Radiography in Practice

-Work and Learning in Medical Imaging-

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SVENSK SAMMANFATTNING

Röntgensjuksköterskor arbetar huvudsakligen inom hälso- och sjukvården med att genomföra bilddiagnostiska undersökningar samt medverka vid intervention (behandlingar) inom medicinsk radiologi. De är ansvariga för omhändertagandet av patienter och användningen av medicinsk teknisk apparatur inom verksamhetsområdet. Röntgensjuksköterskans profession är av intresse att studera på grund av den snabba tekniska utvecklingen som sker inom området samt utifrån förändrade förhållanden för att kunna utföra professionellt arbete.

Syftet med avhandlingen var att empiriskt undersöka centrala aspekter av röntgensjuksköterskans praktiska arbete, hur teknikutvecklingen påverkar röntgensjuksköterskans praktik, sammankopplingar med andra professionella praktiker samt studenters lärande i praktiken för att bli professionella röntgensjuksköterskor.

Metoder: Data insamling gjordes med intervjuer och observationer (Studie I, II & IV), individuella intervjuer användes i Studie III. Data analyserades med en tolkande fenomenologisk metod (Studie I) och utifrån praktikteoretiskt perspektiv i Studie II-IV.

Fynd: Röntgensjuksköterskors arbete med produktion av medicinska bilder kan förstås som en arbetsprocess med tre delar; a) planering av undersökningen, b) produktion av bilderna samt c) utvärdering av undersökningsresultatet. Produktion av bilder upplevdes som det autonoma professionella området. Under arbetsprocessen gör röntgensjuksköterskan olika bedömningar och åtgärder för att säkerställa patientsäkerhet samt för att anpassa tekniken individuellt till den undersökta personen. När undersökningsmetoder med konventionell röntgenteknik omvandlas till undersökningsmetoder med datortomografi istället får planeringsfasen ökad betydelse. Vid användning av metoder med datortomografi sker oftast bildtagningen i en sekvens som på grund av användning av intravenöst kontrastmedel och stråldosrisker kan vara svår att återupprepa. Vid planering av undersökningar är det lättare att veta i förväg hur lång tid själva bildtagningen tar med datortomografi jämfört med konventionella röntgenundersökningsmetoder. Planering av tiden för omhändertagandet av patienter är svårare att planera i förväg eftersom röntgensjuksköterskan har lite information om patienten före själva undersökningstillfället. De involverade professionella praktiker vid radiologiska undersökningar kopplas samman för säkerställande av patientsäkerhet genom materiella ting samt via gemensamma uppgifter och projekt. Samarbete kring innehåll och kvalitet på två artefakter, remissen och den medicinska bilden, är av betydelse för patientsäkerhet inom verksamhetsområdet. Under verksamhetsförlagd utbildning lär sig röntgensjuksköterkestudenter professionell kunskap i praktiken genom att alternera mellan att; a) lyssna och observera eller b) eget agerande. De utvecklar sitt professionella kunnande om de ges möjlighet till att alternera mellan de två olika sätten för lärande i praktiken.

Implikationer: Beskrivningen av röntgensjuksköterskans arbetsprocess är användbar för utbildning av röntgensjuksköterskor samt vid professionellt utvecklingsarbete. De identifierade sammankopplingarna mellan de involverade professionella praktikerna kan användas vid kvalitetsarbete för att säkerställa patientsäkerhet. Resultaten om studenter lärande i praktiken kan tillämpas vid planering och utvärdering av verksamhetsförlagd utbildning.

LIST OF PAPERS

This thesis is based upon the following papers, which will be referred to in the text by their roman numbers (I-IV).

I: Lundvall L-L, Abrandt Dahlgren M, & Wirell, S. (2014) Professionals' experiences of imaging in the radiography process - A phenomenological approach. *Radiography* 20 (1) 48-52.

II: Lundvall L-L, Abrandt Dahlgren M, & Wirell, S. (2015) How do technical improvements change radiographers' practice – A practice theory perspective. *Radiography* 21 (3) 231-235.

III: Lundvall L-L, Dahlström, N, & Abrandt Dahlgren, M. Ensuring Patient Safety in Medical Imaging: Interconnected Professional Practices. Revised and submitted manuscript.

IV: Lundvall L-L, Dahlström, N, & Abrandt Dahlgren, M. Radiography students making sense of clinical placements: developing professional knowing in practice. Manuscript.

ABSTRACT

Those following the profession of radiographer mainly work in the healthcare sector, with image production in medical imaging or with radiotherapy treatments. Radiographers are responsible for patient care and handling technology in this professional field. Radiographers' practice is interesting to study in relation to technical developments and changing conditions for performing professional work.

The general aim of this thesis was to empirically explore the main features of radiographers' work, how advances in technology affect radiographers' practice, interconnections with other practices and students' learning in practice on the way to becoming professionals.

Methods: Data was collected using interviews and observations (Papers I, II & IV). For Paper III, individual interviews were conducted. Data was analysed using a phenomenological interpretative method (Paper I) and practice theory perspective (Papers II–IV).

Findings: Radiographers' professional work with image production was seen as a process comprising three phases: planning the examination, producing the images, and evaluating the images. During this process, radiographers make judgements to ensure patient safety and adapt the technology in use to the individual patient. When conventional imaging techniques are converted into examinations performed by Computer Tomography, the planning phase of radiographers' work process becomes more important. Technology improvements also mean that the technical aspects of radiographers' work with image production are easier to foresee in scheduling examinations. The caring aspects however are difficult to plan for because of little information about the patient before the examination. The professional practices involved in medical imaging interconnect to ensure patient safety through materiality and common tasks and/or projects. The content and quality of two artefacts, the referral and the image, in these interconnections are important in collaborative work to ensure patient safety within medical imaging. Radiography students learn professional knowing in practice i.e. practice-as-work, practice-as language and practice-as-morality, during their clinical placements through alternating between two modes of participation: either observing and listening or acting by themselves. The students developed knowing in practice if the other practitioners allowed them to alternate between these two modes of participation.

Implications: The description of radiographers' general tasks and responsibilities in a work process can be used for both educational and professionalization purposes. The identified interconnections between involved professions are useful for quality improvement to secure patient safety. The findings about development of knowing in practice can be used in the planning and evaluation of clinical placements for students.

INTRODUCTION

This thesis is about work and learning in medical imaging, with a special focus on radiographers' practice. Radiographers work in departments of medical imaging, radiotherapy and nuclear medicine in the healthcare sector. The scope of their professional work covers the production of medical images using different modalities, and the performance of radiotherapy treatments (The International Society of Radiographers and Radiological Technologists [ISRRT], 2004; European Federation of Radiographers Society [EFRS], 2018). They are responsible for patient care and for handling technology in their professional area (ISRRT, 2004 & EFRS, 2018).

The research for this thesis was conducted in Sweden, where the professional scope differs from the European recommendations (EFRS, 2018). Swedish radiographers work within medical imaging and interventional radiology. The title of the profession is radiological nurse (SFS 1993:100). There are approximately 4000 radiographers in Sweden (Socialstyrelsen, 2018). The profession studied in this thesis will still be named radiographer because this is the most widely accepted title, both globally (Cowling, 2008 & 2013) and in Europe (EFRS, 2011). The main subject in radiography education in Sweden is radiography, in accordance with European recommendations (EFRS, 2018).

It is interesting to study this profession using discourses about professional challenges caused by changing practices and conditions for performing professional work (Scanlon, 2011). There is also global diversity in professional scope, naming of the profession and regulations for radiography education (Cowling, 2008; Cowling, 2013; ISRRT, 2014; EFRS, 2011; EFRS, 2018). Taking an international perspective on healthcare education, Bhutta et al. (2010) and Frenk et al. (2010) identified a need for reforming professional health educations to meet new demands in healthcare. Technological improvements and widespread migration have led to need for the transformation of education in healthcare. The authors claim that curricula for professional educational programs in healthcare are static and old-fashioned, leading to graduates not being prepared for their future work (Bhutta et al., 2010; Frenk et al., 2010). They suggested the development of competency based skills, interprofessional learning and distance learning. The connection between theoretical and clinical education needs to be improved, as do the links between research and education (Bhutta et al., 2010; Frenk et al., 2010).

Returning to radiographers, the changes in their practice are about both the technology itself and also the circumstances of their professional work. Technological developments are on-going due to medical research and technical advancements (Mertz, 2013; Bentourkia, 2012; Comaniciu, Engel, Georgescu & Mansi, 2016). The possibilities for visualizing our bodies with medical images have undergone a great expansion during the last few decades. In practical terms, this means the introduction of new types of techniques for the production of medical images, and also improvements in already-existing technology (Mertz, 2013; Bentourkia, 2012; Comaniciu et al., 2016). This leads to continuing changes in radiographers' work with technology (Aarts et al., 2017). Radiographers should work in accordance with the

principle of ALARA (As Low As Reasonably Achievable) in relation to radiation doses (ISRRT, 2004; EFRS, 2018). However, how radiographers are to work in accordance with ALARA in practice is not clarified, especially in relation to increasing demands for a fast flow of patients in medical imaging (Hayre, Blackman & Eyden, 2016). Discourses about professional work in our time indicate that the increasing impact of managerial control affects the ability to act as a professional (Malin, 2017). Professionals in the service sector in particular are concerned about trends to measure the efficiency of the work performed without take into account the complexity of professional work. There is less time and fewer opportunities to secure high quality and ethical values within professional practices. Some authors declare that this might lead to the de-professionalization of established professions (Malin, 2017; Tatoo, 2006).

Previous research about radiographers' professional practice has demonstrated their competences with image production in practice (Andersson, Christensson, Fridlund & Broström, 2012a; Andersson, Christensson, Jakobsson, Fridlund & Broström, 2012b), role advancement into new professional areas (Hardy, Legg, Smith, Ween, Williams & Motto, 2008; Kelly, Piper & Nightingale, 2008), how the introduction of digital imaging workflows have affected radiographers' practice (Fridell, Aspelin, Edgren & Lindsköld, 2009; Larsson et al., 2007) and learning in practice using digital imaging techniques (Larsson, Lundberg & Hillergård, 2009; Larsson, Aspelin & Lundberg 2013). The ways in which the introduction of new modalities for image production affects radiographers' professional work and inter-professional collaboration in medical imaging have been sparsely investigated. This is interesting to investigate in order to improve our understanding of the dynamics of changing practices.

My own professional background includes working as both a radiographer and an educator in radiography education. During my years as a teacher, there was a national debate in Sweden about the content and naming of the main subject in radiography education. This was my start of my interest in how radiographers' practices are intertwined with both technology and care was illuminated in the literature. My interest in professional work and learning in practice started during my first years of working as a radiographer. This was because my work incorporated a lot of moments of learning within practice. During my years as a teacher, I also discovered that clinical learning is an interesting part of professional learning that needs to be better understood.

BACKGROUND

Striving for recognition as a profession

In this section, I will account for and problematise how international organizations work for the recognition of radiography as a profession with a globally accepted standard of education. In numbers, radiographers constitute a small profession, especially compared to the large groups in healthcare like physicians and nurses. Cowling (2013) claims that the definition and acknowledgement of radiographers' profession and professional work is unclear due to global divergences in the professional scope, education and naming of the profession. This might affect radiographers' opportunities to contribute to healthcare with their expert knowledge (Cowling, 2008).

