Developing the evidence base for image interpretation and descriptive evaluation by radiographers.

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MSc, BSc (hons), BA (hons)

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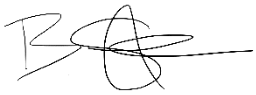
Declaration

I hereby declare that the work presented in this thesis has not been submitted for any other degree or professional qualification, and that it is the result of my own independent work.



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To my research collaborators, thank you for contributing to my ideas and letting me be part of your ideas also, you have all helped to develop my research skills to this moment in time.

Finally, many thanks to my wife Hannah for her support along this journey and for understanding my desire to reach this stage, and to my boys Jasper and Robin…I hope that this thesis, if you ever read it, inspires you in your academic lives and you realise that anything is possible.

Abstract

Introduction

This thesis provides evidence to support the notion of radiographers interpreting radiographic images and providing descriptive evaluations. The role of radiographers providing first line radiographic image interpretation has progressed greatly over recent years with reporting radiographers providing key assistance to managing reporting backlogs and also the development of the preliminary clinical evaluation system evolving from the red dot abnormality detection system. This thesis aims to collate the key findings from nine peer-reviewed and published papers to provide new and original evidence to support radiographers interpreting radiographic images and providing descriptive evaluations, which strengthen the continual development of the evidence base relative to clinical reporting and Preliminary Clinical Evaluation (PCE).

Methods

The salient findings from the results and discussion sections from the nine papers submitted were extracted via thematic analysis, in line with the aim of the thesis. A confirmatory thematic analysis approach was utilised with initial pre-determined themes, given the author's prior knowledge and understanding of the research and the theoretical foundations of the submitted works.

Results

The significant findings from each of the papers generated three key themes covering radiographers' ability to provide a PCE, guidance for provision of PCE and a report, and illustrating the impact of radiographers interpreting and describing abnormalities in PCE and clinical reporting. A number of areas for further investigation in PCE are recommended following the critical analysis. The papers provide new information in areas of practice that had not previously been investigated, including some novel methodology which had previously not been used in studies evaluating PCE.

Discussion

The critical analysis has shown that radiographers are capable of interpreting and describing radiographic abnormalities in the context of PCE, including traumatic chest X-ray presentations. However, it is acknowledged that improvements in PCE performance can be made with specific focussed sessions covering subtle pathologies, comment structure and content. The impact of PCE was illustrated by positively affecting referrers' treatment decisions and reducing false negatives. The progression of reporting radiographers was also demonstrated with greater allocation of reporting time and an increased number of radiographers reporting CXRs.

The findings from the works included have been pivotal in introducing a policy change in the forthcoming updated PCE guidance document produced by the Society and College of Radiographers (SCoR). The document will be published this year and will provide guidance to aid departmental and practice changes. It is clear within the document where the works have shaped the guidance. For example, reiterating the impact and benefits of PCE (paper 3), advocating the implementation of abnormality detection training during preceptorship periods (paper 1), the use of bullet points (paper 6) and short comments (paper 4), comment structure (paper 6), and providing evidence supporting the expansion of PCE into extra-skeletal anatomical areas (paper 8). Evidence of research impact is demonstrated through the number of citations and reads of the papers, and the replication of one of the studies in different modalities introduces translatability of research. The potential wider service and societal implications of these findings are considered to be the enhancement of services offered by radiographers relating to the interpretation of radiographic images, which in turn will improve the service provided by referring clinicians, ultimately improving the experience of patients with improved quality of care. With a more insular view, these studies may increase the worth of radiographers amongst other health professional groups possibly helping to foster improved inter-professional relationships.

Contents

List of Tables and Illustrations

Abbreviations

BSc	Bachelor of Science
NHS	National Health Service
CRAG	Consultant Radiographers' Advisory Group
Pg Dip	Post-graduate Diploma
MSc	Master of Science
PCE	Preliminary Clinical Evaluation
MDCT	Multi Detector Computed Tomography
PET/CT	Positron Emission Tomography/Computed Tomography
PET/MRI	Positron Emission Tomography/Magnetic Resonance Imaging
SPECT/CT	Single Photon Emission Computed Tomography/Computed Tomography
RCR	Royal College of Radiologists
CoR	College of Radiographers
ED	Emergency Department
HEI	Higher Education Institute
RDS	Red Dot System
HEE	Health Education England
SoP	Scope of Practice
CXR	Chest X-ray
SCoR	Society and College of Radiographers
DoH	Declaration of Helsinki
GDPR	General Data Protection Regulation
R&D	Research & Development
HRA	Health Research Authority
REC	Research Ethics Committee
IRAS	Integrated Research Application System
RDM	Research Data Management

USB	Universal Serial Bus

Preface

This thesis has been compiled in alignment with the framework descriptors set out for the attainment of a higher-level education qualification at level 8 to fulfil the requirements of a doctoral degree as stated by the Quality Assurance Agency (QAA, 2014).

- *The creation and interpretation of new knowledge, through original research or other advanced scholarship, of a quality to satisfy peer review, extend the forefront of the discipline, and merit publication.*
- *A systematic acquisition and understanding of a substantial body of knowledge which is at the forefront of an academic discipline or area of professional practice.*
- *The general ability to conceptualise, design and implement a project for the generation of new knowledge, applications or understanding at the forefront of the discipline, and to adjust the project design in the light of unforeseen problems.*
- *A detailed understanding of applicable techniques for research and advanced academic enquiry.*

The following narrative is structured to provide evidence of satisfying the criteria listed above. The works included in this thesis highlight areas of good practice and where improvements can be made to improve individuals' interpretive and descriptive abilities that will subsequently enhance the service provided by radiology. The methods and findings of the works are critically reviewed in the context of other relevant published papers and the analysis is presented in three logical themes. Evaluation of the impact of the works follows the themes, and the thesis then proceeds to a self-reflection and future aspirations section, including ideas for expanding on the papers presented, and a summary section concludes the thesis.

Author background

Barry qualified from the University of Cumbria with a Bachelor of Science (BSc) (hons) Diagnostic Radiography in 2011. His first post was at Walsall Healthcare National Health Service (NHS) Trust in 2011, and he remains at Walsall working now as a Consultant Radiographer. Barry is currently a member of the Consultant Radiographers' Advisor Group (CRAG) at the Society and College of Radiographers and is a registered assessor for the Society and College of Radiographers involved in the accreditation and approval of advanced practitioner applications. He attained his College of Radiographers' Accredited Consultant Practitioner status in February 2021.

During undergraduate training Barry's interest in the recognising and describing of abnormalities began to grow and it soon became a career goal to become a reporting radiographer. This early desire shaped his knowledge and understanding and provided a clear career pathway. Barry's reporting journey began in 2015 with the acquisition of a Post-Graduate Diploma (PgDip) in radiographic reporting and completed his Masters (MSc) dissertation in 2017. In late-2017, Barry acquired the adult chest and abdomen radiographic reporting qualification, and in 2023 became qualified to report paediatric chest X-ray examinations.

Barry's research interests have always been based around reporting and preliminary clinical evaluation. Peoples' differing opinions and abilities regarding the recognising and describing of radiographic abnormalities has always been of interest. He has always had a desire to teach others often via presentations to colleagues in the Radiology department, students and other health professionals across the Trust and Higher Education Institutions, usually looking at techniques and pathological appearances on radiographs.

Due to the nature of image interpretation, Barry's research interests are grounded in observer performance studies with the assessment of ability before and after educational interventions, which are inherently of a quantitative nature with use of statistical analyses. Mixed methods approaches are also used to investigate the opinions and experiences of other reporting radiographers, radiology departments and referring clinicians, which introduces qualitative elements in to his research practices.

1. Introduction

This introduction section provides brief background information on clinical reporting and abnormality detection systems outlining the progression to preliminary clinical evaluation (PCE) and where PCE sits in the context of enhanced and advanced radiographer practice. The section concludes with a brief the rationale behind each of the included works.

1.1 Background

The profession of diagnostic radiography has progressed considerably since the beginning of the century. The mainstays of radiological imaging have encountered several technological advances that have led to the progression of digital radiography with film-less imaging, touchscreen and wireless technologies that enhance the users' workflow and interpretation, and the improvement in Computed Tomography (MDCT) with invention of multi-detector arrays providing more complex scans with greater detail and quicker scans. New technology has also led to the development of new and hybrid imaging modalities such as positron emission tomography (PET)/CT, PET/magnetic resonance imaging (MRI) and single photon emission computed tomography (SPECT)/CT, for example.

Along with these advancements, possibly the most attractive development for the workforce is that of extended practice in that many elements of the current role of the radiographer now cover practices that were once confined to the domain of the medical profession. There are a multitude of opportunities for enhancing and advancing practice across several modalities and pathways. Formal clinical reporting was traditionally only undertaken by radiologists, however, the latest workforce census noted that clinical reporting by radiographers had developed considerably with 81% of Hospital Trusts using reporting radiographers to reduce backlogs, driven by radiologist vacancies, and increasing demand (Royal College of Radiologists, 2023). Given the current workforce climate this is likely to increase in view of the predicted 40% shortfall of radiologists by 2027 (Royal College of Radiologists, 2023). In the case of interpreting and reporting radiographs, radiographers have become integral to this key aspect of providing and maintaining optimal X-ray service provision.

Reporting background

A radiologist recognised, as early as 1971, that radiographers could potentially help to reduce the pressure on radiologists by being able to recognise differences between normal and abnormal appearances on radiographs, subsequently reducing the reporting burden on radiologists (Swinburne, 1971). The ability of radiographers to be able to interpret images became a frequent topic of discussion between the Royal College of Radiologists (RCR) and the College of Radiographers (CoR). This early initiation helped to lay the foundations for the path that today's reporting radiographers walk along. Research in the 1980's demonstrated that many X-ray examinations waited weeks and months to be reported (Berman et al., 1985), and that 39% of missed abnormalities in the Emergency Department (ED) were clinically significant (Vincent et al., 1988). It became evident that there was a void to be filled regarding the need for reports to be produced within an appropriate time frame to ensure patients received optimal care; these concerns and issues remain prevalent in the present day.

The notion of radiographers providing a report on a radiograph was first introduced when a pilot study was launched in Leeds in 1993 whereby two radiographers attended teachings and lectures by radiologists concerning the reporting of ED radiographs. Results were favourable with radiographers returning 92% accuracy when compared with the radiologist's official report (Robinson 1996). In 1995, the first Society of Radiographers accredited post-graduate training course designed specifically for radiographers was launched at Canterbury & Christ Church University (Canterbury Christ Church University, 2023). The actualisation of a dedicated Higher Education Institution (HEI) course focussed on training radiographers to report radiographs will have appeased the concerns of the RCR regarding formal and standardised training and assessment. Though, even to this day amongst some radiologists, the permitting of radiographers to report any radiological studies remains a contentious subject.

Radiographer abnormality flagging systems background.

The red dot abnormality flagging system, or red dot system (RDS) that is used by many radiology departments in the United Kingdom (UK) was first trialled in 1985 (Berman et al., 1985), and is still in place in most departments today. The RDS was designed to permit radiographers to indicate to the referrer regarding the presence of an abnormality on the obtained images. This was often performed by physically placing a circular red sticker on the radiograph film, though over the years this evolved and many iterations of the “red dot” have been utilised (Snaith et al., 2014). The RDS was perceived to be a useful service development and provided opportunity for radiographers to contribute to the care of patients. However, the ambiguity of placing a notifying marker on the image to flag an abnormality can inadvertently lead to misunderstanding or misinterpretation by referrers depending on the level of experience and/or interpretative ability. This could lead to incorrect decisions being made with regards to patients’ treatment and management. Consequently, it was proposed that the abnormality flagging system needs to be more specific and instructive to prevent misdiagnosis and reduce false negative and false positive interpretations, subsequently the idea of radiographers providing an informal written descriptive comment, or a preliminary clinical evaluation (PCE), was put forward.

The College of Radiographers’ (CoR), in a 2004 UK council report (Evans, 2004), as highlighted in Hardy & Culpan, (2007), first suggested the need to evolve from the RDS to first line commenting interpretation and have persisted with a long-term aim of PCE to replace the RDS (Society and College of Radiographers, 2013). The PCE provides a more directive method of flagging an abnormality through provision of descriptive informational content. Despite much of the research illustrating the ability of radiographers’ to competently provide a PCE, the literature also demonstrates that there has not been as quick or as wide implementation of the PCE system (Harcus & Stevens, 2023; Snaith & Hardy, 2008), as would have been hoped for or expected by the SCoR. The current reasons for this are not clear at present, though previous research by Lancaster & Hardy (2012) argues that education, confidence, and technology are the biggest barriers to implementing a PCE system. Updated research is required to determine whether these issues are still prominent today or if there are other contributory factors for the slow implementation.

1.2. Enhanced and advanced radiographer practice.

The CoR Education and Career Framework (College of Radiographers, 2022) underlines the knowledge, skills and attributes that are requisite for participation in a PCE system that fall within the remit of a practitioner radiographer. The framework also states that the specific curriculum for a diagnostic radiographer should include,

> "Preliminary clinical evaluation of images relevant to 'first post' competence, including structure and terminology in preliminary clinical evaluation" (College of Radiographers, 2022).

This statement shows that the CoR clearly see PCE as a key facet of the radiographer's role and this is further reiterated with the currently unpublished but updated PCE guidance document that is nearing completion and publication (Society of Radiographers, n.d.). The recognising and describing of abnormalities is considered to be a core competency for all newly qualified radiographers, certainly it is expected that diagnostic radiographers can differentiate between normal and abnormal anatomy and can apply this knowledge to clinical decision-making (College of Radiographers, 2022). These skills are closely related to clinical reporting and may develop an individual's desire to train to become a reporting radiographer, and in this regard PCE could be considered as a bridge between the first two stages on the career trajectory outlined in figure 1, thus initialising a reporting career pathway. The submitted papers relative to PCE provide support to implement a PCE system and may serve as a catalyst in the development of future reporting radiographers, especially so in the early phases of the diagnostic career trajectory.

Figure 1. Example of diagnostic radiographers' career trajectory (Society and College of Radiographers, 2021)

A new level of practice, termed enhanced practice, has emerged, which as Snaith & Beardmore, (2021) comment, represents practitioners who have higher skill levels that contribute significantly to patient care and service. It has also recently been suggested that with robust governance framework, PCE may become recognised as enhanced practice (Lidgett et al., 2023). The SCoR outlines reporting by radiographers as enhanced practice, and as such there is no expectation that the four pillars of higher practice need to be fulfilled (College of Radiographers, 2022). Enhanced practice radiographers may contribute to any of the four pillars of practice (clinical practice, education, leadership and management, and research and development), but most likely with emphasis on clinical practice that, in the context of this thesis, would likely be clinical reporting or potentially PCE. In comparison, an advanced practitioner would be expected to regularly undertake activities that satisfy all four pillars of practice (College of Radiographers, 2022), and the multi-professional framework produced by Health Education England (HEE) (Health Education England, 2017b) sets the standard, encompassing the capabilities expected for the level of advanced clinical practice. Amongst enhanced and advanced practitioners the fulfilment of the clinical practice pillar likely takes precedence over other pillar considerations, underlined by the increase in the number of chest X-ray reporting radiographers over recent years (Stevens et al., 2021). The growing numbers of reporting radiographers aligns with the recent and prior Richards' Review of Diagnostics (Richards, 2020) that included a recommendation of increasing the number of advanced practitioner radiographers reporting radiographic images by at least 50%.

This section has provided a brief introduction of the literature relating to radiographers interpreting radiographic images and describing abnormalities, and where this practice is placed in the context of enhanced and advanced practice. The next section summarises the rationale for undertaking each of the studies that provide the fundamental underpinning of this thesis.

1.3 Rationale behind each of the works

The nature of each of the submitted works were carefully planned to be fundamentally based in the topic of image interpretation by radiographers, with the prospect of submitting for the award of PhD by Published Works as a potential end point. The nine publications included in this thesis focus on developing evidence to support the progression of radiographers when interpreting and describing X-ray findings. The main areas include highlighting the current state and progression of reporting radiographers and providing guidance for practice, and undertaking research relating to PCE content, structure, impact, and the effects of training on ability.

Paper 1.

The impact of focused training on abnormality detection and provision of accurate PCE in newly qualified radiographers. *Stevens BJ & Thompson JD (2017), Radiography, February, Volume 24, Issue 1, 47 - 51.*

The premise for paper 1 was derived from personal clinical experiences and discussions regarding the differences in training and exposure to PCE of regular cohorts of newly appointed, first-post radiographers. Paper 1 aimed to assess first-post newly qualified radiographers' ability to recognise and describe a variety of traumatic skeletal abnormalities, in pre- and post-training phases. Several studies looking at the effects of training on ability had previously been published (Hardy & Culpan, 2007; Hargreaves & Mackay, 2003; Mackay, 2006; McConnell & Webster, 2000) but included participants with many years' experience or an increased knowledge and awareness of trauma presentations, none had specifically investigated the ability of newly qualified radiographers. This study provided new knowledge and added to the current PCE evidence base.

Paper 2.

A survey assessment of reporting radiographers' scope of practice in the West Midlands. *Stevens BJ (2019), Radiography, Volume 25, Issue 3, August 2019.*

The impetus for article 2 came from a published position statement from the Royal College of Radiologists (RCR), in which there were disparaging comments regarding the reporting of medical images by non-medical professionals and those reports not being actionable and only being descriptive (Royal College of Radiologists, 2017). The objective here was to provide some challenging evidence and by doing so shine a light on the reporting radiographers in the West Midlands region. This article illustrated that there has been progression in terms of numbers of reporting radiographers and scope of practice (SoP) and how radiographers' reports are actionable evidenced by the inclusion of suggestions of referral to other departments, for further imaging and recommendation of treatments.

Paper 3.

The value of preliminary clinical evaluation for decision making in injuries of the hand and wrist. *Stevens BJ & Thompson JD (2019), International Emergency Nursing, Volume 48, January 2020.*

Paper 3 was published in an international nursing journal to promote the benefits of the PCE system outside the boundaries of *Radiography*, where the readership is already informed, supportive and understanding of the PCE ideals. We aimed for a wider reach based in emergency nursing; those who the PCE may benefit the most. No previous research had been published that assessed the impact of PCE on Emergency Department (ED) referrers decision making. The findings from this study implied that the PCE can positively impact treatment decisions, improves ED referrers' localisation accuracy, increases interpretive confidence, and can reduce false negative diagnoses. Prior to this study there had been no published research investigating how the PCE can affect referrers' interpretive ability and management of patients.

Paper 4.

An analysis of the structure and brevity of preliminary clinical evaluations describing traumatic abnormalities on extremity X-ray images. *Stevens BJ (2020), Radiography, Volume 26, Issue 4, 302 – 307.*

The formation of a PCE comment had always been an area of interest to investigate and with paper 4 the emphasis was looking specifically at the comment structure, terminology, and the number and types of words used. Previous work had suggested the *What, Where, How* method (Harcus et al., 2014) as a structural guide when forming a PCE, but there was no published research evaluating the structure and content of radiographers' PCE comments.

Paper 5.

Radiographers reporting chest X-ray images: Identifying the service enablers and challenges in England, UK. *Stevens BJ, Skermer L & Davies J. (2021), Radiography, Volume 27, Issue 4, 1006-1013*

In a similar manner to paper 2, paper 5 was designed to highlight the work of reporting radiographers by promoting the progression of, and emphasising the reliance on, radiographers who report chest X-rays images (CXRs) in NHS hospitals in England. Previous research had provided a generic overview of the challenges of advanced practice (Culpan et al., 2019), but it was a desire of the author to specifically assess the barriers and service enablers of CXR reporting radiographers, and this study identified the issues and positive aspects associated with training and employing radiographers to report CXRs. It also provided an updated analysis on scope of practice and the number of sessions afforded to reporting CXRs, which had not been published since Stevens, (2019).

Paper 6.

What information is required in a preliminary clinical evaluation? A service evaluation. *Harcus JW & BJ Stevens (2021). Radiography, Volume 27, Issue 4, 1033-1037.*

Following on from looking how radiographers structure their comments in paper 4, paper 6 looked at what types of information ED referrers would find most useful in a PCE comment. Once again there were no published studies specifically looking at this key aspect of the PCE system; what do the key users want or need from the PCE comment? A wide range of ED referrers were asked to indicate which aspects of the *What, Where, How* model they would find most useful. Consequently, this study provided in-practice evidence of service users' preferences and expectations of the PCE system.

Paper 7.

Radiograph report style preferences of referrers at a district general hospital in the West Midlands, England, UK. *Stevens BJ (2022). Radiography, Volume 28 Issue 2, 296-303.*

It was a logical progression from paper 6, with the principle of assessing referrers opinions of abnormality description preferences laying the foundation for paper 7, in which all referrers from varying referral sources were asked for their style preferences for reports of CXR and skeletal radiographs. The idea behind this study was to investigate if referrers prefer different styles of report dependent on their referral location and specialty. The main aim was that the findings would provide a guide for reporting radiographer colleagues to maximise their reporting efficiency and to improve X-ray reporting services.

Paper 8.

The efficacy of preliminary clinical evaluation for emergency department chest radiographs with trauma presentations in pre- and post-training situations. *Stevens BJ & Thompson JD (2022). Radiography Volume 28, Issue 4, November 2022, 1122-1126.*

Although the PCE is seen as the evolution of the red dot scheme, which is commonly used for ED extremity examinations, SCoR guidance implies that the PCE system can be used for all examinations (The Society and College of Radiographers, 2013). Recent studies indicate the inclusion of CXR examinations in the PCE system in the ED setting (Alexander-Bates et al., 2021; Neep et al., 2019), but there has been no published assessments of the ability of radiographers to accurately recognise and describe traumatic presentations on CXRs. A secondary aim to this study was to assess the effect of a training intervention using pre-recorded tutorial videos.

Paper 9.

Radiographer abnormality flagging systems in the UK – A preliminary updated assessment of practice. *Harcus JW & Stevens BJ (2023) Radiography, 29, 234-239.*

The only appraisal of how widespread the usage of PCE is across the UK was published in 2008 by Snaith & Hardy, and despite the subsequent documentation published by the SCoR regarding the transition to PCE from the RDS in 2013 there has not been an updated evaluation of the current state of practice regarding the use of PCE. This study aimed to provide up-to-date evidence of implementation and use (including anatomical areas and which pathologies), and to generate an overview of the governance issues/practices that arise such as training and/or auditing of those who participate in a PCE system.

This section provided some background context regarding clinical reporting and the use of PCE, and provided brief rationales outlining the motivators for each of the studies. The next section will provide information on the ethical consideration undertaken when compiling the works for this thesis.

2. Ethical considerations

This section will provide an overview of the ethical considerations that were undertaken when competing the submitted works. A reflective review of the ethical processes when compiling this thesis is also put forward.

2.1. The importance of ethics in clinical research.

Ethical considerations in research are of paramount importance ensuring that any harm to patients is minimised and that research is undertaken with integrity and respect for participants. The Declaration of Helsinki (World Medical Association, 2013) and the Data Protection Act UK 2018 (UK Government, n.d.) provide governance to any research activities that are undertaken in the UK and aim to ensure that best practice is adhered to at all times.

2.2. Declaration of Helsinki

The relevant and appropriate aspects of the Declaration of Helsinki (DoH) (World Medical Association, 2013) were adopted throughout each of the submitted papers. The DoH outlines key guidance for research that involves human subjects ensuring that there is scientific and ethical justification for a study. All researchers that undertake research involving human participants should adhere to these principles. The DoH also emphasises that all participants should be volunteers who are adequately informed about the purpose, risk and benefits of the research prior to consenting to participate. The importance of protecting the privacy and confidentiality of research participants is stressed as a key component of the declaration. Ethical review by an appropriate independent committee or approval to proceed is a requisite prior to any study commencing, communications with the local R & D department can guide the necessity of this.

2.3. General Data Protection Regulation (GDPR) and Data protection act UK 2018

The GDPR is a European Union law that insists that the processing of research data is managed with transparency, in a lawful and fair manner. The GDPR is implemented in the UK via the Data Protection Act 2018 (UK Government, n.d.), which governs the processing of personal data in the UK, and this is of particular importance to studies that anonymise participant data. Importantly, anonymised data may still be personal data depending on the level and extent of removal of identifiers within a dataset. Therefore, it is vital that the data are securely controlled making it impossible to classify the data for those external to the research team.

2.4. Ethical review

All of the papers included in this thesis were approved by the local Research and Development (R&D) department at authors' employing NHS Trust, and for papers 6 and 9 the co-author's employing HEI ethics department also approved the studies prior to undertaking. For each of the papers, the Health Research Authority tools *Do I need NHS Research Ethics Committee (REC) review?* (Health Research Authority, 2022a) and *Is my study research?* (Health Research Authority, 2022b) determined that the nature of these studies did not warrant full REC review. However, following advice and guidance from the local R&D department regarding paper 5, an application was submitted through the Integrated Research Application System (IRAS) (Health Research Authority, 2023) to uphold good practice in view of the nation-wide, multi-site nature of this study.

There was a change of management in the local R&D department in 2020 that introduced a more structured and formal approach to approving studies, prior to this date the production of approval documents were not regularly issued. Consequently, the approval documentation for paper 3 could not be provided as evidence for this thesis, however a saved screenshot of the HRA tool from 2017 shows that the study was determined to be service evaluation thus did not require ethical approval. A learning point here is to always request an official approval letter from the local R&D department irrespective of the outcome determined by the HRA tool for personal records and to uphold good Research Data Management (RDM) practices. A short document for each of the studies outlined the rationale, the objectives, and the intended methods. Participant Information Sheets were also produced for each of the studies. These documents were submitted to the local R&D department for review, input, and ratification as required. All participants provided written or electronic consent confirming that they understood what their participation entailed and that their input could be utilised as necessary.

Adherence to the Good Research Data Management (RDM) principles throughout the research cycles of each of the projects within this thesis was followed. However, an official data management plan was only devised for paper 5, which went through the IRAS approval process. On reflection, and for future studies, it is now understood that the data management plan is a fundamental aspect of good RDM and should be produced regardless of the HRA decision tool outcomes and the level of ethical approval required. Many tools are available to help produce a data management plan such as the online tool designed by Digital Creation Centre (2023) that can be used to create, review, and share data management plans that meet institutional and funder requirements.

At the beginning of the data analysis phases, all data generated within the studies were anonymised with no identifiable information attached to the results files. All results files were stored on an NHS Trust private computer requiring a password to access, known only by the author. All results files were backed-up on an encrypted Universal Serial Bus (USB) memory drive, again with the password known only by the author. Data files were shared with co-authors as email attachments when required, but this is recognised as an area that can be improved upon and the author will use Microsoft SharePoint as the secure method of sharing files with co-authors on future projects. This approach to sharing reduces risk and gives the author full control over the content and Microsoft SharePoint has an integrated, automated back-up system as default. There was no pre-publication sharing of the data and the data remained anonymous upon submission and subsequently there was no participant or site identifiable data included in the published papers.

In view of the desire to undertake a large scale, online PCE study, future ethical considerations will include approval from the local R&D department and submission of an IRAS form with a robust accompanying data management plan. The ethical approaches will build on the current processes and the learning points outlined above with all the required documentation being obtained and stored appropriately.

This section provided an overview of the ethical processes that were adhered to when carrying out the studies. The ethical review highlighted some key learning points to take forward with future research projects. The next section will present full text versions of the nine submitted papers.

3. Published Works

The papers listed below are the final versions of the accepted and published manuscripts. The Vancouver reference style is used throughout, as specified by the journals' guide for authors. The papers submitted for this thesis are presented in order of publication date. Each paper will be referred to in the thesis by their corresponding numerical values (1-9).

3.1. Paper 1

The impact of focused training on abnormality detection and provision of accurate PCE in newly qualified radiographers

Stevens BJ & Thompson JD (2017), Radiography, February, Volume 24, Issue 1, 47 - 51.

http://dx.doi.org/10.1016/j.radi.2017.08.007

Introduction

The Preliminary Clinical Evaluation (PCE) is a commenting scheme designed to improve the specificity of the widely adopted red-dot abnormality detection system; the Society and College of Radiographers(1) are advocates of this system and the Standards for Proficiency outline that radiographers should be able to distinguish abnormal appearances and trauma processes(2). Furthermore, there is an expectation that all radiographers have sufficient knowledge of radiographic anatomy and common abnormalities(3), which would facilitate effective participation in a PCE system. PCE provides radiographers with an opportunity to have a positive impact on timely patient management. Effective communication of abnormal findings is considered to reduce the time-to-diagnosis, which may also have an impact on the length of hospital stay(4). Despite recognised benefits, there has been minimal publication of large-scale empirical studies confirming the success of PCE. The uptake of PCE has been slow with the suggestion that this may in part be due to the increase of reporting radiographer activity(5). If PCE is to be a worthy successor to the red-dot abnormality detection system, radiographers must provide a service that is accurate, and an effective driver of improved patient outcomes.

The meta-analysis by Brealey et al(6) suggests radiographers have good accuracy when using a red-dot abnormality detection system, albeit against varying reference standards with associated differential verification biases. Very little exists by way of objective observer studies that assess performance, but a few recent studies aptly illustrate the image interpretation abilities of radiographers.

Piper and Paterson[5] undertook an Alternative Free-Response Operator Characteristic (AFROC) study assessing the effects of training on the abilities of 38 participants (radiographers and nurses) to accurately locate an abnormality and to simply state the nature of the abnormality. Improvements were observed after training with radiographers demonstrating post-training increases in figure of merit (0.63 to 0.73), sensitivity (60% to 69%), and specificity (73% to 83%), respectively.

The FROC study by McEntee and Dunnion[6] indicated that radiographers can accurately detect abnormal wrist images with sensitivity comparable to that of radiologists (radiographers 87.7%, radiologists 88.9%), but specificity is poor (radiographers 64.4%, radiologists 80.5%). McEntee and Dunnion[6] concluded that, although not statistically significant, the number of years of experience could positively affect interpretation skill; they did not however assess the effects of training on performance. Earlier work by Hardy & Culpan[7] has proven that sensitivity and specificity levels do improve following training; 72% to 88% and 50% to 53%, respectively.

With the knowledge of the impact that increasing years' experience can have on the ability to interpret images accurately, it is perceivable that in view of lack of experience, the provision of training for newly qualified radiographers would expedite accurate contributions in a PCE system.

Despite claims of good accuracy, it is thought that PCE has not been widely implemented due to a perceived lack of confidence and inadequate training[2,8] with previous research suggesting that the requirement to provide a written comment caused a reduction in abnormality detection accuracy[7, 9]. However, this is not a universal opinion, where it has been suggested that good red-dot performance indicates an ability to provide a written comment[12]. If training issues do exist, and are not addressed appropriately, then the effectiveness of the PCE could be restricted[9].

Much of the previous work discussing the uptake of PCE focuses on the quality of training and the preparedness of radiographers to provide an accurate PCE comment. Graduate radiographers are expected to have sufficient image interpretation ability, despite a lack of certification of competency[11]. The aim of this paper is to evaluate the fracture detection performance and PCE accuracy of a small sample of graduate radiographers using an objective observer study to assess detection accuracy, and a scoring system to assess commenting accuracy. Given that questions remain about training and the ability of radiographers to provide a comment, this study will operate a pre-and post-training design to assess the impact of focussed training on a graduate radiographer's ability to accurately localise and describe a red-dot type abnormality.

Materials & Methods

Local Research and Development, and the Health Research Authority[13] decided that the project was suitable as service evaluation. The clinical cases used were all obtained more than 12-months prior to this study to ensure that the likelihood of new, previously unreported abnormalities being discovered was extremely low. Where follow-up imaging was available, it was reviewed to ensure that no occult fractures were present on cases used in the observer study. All observers provided written consent.

Case Selection

A three-month audit of abnormality prevalence for all examinations of trauma to single appendicular parts was undertaken in the study centre revealing a 29.4% incidence of abnormality. We used this data to determine the number of normal/abnormal cases (prevalence) for the observer study, and also the distribution of appendicular examinations that should be included. The range of the subtlety of abnormalities within the selected cases was also consistent with the local workload. One of the authors (BS) compiled the caseload based on the findings of the abnormality prevalence audit. Replicating the local clinical workload provides a comparative assessment of participant interpretation, relative to their clinical practice[14]. We performed a sample size calculation to predict the required number of cases, based on six observers completing the study. Obuchowski[13] developed a mathematical model to provide sample size tables for ROC analyses based on the intricate relationships of accuracy, inter-observer variability, patient variability and the correlations in accuracy imposed by the study design. Test alpha was set at 0.05 to control the probability of Type I error, while the power is set at 80%. We estimated that 58 cases would be required for a suitably powered study with a ratio of 4:1 (negative: positive) cases. This ratio was the nearest to the 29.4% prevalence of abnormal cases established from our audit.

The image bank of 58 examinations consisted of 17 abnormal appendicular examinations and 41 normal appendicular examinations. Cases containing normal variants were not excluded and were considered as normal. The mean distribution of each appendicular examination over the previous three months was calculated alongside the percentage occurrence. The percentage occurrence was then applied to the sample size to provide the number of each examinations required. Table 1 summarises the 17 abnormal cases and the gold standard PCE comments, and the 41 normal cases used in this study. The gold standard PCE descriptions are a consensus of two Advanced Practitioner's interpretations, who verified the descriptions of the abnormalities rather than relying on the report. DICOM headers were removed from all cases to ensure anonymity. All annotations identifying fractures or dislocations were also removed. Each abnormal case contained only one abnormality to allow quantification of a single comment. No discrepancies with the original radiological report were identified in the case selection process.

Case	Fracture Location (Score 3: Side, Bone, Location)	Fracture Type (Score 1)	Movement (Score 1)
1	Left Radial Head	Intra-articular	Minimal Displacement
2	Left Scapula (Lateral)	Comminuted	Posterolateral Displacement
3	Right Distal Radius	Buckle	Dorsal Angulation
4	Left Distal Tibial Epiphysis (Lateral)	Longitudinal	Anterior Displacement
5	Left 2nd Proximal Phalanx (Base)	Oblique	Minimal Displacement
6	Left Distal Radial Metaphysis	Buckle	Dorsal Angulation
7	Right Glenohumeral Joint	Dislocation	Posterior Displacement
8	Left Proximal Tibial Metaphysis	Incomplete	Undisplaced
9	Left 5th Metatarsal Base	Transverse	Undisplaced
10	Right 3rd Metatarsal Neck	Stress	Undisplaced
11	Left Distal Radial Metaphysis	Buckle	Dorsal Angulation
12	Left Proximal Metaphysis Proximal Phalanx	Longitudinal	Undisplaced
13	Right Lateral Malleolus	Oblique	Minimal Displacement
14	Right 5th Metacarpal Base	Oblique	Undisplaced
15	Left 4th Proximal Phalanx Neck	Oblique	Lateral Displacement
16	Right 1st Toe Interphalangeal Joint	Dislocation	Plantar Displacement
17	Right 5th Metacarpal Neck	Oblique	Volar Angulation
18 to 58	Normal Cases: Ankle (x7) Elbow (x3) Femur (x1) Finger (x3) Foot (x4) Forearm (x1) Hand (x4) Humerus (x1) Knee (x4) Scaphoid (x1) Shoulder (x5) Tibia (x1) Toe (x1) Wrist (x5)	N/A	N/A

Table 1: Breakdown of the image case mix used showing the gold standard PCE comment for each of the abnormal images.

Observer Performance Study & PCE Scoring

Four observers evaluated the 58 cases on two occasions: (i) pre-training and (ii) post-training. All observers were in a preceptorship period; eight weeks of training elapsed between the two evaluations. We based our sample size calculation on 6 observers, but only 4 were able to complete the study. For one of the observers, it transpired that they did not fulfil the criteria of being newly-qualified and first-appointment, and for another there was an unavoidable delay in commencing their employment, therefore they were excluded from the study. An eight-week training schedule, separating the pre- and post-training evaluations, consisted of intensive educational sessions designed to deliver information relative to abnormality detection. The sessions were designed and delivered by one of the authors (BS), whom is an Advanced Practitioner. The introductory session covered basic terminology and concepts, which familiarised participants to a systematic approach of detecting a fracture, forces and fracture patterns, established vocabulary, and a model of forming a comment. All appendicular body parts were covered; each session followed the same format, which included radiographic anatomical knowledge, common fractures, assessment lines and measurements, concepts relative to each body part and the relevant abnormal cases, as well as examples to practice forming a comment.

All observers were trained to use the software for the observer study and how to approach the study. They were given a test set of 10 images with which they were asked to localise suspicious areas and provide a PCE comment. This test-set could be repeated until the observer was confident with the data collection method. Each case could include 2-4 images, depending on the type of examination. Observers were instructed to mark all areas suspicious of fracture/dislocation with a mouse click; this prompted an unmarked slider-bar rating scale to appear with which they could indicate confidence (1-10) in their decision. Moving the slider further to the right indicated increased confidence. Since multiple images were available, it was possible that a fracture could be identified on more than one image. In such cases, we took the highest rating; it was not necessary for the observers to mark the fracture on all projections for it to be deemed a successful localization. An acceptance radius classified the accuracy of observer marks. All image evaluations were completed on a 20" LCD flat panel monitor at 60Hz (NEC MultiSync LCD 2090UXI, 600 x 1200, NEC Display Solutions, Itasca, Illinois, USA) using ROCView(16) to record observer responses. Each image evaluation was completed in a different randomised order.

For each localisation, the observers were also asked to provide a PCE comment. Pre-training comments were based on experience from undergraduate education. Post-training they were expected to be familiar with the components of an accurate PCE comment, following the eight week training programme. They were scored on the following components, with each assigned a single point for a maximum score of 5 for each comment: name of bone, location of fracture, anatomical side (L/R), fracture type, and the presence of any movement, such as displacement or angulation. A gold standard comment was agreed by two experienced musculoskeletal reporting advanced practitioners.

Statistical Analysis

We are interested in the accuracy of the clinical comment and the precise localisation of abnormalities. The equally weighted jack-knife alternative FROC JAFROC (wJAFROC) figure of merit is sensitive to location information and defines probability that a true abnormality is rated with higher confidence than a false localisation(17). Data was analysed using Rjafroc; an implementation of wJAFROC analysis in the R programming language. A difference in abnormality detection between pre- and post-training was considered significant if the result of the overall F-test was significant and the 95% confidence interval (CI) did not include zero. Test alpha was set at 0.05.

Results

A significant difference in fracture detection performance was found between pre- and post-training evaluations for a fixed reader random case analysis (F (1,57) = 10.57, p = 0.0019). The reader averaged wJAFROC FOM and 95% CIs for pre- and post-training were 0.619 (0.516, 0.737) and 0.703 (0.622, 0.852) respectively. The reader averaged wJAFROC curves are displayed in Figure 1. All readers demonstrated improvement from pre- to post-training, as evidenced by the increase in wJAFROC FOM, Table 2.

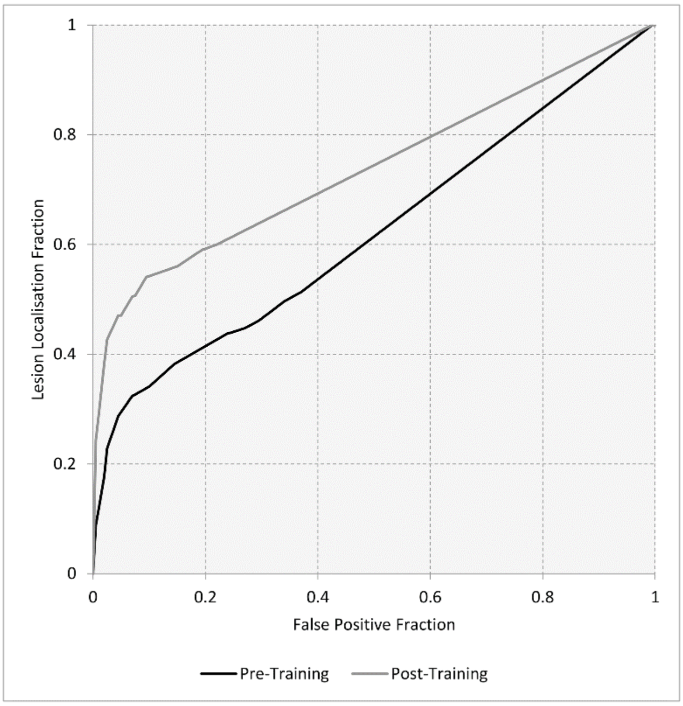

Figure 1: The observer averaged wAFROC curves for pre- and post-training image evaluations.

Reader	Pre-Training wJAFROC FOM	Pre-Training PCE Score	Post-Training wJAFROC FOM	Post-Training PCE Score
1	0.680	13	0.789	39
2	0.570	18	0.730	31
3	0.662	29	0.684	28
4	0.564	8	0.742	26
Mean	0.619	17	0.737	31

Table 2: Comparison of each reader's pre- and post-training wJAFROC FOM and PCE scores.

Abnormality (fracture or dislocation) detection was assessed on a case-by-case basis for the 4 readers in this study to identify further training needs. Reader averaged detection rates improved from pre- to post-training, 42% and 56% respectively. From these cases, it was apparent that these novice observers had difficulty in detecting cases with undisplaced fractures (cases 8, 10, & 12). None of the readers could detect these abnormalities post-training. Another trend was observed for distal radius fractures in paediatric patients, where each fracture (cases 3, 6, & 11) was only successfully localised by one reader. There was a 50% reduction in false localisations after training.

The PCE score was composed of five criteria: bone, location, side (L/R), fracture type, and movement. Table 3 illustrates the increases in each of the PCE criteria following the training period. In cases where the fracture was not localised the PCE score was generally consistent with this event; however, it was still possible to achieve a PCE score if the precise site had been missed (i.e. indicating the correct anatomical side). Additionally, in some cases in the pre-training evaluation the PCE score was still low even when the fracture had been successfully localised.

Scoring Criteria	**Participants' combined PCE scores**		**Score change between pre and post test**
	Pre-training	Post-training	
1 – Correct Bone	23	34	+ 11
2 – Correct Location	19	34	+ 15
3 – Correct Side (L/R)	15	23	+ 8
4 – Fracture Type	6	18	+ 12
5 – Displacement/Angulation	5	15	+ 10
Total	68	124	+ 56

Table 3: Combined scores of users' comments for each of the positive cases using the criteria outlined and against the gold standard.

Discussion

We found a statistically significant improvement in fracture detection as a result of a focused 8-week training program. We have also been able to demonstrate an improvement in the accuracy of a PCE comment as a result of this training. If a PCE commenting system is to be successfully introduced then the radiographers that use this system must demonstrate equal, if not superior accuracy to that of the previously used red dot system.

The increases in performance we observed following the training phase of the study substantiates the study by Hardy & Culpan[(7)] that assessed 115 radiographers' abilities to recognize and describe radiographic abnormalities following attendance at a red dot study day course. Their results showed that following training, red dot sensitivity and specificity improved alongside abnormality description. Further correlation is seen with the findings of Piper and Paterson[(5)] who also reported increases in performance following training; despite their significant findings it was concluded that further work is needed to evaluate performance in image interpretation.

Detection rates increased for all but one reader. Interestingly, this reader (participant 3) produced a very similar PCE score in both pre- and post-training. This may indicate a difference in undergraduate education, as their pre-training score was much higher than the other readers. However, the 50% reduction in false localisations reveals that the intensive training sufficiently improved the reader's ability to recognise normal appearances, echoing the work of Wright & Reeves[16]. The overall improvement in PCE score from pre- to post-training was evident in all of the 5 criteria used to score the comment; with the greatest improvement (score +15) observed in the description of the correct type of fracture. This improved appreciation of fracture morphology is recognised as providing benefits in diagnosing and managing the patient[19].

Two participants correctly localised and described a fracture of the second proximal phalanx on the PA wrist projection (case 5) in the post-training test compared to zero participants in the initial test. This suggests improvement in the overall search of the image. Discussion of the satisfaction of search phenomenon should be included in any training program; whereby the detection of one abnormality interferes with detection of another and is often affected by knowledge of common fractures[20]. This level of understanding may not manifest itself in the search strategy of newly qualified radiographers.

In this study we have a trend of a failure to detect buckle fractures of the paediatric distal radius, and this correlates with the findings of previous work[21]. There were also difficulties in detecting subtle and undisplaced fractures; all of these findings could help direct training for newly qualified radiographers. We recommend that intensive PCE training should be included in the preceptorship program or during the transitional period from graduate to independent practitioner. It must be stressed though that the issue of sustaining any improvements in performance is just as challenging as attaining the desired level. Previous work by Mackay (2006) indicated that the immediate improvements in abnormality detection following training were not demonstrable after 6 months; reinforcing the need for regular CPD sessions to maintain standards, not just for newly qualified radiographers but also those who are more experienced. For the newly qualified radiographer the transition from student to practitioner can be quite daunting. However, the pressure of contributing successfully to a PCE system can be reduced by this comparatively simple, cheap and regular departmental training intervention.

This study has demonstrated the effectiveness of the method we proposed; the study should now be repeated with a larger sample size and over a larger number of cases in order to generalise the results to the population of newly qualified radiographers. However, the initial results are encouraging, where we have demonstrated the effectiveness of a focussed training programme to improve fracture detection rates and the accuracy of a PCE comment. Experiential learning, peer support and educational reading cannot be excluded as potential influences on the performance increase from pre- to post-training evaluations, but it would not be practical to conduct this study in isolation of any these external factors.

Future work could also assess the impact of the accuracy of a PCE comment on emergency practitioners' evaluation of the image, and the speed and appropriateness of care delivered to the patient as they return to the emergency department.

