Image acquisition in general radiography: the utilisation of DDR

**Word count: 3, 946**

# Abstract

**Objective:** This article explores image acquisition with DDR. General radiographic technology continues to advance therefore it remains paramount to continually reflect on DDR hardware and software amongst radiographers in an imaging modality that constitutes approximately 90% of all radiological examinations.

**Method:** This article reports findings from a wider ethnographic study of two general radiography environments in the United Kingdom (UK). Participant observation and semi-structured interviews were the methods used to uncover original data.

**Results:** Two key themes are discussed. Firstly, ‘the extent of DDR knowledge’ amongst radiographers is examined. The findings uncover that not all radiographers have an adequate knowledge base with DDR technology. Secondly, ‘pitfalls and near misses with DDR’ is discussed. This theme highlights the potential danger of radiographers ‘over-repeating’ X-ray examinations, coincided with the occurrence of radiological incidents whereby a patient is exposed to ionising radiation with no added benefit.

**Conclusion:** This paper concludes by challenging the current ‘skill base’ to operate DDR equipment. In addition, new pitfalls and near misses are highlighted, which may help forestall radiation incidents in the future. Dose and image optimisation remain central tenets to the role of the radiographer.

**Advances in knowledge:** Few studies have challenged image acquisition with DDR. This study adds to existing knowledge by uncovering original phenomena that may initiate discussions within the radiography community and continually enhance healthcare delivery.

# Introduction

This article explores image acquisition within the direct digital radiography (DDR) environment. Image processing using DDR is important to evaluate as healthcare continues to rely on technological advances to facilitate patient care and experiences.1,2 The development of technology within general radiography has progressed rapidly in recent years. The introduction of computed radiography (CR) enabled the exploration of dose optimisation within general radiography,3,4 yet the advent of DDR has identified further improvements in image optimisation.5 DDR is reported to offer ‘easy availability, lower costs, faster imaging times, combined with excellent resolution, imaging contrast and lower dose for patients.6 (p.425) In addition, radiographers in the United Kingdom (UK) are required to keep ionising radiation ‘as low as reasonably practicable’ (ALARP), whilst maintaining an optimum diagnostic image.7,8 To date, numerous experimental studies have identified dose optimisation by utilising digital technologies,9-13 yet whilst these studies demonstrate methods of dose reduction by employing innovative techniques, previously reported findings from this study identified the problematic use of DDR in contemporary practices.14 Snaith15 importantly recognises this potential dichotomy, challenging whether evidence based radiography is actually happening or whether clinical practices are drifting and/or creeping away from evidence based research.

The National Health Service (NHS) and Society of Radiographers (SoR) affirm that practitioner skills should continually improve health and save lives of patients16 (p.1), 17 (p.2), yet it is important to acknowledge that radiographers are humans and may experience limitations in knowledge and/or make errors within the clinical environment. The National Institute of Medicine (NIM) recognise the importance of reflecting on errors/near misses in practice in a publication titled ‘To Err is Human – Building a Safer Health System’.18 The Royal College of Radiologists (RCR) and the SoR support this assertion because if/when errors do occur they should be recognised and used as opportunities to avoid future errors and improve radiographic services.19 Few studies have challenged the potential implications of new radiographic technologies for diagnostic radiographers and patients in general radiography. Advancing technology is often ‘pushed’ into working environments, requiring practitioners to adapt and undergo additional training for optimal clinical use.20 In response, this paper focuses on image acquisition and associated pitfalls and near misses following the introduction of DDR in order to help forestall poor performances in the future. Messer and Meldrum21 remind the reader that failing to recognise areas of improvement can lead to overt denials in errors occurring within healthcare environments. The objectives of the study were to explore the utilisation of image acquisition with DDR in two typical radiographic departments.

# Methodology

Qualitative methods allowed the researcher to explore radiographic cultures underexplored within the DDR environment. This large study has findings related to dose creep and person-centred care that have been previously reported.14, 21 This article reports additional findings from the same study.