A competence description for radiographers' practical work is presented by the International Society of Radiographers and Radiological Technologists (ISRRT, 2004), with the goal of clarifying their professional role through a description of their tasks and responsibilities. The required competences are presented in relation to the usage of technological equipment, the performance of image production and patient care. Quality assurance in relation to radiation doses and image quality are identified as a part of radiographers' professional responsibilities (ISRRT, 2004). The description of learning outcomes for radiography educational programs in Europe includes a description of the required core competences. These are common competences for all radiographers; i.e., for work within medical imaging, nuclear medicine and radiotherapy (EFRS, 2018). These competences are presented in eleven categories covering technology, medicine, patient care, quality assurance, research/ audit and professional competences. There are also special core competences for each speciality (medical imaging, nuclear medicine and radiotherapy). Common themes in these competence descriptions (ISRRT, 2004 & EFRS, 2018) are that radiographers' professional work contains knowledge and competences in technical, medical and caring areas. Professional competences about how to act professionally and take responsibility for one's own necessary development are described in the EFRS's description (EFRS, 2018), but not in the ISRRT's (ISRRT, 2004). The naming of the professionals who conduct image production in medical imaging and perform radiation treatments differs around the world, but the EFRS (2011) claims that this profession should be named radiographer.

In summary, there is ongoing work to create a common, globally accepted entry level for radiography education and quality assurance of that education. Bachelor's level is the recommended level for radiography education (ISRRT, 2014; EFRS, 2018). There are guidelines from international organizations about the definition of professional area, scope, naming and accepted level for education (ISRRT, 2004; ISRRT, 2014; EFRS, 2011; EFRS, 2017; EFRS, 2018). European Skill/ Competences qualifications and Occupations (ESCO) upgraded in the year of 2018 radiographer from former being classified as "Technicians and Associate Professionals" into "Professionals" instead (Svensk förening för Röntgensjuksköterskor [SFR], 2018a). The next section will give a Swedish perspective on radiographers' professional scope and education.

Radiography education and professional scope in Sweden

The professional scope in Sweden is narrow compared to international recommendations (ISSRT, 2004 & EFRS, 2018), and therefore the content of Swedish education for this profession differs from international recommendations (ISSRT, 2014; EFRS, 2018). In the following, a historical review of Swedish education in this area will be presented before an explanation is given of how radiography education is arranged nowadays.

Originally, it was physicians (radiologists) who performed image production. Around 1910, nurses started to work with image production (Dillner, 1968). The first regulated training for this professional area was as a specialization within the three or three and a half year nursing education. A specialization module was included at the end of the nursing education (Dillner, 1968). The first curriculum for this was drawn up in 1939 for work in both medical imaging and radiotherapy (Svensk Sjuksköterskeförening, 1940). During the 1960's, nursing education in Sweden was shortened to two and a half years. Specialized education for different areas became separate courses of study after nursing education. Some areas of specialization were changed into new professions instead of nursing. Medical imaging and radiotherapy are examples of these newly introduced professions. In medical imaging, the profession was named radiology assistant and the education was originally two years long (SOU 1964:45). The intended professional scope for a radiology assistant at that time was merely image production. Other tasks, like handling sterile procedures and medical treatments in medical imaging, were to be performed by nurses educated in medical imaging (SOU 1962:4). When the elderly nursing education (which included specialization in medical imaging) ended after some years, the education for radiology assistant was prolonged to two and a half years, with the inclusion of the tasks and responsibilities of nurses (SOU 1966:73).

The next change occurred around 1980, when nursing education was altered to including specializations again (UHÄ, 1981). The educational programs for radiotherapy and medical imaging then became branches of nursing education but as separate elements. The naming of the profession was radiological nurse and led to a licence as a radiological nurse (UHÄ, 1981).

Nursing education in Sweden became a three year educational program at the beginning of the 1990s due to the alteration of Swedish educational programs to match European standards. The specialized parts of nursing education became separate courses after this (SFS 1993:100). How to educate for the profession that performs image production in medical imaging was investigated in an official inquiry (SOU 1996: 138). The Swedish Association for Nurses suggested two possible ways to proceed: either a specialized course after nursing education (40–50 weeks long) or a three year educational program leading to the title of radiological nurse. The Swedish tradition of educating in this area accentuated a combination of care and technology (SOU 1996:138).

Swedish educational programs in radiography nowadays

Since 2000, Sweden has had a three year educational program in radiography leading to a licence as radiological nurse. This educational program has been at bachelor's level since 2008 (SFS 1993:100). The different branches within radiography: medical imaging, radiotherapy and nuclear medicine (EFRS, 2018), are divided in Sweden between three different professions. Education for radiotherapy is a part of the specialization in oncology after general nursing education, and nuclear medicine is included in a profession called biomedical analyst in physiology (SFS 1993:100). Only medical imaging, which has a direct educational program at bachelor's level, leads to its own professional field. This also means that radiological nurse (radiographer) is a small profession in Sweden, with few practitioners.

The Swedish Association for Radiological Nurses (Svensk Förening för Röntgensjuksköterskor [SFR]) is working towards implementing a specialized educational program at an advanced (master's) level for radiological nurses, comprising 60 European credit points (SFR, 2014 & SFR, no year). The content of this course is suggested to include general knowledge about radiography and in depth knowledge of the technology and methodology within one type of modality within medical imaging; for example, Magnetic Resonance Imaging (MRI) or Computer Tomography (CT) (SFR, 2014 & SFR, no year).

In summary, the two sections above describe how radiographers' professional tasks and responsibilities incorporate both patient care and handling technology. Quality assurance of image quality and radiation doses has been identified as a professional responsibility (ISSRT, 2004; EFRS, 2018). How these different aspects of radiographers' professional work are combined in practice is not made clear in these competence descriptions (ISSRT, 2004; EFRS, 2018). The scope of practising differs in Sweden compared to European and international recommendations (ISSRT, 2004; EFRS, 2018). The caring aspect in Swedish education for this area was emphasized in a former official enquiry (SOU 1996:138), but how it differs in practice compared to other countries was not explained.

In the next section, it will be shown how radiographers' practice has been investigated in previous research.

Previous research about radiographers' professional practice

Professional practice can be explained differently depending on which perspective is chosen for investigation. In this section, research of radiographers' professional practice from more holistic viewpoints is described firstly. Secondly research focusing on specific parts of radiographers' practice will be presented.

Previous research from holistic viewpoints

Radiographers' practice has been investigated in the national context of Finland, where the professional scope covers medical imaging and radiotherapy. Through a concept analysis of radiography, both the meaning of the word and radiographers' practical work were illuminated (Ahonen, 2008; Ahonen, 2009). "Constant change" was connected both to radiography as a subject as well as to the practical work performed by radiographers. The characteristics of this practical work were situation-relatedness, duality and expertise in the usage of radiation. Situation-relatedness showed that their work consisted of processes with different actions, goals and responsibilities. The performances and outcomes of these processes differed. People and technology were involved in the processes of both image production and radiation treatments. The people involved tried to find solutions to problems that occurred. Duality was about the character of the radiation: useful for both diagnostic and treatment purposes; can both causes harm and be useful; radiography is both theoretical and practical. Radiographers were identified as central to these practices due to having expertise in the usage of radiation (Ahonen, 2008). Their practical work was described as having three aspects; a) technical radiation usage and radiation protection, b) patient care and c) service to the healthcare sector. The first two aspects were closely connected and were the main features of radiographers' practical work. Service to the healthcare sector showed that they were a part of the healthcare system (Ahonen, 2009). Their practical work was explained at an abstract level as consisting of three phases: planning, implementation and evaluation. All three of these aspects were visible in the description of the tasks performed during the work process (Ahonen, 2009). These studies illustrate that the practice is changeable and dynamic. Ensuring patient safety in relation to radiation protection issues was described, but how the practitioners themselves made sense of their practical work was not investigated in these studies (Ahonen, 2008 & 2009).

There are descriptions of radiographers' professional tasks formulated as competences. The Radiographers' Competence Scale (RCS) was developed in the national context of Sweden (Andersson et al., 2012a & Andersson et al., 2012b). The results of a qualitative study described radiographers' competences from a nursing theory perspective (Andersson, Fridlund, Elgán & Axelsson, 2008). Radiographers' competences were claimed to be covering two main areas, one directly patient-related, and the other indirectly patient-related. The competences in the directly patient-related areas illuminated how radiographers performed examinations in relation to the individual patient through guidance, providing support and being vigilant. The indirectly patient-related competences illustrated how they organized their work, handled the images, ensured quality and collaborated with other

professionals during their practice (Andersson et al., 2008). The RCS consisted of two dimensions, which were named: 1) Nurse initiated care and 2) Technical and radiographic procedures. The instrument was validated and used for assessing radiographers' usage of different competences in a Swedish context (Andersson et al., 2012a; Andersson et al., 2012b). The results of a national survey showed that: "Adequately giving information to the patient" was ranked highest in the dimension of Nursing initiated care and "adapting the examination to the patient's prerequisites and needs" in the dimension of Technical and radiographic procedures. The lowest-rated competences were "participating in quality improvement regarding patients' safety and care" in Nursing initiated care and "preliminary assessment of images" in Technical and radiographic procedures (Andersson et al., 2012b). The RCS has also been used in the context of a university hospital in Lithuania (Vanckavičienė, Macijauskienė, Blaževičienė, Algidas Basevičius, & Andersson, 2017). This study included a self evaluation of radiographers' clinical competences and radiologists' rating of radiographers' valuable competence. Radiographers valued most highly the competences "encouraging and supporting the patient" and "collaboration with other radiographers", whilst the radiologists rated "collaboration with the radiologist" and "independently carry out the radiologist's prescription" most highly. The lowest ratings in both professions were for "guiding the patient's relatives" and "empowering the patient by involving him/ her in the examination and treatment" (Vanckavičienė et al., 2017). Usage of the RCS in these two different national contexts indicates that the importance of the competences and usage differs between diverse contexts.

Radiographers' professional identity was presented as a professional journey through a discourse analysis of articles published in a professional journal in Finland between 1987 and 2003 (Niemi & Paasivara, 2007). Three discourses were identified: technical, safety and professional. The technical discourse illuminated the development of new technology during these years and described the radiographer as a technical expert. In the safety discourse, the radiographer was seen as a protector against safety risks related to radiation. The change in the educational program for radiography during these years, into courses at a university level, was seen in the professional discourse. The professional identity also seemed to have become stronger during these years; likewise, collaborative work with other professions (Niemi et al., 2007).

Previous research focused on specific parts of radiographers' practice

Person-centred care in radiography and adapting the examination in relation to each patient's needs have been put forward as important (Hayre et al., 2016; Hellman & Lindgren, 2014). The introduction of digital image production has led to faster patient flow through the imaging departments with a higher grade of efficiency. For radiographers, this means less time with each patient and has been reported as adding stress to their everyday work. At the same time, patients appreciated the service provided (Hayre et al., 2016). The same view of radiographers' work is presented in a study about plausible future scenarios for radiographers in Sweden (Björkman, Fridell & Tavakol Olofsson, 2017). These authors claim that this will be the future of work as a radiographer in Sweden if there are a sufficient number of

radiographers available for work but no opportunities for career advancement. Hayre et al. (2016) identified this scenario within the practice in the United Kingdom (UK).