Conclusion

This study found a statistically significant improvement from pre- to post-training fracture detection performance. Post-training PCE scores also showed an overall increase. These results were also consolidated by a 50% reduction in false localisations post-training. It is difficult to state any generalisable conclusions and it would be inappropriate to state that these findings are representative of all newly qualified radiographers, due to the small sample size. However, on the basis of these findings we recommend an intensive training program would benefit newly qualified radiographers in providing the necessary framework for participating in a PCE system.

Conflict of Interest

No conflicts of interest influenced this work.

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3.2. Paper 2

A survey assessment of reporting radiographers' scope of practice in the West Midlands.

Stevens BJ (2019), Radiography, Volume 25, Issue 3, August 2019.
https://doi.org/10.1016/j.radi.2019.01.006

Introduction

Reporting radiographers offer a resourceful way of working through the reporting challenges encountered by radiology departments in the National Health Service (NHS) in United Kingdom (UK) in recent years. Radiographers have long been part of the reporting team, accurately providing reports across a number of modalities(1) contributing significantly to reporting workloads(2). The worth of this is also noted in the key recommendation in the recent Care Quality Commission (CQC) review of radiology services in the United Kingdom (UK)(3) which stated that staff and resources should be used appropriately to reduce report turnaround times. In the current economic climate utilising radiographers in innovative ways can help to overcome the challenges in healthcare provision and should be considered integral to collaborative radiology team working(4).

Radiologist vacancies have been persistently high for the previous six years(5), and the number of trained radiologists in the UK remains one of the lowest in Europe with only 48 per million population(6). The demand for radiology services in recent years(7) shows no signs of slowing. Cross-sectional scan activity has risen by between 10% and 12%(6), respectively, and hybrid imaging modalities have yielded up to 37% annual growth in the year to March 2017(8). Yet the number of radiologists has remained low. In England, 112 Trusts indicated the use of reporting radiographers in March 2018 with wide variance of workload ranging from 0.8% to 78.9% of X-ray reports authored by a radiographer, with a national median of 25.7%(9), The recent NHS Benchmarking document highlighted that across the 82 corresponding Trusts, 28% of all X-ray examinations are reported by radiographers(10). This has been documented as providing tangible benefits for patients(11–13). Recent studies have also highlighted the cost-effectiveness and accuracy of reporting radiographers in interpreting chest X-ray images with noticeable impact on the diagnosis to treatment pathway and government targets(14,15).

With the continued capacity and demand issues facing many radiology departments, utilising radiographers effectively by extending agreed reporting boundaries may help overcome the burden of reporting backlogs. A degree of increased responsibility and accountability is inherent with extending scope of practice, and this is reflected in the severity of potential findings, e.g. recognising a lung mass which then requires further investigation. It is stated that a report should provide the referrer with advice on patient management to prompt appropriate care[14]. If radiographers are to provide a report of comparable standards to their radiologist colleagues, then recommendations need to be considered.

The inclusion of recommendations for further action to help refine the diagnosis is considered to impact positively on treatment pathways and is advocated as being good practice(16). Interestingly, a large-scale analysis of three million radiological reports over seven years indicated that only 11% of all imaging reports included follow-up recommendations, and the recommendations in general radiographic reports were only adhered to 42% of the time by referring clinicians[16]. Whilst there are many reasons why recommendations are not followed, such as patient condition improving, or the recommendation being incorrect or unhelpful, a question is raised as to the necessity and importance of such suggestions. However, the report should be grounded in achieving better patient outcomes and the inclusion of relevant recommendations should be given due consideration.

Whilst much of the research to date[17–25] illustrates the abilities of reporting radiographers in producing reports comparable to radiologists in terms of accuracy, none have specifically assessed the helpfulness of the report in terms of the types of advice they include. The aim of the study was to generate an updated and detailed appraisal of the reporting scopes of practice of reporting radiographers in the West Midlands region, including referrals for further imaging, to clinical specialities and suggestion of treatments.

The lead radiographer or service manager in each of the sites was contacted and asked to forward on the invitation email to their relevant reporting radiographers which included the survey link. There were 11 sites that agreed to forward on the survey link. Participants were sought from all reporting radiographers employed at the 11 Trusts. Participants who did not report radiographic images and were not employed at one of the selected sites were excluded from this study.

The survey was accessed on two web-based hosts, Google Forms[27] and Online Surveys[28], due to unforeseen firewall issues at some Trusts. The survey was self-designed and contained basic demographic questions, multiple choice style questions and options for comments if needed. To avoid reducing the potential sample size in what was originally considered to be a small population and with the known low response rates of survey studies, the survey tool was not piloted. A consultant radiographer reviewed the survey to assess content validity and to ensure the questions were suitably aligned to the aims of the study. Minor wording changes resulted. Topics that were covered included adult and paediatric reporting scope of practice i.e. which body parts are reported and from which referral sources, as well as referring for further imaging and to other specialties, and suggestion of treatments (see appendix A). All participants gave consent to participate. No identifiable data was attached to responses to encourage participants to describe their practice openly and honestly. The study was open for six weeks during June and July 2018. The data was exported from the hosts in to Microsoft Excel® (Microsoft Excel, Redmond, WA) and descriptive statistics were generated. Free text responses were analysed manually and categorised accordingly e.g. treatments/chest/antibiotics.

Results

Demographics

Responses were received from 11 Trusts, indicating a target population of 86. The overall response rate was 47% (n = 40). A post hoc power analysis of the study indicated that due to the low response rate the estimated effect was .60, and with α = 05, power (1 - β) was determined to be 0.75(29). The individual breakdown of responses and reporters at each site is illustrated in table 1. Fourteen participants (35%) are qualified to Post Graduate Certificate (PgC) level, 19 (48%) are qualified to Post Graduate Diploma (PgD) level, and seven (18%) hold a Masters (MSc) qualification. The mean (SD, range) participants have been qualified in reporting is 9 (5.7, 1-18) years.

Trust	**Number of Responses**	**Number of Reporters**	**Response rate (%)**
1	6	6	100
2	7	9	78
3	3	14	14
4	9	16	56
5	1	8	13
6	1	9	11
7	1	1	100
8	3	7	43
9	1	4	25
10	6	9	56
11	2	3	67
Total	**40**	**86**	n/a
Mean	n/a	n/a	**46.5**

Table 1. Number of reporting radiographers at each site and response rates.

Scope of Practice

Participants' scope of practice can be analysed by qualification and this is illustrated in table 2. Figures 2 and 3 further illustrate the scope of practice for adults and paediatrics by referral sources. Figures 4 and 5 highlight the different combinations of referral sources and anatomical areas reported for paediatric and adult examinations, respectively.

Table 2. Analysis of scopes of practice by qualification.

		Anatomical Areas Covered					
		Adults			Paediatrics		
Qualification	**Number of Participants**	**Appendicular**	**Axial**	**Chest and abdominal examinations**	**Appendicular**	**Axial**	**Chest and abdominal examinations**
Pg Cert[a]	14	12	0	2	8	0	0
Pg Dip[b]	19	19	19	5	19	19	2
MSc[c]	7	7	7	5	7	7	1
TOTAL	40	38	26	12	34	26	3

a = Postgraduate Certificate; b = Postgraduate Diploma; c = Masters

Figure 2. Distribution of participants' scope of practice and referral sources for adults (ED = Emergency Department; GP = General Practitioner).

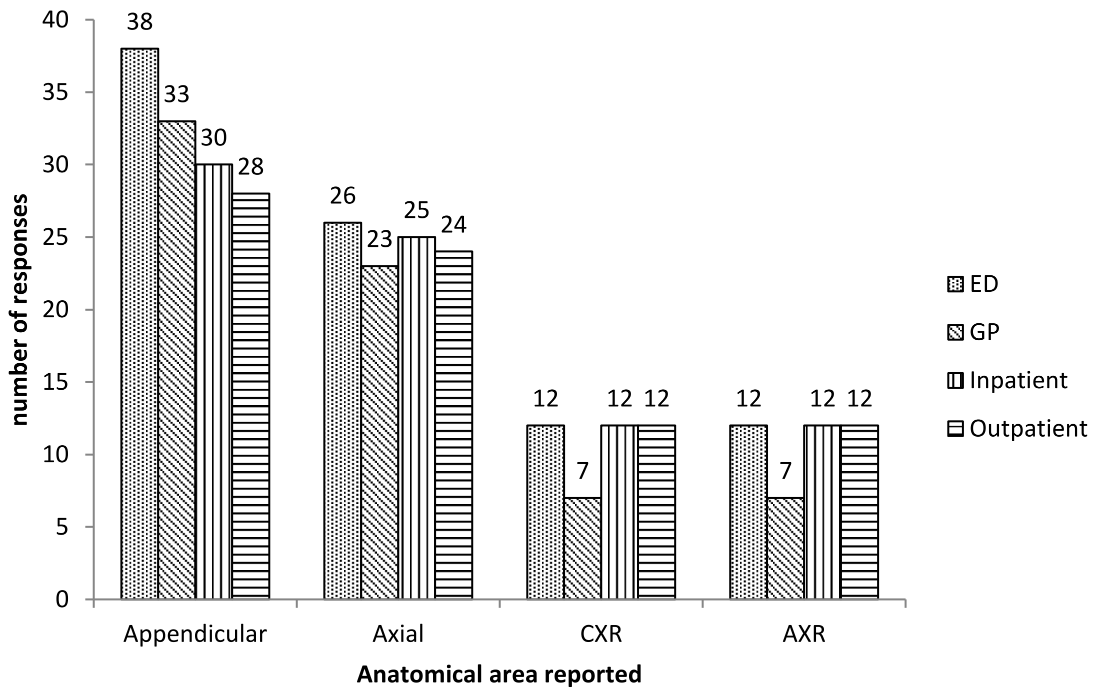


Figure 3. Distribution of participants' scope of practice and referral sources for paediatric examinations (ED = Emergency Department; GP = General Practitioner).

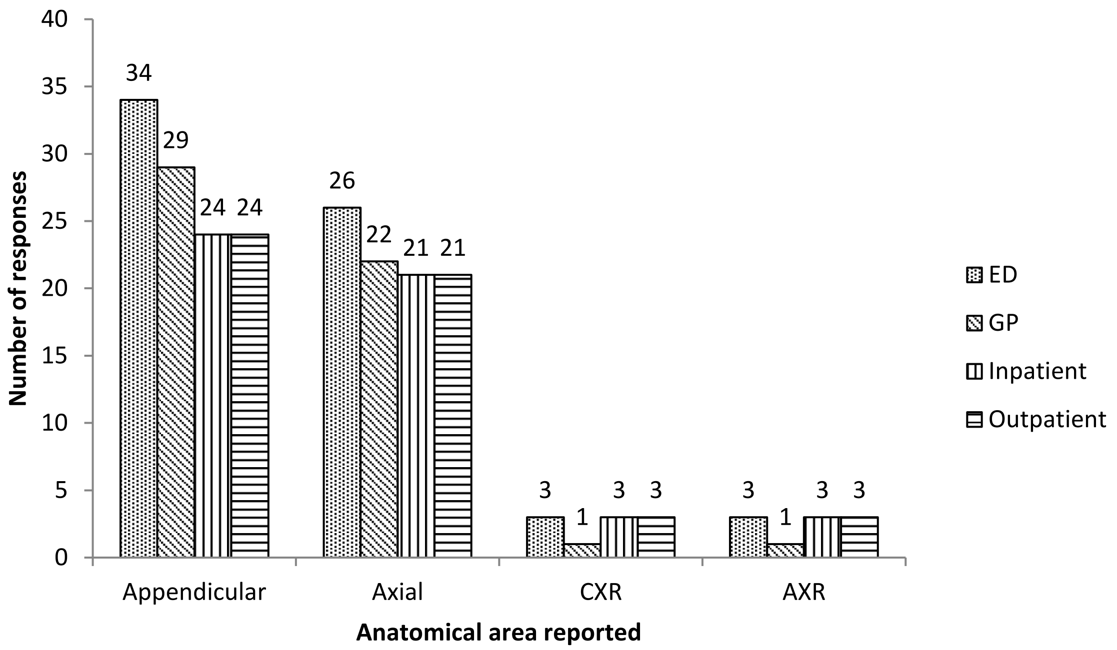


Figure 4. Combinations of paediatric referral sources covered by participants' scope of practice.

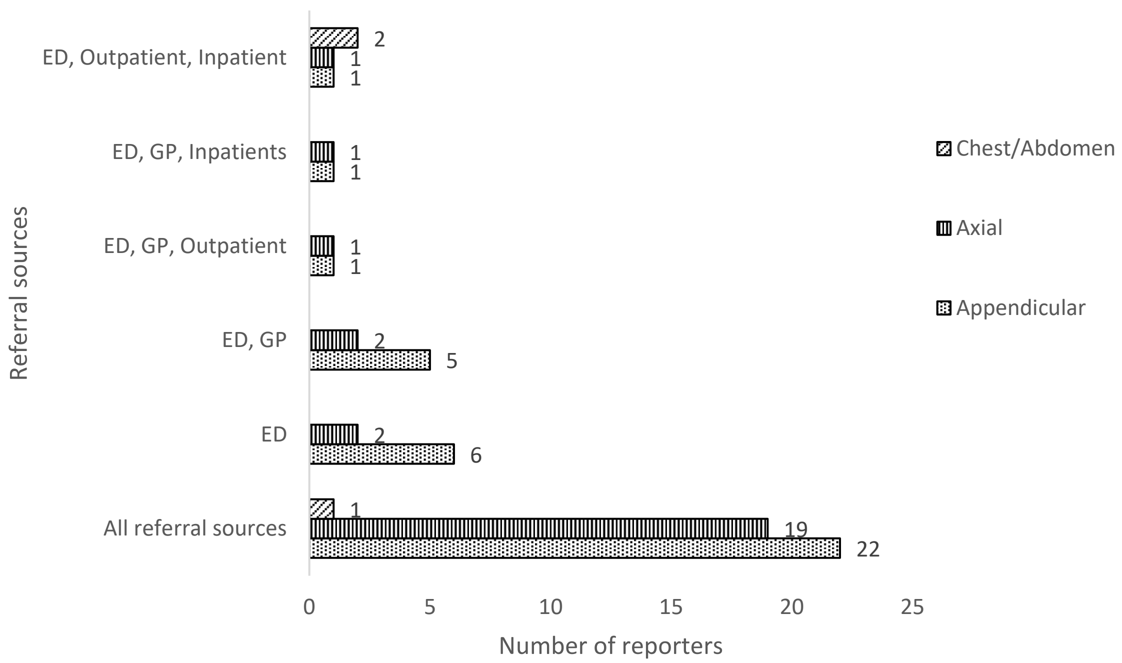
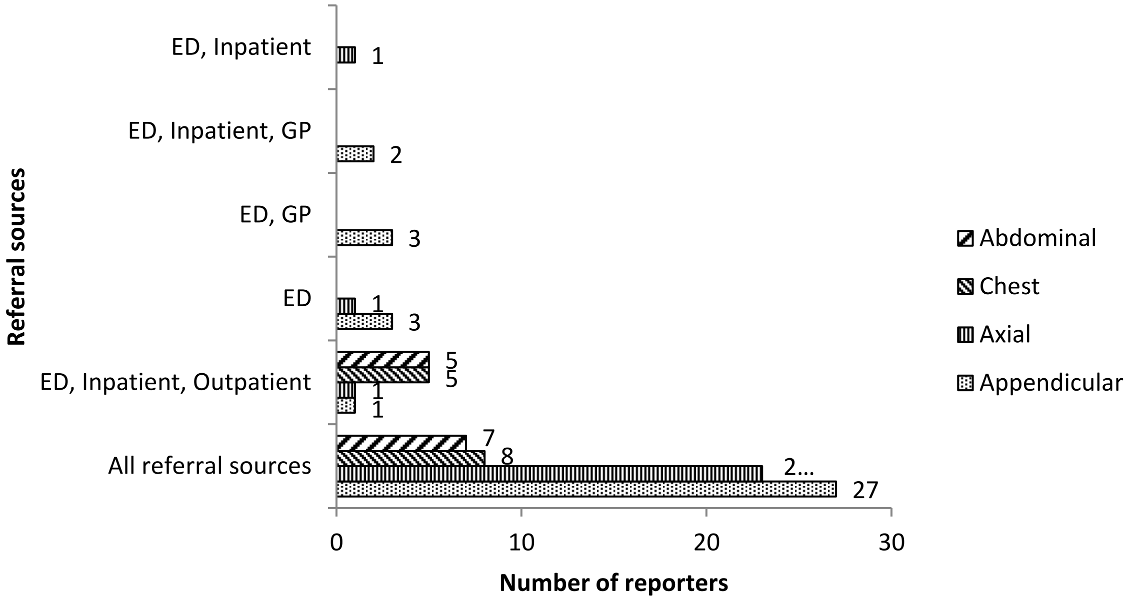


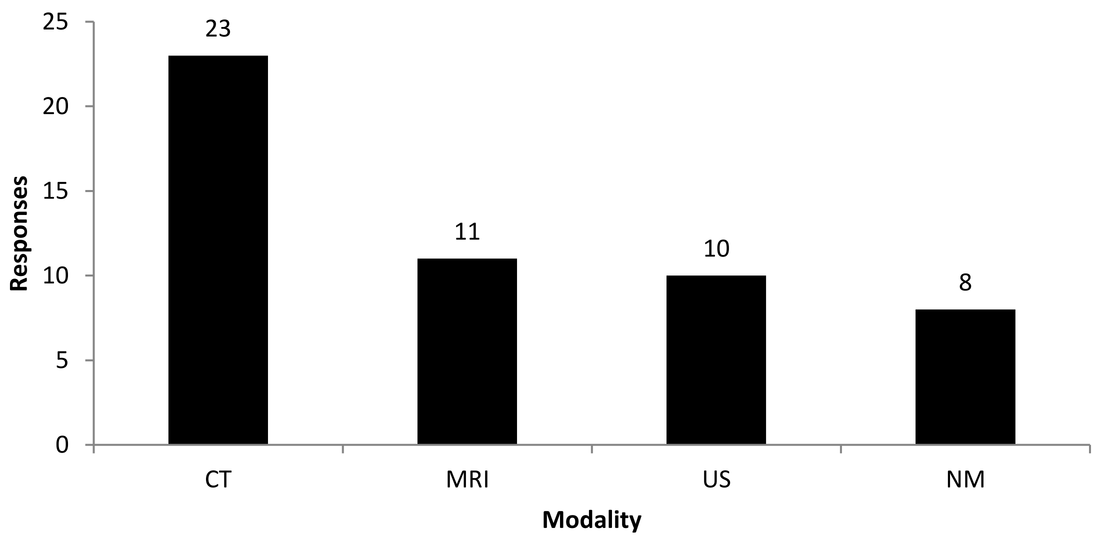
Figure 5. Combinations of adult referral sources covered by participants' scope of practice.



Referring for further imaging

Twenty-seven participants (68%) indicated that they are permitted to refer to other modalities as per local protocol. Twenty-three (85%) of these 27 participants stated that they are active in doing so. Seventeen of the 23 (74%) who actively refer for further imaging can do so by their own accord without discussing with a radiologist. A detailed breakdown of the modalities that participants refer to is shown in figure 6.

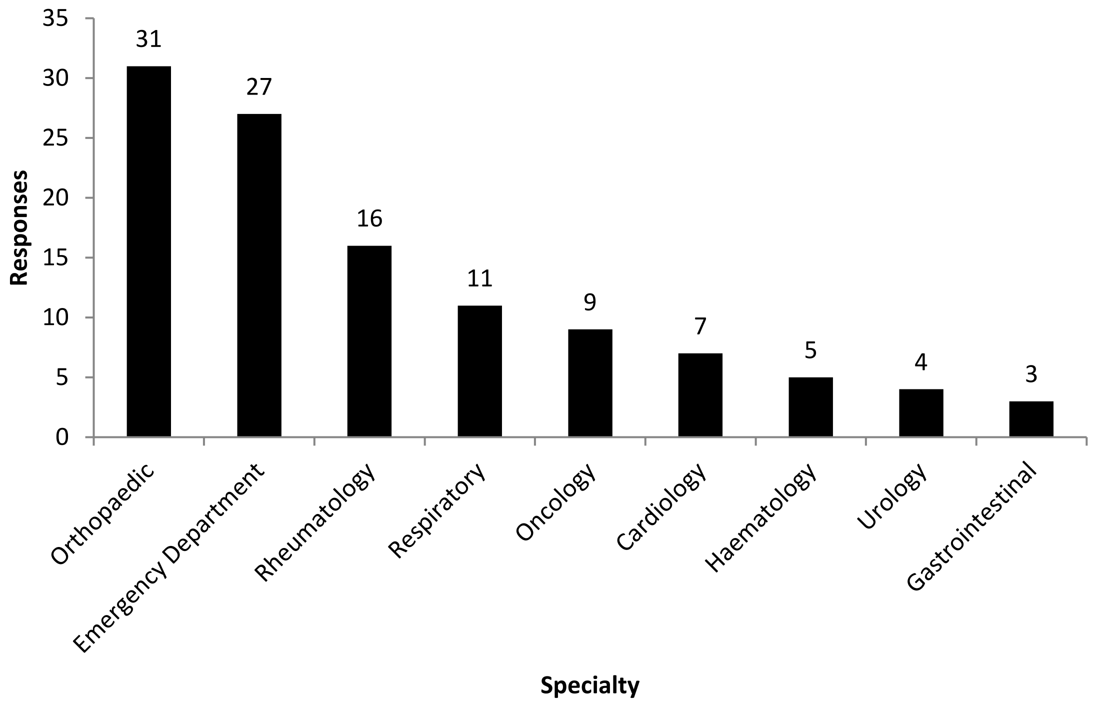
Figure 6. Distribution of further imaging referrals or suggestions.



Referring for specialist teams

Thirty-two participants (80%) indicated that they are allowed to refer to specialist teams as per local protocol, and 98% (n = 31) of these participants stated that they actively refer to specialist teams. A detailed breakdown of the specialities that participants refer to is outlined in figure 7. Twenty-seven of the 32 participants (84%) who refer to specialities do so by their own accord.

Figure 7 . Distribution of the specialties to which participants suggest a referral.



Suggesting treatment

Only nine participants across the whole sample (23%) stated that they suggest treatments in their reports, all of whom report all body parts. These nine participants all suggest antibiotic therapy for infective chest appearances. Two of these nine participants (23%) stated that they also suggest the use of diuretics to treat congestive cardiac failure (CCF), whilst another also suggests the use of anti-inflammatory drugs for treating CCF. Other suggestions for treatment were related to the extremities specifically to immobilisation with wrist splints (n = 2/9, 23%) and neighbour strapping of toes (n = 2/9, 23%).

Discussion

The findings of this survey show that the large majority (n = 34/40, 85%) of participants' scope of practice incorporates appendicular examinations from the ED. This is comparable to previous studies[2,30], and correlates with the increased number of radiographer-led "hot reporting" services previously described[31]. Although, reporting restrictions are still evident regarding the referral sources reported in paediatric and adult categories, with six different combinations of referral sources being reported in each category. This is likely due to local staffing and service needs[2], and is best illustrated by the fact that only one participant (3%) across the whole sample has a reporting scope of practice that encompasses all body areas from all referral sources for adults and paediatrics. This finding resonates with previous research[30], which reported that 51% of reporting radiographers have restrictions on their practice (n = 131/259).

The use of teleradiology companies to provide reporting solutions may also prevent the progression of some reporting radiographers extending their scope of practice. In the year to March 2018, outsourcing of reporting was undertaken by 76% Trusts (n = 102/134) in England[3] with Trusts sending 10% of all X-ray examinations to be reported externally[10]. The combination of radiologist shortages and the impact of the CQC radiology review[3] may lead Trusts to pay to externally reduce backlogs with immediate and visible results rather than invest in advanced practitioners who may take a number of years to be as effective.

Twelve participants (30%) report chest and abdominal X-ray images distributed across six different sites, with two sites having the highest number of reporters (three). The number of participants whose scope of practice encompasses skeletal and chest and abdominal examinations has doubled since previous research in 2015(2), which found that only five radiographers in the Midlands and East region reported skeletal and chest and abdominal examinations. More recent work in 2016[30] suggested there are low numbers of radiographers in the West Midlands reporting chest and abdomen examinations (four and three, respectively). The growth evident in this sample illustrates progression within the region demonstrating an increased reliance on reporting radiographers in meeting demand. However, through analysing the scope of practice of these chest reporters, only seven (58%) report GP chest examinations.

The development of radiographers reporting GP chest examinations can be seen as a key area for progression given the findings from recent studies(20–23). Considering GP chest referrals are the most commonly requested examination, amassing 1.3 million referrals nationally in the year to March 2018(8), maintaining acceptable report turnaround times might prove to be difficult with added pressure from the upcoming implementation of the 28-Day Faster Diagnosis cancer standard in 2020[32]. These mitigating circumstances should be recognised as drivers for reporting radiographers to report these examinations. The additional increase in demand of cross-sectional and hybrid modalities[8], along with the current radiologist shortages[5], strengthens the argument for reporting radiographers to report GP chest examinations.

Only three participants (8%) report paediatric chest examinations, and paediatric GP chest examinations are only reported by one participant (3%). The reasons for this have not been explored in this study but might be similar to previous arguments in which paediatric examinations may be more likely to receive a discrepant report than adults[12], with potentially greater consequences.

A high number of participants (n = 23/27, 85%) stated they actively suggest further imaging, and by suggesting further action, which helps to refine the diagnosis[15]. It is interesting to note that a third of participants are prevented from referring for further imaging by protocol, inferring it is not the individual's choice but their local operating procedure preventing them from including advice relative to further imaging investigations. It would be interesting to explore if all reporters would refer for further imaging if given the opportunity, and any reasons for refraining.

The suggestion of referral for a specialist opinion is also considered to be advice that requires further action[15]. The large majority of participants are allowed to refer to specialist teams as per local protocol, and the large majority of these participants are active in doing so (n = 31/32, 97%). The main specialties that participants suggest referral to are orthopaedics, followed by ED. This reflects the finding that 85% (n = 34) report appendicular ED examinations and 65% (n = 26) also report axial ED examinations. The lesser referred-to specialities reflect the reduced amount of abdominal examinations undertaken and the small number of reporters who cover these areas. The inclusion of content which assists the referrer in furthering patient management is recognised as good practice[15], and in this respect these participants exhibit attempts to fulfil Standard 1 set out by the Royal College of Radiologists' standards for interpretation and reporting of imaging investigations[5].

Despite those who suggest treatment having scopes of practice that encompass all body parts, there is a predominance of chest-specific recommendations with only a small number of immobilisation suggestions for extremities. Although research has proven that just over half of the follow-up recommendations in chest radiograph reports are adhered to[18], a key chest interpretation textbook[33] advises adoption of the "six-week rule" follow-up for infective appearances, stating antibiotic therapy as the appropriate treatment. Experiential learning through comparing gold standard reports during training is possibly another contributing factor in reinforcing the inclusion of this suggestion. The use of diuretics to relieve congestive symptoms and fluid retention is recommended for all types of heart failure[34], and therefore the suggestion of this treatment can be considered good practice. However, the suggestion of non-steroidal anti-inflammatory drugs (NSAIDS) for heart failure patients should be avoided due to the increased cardiovascular morbidity and risk of death in elderly patients using diuretics[35,36].

It is unclear why suggesting treatments for extremity injuries is not practiced by more participants. Over half of participants (n = 27, 58%) are afforded the autonomy to refer for further imaging studies, and to other specialities (n = 32, 80%), yet over three quarters of the sample abstain from suggesting treatments. Extremity treatment recommendations may not have been frequently offered during training experiences, and this may simply be a continuation of preceding practices. The absence of treatment and fracture management teaching in reporting course curricula may have also compounded this issue. It is the radiographer's prerogative to practice within their capabilities and by not offering treatment suggestions they demonstrate awareness of their limitations determined by education and the extent of their competence(37).

It is acknowledged that suggesting treatment options is not widely practiced by reporting radiographers and this is an area where further progress could be made. It is encouraging to see that all chest reporters are active in suggesting appropriate treatment for infective appearances. Further advancement here could potentially include suggesting pneumothorax and pleural effusion treatments in line with the British Thoracic Society guidance(38), with prior local agreement and training. There is also opportunity for increasing the frequency and range of treatment suggestions for extremity examinations. Progression here may include collaboration with the ED to develop an injury management framework outlining treatment and follow-up plans for report inclusion that might help to streamline patient flow.

Study Limitations

A limitation of this study concerns that of the response rate, which is less than half of the targeted population across the 11 active sites. It is important that the potential effects of non-response bias are appreciated by the reader and they recognise that this sample cannot be considered representative of all reporting radiographers in the West Midlands region. However, this is the first study of its type for this region and does provide an interesting insight in to referral allowances and practices and provides routes for further investigation. Another limitation is that the body part that participants are referring and the type of examination they are suggesting further imaging for has not been evaluated. Similarly, this has not been explored regarding referring to specialist teams, but this is recognised as another interesting area for future study. Finally, the survey method is reliant upon participants' honesty and integrity. Analysis of the demographic data shows no duplicate responses and it is assumed that there are no falsified responses. In order to gain a true perspective of the content of reports authored by radiographers, departmental audits would provide defining results. However, this would also provide a number of logistical challenges to undertake on a wide scale.

Conclusion

The low response rate in this study does place limitations on the overall generalisability of study findings. Almost 50% of reporting radiographers within the West Midlands participated and as such there are important outcomes which cannot be considered generalisable. Study data does provide an interesting insight in to the reporting scopes of practice of those who participated. Limitations in reporting paediatric and adult examinations are seen across the sample, most notably in paediatric chest and abdominal images from all referral sources and adult chest images from the GP. Consequently, these are identified as realistic areas for further progression. Analysis of the data implies that those participants who are permitted to do so, do actively refer to other modalities and for specialist opinions. A small minority suggest treatments that are mainly chest-specific; as such this is also seen as an area where further progression could be made.

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3.3. Paper 3

The value of preliminary clinical evaluation for decision making in injuries of the hand and wrist

Stevens BJ & Thompson JD (2019), International Emergency Nursing, Volume 48, January 2020, [*https://doi.org/10.1016/j.ienj.2019.05.001*](https://doi.org/10.1016/j.ienj.2019.05.001)

Introduction

Background

A preliminary clinical evaluation (PCE) is a focused descriptive comment provided by radiographers in order to direct referrers to abnormalities on trauma radiographs (1). The PCE is provided to the referring practitioner immediately and is visible alongside the images when the radiographer completes the examination. The PCE can include valuable information on the type of fracture or dislocation, specific bone or joint location and any misalignment of anatomy. This enhanced method of communication, in comparison to a 'red-dot' system, has expected benefit to emergency department (ED) practitioners, including emergency nurse practitioners (ENP), emergency-care advanced clinical practitioners (EC-ACP), who may have variable experience in reviewing trauma radiographs due to their broad, multifaceted roles.

The Emergency Care – Advanced Clinical Practitioner.

The progression of advanced practice has led to the approved Royal College of Emergency Medicine (RCEM) role of the EC-ACP and is designed for health professionals to re-train to extend their skill-set. The EC-ACP curriculum is modelled on the first three years of emergency medicine training and qualified individuals would be expected to be operating at the level of an ST3 doctor working in the emergency setting (2). As such, the EC-ACP syllabus (3) includes knowledge of extremity fractures and dislocations as a common competence.

Non-Medical Referrers' Image Interpretation

The Royal College of Nursing (RCN) recognises the value of non-medical referrals for providing improvements in care pathways and role extension for nurse practitioners (4). Combined with a PCE system there is potential for improvements in service delivery, but previous work suggests low numbers of nurses in the emergency setting with formal image interpretation training (5). This may be a limiting factor in the provision of this service and the efficacy of it requires investigation.

Previous research has indicated that the ability to recognise normal and abnormal appearances can decline if image interpretation training is not performed regularly [6,7]. It is likely that a lack of practice in the clinical environment, caused by irregular shift patterns and department rotations could contribute to this effect. To counteract this, knowledge and skills should be maintained with refresher sessions every six months [6], especially if practitioners are not regularly viewing radiographs.

Given the differing expertise of ED practitioners [6,7] there is always the risk of interpretation error. Upper limb imaging referrals are prevalent, but this does not necessarily equate to familiarity or high interpretation skill since bony abnormalities of the wrist, hand and fingers have been reported to be missed with varying predominance from 33-44% [9,10]. As an example, a lunate dislocation provided the largest number of errors among nurses with a false negative error rate of 27.3% [8]. It is conceivable that wide variations in ability do exist, and additional training would likely be a welcome consideration.

Radiographer input

An immediate formal report is known to be advantageous to patient outcomes. The implementation of immediate reporting is shown to be cost-effective by increasing service productivity [12], by informing patient management at time of attendance [13], and by reducing interpretative errors in the ED [14]. However, immediate reporting is not currently available in all places or at all times, so an alternative is required.

The effectiveness of the PCE system is reliant on the combined ability of the radiographer to communicate the findings and the referrer to correctly interpret the written statement alongside the images. Numerous studies have highlighted the effectiveness of radiographers to recognise fractures to standards comparable with radiologists [15,16]. However, it is acknowledged that radiographers may require additional training to ensure a successful implementation of a comment-based system [15,17,18]. Nonetheless, radiographers are perfectly placed to provide contributions to supplement the decision-making of ED practitioners.

The use of the PCE system is advocated by the Society and College of Radiographers (SCoR) for every trauma radiographic examination[1] but a basic understanding of anatomical and radiographic terminology is needed if the PCE is to be acted on appropriately. Controversy exists surrounding the requirement of formal pre-registration image interpretation training, as nurses do not currently receive this[19]. Acquiring the skills and knowledge to accurately interpret trauma radiographs without training may require extensive experiential learning.

The aim of this research is to understand the impact of PCE on the treatment and management decisions made by the referrer, prior to receiving a formal report. A secondary aim of the study is to compare the image interpretation performance of the ENPs and the EC-ACPs.

Methods

This observer study assessed the fracture detection performance of ENPs and EC-ACPs and the impact of a PCE on treatment decisions in upper limb trauma, during April to October 2018. In this study, we were interested in following aspects of the image interpretation process.

1. Can the participant correctly identify a case as abnormal, via provision of a management plan?
2. Can the participant correctly localise the abnormality?

Ethical Considerations

Research Ethics Committee approval was not necessary as the study was deemed to be service evaluation by the local Research and Development team and the Health Research Authority online decision tool(18).

Image Bank Formation

A local audit of abnormality prevalence in singularly requested radiographic examinations of the wrist, hand, fingers, thumbs and scaphoid bones in the three months preceding the study indicated 35% overall prevalence of abnormality (Table 1). The distribution and prevalence of abnormality across these areas is shown in Table 1. This guided the formation of the image banks and ensured that the caseload was comparable to that of normal clinical practice allowing a true comparative assessment of abnormality detection ability(21). The severity and complexity of the abnormal cases were representative of the local clinical workload and were drawn from the local Picture Archiving and Communication System (PACS). The positive caseload of images was generated by asking two radiographers to view 100 positive images with abnormality prevalence derived from the aforementioned audit (35 wrists, 27 hands, 26 fingers, 7 thumbs and 6 scaphoids). They were asked to simply indicate if they could identify the abnormality. The final selected images included those in which the abnormality was seen by both radiographers, those seen by only one radiographer and those missed by both radiographers. This ensured that the caseload of images contained varying difficulty.

The selected examinations were presented in two different sets. Image set A comprised of 149 examinations including 52 abnormal cases, covering the hand and wrist incorporating focussed examinations of fingers, thumbs and scaphoid series. Whereas image set B only contained the 52 abnormal cases.

Table1: Distribution and prevalence of the abnormal images within the initial 3-month audit and the image bank

	Number of examinations in 3-month audit (%)	**Number of positive exams in audit (%)**	**Number of exams in image bank (positive/total)**
Wrist	318 (30)	129 (35)	17/45
Hand	278 (26)	99 (27)	14/39
Fingers	285 (27)	95 (26)	14/40
Thumb	125 (12)	26 (7)	4/18
Scaphoid	49 (5)	22 (6)	3/8
TOTAL	**1055**	**371**	**52/149**

Abnormality Localisation

Images in set A were presented with no PCE. Data derived from image set A was used to determine participants' accuracy in determining normal and abnormal appearances, including the participants ability to accurately identify the location of the abnormality. Participants were instructed to locate complete fractures in the middle of the fracture line, to locate buckle fractures at the cortex, and to locate dislocations at the proximal articular surface of the dislocated joint; accuracy was assessed using ROCView[22]. Participants were informed that the presenting mechanisms of injury (MOI) were those commonly seen in practice relative to each body part i.e. fall on outstretched hand, punch injuries, hyperextension injuries and crush injuries. Images were display using ROCView, thus allowing the participants to localise any area identified as abnormal; they did this by using mouse clicks on the suspicious area of the image and provided a confidence rating (scale 1 to 10). In the cases where the abnormality was identified on more than one projection, the highest confidence rating was recorded. Observers did not have to mark the abnormality on all projections for it to be deemed a successful localisation. The accuracy of localisations provided by participants was judged through comparison to reference localisations (mouse clicks) made by the principal investigators in ROCView. This was done automatically by ROCView but a manual review of localisations could be performed as required. All image evaluations were completed on a 20" LCD flat panel monitor at 60Hz (NEC MultiSync LCD 2090UXI, 600 x 1200, NEC Display Solutions, Itasca, Illinois, USA). Observers were given a short tutorial session on how to use ROCView (22) prior to taking their first evaluation. A set of test images allowed participants to practice localising suspicious areas; this could be repeated as often as required until they were confident with the method.

Image set B comprised of the 52 abnormal images only, presented in a different random order to image set A, but each case had an accompanying PCE. The localisation accuracy of the participants was compared for evaluations with and without the PCE comment. The PCE for each abnormal examination was verified by two experienced advanced practitioner musculoskeletal reporting radiographers (15 years' experience). Each PCE followed an identical format; type of abnormality, bone and location, and any movement e.g. transverse fracture, distal radius, mild dorsal angulation. Image set B was used to assess the participants' ability to make the correct treatment decisions based on the PCE.

Treatment decisions

The assessment and treatment model that is used for 'majors' patients can also be applied to 'minors.' The desired outcome in the ED is to implement an intervention resulting in discharge home, to GP, or follow up, occasionally patients may be transferred to an alternative service[(34)]. In view of this, participants indicated a management and follow-up plan for all the cases they observed in set A and set B on a printed answer sheet. Treatment decisions were selected from the options presented in Table 2. An experienced Consultant in Emergency Medicine viewed the positive cases and provided the gold standard treatment decisions determined by their perceived severity, to which all participants' answers were compared. A correct decision in each of the categories provided one point. The optimal decision, management and follow-up plan had a maximum score of three. Decision choices were restricted to broad categorisations to prevent an excessive list of similar treatment options. Rarely two options were provided in the management category, in these instances the more advanced option was used as the participant's given answer.

Table 2: Categories for describing management and follow-up plan.

Decision (1-point)	Management (1-point)	Follow-up (1-point)
1. Discharge 2. Treatment	1. None 2. Support Strapping 3. Support Splint 4. Cast 5. Reduction and cast 6. Surgery	1. None 2. GP 3. Emergency Department Clinic 4. Trauma & Orthopaedic/Fracture Clinic 5. External referral

Statistical analysis

Analysis of each participant's decision scores for the 52 abnormal images in image sets A and B was undertaken with a one factor ANOVA with repeated measures. The ANOVA test can determine any statistical differences in the decision-making of participants when provided with descriptive comments. A statistically significant difference in favour of the image set B scores will indicate that the PCE has positively affected ED practitioners' decision-making. Test alpha was set at 0.05.

Participant Recruitment

Participants were recruited from a pool of ED practitioners in one National Health Service (NHS) district general hospital in England, United Kingdom (UK). Doctors, ENPs and EC-ACPs were all invited to participate. Participants were grouped according to their professional role. Simple demographic questions at the beginning of the answer sheet allowed assessment of any trends relating to staff group or number of years' experience. No participants had undertaken any external image interpretation education, and none held a formal image interpretation qualification. Participants' knowledge of image interpretation was acquired through prior experiential learning and on-the-job teaching. Participants in both staff groups were randomly block assigned to sub-groups. Each sub-group had a pre-determined sequence to undertake either image set A or image set B in the first instance. Following a minimum wash-out period of eight-weeks, participants then interpreted the alternative set of images, Figure 1. This crossover design is robust with balanced group numbers and uniformity throughout.

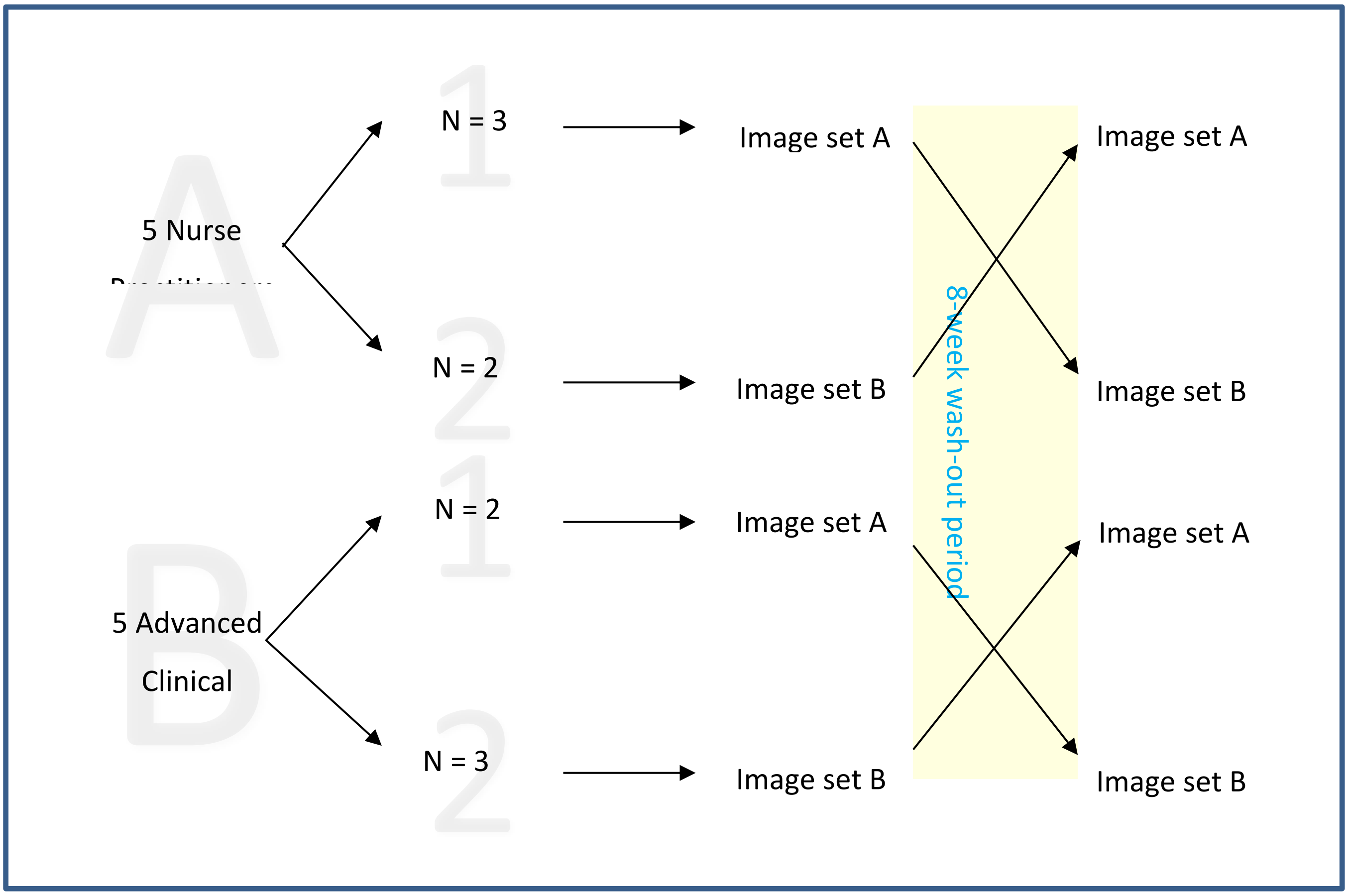

Figure 1. The cross-over design of the study showing the pathway of the four sub-groups.

Results

Sample demographic and experience

The sample of participants consisted of ENPs (n = 5) and EC-ACPs (n = 5), there were no participants from the doctor staff group. Participants were asked how many years' experience they had in requesting and interpreting radiographic images. There was no statistical difference in the number of years' experience requesting and interpreting radiographic images; ENP group (M=10.4, SD=3.2, range=6-15) and the EC-ACP group (M=5, SD=6.2, range=1-16); t(4)=1.902, p=.130.

Abnormality Localisation Accuracy and Confidence

All participants demonstrated improved accuracy in the correct localisation of abnormalities in set B (with PCE) compared with set A (without PCE). The greatest improvement was seen amongst the EC-ACP group (+19, +16, and +13 correct localisations), with the lowest increase (+1) in the ENP group . Table 3 illustrates the number of cases correctly interpreted as abnormal and the number of correct localisations for each participant in set A and B. The number of correct localisations increased from set A to set B, with provision of the PCE, the greatest improvement was seen in the EC-ACP group.

Table 3. Comparison of cases interpreted as abnormal and number of correct localisations for each user group in set A and B.