## Selection of sites

Research sites were selected because DDR was installed and used by radiographers on a day-to-day basis. Site A and B were acute trauma centres, which utilised DDR for a number of general imaging procedures. Ethical applications were submitted and approved by each hospital Trust located in the south east of England (approval numbers - site A - ref: 2012/RADIO/02 and site B - ref: R&D449). Participants were selected based on three inclusion criteria; be registered as a diagnostic radiographer with the Health Care Professions Council (HCPC), willing to participate in the study and have recently worked within the general imaging department operating DDR technology.

## Ethnography

Ethnography can illuminate behaviours of individuals and groups within a particular culture. Empirical fieldwork recorded behaviours and actions of radiographers within the X-ray room(s) aiming to understand the actions and experiences of radiographers acquiring radiographs with DDR. Participant observation(s) allowed the researcher to collect rich data investigating image acquisition, supporting the development of the interview schedule with radiographers. The use of interviews were later conducted to ‘clarify the nature of situations observed by the researcher’ in the clinical environment and reduce any observer bias in data collection and analysis.

## Participant Observation

Overt participant observation began in October 2012 and finished in March 2013. As a registered diagnostic radiographer with the HCPC the author was obliged to intervene if a staff member and/or a patient became at risk throughout the observations. This is important to consider methodologically in this paper because on occasions the author did intervene to prevent radiological incidents from occurring in the clinical environment, which is discussed later. Advantages of overt participation include complete openness with the research participants and the ability to openly collect data whilst informally discussing aspects of image acquistion.23 Finally, as an overt observer it was less likely for the researcher to ‘go native’ thus remaining an observer and not wholly a participant.24 It is important to note the potential of observer effects in ethnographic research. During the observations some radiographers altered their radiographic practices, demonstrating the occurrence of the Hawthorne effect.23, 24 However, following two months of observation participants became familiar with the researchers presence and his use of insider knowledge as a diagnostic radiographer, minimising the Hawthorne effect.23 Whilst insider knowledge is important to learn, understand and collect cultural phenomena, minimising observer bias remains paramount. Hammersly and Atkinson22 (p.100) assert that the role of the ethnographer is to remain objective, accessible and friendly and therefore may adopt a variety of roles that maintains a more or less marginal position. Ethnographers must be intellectually poised between ‘familiarity’ and ‘strangeness’, whilst socially poised between ‘stranger’ and ‘friend’.22 (p.100) This on-going reflexive approach by the researcher with the participants limits the possibility of observer bias towards researched phenomena.

Participant observation allowed the exploration of local cultures in accordance with the research objectives using inductive reasoning by observing ‘what radiographers do and how they do it’. The rationale for this inductive approach stems from the authors philosophical perspective of interpretivism and social constructivism, allowing the data to emerge within the radiographic culture(s). Upon seeking informed consent observations of radiographers began. Throughout the observations 36 radiographers were observed over 19 days. Research sites, radiographer experience and professional rank are depicted in table 1 for the reader.

**Table 1: Radiographer experience and professional rank during in study**

|  |  |  |  |
| --- | --- | --- | --- |
| Site | No. participants with experience ≤ 5 years (observations and interviews) | No. participants with experience≥ 5 years (observations and interviews) | Professional Rank |
| Band 5 | Band 6 | Band 7 |
| A | 10 | 18 | 12 | 11 | 4 |
| B | 19 | 11 | 14 | 12 | 5 |
| Total | 29 | 29 | 26 | 23 | 9 |

Observations identified ‘what radiographers did’, supported with informal discussions surrounding the use of the DDR at each site. Observations were detailed in nine dimensions, as identified in table 2.25 (p.5) Site A had used DDR since 2006 and site B since 2011. Hand written notes captured behaviours, attitudes and views of radiographers documenting clinical experiences. This was later analysed and informed the development of the interview schedule.