Radiographers' view of the importance of having enough time to create trust and patient participation in the examination is put forward for examinations using both Computer Tomography (CT) and Interventional Radiology (IR) and Magnetic Resonance Imaging (MRI). This is described as being important for the tailoring of person-centred care (Hellman et al. 2014; Lunden, Lundgren & Lepp, 2012; Munn, Jordan, Pearson, Murphy & Pilkington, 2014). The patient's need for information in order to be able to participate and go through the examination or treatment is emphasized. The information given should, from the radiographers' perspective, be both individualized and also continuous during IR and MRI because there are uncertainties about how the treatment/examination will continue (Hellman et al., 2014; Lunden et al., 2012; Munn et al., 2014). The difficulty of not having advance information about patients' anxiety or claustrophobia while being scanned in an MRI scanner was described by Munn et al. (2014). In practice, this meant that radiographers had to be sensitive to signs from patients and had to try to adapt the scanning procedures so patients were able to go through the examination (Munn et al., 2014). Working with radiotherapy also includes providing care and handling technology (Bolderston, Lewis & Chai, 2010). The importance of person-centred care was emphasized by these authors, but tight scheduling could affect the opportunities to enable such care. When the patient was scheduled for several radiation treatments, it was easier to build a relationship, and this facilitated radiographers' work. The technical aspect was described either as a separate part or as interconnected with care (Bolderstone et al., 2010).

The need for compassionate care in radiography was discussed by Bleiker, Knapp, Hopkins & Johnston (2016). This is identified as being important for providing high-quality care. The time aspect, with short patient-client meetings in radiography and the patients' expectations of fast service, is seen as a limiting factor for being able to provide such care (Bleiker et al., 2016). Out of the culture of medical imaging, with task orientated work during a short patient encounter, different strategies for solutions were presented. The use of empathy and emotional intelligence was identified as important for being able to give care. The authors stated that there is a need for an evidence-based definition of compassionate care in radiography practice (Bleiker et al., 2016).

How radiographers reason about providing person-centred care during MRI scans of patients with spinal metastasis was investigated in a qualitative study (Strand, Törnqvist, Rask & Roxberg, 2018). Two different strategies were recognized. One was to always follow the standard for performing the examination and to give care in a standardized manner. The second took into account each person's specific medical problems and needs and adapted the given care in relation to this. In practical terms, this meant: listening to the patient to understand their needs, individualizing positioning in the machine, strategies for communication etc. The authors concluded that radiographers who gave person centred care seemed to have more knowledge

about the patients' underlying diseases and what this could mean for a patient's ability to go through an MRI examination (Strand et al., 2018).

Strudwick (2014) identified the image as a cultural artefact produced in medical imaging. At the same time, the image connects the radiographer to professionals in other departments (Strudwick, 2014). Since the introduction of digital images and the Picture Archiving and Communication Systems (PACS), the images have been easily accessible to professionals outside medical imaging and have been used for the planning of treatments and communication with patients (Fridell, Aspelin, Felländer-Tsai & Lundberg, 2010; Tillack & Breiman, 2012). The images can be seen and judged by all personnel with access to the PACS system (Strudwick, 2014). The radiographers were concerned about the quality of their images because the production of diagnostic images is a part of their professional role. The author declared that quantifying the quality of images was easier than judging the quality of the patient-radiographer interaction because this was not verified on the images (Strudwick, 2014). This was a dilemma for radiographers. Performing the examination in a pleasant manner and without pain but without producing images of diagnostic quality does not help the patient in the long term. So radiographers had to find a balance between the process of image production and the product (the image) itself. This image, as a visible product of their professional work, was identified as specific to radiographers' professional role. Not all parts of radiographers' work were shown on the images (Strudwick, 2014).

In summary of the previous studies reviewed in this section: giving information to the patient in an individualized manner is emphasized to be important for providing person-centred care (Hellman et al., 2014; Lunden et al., 2012; Munn et al., 2014); likewise, the individualization of how to position the patient in the machine (Strand et al., 2018). Poor information ahead of the examination (Munn et al. 2014) and short patient encounters are identified as factors affecting radiographers' ability to deliver person-centred care (Hayre et al., 2016; Bleiker et al., 2016; Bolderstone et al., 2010). The review of previous research shows that there are organizational and environmental factors influencing the caring aspect of radiographers' professional work and responsibilities. Competence descriptions show common and regular tasks of radiographers' practice (Andersson et al., 2012a; Andersson et al., 2012b), and the way in which competences are used differently in diverse contexts (Andersson et al., 2012a; Andersson et al., 2012b; Vanckavičienė, et al., 2017). Andersson et al., (2012a) & Andersson et al., (2012b) did not focus on patient safety aspects. Image quality is put forward as an important and visible part of radiographers' professional responsibilities. Image quality however does not reflect the quality of radiographers' practice with providing care to the patient (Strudwick, 2014). Technology development leads to shorter patient encounters and there are indications that this affects the ability to provide person-centred care in radiography practice (Hayre et al., 2016; Bleiker et al., 2016).

The following section will examine clinical advancement for radiographers, including other professional tasks and responsibilities.

Changing professional scope

Cowling (2008) expressed concern about radiographers' options to expand their professional role into new areas of practice due to the diversity in scope and education as well as unclear recognition of the professional area. The need for improved service in healthcare initiated the clinical advancement of radiographers, with higher grades of responsibility and the performance of tasks that have traditionally belonged to radiologists (physicians specialized in radiology) (Hardy et al., 2008; Cowling, 2013). This was one of the main reasons for the development of advanced radiography practice in the UK, which is at the forefront of the profession, with four clearly defined levels of clinical work for radiographers (Kelly et al., 2008; Cowling, 2008; Cowling, 2013). In some parts of the world, there has also been a shortage of radiologists, especially in remote areas in some parts of Australia and Africa, but also in the UK (Ekpo, Egbe & Akpan, 2015; Cowling, 2013; Kelly et al., 2008). This has facilitated in the beginning for radiographers to report on images and to perform examinations that were previously conducted by radiologists (Kelly et al., 2008).

Hardy and Snaith (2006) discussed how to define the change of radiographers' professional scope into new areas of practicing. Role development into "advanced practice" was suggested for the naming of radiographers' advancement into higher levels of clinical responsibility, with duties traditionally belonging to radiologists (Hardy et al., 2006). The term "extended role" was suggested when radiographers developed their traditionally professional role with new tasks but gained no advancement in responsibility. The authors exemplified "extended roles" with how technical advancements have affected the development of new tasks and responsibilities within radiographers' own traditional professional area of image production (Hardy et al., 2006).

This work in the UK has been in progress for more than thirty years, but there is still diversity in how radiographers' advanced practice has been implemented (Snaith, Hardy & Lewis, 2015; Milner, Culpan & Snaith, 2016). The effects of advanced radiography practice on providing better services in healthcare have been evaluated. Cost-effectiveness was reported for image interpretation of conventional chest examinations when radiographers perform the reporting instead of a radiologist (Bajre, Pennington, Woznitza, Beardmore, Radhakrishnan, Harris & McCrone, 2017). In a review, Hardy, Johnson, Sharples, Boynes and Irving (2016) have evaluated how the introduction of advanced radiography practice has affected the provision of health services. The results showed cost reductions and no differences in patient morbidity between a radiographer or a radiologist reporting on musculoskeletal trauma images (Hardy et al., 2016). There was interest in clinical development among radiographers in countries that have not yet developed an advanced practice (Moran & Warren-Forward, 2011; Moran, Taylor & Warren-Forward, 2013), even though changing practices and professional boundaries are a long-term project (Snaith et al., 2015; Page, Bernoth & Davidson, 2014). For the implementation of advanced practice, the authors identified that it was important to have the right legal framework and strong leadership (Page et al., 2014). Next section will examine previous research about how technology development has affected radiographers' practice.

Technology development in radiographers' practice

Previous studies about technology development in this field have mainly focused on how the introduction of digital imaging has affected radiographers' practice.

There are studies conducted in a Swedish context (Fridell et al., 2009; Larsson et al., 2007). The introduction of digital imaging changed radiographers' professional role and their image production practice, and Picture Archiving and Communication System (PACS) has impacted upon the organization of work in medical imaging (Fridell et al., 2009; Larsson et al., 2007). Radiographers' professional skills around image production changed from being an expert on exposure parameters to focusing on patient safety in relation to radiation doses instead. The reason for this shift of focus was that during work with analogue imaging techniques, it was important to estimate the exact exposure in relation to each patient. Otherwise, the image might be over- or underexposed and not useful for diagnostic purposes. With digital imaging techniques, it became possible to process the image even if the exposure is not optimal. In practical terms, this meant that it became important to use as low exposure as possible while still attaining diagnostic-grade images (Fridell et al., 2009; Larsson et al., 2007). How the radiation doses were optimized in practice was not investigated in these studies (Fridell et al., 2009; Larsson et al., 2007).

Radiographers acquired new tasks and responsibilities when working with PACS systems, which in analogue workflows had been performed by other professionals, such as assistant nurses and radiologists. This added stress to radiographers' everyday work (Fridell et al., 2009; Larsson et al., 2007). Within digital workflows, the radiographers acquired the responsibility for judging image quality before sending the patient away from the radiological ward, which was a responsibility that had previously belonged to radiologists. This meant more responsibility, but also a higher degree of independence (Larsson et al., 2007). Radiographers' consulting with radiologists about diagnostic and image quality, which had previously been commonplace, became a rare event. This was because they no longer had to gather around the physical images to view them. Working within a digital image workflow led to radiographers and radiologists working in different physical areas of the departments of medical imaging. As a result, radiographers began to collaborate more with colleagues regarding these issues (Fridell et al., 2009).

Radiographers' image production practice changed when digital workflows were introduced (Fridell et al., 2009; Larsson et al., 2007). It became easier to communicate and co-operate with referent physician and other units through PACS because it was possible to see digital images in several locations simultaneously. This was advantageous in small local units located at a distance from large hospitals. Image production could be performed within these small units and viewed at a larger hospital by a radiologist for consultation before the patient was referred to a specialist at a hospital. This meant better service to the remittent and a more efficient workflow (Fridell et al., 2009; Larsson et al., 2007; Aarts et al., 2017; Tan & Lewis, 2010). For referring physicians, access to PACS led to learning about the interpretation of images. They also started to use the digital images in dialogue with

their patients in order to explain their diseases and help to plan the treatments (Fridell et al., 2010; Tillack et al., 2012). This is in line with results from a review about how the introduction of PACS has affected radiology practice and the service provided in healthcare (Alhajeri, Aldosai & Aldosari, 2017). The authors stated that using PACS allowed new forms of communication and collaboration that were successful for healthcare, but that new generations of PACS systems need to be better customized to their users (Alhajeri et al., 2017).

The technology in use with digital imaging became more technically deterministic, with pre-planned protocols in the machines and a clearly defined path for how the work should be performed, including defined and separated tasks between the professions involved (Fridell et al., 2009; Larsson et al., 2007). The practitioners experienced that the technology had not been built with the viewpoint of medical employees in mind. For radiographers, this meant that, when working with digital imaging production, they got the feeling that the actual production of the image was like a “black box”. When technical problems occurred, they did not know how to resolve them. Instead, they had to call in technical experts (Fridell et al., 2009; Aarts et al., 2017). To enable the handling of equipment in a safe and efficient way, the importance of explanation of the “underlying processes” of the technical device during the introduction of new technology was emphasized (Aarts et al., 2017). This leads into previous studies about radiographers’ learning in practice.