		User groups									
		ENP					EC-ACP				
		1	2	3	4	5	1	2	3	4	5
Set A	Interpreted as Abnormal [a]	48	40	50	51	36	26	36	52	51	35
	Correct localisations	43	41*	47	50	32	26	35	45	35	34
Set B	Interpreted as Abnormal [a]	52	52	52	52	52	52	52	52	52	52
	Correct localisations	49	51	51	51	44	45	46	51	51	47
	% increase of correct localisations from set A to B	12	24	9	2	38	73	31	13	46	38

[a] Determined by provision of a treatment management plan

* one case had no management plan but had correct localisation

No participants correctly localised all abnormalities in set A and set B. We ran a paired-samples t-test to compare the number of correct localisations without the PCE and with the PCE. There was a significant rise in correct localisations with the PCE (Mean=51.4, SD=3.13) compared to without the PCE (Mean=40.3, SD=7.98); $t(9)=-5.8$, $p < 0.001$. A paired-samples t-test was also conducted to compare participants' mean localisation confidence without the PCE comment and with the PCE comment. There was a significant rise in confidence with the PCE (Mean=8.77, SD=1.15) compared to without the PCE (Mean=7.59, SD=1.49); $t(9)=-5.51$, $p < 0.001$.

In set A, two of the positive cases were only correctly identified by one participant, a subtle buckle fracture of the proximal metaphysis of the first metacarpal on a thumb case and subtle buckle fractures of the third and fourth proximal phalanges on a hand case. Additionally, only three participants recognised a dorsally displaced, Salter-Harris Type 1 injury of the distal radial epiphysis, with only medium to low confidence. Nineteen of the 52 positive cases were paediatric, and only 10.5% of these cases (n = 2) had a 100% participant localisation rate. Only 10 of the 33 (33%) positive adult cases had a 100% participant localisation rate.

Management Decision Scores

A repeated measures ANOVA determined that mean management decision scores were statistically significant between the two image sets ($F(1, 520) = 104.92$, $P = 0.001$) with a higher decision score achieved in the presence of the PCE comment (Table 4). The mean difference and 95% confidence interval between the decision score achieved from A-B was -.506 (-.409, -.603).

Table 4. The provision of a PCE produced an increase in participants' decision scores from image set A to image set B.

Test	Mean (SD)	n	Std. Err.	Mean (95% CI)
A	1.74±1.098	520	.048	1.74 (1.648,1.837)
B	2.25±0.743	520	.033	2.25 (2.184,2.312)

The data from image set A showed wide variation in overall sensitivity, specificity and accuracy, in recognising images as normal or abnormal (Table 5). When interpreting the results generated in set A from the perspective of which set of images participants viewed first, the mean sensitivity is highest for those participants who viewed set B first (89%). However, the greatest mean FP is also seen with those who viewed set B first (53 versus 19). Conversely, those who viewed set A first had a greater mean TN (78 versus 44).

Table 5. Breakdown of participants' recognition of the normal or abnormal cases by provision of a management plan, and the mean scores for each group taken from image set A.

	User	TP	FP	TN	FN	Sensitivity	Specificity	Accuracy
ENP Group	1	47	66	31	5	90%	32%	53%
	2	40	10	87	12	77%	90%	85%
	3	50	26	71	2	96%	73%	81%
	4	50	2	95	2	96%	98%	91%
	5	36	23	74	16	69%	76%	73%
	Mean	**45**	**25**	**72**	**7**	**86%**	**74%**	**77%**
	SD	*Not applicable*				**0.12**	**0.25**	**0.15**
	Range	*Not applicable*				**69%–96%**	**32%–98%**	**53%–91%**
EC-ACP Group	1	26	10	87	26	50%	90%	75%
	2	36	30	67	17	68%	69%	68%
	3	51	73	24	1	98%	25%	52%
	4	50	95	2	2	96%	2%	35%
	5	36	24	73	16	69%	75%	72%
	Mean	**40**	**46**	**51**	**12**	**76%**	**52**	**60%**
	SD	*Not applicable*				**0.2**	**0.37**	**0.17**
	Range	*Not applicable*				**50–98%**	**2–90%**	**35–75%**
	Overall Mean	**42**	**36**	**61**	**10**	**81%**	**0.63%**	**0.69%**

(TP=True Positive, FP= False Positive, TN=True Negative, FN= False Negative, SD= Standard Deviation)

Discussion

It is encouraging that participants decision scores for the cases in this study were higher with the accompanying PCE than when they interpreted the images without. The results from the ANOVA analysis showed a statistically significant difference between image sets A and B indicating the PCE impacted positively on the decision making of participants. The results from the paired t-tests suggest that provision of a PCE can positively affect ED practitioners' interpretation of images. Specifically, our results indicate that the PCE can improve abnormality localisation and increase confidence in these localisations. There is no reason to believe that these positive impacts could not be reproduced with other appendicular examinations. The findings in this study support the progression to a PCE system with significant benefits to ENP and EC-ACP performance and patient outcomes.

It is recognised that patient treatments are rarely, if ever, decided solely on interpretation of a radiograph alone. Patient management and follow-up plans are based primarily on the presenting clinical signs and symptoms of the patient [24]. The radiograph should be used as an accompanying aid, and this must be given due consideration when interpreting these results.

Even with a relatively low prevalence of paediatric cases there is a suggestion that there is difficulty in determining these cases as abnormal, particularly those which are subtle. This finding resonates with previous work [17,25] and suggests additional training regarding interpreting paediatric images may be required.

A mean false negative interpretation rate of 24% was seen in set A based on participants' provision of a management decision, which is better than the previously described missed abnormality rates in other ED image interpretation studies [9,10].

Considering the findings relating to which set of images were viewed first, it can be inferred that the set of positive images, set B, may have affected participants' perception of the abnormality prevalence in set A, and that the mix of positive and abnormal cases in set A may have inherently provided reference standards of normal and abnormal appearances in those participants that viewed set A first. This illustrates how prior exposure to an image bank with high prevalence of abnormalities can affect perceived interpretive ability and provides support to the findings of Hardy et al (2016), in that an individual may over-estimate their ability to identify abnormalities. This should be a consideration when planning any image interpretation teaching.

Differences in image interpretation performance are evident in sensitivity, specificity and accuracy between both groups, in favour of the ENP group. A plausible explanation for this is that the EC-ACP role is a relatively new development in the study centre and the mean number of years of experience of the EC-ACP group in requesting and interpreting radiographic examinations and treating patients less than half that of the ENP group. This aligns with the work of Hardy and Barrett [3] who reported that interpretation ability increases with experience. Further evaluation indicates that the 5 years mean experience for the EC-ACPs is inflated by one participant who reported 16 years previous experience of requesting and interpreting X-rays as a nurse, with this removed the mean years' experience would be 2.25. Additionally, EC-ACP user 4, who scored 2% specificity had the lowest number of years' experience. Other possible reasons for this low specificity include misunderstanding of the briefing, loss of interest mid-test or perhaps the effects of viewing image set B prior to set A, therefore assuming all cases were positive. Given these findings, the PCE would likely be of benefit to those practitioners who have less experience of interpreting radiographs.

The potential of the PCE can be realised with successful collaboration and effective inter-professional relations and might then be thought of as a useful decision-making aid in the same way as immediate radiographer reporting is considered to be. Inter-professional working can be difficult due to institutional issues and deep-rooted traditions that might hinder effective communication. It has been suggested that a culture of tribalism within the radiography profession inhibits inter-professional working(26). The benefits of interprofessional education in the ED include positive outcomes in patient satisfaction and ED culture with improved team behaviour and reduced clinical error rates(27). Effective inter-professional collaboration should be considered a cornerstone of optimal care. However, the existence of inter-professional hierarchies of power contributes to ineffective communication within healthcare(28). Hierarchical issues are reported among medical colleagues who exhibit protectionism when their professional status is threatened by interprofessional education(29). Junior ED practitioners still forging their professional identities may view a radiographer providing a "first line" interpretation as encroaching into medical boundaries, conflicting with their perceptions of hierarchy(30), consequently resistant attitudes may ensue. The idea of utilising radiographers' image interpretation opinions is not such an unusual concept. Collaboration has previously shown improvements in ED practitioners' performance when assessing wrist and CT head images with radiographers' opinions impacting positively on the decision making of doctors(31).

Given the reported interpretive accuracies of radiographers(6,8,15,32,33), the application of prompt image feedback should be considered a viable service development. The interpretive abilities of junior doctors are reported as being substandard(34), with sensitivity and specificity levels below those of radiographers(8). With some adaptation, ROCView, or a similar software application could be used to assess year-on-year interpretation skill. However, this functionality is not currently ready. A recent analysis of out-of-hours (OOH) orthopaedic discrepancy rates indicated that of the patients who were recalled to change their initial management plan, almost all discrepancies (n = 134/147) were concerning a missed fracture(35). It is permissible that, given the results of our study, the provision of an immediate and accurate PCE in the OOH setting might prevent such occurrences, resulting in improved utilisation of resources and reduction of patient anxiety.

Whilst this study has highlighted how the commenting system can impact positively on practitioners' treatment decisions and reduce their false negative errors when interpreting hand and wrist radiographs, the wide scale implementation of the PCE system remains delayed. The reasons for this are not entirely clear but the lack of supporting evidence may be an issue. Confidence, education and technological issues have also previously been considered prevalent factors to slow implementation [36,37].

In England, 112 Trusts indicated utilisation of advanced practitioner radiographers to overcome reporting capacity and demand issues in March 2018[38]. This increases the likelihood of radiology departments providing an immediate formal report, but also likely has a detrimental effect on the necessity of PCE systems. Although, the actual amount of radiographer time dedicated to reporting is seen with broad differences[39]. The real benefit of a PCE system may only be realised in the OOH setting given the knowledge that ED interpretive errors are more likely to occur outside standard service hours when there is reduced senior clinical support[11], and when the hot reporting service is not available. Considering the reduced reporting time of some reporting radiographers and the increased workloads for radiologists[40], it is possible that several trauma radiographs may not receive an immediate report before the patient is discharged and will contravene National Institute for Health and Care Excellence (NICE) guidance[41]. This could have potentially detrimental effects on patient care. The provision of an accurate PCE has the potential to bridge this gap in service by providing an initial interpretation to aid patient management. Conversely, in those Trusts that are able to adhere to the NICE 'hot reporting' guidance[41], there may not be a need for a commenting system. This provides an interesting avenue for further investigation to determine the current barriers to, and drivers for, implementing a PCE system.

Limitations

The generalisability of our findings are reduced by the small number of participants in this single centre study and is compounded by the absence of any participants from the medical profession. Despite the inclusion of an 8-week wash-out period there is a small chance that images/cases could be remembered. However, the improved statistical power of a matched observer study must be considered against this.

We recognise that some of the positive cases used could be managed with different approaches as dictated by the patient and other external factors, and the use of a single gold standard may have reduced the amount of correct decision scores of some participants.

Considering participants were aware that the presenting MOIs were those commonly encountered, a question is raised regarding knowledge of fracture patterns and associated forces. It is possible that this would be no different to the expectations they would have from assessing the patient during initial triage. This provides potential opportunity for additional teaching.

Conclusion

This study has shown that provision of a PCE can positively impact upon ENPs' and EC-ACPs' management decisions, it can improve abnormality localisation accuracy and increase interpretive confidence. It can also help reduce false negative diagnoses. In view of our findings, the introduction of formal image interpretation for ENPs and EC-ACPs as a mandatory requirement will likely enhance the service provided by non-medical referrers. This in turn will increase the efficacy of the PCE system. Therefore, the Emergency Department and radiographers should work together to ensure a robust PCE system exists for when a "hot reporting" service is not available.

Conflict of Interest

None.

Funding

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3.4. Paper 4

An analysis of the structure and brevity of preliminary clinical evaluations describing traumatic abnormalities on extremity X-ray images

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Introduction

The preliminary clinical evaluation (PCE) system is an abnormality flagging system that provides opportunity for the radiographer to have greater input into the patient management process. The PCE system permits the radiographer to provide an immediate descriptive comment directing the referrer to any traumatic abnormality that is present on the image. The SCoR first introduced the idea of the PCE system in 2006[1], however it is not yet embedded as normal practice with many hospitals in the United Kingdom (UK) still using a red dot abnormality flagging system[2]. Confidence, training and information technology (IT) systems[2,3] have previously been cited as potential obstacles to implementation. The continued improvement and development of radiology services may also have an impact on the necessity of the PCE system. The increased utilisation of reporting radiographers and "hot reporting" services[4], as well as the introduction of radiographer-led discharge arrangements may have curtailed the need for PCE during normal working hours. However, the availability and extent of "hot reporting" cover varies across each Trust. Subsequently, the PCE system can be considered to be a valuable service development with recent work illustrating the positive effects on patient management decisions made by referrers[5].

It is likely that radiographers will require additional training to ensure successful implementation of the PCE system, given previous research findings[6–9]. The ability to convey a clear and concise message is a key characteristic of the PCE, and radiographers must be able to communicate their clinical judgements in an unambiguous manner[1]. It is suggested that keeping the description of an abnormality to a minimum can reduce confusion and mismanagement[10]. As such, the structure of any radiological opinion needs to allow easy transfer of the information that it is attempting to convey[11]. Therefore, it should be recognised that the effectiveness of a PCE is in part due to its structure. If an imaging department is not suitably prepared, whereby radiographers have not had adequate training, introducing a commenting system may lead to inaccurate abnormality descriptions[7]; and this could lead to patient management errors.

This study was part of a scoping exercise to identify any local training needs that may inhibit a successful transition to a comment-based abnormality flagging system. Many studies have reported the ability of radiographers in recognising and describing abnormalities[7,12-16,] but none have specifically evaluated the lexical construction of PCE comments. This study aims to assess radiographers' ability to form a concise description of radiographic abnormalities by evaluating their structure and brevity.

Methodology

Research Ethics Committee approval was deemed to not be necessary as this study was determined to be service evaluation by the local Research and Development team and the Health Research Authority online decision tool[17]. The study was carried out in a National Health Service (NHS) district general hospital in the West Midlands region of England, United Kingdom (UK).

A prior small pilot study was undertaken, and the feedback received was favourable with only minor amendments made to the wording and layout of the finalised tool. The participants in the pilot did not take part in the main study and different cases were used in the main study. A convenience sampling approach was utilised owing to the ease of accessing and recruiting participants, as well as the availability of resources in the research centre. Prospective participants for the main study were sought via departmental posters, face-to-face conversations and electronic mail communications with radiographers. The invitation was open to all radiographers in the study centre (n = 48). The only exclusion criteria applied was that participants must not have had any formal post-graduate image reporting training. A red dot abnormality flagging system is currently in use in the study centre. A number of brief image interpretation talks have previously been provided covering a range of extremity examinations, but there had been no dedicated teaching specific to PCE commenting.

All participants were asked to confirm their consent prior to taking part and were provided with basic information about the study, which included notification of their right to withdraw at any time. All images were interpreted using a DICOM viewer 18 on a 20" LCD flat panel monitor at 60Hz (NEC MultiSync LCD 2090UXI, 600 x 1200, NEC Display Solutions, Itasca, Illinois, USA). Interpretations were carried out under ambient fluorescent lighting conditions on the same type of monitor as in the clinical environment; however, background noise levels were not recreated.

As this study was not assessing participants' ability to detect abnormalities but assessing the lexical structure and brevity of their abnormality descriptions, all cases were a mixture of 35 abnormal appendicular images (5 hand cases, 5 wrists, 5 elbows, 5 shoulders, 5 feet, 5 ankles and 5 knees). All cases were anonymised and were presented randomly with no immediate repetition of the same body part. Participants were asked to describe any abnormalities they detected as they would do if they were using a PCE commenting system in clinical practice. Participants were informed that the study was based around their comments, but the assessment of their structure and brevity was not disclosed. It was considered that this may have provided bias against participants' natural performance and potentially affected their perception of what they deem to be an adequate comment.

Data analysis

Participants' typed their answers in to an online host[19]. Using an online host generated a spreadsheet of all answers that could be easily exported. Participants' comments were evaluated using a text analyser tool[20] to ascertain the number of words used in comparison to gold standard PCE comments. The gold standard comments were constructed by a Consultant Radiographer and agreed by an experienced Advanced Practitioner reporting radiographer. The gold standard PCE comments were formed in line with the *What, Where, How* model[21] using descriptive words only. The text analyser also provided two vital measurements; lexical density (LD) and the Gunning-Fog (G-F) index, which indicates the readability level. Overall, mean scores for each case were also generated from pooling all participants' answers.

Lexical density

The measurement of LD concerns the difficulty in processing a piece of text. The grade provides an illustration of informational content of the text. The LD in this study is derived by removing stop words, such as "the", "a", "an", "in", leaving mainly lexical words, before applying the following formula[20];

$$LD = (\text{lexical words}/\text{words}) \times 100,$$

Therefore, it would be expected that a PCE comment describing an abnormality will have a high LD given the aim to produce a brief comment filled with descriptive content.

Gunning-Fog index (readability level)

The G-F index provides the readability level of a piece of text by indicating the number of years of formal education the reader must have in order to read and understand the text at the first attempt[22].

The multiple polysyllabic words inherent with describing anatomical abnormalities may require extra effort to fully understand their meanings due to the Latin origins and the many prefixes and suffixes. Therefore, a high G-F index score for a PCE comment can be considered an indication that the content is at a level suitable for its intended reader.

Each comment was also scrutinised using a scoring system to assess PCE accuracy *based on* the *What, Where, How (WWH)* model[21]. Each component of the model was weighted according to perceived importance and usefulness following anecdotal discussions with the Emergency Nurse Practitioner (ENP) referrers in the study centre (see table 1). The comment scores of participants were then assessed using a one-sample t-test to ascertain any statistical significance when compared with the gold standard PCE score.

Table 1: Scoring system used when assessing comment structure.

Element of model	Element of comment	Weighting factor
What	Type of abnormality	2
Where	Bone & location	2
How	Any movement e.g. angulation or displacement	1

The analysis of participants' answers only comprised of cases that included at least one correct element of the *WWH* model, when compared to the gold standard. Cases in which participants did not recognise the pathology and those with incorrect comments were omitted from the analysis. This was to prevent inaccurate interpretation of the data and to provide a truer representation of participants' performance.

Results

Twenty-one participants took part in the study (11 female and 10 male). The overall mean (SD, range) number of years since qualification was 2.9 (3.19, 9.5).

The mean (SD, range) number of words participants used was 9.5 (3.89, 14.9), compared to 5.6 (1.46, 7) for the gold standard comments. There were no occurrences of any participant using exactly the same number of words as the gold standard.

The mean (SD, range) lexical density of participants' comments was 73.8 (4.02, 20.1), whereas the mean lexical density for the gold standard comments was 100, (0, 0). The mean Gunning-Fog indices for participants was 15.1 (3.79, 18.3), and 20.7 (6.82, 22.6) for the gold standard comments. Further breakdown of the mean LD, G-F indices and words used for each of the individual cases can be seen in table 2.

Table 2: A case by case illustration of the mean scores from the sample with the gold standard scores for comparisons.

			Gold Standard			All Participants		
Case	**Body Part**	**Gold standard comment**	**Words**	**Lexical Density**	**Gunning-Fog index**	**Words**	**Lexical Density**	**Gunning-Fog index**
1	Wrist	Lunate volar dislocation	3	100	14.5	10.5	72.9	16.2
2	Foot	Oblique fracture, 5th proximal phalanx mid-shaft, undisplaced	6	100	15.3	11.2	70.2	12.4
3	Hand	Oblique intra-articular fracture, 5th metacarpal base, dorsal displacement	8	100	18.2	13.0	66.3	12.2
4	Wrist	Buckle fracture, distal radial metaphysis, undisplaced	5	100	18	9.8	72.9	13.2
5	Shoulder	Gleno-humeral joint, posterior dislocation	4	100	31.6	8.8	72.3	19.0
6	Knee	Transverse fracture, proximal tibia, minimally displaced	6	100	22.4	15.3	72.6	18.3
7	Shoulder	Gleno-humeral joint, posterior dislocation	4	100	31.6	8.1	70.0	27.8
8	Wrist	Intra-articular transverse fracture, radial styloid process, undisplaced	6	100	9	9.0	73.4	12.9
9	Hand	Transverse fracture, distal metaphysis 2nd metacarpal, undisplaced	6	100	15.7	9.3	71.4	10.1
10	Foot	Comminuted, intra-articular fracture calcaneus, undisplaced	4	100	21.6	8.9	75.5	17.1
11	Elbow	Oblique fracture, radial head, undisplaced	4	100	21.6	13.1	74.9	13.2
12	Hand	Oblique fracture, 5th metacarpal base, undisplaced	5	100	18	8.0	74.9	10.8
13	Foot	Transverse fracture, 5th proximal phalanx base, undisplaced	6	100	9	9.6	73.8	10.7
14	Shoulder	Gleno-humeral joint, anterior dislocation	4	100	31.6	8.2	77.6	20.2
15	Ankle	Oblique fracture, distal tibia/epiphysis, minimal displacement	6	100	29	10.1	75.5	15.0
16	Wrist	Transverse fracture, distal radial physis, marked dorsal displacement	8	100	13.2	11.6	68.4	20.8
17	Ankle	Oblique fracture, lateral malleolus, mild displacement	6	100	29	9.0	76.6	14.4
18	Elbow	Supracondylar fracture, distal humerus, undisplaced	4	100	21.6	10.0	82.8	14.9
19	Knee	Buckle fracture, proximal tibial metaphysis, undisplaced	5	100	26	9.7	75.4	15.5
20	Foot	Transverse fracture, 5th metatarsal base, undisplaced	5	100	10	9.5	66.3	10.7
21	Knee	Transverse fracture, medial tibial spine, marked displacement	7	100	19.9	7.8	72.8	18.3
22	Elbow	Longitudinal fracture, radial head lateral aspect, undisplaced	6	100	22.4	6.2	86.4	16.1
23	Knee	Osteochondral fracture, lateral femoral condyle, marked displacement	7	100	25.6	None*	None*	None*
24	Elbow	Longitudinal fracture, anterior capitellum, marked superior displacement	7	100	31.3	5.9	77.5	15.6
25	Hand	Intra-articular fractures, 3rd/4th proximal phalanges bases, undisplaced	6	100	15.7	13.5	69.1	11.8

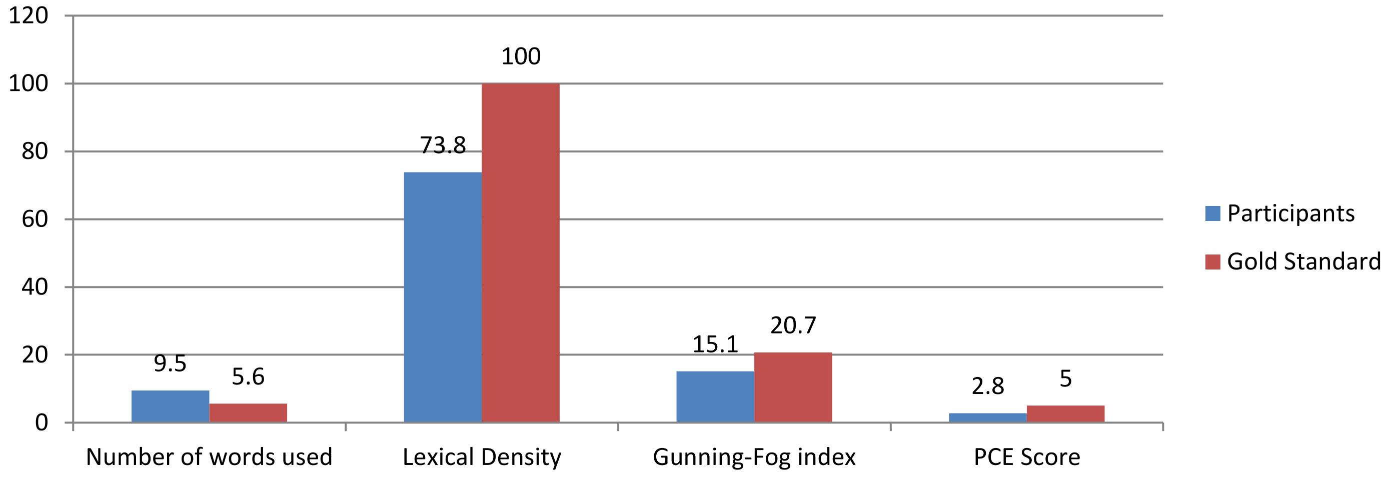
26	Ankle	Antero-lateral dislocation, subtalar joint	4	100	21.6	9.0	74.5	17.5	
27	Hand	Transverse fracture, 5th metacarpal proximal shaft, undisplaced	6	100	15.7	8.0	70.5	11.3	
28	Wrist	Transverse fracture, distal radius, undisplaced	4	100	11.6	10.9	75.4	12.1	
29	Elbow	Comminuted fracture, capitellum, marked superior displacement	6	100	29	8.8	74.2	17.1	
30	Ankle	Longitudinal fracture, distal tibial epiphysis lateral aspect, mild anterolateral displacement	10	100	24	8.7	77.9	18.0	
31	Foot	Transverse fracture, 5th metatarsal base, undisplaced	5	100	10	7.7	72.4	9.5	
32	Ankle	Oblique intra-articular fracture, anterior calcaneus, undisplaced	5	100	26	7.3	74.4	15.7	
33	Shoulder	Oblique fracture, greater tuberosity lateral aspect, undisplaced	6	100	22.4	8.4	71.1	14.5	
34	Knee	Tibio-femoral joint anterior dislocation	4	100	21.6	8.5	76.0	18.2	
35	Shoulder	Transverse fracture, mid-diaphysis clavicle, marked inferior angulation	7	100	19.9	8.7	74.1	12.2	
			5.6	**100.0**	**20.7**	**9.5**	**73.8**	**15.1**	Mean
			10.0	100.0	31.6	15.3	86.4	27.8	Max
			3.0	100.0	9.0	5.9	66.3	9.5	Min

*Key: * = no correct PCE to generate a score*

The mean (SD, range) PCE score for the group was 2.8 (0.34, 1.17), compared to 5 (0, 0) for the gold standard comments. The number of years participants have been qualified had no significant impact on PCE scores. A one-sample t-test was undertaken to determine any statistically significant difference between the mean PCE score of the sample and the gold standard score of five. There was a statistically significant difference of 2.2, t(21) = -29, p = .001, between the mean PCE score of the group and the gold standard. A comparison of all mean scores can be seen in chart 1.

A moderately significant negative relationship exists between number of years qualified and the number of words used (r = -.472, p = .031), and between years qualified and the lexical density of comments (r = .565, p = .008). A strong negative relationship is seen between the number of words used and lexical density (r = -814, p = .001). A strong positive correlation is present between mean PCE scores and the number of words used (r = 0.7, p = 0.001).

Chart 1. Comparison of the mean scores of participants against the gold standard.



The descriptions of the anterior and both posterior gleno-humeral dislocations (cases 14, 7 and 5) provided the top three highest PCE scores of 4.9, 4.5 and 4.4, respectively. Other high PCE scoring cases were the lunate and tibiofemoral dislocations (cases 1 and 34), scoring 4.2 and 4, respectively.

All participants failed to correctly match any element of the gold standard PCE in case 23, a lateral femoral condyle osteochondral fracture. Six participants (28%) registered a score for case 21, a displaced medial tibial spine fracture, with a low mean score of 2.2. Displaced fractures of the capitellum and distal tibial epiphysis (cases 24 and 30) were correctly identified by 10 (48%) and 11 (52%) participants, with mean PCE scores of 2.3 and 2.4, respectively. An undisplaced fracture of the radial head, case 22, was correctly identified by 11 participants (52%) with a mean PCE score of 2.2. Some examples of participants' answers for the cases with the highest and lowest mean PCE scores are shown in table 3.

Table 3: A selection of participants' answers from the cases with the highest and lowest scoring Preliminary Clinical Evaluations.

Case Number	Gold standard PCE	Examples	PCE Score
14	Gleno-humeral joint, anterior dislocation	*"Anterior dislocation of left GH joint"* (User 20)	5
		"Anterior dislocation of the left shoulder" (User 17)	5
		"Anterior dislocation of the left humeral head from the glenoid fossa" (User 7)	5
23	Osteochondral fracture, lateral femoral condyle, marked displacement	*"Fracture proximal fibula" (User 20)*	0
		"Radiolucent area seen at proximal end of the right tibial shaft" (User 5)	0
		"Abnormality noted on anterior aspect of proximal end of tibia. Lipo-haemarthosis seen; Prominent fat-pads surrounding patella" (User 15)	0

Discussion

The findings from this study suggest that participants used too many words in their PCE comments resulting in reduced descriptive content. The reduced Gunning-Fog index score indicated that the comments were not at the same reading level as the gold standard and this correlates with not conveying the image findings accurately. However, obvious and common pathologies were easily described with fewer words, in a lexically dense sentence at a reading level close to the gold standard. In the cases of the gleno-humeral dislocations this could be due to easily recognising the significant deviation of normal anatomical alignment and the regular frequency in which participants see these abnormalities in clinical practice. While six participants missed the lunate dislocation, those who recognised the abnormality were describing it with a high degree of accuracy.

Although this study was not optimised to assess true interpretative ability, it is concerning that the markedly displaced osteochondral fracture of the lateral femoral condyle was not correctly identified by any participants. Possible reasons for this may be due to gross displacement of the fracture fragment skewing the participants' perceptions of normal anatomy, overlying anatomy creating uncertainty or lack of knowledge. Along with the other aforementioned cases with a high frequency of missing the abnormality, this provides another area where further training is required.

Manning-Stanley et al[(23)] report a strong negative correlation between reporting radiographers' experience and report length, and the same finding was also evident in this study. The longer participants have been qualified, the fewer words they used with increased lexical density, and this follows the expected trend for this combination of conditions. The concurrent increases in mean PCE score and the number of words used suggests a lack of understanding as ideally this relationship would be an inverse one with the comment being short with a high PCE score. Importantly, the context must be acknowledged, and a short description must describe the abnormality sufficiently.

Utilising the *What, Where, How* model[21] provides a simple framework by which one can coherently structure a clear and concise comment to describe findings appropriately. Considering that the minimum aim of the PCE is to identify the abnormality with accurate localisation, it could be argued that the *How* element of the comment is not that important to referrers in the Emergency Department (ED). This element was most commonly omitted from participants' answers in this study; possible reasons for this include lack of knowledge and understanding. Anecdotal evidence from discussions with ENPs in the study centre suggests that descriptions of movement are considered to be least useful. The description of movement of body parts and fragments may only be of importance for surgeons planning surgery, and therefore may be best reserved for the official report.

Being able to structure findings in a cohesive and accurate manner can be challenging especially with abnormal findings as a greater desire for more descriptive detail then prevails[24]. Brevity, defined as "the quality of expressing much in few words"[25] is the greatest challenge of the PCE. Considering the radiology report, it is suggested that the use of sentences beginning with "there is…" or "there are…" can become monotonous[26], rephrasing these sentences can improve brevity. Applying this ideal when constructing a PCE comment would improve communication by reducing the number of words and consequently increasing lexical density and readability level. The use of an electronic taxonomy has been suggested to remove ambiguity and provide structure and support[27]. Given the findings in this study, an electronic taxonomy may be an appropriate method to overcome these issues, if local IT systems permit.

Awareness of potential training issues may provide understanding as to the provision of a lengthy or vague comment. This could be compounded further clinically knowing the dynamic, often rushed, environment in which radiographers are expected to interpret images. Considering the increasing service demands and patient throughput[28] perhaps a short PCE comment no longer than one sentence might be the most practicable approach. This provides an interesting opportunity for further research regarding the PCE content preferences of referrers.

Whilst PCE skills may be best refined in the undergraduate setting whereby confidence can be developed without fear of reprisal or a significant untoward clinical outcome, it is recognised that departmental training can also be improved[9]. PCE skills can be shared in a less formal manner in the clinical setting than the postgraduate education inherent with reporting qualifications, due to learning not needing to be certificated by a Higher Education Institution. The content of any training sessions should be guided by the aims and objectives of the desired learning outcomes; radiographer ability at a local level should dictate the delivery in terms of intensity and frequency.

At present there is no guidance with regards to the depth and breadth of PCE teaching that departments can follow. SOR guidance[1] provides no stipulation of content but reiterates the need to further develop and assess skills relating to writing a descriptive comment as part of continuing professional development (CPD). Regular CPD sessions may be the best approach to maintain the necessary skills for participation in a PCE system.

Limitations

The generalisability of these results is reduced by the low number of participants and only being a single centre study. Readers should consider the effects of participants not being aware of the assessment against the gold standard comment structure, and with this knowledge how their answers may have been affected. There were a number of gaps in participants' answers due to not recognising the abnormalities. Considering the focus of this study, highlighting the abnormalities to allow participants to provide answers for every case would have generated more robust findings.

Participants' confidence in writing a comment may have been positively affected by the image bank containing only positive cases. It is possible that towards the end of the test participants may have refined their commenting style and content due to repetition of positive findings, though it is thought the random viewing order will have reduced this effect. Further research should include extending the image bank to include axial examinations or chest X-ray examinations.

Conclusion

Participants provided PCE comments with too many words and reduced descriptive content, which were not at the same reading level as the gold standard. Participants in this sample would likely benefit from dedicated training relating to PCE structure. Additional areas for teaching include reviewing fracture patterns and terminology, as well as less common and subtle abnormalities. These issues may arise in other clinical departments and might be considered reasonable areas for further training relating to PCE implementation and participation.

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3.5. Paper 5

An analysis of the structure and brevity of preliminary clinical evaluations describing traumatic abnormalities on extremity X-ray images

Stevens BJ (2020), Radiography, Volume 26, Issue 4, 302 – 307.
https://doi.org/10.1016/j.radi.2021.03.006

The chest X-ray (CXR) is the most commonly performed X-ray examination with 8.3 million requests in England, United Kingdom (UK) in 2019-20, a 0.8% increase since 2018-19[1], yet the urgency for reporting these images often does not take priority. It is known that in National Health Service (NHS) hospitals in England, UK, many CXRs can remain unreported for many weeks[2]. Increased demand and reduced reporting capacity can lead to lengthy report turnaround times, potentially impacting upon timely patient management. Lengthier report turnaround times will also increase the likelihood of local key performance indicators (KPI) being breached. Consequently, radiology departments may implement a number of different mitigation strategies to ensure patient safety is maintained.

Common strategies include insourcing, outsourcing and auto-reporting, although these come with increased cost and clinical risk. However, this can practicably be solved by reporting radiographers. Utilising radiographers as reporting resources provides a more cost-effective and safer alternative for managing CXR backlogs[2]. Previous research has shown increasing numbers of chest reporting radiographer regionally[3]. A more recent study illustrated the efficacy of radiographer reporting CXRs[4], and earlier work has also asserted comparable accuracy to expert thoracic radiologists.[5] Despite these positives, many challenges can hinder the progress of advanced practice developments.

It is likely that many radiology departments will have encountered an obstacle when attempting to develop a reporting radiographer service. The systematic review by Culpan et al.[6] outlined a number of the potential barriers to the progression of advanced practice, broadly categorised as lack of funding, radiographer staffing issues and lack of radiologist support. Likewise, a number of factors can facilitate the development of advanced practice, such as service redesign and improvements, responding to demand[6], responding to service needs, radiographer career development, and radiologist shortages[7.] Despite numerous studies evaluating the accuracy of reporting radiographers[4,5,8–11], none have specifically investigated why the reporting of CXRs by radiographers may be progressing at some Trusts but resisted at others.

This study aims to establish the service enablers and challenges associated with training and employing radiographers to report CXR images in acute hospital sites in England, UK. Secondary aims include calculating the number of sessions allocated to reporting radiographers for CXR reporting, and evaluating any restrictions on reporters' scope of practice (SoP)

Method

An online survey method was used for this study. The authors' local Research and Development (R&D) department approved the study. An Integrated Research Application System (IRAS) form was submitted and the project was given Health Research Authority (HRA) approval without the need for ethical approval.

The Research and Development (R&D) departments in 146 National Health Service (NHS) Trusts (non-specialist and specialist) in England were approached seeking authority to approach their respective radiology departments. Once approval was granted an email invitation with a hyperlink to access the online survey was sent to a senior member of the radiology department. The survey was open for 10 weeks during August to October 2020, accessible via an online host (Online Surveys, Jisc, Bristol, UK). Reminder emails were sent after three and six weeks. A notification was also posted on Twitter seeking participants in the Trusts with R&D approval. A pilot of the survey was undertaken with the local R&D manager resulting in minor amendments to question lay-out and wording.

The survey comprised of a mixture of qualitative and quantitative questions designed to generate an overview of participating departments' stance regarding radiographers reporting CXRs. Participants could not progress to the survey without agreeing to the consent statement on the first page of the survey. The survey asked for the Trusts' name and position held by the person completing the survey to monitor responses and to recognise duplicate responses. It was clearly stated that this information would not be disclosed publicly. Each completed survey was assigned a unique reference number (URN) to identify different responses. Data was exported into an Excel spreadsheet where manual thematic analysis was performed. An inductive approach to thematic analysis was used by the team. The answers for each question were read through by the authors, which then determined the themes. Pertinent answers were then recorded under each theme as potential evidence to use in text. Descriptive statistics were also generated.

Findings and discussion

Demographics

R&D approval was granted in 84 of the 146 (58%) Trusts that were approached; 18 Trusts (12%) declined to participate, and the survey was unable to be arranged in 44 other Trusts (30%). Seventy-six responses were received with one duplicate entry, providing a final sample size of 75 (89% response rate). The survey was completed by a variety of senior roles with wide ranging nomenclature (chart 1). There was a good regional distribution of responses across England (chart 2). The regional borders used are shown in figure 1.

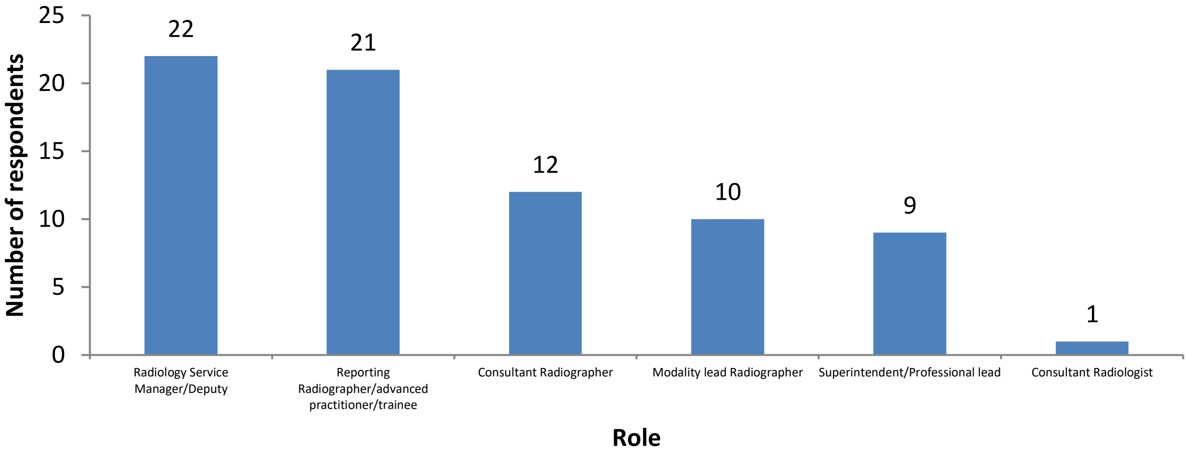

Chart 1: Number of respondents and roles of those who completed the survey.

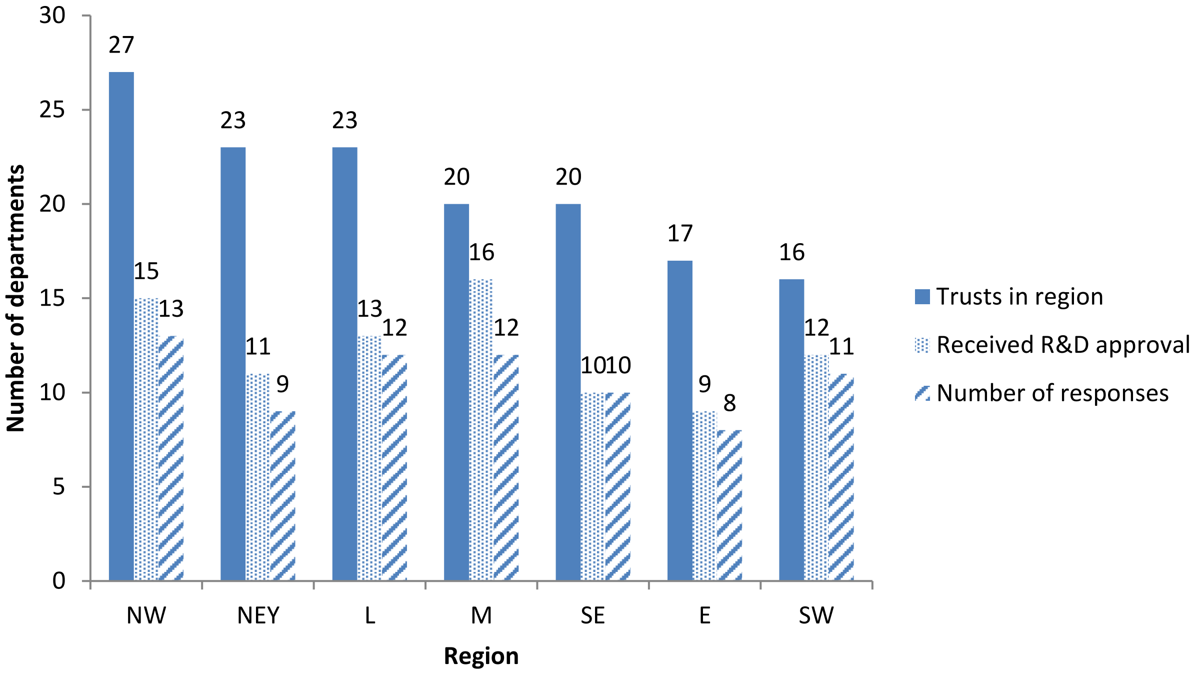

Chart 2: Regional distribution of the departments that responded to the survey.

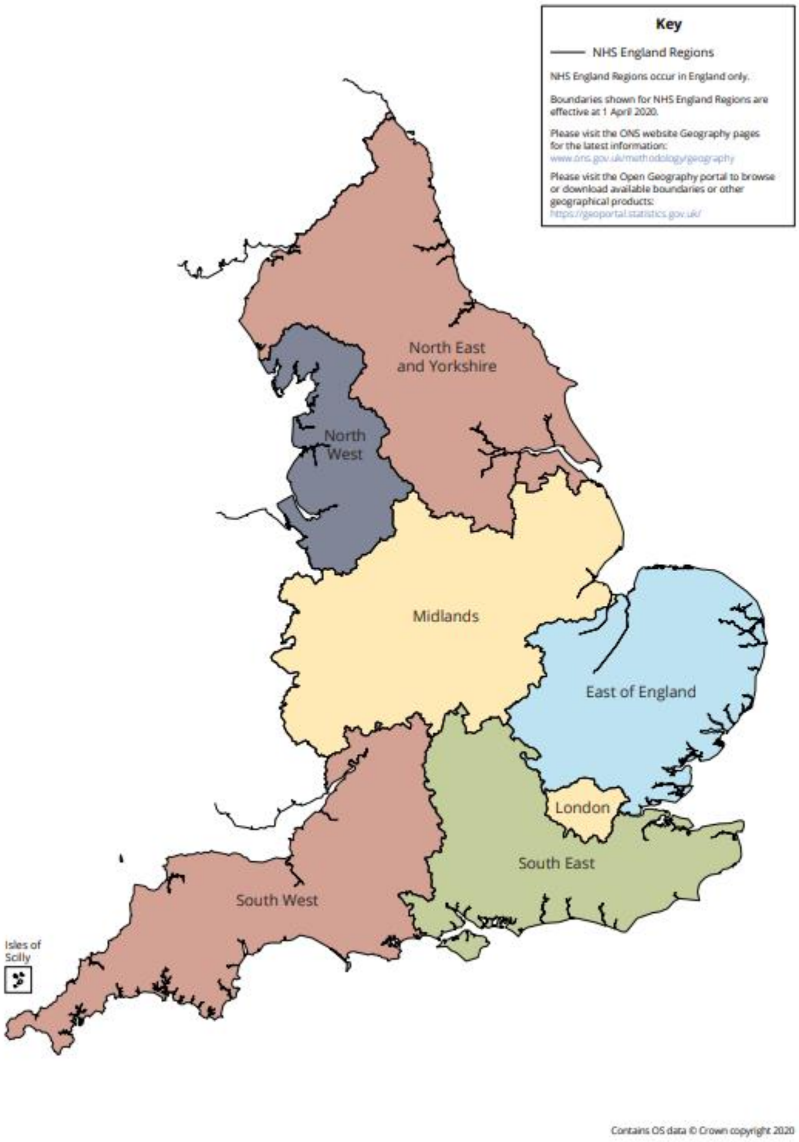

Figure 1: NHS England regions[12]

It was apparent that issues relating to staff were the commonest barrier to not training or employing CXR reporting radiographers. The themes that emerged relating to the drivers for training and employing CXR reporting radiographers include; capacity and demand, finances, workforce development and service improvement.

<u>Challenges to overcome for training and employing CXR reporting radiographer.</u>

Reporting radiographers' roles already fulfilled.