**Table 2: Features observed within the DDR environment**

|  |  |
| --- | --- |
| Features Identified | Features of X-ray Environment |
| 1. Space | Identification of the surrounding layout of imaging department and equipment to the other clinical rooms and areas.  |
| 2. Actors | The radiographers involved in the situation and their pseudonyms. |
| 3. Activities | The various related activities of radiographers utilising DDR. |
| 4. Objects | The physical elements present e.g. in the X-ray room and X-ray equipment.  |
| 5. Acts | The actions of radiographers producing images of diagnostic quality. |
| 6. Events | Activities of radiographers, such as image acquisition within the X-ray room. |
| 7. Time | The time sequence in performing a DDR examination and finishing it. |
| 8. Goals | The activities people are trying to accomplish in particular situations. |
| 9.Feelings | Emotions in particular contexts. |

## Semi-structured interviews

Twenty-two semi-structured interviews were undertaken at sites A and B. The radiographers observed were invited to attend the interview. This was important because it allowed the researcher to discuss ‘what had been seen and discussed’.23 Variation of radiographic experience was important in this study because it provided alternate points of view, producing rich and varied data.26, 24 Interviews explored how much knowledge and/or understanding radiographers had with DDR. Further, errors and nears misses were explored with the aim of uncovering radiological hazards. A digital audio device was used to record participants’ voices verbatim and is represented by quotations. Participants are represented by a gender specific pseudonym, maintaining anonymity. Thematic analysis was employed to analyse the qualitative data at sites A and B.The collated data was gathered, compared and divided into general themes. The questions (and prompts) posed to radiographers to better uncover the utilisation of DDR are detailed below, enhancing reproducibility:

1. *Can you tell me how much knowledge and/or understanding you have about DDR?*
	1. *Prompt – Is this appropriate?*
2. *Do you think technology such as DDR is having an affect on the radiographic profession? If so or not can you provide some examples of this?*
	1. *Prompt – How about radiography students?*
3. *Can you identify areas where DDR hinders your clinical practice?*
	1. *Prompt – Danger of over-repeating X-ray examinations?*
4. *How do you feel about the environment, setting and arrangement of the DDR equipment? And how do you think this could be improved for the operator?*
	1. *Prompt – Detector selection? Patients receiving a radiological exposure with no radiograph produced.*

## Trustworthiness of qualitative data

In order to test the reliability and validity of this paper, credibility, transferability, dependability and confirmability were considered as part of the larger study. These remain the most useful criterion within the radiography qualitative framework ensuring trustworthiness of data.26, 27 (p.65)

# Results and discussion

The results presented in this article are part of a larger dataset uncovered. The scope of this paper discusses the ‘extent of DDR knowledge’ and ‘pitfalls and near misses with DDR’. It is important to note that the data highlighted in this paper cannot be fully generalised, yet the findings may resonate with other radiographers nationally and/or internationally.

## Extent of DDR knowledge: are radiographers being deskilled?

A common theme identified within the study challenged the extent of knowledge of DDR technology amongst radiographers. This was first documented by informal discussions with participants. Initial discussions revealed that radiographers may not have sufficient knowledge when undertaking radiographic examinations using DDR. In the UK radiographers have a pivotal role in modern healthcare and it is generally accepted that practitioners operating general X-ray equipment have an adequate knowledge base concerning image acquisition, thus facilitating the production of a digital radiograph.28, 29 Geoff, a participant in the study reported the importance of receiving theoretical knowledge at his University, enabling him to ‘know how’ radiographs are produced in the clinical environment:

Geoff: *“They [University] covered everything. They basically teach you all the products that are involved, what the products are made up of - the detectors, how they’re produced, how they’re manufactured, what they do.”*

Firstly, this narrative suggests that Geoff has received sufficient knowledge of image acquisition with DDR technology. Secondly, it affirms that if Geoff has knowledge of DDR hardware/software, Geoff can consider dose optimisation, as identified within the literature.10, 11 This arguably suggests that an appropriate level of knowledge of advancing technology remains essential within a ‘digital era’ to produce images of diagnostic quality. However, other participants in this study acknowledged limited knowledge with DDR technology in the clinical environment:

Elizabeth: *“I don’t know any of the aspects behind how it [DDR] works. I think that’s a lack of knowledge that we don’t actually have [sic].”*

Emile: *“Up to now - I have to be honest with you - I still don’t quite understand the concept [of DDR]. Though I can imagine what is going on I would like to know. Maybe it’s not within my level, but you’d want to know the technical side of things a bit more, so that you understand the process.”*