Learning in radiography practice

How radiographers learn their professional tasks in digital imaging production were investigated by Larsson, Lundberg & Hillergård (2009) and Larsson, Aspelin & Lundberg (2013). Two levels of learning strategies were identified, depending on whether the tasks were known or unknown to the radiographer. Existing knowledge led to a more holistic approach to learning new tasks. Unknown tasks led to the learning consisting of reading and understanding different manuals and/ or method descriptions. Inexperienced radiographers also learned through collaboration with experienced ones. There were also differences in how they evaluated the images produced; an experienced radiographer evaluated how well the images visualized the pathology and the inexperienced relied upon defined criteria in method descriptions (Larsson et al., 2013). The authors identified two different levels of acting in practice: routine or reflective (Larsson et al., 2009). During routine acting, the radiographer was more dependent on manuals and documents about how to perform the work. Reflective acting was when they could act more flexibly in relation to the circumstances, in both the planning and performance of actions. Being on a level was not static; it changed in relation to the conditions. There are similarities between the description of routine and reflective acting (Larsson et al., 2009) and the results in Strand et al.’s (2018) study about different ways of providing care to patients with spinal metastases.

Another study about radiographers’ learning of professional tasks is an evaluation of education based on simulation for developing radiographers’ competence in intravenous pharmacotherapy (Aura, Jordan, Saano, Tossavainen & Turunen, 2016). The results showed that their clinical competences improved because they became

more accustomed to acute situations through typical scenarios for medical imaging. Learning was enacted through practical performances and interprofessional collaboration during simulation, which could be applied during clinical work (Aura et al., 2016).

Radiography students' learning of radiography has been investigated in a review (Holmström & Ahonen, 2016). The authors claim that previous studies on this subject were mainly investigations of students' experiences of different learning methods, in both the theoretical and clinical parts of the curriculum. These investigations were conducted using quantitative questionnaires, which were mostly constructed from other professional contexts. The authors declare that qualitative studies about radiography students' learning are needed for the development of both the theoretical parts of the curriculum and students' learning in practice (Holmström et al., 2016).

Turning back to technical developments, one benefit of such developments in medical imaging is that radiographers' work became physically easier (Aarts et al., 2017; Larsson et al., 2007). But at the same time, these technical alterations demanded them to be flexible and to keep up with all the changes of the technical devices. Future scenarios for the profession suggested that it would become either less autonomous due to rigid technical solutions that radiographers have to master or a more important profession because the work will become more multifaceted and necessary within healthcare (Aarts et al., 2017). Björkman et al. (2017) emphasize the importance of access to career advancement in a study of plausible future scenarios for Swedish radiographers. The authors assume that there will be opportunities to take more responsibility for patient care and performing examinations with advanced modalities. They also stated that continuous education is needed to achieve this future scenario (Björkman et al., 2017).

Summarizing of this section; the introduction of PACS led to radiographers working more independently and more within their own profession (Fridell et al., 2009; Larsson et al., 2007). They had gained a higher grade of responsibility for image quality and felt a greater sense of responsibility for the radiation doses given to the patient. Digital imaging workflows meant that medical imaging provided a better service to other departments within healthcare that used the images in their work (Fridell et al., 2009; Alhajeri et al., 2017). This also meant that the products of radiographers' work became more visible (Strudwick, 2014). Learning new technology in practice is important for radiographers (Aarts et al., 2017; Fridell et al., 2009; Larsson et al., 2008). Few studies were found addressing radiographers' learning within practice.

Viewing this section from a professionalization perspective, the concepts of role extension and role expansion can be used. Murphy (1970) suggests that clinical advancement could either be through role extension into professional areas that traditionally belong to other professions or by the development of the profession's own traditional area of practising, recognized as role expansion. The author exemplified this from a nursing perspective (Murphy, 1970). When specifically defined tasks and responsibilities are delegated from physicians to nurses, this is role

extension. Role expansion is a process whereby professionals expand their knowledge through university based studies to fill gaps in their knowledge of their own professional area. Role expansion leads towards new ways of performing professional work (Murphy, 1970). By using these concepts to scrutinize the development of radiographers' practice in relation to the introduction of PACS, the change in radiographers' practices can be seen as both role extension and role expansion. The shifting of responsibility for image quality from radiologists to radiographers (Fridell et al., 2009) can be seen as role extension. Radiographers' changed relation to radiation doses and technology in use (Fridell et al., 2009; Larsson et al., 2007; Aarts et al., 2017) can be understood as role expansion, with a need for new knowledge. This has also led to new ways of practising.

Summarizing the background; ongoing work and research into the acknowledgement of radiographers as professionals and the development of advanced radiography practice (Hardy et al., 2008 & Kelly et al., 2008) can be seen in two different discourses about professions and professionalism. The first discourse has its historical roots in the first formulated definition of what characterizes a profession (Evetts, 2006; Friedson, 2001). The definition of a profession was a high grade of independent work with a defined base of knowledge. This way of defining a profession can be seen as the division and legalization of professional knowledge into specific professional areas. But the continuing specialization of what professionals did and a growing demand for professional work in the service sector of welfare societies blurred this definition of what characterizes a profession. This led to an ongoing debate about what does characterize a profession. Evetts (2006) formulated a pragmatic definition of professions as occupations that are knowledge based, and mostly work in the service sector. Professionals have received education to a higher/ additional level as well as occupational training and experience. Some professional groups are licensed to a specific professional area and others have links to politics in their professional work (Evetts, 2006, pp. 135–136). Issues around professional identity, culture, normative values and socialization into a profession can be seen as parts of this discourse (Evetts, 2006).

The other discourse about professions and professionalism has developed from occupational training and the accreditation of delivered work (Evetts, 2006; Friedson, 2001). This takes an organizational perspective, aiming to distribute a defined service to customers. It could lead to a higher degree of control over the professionals' work. The work became more standardized, controlled and measured against defined outcomes. Due to managerial control, professionals might lose control and authority over their work and professional responsibilities. Professionalism, from this perspective, means to complete required, defined tasks in an efficient and effective manner (Evetts, 2006). The ongoing work with professionalization issues for radiographers can mainly be seen in terms of the first of these discourses. Studies on radiographers' practice showing a rapid flow of patients through medical imaging (Bleiker et al., 2016; Hayre et al., 2016; Munn et al., 2014) indicate that the second discourse can also be seen within practice. But it is not clear whether it is technical or organizational factors that cause this scenario.

Discourses about professions in the twenty-first century address professional work as dynamic and changeable, with the boundaries between professions and different disciplines becoming blurred due to constant changes in the circumstances under which professional work is performed (Scanlone, 2011). Technical developments in practice (Fridell et al., 2009; Larsson et al., 2007 & Aarts et al., 2017) and advanced radiography practice (Hardy et al., 2008 & Kelly et al., 2008) might be seen from this perspective.

RATIONALE

Competence descriptions of radiographers' work show common, regular and required tasks. But how these are used, blend together during practice and alter in relation to interconnection to other professionals cannot be shown through competence descriptions.

Learning technology in practice has been identified as a key issue for radiographers, but how learning occurs within practice and how students learn during clinical placement are questions that have been only sparsely investigated.

AIM OF THE THESIS

The overall aim with this thesis is to empirically explore the main features of radiographers' work, how advances in technology affect radiographers' practice, interconnections with other practices and students' learning in practice on the way to becoming professionals.

SPECIFIC AIMS OF THE PAPERS:

I: To explore, from the perspective of the radiographer, the general tasks and responsibilities of their work.

II: To explore how technical development affects the relations between different actors and their actions in the practice of computed tomography.

III: To explore, from health professionals' perspectives: a) how different professional practices involved in Medical Imaging connect, and b) how the arrangements of these practices enable or constrain collaborative work and patient safety.

IV: To investigate how radiography students make sense of professional knowing in practice during clinical placements.

THEORETICAL FRAMEWORK

Two different theoretical perspectives were chosen for the investigation of diverse aspects of radiography practice. Phenomenology was used to explore the main features of radiographers' practice (Paper I). A practice theory perspective was used to examine the interconnections with other practices (Paper III) and how technological advancements affect practice (Paper II). Radiography students' learning within practice was investigated by using a practice theory perspective about professional knowing in practice (Paper IV).

Phenomenology

Phenomenology (Paper I) was originally a philosophy that addressed people's experiences of phenomena in their life-worlds. Modern phenomenology was invented by Husserl, who reinstated logical analysis into philosophy, but did not introduce phenomenological research methods (Bjurwill, 1995; Sokolowski, 2000; Szkarski, 2004; Qutoshi, 2018).

Central to phenomenology are phenomena, intentionality, bracketing and epoché. A phenomenon exists in people's life-world. The phenomenon is a combination of how it has come into people's awareness (noema) and their meaning-making of the phenomenon (noesis). The process of meaning-making about a phenomenon (a combination of noema and noesis) is called intentionality (Sokolowski, 2000; Szkarski, 2004). Practically this means that, when a person experiences a phenomenon, their mind is directed towards that phenomenon and gives meaning to it. Phenomenological philosophy assumes that reality (life-world) is constructed through the interaction between consciousness and the objects in the life-world (Sokolowski, 2000; Szkarski, 2004). Lived experiences are people's experiences of the pre-reflective consciousness of their life-world (Dowling, 2007). Intentionality is essential for creating a phenomenon from the mental experiences and objects in the life-world (Sokolowski, 2000; Szkarski, 2004).

Bracketing and epoché are used for the investigation of a phenomenon and for the identification of the essence, the characteristic parts, of that phenomenon. Bracketing means that people's previous knowledge and experiences about the phenomenon are set aside in order to obtain a true description of the phenomenon (Dowling, 2007). Epoché is an investigation of a phenomenon from "the thing itself". Free performance variants are used to discover the essence of a phenomenon out of people's lived experiences. The essential parts of a phenomenon are the aspects that do not vary (that is the phenomenon's core). The aspects that do vary are existential and are not a part of the true description of the phenomenon (Sokolowski, 2000; Szkarski, 2004).

Phenomenological philosophy has been used to develop research methods about people's experiences of different phenomena. Phenomenological analysis results in a description of the core of a phenomenon and demonstrates how it is shown to people in a defined life-world. There are different branches of phenomenological research methods. Descriptive phenomenology has close links with Husserl's philosophy,

with a focus on mental processes (Giorgi, 2006). This sort of phenomenology does not take into account how context and culture impact upon people's experiences. Other branches of phenomenology have combined it with other philosophies for the interpretation of phenomena; for example, existential phenomenology or hermeneutic phenomenology (Dowling, 2007; Giorgi, 2006).

Phenomenology was useful for the description of the core of radiographers' lived experiences of their professional work, as presented in Paper I. For the investigation of how technological advancements in radiographers' practice affect their practice and how different practices interconnect to ensure patient safety, a practice theory perspective was used as the theoretical framework for Papers II & III.

