noticed you'd said was that if it's less than, was it 3mm, you leave alone.

M Yes.

Q So basically you are using the automation as the gold standard, not the gold standard, as in you are relying on that and you wouldn't move it?

M Yes.

35: Automation
Automation by Mark Collins

39: Target volume
Target volume by Mark Collins

115: OARs
OARs by Mark Collins

199: Complexity/Ease
Complexity/Ease by Mark Collins

45: Bladder volume
Bladder volume by Mark Collins

39: Target volume
Target volume by Mark Collins

35: Automation
Automation by Mark Collins

39: Target volume
Target volume by Mark Collins

149: Dose
Dose by Mark Collins

39: Target volume
Target volume by Mark Collins

39: Target volume
Target volume by Mark Collins

35: Automation
Automation by Mark Collins

35: Automation
Automation by Mark Collins

Q Yes, okay.

M It comes down, I was in one of the imaging meetings a while back and they were wanting to standardize the actual matching, because when they try and audit things and say well is this good, is this bad, then if you are relying on ten radiographers all doing their own match, they will all match in a slightly different way. whereas if you standardise it so it is all an automatic match you've got a lot better data to say that yes this is a good technique, this is a bad technique, this is the results so we can make any changes or do things from there. It is quite good in that respect but then some people do tweak it less than 3mm and some people don't so you've still got the ...

Q Okay, that's a really interesting point you raised there about, so like variation across radiographers. Do you have a feel that that exists then within the department?

M Yes definitely does.

Q Yes.

M Like I said some people do manipulate it, some don't. And even coming down to asking me questions, because I was an image support radiographer for a while so I am seen as more experienced a person. There are some staff which ask me a lot more questions, even though they have been in theory trained and qualified in it for a good couple of years they still ask me. Even sometimes basic stuff which I just go, yes, do that. Just instant decision. So it, I think it comes down to individuals. Yes there's definite differences.

Q And is there an attempt to kind of try and, so as a department you want to try and reduce that and almost go more ...?

M Well that's what the protocol says.
0:07:38
Q Yes, protocol ...

M It says if you are not sticking to it then you're not sticking to it. So if people are manipulating it or changing it then it is on their own, they are going against protocol. But it is when you, when we were trained at first you were trained to do a manual match so it is knocking it out of people, get that out of the system, don't tweak it by 2mm when you've got that extra coverage.

Q And I guess sticking on the automation theme, what do you think about the results you typically get using the automatic?

M 95% that it is really good.

Q Okay, is it, is that across all sites is it?

M Ye, I'd say, there's obviously the ones, the pancreas, breasts can be quite bad as well with the auto matches. But your standard pelvis, lungs, head and necks do tend to be quite

35: Automation
Automation by Mark Collins

181: Variation in practice
Variation in practice by Mark Collins

157: Consistency
Consistency by Mark Collins

181: Variation in practice
Variation in practice by Mark Collins

86: Confidence
Confidence by Mark Collins

113: Protocol
Protocol by Mark Collins

35: Automation
Automation by Mark Collins

113: Protocol
Protocol by Mark Collins

35: Automation
Automation by Mark Collins

35: Automation
Automation by Mark Collins

Q Okay. And with this patient, and then I guess pelvis patients in general, how quickly do you get a feel for when you would treat or not on something like this?

M I is almost instant.

Q Okay.

M Certainly from my point of view, I am just, you are just focusing on the things that come in your head quite quickly. Certain with the VMATs as well, the only other thing that you check for on this would be a contour change which you can't see on this.

Q Okay.

M If you get like a [unclear: 0:09:30] you'd be able to see it but then that's the only thing you'd be looking for. So it does go through really quite quickly. When I've worked with people that are level one or only just recent level two, then I am writing results down while they're still reviewing. So I am, I am always normally quiet ahead of other people that are doing it.

Q Okay, do you mind just telling me just briefly what the level one and level two is, just so I am clear?