Annabelle: *“Definitely. And I think I can honestly say that I don’t have the necessary understanding and I am using it [DDR] without that knowledge. And I think it’s important.”*

The data above suggests that whilst participants undertake general radiographic examinations, they may lack essential knowledge of ‘image acquisition processes’ associated with DDR. A core principle of radiographic practice is the optimal delivery of ionising radiation whilst producing radiographs of diagnostic quality, yet without appropriate knowledge of technological hardware and software radiographers may lack an ability to optimise images and keep doses ALARP. Previous studies have highlighted that newly qualified radiographers’ may struggle to justify radiological requests29 and perform radiographic duties in theatre,30 yet the data above suggests that radiographers of varying experience may struggle with digital hardware and software in contemporary practices and thus may fail to acquire optimum radiographs as expected. Further, the introduction of advancing technology enabled radiographers to question the ‘required skill’ to produce a digital radiograph:

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

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

Harold and Elizabeth suggest that the introduction of DDR enabled radiographers to produce radiographs ‘without as much knowledge’, because the technology ‘does it for them’. This is important to discuss. On the one hand, radiographers may appear to have adequate knowledge due to the production of ‘a diagnostic image’. Yet, on the other hand, the lack of knowledge acknowledged by participants may remain unknown to radiology managers. Not only does this suggest a paradox of image acquisition, it suggests that radiographers may be ‘getting by’ in acquiring images with DDR. In the past, Ferris31 (p.81) identified ‘deskilling’ due to the removal of ‘reporting sessions’: ‘they (radiologists) just took it (reporting) off us’. This paper suggests an alternate facet to ‘deskilling’ challenging whether radiographers are beginning to rely on DDR to produce digital radiographs for them. Two arguments affirming this stand out. On the one hand, if radiographers begin to rely on DDR to acquire radiographs, this may benefit patients. For example, limiting radiographer subjectivity to produce images of diagnostic quality may enhance the delivery of ionising radiation following a recent suggestion (by the larger study) of suboptimal X-ray exposure selection using DDR.14 Examples of technological advances limiting human control are well-established within aeronautics, using autopilot technologies to improve airline safety. On the other hand, there is a danger that if practitioners decide to rely on DDR technology, this may lead to radiographers abusing technological advances, which may further hinder dose optimisation, gradually becoming the ‘cultural-norm’. Similarly, cultural-norms that have led to errors within aeronautics and identifiable in an observational study exploring the National Aeronautics and Space Administration (NASA).32 The study concluded that accidents on missions occurred due to small changes of behaviours by staff, which gradually became the norm. This suggests that radiographic cultures must find a balance between utilising DDR optimally, without abusing its advances. This remains paramount if radiographers are to maintain professional integrity and accountability as Braverman33 reminds us that advances in technology can deskill workforces:

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

 The conjecture that radiographers may become servants to DDR equipment is important to challenge in both contemporary and future radiographic practices. If radiographers feel they do not possess adequate knowledge of image acquisition processes with DDR hardware/software it could be argued whether radiographers are able to exploit advantages of DDR technology in order to facilitate dose optimisation. Further, if radiographers are to remain as image acquisition experts within the general imaging environment they must begin to critically reflect on technological advantages and limitations associated with radiographic equipment. This will ensure that radiographers do not become servants to machinery, but holistic healthcare practitioners.

##  To ‘err is human’: radiographic pitfalls and near misses using DDR

An additional theme central to image acquisition is ‘pitfalls and near misses with DDR’. It is reported that DDR facilitates patient care because examinations result in fewer retakes and reduce levels of ionising radiation.28 One advantage observed in this study was that DDR allowed radiographers to make immediate adjustments to radiographic positioning post-exposure, limiting patient discomfort:

Observation: *Patients requiring repeat radiographs with DDR were re-positioned immediately due to the technologies ability to produce immediate image acquisition. This allowed radiographers to critically reflect on digital radiographs* and *‘adjust’ or ‘re-position’ a patient to ensure sound positioning. These observed practices highlighted that patients were not required to be ‘fully repositioned’ if a repeat radiograph was required.*