It is encouraging that the commonest reason for not having any CXR reporting trainees is that they are not needed due to already having a cohort of reporters with fulfilment of current roles and no requirement to expand capacity (n = 13/41, 31.7%), underlining widespread service development;

> *"Currently 3 reporting radiographer qualified in Chest reporting…re-evaluation as to whether further reporting radiographer are required." URN078*
>
> *"We already have 4 trained AP's in chest reporting. No more required at present." URN503*

Interestingly, the recent Recovery and Renewal Review for Diagnostics15 suggested that although hospital attendances and demand fell dramatically in the early phases of the COVID-19 pandemic, it is expected to return to normal levels and will require greater staffing numbers in the future. The review indicated that an additional 500 advanced practitioner radiographer will be required across all modalities. This raises an interesting issue and implies the notion that forward-planning must be at the forefront of CXR reporting service developments.

Radiologist staffing issues

The commonest sub-theme of staffing issues preventing the training of reporting radiographers was the lack of radiologist support (n = 7/41, 17.1%), and this was also a stated reason for not employing reporting radiographer (n = 4/22, 18.2%). These occurrences were spread out across all regions, except the North East and Yorkshire, though the reasons for this have not been explored here. The lack of radiologist support possibly stems from the time constraints associated with increased cross-sectional and hybrid imaging scans[1] requiring longer reporting times, and the persistent radiologist vacancies.[2,13] It has previously been acknowledged that many underlying cultural barriers exist, born out of professional protectionism, which transpires to hinder the development of advanced practice.[6] radiologists are the key stakeholders regarding the CXR reporting service and provide the greatest challenge to further progression. The lack of support is a major barrier, and can have devastating effects on the confidence of reporting radiographer when qualified;

> "*…a severe lack of support from radiologists…found it increasingly difficult to approach with problems we have had with regards to a report or advice*." URN112

> *"…not a good experience when it came to mentorship, has affected their progress and confidence to perform the role autonomously." URN934*

It would be wrong to convey the only radiologist response in this study as the voice for all radiologists, and it is likely that many contrasting opinions exist. However, insight is provided as to why some radiologists may be opposed to radiographer reporting CXRs;

> *"I do not see the rationale for a reporting radiographer to report a CXR that a radiologist is available to do…the lack of the 6-8 years medical training that a radiologist has undertaken puts the radiographer at a significant disadvantage in interpreting and conveying the findings of a CXR" URN350*

The influence of radiologists on advanced practice progression cannot be overlooked. These viewpoints hold power with regards to allocating CXR reporting duties to radiographers and the support of local radiologists is paramount in developing a successful reporting radiographer CXR service, and to ensure amicable team working. Recently, the Royal College of radiologists (RCR) expressed reservations about non-radiologist reporting of anything but basic minor trauma images[16]. It is possible that this perspective is still influencing some radiologists, leading to reduced support for this type of advanced practice. Previous research has illustrated the potential impact[6,7] and our findings show how radiologists can affect the provision of initial opportunity and ongoing support, to the detriment of radiographer.

Radiographer staffing issues

Even without any opposition from radiologists, it was disclosed that there was no desire amongst radiographers to take on the role (n = 5/75, 6.6%). A lack of interest from radiographers was a surprising reason for not having any reporters in post. One participant described the lack of interest in CXR reporting owing to the increased accountability and responsibility;

> "N*o appetite to take on CXR reporting as they feel there is too much potential litigation involved in this area of Advanced Practice." URN031*

The unwillingness to want to progress or develop through a fear of failure is a surprising finding. There is no published literature proposing a reluctance of radiographers to undertake advanced practice. These infrequent occurrences were confined to the South East (3 occurrences) and the South West (2 occurrences), and although occurring with low frequency may be a new, emerging phenomenon. One participant described previous reluctance from radiographers to engage with CXR reporting but with senior departmental, a change in culture and ethos has followed;

> "*… resistance originally for radiographer to perform CXR reporting…clinical director has supported this role… changed the whole departmental rota to achieve a reporting rota. Prior to this it was ad hoc*" *URN338*

The lack of desire to engage could stem from the fear of missing a major pathology. However, an appropriately trained radiographer reporting within their capabilities with clearly-defined protocols can be assured that they will be covered by Trusts' vicarious liability insurance, and as a SCoR member will also benefit from personal professional indemnity cover[19]. This should be made explicit to any potential trainees. Additionally, the fear of litigation may arise from a lack of confidence or the perception that inadequate radiologist support may prevent them from attaining the required competency; although this has not been explored in this study it does raise an interesting topic for further investigation. Possible solutions to this challenge include regionalised clinical education centres led and supported by consultant and advanced practitioner radiographer, such as an academy-type set-up[17] or a "hub and spoke" model[18]. These approaches to reporting education provide a logical approach to overcoming issues associated with lack of support and could help to allay any litigation fears.

The 2018 workforce survey from the Society of radiographer (SOR)20 reported the issue of staffing levels being under pressure affecting training places, and in our study inadequate radiographer establishment was cited (n = 4/41, 9.75%) as being causative for not having any current trainees;

> *"Lack of backfill for training, department severely understaffed and no capacity to allow radiographer the time to train and go to university." URN546*

> *"No radiographer currently at the required level to complete the course."URN626*

The SOR report showed recruitment difficulties in other modalities too, with an overall vacancy rate in England of 10%[20], which may impact on the availability of higher grade staff to undertake training. This remains an area for action if the recently published recommendations regarding reporting radiographer are to be upheld[12,15].

Service enablers for training and employing CXR reporting radiographer

Thirty-three departments (44%) had at least one (mean 1.6, SD 0.9, min 1, range 4) radiographer studying on a CXR reporting module, further breakdown is shown in chart 3. Of these 33 departments, only one department did not currently employ any radiographer reporting CXRs.

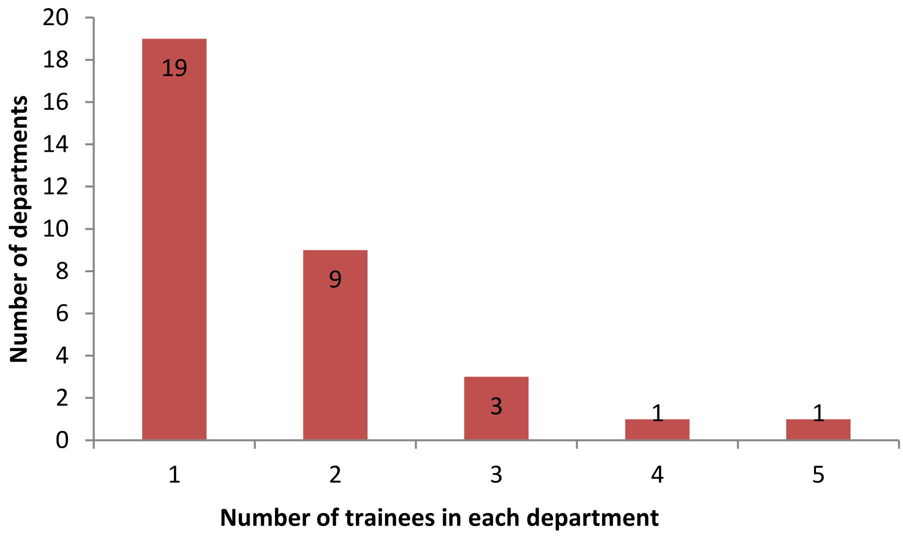

Chart 3: The number and distribution of departmental trainees across the sample.

Most departments (n = 53/75, 71%) indicated that they currently employ at least one (mean 3, SD 0.34, min 1, range 12) CXR reporting radiographer, further breakdown is shown in chart 4. More than half of these departments (n = 28/53, 53%), with radiographer reporting CXRs, had at least one current trainee.

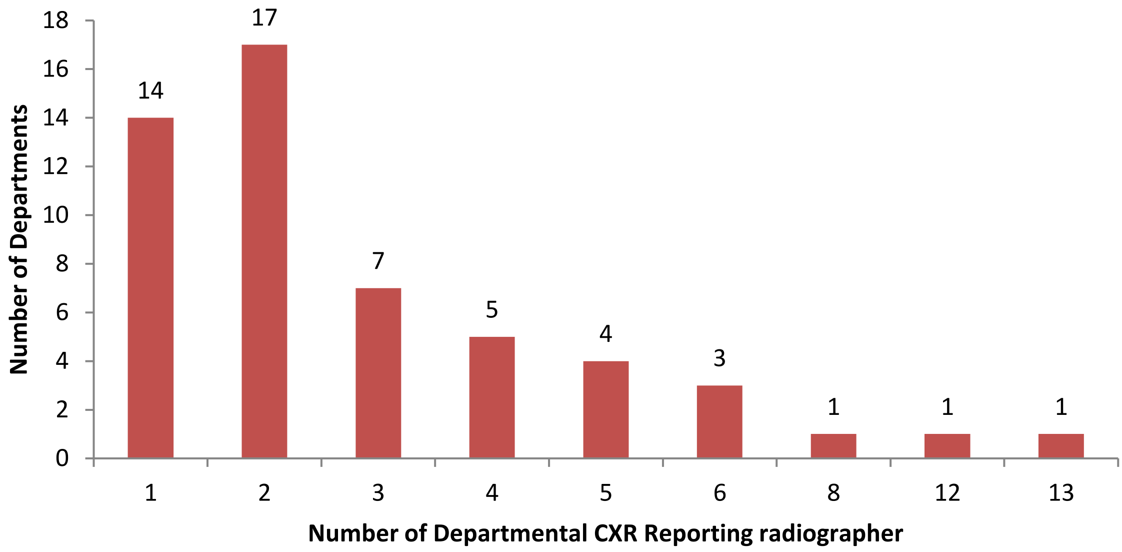

Chart 4: The number and frequency of radiographer reporting CXRs across the sample

Capacity and demand issues

The reasons for training and employing radiographers are similar, and are often multi-factorial, rarely singular, but do substantiate the previously described drivers for developing advanced practice[6,7]. The main driver specific to training radiographers to report CXRs was the desire to enhance existing departmental provisions, illustrated by a desire to improve on the current service inefficiencies specifically that of report turn-around-time (TAT) (n = 15/28, 54%);

> *"Capacity for reporting is insufficient to meet demand. Aim to move towards chest hot reporting in the future" URN557*

> *"Improve turnaround time for CXR reports" URN626*

The employment of CXR reporting radiographers was commonly driven by the aim of improving reporting capacity to deal with demand and maintain backlog (n = 21/53, 40%), along with perceived improvements to the reporting service (n = 20/53, 38%). Being able to release radiologists for other reporting duties (n = 8/53, 15%) was another indication for employing CXR reporting radiographers, and a small number of departments indicated that it was a response to radiologist shortages (n = 4/53, 8%). The perception of being unable to meet current demand is supported by recent data published on NHS Model Hospital20 that shows the national median for X-ray activity up to March 2020 was 136,290 examinations and the number of reports, including outsourcing, was 123,660 providing a shortfall of 12,630 unreported examinations. This illustrates that current radiographic reporting provisions are not sufficient. Consequently, some departments may have no option but to outsource reporting to negate any clinical risks, but this does come with increased costs.

Finances

A small number of responses indicated that the training of radiographer (n = 4/28, 14%), and the employment of CXR reporting radiographers (n = 7/53, 13%), was seen as a way to address the associated pressures and financial inefficiencies by reducing outsourcing;

> *"…had to out-source chest reporting services with substantial cost. It is assumed that the reporting radiographers will drive the reporting service forward at a minimal cost" URN763*

> *"On-going need to outsource plain film reporting" URN552*

The desire of departments to move away from the burden of outsourcing by preferring to train and develop their own radiographers is consistent with previous recommendations[2]. This could be interpreted as a more prudent use of restricted funds but also demonstrates an appreciation of, and willingness to develop, the radiographers available. The availability of Government funds[21] to train radiographers was also considered to be contributory in some departments (n = 4/33, 12%), two in the North West and in the South East, respectively;

> *"HEE funding as part of cancer plan." URN120*

> *"…tackling our outsourcing expenditure on reporting, this combined with the extra funding given" URN016*

Conversely, three responses (4%) implied that lack of funding was a compounding factor for not having any current trainees; a factor identified previously.[6] A recent Health Education England (HEE) funding opportunity was widely publicised promising to invest in 300 extra reporting radiographers as part of the Cancer Workforce Plan.[21] It is possible that this funding stream was accessed in those four departments but was perhaps used for a different cancer pathway, such as for a Computed Tomography (CT) virtual colonoscopy trainee. Though, this was not explored in this study but does provide a potential path for further research. Upon examining the responses further, the demographic data demonstrates no regional pattern to these occurrences.

Workforce development

Developing the workforce to ensure longevity of the reporting radiographer service, was a common reason for training a radiographer to report CXRs and is viewed as an effective way to improve recruitment and retention of staff (n = 11/28, 39%). Acknowledgement of the individual and the subsequent impact on radiographer workforce development was also a prevalent factor in the employment of CXR reporting radiographers (n = 14/53, 26%);

> *"Job satisfaction and promote advanced practice" URN599*

> *"Career progression at level 7 Career pathway" URN619*

Being able to identify the value in developing radiographers with clear career progression should be applauded and advocated as an appropriate method of maintaining staff engagement. A point reiterated by the recent national Getting it Right First Time (GIRFT) radiology report[12]. Many departments see the reporting of CXRs as the logical progression for current reporters, with career progression noted as being a key factor in maintaining the service;

> *"Increased chest reporting capacity and provide greater resilience - Continue to develop existing reporters - Continue to improve plain film standards - Promote recruitment and retention of radiographers" URN962*

> *"…extending our reporting services to longer days 7 days per week for MSK and CXR/AXR….to achieve instant reporting for images taken in working hours." URN958*

The desire to improve the reporting service for the benefit of patients is prevalent throughout; and should form the basis of all service and advanced practice developments. A small cohort (n = 8) longitudinal case study reported that consultant radiographers believed that their appointments had been beneficial to service delivery and quality of patient care.22 In addition to this, the impact of advanced practice radiographers has been illustrated as offering more than just reporting but also supporting service delivery[23]. Though, it is interesting to note that the systematic review by Hardy et al.[14] found limited evidence of advanced practice impacting positively on patient outcomes and service quality. Empirical research assessing the impact of CXR reports by radiographers on patient diagnosis and management decisions would provide necessary data to promote the patient-specific benefits of this service development.

It is clear that those departments that do employ CXR reporting radiographers appreciate the value of their skillset. Participants (n = 5/53, 9%) indicated their forward planning and training regime in order to future-proof the service with one participant providing an interesting forethought regarding the potential increase in CXR reporting backlog post-COVID-19;

> "*…clear requirement for a drastic increase in workforce to handle the ever-rising demand…even before COVID-19. If we do not address the skill shortage now, we will face major difficulties down the road*." *URN363*

Future-proofing the service by training more reporting radiographers is a sensible approach given the year-on-year increase in demand for CXR examinations1 the persistent radiologist shortages[2,13] and a likely post-COVID-19 surge in examinations. CXR reporting backlogs may well increase when post-pandemic normality is resumed; therefore, preparation is vital.

<u>Reporting sessions and scope of practice</u>

Reporting sessions

The progression of radiographers reporting CXRs is illustrated further by the number of reporters currently practicing. Previously it was stated that only 39 out of 259 (15%) reporting radiographers reported CXRs in England in 2015.21 Our data shows a marked increase with 121 out of 160 (76%) reporting radiographers reporting CXRs, across 53 departments. The mean (SD, min, range) number of reporting sessions (4 hours per session) allocated to CXR reporting is 3.5 (0.18, 1, 9) equating to 14 hours a weeks. The mean (SD, min, range) number of total reporting sessions is 5.3 (0.21, 1, 9) equating to 21.2 hours, and represents a considerable increase of almost 50% when compared with previous work that reported a mean 14.5 hours per week.21 This growth indicates an increasing dependence on radiographers to reduce reporting workloads.

Thirty-nine of these reporters (32%) have 100% of their reporting sessions allocated to CXR reporting. Two reporters have 10 sessions a week allocated to report CXRs, though questions are raised regarding how this affects their ability to fulfil the Four Core Domains of higher practice, as is expected of advanced practitioners[22]. Further breakdown of the number of sessions for these CXR-only reporters is shown in chart 5. Reporting only CXRs suggests that reporters either bypassed the traditional pathway of undertaking musculoskeletal (MSK) training first or no longer report MSK examinations, underlining the necessity for this service development in some departments. The accelerated process of bypassing MSK training facilitates the radiographer in being competent to report CXRs by 2-3 years thus providing quicker financial gains for the Trust. These findings substantiate previous assertions that radiographers contribute significantly to reporting capacity[23] and that there is an increasing reliance on radiographer to meet CXR reporting demand[3].

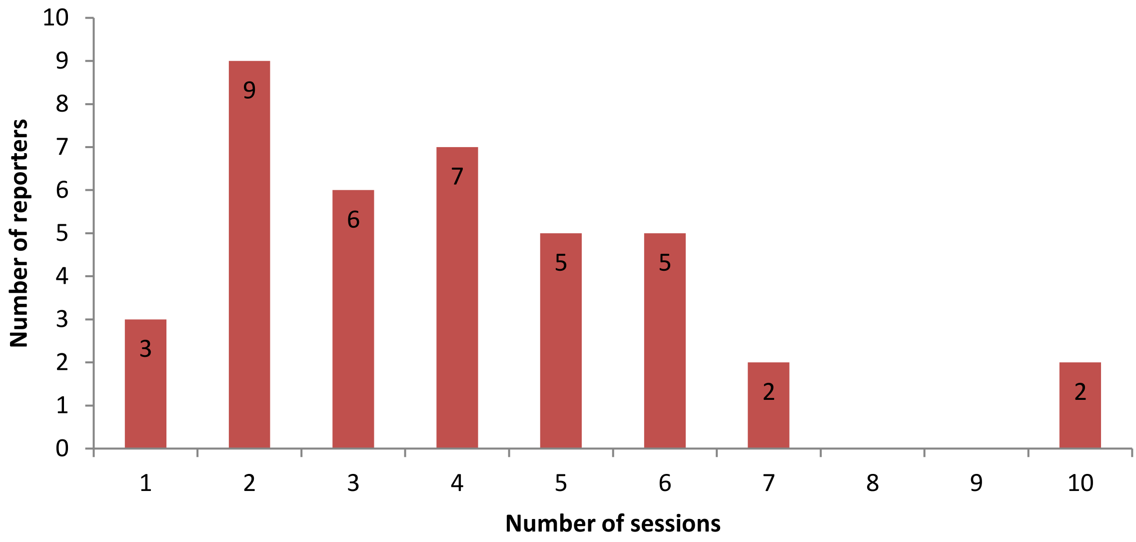

Chart 5: Distribution of the number of sessions allocated to the reporters who only report CXRs.

Scope of Practice

Wide variations in SoP were reported and these are illustrated in chart 6. Recent studies found that reporting radiographers' SoP are restricted by patient age3,[21], and this type of restriction was also most prevalent in this study (n = 21, 40%). However, there were numerous discrepant views on the age definition of a paediatric patient;

> "*…no restriction apart from children under 12 years*", URN652

> "*No paediatric chests under the age of 16 years*" URN557

> "*Adults only, i.e. over 18 years old. All referral sources accepted*", URN561

There were also several different combinations of referral source and age with varying stipulations restricting SoP;

> *"No GP and OP in the first year following qualification" URN557*

> *"GP only after 12 months post-preceptorship with an additional 100 reviewed by a consultant radiologist" URN950*

Culpan et al.[6] suggest these variations are likely related to local demand and/or radiologist shortages. Alternatively, the differing combinations of restrictions with varying stipulations could be construed as a way of radiologists maintaining control over the CXR reporting service, perhaps reflecting the varying degrees of radiologists' acceptance of advanced practice. A nation-wide adoption of the reporting standards outlined by Woznitza et al.[24] might help to reduce these types of variations in service provision.

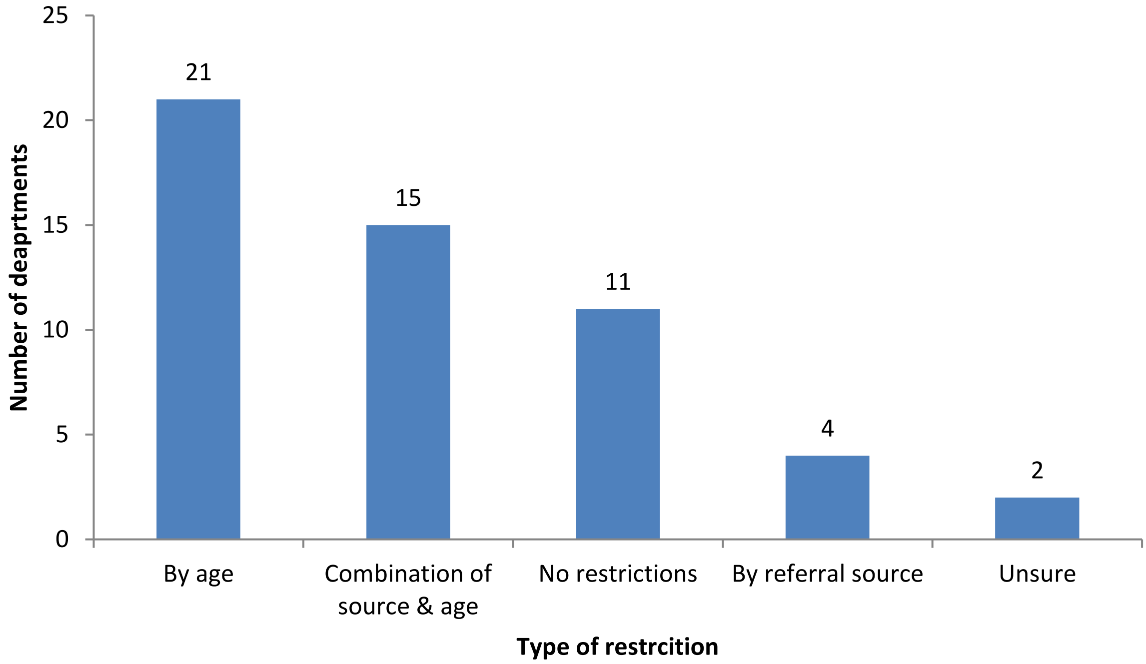

Chart 6: Distribution of restrictions on CXR reporting scope of practice

The benefits of CXR reporting radiographers may not be experienced in some departments, but those that do embrace advanced practice evidently encourage their reporting radiographer to develop further. Examples of pushing reporting boundaries were described, demonstrating worth and confidence in the abilities of reporting radiographers.

> *"…two of our CXR reporters also report CT lung nodules. Two further in training." URN948*

> *"Consultant radiographer have trained to report CT pelvis scans for ?NOF# patients…respected and valued by our clinical and divisional directors." URN473*

Extra-modality reporting realises a previous foresight suggesting that progressive departments may inadvertently widen the variations in practice[23]. However, these types of developments may become commonplace in the future if local capacity and demand issues ensue in other modalities as forecasted[15].

Limitations

Despite the excellent response rate, there were 44 Trusts in which the survey was not set-up. This was due to either no response from the R&D departments or local restrictions on the setting-up of new studies other than those specific to COVID-19. It is unfortunate that these Trusts were unable to approve the study, as the response rate would have been increased.

The effect of skewed responses needs to be acknowledged given the majority of responses being from radiographers and only one radiologist. It is recognised that each profession will have differing opinions and this needs to be appreciated when interpreting the results. Canvassing the opinions of only radiologists would give an idea of any contrasting opinions and provides an avenue for further investigation.

Conclusion

This study shows that the majority of departments employ radiographers to report CXRs, and almost half of all responding departments had at least one current trainee. The enabling factors associated with training and employing CXR reporting radiographers predominantly arise from financial pressures, service improvements to reduce backlog and improve turn-around-times and developing the radiographer workforce. The main challenges originate from staffing issues; generally, the lack of radiologist support, unsuitable staff, inadequate staffing levels and lack of radiographer interest. In order to prevent accountability concerns impacting on continued progression in this area of advanced practice, it is recommended that departments explicitly inform any potential trainees of the legal protection that they will be afforded when reporting within their agreed SoP. Wide variations in SoP are still evident but the number of reporting hours allocated to reporting radiographers per week demonstrates progression highlighting the continuing reliance on reporting radiographers.

These conclusions provide an up-to-date evaluation of the service enablers and challenges associated with radiographers reporting CXRs in England, UK. It is hoped that these outcomes can provide supporting influence for the continuing development of advanced practice in radiographer departments in the future.

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3.6. Paper 6

What information is required in a preliminary clinical evaluation? A service evaluation

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https://doi.org/10.1016/j.radi.2021.04.001

Introduction

The Society of Radiographers has, for some time, envisaged that a preliminary clinical evaluation (PCE) abnormality flagging system should replace the red dot system within radiology and emergency departments (ED).[1,2] Indeed, it is indicated it should be a core competency for graduate diagnostic radiographers that they can provide a comment on a range of radiological investigations.[1,2] The difference between the two systems is that the PCE system permits the radiographer to immediately provide a brief comment describing any abnormality that may be present, rather than just highlighting there may be an abnormality. This system provides the ED practitioner a radiology opinion prior to a formal report being available.[2,3] and can have a significant impact on patient management.[3-6]

Whilst the advent of immediate "hot" reporting services in some UK Trusts likely curtails the need for the PCE service during normal hours, this service development can be valuable in those Trusts that do not have "hot reporting," the true benefit of the PCE will likely be seen in the out of hours setting when "hot reporting" is not available. However, despite this vision a previous audit of current practice identified that only 2.5% of NHS Trusts surveyed employed a PCE system as the preferred non-reporting method of image review by radiographers,[3] and a number of barriers to the implementation of PCE have been identified which may have a significant impact on the practice becoming more commonplace.[5,6]

Previous research has suggested that further training and education of radiographers is required to improve the accuracy[7-10] and structure of PCEs,[11-15] however, there is little documented evidence to indicate what information actually needs to be included in a PCE and what ED clinicians require from the service. It is clear that the use of PCE needs to fall within clear clinical governance and audit mechanisms but without clear appreciation of what information the PCE should contain and how it is to be used clinically, ongoing quality of the system will be difficult to employ and evaluate. As stated, one of the aims of the PCE in comparison to the red dot is to reduce ambiguity in the opinion by describing the abnormality and ensure that patient management is appropriate[3-6] though the PCE is not required to provide the same level of information as a formal report.[2,6] So what is it that clinicians require from a PCE?

Several proposed structured approaches have been developed[12-15] yet there is minimal consideration of how useful the information provided in these systems might be to a clinician managing the patient. The *What, Where, How*[12] (Fig.1.) and similar *What, Where, What is it doing*[15] models both proposed a systematic framework for radiographers to form a PCE comment and the former has been used in student radiographer education. Anecdotal evidence from a small sample locally suggests that all elements of such a structure may not be required,[11] though the reasons why are not documented in the literature. Other approaches to scoring the content of a PCE for assessment purposes[13], and a taxonomy to allow the selection of the anatomical and pathological information to systematically formulate the PCE[14] have also been proposed, but again do not necessarily address the issue of what is actually required.

In preparation for the local implementation of a PCE scheme at a UK NHS Trust, this service evaluation aims to identify what information clinicians most require to aid their decision making and therefore what information is required within a PCE. The findings from this study aim to add supporting evidence to identify and address issues affecting the further implementation of the PCE system.

<u>Methods</u>

Local approval from the Trust's Research and Development (R&D) department where the study was undertaken, and ethical approval (ref. MREC 19-093) from the co-author's institution were both received prior to commencing the study. A convenience sampling approach was used to recruit participants due to ease of access in the study centre. Participants were approached on an individual basis and were recruited via face-to-face invitations. An anonymous paper-based questionnaire was distributed to ED referrers who triage patients, request and review X-ray examinations; and will likely be the beneficiaries of a new PCE system. Radiology reporters were also asked for their opinion on what information they perceive to be most beneficial. Thirty individuals from across the ED and Radiology departments were approached and asked to complete the questionnaire. All subjects who were approached were permanent members of staff, though it must be made clear that not all staff were approached due to availability and/or the misalliance of shift patterns during the data collection period. The potential bias associated with this method of sampling, such as the under-representation of some staff groups, should be acknowledged.

Reporting professionals (radiologists and radiographers) would be heavily involved in the implementation, training, and governance of such a scheme, therefore their involvement was also sought. Since the aim was to identify the types of information to be included in a PCE that would be considered most useful to ED referrers, and not what information radiographers thought was needed, radiographer practitioners were not included in the study. A pilot study was undertaken with the local R&D manager resulting in minor amendments to question lay-out and wording.

Participants were asked to identify their job role under pre-defined categories to ensure anonymity and to allow differentiation of the opinions of the different staff groups. Informed consent was gained from each participant and the participants were requested not to include any identifiable information in their responses.

Questions were a combination of multiple choice, Likert scale, and free-text to collate opinions on what aspects of a PCE were the most and least useful. The *What, Where, How* method[12] (Fig.1) was used to frame the types of information that might be included. This was chosen as there are several similar iterations of this type of model from different authors[12,13,15] and it was also used as part of a previous study looking at the structure of PCEs.[11] Participants also had the option to identify other aspects which were not included in this model that might be of use and to provide any further opinion on the structure and content of a PCE.

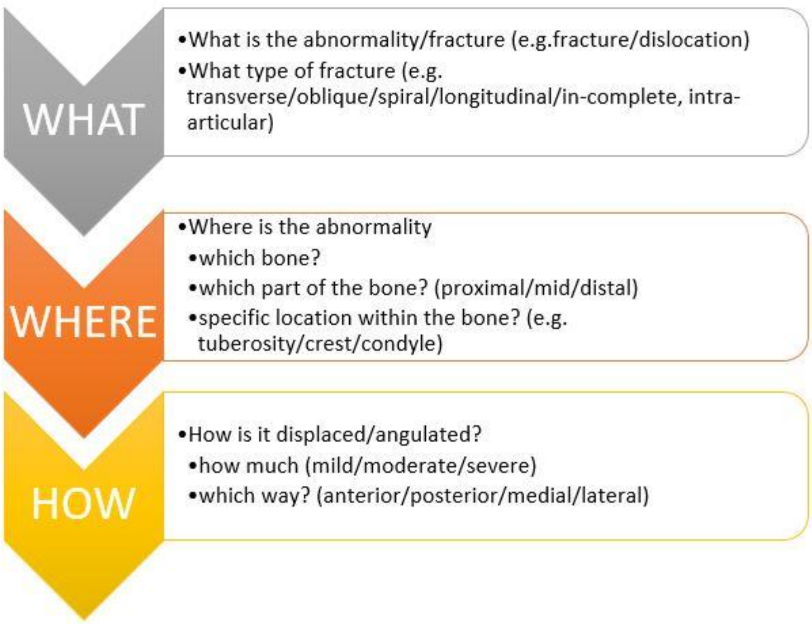

Fig. 1: WHAT, WHERE, HOW model for PCE[12]

The median and mean values of the ordinal data of the Likert scale for each of the seven categories of information suggested within the *What, Where, How* model[12] was collated for each of the two departments, and in total. Due to the ordinal and non-parametric nature of the data; Mann-Whitney U test was used to assess for differences in median scores between the departments using IBM® SPSS®

Statistics (v.26, 2019). Descriptive analysis of the variations between perceived importance of each section, and preferred styles of comment, were performed due to the small sample size.

Results

Thirty surveys were completed, a response rate of 100% of those deployed; 33.3% (n=10) were reporters from Radiology and 66.7% (n=20) from ED staff. In total, 60% (n=18) were medical clinicians, and 40% (n=12) were other health professionals in extended roles. A breakdown of the staff groups that took part are shown in Table 1.

Role	Number of Participants
Emergency Department	
Consultant	10% (n=3)
Registrar	23.3% (n=7)
Doctor	6.7% (n=2)
Emergency Nurse Practitioner (ENP)	13.3% (n=4)
Advanced Clinical Practitioner (ACP)	13.3% (n=4)
Department Total	66.7% (n=20)
Radiology	
Consultant Radiologist	10% (n=3)
Registrar Radiologist	10% (n=3)
Reporting Radiographer	13.3% (n=4)
Department Total	33.3% (n=10)
TOTAL PARTICIPANTS	**100% (n=30)**

Table 1. Number of Participants by Job Role

The collated results of the questionnaire for each of the participating staff groups are displayed in Table 2 and Table 3. Each participant ranked different types of information derived from the components of the *What, Where, How* model.[12] Participants provided their perceived level of importance to a PCE using the 5-point Likert scale; 1 being no use to 5 being of significant use. The types of information included; what the abnormality is, type of fracture, which bone, where on the bone, is it displaced or angulated, the direction of movement, and how much movement.

Overall, participants ranked all aspects of the *What, Where, How* as useful (median=5) with the exception of *how much movement* which was perceived as marginally less important (median 4.5). ED clinicians, and the main end-users, found all aspects of equal importance. Both the ED clinicians and Radiology reporters found *which bone* and *what abnormality* to be the most useful (median = 5 for both groups in both aspect).

There was more discordance between the two groups over other aspects of the model. Whilst ED staff indicated all aspects were of similar use (median = 5), Radiology reporters indicated *type of fracture* (median = 4), *where on bone* (median = 4), *is it displaced/rotated* (median = 3.5), *in which direction* (median = 3) and *how much movement* (median = 3) to be less significant. According to Mann-Whitney U, there was a significant (P = <.05) discrepancy in opinion between the groups for *type of fracture* (P = .019), *where on bone* (P = .024), *is it displaced/rotated* (P = .006), *in which direction* (P = .003), and *how much movement* (P = .001).

Participants were asked to indicate what they considered to be the most and least significant component of the model. The *Where* was considered to be most significant (n=18, 60%), followed by *What* (n=11, 37%). No participants considered the *How* to be significant, but one participant (3%) considered all components to be significant.

Half of participants (n=15, 50%) considered the *How* to be least significant. The *What* was only considered least significant by one participant (3%) and the *Where* was not considered least significant at all (n=0, 0%). Interestingly, 14 participants (47%) did not consider any of the components to be least significant, 13 of these were from the ED group.

The majority of participants (n=23, 77%) indicated that a bullet-point style would be their preferred format of comment.

One ED clinician identified the proposed system as being

> "*very helpful addition to ED care*" and another "*the content is very useful.*"

They also identified the necessity for a radiology opinion;

> "*timely reporting is clinically very important*."

As well as providing opinion on the content, radiology staff also provided some insightful comments which outline some key considerations when setting up such a scheme, such as impact on departmental workflow:

> *"must be easily accessible so it impacts as little as possible on workflows."*
>
> *"A simple and rapid process is still required to alert the referrer to any abnormality."*

Clear governance procedures must outline the system to both departments;

> *"Indication on image so ED staff aware of comment."*
>
> *"Overt caveat that this is not a formal report with each comment"*

Even with a simple and structured approach to comments, there is a necessity for training and support for radiographers;

> *"Simplicity of what/where/how is good. Staff would need formal training having to do this robustly."*

Response	Department	Role	What Abnormality Is	Type of Fracture	Which Bone	Where on Bone	Is it Displaced /Rotated?	In Which Direction?	How Much Movement ?
1	**Radiology**	rad reg	5	3	5	5	5	4	3
2	**Radiology**	rep rad	5	4	5	4	3	3	3
3	**Radiology**	rep rad	5	5	5	5	5	4	4
4	**Radiology**	rep rad	5	5	5	5	4	3	1
5	**Radiology**	rep rad	5	3	5	3	3	2	2
6	**Radiology**	cons rad	5	4	5	4	5	5	4
7	**Radiology**	cons rad	5	4	5	4	5	5	5
8	**Radiology**	rad reg	5	1	5	4	1	1	1
9	**Radiology**	cons rad	5	3	5	3	3	3	3
10	**Radiology**	rad reg	5	5	5	3	3	3	3
RADIOLOGY		**MEDIAN**	**5**	**4**	**5**	**4**	**3.5**	**3**	**3**
		MEAN	**5**	**3.7**	**5**	**4**	**3.7**	**3.3**	**2.9**
11	**ED**	ed reg	5	5	5	5	5	5	5
12	**ED**	ed reg	5	5	5	5	5	5	5
13	**ED**	ed cons	4	4	4	4	4	4	4
14	**ED**	enp	5	5	5	5	5	5	5
15	**ED**	ed reg	2	5	5	5	5	5	4
16	**ED**	enp	5	5	5	5	5	5	5
17	**ED**	ed dr	5	4	5	4	5	5	5
18	**ED**	ed cons	5	4	5	5	5	5	5
19	**ED**	enp	4	5	5	4	5	4	3
20	**ED**	acp	5	5	5	5	5	5	5
21	**ED**	ed reg	5	4	5	4	5	3	3
22	**ED**	ed reg	5	5	5	5	5	5	5
23	**ED**	acp	4	4	4	4	3	3	3
24	**ED**	ed dr	5	2	4	3	5	3	4
25	**ED**	enp	5	5	5	5	5	5	5
26	**ED**	ed cons	5	5	5	5	5	5	5
27	**ED**	acp	5	5	5	5	5	5	5
28	**ED**	acp	5	5	5	5	5	5	5
29	**ED**	ed reg	5	5	5	5	5	5	5
30	**ED**	ed reg	5	5	5	5	4	5	5
ED		**MEDIAN**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
		MEAN	**4.70**	**4.60**	**4.85**	**4.65**	**4.80**	**4.60**	**4.55**
MEDIAN	**TOTAL**		**5**	**5**	**5**	**5**	**5**	**5**	**4.5**
MEAN	**TOTAL**		**4.81**	**4.27**	**4.91**	**4.41**	**.38**	**4.10**	**3.93**
Mann-Whitney U Test between groups median (p=)			**0.136**	**0.019**	**0.204**	**0.024**	**0.006**	**0.003**	**0.001**

Table 2. Likert scores per participant

Response	Department	Role	Most significant information	Least significant information	Preferred style
1	Radiology	rad reg	what abnormality	how much is displaced	bullets
2	Radiology	rep rad	what abnormality	angulation/displacement	bullets
3	Radiology	rep rad	what abnormality	n/a	bullets
4	Radiology	rep rad	where	how	bullets
5	Radiology	rep rad	where	displacement	bullets
6	Radiology	cons rad	where	angulation/displacement	sentence
7	Radiology	cons rad	where	how	bullets
8	Radiology	rad reg	where	type	bullets
9	Radiology	cons rad	where	how	bullets
10	Radiology	rad reg	what abnormality	displacement/rotation	bullets
RADIOLOGY TOTAL			**What - 40% (n=4)** **Where - 60% (n=6)** **How - 0%**	**What - 10% (n=1)** **Where - 0% (n=0)** **How - 80% (n=8)** **None - 10% (n=1)**	**Bullets - 90% (n=9)** **Sentence - 10% (n=1)**
11	ED	ed reg	where	n/a	bullets
12	ED	ed reg	what abnormality	how	bullets
13	ED	ed cons	what abnormality	n/a	sentence
14	ED	enp	where	n/a	sentence
15	ED	ed reg	n/a	n/a	sentence
16	ED	enp	where	all significant	sentence
17	ED	ed dr	the diagnosis	n/a	sentence
18	ED	ed cons	diagnosis	n/a	sentence
19	ED	enp	what abnormality	how	bullets
20	ED	acp	where	n/a	bullets
21	ED	ed reg	what abnormality	how	bullets
22	ED	ed reg	where	displacement	bullets
23	ED	acp	where	angulation/displacement	bullets
24	ED	ed dr	what abnormality	n/a	bullets
25	ED	enp	where	n/a	bullets
26	ED	ed cons	where	n/a	bullets
27	ED	acp	where	n/a	bullets
28	ED	acp	where	n/a	bullets
29	ED	ed reg	where	how	bullets
30	ED	ed reg	where	displacement	bullets
ED TOTAL			**What - 35% (n=7)** **Where - 60% (n=12)** **How - 0%** **All - 5% (n=1)**	**What - 0% (n=0)** **Where - 0% (n=0)** **How - 35% (n=7)** **None - 65% (n=13)**	**Bullets - 70% (n=14)** **Sentence - 30% (n=6)**
OVERALL TOTAL			**What - 37% (n=11)** **Where - 60% (n=18)** **How - 0%** **All - 3% (n=1)**	**What - 3% (n=1)** **Where - 0% (n=0)** **How - 50% (n=15)** **None - 47% (n=14)**	**Bullets - 77% (n=23)** **Sentence - 23% (n=7)**

Role key: cons rad = Consultant Radiologist, rad reg = Radiology Registrar, rep rad = Reporting Radiographer, ed cons = ED Consultant, ed reg = ED registrar, ed dr = ED Doctor, enp = Emergency Nurse Practitioner, acp = Advanced Clinical Practitioner

Table 3. Participant preferences

Discussion

Despite the Society of Radiographers outlining that PCE was its preferred option for radiology flagging systems 15 years ago, [1,2] and it gaining popularity particularly in the UK and Australia,[3,4,6,7,10-15] it is still not commonplace.[3,5,6] There are many reasons for this which have been identified in the literature[3,5,6] but this study focussed on assessing what format and information would be most desirable by referring clinicians and reporting professionals.

ED clinicians for the most part found all aspects of the *What, Where, How* useful, in particular the *Where,* but to a slightly less extent when considering how much displacement was involved (median = 4.5). This is perhaps understandable since part of the rationale for the PCE system over red dot is to reduce ambiguity of where the red dot was indicating on the image; yet it is clear that clinicians do want more information than simply where it is. These results imply that ED clinicians would want information pertaining to what the abnormality is, where it was (more specific than simply which bone) and if there was displacement present

In contrast, the smaller cohort of Radiology reporting staff considered the inclusion of information on the presence and severity of displacement as being of less importance though, again, highlighted that information on the type and location of the abnormality was of relevance. Whilst it might be argued that the PCE scheme is to assist referring clinicians and, therefore, what radiology staff consider to be important may be of lesser significance as they are not the end-users; it is imperative that these staff are integral to the implementation and governance of a PCE scheme, in addition to training participants in the scheme. Reporters will be heavily involved in the governance of such a scheme and in educating and supporting the radiographers undertaking the PCE writing. All the insightful considerations illustrated in their responses are aspects that have been considered in previous literature outlining the development of PCE systems.[2-15] but this study provides further evidence of their importance.

When considering the structure of the radiology report, the impression or conclusion section summarises the examination and sometimes is thought to be the most important aspect.[16-20] The report should be structured in such a way that clinicians are familiar with the content and structure, should contain pertinent and relevant information for the referrer, and be written in a way that the referrer can understand without ambiguity. A PCE is the radiographer's impression and whilst the PCE is not a clinical report, some of these considerations might be regarded transferable in that it should be structured, provide useful and relevant information, and be easy to follow by the clinician.

Research suggests that the most concise, and often preferred, summation of examination findings is conveyed via a numbered list of summary statements,[16-19] and our results indicate that a bullet-style comment would be most preferred for the PCE. This preferred style implies that the PCE should be a short comment, without excessive wording, and is supported by a recent study which suggested a similar style.[11] Bulleted or listed findings will likely provide clearer conveyance of the radiographer's interpretation, and provide a more consistent structure which is both helpful to the clinicians[16,18] and the radiographer. The format and writing of a PCE has been considered a potential barrier to radiographers being confident in undertaking such a role,[5,11,12] so the use of a structured tool to educate radiographers to produce a PCE may help facilitate overcoming this.

When the radiographer provides their impression of the examination in a PCE, they need to convey the information that is most useful to the clinician. One of the marked benefits of this scheme over the red-dot is that it aims to reduce ambiguity for the clinician as to what the radiographer is highlighting. [2-4] The structure, content and information provided within a PCE might also be considered, to an extent, similar to a report in that it needs to be able to answer the clinician's clinical question and provide pertinent, relevant information to aid in their clinical decision making and patient management.[16-20] Its use in the ED department, in skeletal trauma, is the setting where the PCE is most likely to be used and was so for this study. It is important, therefore, to consider what information is most likely to be of use to the ED clinician and this may actually differ from what the individual writing the PCE (or report) might perceive. Dialogue with ED referrers will be beneficial for the radiographers in terms of realising what information they should be including in their comments, whilst also strengthening the working relationships between the two departments.

It must be recognised that this study was a small service evaluation within a single UK NHS hospital and, whilst it highlights some important factors which will be considered when establishing a local PCE scheme, the conclusions may not necessarily be representative of a wider workforce, though potentially could be similarly reproduced more widely. Although job role and grade was taken into account, we have not considered the impact of experience or previous education in the responses of the participants. The use of a single model to structure PCE comments may have influenced the participants but it has highlighted that simple, standardised format may be of preference.

Conclusion

This survey provides local insight in to the types of information ED referrers would find most useful in a PCE comment. ED clinicians for the most part found all aspects of the *What, Where, How* useful, in particular the *Where,* but to a slightly lesser extent when considering how much displacement was involved. Specifically, ED clinicians want information pertaining to *what the abnormality is* (i.e. the type of injury), where it was (more specific than simply which bone) and if *displacement* is present. It is hoped that the findings of this study will help support the establishment of a robust PCE scheme locally, and add to the wider evidence-base to support such practice becoming more widely utilised.

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3.7. Paper 7

Radiograph report style preferences of referrers at a district general hospital in the West Midlands, England, UK

Stevens BJ (2022). Radiography, Volume 28 Issue 2, 296-303.
https://doi.org/10.1016/j.radi.2021.10.001

Introduction

The radiology report is an official interpretation of an imaging study provided by an appropriately trained medical professional(1) and is the method of communicating findings to all who view the examination images. Many articles and guidelines have been published proposing suggestions for the optimal radiology report style(2–5) with some authors recommending that detailed reports are preferred to brief reports(6,7), even for normal examinations(6). However, this is open to subjective interpretation and, considering the increased demand and radiologist shortages across the National Health Service (NHS), may not be currently achievable or universally adhered to in England, United Kingdom (UK). On the contrary, and specifically regarding normal chest X-ray images, McLoughlin et al(2) argue that clinicians prefer a brief description of findings, and that simply "normal examination" would be sufficient. It is possible that different referrers may prefer different styles of description and this may vary across the different imaging modalities with some styles being considered easier to read depending on a number of clinical variables such as; referrer role, report reading setting and presenting condition(s) of their patient(s). X-ray examinations are the most widely and most frequently requested imaging modality in the United Kingdom (UK)(8) and are increasingly reported by advanced and consultant radiographers(9).