M Yes, we've got a protocol in place so that people trained to level one, so they have a certain tolerance that they can actually accept obviously. It generally, for the pelvis, thorax, it'll be, I think it's 7mm, and then anything over there they'd have to get someone else in. contour change it is, they have a certain tolerance. It's a 1 cm, other than that they get too involved. And rotation as well. If they have a certain degree ...
0:10:39
... of rotation then they can accept. So it is just levels, they have a limit on what they can accept up to and the levels twos don't. They just, they obviously had the training and are more experienced in what to do on those points.

Q And across the department, I don't know if you know this off the top of your head, but roughly how many people maybe in a percentage if that's easier, are kind of level one and level two trained?

M Probably about 15 level twos, might be less than that but I think it's about that. And then the majority, about 75% are level one trained. Which is an issue. There's always issues, oh I want this training but it is the time to do it. can't train everybody can you.

Q Okay.

M But once the, I think this is going to be another question later so I don't know whether you want me to answer this now. the way that it is set up, with the level ones you're starting

197: Time of decision
Time of decision by Mark Collins

197: Time of decision
Time of decision by Mark Collins

197: Time of decision
Time of decision by Mark Collins

141: Current practice
Current practice by Mark Collins

141: Current practice
Current practice by Mark Collins

183: Training time
Training time by Mark Collins

to instill the reviewer really early on so that's with 3D and 2D, I've noticed that you are basically doing the matching process from early on. So it is the problematic ones where the experience comes in of what to do. I think that is really the main difference between a level one and the level two is that it is knowing, and having the experience of what to do when things don't fit protocol.

Q Okay, that's good. Yes, I'll pick that up in a little bit if that's okay, I'd be really interested to hear some of your thoughts, some more thoughts around this. So let's just have a look at this next patient, so the next one was a lung, if we can bring that up. So would you, by looking at that, the difference between a lung and the bladder, do you have a different process that you follow? Do you have different ...?

M I think it's very similar process. It is looking for the big changes first and then getting down to the finer details. So just looking at that I can see there's slight contour change but most of it is looking like what it should be. So I am thinking there's not going to be vast differences there. Then it is getting down to what will make a difference. So the, my thought process is that ultimately it has got to have completely changed to not treat them. If there's something, we would get physics involved for a lot of things like contour change and they wouldn't come along and say don't treat this, certainly if it's a category one patient, it would be well let's get this treated. So don't leave the patient on the bed for another 10 minutes whilst physics come in and make decisions. Most of the time I don't get physics involved until the, after so that, and if it is safe to treat we treat.

Q Okay, has that changed over time?

M Yes.

Q Yes, has that as a department, as a kind of, what's the word I'm thinking of, like a culture? Is that in terms of involving physics less or do you personally think ...?

M Me personally it is, I don't get them involved as much but I think as a department we rely on them a lot more. It depends on the reviewer really. If they've got the ...
0:14:56
... confidences to make the decision they'll make the decision. But if they are unsure then it is always easier to say I'll get someone else to make that decision. So as long as someone else is taking that responsibility I think they are happy to say yes. But it is getting the confidence once they've got the confidence to say yes and have seen lots of things then they are accepting.

Q Okay, and again I guess similar question to before in terms of, this image comes up on screen. Again how quickly do you say yes I am happy to treat this, or actually no?

M It is fairly quick really. It comes down to the way that we work anyway. You're looking for things that are wrong and if there's not many things that are wrong then just going to go with it really. When things are right obviously. It is practically an instant decision,

Q In terms of what, if I was to say what are your priorities on this plan in terms of the

84: Manage problems
Manage problems by Mark Collins

147: Order
Order by Mark Collins

37: Gross review
Gross review by Mark Collins

47: Weight loss
Weight loss by Mark Collins

60: Physics input
Physics input by Mark Collins

197: Time of decision
Time of decision by Mark Collins

60: Physics input
Physics input by Mark Collins

82: Confidence
Confidence by Mark Collins

82: Confidence
Confidence by Mark Collins

60: Physics input
Physics input by Mark Collins

197: Time of decision
Time of decision by Mark Collins

various kind of clinical things really?