Radiographers acknowledged this advantage using DDR whereby patients remained in their ‘radiographic position’ upon reviewing a radiograph. This enabled radiographers to make ‘fine adjustments’ to produce a radiograph of diagnostic quality:

Emile: *“You can quickly adjust because the patient is probably in the same position… with DDR you can actually see as soon as the image comes out: you look at it and you think “Oh, I think I need to adjust my angle.”*

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

The advantages cited by radiographers above provides insight of immediate image acquisition DDR technology whereby patients may benefit. Historically, FS and CR required radiographers to process an image in the viewing room, decide if a repeat was required and re-X-ray a patient if necessary, which may have cause additional discomfort. Whilst ‘the ease’ of repeating radiographic examinations is arguably less problematic with DDR, one caveat identified in this research is the danger of ‘over-repeating’ radiographic examinations:

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

Abigail: *“I think with DDR it’s so easy to repeat something. It’s so easy to do, and sometimes I’ve done it myself - where I’ve repeated something and I think “I don’t think I would have repeated that if it was CR.” You look at it differently and you think “The positioning - if I just turn that a tiny little bit…” and you think “Oh, just do it again.” And before you know it, you’ve done it three times…So I think that DDR is increasing the amount of repeats I do. I think it’s just so easy to repeat, if you know that something’s not quite right, you’re inclined to say “Oh, I’ll just take it and see what happens.”*

A recent publication stemming from the authors full dataset identified that patients may be hurried or rushed using DDR suggesting a diminishment in person-centred care.21 Further, this study adds to existing knowledge by challenging whether advancing technology enables radiographers to have a ‘hit and miss’ approach to image acquisition as radiographers can ‘…just do another [X-ray] if it’s not quite right’. Patient safety plays an important role in healthcare affecting the entire radiological pathway34 and whilst Peloschek et al35 affirm that the wide dissemination of DDR has facilitated the clinical environment by producing enhanced images of diagnostic quality, this article highlights some potential pitfalls.

 A ‘near miss’ uncovered by radiographers was the incorrect selection either ‘wall’ or ‘table’ detector, requiring the researcher to intervene (as discussed in the methodology). Selecting the wrong detector in the clinical environment would expose a patient to ionising radiation without the production of a digital radiograph, thus adding no net benefit to the patient. This ‘near miss’ was observed several times and later explored during one-to-one interviews to understand if it was a common occurrence amongst radiographers upon image acquisition. Radiographers acknowledged that during their daily practices this had occurred and remained a ‘safety issue’ resulting in patients being exposed to unnecessary levels of ionising radiation without the production of a digital radiograph:

Fred: *“There’s one really annoying thing with the [DDR] equipment that we use, which is that it will expose when it’s not over a detector.”*

Sharon: *“Sometimes it [DDR] will let you expose even though it’s not in the right place. The whole bucky can be in a completely different, random place. Its safety measures are backwards - they’re actually anti-safety measures. Even when you’ve got it linked up/locked in and it’s not in the right place sometimes, it lets you expose.”*

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

The data above highlights that patients have been exposed to unnecessary levels of ionising radiation within the DDR environment. This radiological incident remains central to reflect upon and notifiable under IR(ME)R legislation where a dose ‘much greater than intended’ has been delivered to an individual.36 It suggests that a combination of advancing technology and ‘practitioner error’ may lead to patients receiving ‘higher doses than necessary’, with no added benefit. Scalliet37 maintains that errors and anomalies can remain undetected for long periods if unreported, however by recognising such pitfalls and near misses this article may encourage radiographers, radiology managers and manufacturers to critically reflect on such radiation incidents. This is important to consider amongst radiographers nationally and internationally because X-ray incidents (however small) may pose added radiobiological risks to patients.8 Further, because radiographers are required to keep ionising radiation ALARP it remains paramount for the radiographic community to continually discuss, reflect and feedback limitations of advancing equipment to ensure optimum patient care delivery.