The reporting styles of radiographers will primarily be shaped by their supervisors, mentors and their reporting colleagues who provided assistance throughout their training. It may be that reporting radiographers continue to develop their reporting style following qualification as they forge their own reporting identity. It is also likely that reporting styles of radiographers will be further moulded to fit with local traditions and expectations. In line with the understanding that reports by radiographers will be equivalent to their radiologist counterparts, there is an expectation that reports by radiographers will provide an accurate interpretation of the examination, offer a diagnosis and provide appropriate suggestions for further imaging, investigations or patient management(1).

Whilst reporters formulate their own reporting styles with individual lexical characteristics, thought must be given to the referring clinicians who read and attempt to understand the report content. The length of the report may deter referrers from reading reports(10), and it has also been suggested that standardisation of reporting styles would be beneficial for General Practitioner (GP) referrers as a way to reduce report vagueness(11). Brevity, clarity and pertinence are assumed to be key attributes of a good report, all adding credibility to the report(3). It is recognised that considering the wide-ranging preferences of referrers there may not be a universally accepted report style(12). Given the possible impacts of the clinical variables on referrer preferences it may be appropriate to tailor reports to best aid patient outcomes. The aim of this study is to assess the X-ray report style preferences of hospital-based and community-based referrers in a district general hospital (DGH) in the West Midlands, England, UK.

Methodology

This electronic survey study used convenience sampling due to the ease of access and ability to approach potential participants. The study was approved by the local Research and Development (R&D) department. Ethical approval was not required for the study, which was considered to be service evaluation by the Health Research Authority (HRA) tool(13). A pilot was undertaken with a small section of hospital-based referrers prior to the survey being launched, no significant structural changes were needed, and these responses were included in the overall sample.

The survey was hosted online (Online Surveys, Jisc, Bristol, UK). An electronic mail (e-mail) invitation was sent to all hospital-based and community-based staff (n = 356) who had requested imaging examinations in the six months prior to the study start date, seeking their participation in the study. The invitation e-mail included the electronic link to access the survey. Weekly reminder emails were sent, and a weekly notification was also published in the Trust's daily communications bulletin for the duration of the study. The study was open for 31 days during July 2021. The survey began with simple demographic questions to allow grouping of specialties and job roles. Participants were asked their views on the inclusion of recommendations and advice in the reports they receive. Mock reports (skeletal and chest) were presented with four different styles and participants were asked to indicate which style of report they preferred, style one (S1): short sentence, in depth, paragraph; style two (S2): short sentence, brief, bullet-points; style three (S3): long sentence, in-depth, paragraph style; or style four (S4): long sentence, brief, bullet-points (figure 1). The results were exported into Excel for manual analysis.

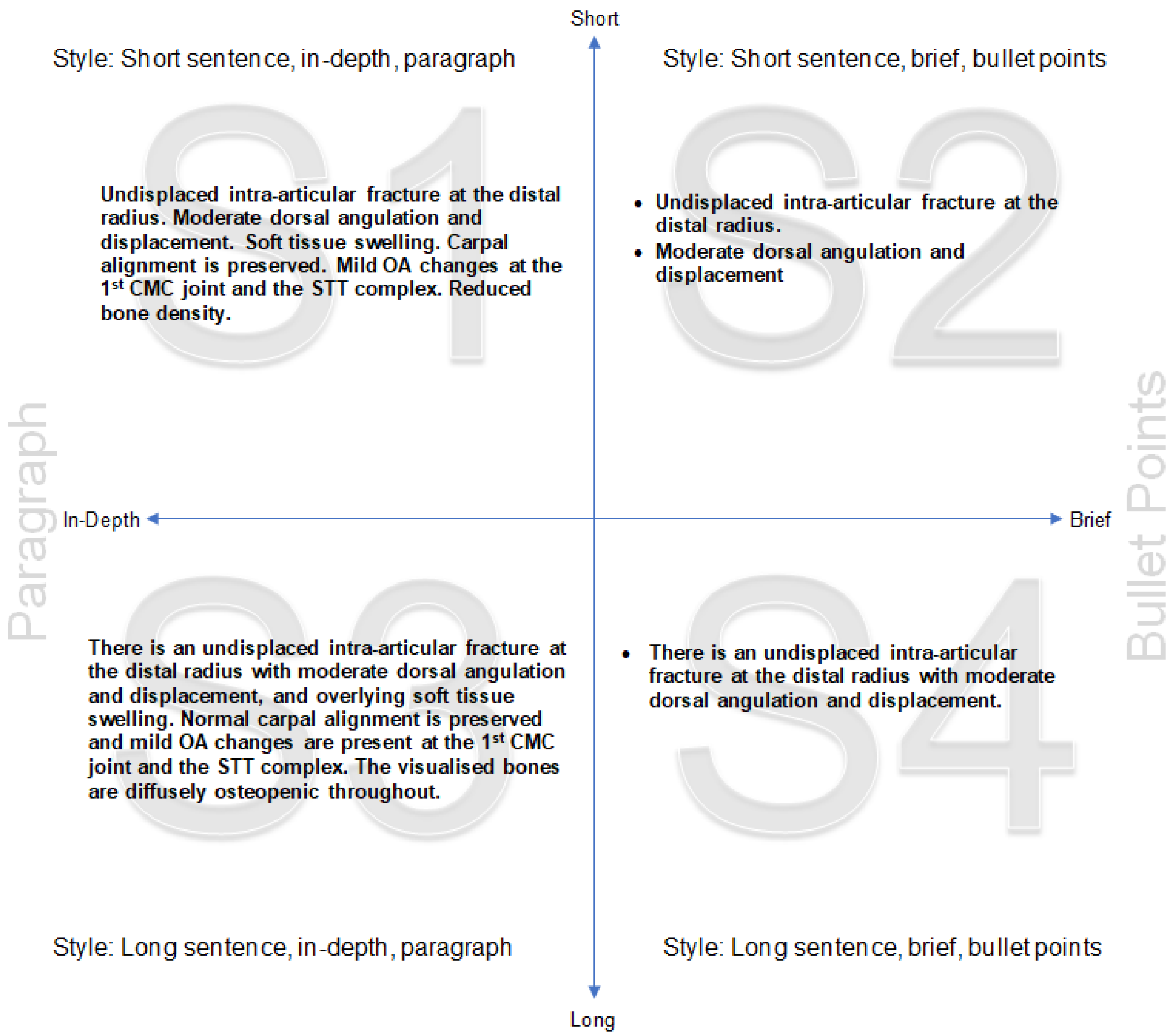


Figure 1: An example of the skeletal report style model illustrating the different combinations (report content is fictional to emphasise style).

<u>Results</u>

There were 114 participants from the identified population of 356, giving a response rate of 32%.

Demographics

The clinical roles and number of participants per group is illustrated in chart 1, and participants' clinical specialities are shown in chart 2. The mean number of years participants have been qualified was 15.6 years (SD 10.61, minimum 1, range 45).

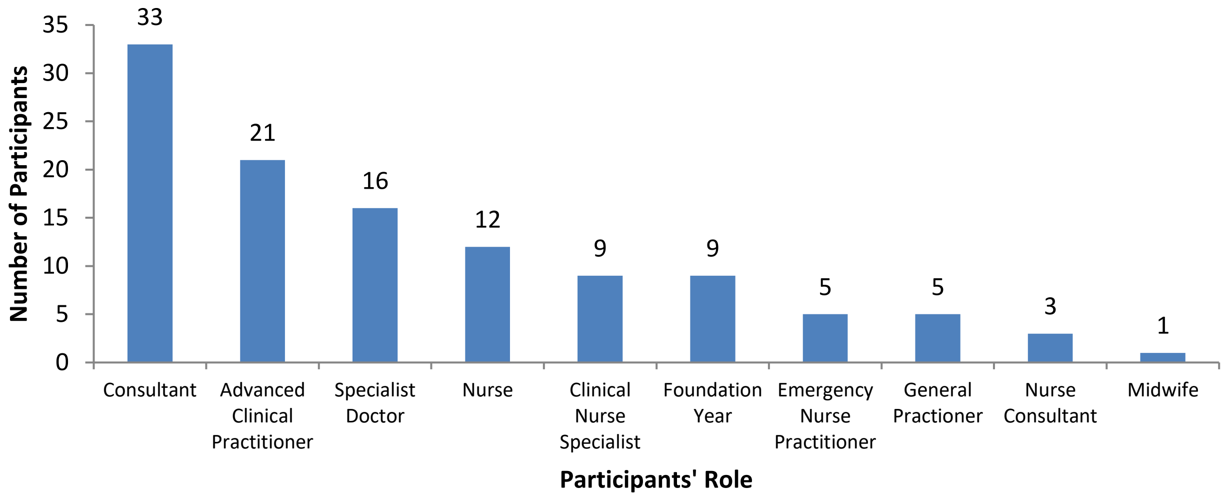


Chart 1. A breakdown of the number of participants per clinical role.

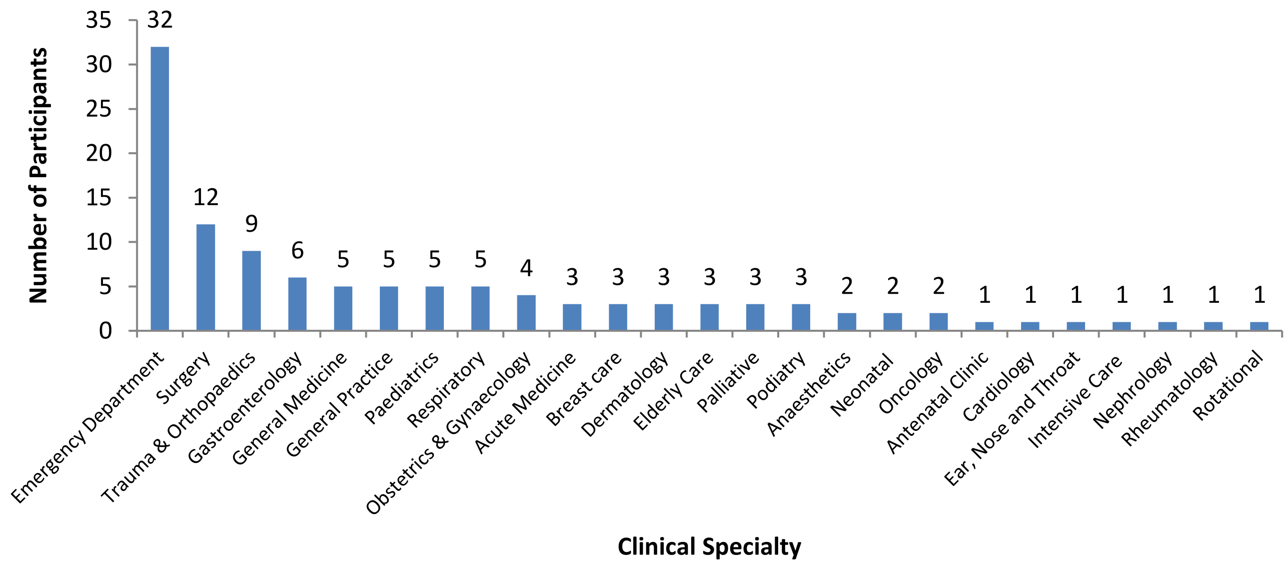


Chart 2: A breakdown of the number of participants per clinical specialty

The majority of participants undertake their X-ray report reading on wards (n = 41, 36%), followed by in the ED (n = 33, 29%), in the outpatient clinics (n = 33, 29%), or in other areas including theatres and personal office (n = 2, 1.8%), and GP surgery (n = 5, 4%).

Recommendations and advice

Nearly all of the participants stated that they find the inclusion of recommendations and advice to be useful (n = 109, 96%). The five participants (4%) who do not find recommendations and advice to be useful were consultant doctors. The large majority of participants indicated that they act on the recommendations and advice in the report most of the time (n = 73, 64%). Further breakdown is shown in chart 3.

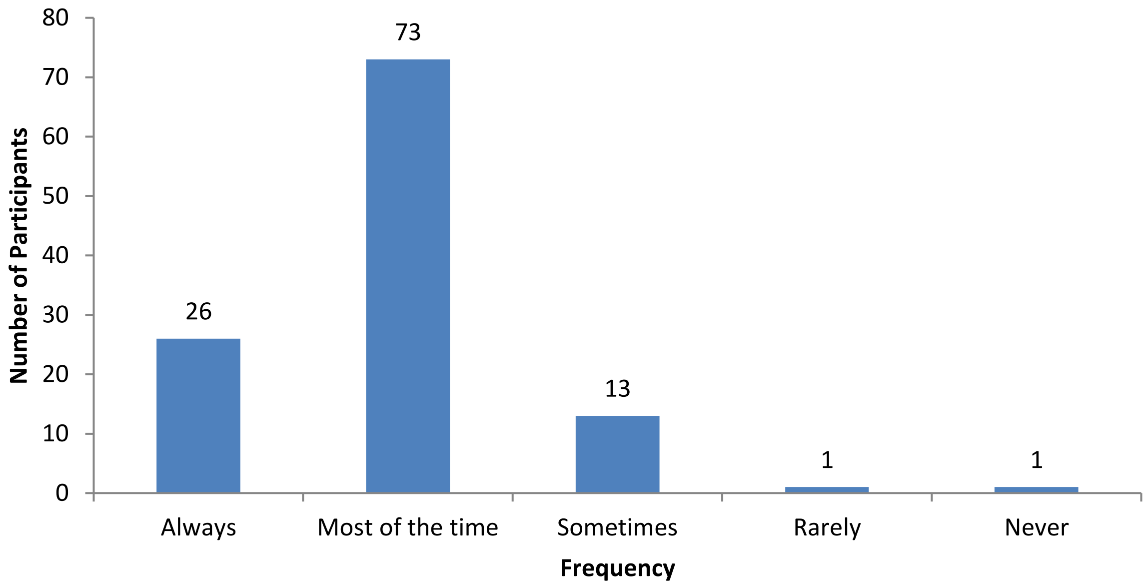


Chart 3: A breakdown of how often participants act on recommendations and advice in the report.

Participants were asked if they have any other opinions on the inclusion of recommendations and advice at the end of the report, and suggestions regarding the length of the report was common;

> “Detail seems to vary a huge degree dependant on who has reported.” *(Unique Response Number 355)*

> “Sometimes…there isn't enough information in the report” *(URN 363)*

A pertinent issue closely associated with report detail and suggested as an important aspect was the inclusion of a list of possible diagnoses;

> “…more differential diagnosis would be more beneficial…recently 2 TB patients turned out to be cancer” *(URN061)*

> “…it is important to include the possible differential diagnosis” *(URN 399)*

Whilst many found the inclusion of recommendations to be beneficial to them, there were some responses that did not deem them to be useful;

> “As a consultant orthopaedic surgeon, I do not often need the recommendations, but I think they would be extremely helpful for less experienced colleagues” *(URN 362)*

"No, as the consultant will review most of the CXRs in neonates" *(URN 345)*

Report styles

Skeletal reports

Seventy-nine participants (69.3%) request skeletal X-ray examinations for their patients. More than half of responses prefer S2 for their reports (n = 42, 53.2%), which consists of short sentences, brief, bullet-point (chart 4). Further breakdown of the skeletal report style preferences from the different clinical roles are shown in chart 5.

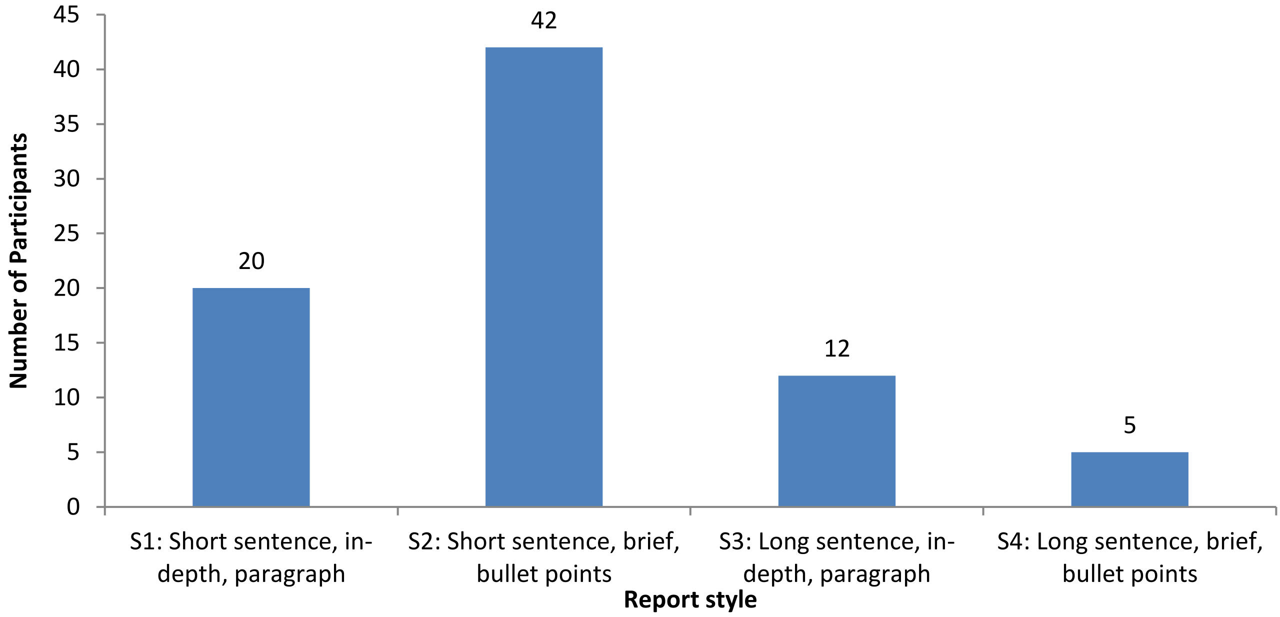
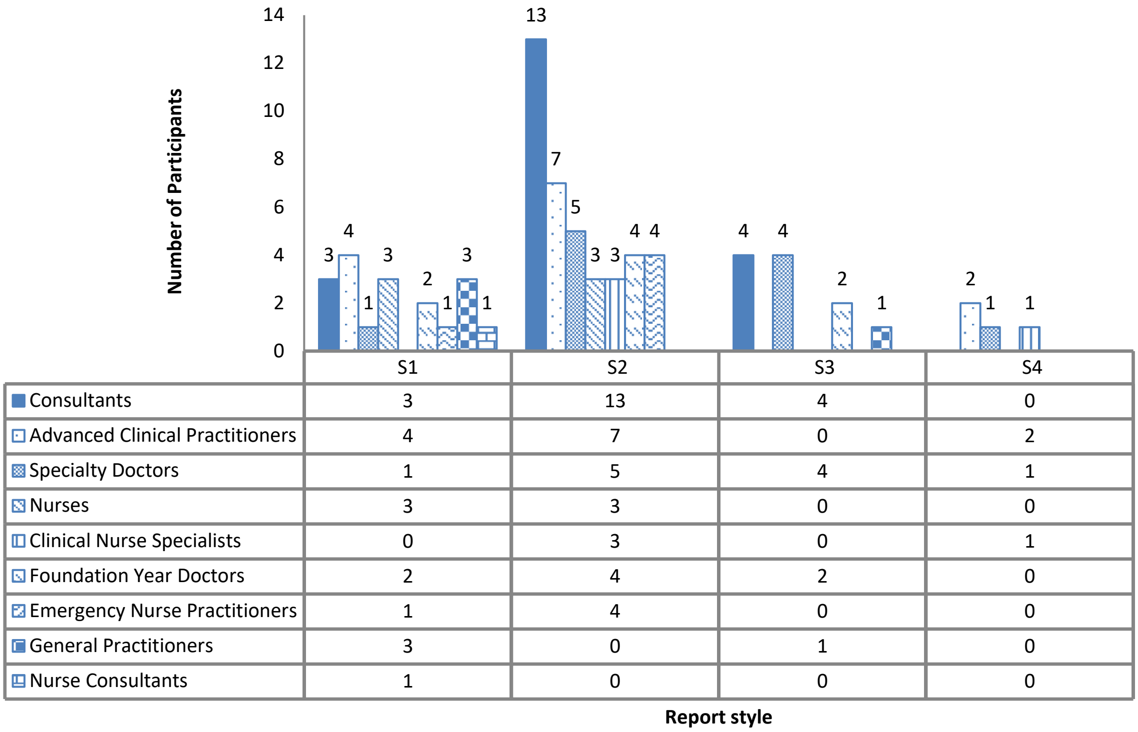


Chart 4: Skeletal X-ray report style preferences



	S1	S2	S3	S4
Consultants	3	13	4	0
Advanced Clinical Practitioners	4	7	0	2
Specialty Doctors	1	5	4	1
Nurses	3	3	0	0
Clinical Nurse Specialists	0	3	0	1
Foundation Year Doctors	2	4	2	0
Emergency Nurse Practitioners	1	4	0	0
General Practitioners	3	0	1	0
Nurse Consultants	1	0	0	0

Chart 5: A breakdown of skeletal report preferences by clinical role

Chest reports

One hundred participants (87.7%) request chest X-ray examinations. The majority of these responses (n = 45, 45%) indicated preference of S2 for their reports, consisting of short sentences, brief, bullet-points (chart 6). Further breakdown of the chest report style preferences of the different role groups are shown in chart 7.

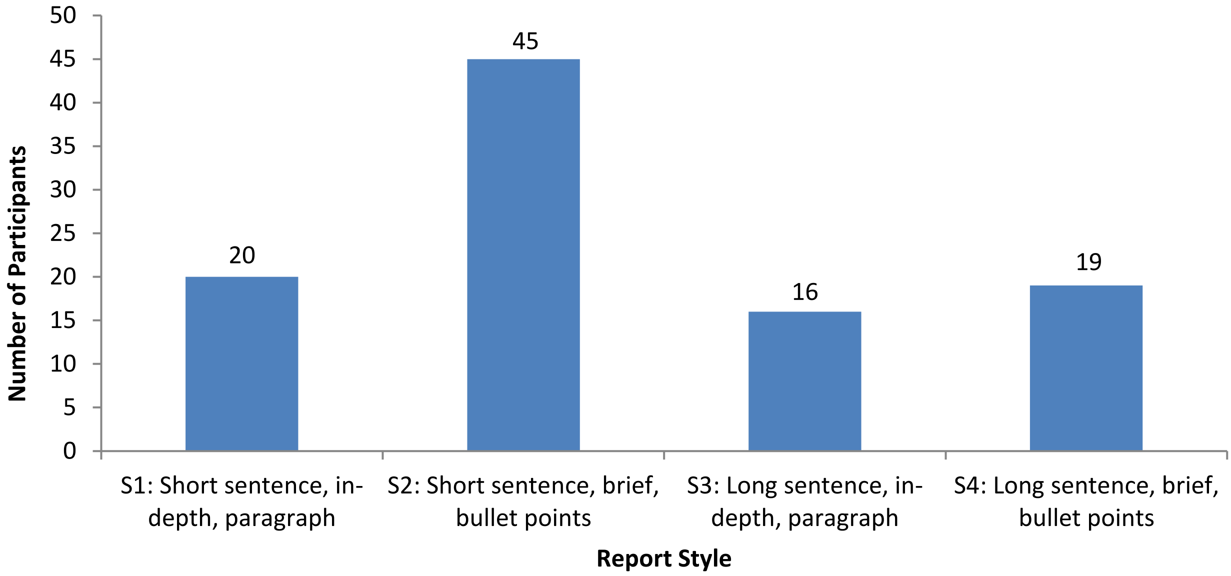
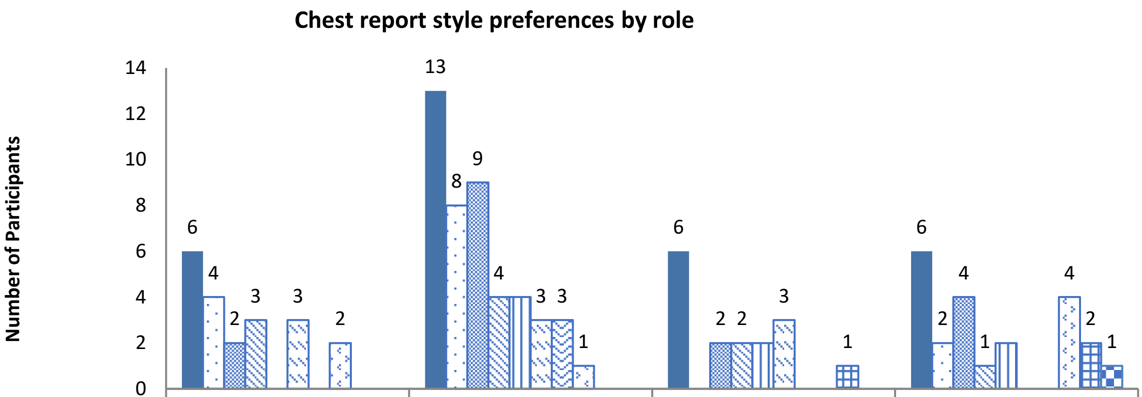


Chart 6: Chest X-ray report style preferences



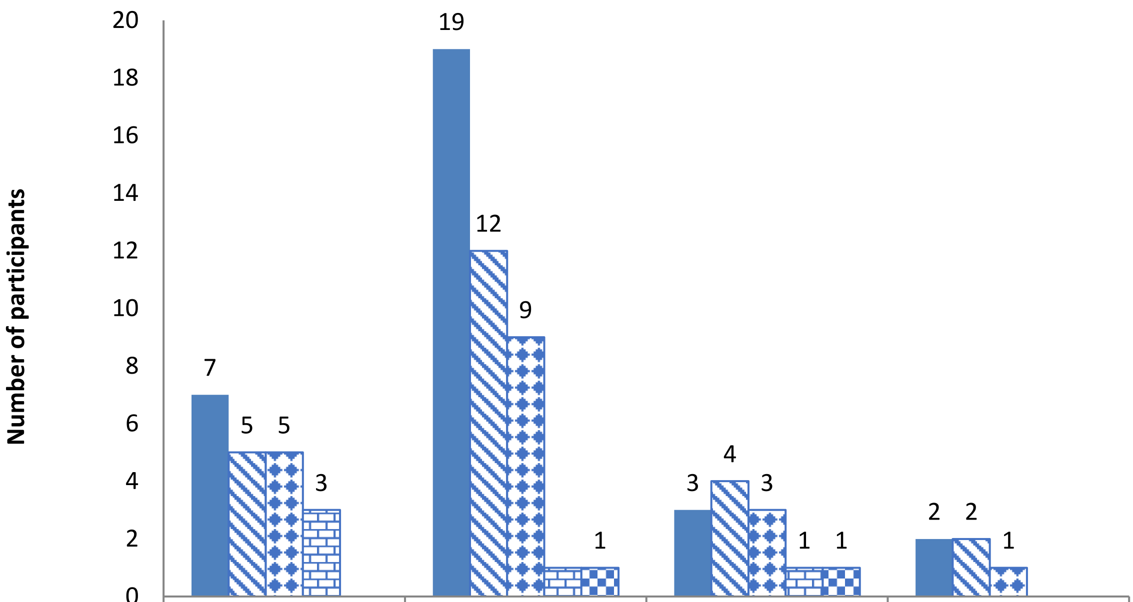
	S1	S2	S3	S4
Consultants	6	13	6	6
Advanced Clinical Practitioners	4	8	0	2
Specialty Doctors	2	9	2	4
Nurses	3	4	2	1
Clinical Nurse Specialists	0	4	2	2
Foundation Year Doctors	3	3	3	0
Emergency Nurse Practitioners	0	3	0	0
General Practitioners	2	1	0	4
Nurse Consultants	0	0	1	2
Midwife	0	0	0	1

Report Style

Chart 7: A breakdown of chest report preferences by clinical role

In the ED setting, referrers mostly prefer S2 for skeletal reports (n = 19/32, 59%), and those who are requesting CXRs also prefer S2 (n =17/30 57%). Brief, bullet-point reports are preferred by the ED Emergency Nurse Practitioners for skeletal examinations with short sentences (n = 4/5, 80%) or a long sentence (n = 1/5, 20%), and they prefer CXR reports with short sentences (n = 3/3, 100%).

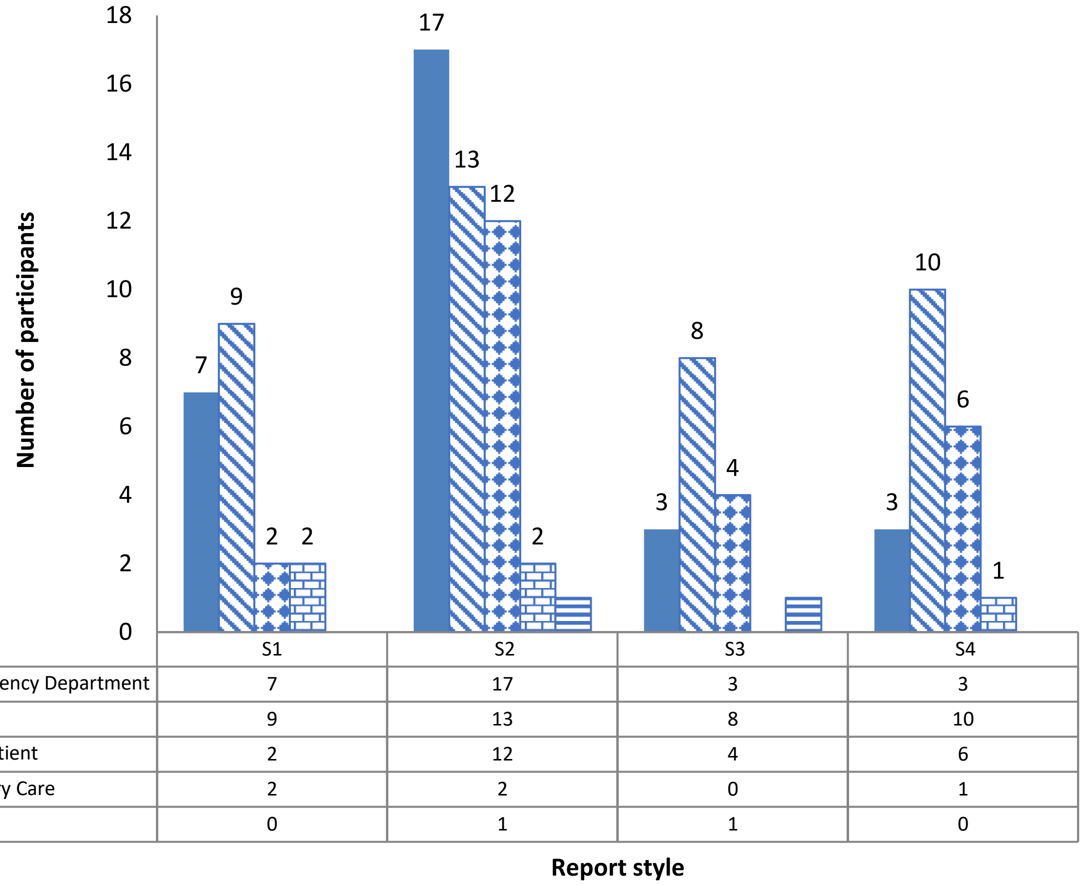
Consultants in the ED prefer S2 for their skeletal and CXR reports (n = 4/4, 100%). Consultants in trauma and orthopaedics prefer S1 for their skeletal reports (n = 3/3, 100%). Whilst there was only a small number of responses from the primary care setting (n = 5/114, 4%), it is interesting nonetheless that four of the skeletal responses (80%) and three (60%) of the chest responses suggest that S1 and S3, with short or long sentences, more detail and in paragraph form might be more preferential. Further breakdown is shown in charts 8 and 9.



	S1	S2	S3	S4
Emergency Department	7	19	3	2
Ward	5	12	4	2
Outpatient	5	9	3	1
Primary Care	3	1	1	0
Other	0	1	1	0

Report style

Chart 8: Participants' skeletal report style preferences by location of reading report



	S1	S2	S3	S4
Emergency Department	7	17	3	3
Ward	9	13	8	10
Outpatient	2	12	4	6
Primary Care	2	2	0	1
Other	0	1	1	0

Chart 9: Participants' chest report style preferences by location of reading report

<u>Discussion</u>

The findings from this survey study illustrate that the report style preferences of referrers can vary, but the majority of participants prefer a report style that consists of short sentences, is brief with bullet-point format. The large majority also find the inclusion of recommendations and advice as useful, regularly acting on the provision of such information, which is reassuring to know and also supports the notion that all reports should be actionable(1).

Earlier studies have implied that hospital consultants prefer detailed reports to brief reports(6,7). Though it has recently been suggested that consultants may be less likely to read reports if the text is too long(10), the findings in the current study add support to this latter assumption by illustrating that the majority of consultants prefer reports that are brief with short sentences or a long sentence. Paradoxically, it is also apparent that referrers may desire more detail in their reports, including the offering of differential diagnoses. A balance should be sought to prevent the length of the report becoming unappealing to the reader(10). Removing redundant words or repetitive phrases can help improve conciseness(3), allowing the author to include more informational content thus increasing detail. This will ensure reports are brief, and will improve the effective communication of findings, increasing the likelihood of readers understanding the content[4].

Stark differences exist in the style preferences between referrers who read their reports in the primary care setting, the outpatient department and the ED. Although the reasons for this were not explored, it is evident that those who read their reports in more sedate environments prefer more detailed reports. Previous work[14] supports this claim reporting that the majority of GPs prefer detailed reports seeing the inclusion of recommendations for further investigations, referral and/or treatment as valuable components of the report. It is possible that due to the detached model of care in the GP setting whereby it may be days or weeks before the patient is seen again that GPs desire more detailed reports (S1 and S3) for their results consultation. However, it is clear that a focussed investigation regarding the report preferences of GPs is required here to substantiate this theory, highlighting an interesting area for further research. Responses from the T&O consultants who read their reports in the outpatient clinic also suggest that they prefer short but in-depth reports (S1). Potential reasons for this may include the discussing and planning of potential surgical procedures, which could be facilitated with more informational content.

In comparison, the dynamic nature of the ED is likely contributory to the ED referrers preferring short, briefer reports (S2) given that ED attendance figures have continually increased over the last 2 years[15]. The added pressure of time constraint may also be a factor considering their objective is to assess and discharge the patient, arrange a follow-up or refer to an alternative service, within a four-hour target[16]. Referrers in the ED can also reassess their patients in quick succession following their X-ray examination to correlate brief report findings and undertake additional imaging examinations, clinical tests and laboratory-based tests, if required. Interestingly, the preference of ED referrers for a bullet-format report correlates with previous work in which the bullet-format was also preferred by ED referrers for a preliminary clinical evaluation[17].

The style examples provided in this study all portrayed positive findings, subsequently the report preferences for normal examinations were not evaluated. Although, it has previously been argued that a "normal examination" report should be sufficient[2], however given the litigious nature of modern healthcare it could be that an ultra-minimalist approach would not be well received especially if medico-legal proceedings were to be brought. Vague reports have been proven to be commonly associated with medical malpractice litigation[18], and can reduce GP satisfaction of the service provided[11]. A more suitable approach maybe to adapt an abridged version of the good practice guidelines for radiological reporting, incorporating a balanced and clear description of negative findings, as outlined by the European Society of Radiology[5].

Limitations

Given the anonymous nature of this study there was no way of monitoring for duplicate responses, it is hoped that participants' own professional standards would have prevented them from trying to skew the results. The method of acquiring referrers' email addresses unfortunately did not return individuals' job role as this information is not provided when submitting an imaging request. To manually search each participant's job role was considered to be overly time-consuming and beyond the scope of this study. Consequently, it is not possible to assess the proportion of engagement and non-responders by job role. The low response rate is acknowledged as being a limitation and whilst the inclusion criteria identified referrers during the previous six months, it is possible that some referrers may have been excluded from the sample. Regrettably, this sample did not provide a large enough response from GPs to assess if significant differences in preferences exist between community-based and hospital-based referrers. The potential effects from the non-responding referrers on the study findings need to be recognised. There were a small number of entries in the free comments section that suggested some participants may have based their responses on a variety of imaging modalities and not just X-ray examinations, even though the focus on X-ray examinations was stipulated throughout the survey. Readers must appreciate how this might have affected the responses provided.

Conclusion

Short and brief report styles are preferred by the majority or participants for skeletal and chest X-ray examinations, therefore it is recommended that reporters utilise this style with the specific inclusion of bullet-style format for patients presenting from the ED. Acknowledging that report styles could be optimised depending on the referrer, referrer setting, and/or anatomy might improve reporting workflow and enhance the service users' experience, ultimately benefitting the patient. Future study recommendations include a focussed evaluation of report style preferences of GPs as well as a wider study assessing referrer preferences for the reporting of examinations with negative findings.

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3.8. Paper 8

The efficacy of preliminary clinical evaluation for emergency department chest radiographs with trauma presentations in pre- and post-training situations.

Stevens BJ & Thompson JD (2022). Radiography Volume 28, Issue 4, November 2022, 1122-1126. https://doi.org/10.1016/j.radi.2022.08.011

Introduction

Preliminary clinical evaluation (PCE) was introduced as an abnormality flagging system to improve the communication of positive findings on extremity radiographs, replacing the red dot system, predominantly used in an Emergency Department (ED) setting[(1)]. Previous studies have investigated various elements of the PCE system including the effects of focussed training[(2)], accuracy[(3,4)], impact on patient management[(5)], common errors[(6)] structure of the written comment[(7)], and the type of comment preferred(8). The benefits of the PCE system for extremity X-ray examinations are that it reduces interpretation errors[(5,9)] and increases confidence in decision making by referrers[(5)]. Some studies have described the expansion of PCE in abdominal X-ray examinations[(10)] and Computed Tomography (CT) colonography[(10,11)]. To date, there have been no studies specifically assessing the possibility of extending the scope of the PCE service to include other body parts that often present with traumatic mechanisms of injury, such as the chest. Recent research has indicated the inclusion of the chest X-ray (CXR) in a PCE system in at least one institution[(6,12)] though there has been no published assessment of performance showing how, or if, training can improve radiographers' abnormality detection and/or commenting accuracy.

The CXR is the most requested radiographic examination[(13)] and contributes a large portion of a general radiographer's daily workload. As previously suggested[(5)], the PCE will likely be most useful in the out-of-hours (OOH) setting in which urgent radiology reports may be provided by off-site reporting agencies or in the following days or weeks. Subsequently, a PCE comment for a CXR examination suspected to have traumatic findings has the potential to reduce mismanagement and expedite correct management and treatment.

This study aims to assess radiographers' ability to localise common traumatic pathologies and to accurately describe the pathology, in pre- and post-training conditions.

Method

This observer study was performed in a district general hospital in the West Midlands region of England, United Kingdom (UK). The Health Research Authority tool[14] did not classify this work as research but local institutional approval was provided. Participants were invited by poster advertisement and in-person discussions. Participants consented to allow their data to be used in this evaluation. Participants were required to localise an abnormality and describe the appearance, to generate a PCE.

Image bank formation

A 3-month survey revealed an average of 31±4.6 (range 26-35) CXR examinations performed in the OOH setting (8pm-8am) for ED patients. This was not considered to be an adequate caseload to provide a meaningful number of positive cases. Subsequently, the image bank caseload was increased to 58 based on the sample size estimations used for observer studies[15]. This was considered adequate to keep the image bank at a practicable size to prevent observer fatigue. An earlier survey of trauma X-ray examinations in same centre indicated a 35% abnormality prevalence[5]; this was applied to the current study to produce an image bank with 20 positive cases. The caseload was not enriched with positive cases beyond those identified in a prior survey, reducing the risk of overestimating performance[16]. Participants were required to identify the precise anatomical location of a suspected abnormality; 10 cases contained bony pathology (rib, clavicle, or humerus fracture or dislocation) and 10 cases contained a pneumothorax. No clinical history was provided for the cases, but participants were informed that all positive cases presented following a traumatic incident and the diagnostic question consisted of "? Fracture/dislocation and/or ? Pneumothorax".

Scoring system

Participants responses were awarded a maximum of three points, based on abnormality recognition and descriptive accuracy; one point for correct physical localisation, one point for correctly describing what the abnormality is, and one point for correctly describing where it is. All image evaluations were completed on a 30" Barco Coronis Fusion 6MP MDCC-6530 LED colour monitor (Barco, Duluth, Georgia, USA). Localisation data were recorded with ROCView[17].

Participants were instructed to localise a pneumothorax by marking the image in a rib space avoiding bony anatomy (Image 1), and to localise a bony abnormality they were informed to accurately mark the bony anatomy. These points helped to determine whether participants have accurately localised the abnormality. Participants were advised to spend no more than two minutes appraising each image to closely replicate the time they would spend reviewing images in clinical practice. Participant localisations of pathology were used to determine scores in a 2x2 matrix (true positive, false positive, true negative, false negative), which allowed calculations of sensitivity, specificity, and accuracy. All participants completed a training dataset to ensure they would complete the task correctly. Participants typed their descriptive answers in to an electronic answer sheet and these were compared to a benchmark PCE prepared by a Consultant Radiographer and corroborated by an Advanced Practitioner Reporting Radiographer with 15 years' experience. The scoring system is defined in Table 1.

Score	0	0.5	1
Localisation	Incorrect, or no localisation(s)	Correct and incorrect localisation(s)	Correct localisation(s) only
PCE Score A	Incorrect type of abnormality	N/A	Correct type of abnormality
PCE Score B	Incorrectly describing location	N/A-	Correctly describing location

Table 1: The scoring system used to assess participants answers

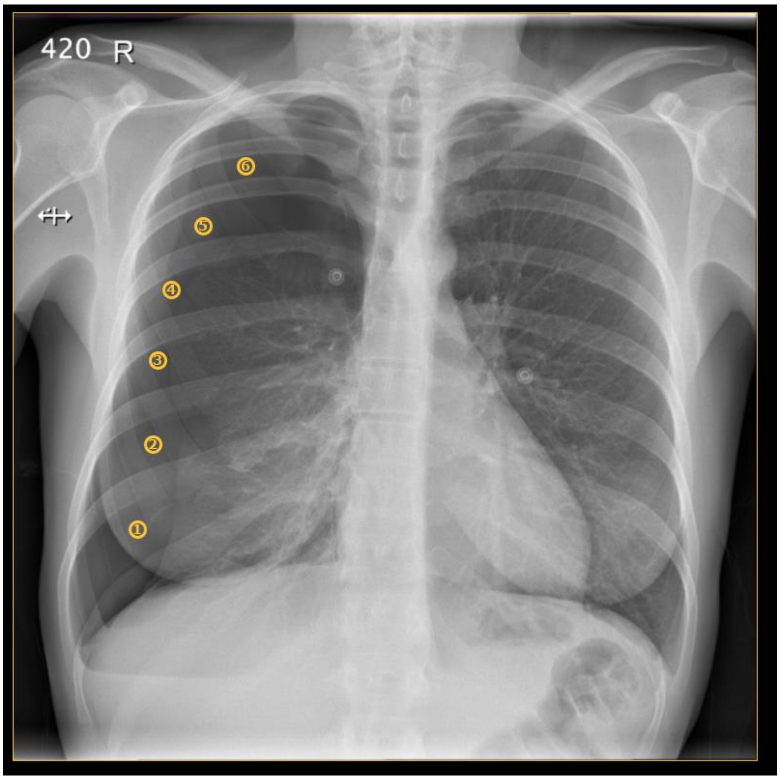


Image 1: Examples of how to mark a pneumothorax for analysis purposes. Participants only had to mark the image once.

Training intervention

Following their initial test, participants were provided with three pre-recorded online video tutorials lasting 30-45 minutes each, on consecutive weeks. The training sessions included an introduction to a systematic search strategy for recognising abnormalities in CXR examination, how to structure a PCE and practice cases to review at their own pace. The training was developed by a Consultant Radiographer. A minimum 6-week wash-out period between pre- and post-training tests was applied to reduce the potential of case memory.