M For this one it is obviously making sure that the tumour is covered, because if that's not covered then there's no point in carrying on. That would have to be a clinical decision then. And then it is your organs at risk, so are we going to be blasting away at a particular organ. Increase the dose of organ at risk. And then take it from there really.

Q Yes, and if the tumour was kind of closer to the spinal cord for example, would that change how you, would it still be, would PTV still be your initial priority?

M Yes, it would, well the closer, it depends on what matching advice you get as well because there's quite a few that come through with specific matching advice. So if it says match to cord, coverage is okay, then that's obviously what your focus is. With all SBRT, SABRE patients they all, pretty much all covered for matching advice.

Q Who does that come from, who writes that down?

M The clinician.

Q The clinician, right okay. So why might they match the cord rather than match the tumour? What, do you know what makes them ...?

M Well certainly with the SABREs is that it depends on their, forgotten the term, the tolerances that they accept.

Q Okay.

M The general term for it but, yes if there's particularly concerned about the cord dose or it is pretty close to what it should be then they would say match to cord. But then whenever you get a doctor down and they say well we've matched the cord but doesn't look like you are covering. Obviously I want it to cover but then just ensure ...
0:18:18
... that you are not going towards cord or whatever. It is one of those things where you've got to pre-empt what the doctors think as well.

Q Do you have to compromise in a situation like this?

M Yes, there's quite a few occasions where we have to compromise on these things. But that all comes with experience really.

Q Okay, great, and then the last one was a head and neck patient. I guess people, you might hear people call these kind of, complex technique or like a more advanced technique. I guess the first thing that I noticed was the number of different volumes that our contour, on here when you load it up. So with all those different contours, how do you again kind of decide which contour is the most important and how do you decide if there's an order of them or ...?

39: Target volu... Target volume by Mark Collins
63: Meidc input Medic input by Mark Collins
115: OARs OARs by Mark Collins
113: Protocol Protocol by Mark Collins
115: OARs OARs by Mark Collins
63: Meidc input Medic input by Mark Collins
63: Meidc input Medic input by Mark Collins
113: Protocol Protocol by Mark Collins
63: Meidc input Medic input by Mark Collins
63: Meidc input Medic input by Mark Collins
115: OARs OARs by Mark Collins
39: Target volu... Target volume by Mark Collins
84: Manage pr... Manage problems by Mark Collins
53: Compromise Compromise by Mark Collins

M Yes, well with the head and neck ones it is just checking the spinal cord really. So making sure that the spinal cord is safe. Once that is agreed then start looking at coverage. So you'd go with the GTV, making sure that is alright. And then it is just checking your nodal volumes then after that. With this, the shoulders look, there, clavicle is looking at fairly similar positions. Looks like there's been quite a lot of weight loss so again just looking for giveaway signs that everything is still covered and whether it is just weight loss or whether we could actually manipulate it. Actually yes this guy needs to push his shoulders up as it looks like we are going to miss something. So as long as it looks like you are covering everything that you should do then go ahead and treat. If you are not then, try and act upon what you see.

Q Okay, yes and what would tell you on there that the shoulders were in a, it was shoulder position rather than weight loss/

M The, again looking at the clavicle position. Making sure that things are still where they should be and you can see some of the other bits of soft tissue as well which are visible with that contrast, so just seeing that they are in the same position, muscles and things. As long as they are in the right position then ...

Q Okay, yes, okay great. In terms of the soft tissue, I mean there's a number of different structures isn't there within that soft tissue. Do you kind of focus on specific types of structure? So like you mentioned muscle for instance, would you use muscle to match to or ...?

M It just depends on what it is.

Q Okay.

M If you can make things out like vessels and things, go with those, it is seeing what you can see. If you can see bits of anatomy then go yes that's there and that is still there.

Q Okay.

0:21:47
M It all depends on what you can see and what you can't.