# Conclusion

This paper provides original insight of current knowledge, pitfalls and near misses using DDR in contemporary practices. Some radiographers recognised a lack of knowledge concerning image acquisition processes associated with DDR technology. This lack of knowledge led radiographers to challenge the current ‘skill base’ required by radiographers to produce images of diagnostic quality because DDR ‘does it for them’. Further, this paper highlighted pitfalls and near misses associated with image acquisition using DDR. Whilst findings suggest that DDR may alleviate patient discomfort by enabling ‘quick’ repeats, two concerns should be critically reflected upon. Firstly, radiographers should remain conscious of the dangers of ‘over-repeating’ radiographs. Secondly, radiographers in this study highlight the potential for patients to be exposed to ionising radiation without any added benefit following the incorrect selection of a digital detector. This suggests that patients may receive greater doses than intended through improper detector selection thus adding to potential stochastic affects associated with ionising radiation. Overall, the findings presented in this paper offer insight requiring further discussion, collaboration and reflection within the radiographic community.

# Recommendations

* It is suggested that clinical environments propose a ‘DDR champion’ who can be responsible for learning and continued professional development activities and thus responsible for ensuring best practice.
* Collaborations between radiographers, radiology managers and manufacturers (of X-ray equipment) remain paramount in order to discuss challenges highlighted within this paper. Collaborations between practice partners and vendors may help forestall future incidents by equipment re-design.

# Conflict of interest

None.