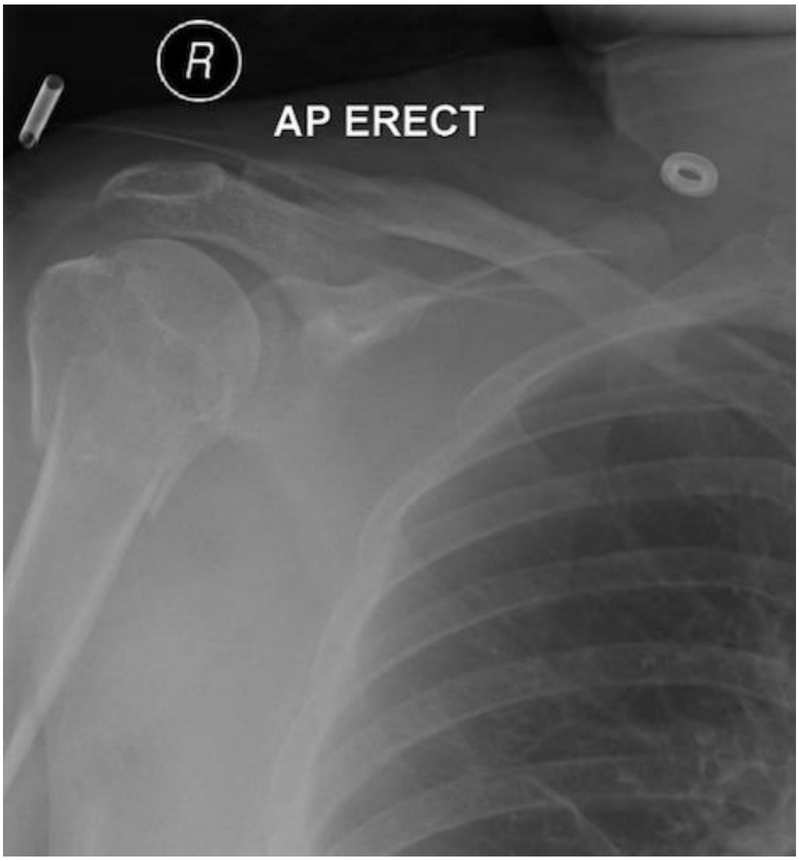
Results

Eleven participants were recruited but only nine completed the study. Two participants could not complete due to a combination of sickness absence and the data collection phase ending. Mean post registration experience was 4.1±5.2 years (range 1-17). The mean time between pre- and post-training evaluations was 84±14 days (range 59-104). Overall, pooled sensitivity remained consistent (78.9% to 78.8%) following training, whereas pooled specificity and accuracy showed moderate improvement, 79.0% to 89.9% and 78.9% to 86.0% respectively. Accuracy in localisation and PCE scores are also improved. Individually, n = 5 participants (55.5%) improved their sensitivity score on their post-training test, n = 6 (66.6%) improved their specificity, and n = 6 (66.6%) improved their accuracy. A summary of pooled and individual sensitivity, specificity and accuracy can be found in Table 2.

	User	A	B	C	D	E	F	G	H	I	Pooled
Pre	Sens. (%)	80.0	85.0	66.7	82.4	85.0	85.0	61.1	80.0	85.0	78.9
	Spec. (%)	68.4	84.2	82.5	51.2	81.6	100.0	75.0	78.9	89.5	79.0
	Acc. (%)	72.4	84.5	77.6	60.3	82.8	94.8	70.7	79.3	87.9	78.9
Post	Sens. (%)	65.0	75.0	88.9	65.0	65.0	90.0	85.7	85.0	90.0	78.8
	Spec. (%)	86.8	76.3	67.5	97.4	100.0	97.4	91.9	97.4	94.7	89.9
	Acc. (%)	79.3	75.9	74.1	86.2	87.9	94.8	89.7	93.1	93.1	86.0

Table 2: Pooled and individual sensitivity, specificity, and accuracy pre- and post-training intervention.

Most participants improved their mean score on the post-test (n = 6, 66.6%). Overall, participants performed better at correctly localising a pneumothorax compared to skeletal abnormalities, in the pre-test (78 vs 55) and the post-test (82 vs 56.5), respectively. There were 10 instances of 0.5 scoring for localisations in the pre-tests, whereby there was a correct localisation and an incorrect localisation, and one instance in the post-tests. The right ACJ dislocation had the greatest difference, + 6, in pooled post-test PCE scores compared to the pre-test. The right surgical neck/humeral head fracture had a negative difference, -5, in pooled post-test PCE scores compared to the pre-test. This case is illustrated in Image 2. A 33% drop was evident in the number of participants correctly describing what this abnormality was, and a 29% drop in the number of participants correctly describing where the abnormality was, in the post-tests. Further breakdown can be seen in tables 3 and 4.



Benchmark	Pre (score)	Post (score)	User
Right Surgical neck/humeral head fracture	Right neck of humerus fracture, no humeral head displacement from the Glenoid cavity (2)	no comment relevant to right humerus (0)	A
	Fracture of right humeral head (2)	no comment relevant to right humerus (0)	E

Image 2. Right surgical neck/humeral head fracture. This case had the greatest drop in pooled PCE scores from the pre-test to the post-test (-5). Examples of inconsistent performance contributing to reduction of PCE scores for the right surgical neck/humeral head fracture case are provided for 2 participants. For each participant they failed to localise the abnormality in the post-test and made no comment relevant to this anatomical area.

	Pooled Correct Localisations		
Examination groups (number of cases)	Pre	Post	TOTAL
Rib #s (3)	6.5	6.5	13
Clavicle # & ACJ (2)	6.5	9	15.5
Humeral head/neck/greater tuberosity #s (5)	42	41	83
Left pneumothorax (3)	23.5	26	49.5
Right pneumothorax (7)	54.5	56	110.5
Overall	**133**	**138.5**	**271.5**

Table 3. Pooled correct localisations for the pre- and post-tests categorised into examination groups. A more detailed table outlining individual performances for each positive case is presented in the supplemental material.

	Pre		Post		Total		
Abnormality Description	A	B	A	B	Pre	Post	Diff.
Right ACJ dislocation	1	1	4	4	2	8	6
Left Pneumothorax	7	5	8	8	12	16	4
Left 7th/8th rib #	4	3	6	4	7	10	3
Right Pneumothorax	4	4	5	6	8	11	3
Left Pneumothorax	8	7	9	9	15	18	3
Right 3rd rib #	2	0	2	3	2	5	3
Right surgical neck of humerus #	7	7	9	7	14	16	2
Right Pneumothorax	8	8	9	9	16	18	2
Right Pneumothorax	8	8	9	9	16	18	2
Left surgical neck of humerus #	9	5	9	7	14	16	2
Left distal clavicle #	4	5	5	5	9	10	1
Right Pneumothorax	9	8	9	9	17	18	1
Right Pneumothorax	9	8	9	9	17	18	1
Right Pneumothorax	9	8	9	9	17	18	1
Left Pneumothorax	9	8	9	9	17	18	1
Left surgical neck of humerus #	8	5	7	7	13	14	1
Right Pneumothorax	8	7	7	7	15	14	-1
Left 9th rib #	1	1	0	0	2	0	-2
Left humeral head/greater tuberosity #	9	4	6	4	13	10	-3
Right Surgical neck/humeral head #	9	7	6	5	16	11	-5
	133	**109**	**137**	**130**	**242**	**267**	**25**

Key - A = What (abnormality type); B = Where (anatomical location)

Table 4. Participants' Pooled PCE Scores

Discussion

This study suggests that radiographers can contribute to the identification of traumatic CXR findings and there may be some benefit of short and intensive recorded video tutorials to help radiographers develop skills in recognising and describing fractures and pneumothoraces on chest X-ray images. More than half of the participants showed improvement in sensitivity, specificity and/or accuracy scores, and their overall PCE.

Incorrect localisations were far less prevalent following training. This could be a result of the tutorial videos reinforcing the premise of the PCE to focus on the traumatic abnormality rather than being concerned about other appearances, such as heart size or consolidation. The greatest positive difference in PCE scores from the pre- to post-test was seen in the right ACJ dislocation (+6). This may illustrate the benefit of the training in reiterating the importance of comment structure and terminology. The decrease in PCE scores for the right surgical neck/humeral head fracture (-5) indicates a lack of consistency when using anatomical terminology and perception errors as outlined in the examples provided.

Participants performed better at recognising and describing pneumothoraces than the bony abnormalities. British Thoracic Society guidelines[18] state that the depth of a pneumothorax should be determined by the interpleural distance measured at the level of the hilum; small is classed as less than 2cm and large is greater than 2cm. The guidelines in America differ slightly in that depth is determined by the lung apex to cupola distance[19]. Interestingly, in this study the pneumothorax cases (n = 3) that had the fewest correct localisations by participants in both tests were those that are classified as small using the British guidelines, and the case with the fewest correct localisations (pre-test, 4 out of 9 and post-test 5 out of 9) had a 1.61cm apex to cupola distance. This suggests that whilst radiographers in this sample can accurately locate large pneumothoraces, there may be need for further training and education to improve detection of apical pneumothoraces, specifically if the pneumothorax is small in volume. The presentation of a pneumothorax can vary from asymptomatic to life-threatening[20], and small pneumothoraces typically resolve with no treatment and only monitoring[21] but this does not detract from the importance of identifying a pneumothorax at the earliest opportunity. The impact of missing a pneumothorax can lead to failure to treat and can have wide-ranging outcomes for the patient[22].

Our results also suggest that bony abnormalities overlying the thorax such as the right 3rd rib fracture, or those that are more subtle like the left 9th rib fracture at the inferior margin of the image, may be more challenging for radiographers to recognise and subsequently would require additional attention with regards to further training sessions. A possible reason for this could be attributed to inattentional blindness[23] whereby observers were over-focussed on the task of looking at the lungs or the large humeral bones that they simply did not see the superimposed or subtler abnormalities. The cases with fractures of the ribs (n = 3) and distal clavicle (n = 1) and acromioclavicular joint dislocation (n = 1) returned the fewest correct localisations amongst the bony abnormalities, whereas those cases with fractures involving the head and surgical neck of humerus (n = 5) returned the most correct localisations. This suggests that further focused training may be required to reinforce observers' search patterns and to reiterate the importance of reviewing these areas when assessing the image.

Whilst our results suggest benefits of focussed training for recognising and describing abnormalities, it is accepted that radiographers may already be providing PCE comments for CXR in some institutions. However, chest examinations account for the biggest proportion of non-participation in a PCE system, accounting for 53% of all instances[12]. Interestingly, the study by Alexander-Bates et al[6] also indicated that that traumatic chest examinations had the highest percentage of participants who were unsure or never provided a comment for a CXR examination, possibly due to reduced confidence, knowledge and/or understanding. Additionally, for those who did provide a comment on the CXR examinations, the overall sensitivity and specificity scores were 71% and 99%, respectively, showing excellent ability to recognise normal appearances but with room for improvement regarding describing CXR abnormalities. The study by Alexander-Bates et al (6) used a correct comment as the determinant of accuracy, whereas our study used a correct localisation; however, the sensitivity and specificity scores in our study, of 79% and 90%, respectively, were comparable. This suggests that there might be a need for additional training in CXR abnormality detection for radiographers participating in a PCE system, in which CXR examinations are within the scope of practice.

Previous PCE studies[2,24] using pre and post training image interpretation tests reported increases in both sensitivity, specificity, and accuracy, respectively, which contrasts with the findings in this study in which only specificity and accuracy increased. The study by Stevens & Thompson[2] utilised face-to-face teaching with 56 days between the pre- and post-tests. Williams et al[24] used the same method of delivery of teaching via recorded PowerPoint presentations as our study, with the addition of online content and textbook teaching, and had 112 days between tests, which is greater than the time frame in our study. It is possible that if there was additional supplementary teaching content in our study, to compliment the recorded PowerPoint tutorials, this could have helped to increase the sensitivity from pre- to post-test and provides an interesting consideration for future studies.

Limitations

A small sample size may limit the generalisability of these findings, but they do provide insight into the challenges of implementing a PCE system that incorporates CXR. The mean number of days between tests was longer than originally planned, this was caused by several participants and an author contracting COVID-19, and consequently most post-test dates had to be rescheduled. Due to the extended washout period, it is possible that those participants who had the longest break between the first test and viewing the training material, and the second test may not have retained the knowledge gained, and how this may have impacted on participants' performance and overall findings needs to be acknowledged. The use of pre-recorded tutorials prevented participants from having opportunity to immediately interact to seek clarification as would be the case with face-to-face teaching, and the impact of this should be considered alongside the results. This may also suggest that short, focussed training is not as effective as continued improvement in knowledge over time. However, experiential knowledge, by nature, is very difficult to measure.

It is also accepted that the direct nature of the task, where the participants knew that they were looking to establish no pathology, or either a fracture or pneumothorax may have influenced performance. In addition, co-existing pathology was not considered. However, this type of experimental control is valuable when assessing performance.

Conclusion

Radiographers can contribute to the identification of traumatic CXR findings sufficiently. Improvement in performance was evident in most participants' abnormality localisations and PCE scores, following the training intervention. The pooled results showed increases in specificity and accuracy. The study highlighted areas of CXR PCE provision that require further training, such as detecting superimposed or subtle abnormalities. Further investigation assessing the localisation and description of non-traumatic CXR pathologies is recommended to supplement the results presented here. This study provides additional support to the growing PCE knowledge base, and it is hoped these findings can support the development of future PCE systems.

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3.9. Paper 9

Radiographer abnormality flagging systems in the UK - A preliminary updated assessment of practice.

Harcus JW, Stevens BJ. Radiography (2023). Volume 29, Issue 1 :234-239.
https://doi.org/10.1016/j.radi.2022.11.014

Introduction

The Society and College of Radiographers (SCoR)[1,2] has, for some time, envisaged that a preliminary clinical or image evaluation (PCE/PIE) abnormality flagging system, otherwise known as the 'comment', should replace the red dot flagging system within radiology and emergency departments (ED). The difference between the two systems is that the PCE system permits the radiographer to immediately provide a brief comment describing any abnormality that may be present, rather than just highlighting there may be an abnormality present and thus reducing the ambiguity and lack of specificity which may be seen with red dot[3-5] prior to a formal clinical report.

The SCoR[2] has also considered commenting to be within the scope of practice of graduate radiographers and outlined expectations on higher education institutions (HEIs) to ensure graduates have the necessary skills to undertake commenting post-qualification which can then be developed further. Whilst it has been embedded in the pre-registration curriculum since at least 2009,[6] it is uncertain to what extend those commenting skills are then being utilised in practice.

Despite this vision being around since at least 2006, the fact commenting is now heavily integrated into undergraduate radiographer education[6], and that PCE is the subject of numerous research studies,[3-5,7-12] both in the UK and Australia (where interest is rapidly growing); the use of PCE still appears somewhat regional and not universally employed in the UK. A national audit in 2007[4] identified only 2.5% of Trusts used PCE as the preferred method of image review by radiographers. Additionally, neither the SCoR[2] or Health and Care Professions Council (HCPC)[13] have updated their guidance on expectations of the graduate radiographer's role in terms of image interpretation since 2013.

This evaluation project aimed to provide an updated perspective on the previous study undertaken by Snaith and Hardy in 2008[4] and provide a contemporary overview of the use of PCE within NHS radiology and minor injury departments in the UK. Whilst the concept of PCE is over 15 years old, its implementation into wider practice in the UK and internationally appears limited. It is envisaged that by providing further insight into the use of the PCE in the UK, it will help to understand the breadth of the scheme since this has not been widely investigated in the literature since 2008[4].

Methods

Ethical approval was granted by XXXXXXX Research and Ethics Committee on 28th October 2021 (ref. MREC 21-006)

A cross-sectional online survey was utilised based upon the previous study by Snaith and Hardy in 2008.[4] The template of this survey was kindly provided by the previous authors who were also invited to take part in the study. The previous study was done in paper form by post, however, due to implications of the COVID-19 pandemic, financial cost, and the further advent of technology in the last 15 years, it was decided to undertake the survey using the Jisc Online surveys© platform. In common with the previous survey[4] the questionnaire consisted of a combination of multiple choice and open-ended free text responses requesting factual, and not opinion-based information on the flagging and reporting services within the Trust. Questions were focused on areas including the types of flagging and reporting systems operated, scope of the systems employed, required education of participants, and the role of audit.

The previous survey[4] was targeted directly to all hospitals in the UK with and ED or minor injury service, a list of which was accessed via the British Association of Emergency Medicine (BAEM) online directory which is no longer accessible. According to the Kings Fund, in 2019, there were 223 NHS Trusts in the UK, though it was not possible to identify all ED and minor injury units in the UK. Therefore, considering the developing role of social media in health research,[14,15] the online survey was posted via Twitter for a six-week period between January and February 2022.

The survey was designed to obtain an overview of flagging systems within NHS Trusts so was aimed towards radiology service managers, superintendent radiographers, or other staff overseeing reporting services within Trusts offering ED and minor injury services. To avoid duplication and try and ensure responses from appropriate persons only NHS Trust and job role, under pre-determined criteria, were requested in the survey. Otherwise, no identifiable, and no personal data, was requested. Implied consent was obtained through the inclusion of a detailed participant information sheet prior to commencing the study. Participants were able to withdraw from the study up to two weeks from the closure date, after which time hospital/Trust data was removed. Only the authors had access to responses. Descriptive statistical analysis was performed using Microsoft Excel.

Results

The study returned 31 responses, 30 from England and 1 from Scotland. Most responses were from those who manage radiographer abnormality systems within the department e.g., consultant radiographer (n = 17, 54.8%), followed by superintendent radiographer (n = 8, 25.8%), then department manager (n = 3, 9.7%) and radiology services manager (n = 3, 9.7%).

Service Provision

All sites have a 24-hour Emergency Department (ED). Only 2 sites (6.5%) operate a 24 hours "hot" reporting service, 16 sites (51.6%) offer a restricted hours service and 13 sites (41.9%) do not have a "hot" reporting service. Most Trusts (n = 28/31, 90%) operate a Red Dot system, eight Trusts (26%) operate a PCE flagging system, with five these Trusts (16%) having a hybrid of both systems and only one Trust (3%) does not operate any type of abnormality flagging system. The PCE system is only in use at Trusts that have no hot reporting service (n = 4/8, 50%) or a restricted hours hot reporting service (n = 4/8, 50%) (Table 1).

	PCE System		**Red Dot System**	
"hot" reporting service availability	**No**	**Yes**	**No**	**Yes**
No	9	4	2	11
Yes - restricted hours	12	4	1	15
Yes - 24 hours	2	0	0	2
Total	**23**	**8**	**3**	**28**

Table 1. Abnormality flagging system usage relative to hot report service availability.

Scope of Practice

A wide range of anatomical areas were indicated as being included in both systems following the same trend, most commonly appendicular and axial skeleton, then chest and abdomen being least common (Chart 1; Within charts 1, 2 and 5, N/A indicates such practices are not employed/applicable at the site). Radiographers only indicate normal appearances at one site (3%) using the red dot system and three sites (10%) using the PCE system (Chart 2).

The commonest chest abnormalities flagged using the red dot system were traumatic abnormalities, such as pneumothorax (n = 12/28, 43%) and fractures (n = 6/28, 21%). Those using the PCE system had a wider remit with three sites being permitted to comment on anything abnormal (n = 3/8, 38%), describing pneumothoraces was next most common (n = 2/8, 25%) (Chart 3).

The commonest abdominal abnormalities flagged using the red dot system was anything abnormal (n = 4/28, 14%) followed by foreign body (n = 3/28, 11%). Both these abnormalities were seen with equal frequency with those using the PCE system (n = 1/8, 12.5%) (Chart 4).

Chart 1. Which anatomical areas are included in your abnormality flagging system?

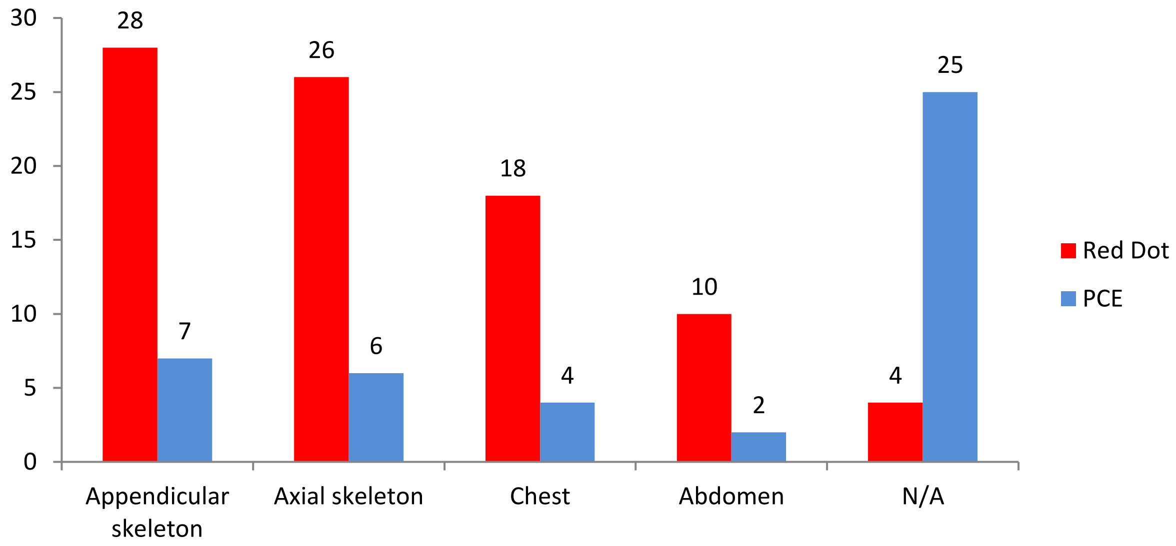


Chart 2. In relation to your abnormality flagging system(s), which context do radiographers identify images

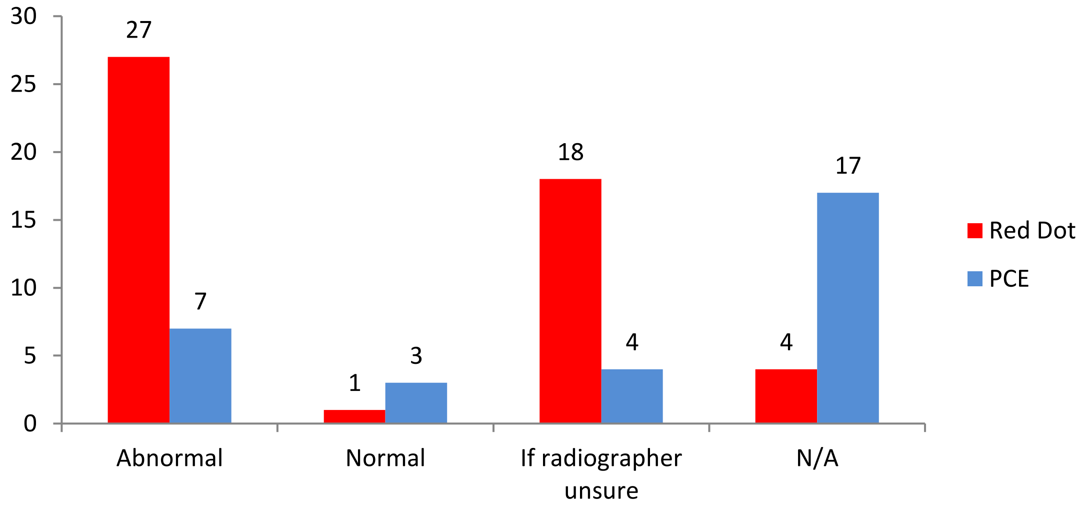


Chart 3. Chest abnormalities that are flagged in each system

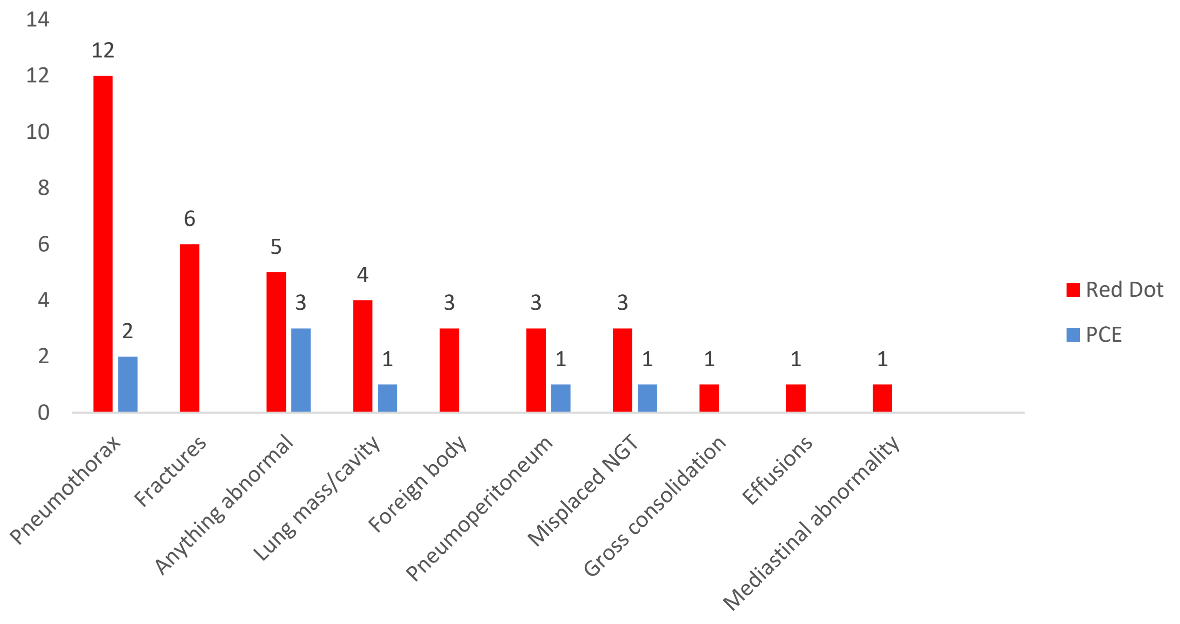
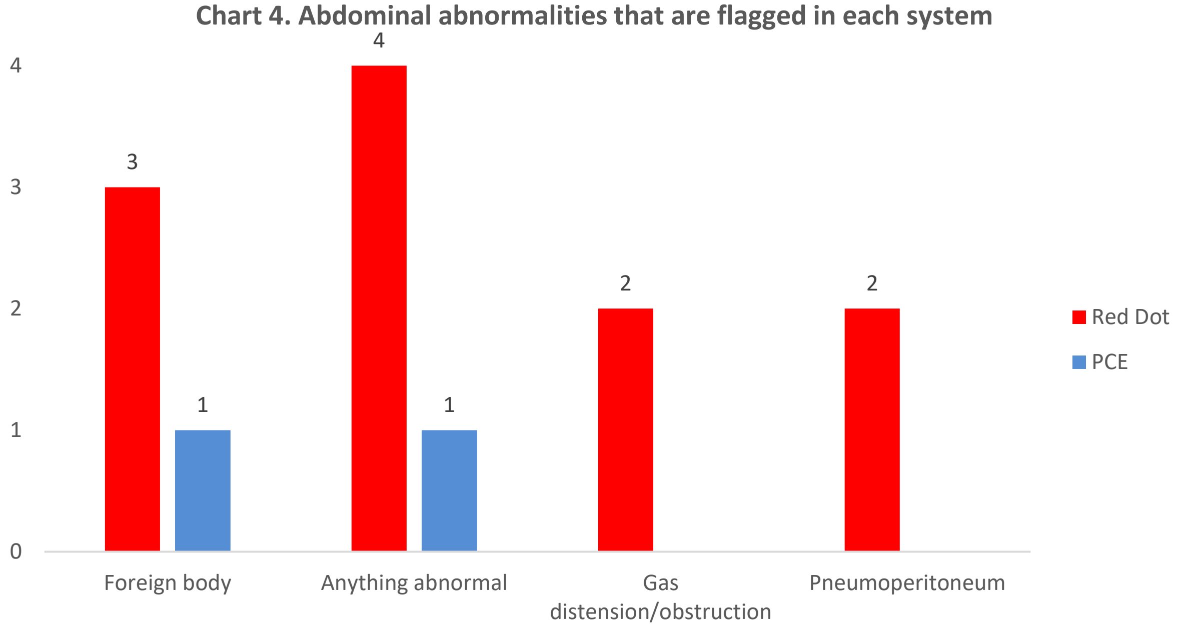


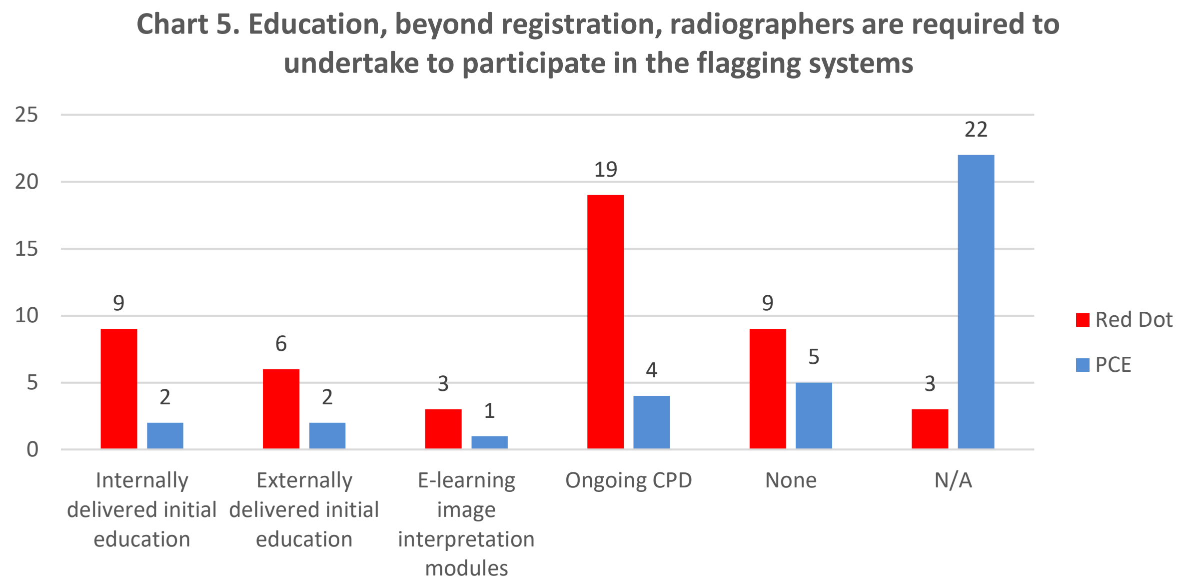
Chart 4. Abdominal abnormalities that are flagged in each system



<u>Education</u>

Only two sites (6%) reported that they require a minimum period of clinical experience before participation is permitted in the red dot system. None of the sites that have a PCE system require a minimum period of clinical experience.

Beyond registration, radiographers are required to maintain ongoing CPD education at 19 (68%) sites for red dot systems and four (50%) sites for PCE. No ongoing education was required at nine (32%) sites for red dot and five (63%) sites for PCE. Further breakdown is shown in chart 5.



Mandatory/Voluntary

Mandatory participation was only required at eight sites (29%) with red dot systems and only two of these sites (25%) undertake audits of practice. Mandatory participation was only required at two sites (25%) with PCE systems and only one of these undertakes an audit of practice. Three of the six sites (50%) where participation was voluntary also undertook audit of practice.

Audit of Practice

Participants were asked if they had a regular audit process for assessing accuracy. Only eight sites (29%) with red dot systems, and four sites (50%) with PCE systems indicated that they undertake regular audits of practice.

The free text comments section regarding audit design and regularity provides insight into the diverse methods departments use to assess radiographers' participation. When asked about their audit process participants indicated that the reporting radiographers play a central role in undertaking the audits and assessing radiographers' comments and providing feedback.

"Not formally but reporting radiographers feedback to individuals"

"… to be completed by the MSK and chest reporting radiographer team"

The comments also highlighted that the interval at which audits are undertaken are seen with wide variance;

"Monthly" "Every 2 months" "Quarterly clinical audit" "Ongoing audit" "Annually"

Discussion

The aim of this survey was to provide an updated overview of the use of radiographer abnormality flagging systems in the UK, however, given the relatively low number of responses these results only provide an insight into practice in comparison to the survey in 2008[4].

The current study only received responses from hospitals, rather than minor injury units, and all offered a 24-hour ED service, however only a small proportion operate a 24 hour "hot" reporting service (6.5%, n=2) and 51.6% (n=16) a restricted service. With the remaining 41.9% (n=13) not offering a "hot" reporting service at all, this appears to indicate that radiographer abnormality flagging systems do have valid role with ED departments to assist clinicians.

97% (n=30) of respondents, compared to 92.8% in 2007, operate some form of flagging system and 27% (n=8) operated a PCE system (or hybrid) in comparison to 21.5% in 2007[4]. Those sites who only operate PCEs has increased also from 2.5% to 9.7% (n=3). Since the previous study, the SCoR published guidance on clinical reporting and PCE which provided clearer guidance and expectations on the role of PCE[2] and it certainly appears that the use of PCE has grown in use in the past 15 years. Despite this guidance and the SCoR's vision for PCE to replace red dot, many HEIs including PCE as part of their curriculum[6,16] and the growing body of evidence[3-5,7-12] on PCE, 90% of sites still operate a red dot system (or hybrid approach) so this is still by far the most popular form of flagging, though this is less than the 96.8% in 2007 so there has been a change in emphasis.

The scope of practice undertaken by such systems was not evaluated by Hardy and Snaith,[4] however, our study identifies that for both red dot and PIE, evaluation of skeletal trauma is more common than the chest and abdomen X-ray. Historically red dot and clinical reporting systems were predominantly based around skeletal trauma, with evaluation of the chest X-ray and other modalities being relatively more recent developments. This is reflected in the education at pre-registration level being aimed more clearly at skeletal trauma than other areas.[16,17] Confidence in being able to undertake PCE has previously been demonstrated to be a barrier to implementation of such practices.[5] The complexity of chest X-ray interpretation, in comparison to skeletal trauma, may be contributory to the relative lack of participation.

It is interesting to note that only 13% (n=4) of sites directly indicate whether the image is normal, but a much larger proportion (71%, n=22) identify if the radiographer is uncertain of findings. One of the noted limitations of the red dot systems was the ambiguity of the system if an abnormality was not flagged[3-5] and the PCE was designed to help reduce this, however, only 3 of the 8 respondents (37.5%) indicate where the radiographer is unsure. Another barrier to implementation of PCE has been perceived to be a fear of getting it wrong[5] so it might be suggested as a requisite of such systems that to both help support radiographers' confidence but also to aid clinicians that the opportunity to provide and 'uncertain' response be included. Only 1 site out of 28 (3.4%) using the red dot system would indicate that the image is normal so implying yet again a large proportion (64.2%, n=18) did indicate uncertainty by the radiographer, which might be seen as being more preferable than not red dotting an image if they were uncertain.

As noted, abnormality flagging systems have primarily been utilised within the trauma and emergency setting and within the context of the chest X-ray, indication of a pneumothorax is most common pathology identified using the red dot. However, it is interesting to note that, although in small numbers, the use of the PCE most commonly considers any abnormality demonstrated and is not restricted to trauma alone. Defining scope of practice within any aspect of health is of utmost importance to allow health professionals to be able to work safely and effectively. For tasks such as image interpretation, either flagging systems or clinical reporting, a clearly defined scope of practice and scheme of work outlining the activity is essential for both the referring clinician and individual undertaking the task, therefore, it must be made clear what aspects are and are not covered by the flagging system.[1,2]

Related to scope of practice is the education required by participants to undertake RDS within departments. Image interpretation training is now heavily incorporated within pre-registration programmes, however, there is marked variation in the breadth and level of education, nor is the writing of PCE education universal.[16] Only 3 of 8 (37.5%) of sites offering PCE offered some additional training, and 32.1% (n=9) of sites offered initial education for red dot systems. Hardy and Snaith[4] found 90% provided initial education compared to a combined 53% (16/30) in the current study which suggests there is perhaps more reliance on pre-registration education currently. Given the lack of specificity in the requirements of image interpretation pre-registration education by professional and statutory regulatory bodies (PSRBs),[1,2,13,16] and the extensive evidence base supporting the role of initial and on-going education[8,12,17] in improving confidence and accuracy, it may be considered highly desirable that some form of initial and on-going learning be a requisite of flagging systems.

The HCPC standards of proficiency[13] do indicate that diagnostic radiographers in the UK need to be able to differentiate normal and abnormal appearances, and be able to communicate them appropriately, yet there is no specific requirement to participate in RDS, despite the vision of the SCoR.[1,2] Mandatory participation was demonstrated in 30% (n=9) of the sites, in comparison to 26.1% in 2007[4] which suggests there is minimal change in participation in the interim period. Despite the increased evidence base to support such practices, it appears some of the barriers to participation remain. [5,7]

Similar minimal change compared to the previous study is the role of audit in the governance of such systems. In 2007 there were 31.3% of sites who had some form of audit process of RDS systems, the current study indicates this is 40% (n=12) overall, and 29% and 50% for red dot and PCE respectively. Whilst other sites indicated there were informal mechanisms for feedback, it is apparent that in many instances practices are not being supported by mechanisms for quality assurance or to provide support to participants which might be considered essential as part of any effective clinical governance scheme.[18]

<u>Limitations</u>

The aim of this study was to provide an updated overview of practices from Snaith and Hardy's 2008 survey.[4] Unfortunately, the low response rate and small sample size means any significant conclusions cannot be drawn and this study must be viewed as only indicative of any changes in practice in the interim. It is recognised that the recruitment strategy likely played a role in the small response rate. In addition, it may be considered that participants may represent departments who may be more proactive in the implementation and management of RDS systems and therefore potentially introducing bias into the results. The authors, therefore, identify that this current study is only a preliminary updated assessment on practice, one which needs to be undertaken on a much larger scale to provide a true reflection on current practice.

Additionally the term "hot reporting," defined by the Care Quality Commission[19] as a report returned within an hour, was not defined in the questionnaire. This ambiguity may have led to participants not being able to respond appropriately to this part of the questionnaire.

Conclusion

Within the confines of the study it might be considered that despite the vision of the SCoR there appears to be quite minimal change in RDS practices in the UK. There does appear to be some increase in the use of RDS generally, a higher proportion of PCE systems in comparison to red dot, and a growing scope of practice outside of skeletal trauma but, in contrast, many practices such as the use of education, audit, and mandatory participation do not necessarily show much development in the past 15 years. Despite the growing evidence base, the guidance offered governing the application of PCE is quite ambiguous and has not been update for over a decade. Whilst a wider scale study is required, the results of this preliminary study indicate the vision of the SCoR for the PCE to be considered standard practice for radiographers remains a long way off.

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This section provided full text versions of the papers submitted as part of this thesis. The following section outlines the intellectual ownership and contribution to each of the papers of the author and co-authors.

4. Intellectual ownership and contribution

This section describes how the completion of the submitted papers by the author meets criteria set out in the CoR Research Strategy (College of Radiographers, 2021) and the multi-professional framework for higher level practice (Health Education England, 2017b). The types of intellectual ownership and percentage of contribution of each co-author for each paper are presented in table format with accompanying written agreements.

The initial concept and design for all articles were led by the author, apart from papers 6 and 9 which were co-conceived during a networking event with the named co-author. In papers 1, 3 and 8, the co-author helped and provided guidance on the design element of these studies due to their widely published expertise in nature of the investigation, as well as the other remaining elements as outlined. In paper 5, the co-authors were invited to help with the data analysis, drafting, revision and final approval of this study. Both co-authors were work colleagues, an advanced practitioner and a consultant practitioner, both of whom had never been involved in any empirical research at this point. This was an attempt to introduce and develop research interest amongst departmental colleagues to foster the culture of valuing research aligning with aim 1 of the recent CoR Research Strategy (College of Radiographers, 2021), which is to embed research at all levels of radiography practice and education. The aim of the collaboration fits with aim 1.1,

> "*Develop a radiography workforce that engages critically with research to ensure that care provided to service users is based on the best available evidence.*"

As well as recommendations 1.1.3 and 1.1.5 of the strategy, as outlined below, respectively.

> "*All four levels of practice - assistant, practitioner, advanced and consultant – must include the domain of research, as noted in the Education and Career Framework and the multi-professional frameworks for higher levels of practice.*"
>
> "*Engagement in evidence-based practice and research activities to be evaluated at annual staff appraisals*."

The multi-professional framework for higher level practice outlines research as one of the four pillars underpinning advanced clinical practice (Health Education England, 2017b). The collaboration for paper 5 allowed all authors to develop their skills and knowledge in the research domain, relative to aim 4.1 of the multi-professional framework below.

> "*Critically engage in research activity, adhering to good research practice guidance, so that evidence-based strategies are developed and applied to enhance quality, safety, productivity and value for money*."

The types of intellectual ownership and percentage of contribution of each co-author for each paper (1 to 9) is illustrated in table 1, using amended criteria from the recommendations made by the International Committee of Medical Journal Editors (ICMJE) (ICMJE, 2022).

The type of contribution is summarised as,

a) Concept and Design
b) Data Collection
c) Data Analysis
d) Drafting and Revision
e) Final Approval

Table 1. Percentage and type contribution of all authors of the included works.

Authors	I	II	III	IV	V	VI	VII	VIII	IX
BS	**70** **abcde**	**100** **abcde**	**70** **abcde**	**100** **abcde**	**70** **abcde**	**50** **abcde**	**100** **abcde**	**70** **abcde**	**40** **abcde**
JDT	30 abcde		30 abcde					30 abcde	
LS					20 cde				
JD					10 cde				
JWH						50 abcde			60 abcde

Confirmatory statements of co-authors' contributions are provided on the following pages.

I, **John Thompson (JD)**, confirm I was a co-author on the published articles referenced below and Iagree with the level of my contribution as is illustrated.

I. The impact of focused training on abnormality detection and provision of accurate PCE in newly qualified radiographers. *Stevens BJ & Thompson JD (2017), Radiography, February, Volume 24, Issue 1, 47 - 51.* [*http://dx.doi.org/10.1016/j.radi.2017.08.007*](http://dx.doi.org/10.1016/j.radi.2017.08.007)

Author	Type and Percentage ofcontribution
BS	70 abcde
JD	30 abcde

Signed  Date: 09/10/2022

III. The value of preliminary clinical evaluation for decision making in injuries of the hand and wrist. *Stevens BJ & Thompson JD (2019), International Emergency Nursing, Volume 48, January 2020, 100775.* [*https://doi.org/10.1016/j.ienj.2019.05.001*](https://doi.org/10.1016/j.ienj.2019.05.001)

Author	Type and Percentage of contribution
BS	70 abcde
JD	30 abcde

Signed  Date: 09/10/2022

VIII. The efficacy of preliminary clinical evaluation for emergency department chest radiographs with trauma presentations in prep and post-training situations. *Stevens BJ &Thompson JD (2022). Radiography Volume 28, Issue 4, November 2022, 1122-1126.* https://doi.org/10.1016/j.radi.2022.08.011

Author	Type and Percentage of contribution
BS	70 abcde
JD	30 abcde

Signed  Date: 09/10/2022

I, **Laurence Skermer (LS)**, confirm I was a co-author on the published article referenced below and I agree with the level of my contribution as illustrated below.

V. Radiographers reporting chest X-ray images: Identifying the service enablers and challenges in England, UK. *Stevens BJ, Skermer L & Davies J. (2021), Radiography, Volume 27, Issue 4, 1006-1013.* *https://doi.org/10.1016/j.radi.2021.03.006*

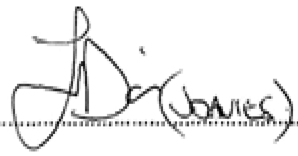
Author	Type and Percentage of contribution
BS	70 abcde
LS	20 cde

Signed .... Date 5/10/22 ....

I, **Joanne Davies (JD)**, confirm I was a co-author on the published article referenced below and I agree with the level of my contribution as illustrated below.

V. Radiographers reporting chest X-ray images: Identifying the service enablers and challenges in England, UK. *Stevens BJ, Skermer L & Davies J. (2021), Radiography, Volume 27, Issue 4, 1006-1013.* *https://doi.org/10.1016/j.radi.2021.03.006*

Author	Type and Percentage of contribution
BS	70 abcde
JD	10 cde

Signed  Date 28/9/22

I, **James Harcus (JH)**, confirm I was a co-author on the published articles referenced below and I agree with the level of my contribution as illustrated below.

VI. What information is required in a preliminary clinical evaluation? A service evaluation. *Harcus JW & BJ Stevens (2021). Radiography, Volume 27, Issue 4, 1033-1037.* *https://doi.org/10.1016/j.radi.2021.04.001*

Author	Type and Percentage of contribution
BS	50 abcde
JH	50 abcde

Signed………  ………………………Date…6/10/2022………………………………………….

IX. Radiographer abnormality flagging systems in the UK - A preliminary updated assessment of practice.

Harcus JW, Stevens BJ. Radiography (2023). Volume 29, Issue 1 :234-239. https://doi:10.1016/j.radi.2022.11.014

Author	Type and Percentage of contribution
BS	40 abcde
JH	60 abcde

Signed……  ………………………………Date………15/2/2023…………………………………….

This section demonstrated the intellectual ownership and contributions of all co-authors and illustrated how the author meets criteria set out in the CoR Research Strategy (College of Radiographers, 2021) and the multi-professional framework for higher level practice (Health Education England, 2017b). The next section will review the methods used throughout the submitted works.

5. Review of methods

This section will critically analyse the methods used in the submitted works and will provide justification for their use and suitability for the aims of the studies. The following methods will be appraised, the free-response operator characteristic (FROC) method covering localisations and descriptive evaluations for the observer-based studies, and the cross-sectional survey approach.

5.1 Observer studies

5.1.1. Background of Receiver Operator Characteristic (ROC) method

The Receiver Operator Characteristic (ROC) method provides a statistical measure that assesses the performance of classification systems in determining the presence of pathology. Traditionally, the ROC method is used to compare the diagnostic performance of two different tests or technologies by providing a combined assessment of system and observer performance. ROC methodology is useful for assessing observers' confidence that an image contains a pathology or not (Hillis et al., 2017), such as the presence of diffuse disease similar to pneumonia on a CXR. Considering the nature of the ROC method, the true positive (TP) and false positive (FP) cases are essential components in determining observers' performance and they are plotted against each other to create an ROC curve. The ROC curve provides a graphical representation of performance representing a combined measure of sensitivity and specificity over a range of different thresholds (Hajian-Tilaki, 2013). The area under the ROC curve (AUC) can be used as a single figure of merit (FOM) to describe overall system performance and can be used to perform a statistical comparison to an alternative test or modality. However, the ROC method does not account for location data and is recognised as having limited value and effectiveness in observer tasks that require precise localisation (Thompson et al., 2014), which makes it not suitable for all tasks and this is recognised as a limiting factor.