Q Okay, great, that's really good thanks. So thinking kind of, I guess more generally about IGRT as a whole, I guess there's two kind of things that people talk around in terms of like soft tissue matching and bony matching. Do you do different things for different anatomical sites? Would you kind of group them into those two groups here or not?

M Well as a general rule of thumb we tend to go with the bony match in this department, because that's what we've come to do from the 2D side of things, because that's what we do. And it tends to be that your bony match is the more stable. It is just that with 3D you can obviously see your sort tissue so if there's doubts over coverage then you can obviously see it.

Q Okay, I guess the other scenario that is mentioned in the literature is about online

115: OARs
OARs by Mark Collins

39: Target volume
Target volume by Mark Collins

47: Weight loss
Weight loss by Mark Collins

39: Target volume
Target volume by Mark Collins

50: Immobilsation
Immobilsation by Mark Collins

182: Patient position
Patient position by Mark Collins

112: Normal tissue
Normal tissue by Mark Collins

40: Soft Tissue/Bone
Soft Tissue/Bone by Mark Collins

40: Soft Tissue/Bone
Soft Tissue/Bone by Mark Collins

imaging and offline imaging, and you touched on that a couple of times when you were reviewing them. In terms of like the process you go through, do you do things differently in one setting than the other?

M Maybe very slightly, just take slightly longer offline review. That is what the process is there for, so that you do an online review to say is it treatable, go ahead and treat, and then the offline is where you do take your time more. But generally looking for the same things anyway. It is whether you notice them straightaway for the online review and then you can look later. But generally it is the same.

Q Can you think of any examples of where you made a decision online and then for some reason you reviewed it offline afterwards and thought actually that was the wrong decision?

M There is occasions, but I can't think of any specific ones. It is normally a few millimetres that's slightly different which doesn't make much of a difference really. I've not noticed anything unless someone else has picked it up. I am not aware of it, but yes.

Q Does that happen, that was the next thing I was going to ask you actually, in terms of, because I get the impression that you might review something online and then a colleague might review it offline. Is there many situations crop up where that colleague would come to you, actually you did this and I would have done something slightly differently?

M I think it depends on where we are working, what we tend to do is review stuff online and if the review is there then they would put their notes down and it comes down to timing. If you've got the time to sit there and review it. But we tend not to have the actual time to sit down and review it now. Because the amount that we are actually scanning and if you are on a paper light machine then with Synergistic, then you can't, once you've connected with Synergistic then you break the link and then you can't then scan. It is all interlinked. So it is a lot harder to review offline because you need the time when you're not scanning to be able to get the terminal and say I am going to be offline now. And tend to be the same thing on the Paper Light ...
0:25:36
...machine, which is prostate. Seeing prostate after prostate, so you get familiar fairly quickly as to what things should look like and what shouldn't do. And with the enemas, they tend to be 90-90% tend to be pretty good now.

Q Okay, cool. You mentioned that a couple of times about time which I think is really an interesting one in the real world that you work in. is that something you feel some days is kind of against you?

M Yes. It is, ideally it would be, you'd have all the time in the world to be able to spend on these things but when you've got a chance to do, you've got meetings to go to, you've got breaks to do, lunches, other issues to sort out. The actual time that you get to review is minimal. So actually the review that you do online is vital, the time that you get for that is vital. If you do review it offline anyway then you've got those thoughts in the back of your mind and then you can just go right yes that's what I thought, I am just going to verify that's what we still think and go with it.

54: Online/Offline
Online/Offline by Mark Collins

54: Online/Offline
Online/Offline by Mark Collins

97: Time constarints
Time constraints by Mark Collins

97: Time constarints
Time constraints by Mark Collins

68: Knowledge from previous decisions
Knowledge from previous decisions by Mark Collins

197: Time of decision
Time of decision by Mark Collins

54: Online/Offline
Online/Offline by Mark Collins

97: Time constarints
Time constraints by Mark Collins

Q Does that cause you to feel pressured sometimes?