Practice theory

Practice theory is an approach encompassing theories about activities and the organization of practices. Some parts of practice theories focus on the organizational aspect of the practices, while others illuminate the activities that take place within a practice. Practices embrace both social processes and the activities performed by humans and non-humans. Social processes emerge from the activities in practice (Feldman & Orlikowsky, 2011). A practice theory perspective comprises theories with diverse focuses (Schatzki, 2012). Some emphasize the relations between materiality and humans instead of human consciousness. Human knowledge is seen as being implanted in both people and materiality, i.e. bodies and artefacts (Fenwick, Nerland & Jensen, 2012). Other types of practice theories take also into account the psychological aspects of human life as part of practices; for example, learning, communication, identity and reason (Schatzki, 2012). This thesis aims to explore practitioners' intentions with their actions and learning in practice, and therefore these sorts of practice theory perspective were used in Papers II–IV. The following will provide an overview of these types of practice theories.

Practices consist of external structural arrangements and the practice where an activity takes place (Kemmis, 2005; Kemmis, 2009; Kemmis, 2010 & Kemmis, 2012). External structural arrangements and practices together form social sites (Schatzki, 2002). These external arrangements are formed by material-economic conditions, social structures, traditions and the actions in the practice. Relations between the actors in practice also affect the activities that take place (Schatzki, 2002; Kemmis, 2009; Kemmis, 2012). The arrangements are bundled in a characteristic way and relate to the specific practice where activity takes place (Schatzki, 2002). In the practice, practitioners perform actions, bodily doings and sayings (Schatzki, 2002). Kemmis (2012) argued that relating is a part of activity in practice.

The activity is physically, semantically and relationally connected (Kemmis, 2005, 2009 & 2012). Knowledge about how to perform an activity in practice is situated and learned through participating in that practice. To know how to act is something active and is therefore named knowing. Knowing in practice incorporates both practical knowledge and situated knowledge about how to act within a specific practice. Knowing in practice is connected to materiality, language and relational aspects, described as: practice-as-work, practice-as-language and practice-as-morality

(Gherardi, 2000; Gherardi, 2001; Gherardi, 2009 & Gherardi, 2015). Practical doings performed by bodies and materiality are physically connected. Knowing how to use the body in the performance of bodily doings is embodied knowledge, which is learned through the senses. These doings are repeated several times until the knowing is “set in the body” (Gherardi, 2000). Schatzki (2002) recognizes bodily knowing as practical understanding, as the knowing of what to do in practical terms and as being able to perform the practical actions. Spoken and written language are semantically connected (Kemmis 2005, 2009 & 2012). Language is used for building relations and for verbalizing what happens in practice. Knowing how to use this language in practice is learned through participation in the linguistic part of practices (Gherardi, 2000 & 2015).

The actions of doing and sayings are combined into tasks and projects that can be parts of one or several practices (Schatzki, 2002). In this way, activity connects different practices. The activity is structured in a specific way for each practice, and this can be seen as the logic of practice (Gherardi, 2000 & 2015). The actions are held together through the practitioners’ shared understanding of how to carry out the activity in practice (Schatzki, 2002). Gherardi (2015) emphasizes that activity in practice is more than just the performance of actions. There are also aesthetic and normative professional visions embedded in practice which is visible through how practitioners produce and reproduce practice through activity. Kemmis (2012) and Schatzki (2002) argue that there are teleo-affective structures in practice which are normalized and commonly shared end-results with the activities in practices. Schatzki (2002) identified aesthetic values of practice as a general understanding of what happens in practice.

Human activity is also relationally connected, meaning that relations impact upon the activity that happens in practice. Relations in practice are shared but not always coequally, meaning that relational aspects can cause power imbalances or conflicting interests (Feldman et al., 2011). The arrangement is relational to practice in a way that can affect the activities. The arrangements can have causal relations to the actions in practice, leading to specific actions. There are also relations that prefigure actions, i.e. making sense of which actions should be performed, making the actions either easier or harder. Relations between the arrangement and practice can also be co-constitutive, meaning that they are necessary for the continuation of the activities in practice (Schatzki, 2002). Materiality is relational to the human activity and social processes that come out of the activities. Different practices can connect through materiality and build up nets of practices (Schatzki, 2002). The involved actors also relate to each other in ways that affect the activities (Kemmis, 2005, 2009 & 2012). The actions and interactions between actors, activities and arrangement are dynamic and changeable. Practices are situated in time and space (Schatzki, 2002).

METHODS

Paper I & Paper II

Study design

Data was collected simultaneously for both papers by using interviews and observations. Interviewing was chosen to obtain data about radiographers’ lived experiences of their professional practice concerning the main features of their practical work, technical developments and boundaries with other professions. After a preliminary analysis of the interview data, data collection continued with observations of radiographers during their work with Computer Tomography (CT) and Magnetic Resonance Imaging (MRI). The aims of these observations were: to identify general tasks and responsibilities, and determine how the alteration of conventional imaging techniques into multi-dimensional techniques had affected their practice.

Sampling and data collection using interviews

A purposeful sampling procedure was used to obtain variation in the interviewees’ experiences. For the sampling procedure, see the method sections in Papers I & II. There were eight (N=8) interviewees in total. All of them worked full time as radiographers. For a description of the interviewees, see Table 1.

Table 1. Description of the interviewees in Papers I & II (Lundvall, 2014)

Age	39 (26–53) Md (Range)	
Men/ women	3/ 5	
Years of work experience	13.5 (2–29) Md (Range)	
Type of clinic	University clinic (N=1)	Four (4) interviewees
(Employment at the time of the interview)	Municipal clinic (N=2)	Three (3) interviewees
	County district hospital (N=1)	One (1) interviewee
Specialist field in radiography	Magnetic Resonance Imaging (MRI) (N=1)	
(Working 50% or more in this field).	Computer Tomography (CT)	(N=1)
	Skeletal radiography	(N=1)
	Intervention radiology	(N=1)

The interview guide consisted of four questions, open in character, and was designed to gather data about radiographers' lived experiences from their practice (Table 2). The interview guide was tested in two pilot interviews, which were both used in the studies. All interviews were conducted under undisturbed conditions. The interviewees chose the place for the interview. The interview guide was sent in advance by email. However, the first interviewee did not receive the guide in advance and this became the shortest interview (25 minutes). Total interview time was 375 minutes (range 25–71 minutes). All the interviews were recorded using a digital voice recorder and were transcribed after each interview. LL conducted and transcribed all interviews.

Table 2. The interview guide for Paper I & Paper II (Lundvall, 2014)

Interview questions	Constructed mainly for Paper
Describe an ordinary situation that you have experienced when your knowledge as a radiographer was important.	I
Describe a situation when you learned new technology!	II
Describe an ordinary situation when your professional knowledge was important for taking care of patients	I
What do you know, as a radiographer that other professionals at your place of work (both on your ward but also other professionals you meet during work) do not know?	I (Only partly used in Study I)

Data collection using observations

The observations were conducted in a middle-sized clinic in the southern part of Sweden. The head of department was contacted by telephone and asked for permission to conduct observations of radiographers during their daily work with Computer Tomography (CT) and Magnetic Resonance Tomography (MRT). After the first contact, written information was sent by email to the head of department, who informed employees about the study before the observations started. The observations were conducted by LL, who wore hospital clothing during the observations but did not participate in the work. The observations lasted for one week with a total of ten separate observation periods. The duration for each observation varied between two and four hours. Directly after each observation, field notes were written up. All sets of field notes were organized in the same way: 1) a description of the observations, 2) theoretical notes, and 3) a suggested focus for the next observation.

Data analysis: Papers I & II

Data from both the interviews and the observations was used in the analyses for Papers I & II. The data analysis was mainly conducted by LL and discussed in the research team. The data analyses were also presented and discussed at research seminars.

Paper I

Specific aim of Paper I was to explore, from the perspective of the radiographer, the general tasks and responsibilities of their work. A phenomenological interpretative method with six steps was used (Colaizzi, 1978; Szklarski, 2004). A description of the phenomenon is attained by using the first five steps. The sixth step leads to a verification of the description of the phenomenon. Colaizzi (1978) suggested member-checking and Szklarski (2004) recommended focus group interviews for the sixth step. All the data was used and analysed by using the first five steps of the method (Colaizzi, 1978; Szklarski, 2004).

Paper II

Specific aim of Paper II was to explore how technical development affects the relations between different actors and their actions in the practice of computed tomography. The data analysis was conducted in two steps. Firstly, an inductive analysis was made and, secondly, an abduction. The inductive analysis was inspired by Patton's description of qualitative analysis (Patton, 2002). The data sets were re-read several times in order to become familiar with the data. Meaning units regarding how technical developments affect radiographers' practice were identified and underlined in the data. These meaning units were analysed and sorted into seven different codes. These codes were named for the content in each one: 1) need for learning, 2) anxiety, 3) easier practical doings, 4) the image, 5) relations during work, 6) changed machines, and 7) time aspect. The first inductive analysis led to a description of the meaning of the data about how technical developments affect radiographers' practice.

Abduction was achieved by analysing the codes from a practice theory perspective. The events that were important in relation to the research questions were identified in the codes (Patton, 2002; Srivastava & Hopwood 2009). An iterative process moving between the empirical data in the identified codes and practice theory perspective, in accordance with Kemmis (2005, 2009 & 2012) and Schatzki (2010), led to the identification of four themes with data derived from different codes. These four themes illustrate how technical development, involving a switch from conventional imaging techniques into usage of CT techniques, has altered radiographers' practice. For a description of how the different codes have contributed to the themes, see Table 3. The code "the image" was not used in the final result.

Table 3. Description of how different codes have contributed to each theme, Paper II (Lundvall, 2014)

Codes	Themes
Changed machines Easier practical doings	Changed materiality makes the practical action easier
Changed machines Easier practical doings Anxiety Time aspect	New machines cause conflict between the arrangements of the work and the patients' needs
Changed machines Learning Relations during work	Changing materiality prefigures learning
Changed machines Learning Relations during work	How the connections between different practices lead to moments of practical reasoning in the radiography process with CT

Paper III

Study design

A qualitative design was used with individual interviews as the means of data collection. The interviewees were professionals representing three different professions involved in Medical Imaging: medical physicist, radiologist and radiographer. The theoretical framework for the study was Schatzki's (2002 & 2012) description of the organization of activities in practice and the interconnection in between practices. According to Schatzki (2002 & 2012), both humans and materiality perform actions in practice; through bodily doings and sayings. These actions are combined into tasks and projects, which can be regular, occasional, irregular or rare. The actions, tasks and projects are organized and bundled together through the practitioners' practical and general understanding of the practice, the rules to follow and teleo-affective structures about achievable goals with the activities (Schatzki, 2002 & 2012). Practices interconnect through physical objects used in a manifold of practices. There are also interconnections through common projects, ends or rules and activities (Schatzki, 2002 & 2012).

Sampling and data collection

There were fourteen interviewees altogether. For a description of the interviewees, see Table 4. The workplaces of the interviewees were: a university hospital (N=5), a district hospital (N=7) and a local hospital (N=2). For sampling procedures, see the method section in Paper III.

Table 4. Description of the interviewees (Paper III).