5.1.2. Limitations of Receiver Operator Characteristic (ROC) method

The absence of location data is a major limitation of the ROC method and is the reason that ROC would not have been suitable for fulfilling the aims of papers 1, 3 and 8. These studies required participants to provide precise localisations on the positive cases. However, the exclusion of location data and the inability to detect small differences between observers (Chakraborty, 2010) along with other associated issues that can arise, such as interpretive variability amongst observers, case variation, varying acquisition technical factors and processing software (Joy et al., 2005), meant that ROC was not considered to be useful. A key issue of ROC, as recognised by Chakraborty, (2010), is that the binary nature of ROC prevents differentiation of multiple suspicious regions and/or multiple lesions, and in order to understand the interpretive issues that may be present amongst observers it was paramount that all areas of the image could be scrutinised and localised by the observers, as necessary. The pertinent issue that manifests with the ROC method is when a location-level FP and a location-level false negative (FN) mistake occur on the same interpretation, and effectively “cancel” each other out to create a “perfect” image-level TP (Chakraborty, 2013). A clinical example put forward by Thompson et al., (2014) illustrates how the exclusion of location information can provide a false representation of interpretive performance. A CXR containing a single lesion (Image 1) incorrectly interpreted by an observer who identifies a lesion mimic (FP) in a different anatomical location as a positive finding would still return a TP result and therefore the interpretive ability of the observer would be falsely represented. It would be unclear what the observer had deemed to be abnormal, and this is also the concern with the red dot abnormality detection system. Red dot notifications are ambiguous with no direction regarding the perceived abnormality and may lead to mismanagement of fractures and/or dislocations.

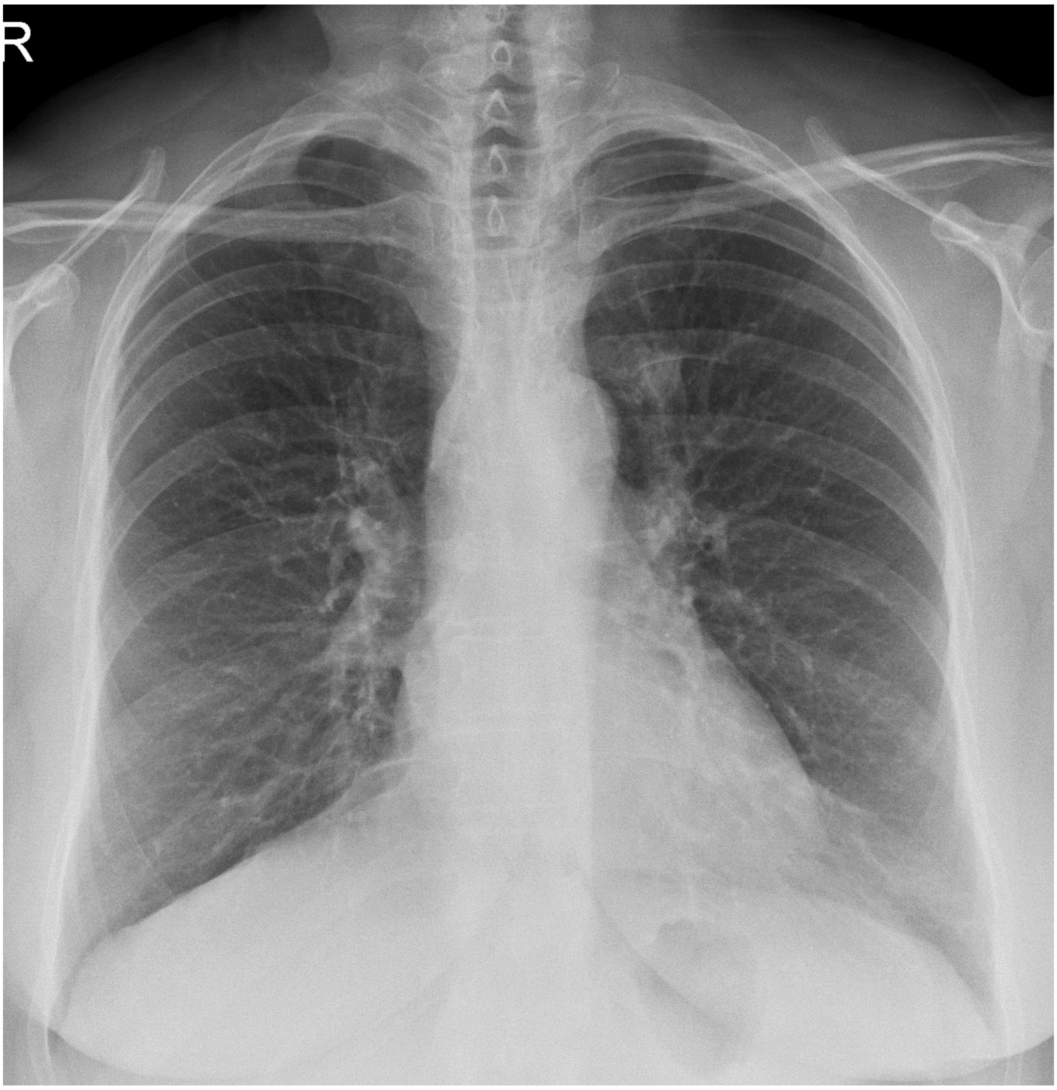


Figure 2. In the traditional ROC method, an observer may interpret the left pericardial fat as hazy consolidation (FP) and may miss the small left supra-hilar mass (FN), but this interpretation would be recorded as a true positive (TP) score.

Metz, (2008) recognised that not all image interpretation tasks fit with the normal and abnormal classification but are often more complicated than this. Consequently, the ROC methodology has been further developed to fit image interpretation tasks that are not confined to two-class classifications, where more than a single rating is required for certainty of the decision making (successful interpretation, or not). In addition to this, considering the aims of papers 1, 3, and 8, a location sensitive method of assessment is a good match for the task that is performed when providing a PCE and assessing localisation accuracy. The free-response receiver operator characteristic (FROC) method provides a more realistic and detailed evaluation of an individual's diagnostic abilities and was well suited for papers 1 and

8 in which the aims were to assess observers' ability to localise fractures or dislocations that are often positioned in a relatively small area of the radiograph. It was essential, in the context of papers 1 and 8, that the area of the radiograph of which observers perceived to be abnormal could be clearly identified.

5.1.3. Development of Free Response Operator Characteristic (FROC) method

The FROC paradigm was first applied to a clinical problem in the seminal paper by Bunch et al., (1977), a lesion localisation task comparing a conventional analogue chest imaging device with a prototype digital imaging device (Chakraborty, 2013). The FROC method can be used to assess observer performance when interpreting medical images. Current use consists of observers identifying all suspicious areas of an image and providing a rating for how likely they think the area is to be abnormal. This is often facilitated by software that allows an observer to localise suspicious areas using mouse clicks and provide a confidence rating to each localisation. This level of precision means that it is very unlikely that an observer could be incorrectly rewarded for identifying something that was mimicking disease in a medical image (false positive). Additionally, the FROC method provides a higher statistical power than ROC (Chakraborty, 2010), which given the small sample sizes in papers 1, 3 and 8, was another key factor determining the use of this method.

5.1.4. Abnormality localisations

Papers 1 and 8 were both based on participants' abilities to recognise and describe an abnormality on a radiographic image, before and after a training phase. One of the aims for these studies was to determine accuracy of interpretation using physical localisations, essentially, we wanted to know if participants were recognising the abnormality in the correct area, and able to provide a sufficiently detailed qualitative statement to describe the position and nature of the abnormality. The FROC method was the ideal approach to fulfil this aim of assessing accuracy of interpretation due to the requirement of observers to physically localise each image by marking the digital radiographic image. Each observers' localisations were compared to a truth marking with a pre-defined acceptance radius, determined by the author. This is an automated method of determining whether the observers had correctly identified the pathology. In papers 1, 3 and 8, observers were provided with image banks with anonymised real-life cases relative to each of the studies and observers provided their localisations and confidence ratings using ROCView computer software (Thompson et al., 2012). Participants then provided a confidence rating specific to the abnormality they had marked, which formed 'mark-rating' pairs that are used to determine the figure of merit (FOM) used in statistical analysis. Using real anonymised cases that closely replicated the local clinical workload ensured that the studies were clinically relevant. This also provided a realistic assessment of observer performance and subsequently illustrated common anatomical areas that may require additional training to improve abnormality detection abilities prior to implementation of the PCE system. FROC not only allows observers to physically localise an abnormality, but the provision of a confidence rating of the abnormality they have marked provides interesting insight into how observer confidence can affect diagnostic accuracy. The ability to precisely localise an abnormality is a key facet of PCE, and the FROC method was ideal for assessing radiographers' ability to localise an abnormality. Consequently, a location sensitive method, such as FROC, was a good match for the tasks that were being performed within papers 1, 3, and 8.

The localisation aspect associated with FROC was utilised in paper 3, though this study was not suited for Jack-knife Free Response Receiver Operating Characteristic (JAFROC) analysis due to the different image bank sizes (set A with 149 examinations including 52 positive cases, set B with 52 positive cases only). A fully cross-matched study is more satisfactory for this type of statistical analysis. Utilising the localisation-only aspect provided by ROCView in this study allowed us to assess whether observers were looking in the right areas and correctly clicking the abnormalities, and to evaluate if the confidence of their localisations/interpretations was increased with an accompanying PCE. Certainly, interpretive confidence of ED referrers would likely increase with a positive PCE description alone, but the localisation aspect provided reassurance that observers were looking at the correct anatomy. If ED referrers were looking at the wrong part of an image relative to a positive accompanying PCE then this would likely have implications for the patient. The localisation aspect in this instance provided reassurance that referrers were looking at the correct part of the image.

5.1.5. Statistical analysis

Quantitative statistical analysis was undertaken using Jack-knife Free Response Receiver Operating Characteristic (JAFROC), which considers an observer's sensitivity (the ability to correctly detect true abnormalities) and specificity (the ability to correctly identify true non-abnormalities) and generates a single figure of merit (FOM). The single FOM provides an easier visual guide regarding which performance is better i.e., pre- or post-training test interpretations.

5.1.6. Descriptive evaluations

In papers 1 and 8, a third layer of interpretive assessment was included in the form of observers providing a short comment describing the abnormality they have localised on the image. This provided interesting insight into how well localisations correlate with the descriptions. So, if observers are localising the abnormality correctly but provide an incorrect description then this would indicate issues with anatomical knowledge, and also, conversely, if they are localising incorrectly but describing correctly. Frequent trending mismatches of localisation and descriptions were considered to be indicative of areas that may require additional or ongoing training for those who may participate in a PCE system. A simple scoring system was devised to assess the accuracy of the descriptive comments compared against a pre-defined benchmark comment, which followed a consistent reproducible format based on the *What, Where, How* method (Harcus & Wright, 2014). In paper 1, which was using extremity examinations, participants could score a maximum of five points for a comment with the correct anatomical side (L/R), name of bone, location of abnormality, abnormality type, and the presence of any movement, such as displacement or angulation. For example, "right, radius, styloid process, oblique fracture, mild displacement." In paper 8, which used CXR images with pneumothoraces and skeletal abnormalities, using the *What, Where, How* method would not have been appropriate for describing a pneumothorax therefore the scoring method had to be altered slightly to allow a uniform assessment of any comment for either of the anatomical abnormalities. Also, the understanding of what content referrers find most useful in a PCE, as realised from paper 6, helped to shape the scoring system in paper 8 with participants gaining one point for correctly describing what the abnormality was and one point for correctly describing where the abnormality was. For example, "right, pneumothorax", or "right, humeral head fracture." A third point was awarded for the correct physical localisation using ROCview (Thompson et al., 2012).

In paper 4, a lexical evaluation of descriptive comments was undertaken which analysed the number of words and the types of words used. This was done using a free-online software (King & Flynn, 2019). Sterne, (2005), acknowledges that the use of online software tools provide new avenues for research resulting from opportunities to expand existing research interests. In support of this, it is likely that the data analysis in paper 4 would have taken a different route if the function of the software to digitally analyse the texts to provide the lexical density and the Gunning-Fog index scores, respectively, was not available. The analytical output from the online software was instant. All texts that were inputted underwent the same analyses by the computer, this removed the possibility of human error that may have skewed results. It is for these reasons that the use of computer analysis of data is a preferred method of the author due to the speed and the removal of the burden of manual analysis. Moving forward, in future studies the possibility of using computer software to undertake part or all of the data analysis will always be explored.

5.2. Cross-sectional surveys

The cross-sectional survey method is not well suited for assessing trends or developments over a time period, such as a population's health or the impact of interventions, but it is considered to be a valuable method of collecting data at a specific point in time (Babbie, 2016). The use of a survey in papers 2, 5, 6 ,7 and 9, was justified considering the information being sought was regarding service provision and/or personal preferences.

5.2.1. The challenges of surveys

Considering the non-funded status of the studies in papers 2, 5, 6, 7 and 9, and easy access to online survey hosts, the electronic survey approach was utilised owing to the significant cost-savings when compared to a traditional postal survey (McNeill & Chapman, 2005). A paper survey approach was utilised in paper 6 as it was perceived to be easier to generate a bigger sample from directly asking staff members to complete the survey in a face-to-face conversation. The dynamic and often hectic environment of the ED was thought to be a hindrance to potential participants reading an email, clicking a link and completing an electronic survey.

The survey method offers a way to obtain a representative sample from an identified population (Bell, 2010; McNeill & Chapman, 2005), and, as recognised by Polit & Beck, (2004), provides a direct way of finding out what people think, feel or believe. Additionally, the desire to gather data quickly, due to time-constraints associated with clinical practice along with other work commitments, and being able to visualise responses being returned were also deciding factors in choosing this method. One of the accepted limitations of the electronic survey method is that a lower response rate is to be expected than that generated with postal surveys (Scott et al., 2011), this is corroborated by more recent research by (Lewis et al., 2016) which reiterated the lower sample rates with electronic surveys, but not significantly different from postal survey response rates. McPeake, (2014) outlines a number of reasons that can affect response rates which may have been contributory in papers 2, 5, 6 7, and 9, such as “survey saturation” whereby healthcare professionals are constantly asked to complete surveys in different aspects of their practice, or individuals may have moved posts and email addresses may be out-of-date and/or inaccurate.

5.2.2. Response rates

Paper 2 had a 47% response rate (n = 40/86), paper 5 had an 89% response rate (n = 75) from the 84 NHS Trusts in which the study was approved, though 146 sites were originally contacted. Paper 6 had a 100% response rate from a sample target of 30 participants (20 from ED and 10 from radiology). These participants were approached to participate based on the required characteristics and geographical location but this selection method within a defined group is not random, consequently sample biases may have been present (Reid and Boore 1987). Paper 7, whilst having the highest sample size (n = 114/356), yielded the lowest response rate. Paper 9 had 31 responses, but it was not possible to determine the current population of potential sites. Latest data provided by Kings Fund from 2019 stated that there are 223 NHS Trusts in the UK, but it was not possible to determine a definitive list of ED and minor injury units (MIU) when carrying out the research for paper 9. Using this data, the estimated response rate for paper 9 may be as low as 14% (n = 31/223).

In the five papers that utilised the survey method of data acquisition, only two achieved over 50% response rate (papers 5 and 6) and the response rates were below 50% in papers 2, 7 and 9. It is argued that the aim of any survey study is to obtain not the highest response rate, but the highest quality of responses appropriate for that study's aims (Holtom et al., 2022). Although there is no recommended minimum response rate for surveys, recent research has suggested that online survey studies have an average of 44% response rate (Wu et al., 2022). It is reassuring that the online surveys used in papers 2 (47%) and 5 (89%) yielded better than average response rates. Holtom et al., (2022) note that there has been a steady increase in response rates since 2005, increasing from 48% to 68% in 2020, possibly due to survey design improvements and the offering of incentives. Unfortunately, the offering of incentives was beyond the capabilities of the submitted non-funded studies, but this is recognised as a potential tactic to increase response rates in any funded or sponsored online survey studies in the future. Many non-monetary approaches were utilised to improve response rates such as piloting the surveys, and personalised invitations and reminders (Shiyab et al., 2023). Whilst there is no consensus on an acceptable response rate for surveys, Holtom et al., (2022) propose that the reliance on response rate as an exclusive indicator of study quality and the comparison against a benchmark should be avoided due to the inter-connected relationships of researcher–participant, participant qualifications, participant motivation, survey length and complexity, the number of times the survey is administered and the cultural and national context.

All of the surveys were either solely self-designed (papers 2, 5 and 7) or co-designed with the co-author (papers 6 and 9). The benefit of self-designed surveys is that questions can be tailored to fulfil the aims and objectives in each of the studies. All of the survey studies used a mixed qualitative and quantitative approach with a combination of open-ended and closed-ended questions. Closed-ended questions are grounded in quantitative research and provide numbers and statistics to understand trends, whereas open-ended questions are considered useful for understanding what participants think about a service, but, as Dawson (2009) recognises, the gathering of opinions can make analysis of the dataset quite complex. The combination of open and closed-ended questions is useful for investigating how participants interact with a service whilst also finding out perceptions of that service (Dawson 2009), therefore the survey method was a good fit to fulfil the aims of papers 2, 5 and 7.

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5.2.3. Sampling

Determination of sample size is a key component of research design to ensure that findings are representative of the population from which participants are selected. On reflection, it is recognised that the worth of findings in the survey studies could have been strengthened with the application of prospective power analyses, determined prior to the data collection phases. A post-hoc power analysis was undertaken in paper 2, but it has since been argued that post-hoc power analyses can be misleading and it would be better to use confidence levels (Dziak et al., 2020). Papers 6 and 7 were proof-of-concept studies evaluating local level services and at the time of planning and carrying out these studies, determining a power calculation was not a considered to be a deciding factor in the undertaking of these survey studies. Though moving forward, it is acknowledged that provision of a prospective power analysis will ensure that an adequate sample size has been obtained, and will subsequently add weight to any study findings whilst increasing generalisability. Paper 2 had a regional remit and papers 5 and 9 were based nation-wide, on review it is accepted that these studies due to their wider population reach should each have undergone a prospective power analysis to maximise the impact of the findings and to ensure an optimal number of responses were obtained.

There was a deliberate selection of groups of participants in the included studies and the subjective approaches to selecting participants with the most appropriate members of subcultures being approached to participate relative to the aim of each individual study. This represented a combination of convenient sampling and purposive sampling (Harding, 2019). This purposive-convenient sampling approach was utilised in papers 1, 3, 4, 6 and 8 given that all participants were willing volunteers who were readily available in the study centre. Purposive sampling is recognised as being similar in principle to judgement sampling (Harding, 2019), due to the deliberate choice and selection of participants. There are limitations with this method of generating a sample as it naturally excludes any random process of selection and results cannot be extrapolated to provide population results (National Audit Office, 2010). However, this method of sampling is useful to provide an illustrative example from a well understood population (National Audit Office, 2010), which fitted well with the aims outlined in each of those papers.

Harding, (2019) recognises that the deliberate choosing of participants who will best fit the purpose of a study can lead to bias, consequently the type of approach for recruitment is something that will be given extra attention when planning future studies. Interestingly though, the sending of surveys to clearly defined and refined populations, such as those selected for the studies submitted, is recognised as having a positive impact on the response rate (Wu et al., 2022). Although the purposive-convenience sampling approach may be considered a weakness, on these occasions it was utilised out of necessity due to the specialised areas of investigation coupled with reduced resources, such as funding and dedicated time that can hinder research expansion. Papers 2, 5, and 9 used a quota sampling approach, though there was also an element of purposive selection given the focussed population, in attempts to obtain samples that are representative of the population. This sampling method coupled with the electronic survey approach provided a quick and cheap way of obtaining a sample but does have a strong possibility of bias (National Audit Office, 2010). There is a trade-off between obtaining an effective sample size within the constraints of the project, which may increase costs, and the completion of the study within a time frame in which the findings remain relevant (Serdar et al., 2021). Considering the context of the submitted studies and the small population of radiographers and ED referrers, these sampling approaches were considered to be appropriate and earlier relative studies have also utilised convenience sampling (Hardy & Culpan, 2007; Hargreaves & Mackay, 2003; Hazell et al., 2015; Mackay, 2006; McEntee & Bergin, 2010), judgement sampling (Coleman & Piper, 2009; Piper & Paterson, 2009), and quota sampling approaches (Brown & Leschke, 2012).

5.2.4. Data analysis

In the papers that utilised a mixed methods approach, the different types of data were analysed in different ways. In paper 2 for example, the small proportion of the questions that encouraged free-text responses regarding treatment suggestions were analysed with a basic manual process due to only consisting of a small aspect of the survey and not generating a wide variance of responses to warrant a true qualitative analysis process. Likewise, in papers 6, 7 and 9, there was only one section for participants to provide any additional comments to supplement their quantitative responses, therefore a simple manual analysis was undertaken, in each instance, to illustrate any recurring topics. Descriptive statistical analyses were completed with Excel (Microsoft, 2024). In paper 4, a content analysis was undertaken using a freely available online software which analysed the lexical components of participants comments, as outlined in section 5.1.6. The author undertook manual analysis of PCE structure and accuracy assessed against the pre-determined benchmark using pre-established marking criteria. In paper 5, a manual inductive thematic analysis was utilised whereby the authors identified common themes as they arose when reading and analysing the dataset. The inductive approach, often referred to as moving from the particular to the general (Harding 2019), allowed the author and colleagues to evaluate a qualitative dataset by evaluating many individual contributions and interpreting their meaning in the context of existing literature and the current climate. It is acknowledged that this thematic analysis may have been improved by using a computer software such as NVivo (QSR International, 2020). The use of NVivo (QSR International, 2020) was considered initially, however there were issues with accessibility and user licences locally that unfortunately made this approach more of a burden rather than assisting the process.

This section reviewed the methods used throughout the submitted papers and provided justification for their use and inclusion. The next section will explore how the themes of the narrative were generated.

6. Theme development

This section provides discussion relating the development of the themes which form the critical analysis of the thesis. The process undertaken to determine the themes is explained with supportive literature.

A rudimentary thematic analysis was undertaken of each paper, which is a method of analysing text and identifying any meaningful trends in the data that offer insight by identifying unique and idiosyncratic meanings across a dataset (Braun & Clarke, 2012). The aim of the thematic analysis was to highlight the most noticeable patterns throughout the submitted papers to meet the objectives of this critical review. Considering the author's prior knowledge and understanding of the research and the theoretical foundations of the submitted works, a confirmatory approach was used, which differs from a deductive approach in that themes are determined, a priori. Salient findings and pertinent points were extracted from the results and discussion sections of the submitted papers, in line with the aim of the thesis. It is recognised as being a less-common approach, it typically uses existing data with pre-determined specific codes/analytical categories and is thought to be "hypothesis-driven" (Guest et al., 2012). The following hypotheses were used to extract the points of significance within the relevant sections of each paper to develop the main themes,

- Radiographers have sufficient ability to recognise and describe abnormalities.
- Radiographers' performance can increase with provision of guidance.
- The provision of a PCE can have positive impacts on service provision.
- Reporting radiographers are key aspects of reporting services.

The process of creating themes by comparing codes generated from the submitted works is built on a grounded theory approach with positivist epistemological tendencies in that each of the final themes are supported by several findings generated from within a number of the submitted papers (Guest et al., 2012). Although this confirmatory approach meant that embryonic themes had already been created, the six phases that constitute a thematic analysis, as described by Braun & Clarke, (2006), were still followed to provide a structured framework when evaluating the submitted works.

Phase 1. Familiarisation of the data - Each of the submitted works were read and re-read. This provided opportunity to re-visit the papers to appraise each as needed. The papers were grouped primarily on their main area of subject investigation i.e., reporting radiographers or preliminary clinical evaluation, and notes were taken regarding the research aims, methodology, findings, and discussions.

Phase 2. Generating initial codes - Initial lists were produced manually for each of the papers grouping interesting and relative content that was thought to be useful with regards to generating themes.

Phase 3. Searching for themes and, *Phase 4. Reviewing themes* – These two phases were carried out simultaneously. The lists of codes were reviewed and analysed to develop primary themes that were considered to be in their infancy and were open to further development in the next phase.

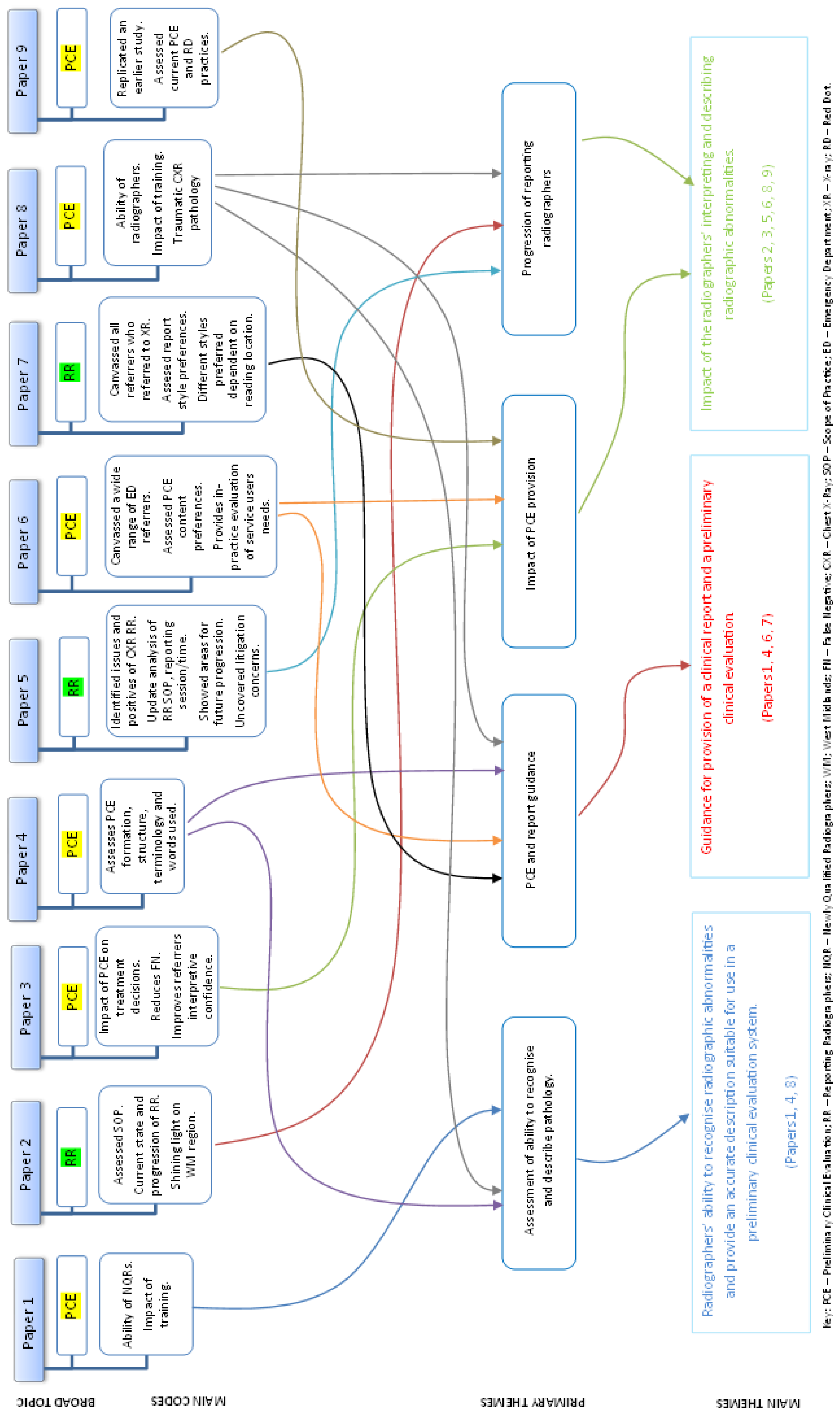
Phase 5. Defining and naming themes – Three key stand-out themes were finalised following this phase aligning with the prior-formed themes, and a number of papers providing findings that support more than one theme. The three themes were determined as follows,

1. Radiographers' ability to recognise radiographic abnormalities and provide an accurate description suitable for use in a preliminary clinical evaluation system. (Papers 1, 4, 8)
2. Guidance for provision of a clinical report and a preliminary clinical evaluation. (Papers 1, 4, 6, 7)
3. Impact of radiographers' interpreting and describing radiographic abnormalities. (Papers 2, 3, 5, 6, 8, 9)

Phase 6. Producing the analytical thesis – The analytical narrative of the themes is what is presented in the proceeding Themes section of this thesis. This section will provide a summation of the themes providing critical analysis of the submitted works.

A simplified version of the above process has been devised by Saunders et al., (2023), in which the 6 phases have been condensed in to 3 steps of reading, coding, and theming. The authors argue that their simpler approach provides clear and simple instructions for practical thematic analysis and can yield quicker results, which is more appealing for clinicians who have variable time constraints. The process by Braun & Clarke, (2006) was utilised by the author due to the seminal nature of the work and being comfortable with the described systematic approach, though it is recognised that the simplified version (Saunders et al., 2023) could have been applied in this situation and will likely be utilised in future thematic analyses.

Figure 3. Schematic diagram illustrating how the themes were formed.



This section has discussed how the confirmatory thematic analysis was undertaken with supporting external literature, and visually illustrated how the themes were generated. The next section will critically review the papers in the context of the three themes.

7. Themes

This section synthesises and analyses the contribution of the nine peer-reviewed, published, and original research articles that are linked through exploration of the concept of radiographers interpreting radiographic images and describing abnormalities. All articles were published over a five-year period, 2018 to 2023.

7.1. Radiographers' ability to recognise radiographic abnormalities and provide an accurate description suitable for use in a preliminary clinical evaluation system[1].

The proposition of radiographers interpreting radiographic images and providing a written description of findings continues to be a controversial issue amongst radiologists (Royal College of Radiologists, 2017). The concerns of the RCR were based on their assumption that reports by radiographers are of no value due to their lack of medical training resulting in reports that are "inevitably observational and descriptive" (Royal College of Radiologists, 2017). The document argued that reports should be actionable, and rightly so, but also that a minimum of five years specialist training post-medical qualification is needed to provide influential opinion to affect whether a patient is discharged, followed up or requires more tests. Though it is possible that the viewpoint of the RCR may have altered over the last 6 years in view of the recently published *Standards for the education and training of reporting practitioners in musculoskeletal plain radiographs* (Royal College of Radiologists, 2022). This document aims to ensure uniformity in the education and assessment of radiographers alongside radiology registrars and suggests that the RCR may now be more accepting of reporting radiographers with the expectation of parity of ability compared to radiologist colleagues. Reporting radiographers undergo intensive training specific to their area of interest and this publication provides re-assurance that they are evaluated against the same formative and summative assessment standards as radiology registrars.

Whilst the competence of a reporting radiographer is externally assessed via an accredited Higher Education Institute (HEI) post-graduate (PG) course specific to the

[1] Derived from papers 1, 4, and 8.

anatomical region(s) that will form the radiographer's scope of practice, this is not the case regarding the provision of a PCE. Radiographers who qualified more than 15 years ago and/or hold the Diploma of the College of Radiographers (Radiodiagnosis) (DCR(R)), will likely not have had any formal teaching regarding describing abnormalities during their initial training but may have attended subsequent Continuing Professional Development (CPD) study sessions. Certainly, there are radiographers who hold DCR(R) who have gone on to complete a PG reporting course, but these radiographers are not of concern in the context of PCE. Conversely, those Radiographers who have qualified in the last 15 years will have been subjected to an undergraduate curriculum that provided teaching relating to PCE, but there is no formal SCoR-approved qualification that states a radiographer is competent to participate in a PCE system. This raises issues regarding the effectiveness of any PCE implementation and the subsequent impact of the service. Participation should be expected as compulsory to establish the service and to ensure continuity of service, therefore consideration should also be given to how radiographers may feel about participating without any support, training or governance protocols in place. It is important that all radiographers are supported appropriately regardless of experience, confidence or ability. Each department should strive to provide optimal conditions for radiographers to participate by offering regular training sessions and audit processes.

The following section outlines the approaches used to assess the impact of focussed training on observer performance in a specific group of radiographers, and a specific anatomical region with limited pathologies, respectively.

7.1.1. Pre- and post-training test approach

The early studies looking at the image interpretation ability of radiographers associated with red dot and PCE were pioneering and certainly provided the bedrock for the many subsequent studies that have followed, and indeed they duly provided the foundation and inspiration for the works included in this section and throughout the remainder of this thesis.

Several observer studies were undertaken that tested how well radiographers can detect radiographic abnormalities (Coleman & Piper, 2009; Hardy & Barrett, 2004; Hardy & Culpan, 2007; Hargreaves & Mackay, 2003; Mackay, 2006; Piper & Paterson, 2009) and ability to describe abnormalities (Hardy & Culpan 2007; Piper & Paterson 2008). These studies utilised pre- and post-training tests to determine if radiographers' ability is improved following educational intervention. This approach is ideal for assessing radiographers' current interpretive abilities and is also for assessing for improvement of performance following the educational intervention. The pre- and post-training approach was used in papers 1 and 8 to assess the impact of the educational intervention by evaluating performance. The previously mentioned studies (Hardy & Culpan, 2007; Mackay, 2006) assessed the abilities of radiographers attending red dot CPD study days; radiographers who likely would have had an interest in traumatic presentations and abnormalities considering their voluntary attendance. Paper 1 followed the same principle of assessing radiographers' evaluations of radiographic abnormalities, though in comparison, paper 1 had a more refined study population that had not previously been investigated and in this respect generated new findings and insight that had previously not been appreciated in the published literature.

Paper 1 was focussed on the ability of first appointment, newly qualified radiographers to recognise and describe abnormalities using PCE. This was considered a unique area to investigate and was derived from encountering many final year radiography students and newly qualified radiographers, that had been employed at the author's workplace over several years, reciting varying perceptions of PCE. Additionally, this area of observer performance had not previously been evaluated which made this approach and the topic even more appealing. The findings of this study illustrated statistically significant improvements in abnormality detection and improvements were also demonstrated in the precision of PCE comments following the focussed training programme.

One of the issues with using the pre- and post-training approach is the difficulty in ensuring that the study design reduces the chances of observers remembering any of the cases. It is important to try to reduce the potential effects of case memory bias that may influence observers' performance. This needs to be considered when appraising the study by Hardy & Culpan, (2007) in which the tests were undertaken before and after a short course, though the length of the course was not stipulated, also the image bank only contained 20 cases with 11 abnormal cases, and the same caseload was used for the pre- and post-training tests. Participants in the study by Piper & Paterson, (2009) attended a 12-hour course over six weeks (six 2-hour sessions) and completed interpretation of a set of test bank cases prior to image viewing workshops and again after the final session. This length of wash-out period and the regular teaching sessions would likely have reduced the chances of memory bias prevailing. In paper 1 we implemented an 8-week interval between the pre- and post-training tests, which was interspersed with weekly teaching sessions, likewise in paper 8 there was a minimum of 59 days (8.4 weeks) between the tests, interspersed with tutorial videos. We believed that these lengths of delay between tests, along with the numerous clinical cases encountered during those time frames, would be sufficient to prevent memory bias affecting the results.

The novelty of papers 1 and 8 is based in the assessment of observer localisations of abnormalities that accompany the written PCEs. The assessment of the abnormality localisations was undertaken with a bespoke software package called ROCView (Thompson et al., 2012). The radiographs in each of the studies were viewed on reporting standard review monitors and observers were required to use mouse clicks to localise an abnormality and to provide confidence rating on a sliding scale. The written PCE comments were analysed manually and benchmarked against a pre-decided standard comment and scoring format. At the time of these studies, this approach had not previously been utilised in the field of assessing radiographers recognising and describing abnormalities. No subsequent observer studies in this research area have replicated this approach and this makes these studies unique in this regard. The benefit of this approach is that the equally weighted jack-knife alternative free-response receiver operator characteristic (wJAFROC) figure of merit (FOM), which is sensitive to location information, defines the probability that a true abnormality is rated with higher confidence than a false localisation (Chakraborty & Berbaum, 2004. The concurrent assessment of PCE comment accuracy indicates whether any relationships exist with the abnormality localisation data that can help to focus teaching to specific areas of recognising and describing abnormalities. The uniqueness of the method used in papers 3 and 8, is that it provides a three-factor analysis of observer performance i.e., localisation accuracy, confidence in localisations, and accuracy of the PCE. Analysis of these facets of image interpretation provides a greater insight into performance, as previously described in section 6 *Review of methods*, whereas previous and subsequent studies assessed PCE accuracy only.

7.1.2. Educational intervention

In paper 1, face-to-face weekly tutorial sessions lasting one hour were used as the educational intervention. The training phase lasted for eight weeks and provided specific sessions covering basic terminology and concepts to familiarise participants with a systematic approach to recognise abnormalities, introductions to established vocabulary and a model to form a comment (Stevens & Thompson, 2018). This type of education intervention with a small group number provided opportunity for learners to interact with the teaching through questions and discussions whilst also providing opportunity for peer-assisted learning. Although the evidence base for peer-assisted learning in radiography is sparse, it is clear that there are benefits for peers learning from each other through this approach (Bain et al., 2017; Elshami et al., 2020; Foulkes & Naylor, 2022; Meertens, 2016).

Paper 8 was focussed on all departmental radiographers with varying degrees of experience and interest and was closer to a more normal representation of a departmental sample. Paper 8 was centred around a singular anatomical region, the chest, and a small number of pathologies. Prior to this study, there had not been any observer studies investigating this niche area of radiographer PCE interpretation. The findings of this study illustrate that radiographers can contribute to detecting traumatic CXR abnormalities and that the use of short and intensive recorded video tutorials may be useful for developing skills in recognising and describing fractures and pneumothoraces on chest radiographic images. Though the improvements in the post-test analyses were not as significant as those seen in paper 1, it is thought that the difference in the education interventions between the two papers may be the reason.

A similar method was utilised by Williams et al., (2019) but their recorded teaching sessions were supplemented by additional textbook teaching and online content also. Consequently, the improvements documented by Williams et al., (2019) were more pronounced than what we saw in paper 8. We utilised the pre-recorded tutorial approach due to restrictions in the study centre owing to the COVID-19 pandemic that restricted group gatherings. This method of providing the education intervention would not ordinarily be the first choice of the author, but the author wanted to remain research active during the pandemic and this adapted approach was thought to be an adequate alternative to face-to-face teaching. However, the improvements in performance of the participants were not as great or as significant as those seen with paper 1. It is conceivable that had we distributed supplementary teaching materials we may have seen greater increases in sensitivity, specificity, and accuracy. Due to the situation at the time of the study, the recorded tutorial approach was a forced option and it is unlikely that this approach will be used again but if it is, the provision of supplementary material would be utilised. Reflecting upon the approaches used in paper 1 and paper 8, the face-to-face education intervention is preferred due to the benefits outlined above as well as the greater improvements observed in radiographers' performances. The author will use the face-to-face educational intervention for any future pre- and post-test observer performance studies. It is interesting to note that a more recent study reported that local training did not influence PCE accuracy, but was likely to increase PCE participation (Lidgett et al., 2023). A possible reason for this could be attributed to the format and frequency of the teaching sessions (2 x 3 hr sessions) used, which may have led to information overload. Interestingly though, in contrast to this viewpoint, a previous study by Neep et al., (2018) reported that an intensive format of education consisting of two days with 6.75 hour sessions returned the greatest improvement in performance, whereas non-intensive education with numerous regular sessions, whilst still being beneficial, can lead to decreased attendance. This presents interesting knowledge to consider when designing future training sessions. One of the limitations of the study by Lidgett et al., (2023) concerns the training only being provided to five band 6 senior radiographers with at least five years' experience, whereas the five radiographers who did not receive any PCE training were band 5 junior radiographers with less than five years' experience. It is difficult to determine the extent of experiential learning influencing the ability of any observers, but this needs to be considered when assessing performance. If the junior radiographers had received the training, it is possible that their accuracy levels may have increased in view of having reduced experiential learning.

7.1.3. Recognising and describing an abnormality for PCE

The findings from paper 1 and paper 8 indicate that following a series of education tutorials, improvements in both abnormality localisations and accurate descriptions can be achieved. In paper 1, which involved extremity abnormalities, a significant difference in fracture detection performance was evident between the pre- and post-training evaluations for a fixed reader random case analysis (F (1,57) = 10.57, p = 0.0019). The averaged wJAFROC

Figure of Merit (FOM) and 95% CIs for pre- and post-training tests were 0.619 (0.516, 0.737) and 0.703 (0.622, 0.852) respectively. The increase in wJAFROC FOM signifies that all participants demonstrated improvement from the pre- to post-training tests. The averaged abnormality detection rate for participants improved from the pre- to post-training tests, 42% to 56%, respectively. These findings correlated with similar post-training improvements by radiographers documented in the study by Piper & Paterson, (2009), which reported an increase in FOM from 0.63 to 0.73, respectively. In paper 8, the pooled pre- to post-test sensitivity remained consistent following training (78.9% to 78.8%), whereas pooled specificity and accuracy showed moderate improvement, 79.0% to 89.9% and 78.9% to 86.0%, respectively. Incorrect localisations were far less prevalent and the pooled PCE scores also showed improvement following the education intervention. Overall, findings here suggest that these participants performed better at localising a pneumothorax compared to skeletal abnormalities. It is acknowledged that a possible reason for this could be attributed to inattentional blindness (Drew et al., 2013), in which observers were over-focussed on assessing the lungs and large humerus bones that they did not appreciate the subtle abnormalities or superimposed rib fractures.

Paper 4 was designed to specifically assess the lexical construction of radiographers' PCE comments by assessing ability to form a concise description by evaluating structure and brevity when compared against a pre-determined benchmark. The impetus for this paper was determined by an interest to investigate how radiographers structured a comment and to evaluate the types and numbers of words used. The main findings from this paper were that participants used too many words in their PCE comments with reduced descriptive content (Stevens, 2020). The findings from this study show that there is an excellent opportunity to develop the way in which radiographers build their PCE comments. No other published literature has assessed this aspect of PCE and the findings here, whilst on a single-centre basis, presents a thought-provoking issue regarding the forming of a comment. The use of an electronic taxonomy has been suggested as a way to produce a clear and concise PCE while reducing ambiguity and providing support and structure (Cosson & Dash, 2015). However, it is noted that local technological barriers may prevent this being a viable option (Stevens, 2020). Earlier work had suggested that the accuracy of radiographer comments may not be as accurate as their detection abilities, even after training (Hardy & Culpan, 2007). Although, the length of the training period may lead to greater improvements in performance, as is evidenced by the findings from papers 1 and 8.

PCE training is included in many UK undergraduate (UG) radiography courses. A survey of newly qualified radiographers at 17 major trauma centres (MTC) in England in 2017 indicated that participants believed that their undergraduate PCE training positively influenced their confidence to describe abnormalities (Stevens & White, 2018). Interestingly though, it has been identified that there is wide variation in all aspects of image interpretation education, and it is suggested that this may lead to variance in interpretive knowledge, skill and confidence between newly qualified radiographers (Hewis et al., 2022). This provides further understanding and supports the rationale for undertaking paper 1, as outlined in section 1.3. Participants in the study by Stevens & White, (2018) also recognised PCE training in the clinical environment as an area for improvement. This amplifies the importance of any departmental training to ensure that educational provisions are sufficient to improve and maintain ability to the required standard, and to increase participation especially so for those with less experience as illustrated by Lidgett et al., (2023). It is also interesting to note that in the study by Lidgett et al., (2023) the junior radiographers, who made up the untrained arm of the study, performed comparably to the trained arm of the study, the senior radiographers. There was no statistically significant differences between the groups' sensitivity, specificity and accuracy scores, respectively, thus suggesting that UG PCE training may be sufficient, and supports the findings of Stevens & White, (2018).

It is clear that radiographers can effectively recognise and describe abnormalities on radiographs, in the PCE context. Performance improvements are evident following a period of training sessions that are regular and short-lasting and provide the key information and knowledge required to interpret radiographic images. However, regardless of the positive outcomes and the benefits of the methods used, papers 1, 4 and 8, identified a number of specific PCE training issues and concerns that require extra attention, and these provide additional learning opportunities for radiographers that will be discussed in the following section.

7.2. Guidance for provision of a descriptive evaluations for preliminary clinical evaluation and clinical reporting.[2]

Although the findings from paper 1 and paper 8 highlight that radiographers' performance in recognising and describing abnormalities can be improved with training, it is evident that further education may be required. This section will offer guidance for improving the provision of a PCE and will introduce style suggestions for clinical reporting, derived from the indicated papers.

7.2.1. PCE training issues

A number of issues were highlighted in papers 1, 4, 6 and 8, that are recommended as needing additional teaching as part of any departmental training programme pertaining to PCE implementation and/or on-going CPD re-fresher sessions.

When considering the findings from paper 1, and the effect that the 8-week training phase had on the performance of all participants, it is recommended that all newly qualified radiographers employed in their first post should undergo a training programme specific to recognising and describing abnormalities in a PCE system during their preceptorship phase. The findings of paper 1, at the time of publication, corroborated those of an earlier study by Hazell et al., (2015) that highlighted improvements in radiographers' sensitivity (84% to 87%), specificity (60% to 70%), and accuracy (72% to 78%), respectively, when providing a PCE following training. Research by Williams et al., (2019) published after paper 1 also produced improvements in performance following training (sensitivity 82% to 86 %, specificity 75% to 85%, and accuracy 82% to 86%, respectively). It is important to acknowledge the small sample size of the study in paper 1, and to appreciate that the findings from this study are not generalisable across all newly qualified radiographers. Another important point to acknowledge is that because the final sample size was reduced from the original calculation, the power of the study will have been reduced. Nonetheless, it is encouraging that the findings of paper 1 follow the same trends as other published literature.