M I think it is just, that's gone out the window now. Just that used to it that I think if you hadn't done it for a while then definitely. I can see it in some other people as well that they don't want to make that decision there and then, they want to review it later.

Q Spend that time, yes, that's interesting. Another thing that you mentioned a couple of times and I'd quite like to pick up a little bit more is around kind of how you work as a team. So you mentioned earlier, I know you used to be in an imaging role and then obviously, so within the team of radiographers I am interested to know how that works in terms of a hierarchy, if hierarchy is the right word. And then how you work with the medics and physics etc and that. Yes, do you mind talking me through?

M Yes. You obviously get asked lots of questions when you are seen as an experienced reviewer.

Q How many would you say, in the department are viewed as somebody such as yourself?

M Well there's currently two other people in the imaging support role now, there was four but they have now become Advanced Practitioners.

Q Is that a recognised role within the department, as in you are given time to do that are you?

M Yes, well ... [laughter] had to do it. When I was doing it I think I got more time to do it, but again just down to rota restrictions generally. Hardly ever see them in that role now, it is all done in their own time. So if there's any training to do then a lot of it is done within the duties of the day as there'd be rotas. It is just difficult timings and things like that. But it is, it does kind of come down to a handful of people really. So I do think that people will have their go-to person as well. So if they get on ...
0:29:47

... particularly well with one experienced person then they will hold that person and if they are not available, I'll go to the next person. All depends on the individual really. And I've noticed that, I mentioned it before that there are other people that get MDT involved a lot more than others, just because it comes down to making a decision. I have been in other meetings as well where they said we are being called for an awful lot of things we don't need to be called for. But it is getting it across ...

Q Yes, is this the medics is this?

M It tends to be physics.

Q Okay, right, okay, yes.

M I think some people think they make all the decisions but they don't. It is, they make the

140: Maintain competence
Maintain competence by Mark Collins

62: Advanced rad input
Advanced rad input by Mark Collins

62: Advanced rad input
Advanced rad input by Mark Collins

141: Current practice
Current practice by Mark Collins

141: Current practice
Current practice by Mark Collins

156: Time/resource constraints
Time/resource constraints by Mark Collins

72: Peers
Peers by Mark Collins

60: Physics input
Physics input by Mark Collins

82: Confidence
Confidence by Mark Collins

63: Meidc input
Medic input by Mark Collins

82: Confidence
Confidence by Mark Collins

60: Physics input
Physics input by Mark Collins

dosemetric decisions and that's it really. If it is positional thing, we can get their input obviously because it will have an impact if we do make changes, particularly on the head and neck patients but ultimately if it is prostate, whatever, if it's a positional thing we don't need to get them. Don't be bothering them. And on the doctor front, it, again it comes down to experience so that the less experienced will say this is the problem, what do you want to do about it. Whereas a more experienced person would say this is the problem, this is what we should do about it, do you want to come and see it, do you want to have a discussion about it or you happy for us to go ahead? So it is getting, if you know what should happen then you get it across but you are wanting some clinical background. It is getting, putting words into the mouth.

Q And do you think different clinicians have, will kind of, I am trying to think of the right word to use, want to be involved more or less? Do you get a feel for that?

M Again there are more clinicians, or some clinicians that are used to dealing with it like Kevin Franks, he's used it loads. So he'll come down, just start using it and say yes this is good, this is bad, this is what I'd do, or I agree with that. Whereas there are some that will just sit there and say right you are going to have to show me what to do. What's happening? And almost look to you to tell them what needs to happen. It is getting the right person in there to say what should happen. It's just getting that experience really.

Q That's quite interesting kind of dynamic isn't it, that you are a radiographer may call a clinician round to review an image but actually the clinician is actually relying on the radiographer to make the decision, it almost like, the gates there that needs to be there doesn't it, yes. An odd one. I guess as a technology it is quite, I mean you as department you are quite a mature department compared to other departments aren't you in terms of how long this has been implemented and been around. But I guess it's still, do you still think there's a bit of a learning curve going on within the department and within different profession?