# References

1. Becker HS, Geer B, Hughes E, Strauss A. *Boys in White – Student Culture in Medical School*. New Brunswick: Transaction Publishers; 1961.
2. Fett, M. *Technology, Health and Health Care*. Canberra: Commonwealth Department of Health and Aged Care; 2000.
3. Herrman T. Computed Radiography and Digital Radiography: A Comparison of Technology, Functionality, Patient Dose, and Image Quality. *Eradimaging*. [Online], Available from: <http://www.eradimaging.com/site/article.cfm?ID=535> (Accessed: 13/01/2016).
4. Willis CE, Mercier J, Patel M. Modification of conventional quality assurance procedures to accommodate computed radiography. Presented at the 13th Conference on Computer Applications in Radiology. Denver, Colorado. 1996; June 7, pp.275-280.
5. Seeram E, Davidson R, Bushong S, Swan H. Radiation dose optimization research: Exposure technique approaches in CR imaging – A literature review’. *Radiography.* 2013; 19(4):331- 338.
6. Bansal GJ. Digital radiography. A comparison with modern conventional imaging. *Postrad Medical Journal.* 2006; 82(969):425-428.
7. Department of Health. *The Ionising Radiation (Medical Exposure) Regulations 2000*, Available at http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH\_4007957 (Accessed: 16th February 2015).
8. ICRP Publication. *Annuals of the ICRP.* Exeter: Elsevier; 2007.
9. Strotzer M, Gmeinwieser JK, Volk M, Frund R, Seitz J, Feuerbach S. Detection of simulated chest lesions with reduced radiation dose: comparison of conventional screen-film radiography and a flat-panel X-ray detector based on amorphous silicon (a-Si). *Investigative Radiology.* 1998a; 33(2):98-103.
10. Bacher K, Smeets P, Bonnarens K, De Hauwere A, Verstraete K, Thierens H. Dose reduction in patients undergoing chest imaging: digital amorphous silicon flat-panel detector radiography versus conventional film-screen radiography and phosphor-based computed radiography. *American Journal of Roentgenology.* 2003; 181(4):923-929*.*
11. Volk M, Strotzer M, Holzknecht N, Manke C, Lenhart M, Gmeinwieser J, Link J, Reiser M, Feuerback S. Digital Radiography of the Skeleton Using a Large-Area Detector Based on Amorphous Silicon Technology: Image Quality and Potential for Dose Reduction in Comparison with Screen-Film Radiography. *Clinical Radiology.* 2000;55(8):615-621.
12. Geijer H, Beckman KW, Andersson T, Persliden J. Image quality vs. radiation dose for a flat panel amorphous silicon detector: a phantom study. *European Journal of Radiology.* 2001;11(9):1704-1709.
13. Geijer H. Radiation dose and image quality in diagnostic radiology. Optmization of the dose-image quality relationship with clinical experience from scoliosis radiography, coronary intervention and a flat-panel digital detector. *Acta Radiologica Supplemen.* 2002;43(427):1-43.
14. Hayre CM. Cranking up, whacking up and bumping up: X-ray exposures in contemporary radiographic practice. *Radiography.* 2016; 22(2):194-198.
15. Snaith B. Evidence based radiography: Is it happening or are we experiencing practice creep and practice drift? *Radiography.* 2016; 22(4):267-268.
16. NHS Constitution. *The NHS Constitution, the NHS belongs to us all.* Available from: <http://www.nhs.uk/choiceintheNHS/Rightsandpledges/NHSConstitution/Pages/Overview.aspx> (Accessed: 27th June 2011).
17. Society and College of Radiographers. *A career in radiography*. Available from: <http://www.sor.org/about-radiography/career-radiography> (Accessed: 14th June 2013).
18. The National Institute of Medicine. *To Err is Human – Building a Safer Health System.* National Academy Press: Washington, D.C; 2009.
19. Society of Radiographers and Royal College of Radiologists. *Team working in clinical imaging.* [Online]. Available at: [http://www.sor.org/sites/default/files/document-versions/BFCR(12)9\_Team.pdf](http://www.sor.org/sites/default/files/document-versions/BFCR%2812%299_Team.pdf) (Accessed: 26/09/2016).
20. Murphy FJ. The paradox of imaging technology: a review of the literature. *Radiography.* 2006; 12(2):169-174.
21. Hayre CM. Blackman S. Eyden A. Do general radiographic examinations resemble a person-centred environment? *Radiography.* 2016 [Online]; 22(4):e245-e251.
22. Hammersley M, Atkinson P. *Ethnography Principles in Practice.* 3rd ed. New York: Routledge; 2007.
23. Hammersley M. *What’s Wrong With Ethnography.* New York, Routledge; 1992.
24. Bernard HR. *Research methods in anthropology: Qualitative and Quantitative approaches.* 2nd ed. CA: Sage; 1994.
25. Barley SR. Technology as an Occasion for Structuring: Evidence from Observations of CT Scanners and the Social Order of Radiology Departments. *Administrative Science Quarterly.* 1986; 31(1):78-108.
26. Adams J, Smith T. Qualitative methods in radiography research: a proposed framework. *Radiography.* 2003; 9(1):193-199.
27. Murphy FJ, Yielder J. Establishing rigour in qualitative radiography research. *Radiography.* 2010; 16(1):62-67.
28. Rushton MN, Rushton VE, Worthington HV. The value of a quality improvement programme for panoramic radiography: A cluster randomised controlled trial. *Journal of Dentistry*. 2013; 41(4):328-335.
29. Bansal GJ. Digital radiography. A comparison with modern conventional imaging. *Postrad Medical Journal.* 2006; 82(969):425-428.
30. Peloschek, PH, Nemec S, Widhalm P, Donner R, Birngruber E, Thodberg HH, Kainberger F, Langs G. Computational radiology in skeletal radiography. *European Journal of Radiology.* 2009; 72(2):252-257.
31. Ferris C. Specialism in radiography – a contemporary history of diagnostic radiography. *Radiography.* 2009; 15(1):e78-e84.
32. Vaughan D. *The Challenger Launch Decision.* Chicago: University of Chicago; 1996.
33. Braverman H. *Labour and Monopoly Capital – The Degradation of Work in the Twentieth Century*. New York: Monthly Review Press; 1974.
34. Pinto A. Caranci F. Romano L. Carrafiello G. Fonio P. Brunese L. The concept of error and malpractice in radiology. *Seminars in Ultrasound, CT and MRI.* 2012; 33(4): 275-279.
35. Peloschek, PH, Nemec S, Widhalm P, Donner R, Birngruber E, Thodberg HH, Kainberger F, Langs G. Computational radiology in skeletal radiography. *European Journal of Radiology.* 2009; 72(2):252-257.
36. Society of Radiographers. *Incident Reporting.* [Online] Available at: <http://www.sor.org/learning/document-library/irmer-2000-and-irme-amendment-regulations-2006-2011/5-incident-reporting> (Accessed: 26/09/2016).
37. Scalliet, P (2006) ‘Risk, society and system failure’, *Radiotherapy and Oncology,* 80 (3), pp.275-281.