[2] Papers 1, 4, 6, 7 and 8

As previously noted, the effects of training on radiographers' abilities to detect abnormalities are well-documented (Hardy & Culpan, 2007; Hargreaves & Mackay, 2003; Mackay, 2006; Piper & Paterson, 2009; Wright & Reeves, 2016), and paper 1 provides a proposal to help ease the transition of newly qualified radiographers into the clinical workplace. Paper 1 illustrated that incomplete buckle-type fractures of the distal radius in paediatric patients were frequently missed, and this correlated with previous work (Nunn & Nunn, 2011), at the time of publication. Paper 8, which assessed the ability to detect traumatic abnormalities on CXRs, also illustrated that radiographers may require focussed training to recognise subtle or superimposed bony abnormalities. Fractures of ribs and abnormalities remote from the main body of the chest, such as acromioclavicular dislocation, proved to be the commonest missed pathology. No other research has been published looking specifically at radiographers' ability to interpret CXRs in the PCE context, despite at least one institution (Alexander-Bates et al., 2021; Neep et al., 2019) indicating that the CXR is included in their PCE scope of practice.

Paper 4 showed that radiographers tended to use too many words with reduced descriptive content when compared to a pre-defined standard benchmark. Coleman & Piper, (2009) had previously suggested that radiographers may lack the vocabulary required for describing abnormalities and that a paper-based tick-box process may be more effective, and the findings from paper 4 appear to corroborate this suggestion. Although, obvious and common pathologies were easily described with fewer words and in a lexically dense sentence, which were closer to the standard benchmark. Other findings imply that less common or subtle abnormalities may prove problematic. This is substantiated by Paper 1, which indicated that subtle undisplaced fractures are commonly missed. Consequently, it is recommended that focussed teaching regarding the types of fracture patterns that are associated with common presentations and/or age categories should be included in any PCE training programme. The phenomenon of Satisfaction of Search (Ashman et al., 2000) should be included in the training package, as proven by the post-training improvements in paper 1. It is important to discuss how the detection of one abnormality can interfere with the detection of another abnormality and how this is often influenced by knowledge of common fractures (Ashman et al., 2000). The study by Verrier et al., (2022) published after paper 1 validates this idea as they identified that 8% of the false negative errors in their study were due to failure of Satisfaction of Search.

It is proposed as a recommendation that the PCE comment should consist of a single, short and concise sentence, following the findings and recommendations in paper 4. The subsequent findings from paper 6 support this recommendation and have generated guidance regarding structure and content for composing a PCE based on the preferences of referring clinician. One of the major findings from paper 6 was that referring clinicians preferred a PCE comment with a bullet style format that is not excessively worded. The PCE should include what the abnormality is, where it is specifically, and if the abnormality is displaced. No study of this type had previously been undertaken and this develops further on the *What, Where, How?* model (Harcus et al., 2014) by providing a simplified way to provide the information that referring clinicians prefer and find most useful. Referrers prefer the PCE to be easy to follow, and it should be structured with useful and relevant information. It could be argued that these preferences are likely due to the dynamic nature of the ED and associated time-pressures. Evaluating the PCE preferences of ED referrers has provided an understanding of what to include in the PCE that had previously not been appreciated. Prior to paper 6 there were no studies in the literature that had asked the referrers what they require from the PCE system, much of the literature is based on radiographers' ability, this therefore establishes paper 6 as a key text in this regard.

The ability of radiographers to recognise and describe radiographic abnormalities can be improved with training, and papers 1, 4 and 8 raise some key aspects of PCE that should be given extra attention however, there are pressing concerns regarding the offering of PCE training that will be discussed in the next section.

7.2.2. PCE Training concerns

There is considerable indirect onus placed upon radiology departments regarding the PCE system but there is limited guidance to aid a successful implementation. In the UK there has previously been limited indication of standards to aspire to and little direction on how to govern such a system, though this is due to change with the forthcoming edition of the new PCE guidance from the SCoR (Society and College of Radiographers, n.d.). In Australia, the Queensland Government produced a toolkit to aid the implementation of radiographers providing a written comment within Queensland public health settings (Queensland Government Department of Health, 2014), which could easily be adapted by any local department to provide a basis for implementing, monitoring and reviewing a PCE system. Whilst an implementation toolkit may be viewed as essential to implementing and sustaining the PCE system, PCE education cannot be overlooked. PCE education is best placed to be delivered via informal departmental teaching sessions, given the lack of formal certification requirement in the UK. Though it is interesting to note the recent launch of a Preliminary Image Evaluation Certification Examination in Australia (Australian Society of Medical Imaging and Radiation Therapy, 2021), which could be adapted in the UK as a way to ensure standardisation of radiographer ability and service provision. The way in which radiographers form their PCE in terms of structure and content is a key aspect of a successful PCE system but it is also an under-researched aspect of PCE.

Improvements in performance were evident in papers 1 and 8 following the educational interventions that consisted of regular, short-lasting teaching sessions covering key concepts relative to PCE. This supports the findings from the study by Hargreaves & Mackay, (2003), which reported increases in sensitivity (76.2% to 81.3%) and accuracy (89.9% to 93%) following a 10-week training programme. None of the aforementioned studies that assessed ability after training offered any suggestion of training content, or length of sessions, and regarding frequency, Mackay, (2006) was the only one to suggest that refresher sessions should be provided with no greater than a six-monthly cycle. However, it is possible that a rolling 8 to 10-week rolling training programme may be most appropriate given the variable content. The areas for additional training as outlined in the previous section may aid departments in devising their training sessions and enhance the service, but overall, the content, duration, and frequency of sessions should be determined on a local level based around scope of practice and departmental preferences.

Considering the lack of published information directing radiology departments on the implementation of a PCE system, especially so concerning the educational aspects, guidance has been provided here highlighting areas for additional training, length and frequency of sessions, PCE structure, and lexical content. There has been no such guidance regarding report style choice specific to referrer location or specialty and this could be considered a useful tool for reporting radiographers, which the next section aims to provide.

7.2.3. Radiograph report style guidance

The reporting styles of radiographers will likely have been shaped by the reports that they have read during their regular clinical practice when following up interesting cases or checking previous reports, for example. Further development will likely have occurred during their training phase via the teaching and learning at the HEI, as well as peer influences. This may then be honed following qualification when confidence increases, and if extra-departmental reporting is undertaken via an external reporting agency. A study published prior to paper 7 looked at General Practitioner (GP) satisfaction of a radiographer-led general radiography reporting service with one of the conclusions being that improvements could be made regarding report content and terminology (Milner & Barlow, 2021). Further suggestions included the utilisation of a standardised report structure and clear instructions when follow-up is or isn’t required (Milner & Barlow, 2021), but no stylistic recommendations were put forward.

Previously published articles regarding reporting style are based on authors opinions (Coakley et al., 2003), the views of a committee (Radiology, 2011), or a review of the literature (Wallis & McCoubrie, 2011). One paper evaluated the preferences of referrers regarding content for abdominal ultrasound (US) and CXRs, but this was assessing clinicians’ preferences regarding the amount of report detail only (Mcloughlin et al., 1995). Paper 7 had a similar aim but encompassed referrers’ preferences for skeletal and CXR reports and asked questions regarding multiple stylistic combinations that could potentially make up the report, such as, paragraph or bullet points, short or long sentences, and brief or in-depth detail. The author was not aware of any other published literature that evaluated preferences in this manner at the time of the study, nor has any been published since. In contrast to Mcloughlin et al., (1995), the study invitation in paper 7 was extended to any staff member who had referred a patient for an X-ray examination in the year preceding the study. This resulted in a greater number of participants with a wider range of opinions from various clinical roles rather than narrowed responses from hand picking the participants. Differences in the sampling approaches were evident with paper 7 utilising a random method, and the study by Mcloughlin et al., (1995), which utilised a non-random convenient method. The non-random convenient sampling method whilst being easy and quick to implement can introduce bias into the results because the sample is not representative of the population (Taherdoost, 2016). The random sampling method in paper 7 is a preferred method as there was no specific group of referrers chosen to participate and all referrers in the defined population had equal probability to respond to the survey and be included in the sample (Taherdoost, 2016).

It is important to recognise the NHS changes that have occurred since the study by Mcloughlin et al., (1995), such as increased patient activity and chronic staff shortages, which will likely have had an impact on the preferences of referrers in paper 7, 27 years later. The findings here offer guidance for creating a report based around the style that referrers find most preferrable. Additionally, it also provides insight into the different styles that referrers prefer based on their environment in which they are viewing the radiographic images. Overall, the findings show that the most preferred style of report for skeletal and CXR reports is one that is brief, with short sentences in a bullet-point format.

This section highlighted training issues and concerns that arose from the aforementioned papers, as a way to offer guidance for improving the provision of a PCE. Report style suggestions for clinical reporting were also proposed based on the preferences of clinicians who regularly refer for X-ray examinations at the local imaging department. The next section will provide evidence demonstrating the impact of radiographers interpreting and describing radiographic abnormalities.

7.3 Radiographic abnormalities: The impact of radiographers' interpreting and describing.[3]

Earlier research asserted that radiology service delivery re-organisation was required for ED patients to benefit directly from the development of radiographer interpretation (Hardy & Barrett, 2004). This section aims to support that assertion by highlighting the extent of impact that stems from radiographers interpreting and describing radiographic abnormalities delivering a multitude of benefits across a number of stakeholders relating to the radiology service, evidenced by the supporting papers.

[3] Derived from Papers 2, 3, 5, 6, 7, and 9.

7.3.1. Preliminary Clinical Evaluation

Previous work has proven the benefits of immediate reporting in the ED setting, including cost-effectiveness through increased productivity (Hardy et al., 2013), informing patient management at time of attendance (Hardy et al., 2008), and by reducing interpretive errors (Snaith & Hardy, 2013). However, prior to papers 3 and 6, there were no studies that published findings underlining the potential impact of the PCE system. The findings in paper 6 suggest that referrers are open and welcoming to the notion of radiographers providing a directive comment describing any abnormality, considering it to be a helpful addition to ED care with very useful content.

When providing a PCE that includes the preferences of the referrer, as outlined in the previous section and described in paper 6, a directive comment can remove any ambiguity that might manifest when using the RDS. The clear conveyance of the description of an abnormality improves the efficiency of the abnormality flagging system and will prevent mismanagement of the patient. This theory is upheld by the findings from paper 3, which was designed to assess the impact of a PCE on treatment and management decisions. Five Emergency Nurse Practitioners (ENPs) and five Emergency Care - Advanced Clinical Practitioners (EC-ACPs) were recruited for this observer study. All participants were required to view two set of images and localise any abnormalities using ROCView (Thompson et al., 2012) in a robust and balanced cross-over design with an 8-week wash out period between viewing each image set. Images in set A (n = 149) were presented with no PCE. Data derived from set A was used to determine participants' accuracy in determining normal and abnormal appearances, including the participants ability to accurately identify the location of the abnormality. Image set B comprised of the 52 abnormal images only, presented in a different random order to image set A, each of these cases had an accompanying PCE. The localisation accuracy of the participants was compared for evaluations with and without the PCE comment. Data derived from set B was used to assess the participants' ability to make the correct treatment decisions based on the PCE. This type of approach had previously not been used in any radiographic image observer performance study and the evaluation of how the PCE impacts on ED referrers was also a novel approach.

Paper 3 has shown that the PCE can have multiple positive impacts, such as, positively affecting patient management decisions with statistical significance ($F(1, 520) = 104.92$, P =

>0.01), which provides substance to the claim by Neep et al., (2019) who speculated that PIE/PCE can complement an ED referrer's diagnosis when an official report is unavailable, though they did not evaluate any tangible impacts. Seminal research in the 1980s by Berman et al., (1985) argued that the false negative errors that were occurring frequently in the ED could be reduced through the introduction of radiographers indicating on the radiographic film that an abnormality is present with the placing of a "red dot". The findings in paper 3 build on this statement by establishing that a PCE provided by the radiographer can also reduce false negative diagnoses by ED referrers, and in this aspect provides further support to the intention of moving from red dot to PCE. Improvement in referrers' abnormality localisation accuracy with increased confidence in those localisations were also demonstrated and to the PGR's knowledge, there has been no other published study that has assessed these positive outcomes; therefore, this again outlines the originality of paper 3. Whilst this was a small local study the findings are reassuring and the potential to widen participation in a subsequent study to evaluate the impact on doctors' decision making is most encouraging.

The findings from paper 9 provide an updated assessment of current PCE practices across the UK. This cross-sectional online survey was based on the previous study by Snaith & Hardy, (2008). Despite the low response rate, the findings showed there is now a greater proportion of departments using the PCE system compared to the red dot system. In addition to increasing numbers of PCE systems, the findings also indicate that the defined scope of practice is expanding to include anatomical areas outside of the traditional appendicular and axial examinations, such as chest and abdominal examinations. It is interesting that 43% (n = 3/7) of departments are expected to indicate anything abnormal on a CXR despite a lack of published evidence indicating that radiographers are competent to do so. Further individual analysis of the three departments shows a mixture of training requirements prior to participating in a chest PCE service; one indicated no training was required. The requirement of training raises an interesting discussion given the findings reported by Lidgett et al., (2023), which stated that there were no positive effects on accuracy following training. Recent research from Australia indicated that CXR is included as part of the PCE SoP in at least two departments (Alexander-Bates et al., 2021; Neep et al., 2019), the findings of which corroborated those in paper 8 by suggesting that additional training is required specific to CXR PCE. The progression of PCE appears slow but the findings from paper 9 are not generalisable and do not provide a complete overview of current PCE practices, therefore further investigation is required to generate a more complete appraisal of current PCE practices.

This section has shown the impact of radiographers writing a PCE with regards to referrers' image interpretation and their decision making, and also acknowledges the progression of PCE SoP. The next section will provide evidence of how the practice of radiographers reporting CXRs can provide positive impacts on the wider radiology service.

7.3.2. The continuing progression and development of reporting radiographers

Reporting radiographers have been utilised for over 25 years in the NHS (Milner et al., 2016; Snaith et al., 2015), yet radiographic reporting workloads have continued to increase over recent years (NHS England, 2020a; Royal College of Radiologists, 2015). Many Trusts utilise insourcing and outsourcing reporting sessions to tackle reporting backlogs (Royal College of Radiologists, 2023), and these are potentially fulfilled by radiologists, incurring additional costs. It is recognised that reporting radiographers can be a more cost-effective alternative (Care Quality Commission, 2018), when considering their availability to report a single modality compared with the multi-modality reporting commitments and daily schedule of a radiologist. Previous work has proven the ability of reporting radiographers to report competently (Piper et al., 2014; Stevens, 2021; Woznitza et al., 2014, 2018), yet there have been many critics of reporting radiographers (Alahmari A, 2020; Donovan & Manning, 2006; Royal Australian and New Zealand College of Radiologists, 2018; Royal College of Radiologists, 2017). Indeed, the only radiologist response in paper 5 provided interesting insight, bemoaning the lack of medical training impeding the ability of a radiographer to interpret and convey findings on a CXR, imitating the stance from the aforementioned RCR position statement (Royal College of Radiologists, 2017). This viewpoint from the sole radiologist-response echoes the stance of Donovan & Manning, (2006), who concluded that without medical training radiographers will never become experts. Though, the volume of subsequent studies provide an abundance of convincing evidence to the contrary.

Paper 2 provides information that highlights the impact of reporting radiographers in the West Midlands region of the UK and paper 5 emphasises the continued progression and impact of CXR reporting radiographers across England. A major contributing factor to the reduced number of sites that responded in paper 5 was the global COVID-19 pandemic, and as a result many R&D departments would not agree to implement any new studies that were not related to COVID-19. The electronic survey in paper 2 was distributed to reporting radiographers at 11 NHS Trusts yielding a 47% response rate (n = 40/86). This was considered a good response rate given the known challenges associated with response rates and survey studies. However, on reflection this number could have been increased by lengthening the data collection period and using further follow-up email. An earlier investigation had reported an uptake in the number of radiographer-led ED “hot reporting” services (Society and College of Radiographers, 2017) and paper 2 provides evidence that upholds this with 85% of participants (n = 34/40) stating they report appendicular examinations from the ED.

An earlier literature review evaluating evidence pertaining to reporting radiographers in general radiography, CT and MRI concluded that reporting radiographers can augment capacity and release radiologist time (Culpan et al., 2019), though there was no aspect attributed specifically to CXR reporting radiographers. The electronic survey used in paper 5 was sent to 146 NHS Trusts in England with 84 participating (58% response rate). Evidence of the impact of CXR reporting radiographers from paper 5 is underlined by widespread service development with a third of Trusts having all CXR reporting radiographer roles fulfilled. Regarding the training and subsequent employing of radiographers to report CXRs, the perceived impacts encompass improvements on service inefficiencies, namely maintaining backlogs, improving reporting capacity and reducing report turn-around-time (TAT). New guidance has been published stipulating that imaging department reporting infrastructure should be sufficient to deliver a maximum 2-week report TAT for all imaging examinations (Royal College of Radiologists & Society of Radiographers, 2023). For general radiography predominantly, all examinations should be reported within 7 days, ideally less than 4 hours for acutely unwell and ED patients, or within 28 days for routine outpatient and GP patients (Royal College of Radiologists & Society of Radiographers, 2023). Given that general radiography activity accounted for more than 21 million examinations in the year to March 2023, 8 million of which were CXRs, it is possible that it is this domain of reporting where the greatest fulfilment of the new report TAT guidance will be realised. This is reinforced by the increased numbers of CXR reporting radiographers discovered in paper 5 showing a 61% rise in 2021, since the previous evaluation by Milner et al., (2016), and it is expected that further increase will have occurred up to the present day. The number of reporting sessions per week documented in paper 5 also exhibits increase of almost 50% since 2016 (Milner et al., 2016). It also emerged that CXR reporting radiographers had a mean of 3.5 sessions dedicated to CXR reporting, equating to 14 hours a week. The amount of time allocated to radiographers reporting CXRs had not previously been investigated and this provides new understanding of a previously unknown aspect of reporting. To-date, there has not been an updated, published appraisal of the number of CXR reporting radiographers, sessions, and/or time allocated to CXR reporting radiographers. Consequently, paper 5 currently remains the only publication that evaluates these aspects of CXR reporting radiographers across England, UK. A recent unpublished survey study of reporting radiographers in the North East and Yorkshire region of the UK reported that over 53% of reporting radiographers are allocated 5-8 sessions, but there was no specification of anatomical region reported in these sessions, and over 58% of reporting radiographers are CXR reporters (Tahir, 2023). These findings complement those in paper 5 showing a clear and increasing dependence on radiographers to reduce reporting workloads over a 5-year period and adds further weight to the previous assertion that radiographers contribute significantly to reporting capacity (Snaith et al., 2015).

Participants responses in paper 5 indicate that a perceived impact from increasing reporting time for CXR reporting radiographers is the releasing of radiologists from CXR reporting. Subsequently, this improves radiologists' availability for more complex reporting duties or MDT preparations, and correlates with the general findings from Culpan et al., (2019) regarding the re-direction of resources for other tasks. This also provides a distinct perspective associated with CXR reporting radiographers. The potential benefit of releasing radiologists is emphasised by the increasing number of cross-sectional examinations (CT, MRI, PET-CT, SPECT), exhibiting an 8.7% increase in the year to March 2023 (NHS England, 2023) compared with pre-pandemic activity levels in the year to March 2020 (NHS England, 2020b). A further acknowledged benefit of CXR reporting radiographers is that they can also provide a means to address the financial burden associated with outsourcing. The extent of reliance on outsourcing is exemplified by the 2022 RCR *Clinical radiology workforce census*, which outlined that 93% of NHS Trusts utilised outsourcing to manage demand for reporting costing a total of £143m (Royal College of Radiologists, 2023). It is established that reporting radiographers provide a range of service delivery improvements related to maintaining reporting demand (Care Quality Commission, 2018), and with regards to outsourcing provide a resourceful way to reduce costs. The points above illustrate the benefits to the reporting service and current practices, but there is also advantage to be gained regarding staff retention and recruitment. Certainly, recommendation 13 of the Richards Review of Diagnostic Services (Richards, 2020) states that there should be a minimum of 50% increase in advanced practitioner roles, including the reporting of radiographic studies. Funding opportunities are available for training senior staff members to become reporting radiographer through the *Cancer Workforce Plan* (Health Education England, 2017a). If radiology departments can leverage the personal development aims and training needs of current staff in line with the Richards recommendation and in conjunction with the Health Education England (HEE) funding, then this would provide a useful method of retaining staff. It was previously suggested that opportunities for radiographers to progress their career along a reporting pathway could influence choice of employment destination (Price & Le Masurier, 2007), radiographers at neighbouring hospitals may see the opportunity to progress in to reporting trainee post as a reason to move. Therefore, changing or developing current radiologist-only radiographic reporting practices to involve reporting radiographers would likely improve any retention and/or recruitment issues.

This section has shown how PCE can impact positively on current practice, such as removing the ambiguity associated with red dot, increasing clinician/observers' confidence and preventing false negative errors and mismanagement. Evidence of the impact of the continuing progression and development of reporting radiographers was also highlighted illustrating the benefits to the wider radiology service and the workforce. The next section will show the types of wider impact of the included published works.

8. Evidence of impact

This section will provide justification for the majority of papers being published in *Radiography* journal and will also highlight the pivotal role of the works in introducing a policy change in new and forthcoming UK guidance. Other areas of impact that the papers have had to date will also be discussed.

8.1. Assessing impact.

Determining the impact of work is recognised as a challenge as the benefits generated by published research may not be immediately tangible to the author. However, measurable impact metrics can be accessed on various digital platforms that show the number of citations, reads and downloads of an article. The University of Salford (University of Salford, 2023) holds a holistic belief that the impact of research is wide-ranging with a multitude of benefits for our world encompassing improvements to society, the economy, the environment, technology, and community wellbeing. To utilise a more focused approach to assessing impact, the *Research Impact Framework* developed by Kuruvilla et al., (2006) identifies four broad areas of health research impact,

1. Research-related impacts,
2. Policy impacts,
3. Service impacts, and
4. Societal impacts.

This framework provides a simple yet effective approach for developing impact narratives and for assessing where published research findings are having the greatest impact. It is used within this work to highlight the types of impact the included papers have had to-date with impact principally in the research-related and policy impact domains. Research-related impact includes citation analysis and influencing the research direction of a fellow researcher. Policy impact relates to how the papers have contributed to shaping professional policy. At present there is currently no published evidence of any service or societal impacts of the included works, however the findings from these studies will hopefully lead to an improvement of the services offered by radiographers relating to the interpretation of radiographic images, which in turn will improve the service provided by referring clinicians and ultimately the experience of patients with improved quality of care. With a more insular view, it may enhance the worth of radiographers amongst other health professional groups possibly helping to foster improved inter-professional relationships. It is important to recognise that it is accepted that not all impacts should be expected or even targeted all the time (Kuruvilla et al., 2006). Overall, these papers illustrate a substantial contribution to the expanding PCE research base with clear evidence of influencing policy change. It is believed that the niche and specific nature of these studies, often providing pioneering results, demonstrates that these works are at the forefront of the clinical development and progression of the PCE system.

8.2. Research-related impacts.

The depth of research-related impacts can be illustrated by undertaking a citation analysis across a number of repositories to generate an understanding of the frequency of which the works have been cited as supporting references in subsequently published literature. The impact of an individual's work is often assessed by the subsequent number of citations in peer-reviewed published research articles suggesting that an article is considered useful by other researchers, though it is acknowledged that the number of citations do not necessarily correlate with article quality (Nightingale & Marshall, 2012). Table 2 below shows the number of citations of each of the included papers and there is also inclusion of some alternative research metrics providing insight into how individuals have interacted with the papers on social media, for example. At the time of submission, the author has 15 published articles in peer-reviewed journals, a *h*-index of 7, an i10-index of 7, and a ResearchGate Research Interest score of 69.2 (accurate as of 06/12/23).

It is not unexpected that the oldest of the included works has the most citations, nor that the most recent three articles have the fewest citations. It is unfortunate that paper 3 has only been cited three times when one considers the design of the paper in assessing the impact of the PCE on the decisions of key stakeholders in the PCE system, as well as the positive findings. The intention behind publishing this article in the *International Emergency Nursing* journal was to provide a wider reach with potentially greater effect in terms of convincing the main benefactors of the PCE service, based on the study findings. Submitting this paper to an international nursing journal, which requires a subscription to read online, may have provided a wider readership to communicate the findings to, but this has been at the expense of potentially increased citations that may have occurred if it was published in *Radiography* journal, which members of the SCoR who are research-active and/or engaged in research have free access to.

Radiography journal was chosen for papers 1, 2, 3, 5, 6, 7, 8 and 9 because it provides a vast radiographer readership with over 500'000 full text articles downloaded per year (McNulty, 2022). *Radiography* journal is an international journal indexed on MEDLINE® with an impact factor of 2.66 and a CiteScore of 2.6, in 2022. Participants and studied subjects were radiographers and the nature of the findings were also contributory in determining dissemination in a journal specific to radiographers. Additionally, considering the low uptake of radiographer commenting and radiographer reporting internationally it was decided that the greatest benefits of these findings would be experienced by UK-based radiographers and UK sites. Another deciding factor was that the *Radiography* journal has been the official journal of the European Federation of Radiographer Societies (EFRS) since January 2016 (European Federation of Radiographer Societies, 2020a), thus providing an extended readership throughout Europe encompassing 100'000 radiographers, 8000 radiographer students, 40 National societies/professional bodies and 60 academic institutions of radiography education (European Federation of Radiographer Societies, 2020b). Overall, submission to *Radiography* journal for these 8 papers offered the greatest potential for the findings to influence changes in practice and/or policy.

Influencing the research direction of a fellow researcher is considered as another example of research-related impact. A fellow researcher may plan, carry out and publish a study that replicates the aims and method of an individual's already published study, introducing translatability of research. There are three examples of this relative to paper 2 that assess the scopes of practice of MRI and CT reporting radiographers (Estall & Mitchell, 2021; Lockwood, 2020; Mitchell & Lockwood, 2023). It is reassuring to know that other researchers appreciate the ideas behind paper 2, and the method utilised, to be interesting and worth replicating in another area of clinical reporting.

Table 2. The current number of citations and usage of the included papers.

	1	2	3	4	5	6	7	8	9
Year of publication	2018	2019	2020	2020	2021	2021	2022	2022	2023
Google Scholar Citations	22 (6)	15 (2)	3 (3)	4 (3)	7 (1)	5 (3)	0	1	0
Scopus Citations	16	14	3	4	8	5	0	1	0
Tweets	15	14	19	10	20	22	10	7	0
Mendeley Readers	73	61	23	27	41	23	6	11	10
ResearchGate Citations	19	15	3	4	8	4	0	1	0
ResearchGate Reads	302	108	55	33	43	32	31	37	33
ResearchGate Research Interest Score	14.1	7.3	0.9	0.8	4	0.9	0.3	0.3	1.6

Number of self-citations in parentheses. Correct as of 06/12/2023.

8.3. Policy impacts.

One of the desired outcomes for the author when undertaking research in the healthcare setting, alongside producing new and exciting results, is for the findings to have an impact upon professional practice through the shaping of new policy or development of new practices that ultimately improve service provision. This is reinforced by aim 2 of The College of Radiographers *Research Strategy 2021-2026* (College of Radiographers, 2021), which aspires to,

> "Increase high quality dissemination of radiography research both within and outside the profession with a focus on maximising impact on patient care and service delivery."

As a member of the SCoR working committee[4] that was tasked with revising the out-dated PCE guidance document produced by the SCoR (Society and College of Radiographers, 2013), the author and colleagues have actively engaged with the findings of this portfolio of works. Evidence of the impact of the PCE-related papers (papers 1, 3, 4, 6 and 8) influencing official UK radiography policy is demonstrated by the influence of the relevant works in the currently unpublished and updated PCE guidance document from the Society and College of Radiographers (n.d.), in which these papers are acknowledged as supporting references. There is clear indication within the document where the findings and recommendations from the papers listed above have shaped the guidance within the document. For example, reiterating the impact and benefits of PCE (paper 3), advocating the implementation of abnormality detection training during preceptorship periods (paper 1), the use of bullet points (paper 6) and short comments (paper 4), comment structure (paper 6), and providing evidence supporting the expansion of PCE into extra-skeletal anatomical areas (paper 8).

It is acknowledged that the included works may not be as influential outside of the UK, especially articles 2, 5 and 7 that provide evidence to advocate and support the work of reporting radiographers, when the reduced implementation of advanced and extended roles in other countries is considered (al Shiyadi & Wilkinson, 2020; Alahmari A, 2020; Cowling, 2008; Elshami et al., 2022; Van De Venter & Ten Ham-Baloyi, 2019; Woznitza, 2014). However, progression is noted in Australia with numerous published studies (Alexander-Bates et al., 2021; McConnell & Baird, 2017; Neep et al., 2014, 2019; Royal Australian and New Zealand College of Radiologists, 2018) grounded in preliminary image evaluation (PIE), which is the accepted terminology in Australia). Implementation in Australia and New Zealand is often resisted, arising from confusion between commenting and formal reporting, perpetuated from a previous position statement from the Royal Australian and New Zealand College of Radiologists (RANZCR) (Royal Australian and New Zealand College of Radiologists, 2018). The Australian Society of Medical Imaging and Radiation Therapy (ASMIRT) published a response in support of radiographers regarding commenting and reporting (Australian Society of Medical Imaging and Radiation, 2019), in which paper 1 was listed as supporting evidence. This illustrates the international reach of the study findings by supporting an international

[4] The SCoR working committee was comprised of a Professional Officer from the SCoR, and selected members from the Diagnostic Radiographers Advisory Group and the Consultant Radiographers Advisory Group.

professional body in their endeavours to develop a radiographer commenting system and progress the profession.

This section outlined the different prominent aspects of impact of the papers whilst providing justification of publication decisions. A self-reflection section follows next, covering aspects of the critical analysis process, reviewing experiences of co-authorship and outlining future aspirations.

9. Future aspirations and self-reflection

The process of completing this PhD pathway provided the ideal opportunity to reflect on the submitted papers and to critically analyse the methods and the findings, and their impact. This section offers insight into the retrospective analysis of the author as they progressed through this process.

This PhD by Published Works pathway has illustrated areas for improvement that will enhance the undertaking of future research projects. It has also been insightful to evaluate the position of the papers and to see how they have contributed to the radiography evidence base. When each of the papers were published, there was a great sense of achievement and self-gratification. Paper 1 was my first experimental study and to be able to analyse the findings and provide recommendations for peers instilled a desire to carry out further research to evaluate other aspects of radiographers' interpreting and describing abnormalities.

Undertaking these studies has kept me actively engaged in research over the last six years and has provided me the opportunity to fulfil the research expectation stipulated within the four pillars of advanced practice (Health Education England, 2017b). Furthermore, the process of critically evaluating the submitted papers and synthesising the key themes into the narrative, whilst understanding the contextual relevance of the papers in juxtaposition of previous and subsequent research, provides additional evidence of meeting the research domain requirements. In addition to this, the findings from the observer studies identified further development needs of individuals, and possibly wider teams, and provide recommendations to address these issues, thus evidencing fulfilment of the education pillar of advanced practice (Health Education England, 2017b). This process has also provided me with the platform to potentially progress into academia at a later stage in my career.

9.1. Philosophical Stance

The critical review of the included papers has provided an interesting insight into the approaches chosen for these research projects. Most of the papers are of a quantitative nature (papers 1, 2, 3, 4, and 8), and some utilised a mixed methods approach (papers 5, 6, 7 and 9). On reflection, there was never a conscious decision to specifically choose one method over another, rather the aims and objectives of the study guided the type of approach required. It is interesting to note that the ontological, epistemological, and axiological foundations that underpin the submitted quantitative papers resonate with the personal preferences of the author. Analysing quantitative data was more comfortable compared to word data; analysing an absolute truth rather than interpreting multiple realities and attempting to eliminate any biases affecting outcomes. These preferences, along with research interests and the nature of observer performance-based research, have subconsciously instilled an objectivist ontology, a positivist epistemology and value free/neutral axiology. When undertaking the mixed methods studies there was a natural leaning towards the opposite ends of the continua concurrently; subjective ontology, interpretivist epistemology and value laden/bound axiology.

9.2. Co-authorship experiences

9.2.1. Positives of co-authorship

Overall, I found writing with co-authors to be very rewarding. Smith (2015) describes the benefits of collaboration as fostering confidence and resilience. This was certainly true throughout the last 6 years as it became less daunting for me to design and start subsequent studies, most evident through the undertaking of two studies (paper 5 and 8) during the challenging restrictions of the COVID-19 pandemic. Working with more experienced authors who were academically based at HEIs has helped to shape my preferred methods of inquiry and style of investigation. My writing skills and style of writing have developed considerably throughout the course of the submitted papers. Having co-authors to review and edit the written work with constructive feedback has been a useful and welcome addition to the research process. Additionally, having a co-author to share the burden of responding to reviewer feedback following submission is another welcome benefit. I found this to be beneficial and certainly eased the strain and stress associated with revising a manuscript.

My development was utilised when I was part of a project where I was the experienced researcher, and my co-authors were novices. I enjoyed the challenge of directing writing tasks and trying to encourage their progress. The opportunity to involve them in the process was viewed as a way to hopefully spark their desire to start their own research journey or to want to be involved in more research projects. I found that having more than one person to contribute to the data collection and analysis, drafting, revision and the final approval stages was welcome as it helped lessen the workload and provided different perspectives on those processes, which enhanced the final outcome (International Committee of Medical Journal Editors, 2022). This study was published and is included in this thesis as paper 5.

9.2.2. Associated issues.

Despite the positive aspects associated with having co-authors there were some issues encountered during the studies that created unease. Task completion delays and the missing of deadlines that I had set were the biggest issues experienced and this created a degree of stress and anxiety. Understandably, co-authors will have their own daily schedules and challenges to contend with, likely with greater importance than that of reviewing a piece of text. The anxiety of the author likely arises from their usual pace of completing writing tasks as a sole author not being met, and perhaps being overly pro-active, resulting in unrealistic expectations. Another factor that may exacerbate these feelings is the time allocated for supported professional activities (SPA), as part of my consultant radiographer job plan, in which research tasks can be completed in a timely manner. Co-authors may not have this luxury. This is something to appreciate moving forwards and when working on collaborative projects in the future, especially so in light of recent research which suggests that lack of dedicated research time (Vils Pedersen, 2023), or a poor departmental research culture (Watts & Snaith, 2023), may hinder commitment to research projects.

9.2.3. Limitations

Limitations exist throughout the submitted papers that prevent the findings from being generalisable across the whole of radiography in the UK. The small sample sizes in mainly locally based studies is recognised as a compounding limitation. Additionally, in the survey studies the effects of non-response bias may have affected the findings and this must be acknowledged. The undertaking of two of the studies were impeded by the COVID-19 pandemic, which markedly reduced participation rate (paper 5) and affected the preferred education intervention approach (paper 8). However, the findings from all of the papers provide original knowledge, adding to the growing evidence base whilst also providing suggestions for future research investigations.

9.3 Future Aspirations

Considering that many of the included papers were undertaken on a local level and/or had a small sample size, there is a desire to produce a larger image interpretation study to be able to build on these findings. Given that the use of PCE is not commonplace in the rest of the world, though it is progressing in Australia (Alexander-Bates et al., 2021; Neep et al., 2014, 2018; Petts et al., 2023), it is thought that undertaking a larger, multi-national study would be best suited for implementation across Europe via access to the EFRS. Members of the EFRS have access to *Radiography* journal so they will already have been exposed to a multitude of research articles relating to PCE, subsequently there is an increased chance that they will have good understanding and knowledge of PCE. This would increase the potential of a multi-national study across Europe being successful. When considering the possibility of undertaking a larger study in other parts of the World, the likelihood of success is reduced due to the under-development of extended radiographer roles (al Shiyadi & Wilkinson, 2020; Alahmari A, 2020; Cowling, 2008; Elshami et al., 2022; Van De Venter & Ten Ham-Baloyi, 2019; Woznitza, 2014). No other countries allow the autonomous nature of providing a free-text comment as is seen in the UK and Australia, but even in Australia it is not a widespread, accepted standard practice. There has even been confusion and misunderstanding regarding the undertaking of PCE, previously being mistaken for clinical reporting in Australia (Australian Society of Medical Imaging and Radiation, 2019; Royal Australian and New Zealand College of Radiologists, 2018). Therefore, it is not deemed appropriate at present to undertake a study outside of Europe. The aim would be to generate a wider understanding of the issues that arose in the included papers to investigate if they are a national or international-issue or whether there are other regional nuances and/or obstacles associated with radiographers providing a PCE.

The ideal study would be hosted on an online website and participants would register online using their professional registration number, they would then be sent an automatically generated username and password. Once access has been granted, the website would provide some background information about the study and what the aims and objectives are, and participants will provide their consent to participate. The website would incorporate the ROCview software (Thompson et al., 2012) and will provide a short training module for participants to understand how to use the software correctly. Upon completion of the study, all answers will be automatically sent to a database or spreadsheet and will be completely anonymised. Analysis will be completed once the required number of responses has been obtained to achieve a pre-agreed study power analysis. The financial, logistical, and technological challenges associated with a study of this magnitude are recognised as the greatest barrier to fulfilling this prospective research idea. It is also recognised that the harnessing of collaborators' expertise is necessary for a study of this magnitude and requires a great deal of planning. However, following completion of this programme there is an intention to secure funding, potentially from the College of Radiographers Industry Partnership Scheme (CoRIPS) or other research funding streams to facilitate the planning, development and carrying out of an online, wide-scale image interpretation study based on radiographers providing a PCE.

Another area for further study incorporates assessing how or if the newly updated PCE guidance document, when published, is impacting on undergraduate training and/or clinical practice. Papers in this thesis informed a number of elements of this document, as outlined in section 9.1.2 *Policy Impacts*, and it would be interesting to know if these findings are influencing HEI undergraduate curricula. Another interesting opportunity for investigation is assessing whether there is any benefit in the application of PCE in other modalities. Whilst a typed or written description of an abnormality is well suited for ED X-ray presentations and workflow, it may be that a written description may not be of any use in acute CT and MRI examinations, given the potential life-threatening urgency of pathology, such as intracranial haemorrhage on CT scans, for example. The most appropriate method of communicating these types of findings would likely be through immediate verbal escalation, which in essence stems from a primary clinical evaluation. Subsequently, this would create sub-categories of PCE, verbal escalation and written description. A survey of current practices evaluating the input of radiographers regarding the conveyance of urgent findings in other modalities would be an interesting development of the current work.

This section has provided insight in to the critical self-reflection process undertaken throughout this PhD by Published Works pathway and has highlighted a number of areas for development for the author when undertaking future research projects and when working with co-authors. The next section will provide a final summary of the thesis.

10. Summary

In summary, radiographers are capable of interpreting and describing radiographic abnormalities in the context of PCE, and the PCE can positively affect referrers decision making. It is acknowledged that improvements in performance can be made with regular training sessions covering specific focussed teaching on pathologies and structure. The progression of reporting radiographers, as demonstrated over the short chronology of the relevant papers, continues with increasing reliance to provide a large proportion of general radiographic reports through evidence of larger numbers of reporters, a greater allocation of reporting time and the increased number of radiographers reporting CXRs.

This thesis has presented a critical narrative synthesising the findings from the nine submitted papers. The curated key findings from each of the papers founded the three themes. Papers 1, 4, 6, and 8, provided contributions to two themes each. Papers 1, 4 and 8, formed theme 1 based on radiographers' ability to recognise radiographic abnormalities and to provide accurate written descriptions suitable for use in a PCE system. Papers 1 and 8 incorporated a unique method of concurrently assessing abnormality location accuracy and PCE accuracy that had never been used before and showed that radiographers' ability to recognise and describe radiographic abnormalities can be improved with training. Paper 4 provided insight into the informational content of PCE comments provided by radiographers. Papers 1, 4, 6, and 7, combined to establish theme 2 to provide guidance for provision of a clinical report and a PCE. Papers 1 and 4 illustrated training issues and provided recommendations to improve performance. The preferences of PCE content and style of ED referrers were discovered in paper 6 and the types of report style preferred by referrers in different referral settings were determined in paper 7. Theme 3 was conceived from papers 2, 3, 5, 6, 8, and 9, emphasising the impact of radiographers interpreting and describing radiographic abnormalities, encompassing PCE and the progression and development of reporting radiographers. Papers 2 and 5 illustrated the continuing and progressive reliance on reporting radiographers, as well as the perceived benefits of CXR reporting radiographers (paper 5). Paper 3 proves how removing the ambiguity associated with red dot and replacing it with PCE impacts positively on practice with increased interpretive confidence in referrers and reduction of false negative errors, and subsequent mismanagement. Paper 6 notes the welcoming attitudes of ED referrers towards PCE, and while paper 9 shows some progression in terms of proportion of sites using a PCE system and the introduction of CXR into the scope of practice, paper 8 recognised that there are areas for further training regarding the inclusion of CXR in PCE system.

The extent of authorship throughout the submitted papers demonstrates an ability to conceptualise, design and undertake a research study. Each of the published papers provide new knowledge from original research studies that satisfied a peer review process. Original contribution to evidence relative to enhancing and advancing radiographic practice is demonstrated throughout all the works included, but most pertinently in those grounded in reporting by radiographers. These works illustrate the progression of advanced practice relative to reporting by radiographers and provides further understanding behind the growth of reporting radiographers. Those papers based on PCE provide evidence of contributing original evidence documenting the novel areas that were explored and provide findings relating to various combinations of specific users, specific anatomy, and structural and content guidance. These papers are placed at the forefront of professional practice with clear evidence of policy impact as well as multiple citations and reads. Overall, this thesis proves fulfilment of the attainment criteria expected of a doctoral degree qualification, as outlined by The Quality Assurance Agency (QAA, 2014).

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Appendix 1 – PhD Cohort Training Course

The Cohort Training course was a required component of the PhD by PW programme. Sessions were provided weekly across the first semester of the PhD programme and were designed to provide a foundation for the PhD pathway.

Date	**Time**	**Title**	**Description/What did I learn**
5th June 2023	10am-12pm	Managing Researcher Relationships and the learning agreement	This session focused on my relationship with my supervisors. It focused on the expectations and responsibilities of the supervisor, my personal tutor, and what is expected of me as a Post-Graduate Researcher (PGR) student. I found this session very useful in understanding what I can expect from my supervisors. It was also useful in being aware of how to complete the learning agreement between myself and my supervisors
9th June 2023	10am-12pm	Ethics and Data Management Training	This session provided guidance on best ethical practice and on how to complete Ethics Applications, however because of the retrospective nature of PhD by Published Works, ethical approvals have already been obtained. This was a useful session in understanding what I needed to do to obtain ethical approval from the university. I also learned an important lesson regarding good data management, which I will carry with me for future

			research studies. Guidance was also provided on secure storage of data and sharing of documents, again this will be utilised moving forward with future studies.
16th June 2023	10am-11am	Mind Your Head: Maintaining Your Wellbeing as a PGR Researcher.	This session discussed strategies to help maintain a work-life balance and my wellbeing during this PhD by Published Works pathway. It was useful and interesting to know what resources are available at the university. It was also reassuring to know that support is there, if/when needed
23rd June 2023	10am-12pm	Introduction to Library Services (ONLINE ONLY)	This introduction session introduced the vast amount support services offered by the library. This session was specifically targeted at PGR students and designed to provide support to find research resources and potential research-training opportunities. It was a little overwhelming to be made aware of the number of resources available, but a very useful session nonetheless.
7th July 2023	10am-12pm	Philosophical Approaches to Research 1: Ontological Foundations	These three sessions were interesting and provided opportunity to reflect on each of the submitted papers with regard to philosophical stances and the approaches used. These sessions helped to develop my awareness of ontological foundations, epistemology and the axiological dimension of my research. The submitted papers were undertaken with total disregard to any types of philosophical approaches and foundations, this was not a thought when planning these papers. But, by reflecting on the paper it was good to see that the
12th July 2023	10am-12pm	Philosophical Stance for Research Methodology	

		2: Epistemological Foundations	types of studies that I had undertaken, and their associated philosophical approaches and foundations, were generally aligned with those that I would choose to apply to my research ideas.
14th July 2023	10am-12pm	Philosophical Stance for Research Methodology 3: Axiological Foundations	
21st July 2023	10am-12pm	Philosophical Stance for Research Methodology 4: Methodological Design	This session was good for forming my philosophical positionality. Examining the research methodologies used in the submitted papers helped to form my philosophical stance, as outlined in section 10.2, incorporating my ontological, epistemological and axiological foundations.

Appendix 2 - 1:1 Writing support session.

Date: Thursday 5th October 2023.

This was a free session organised by the Researcher Development Team at the University of Salford. The session was with Chris Simms a Writing Consultant and Royal Literary Fellow, will be available to provide 1-to-1 writing support.

I provided a 1000-word text sample, which Chris reviewed and provided initial feedback with tracked changes on the document, prior to the session relative to aspects of writing that I requested help with. The online Zoom session lasted for 50 minutes, and Chris went through the tracked changes and comments, providing feedback with suggestions for improvement. Following the session, Chris emailed some resources that were designed to help in using the active voice and also achieving and improving flow between sentences.

Overall, I found this session very useful, and I think it has helped me during the editing phases of producing this thesis.