M Yes.

Q Yes.
0:33:21
M Yes, definitely. Well I think the same happens with, when you're getting the MDT involved. So if you are getting physics involved then a lot of people will ask certain people because they know they will get a sensible answer, a quick answer out of them. Whereas there are some that will come along and just get out reams and reams of paper. All these different things on the computers, I don't know about this and then say I think we should repeat. So not getting the answer that you want.

Q No, no, okay.

M They definitely cherry pick the ...

Q Okay, that's interesting as well, yes.

86: Confidence
Confidence by Mark Collins

63: Meidc input
Medic input by Mark Collins

63: Meidc input
Medic input by Mark Collins

154: Experience from other centre
Experience from other centre by Mark Collins

60: Physics input
Physics input by Mark Collins

M Again it is getting used to individuals. I tend to just shove a chocolate towards their direction, tend to, more approachable.

Q Okay, that's great, and then I guess sticking on this theme of experience, because you've talked about that quite a lot. What is your, I guess I've got two different kind of elements in my research questions about experience, so I've got a research question around experience overall as a radiographer, and then a research question around how having experience as an imaging radiographer impacts how you make decisions. What is your thoughts on those two different kind of scenarios?

M I think, it comes down to, well someone that hasn't got any imaging experience, they aren't making decisions all the time. Or they are making less decisions. They are obviously working in the room making clinical decisions but then when they are not in a clinical basis they are not making those decisions. Whereas a review radiographer will be just constantly making decisions all day every day, so I think they gain the experience a bit quicker.

Q Okay.

M And almost get more confidence quicker.

Q Okay, yes.

M Because they are making those decisions.

Q Okay. And you obviously are a radiographer for quite a long time before you started doing your imaging, do you pull on that experience ...?

M Yes.

Q Is that relevant to being in, to reviewing images do you think?

M Yes.

Q Yes.

0:35:56
M Yes. Because it is, I know the, seeing it from, seeing the more experienced radiographers that aren't here anymore, they have retired, they often used their experience and just say actually I know we are going to be covered so even though it tells me I am getting this error, I am not going to care about that or it doesn't concern me because I know that it's going to be covered or whatever. Whereas somebody that's recently qualified wouldn't make that decision that quickly. Yes, thinking about it, even if they, even if they have more experienced radiographer, recently qualified, trained in something then I think they can make decisions quicker. But again it comes down to individuals. Someone you can train for weeks and weeks and they still don't quite get it. Whereas someone you can just tell something, and they've got it instantly and just happy to go ahead and run with it.

60: Physics input
Physics input by Mark Collins

86: Confidence
Confidence by Mark Collins

209: Quanity of patients
Quantity of patients by Mark Collins

85: Speed
Speed by Mark Collins

86: Confidence
Confidence by Mark Collins

158: Importance of experience
Importance of experience by Mark Collins

158: Importance of experience
Importance of experience by Mark Collins

158: Importance of experience
Importance of experience by Mark Collins

79: Time as rad
Time as rad by Mark Collins

Q And is that related to experience, in your experience?

M Can be.

Q Okay.

M But again even a very experienced radiographer can be, struggle making decisions if they are not comfortable with that type of decision. Or it is just out of their remit. It doesn't necessarily make you a better reviewer, it is just, and there is sometimes the, you just don't get it, it just doesn't come naturally to you. I think it comes down to the individual.

79: Time as rad
Time as rad by Mark Collins

Q If I was like a new radiographer starting today in your department, I've just qualified, would you say that I would need a kind of minimum amount of experience before I should start my imaging training? Do you have a feel for what that time would be if there would be?

79: Time as rad
Time as rad by Mark Collins

M That's a difficult one. I think it does come down to the individual. But I think it is, I think you do need a bedding in period. There are some that would be able to just do it and be able to fly with it and, it would be actually really good. In some of the training that I have done I've noticed that some people do just get it and do brilliant. It is almost like they had the answers written in front of them. Almost do things, word for word like you should do. And then there are some which just don't get it. But that aside, I do think that you should have a minimum time required. I think it will help.