	Medical physicist (N=4)	Radiologist (N=5)	Radiographer (N=5)
Sex (Male/ female)	(2/ 2)	(1/ 4)	(2/ 3)
Age Md (Range)	32.5 (29–47)	42 (35–60)	54 (29–62)
Years of professional experience Md (Range)	6 (2–21)	8 (1–25)	25 (6–35)

The interview guide consisted of four questions, open in character. These questions were designed to collect data about the three different professional practices. The construction of the questions in the interview guide was influenced by the interview method "Interview to the double" (Nicolini, 2009). In this method, the interviewee is asked to describe, to an imaginary person who will do this work the following day, how the work should be performed. This method was found to be useful for exploring how practical work is performed, as well as the rules and logical structures in the three different professional practices. The first three interviews were

conducted with one interviewee from each profession. The quality of the interview guide and the three interviews were discussed at a research seminar. Suggested probing questions were added to three of the questions in the interview guide after the seminar (see Table 5). An additional eleven interviews were then conducted. Total interview time was 202 minutes (median 38 minutes, range 17–57 minutes). All interviewees chose the time and place for their interview. All the interviews were conducted under undisturbed conditions. Nine interviews were conducted at the interviewees' workplace, one in a room at a university, one at the interviewee's home and three via Skype. All fourteen interviews were conducted by LL and recorded using a digital voice recorder. Verbatim transcripts were made by LL.

Table 5. Interview guide Paper III (suggested probing questions in italics).

If you had to tell somebody, who never been to your workplace, what you do during your work, what would you tell them?
Which goals are most important to achieve with your work? - <i>Is there anything that facilitates achieving these goals? - Is there anything that complicates things for you to reach these goals?</i>
What are you responsible for during your professional work? - <i>Are there areas of responsibility that collide?</i>
Tell me about how you collaborate with other professional groups during your work? - <i>Tell me about an event that you have experienced, when you collaborated with other professional groups!</i>

Data analysis

Specific aims of Paper III were to explore, from health professionals' perspectives: a) how different professional practices involved in Medical Imaging connect, and b) how the arrangements of these practices enable or constrain collaborative work and patient safety. All fourteen interviews were used in the analysis. The data analysis was conducted in three steps.

- 1) To attain an overview of the data, all interviews were re-read several times
- 2) Practical and general understandings, rules and teleo-affective structures for each profession were separately traced in the data
- 3) Interconnections between practices were identified in the data, with special attention being given to how these interconnections affected the activities and how the arrangements enabled or constrained collaborative work to ensure patient safety.

Paper IV

Study design

The study used a qualitative design. Data was collected using observations and interviews. Firstly, a case study was conducted using observations and informal interviews. Secondly, an interview study was conducted involving individual interviews. The theoretical framework for the study was a practice theory perspective about professional knowing and learning in practice (Gherardi, 2000, Gherardi, 2009 & Gherardi, 2015). According to Gherardi (2000, 2009 & 2015), professional knowing in practice means being able to perform the practical actions, use the language and act in accordance with the aesthetic and moral values embedded in the practice. Professional knowledge is learned through negotiation, with people and materiality in practice, about the meaning of different words, materiality, actions and situations (Gherardi, 2000, Gherardi, 2009 & Gherardi, 2015). The theoretical framework was used to formulate a focus and aim for the collection of data in the case study and in the analysis of data.

The case study

Sampling and data collection

The case study was conducted at a middle-sized radiological department in Sweden. One final-year student in radiography education in Sweden participated in the study, together with supervisors and other professionals at the actual radiological department. Observations and informal interviews with the student were conducted during the performance of conventional skeletal examinations. The total time was five hours, distributed across four occasions. The focus for the observations was on the actions performed by the student, how language was used and different negotiations around materiality, words and situations within practice. The informal interviews were about situations that had recently occurred. LL asked about how the student had learned from different situations. Field-notes were written up by LL directly after each occasion of observations/ informal interviews. The field-notes were written in chronological order and included descriptions of the settings, the persons who participated, descriptions of each observation, and data from the informal interviews. Memos were written in a separate document.

Data analysis

The field-notes were re-read several times to attain a sense of the data. The student's negotiations about the meaning of different actions, materiality, words and situations were identified. A practice theory perspective (Gherardi, 2000, Gherardi, 2009 & Gherardi, 2015) was used in the interpretation and analysis of these identified occasions. The data from the case study was used together with the theoretical framework (Gherardi, 2000, Gherardi 2009 & Gherardi, 2015) for the study in constructing the interview guide for the following interview study.

The interview study

Sampling and data collection

There were ten interviewees in total, eight women and two men, from four different universities in Sweden. All the interviewees were students in radiography education in their final year of education. Their median age was 29 years (range 22–44). For the sampling procedures, see the method section in Paper IV. The interview guide consisted of four questions, open in character. The questions were designed to obtain data about how radiography students learn knowing in practice (Table 6).

Table 6. Interview guide Paper IV (suggested probing questions in italics).

When you are on clinical placement, what do you get to do there that you have not been through in the theoretical part of your education?
Can you tell me about a situation when you got to act as a radiographer! <i>-What was it that you did with the patient? Why? -What did you do with the apparatus? -Was it something that was particularly important? -Did the referral have any significance for what you did? Why? -What did you do with the images? Why?</i>
How do you act when you do not know what you should do? <i>- In connection with caring for the patient - In connection with settings in the apparatus; - In connection with image production; - In connection with judging image quality; - How did you know that you had done it right? -Why is it difficult?</i>
What helped you to learn during clinical placement?

All ten interviews were conducted via Skype. The interviewees chose the time for the interview. Total interview time was 5 hours and 8 minutes, median time 29 minutes (range 20–42 minutes). All interviews were conducted by LL and recorded using a digital voice recorder. A verbatim transcript of eight of the interviews was made by LL and the final two were transcribed by a person with long experience of transcribing research interviews.

Analysis of data from the case study and the interview study

Specific aim of Paper IV was to investigate how radiography students make sense of professional knowing in practice during clinical placements. Data was analysed using an iterative process between the empirical data and theory (Srivasta & Hopwood, 2009). Firstly, the data from the interview study was analysed. Learning events related to the three dimensions of professional knowing in practice, described by Gherardi (2000, 2009 & 2015), were identified in the data. Secondly, these events were contrasted with the occasions of negotiation identified in the data from the case study. Thirdly, an interpretation of these events was made by using the theoretical framework for the study. This resulted in three themes illustrating how the students learn and make sense of professional knowing in practice.

ETHICAL CONSIDERATIONS

The studies were approved by the regional ethics committee in Linköping (Dnr 2010/ 74-31 & Dnr 2017/ 197-31). They were conducted in accordance with the Helsinki Declaration. All participants in the studies received written information before giving consent to participate, and oral information before data collection started.

Trustworthiness

Trustworthiness is about the quality of qualitative research and includes all parts of the research process and the researcher's role during the process of qualitative research. Lincoln & Guba (1985) initially suggested four criteria corresponding to the accepted criteria for quality in quantitative research. These are: credibility, dependability, confirmability and transferability (Lincoln & Guba, 1985). Later, the same authors (Guba & Lincoln, 1994) added a fifth criterion: authenticity (Connelly, 2016).

Credibility is the most important criterion, and is comparable to internal validity in quantitative research (Lincoln & Guba, 1985; Connelly, 2016). Credibility concerns how well-conducted research can produce valid (true) findings about the studied object. This means that credibility is secured through: a) a study design incorporating multiple viewpoints into the data, b) how the selected method was used, and c) how data was collected and analysed. Multiple viewpoints on the data involve the triangulation of investigators, methods or data sources. Credibility in relation to usage of method means how the selected method was used, in a standardized or non-standardized way. When the method is used in a non-standardized way, the researcher needs to reflect on how this might have affected the data collection and analysis. Techniques for establishing credibility during data collection and analysis are: prolonged involvement in the study context, peer-debriefing, member checking and reflective journaling. Negative case analysis can be used to ensure credibility (Lincoln & Guba, 1985).

Credibility was strengthened through multiple views of the data in Papers I, II & IV. Memos were written throughout the research process during the conducting of all research (Papers I–IV).

Dependability has similarities to reliability in quantitative research and concerns the stability of the collected data (Lincoln & Guba, 1985). Reliability is how the data is measured. In qualitative research, there is no measurement, so instead dependability means the quality of data in relation to the study design, sampling procedures and how the data was collected and handled. Dependability is ensured through a description of the audit trail used for the study and it should be possible to judge this in the reporting of the research (Lincoln & Guba, 1985). Techniques for the maintenance of dependability are: process logs made by the researcher about decisions and things that have happened during the conducting of the study. Peer-debriefing with a colleague about decisions made during the research process is another technique (Connelly, 2016).

The dependability of the data in Paper I-IV is shown in the reporting of the studies. The audit trail for the studies and the decisions made in order to attain trustworthiness in the data are described, and can be judged by readers.

Confirmability corresponds to objectivity in quantitative research. This criterion judges whether the researcher can show how interpretations and conclusions have been derived from the data (Cope, 2014; Connelly, 2016; Lincoln & Guba, 1985). Confirmability is visible through a demonstration in the reporting of the research of how interpretations and conclusions were created from the data. Likewise, in the findings section, quotations from the data support confirmability (Cope, 2014; Lincoln & Guba, 1985). Procedures for guaranteeing confirmability in the analysis of data are: member-checking and peer-debriefing (Connelly, 2016). Lincoln and Guba (1985) also recommended stakeholder checks, independent coding/ analysis and coding consistency checks.

Data quality was discussed at research seminars and in the research team to ensure dependability and confirmability. Quotations from the data in the findings sections in Paper I-IV support confirmability.

Transferability might correspond to the criteria of external validity or generalization in quantitative research. Because of the different focuses in qualitative and quantitative research, there is no interest in qualitative research in demonstrating the generalizability of the findings to a larger population (Lincoln & Guba, 1985). Instead, in qualitative research it is important to provide a thick description of the context, the people being studied and the location so the reader can judge whether it is possible to transfer the findings to other contexts and populations. Transparency in the reporting of the analysis and trustworthiness improve transferability (Connelly, 2016).

Thick descriptions of the people and context studied facilitate the judging of transferability of the findings in Paper I-IV in this thesis.

Authenticity is not related to quality criteria in quantitative research (Connelly, 2016; Cope, 2014). Instead, authenticity refers to how well the research findings can give a realistic view of people's feelings and their world in relation to the inquiry of the study. Techniques for improving authenticity are: the sampling of informants, which can provide rich data about the study object, and descriptions of how well the researchers met the criterion of authenticity in the research conducted (Connelly, 2016; Cope, 2014).

Authenticity was maintained through the purposeful sampling of informants in Papers I, II & III in order to obtain rich data about the study object and the informants' experiences of the studied object. In Paper IV, all informants had an interest in clinical placement (see Method section in Paper IV).

FINDINGS

Main findings (Paper I)

The aim of this paper was to explore, from the perspective of the radiographer, the general tasks and responsibilities of their work. The findings show that radiographers' professional work and responsibilities with image production can be viewed as a process that includes three phases: a) planning the examination b) producing the images and c) evaluating the examination. The result of this process is images that are useful for diagnosis. To achieve this result, the radiographer makes different judgements during each phase and adjusts the technology to each patient's needs. The three phases of the radiography process with imaging will be explained in the following.

Planning the examination included:

Critically reading and assessing the referral before meeting the patient was identified as important. During work with multidimensional techniques like CT and MRI, the radiologist had chosen the method for how the examination should be performed in advance. During work with conventional imaging techniques, the radiographer chose a method in relation to each patient's medical problem and the question at issue, as described in the referral by the referring physician.

When the radiographer met the patient, the accuracy of the description of their symptoms in the referral was checked by *observing and interviewing* the patient. If the symptoms differed from what was described in the referral, the radiographer judged the appropriateness of the question at issue. Identification and judgement of functional impairment and/ or pain was also important because it might affect the ability to visualize the intended anatomy and pathology on the images. The patient's *psychological condition* was also judged by the radiographer because many patients were anxious about undergoing examinations. This might be because they were worried about the diagnosis that can come out of the examination or because they had recently undergone an injury or trauma. It was important to identify these patients because they might need extra time for talking and questions. This was important both for the patient's well-being under examination, and also because it established rapport, making co-operation easier. A worried patient might have problems in understanding information related to the examination; for example, instructions about breathing during image production. An established rapport between the radiographer and the patient eased collaboration and prevented motion artefacts on the images.

The communicative capacity of the patient was also judged because this might also affect the ability to obtain sufficient image quality. Reduced communicative capacity, for example, hearing impairment or language difficulties, was experienced as a challenge for the radiographer because of the limited time available for each examination.

Safety aspects related to the chosen method were crucial to identify. Methods involving iodinated radiation meant that there were special groups of patients for whom radiation doses must be carefully checked; for example, fertile women and children. Counter indications for examinations, like contrast allergy or having implants in the body, were also important to recognize. The latter was a counter-indication for undergoing MRI.

Producing the images included following judgements and tasks;

The radiographer *decided which protocol to use on the modality*. This was undertaken in relation to the selected method for image production, the patient's condition, capacity and needs, and identified safety risks. The informants explained that their ability to do this required knowledge beyond pressing buttons. They knew how to modify the machines' parameters when needed. Their responsibilities also covered medical-technology skills related to giving the patients intravenous or oral contrast for contrast enhancement of the images.

Positioning the patient correctly in the machine before image production was important. The patient needed to be placed correctly in order to attain good visualization of the actual anatomy and pathology. But the positioning of the patient in the machine also had to be performed in a safe and comfortable manner. Sometimes they had to explain to the patient that, even though it was an uncomfortable position, it was important to try to hold it to maintain the image quality.

Verification with the patient so that co-operation is established was about checking before the start of image production that the patient was placed correctly in the machine, and knew about the coming breathing instructions and bodily sensations that might occur when intravenous contrast was used.

Producing the images comprised different practical tasks, depending on which modality was being used. During work with conventional imaging techniques, there were more psycho-motor skills that the radiographer had to perform, such as placing the patient correctly in relation to the x-ray tube in order to obtain the correct visualization. Working with multidimensional imaging techniques meant more work with the machines instead of, for example, choosing the correct protocol and timing the contrast injection to the actual image production. The patient was usually placed in the same position during the whole image production. This phase, producing the images was explained as the autonomous professional part.

Evaluating the examination encompassed;

judging image quality in relation to various different aspects. The radiographer checked that the right anatomical area was included on the images, and evaluated image quality in relation to the visualization of the actual pathology. An experienced radiographer knew when the image quality was adequate in relation to the

conditions for performing the examination. Evaluation of the examinations was both described by the informants in the interviews and also seen in the observations. The radiographer wrote comments to the radiologists if the image quality was poor to explain the conditions while conducting the examination. They considered that they could recognize pathology on the images but only used this knowledge in situations when it could facilitate the patient's diagnostic process. Before the patient left the department, the radiographer explained the next steps in the diagnostic process.

Main findings (Paper II)

The aim of this paper was to explore how technical developments affect the relations between different actors and their actions in the practice of Computer Tomography (CT). The findings are presented under four themes showing how the switch of technology from conventional imaging techniques to CT technique has affected radiographers' practical tasks relating to image production and their relations with different actors within the practice. In the following, these four themes will be presented.

Changed materiality makes practical actions easier

Radiographers' practical work with CT was explained by the informants as easier than with conventional imaging techniques. One reason was that, when a protocol for image production was chosen in the CT machine, all the parameters for scanning were set automatically. Usually no parameters had to be changed. The informants found it difficult to retain control over radiation doses given to patients, even though they felt responsible for this issue. The exposure parameters in the machines' protocols were pre-set by physicists, so the interviewees felt that they had no control over them. The exact function of each protocol was sometimes experienced as hidden because the parameters constituting each protocol were not apparent to the informants. Another reason why the practical work was easier for radiographers was that, during image production with CT compared to conventional imaging techniques, the patient often stayed in the same position during the scanning, i.e. for the entire image production. This made it easier both to position the patient in the machine and also to give information ahead of the examination. The reconstruction of images after scanning was usually accomplished from standardized projections.

New machines cause conflict between work arrangements and patients' needs

This theme was about relations between human aspects and technology. Many patients who came for a radiological examination were anxious about undergoing the examination or suffering from pain. This was often unknown to the radiographers before the patient came to the radiological department because information about the patient when the examination was being planned came from

the referral, which was written by the referring physician for diagnostic purposes. Usually, it included no information that could facilitate the planning of individualized care. The informants also said that the time required to do the CT scanning was usually easy to foresee because generally no extra scans were needed. When planning CT examinations, a standard time was added for conducting the practical work with the patient. But the time for each examination varied in relation to the diverse needs of patients. Because information was lacking ahead of the examination, individualized care was difficult to achieve in practice.

Changing materiality prefigures learning

This theme was also about relations between humans and technology. The informants said that the switch from conventional imaging techniques to CT meant that there was an on-going development of methods for image production. The protocols in the scanners often changed due to technological improvements, and the written methods for image production were also adjusted. This meant that radiographers often had to check the method descriptions in order to know how to act in practice. They also described this as something that could affect their relations with patients. When the informants were not sure about how to handle the technology, it led to feelings of stress and that could affect their relations with patients.

How the connections between different practices lead to moments of practical reasoning in the radiography process using CT

Materiality, for example, machines and computers connected the different professional practices related to image production. Radiographers' practice was connected to radiologists' practice via digital written communication through computers. Usually, they work in different physical areas. The referral was the main information source for the radiologist when deciding upon how a CT examination should be conducted. The prescription about how the examination should be performed was written as a few abbreviated words in the referral notes for instructing the radiographer. These were read and judged by the radiographers in relation to the patient safety risks they had themselves identified. If a modification of the method was needed, these matters were discussed with a colleague or radiologist.

Radiographers' and physicists' practices were connected through the protocols set in the CT machine. The content of these protocols and how the parameters were set steered the radiation doses but the actual dose for each examination was also dependent on how the radiographer performed the examination. Radiation risks might occur if they did not identify a radiation security risk in relation to the actual patient or if they did not properly judge whether the intended protocol was appropriate or not.

In CT practice, part of the teleo-affective structures concerned patient safety in relation to both image quality and radiation doses. These were visible through the construction of the machine protocols and the written instructions about the intended actions of the people involved in the practice. When the visible intended path could be followed, the actions in the practice were easy to conduct. However, the sparse information about each individual patient's medical and psychological status and needs made it difficult to individualize the examinations. This sparse information about the patient also led to moments when practical reasoning about how to continue the practice was important from a patient safety perspective.

Main findings (Paper III)

The aim of this paper was to explore, from health professionals' perspectives: a) how different professional practices involved in medical imaging connect, and b) how the arrangement of these practices both enables and constrains collaborative work and patient safety.

Four interconnections were identified, three in the workflow with image production and one in the development of methods for image production. The quality of two involved artefacts was important for ensuring patient safety. In the following, collaborative work relating to the four interconnections will be presented.

Justification and prioritizing of examinations

The practices of medical imaging were connected to general medical practices through the referral. In the findings of this study, the referral was interpreted as an artefact involving written statements that enabled the justification and prioritizing of the examination. The written information in the referral should give the radiologist enough information about the patient's medical problems/symptoms and the question at issue to enable the selection of the appropriate method for examination and to prioritize when it should be done. This task has become more complex due to the development of the methods and modalities used for image production. This development has also led to that the radiologist often need to discuss the case with the referring physician in order to achieve the goal of radiologists' practice: a correct diagnosis at the right time. The radiologist also has to discuss the case with the referring physician when the referral does not have enough information for a proper justification and prioritization of the examination.

The prescribed and acceptable end of radiologists' practice was the justification of the examination, from the viewpoint of both radiation protection and proper usage of resources within the healthcare system. From the referring physicians' perspective, there were material arrangements that pointed towards other achievable goals, with the need for a rapid flow of patients through the healthcare system. The usage of medical images for assessing a patient's medical status has become more frequent, and radiation protection issues were not clearly expressed in the organization of

healthcare. This means that diverse achievable goals in different practices might collide. Radiologists' intended goal in their practice – a correct diagnosis at the right time – requires both the justification and prioritizing of examinations. When the teleo-affective structures in different practices collide, it can lead to the radiologist either only prioritizing the examination without justification, or also performing actions for justification. Actions for justification involved discussions with the referring physician, which could lead to learning events about each other's practical understanding. If a mutual discussion did not happen, this could be time-consuming and the conducting of the examination could be delayed.

Communication of the diagnosis

The diagnosis of the images was communicated to the referring physician in a written report. Some cases were also communicated during radiological round-table meetings. The written reports were formulated and organized differently depending on the radiologist's habits. This could affect patient safety because it might have an effect on how the referring physician read and interpreted the radiological report. Collaboration between different medical disciplines in round-table meetings has become a common task for radiologists. The treatment for each patient was decided in these meetings. For the radiologists, it meant learning activities about the patient cases in interaction with clinicians.

Conducting the image production

This interconnection was between radiologists' and radiographers' practice. There were common achievable goals about patient safety and diagnostic certainty that connected the two professional practices. In daily routines, the activities of these two professional practices were organized as parallel projects without any connections during image production. Occasional tasks during image production could lead to a need for collaboration in order to realize common achievable goals for both professions. How the practice was arranged to enable occasional collaboration during image production could affect the ability to meet these goals.

The practice was arranged around regular actions and tasks relating to image production for the radiographers through written prescriptions in the referral made by the radiologist about how examinations with CT and MRI should be conducted. The radiographers conducted conventional imaging techniques from method descriptions in order to address the question at issue in the referral. The radiographer met the patient in the radiological department. Reading the referral and the prescription and checking whether there were patient safety risks involved in the examination were emphasized in the interviews as being important for reaching the goal of radiographers' practice: to produce images in a patient-secure way. Image production with good image quality achieved in a patient-secure way was established through the written statements made by the referring clinician and the prescriptions provided by the radiologist about which method to use for image production. The radiographers wrote messages to the radiologist in the referral notes

if something of importance for the diagnostic work had happened during the image production.

Occasionally, the radiographer did not follow the intended chain of actions by following regular actions and tasks for achieving the goal of diagnostic certainty. One type of occasion was when the radiographer discovered that the patient's actual status differed from what was described in the referral in a way which indicated that the method of image production needed to be modified. Another type of occasion was when patient security risks in going through the planned examination were discovered. Occasionally the radiographers identified findings on the images that were important for how the examination should be completed and issues about whether the image quality was sufficient or not. There were occasions when the intended chain of action was not followed. Decisions about whether to continue with other actions to meet the achievable goals of both practices were identified in the interviews as decisions that were taken in radiologists' practice. However, because these were not regular actions and tasks in radiologists' practice, they might interrupt radiologists involved in other activities, tasks and projects. The informants said that the way in which the practices were arranged for this occasional collaborative work affected the quality of the examinations and the ability to ensure patient safety and diagnostic certainty. Teleo-affective structures in both of the involved professions harmonized around these issues, but the practical arrangements could affect the ability to reach the intended goals.