Q What would that be? Putting you on the spot?

M At least a year, I would say, probably two years would be even more beneficial. But like I said you could get somebody that is brand new qualified and they could just pick it up instantly and be brilliant. I am thinking, I would think that a minimum of a year before.

79: Time as rad
Time as rad by Mark Collins

Q Okay, that's really interesting. And then the last thing I was wanting to talk to you about was, again leading on from this, was training. I guess I am interested around a couple of things with your experience. What training you had when you trained as an imager and kind of looking back now reflecting on that, what was good about it ...
0:39:51
... what could have been done maybe differently? And I guess now you, as somebody who trains others, what do you see as being important in training people to be able to make these decisions?

M Well I thought the training I got was good, definitely good. It kind of, it did set me up for what, what I needed really. But ...

139: Workbook/Case studies
Workbook/Case studies by Mark Collins

Q How did the training work?

M It was just case studies, just got some case studies to do, I think it was ten. And then you just got signed off, yes you can review those. There was a little bit of countersigning period. But after, it almost came down to the individual to say are you happy and do you want me

169: self led
self led by Mark Collins

to keep countersigning, yes, I am happy to make that decision. Because the way I see it, as long as you put in a clause, almost a clause of saying work within your limits, if you feel it has got beyond you just call somebody. There's always going to be somebody more experience than you around or someone that's happy to make a decision. It was a quick training, I think it was a couple of days. Two days I think at the most. And then, but then there were less sites that that point. I think we did prostate, lungs and possibly something else. Well prostate, bladder, lungs, oesophagus, whereas now we're doing head and necks, I think there's anuses now, breast and pancreas. There's a lot more sites but the way that our protocol is set up is that it's an auto match anyway. As I said 90% of patients, the auto match is good. It is almost getting to the point where I think the most important thing is experience. You could train somebody and countersign for weeks and weeks and weeks. As soon as you say right that's it, fully trained up. The first non-standard thing that comes along they instantly get somebody else and say what do I do here? Because it is that pressure of making that decision. Somebody else isn't countersigning them to say this is backing up their decision. So I almost think the training needs to be as short as possible and safe as possible, but as short as possible to get them out there doing it and saying right, yes you've, this is giving them examples of what can happen. When a lung collapsed, when bladder isn't what it should be or when you've got lots of gas or lots of faeces, what needs to happen. Once you've got the basics in there then you are covering 95% of them. Then the other 5% they will ask you anyway. It is getting them on the job.

Q Okay, and do you think you can teach that sort of thing in a classroom environment or do you think that is gained by ...

M You just can't cover everything. If you could then you could but you just can't. It is, I think it does come down to just on the job. So like with being student radiographers, you can train them to fill out a case discussion or carry on a case discussion, case report and stuff but once they are actually qualified that's when they start doing the majority of the learning. They learn twice as much once they've qualified than as a student.

Q I guess one thing I am interested about is, I think it is easy for more as somebody who works in universities to say this is how it should happen. In the real world, in that real department, do you think what you've just described is something that's doable.

0:44:18
Would that be doable within this department to kind of get people trained to do like a short sharp ...

M Yes.

Q Is there enough people to then be around to, you know to double check the inexperienced people really?

M Well we do, because of the, if every single machine had an XVI machine then we'd be struggling. But the amount of machines that we have, we do tend to have at least one reviewer and most of them have been trained for a good couple of years. There's not that many that aren't newly trained. But yes, I think if we could put something in place so that as

72: Peers
Peers by Mark Collins

183: Training time
Training time by Mark Collins

35: Automation
Automation by Mark Collins

73: Experiential learning
Experiential learning by Mark Collins

183: Training time
Training time by Mark Collins

138: On the job
On the job by Mark Collins

73: Experiential learning
Experiential learning by Mark Collins

136: Current workforce
Current workforce by Mark Collins

141: Current practice
Current practice by Mark Collins

long as you've got core team, one of that core team available then could almost have an imaging bleep and just say yes, having this problem, so even if that person has got it that's working clinical that day then ...

Q Okay.

M I mean that's what an advanced, imaging advanced practitioner is but they are not always around. Amy is reducing her hours and Helen, I don't know whether she's going to do that role when she gets back. It is getting, it is just getting the people and as long as there's something in place then if it is ticking all the right boxes then go with it.

Q Okay, and do you get the feeling that within the department people are happy to raise their hand and go, I'm not sure about this, in terms of ...?

M Yes, I think it is more that way rather than the other way. I think because we are so protocol driven now it is breeding a less confident radiographer.

Q You think, yes that's interesting, right.

M I think there's no, I think we are getting more confident staff in general, that they are quite happy to shout up and say I don't agree with what decision you make but, I am kind of contradicting myself here, but when it comes down to imaging there's quite a, almost seems quite backwards way of doing it and not willing to take that responsibility.

Q Okay, interesting.

M In an argument process then they'd be quite happy to shout it down. But something when it is clinical decision then less ...

Q Okay, that's interesting, and the last thing, I am conscious of time, was I guess my role and the university's role in all of this, interested to know your thoughts on that. So do you think that we should be teaching and getting students doing this during their pre-registration training, or do you think that it is actually something that should be taught after they've been qualified?

0:47:32

M I definitely think they need some experience of it. So that they are aware of what each thing is there for. So what technology is out there. So a good, well a module on it maybe so they are aware of it. I think it just plants the seed then and they can, it is up to the individual then to find out a bit more if they are interested in it. I think you obviously couldn't teach them too much because it is just ... I think certainly the way I learn better is actually on the job anyway, it is harder. May be able to do things a bit better but ... I prefer a hands on thing. So seeing it there and then, putting it into reality, whereas on paper it doesn't always marry up when you actually get into the clinical setting.

Q Okay, and when do you think we should plant that seed then in terms of the, so with us

62: Advanced rad input
Advanced rad input by Mark Collins

141: Current practice
Current practice by Mark Collins

82: Confidence
Confidence by Mark Collins

86: Confidence
Confidence by Mark Collins

82: Confidence
Confidence by Mark Collins

82: Confidence
Confidence by Mark Collins

202: Syllabus/Delivery
Syllabus/Delivery by Mark Collins

179: limitations
limitations by Mark Collins

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202: Syllabus/Delivery
Syllabus/Delivery by Mark Collins

179: limitations
limitations by Mark Collins

for 3 years in their training, where do you think a good place to put that in would be?

M Definitely not first year because they need to do the basics really first. It is debateable second year, definitely third year. I think would be a good time. Obviously if they've got to grips with the basic and knowing that, how to set patients up. If you can't get that right in the first place the image is going to be pants anyway. So we need to be making sure that is happening. But yes I think by third year should be starting to develop their thinking and problem solving.

Q Okay, and you think that's key to it then do you think, the actual, the problem solving bit rather than actually reviewing the images, yes.

M Yes, it is getting the mindset going really.

Q Okay, yeah.

M Making sure, thinking an appropriate way because they may not, by the second year you may not have that knowledge.

Q That knowledge, okay.

M Yes, still coming to terms with these big long words and ...

Q Okay, yes.

M ... different machines and different staff, but by third year you are more comfortable in your surroundings.

Q Okay, great, that's really good that, absolutely tonnes of stuff in there that has been really helpful. I'll just turn that off.

0:50:09

91: Timing
Timing by Mark Collins

91: Timing
Timing by Mark Collins

202: Syllabus/Delivery
Syllabus/Delivery by Mark Collins

91: Timing
Timing by Mark Collins

91: Timing
Timing by Mark Collins

APPENDIX 14 QUIRKOS INTERVIEW