Collaboration in the development of methods for image production

An artefact (the image) was relational to all the involved professions in the fourth interconnection between practices. There were common teleo-affective structures and achievable goals between medical physicists, radiologists and radiographers that were designed to ensure patient safety. In the findings, there were also signs indicating that the arrangement of medical imaging can either accentuate productivity in terms of the number of examinations performed or prefigure patient safety. It was shown in the interviews that participants expressed needs of collaborative work around image quality, due to the development of modalities and methods of image production for the optimization of radiation doses and the adjustment of protocols. The collaborative work about optimization of doses in relation to image quality; needed involvement of all three professions. In the interviews, it was discovered that parts of all three professions' teleo-affective structures harmonized in this collaborative work, but that they had diverse practical understandings of the practice. Achievable goals in all the involved professions were: to use the lowest possible radiation doses while obtaining sufficient image quality for diagnostic certainty. This collaborative work was seen as important; however, it was described as vulnerable due to increased pressure to achieve high productivity in medical imaging examinations.

Main findings (Paper IV)

The aim of this paper was to investigate how radiography students make sense of professional knowing in practice during clinical placements. The findings illuminated three different ways in which the radiography students make sense of professional knowing during clinical placements. In the following, these three ways will be presented.

Relating to materiality in practice: learning through listening and observing

The importance of observing and listening in practice as initial strategies for learning was emphasized by the students. They described how, to be able to act in practice, it was important to firstly understand the unique material arrangements in each practice. They observed physical things, for example, different radiological equipment, and recognized these from their theoretical studies. The students also observed during the actual clinical placement how the protocols were set in the machines, method descriptions for image production and how the radiographers used specific radiological equipment.

The students found it easier to understand specific terminology and words relating to the machines and protocols, which they knew from their theoretical studies, when they listened to how the professional language was used during practical work.

The students also observed how the practical work with image production was performed by radiographers. This work process was unfamiliar to the students. They described how, in their theoretical studies, they had learned relevant theories related to radiographers' work; for example, patient care, radiation protection, anatomy etc. But the work process, and the sequence in which radiographers' practical actions were performed was important for the students to observe in practice. If there were no opportunities to see the performances in practice before their own turn came, it led to a lot of questions about how the actions should be performed and in what order.

The students declared that there were differences between clinical placements in how the radiographers communicated with patients. Therefore, listening and observing how the radiographers/ supervisors communicated and established relations with patients in the particular setting at hand were important before their own turn came. The students initially imitated the radiographers/ supervisors but after a while they started to use their own expressions and words instead in the communications with patients. The useful parts of their theoretical knowledge about communication and caring, obtained from theories about nursing practice, were translated by the students into radiographers' practice. They could see whether the patients looked confident or not and could listen to what the patients said in order to learn the results of their actions. The students got written or verbal comments daily or weekly about their communication skills from their supervisors, but only sparsely about specific situations with patients.

These findings emphasize the theoretical standpoint that practices are enacted and shaped differently depending on the materiality of a situation (Gherardi, 2005). The findings also show that practice-as-work (Gherardi, 2000) was learned by radiography students through firstly listening and observing before their own practice. In relation to materiality, practice- as-language (Gherardi, 2000) was important to listen to in practice and also see words and utterances in the machines before acting by themselves. Practice as language in relation to care and communication was translated from their theoretical knowledge gained from nursing theories into radiographers' practice. The students also learned practice-as-language through their own actions and participation in practice.

Embodied knowings: Learning through acting in practice

In their theoretical studies, the students had learned some practical skills related to image production through simulated image production with each other. They had learned how different anatomical structures feel and where these are located in the body. This was learned through palpation on each other's bodies, and the students described how they knew this through their senses. This knowing was described as important for being able to perform image production. How to position the patient correctly before image production was also learned theoretically in the training sessions before clinical placements. But because no image was exposed during these training sessions, the students had not seen the results of their actions.

In clinical placement, when the students started to perform image production, they recognized the difficulties involved in positioning and palpating the body of an unknown person. Doing these actions was easier with a friend or student they already knew. From their theoretical studies, they could recognize some anatomical structures on the images. Knowing about how to carry out practical actions with patients before image production was improved by seeing diagnostic images during their clinical placements. This was learned through viewing the images in relation to the body that was being visualized and their own practical actions. The supervisors scaffold the students' observations at the beginning to help them to discover pathology and different anatomical structures on the images. In order to interpret the results of their practical actions, it was important to view the images together with a supervisor.

The performance of image production was a process in which bodily actions, learning and objects were intertwined. Through their feelings in their own bodies, the students learned the actions when they performed examinations. This was about feelings from palpating bodies, touching technical equipment when preparing for image production and placing intravenous peripheral catheters. Through repeating the work process several times, these actions became embodied. The observations and interviews made it clear that, by using their senses, the students were reconstructing previous practical knowing. In order to develop knowing about materiality, there were negotiations with other actors in practice. Relations with others and feeling and sensing materiality facilitated the development of knowing in

practice.

Practice-as-morality, i.e. politics and authority in practice (Gherardi, 2000), inclined the students' learning in practice was identified in the ways in which supervisors allowed the students to act and perform the examinations by themselves, with support when needed. Thus, embodied knowing was enabled through repeated actions.

Dealing with the unexpected: Learning at breakdowns

According to Gherardi (2000), a person who is accustomed to knowing how to act in a practice does not think about their own actions. But these known feelings break down if something unexpected occurs. Then they have to reflect upon previous experiences and knowledge and change their actions in relation to the new situation.

The students described that sometimes it happened, in the process of image production, that the images did not match up to the expected results. The reasons could be that a patient's injuries or unusual anatomy/ pathology led to difficulties in achieving the correct visualization of their body. Technical artefacts might be another reason. The student then had to use their previous theoretical knowledge about anatomy and pathology to interpret the images. Through looking at the images and the patient's body, the student tried, together with the supervisor, to perform other activities and adjust the method used for image production to the actual patient's anatomy or medical status. The supervisor performed the new and unusual actions when it was a totally unknown situation for the student. The student returned to observing and listening instead. To improve the student's learning, it was important for the supervisor to explain the choice of specific actions in relation to the actual patient. These explanations could refer to actions related to the patient; for example, adjusting the positioning of the patient before image production. It could also relate to actions of a technical character, like changing the parameters in the protocols. These explanations helped the students to try to perform actions by themselves if a similar situation occurred later.

Breakdowns could also occur during communication with patients; i.e. learning practice as language. The students encountered patients who became distressed due to sorrow, anxiety or pain. If the students did not know how to handle the situation, they let the supervisor act instead, similarly to the situations in which the materiality arrangement was used. The students instead observed and listened to how the supervisor acted to reassure the patient. The student's knowledge about how to handle these types of situation was supported by mutual discussion with the supervisor afterwards.

These findings show that a breakdown of previous knowledge can happen both in relation to materiality and in relations with patients. During breakdowns in relation to materiality, the content of the unexpected materiality has to be interpreted in relation to previous theoretical knowledge before the performance of new actions can occur. These types of breakdowns led to learning if the practice was arranged in a

way that made negotiations with other actors possible. These negotiations were about actions in relation to the involved materiality. Common to both types of breakdown was the fact that the students observed and listened when these situations were too complex for them to handle. Mutual discussions with other actors afterwards led to an improvement in students' learning about knowing in practice.

DISCUSSION

The findings presented in Paper I illustrate the general tasks and responsibilities included in radiographers' work process with image production. This can be seen as the logic of practice (Gherardi, 2000 & Gherardi, 2015), which incorporates practice-as-work, practice-as-language and practice-as-morality. The findings reported in Paper IV indicate that the work process was unfamiliar to the students from their theoretical studies. Radiographers' professional work with image production has been illustrated through competence descriptions (ISRRT, 2004; EFRS, 2018) and in previous research on radiography practice (Andersson et al., 2012a; Andersson et al., 2012b), which shows their practice-as-work but does not capture practice-as-language or practice-as-morality, the other two dimensions described by Gherardi (2000 & 2017).

There are similarities between the findings presented in Paper I and Ahonen's (2008 & 2009) description of radiographers' professional work. Ahonen (2009) claimed that radiographers are responsible for technical radiation usage, radiation safety and patient care. These claims are in line with the findings reported in Papers I–III but the findings of this thesis indicate that radiographers are also responsible for and involved in patient safety aspects in relation to medical safety issues. The third aspect of radiographers' professional work as identified by Ahonen (2009), i.e. providing services to the healthcare sector, is not clearly recognized in the findings of this thesis. In Paper III, interconnections between practices are shown to be important regarding patient safety aspects. Two such interconnections are identified between radiologists and general medicine that are important for ensuring patient safety. Radiographers are not involved in these interconnections. The findings described in the study by Ahonen (2008 & 2009) are at an abstract level, which makes it difficult to see how professional tasks and responsibilities are used in practice. The findings presented in Paper I contribute to a practice-based understanding of radiographers' general tasks and responsibilities in relation to image production. These findings can be used for professionalization purposes and in educational programmes for radiographers.

Niemi & Paasivara (2007) identified three discourses relating to radiographers' professional identity. These were technical, safety and professional discourses. The technical discourse (Niemi & Paasivara, 2007) illustrates radiographers' professional identity as technical experts in relation to the introduction of new technology. These findings are in line with the findings reported in Paper I, which show that radiographers identify their autonomous professional area as "producing the images". The safety discourse described by Niemi and Paasivara (2007) claims that radiographers are protectors against safety risks related to radiation. The findings presented in Paper II illustrate that the material arrangements, i.e. the visibility of the set parameters in the machines in relation to radiation doses, can make this professional responsibility hard to fulfil. The findings reported in Paper III show that there are also other actors and material arrangements affecting radiation protection issues during justification of the examination, with no involvement of radiographers' practice.

The findings presented in Paper II show that a switching of imaging technique from conventional methods to CT means that radiographers' professional work with "Producing the images" has become easier in practical terms. The findings given in Paper I show that they have knowledge about which protocol to use for image production, but the findings reported in Paper II indicate that, because the parameters in the protocols are experienced as hidden, this makes it hard to have control over the radiation doses given to the patient. This is in line with the findings of other studies (Fridell et al., 2009; Larsson et al., 2008; Aarts et al., 2017) which show that technology within radiography is experienced as technically deterministic, with parameters that are "hidden" from the user. In contrast, the findings reported in Paper II indicate that the planning phase has become more important for ensuring patient safety due to the technology in use. Image production using CT technique is usually performed in a single scan that cannot be repeated due to risks related to the usage of iodinated radiation and intravenous contrast.

The findings given in Paper II also show that there are relationships between technology and human aspects, i.e. person-centred care, in radiography. When planning for examinations performed by CT, the scanning time is easy to predict. Then a standard time is added for patient care and technical medical preparations, such as preparations for giving the intravenous contrast. These tasks with the patient vary and are difficult to plan for because of a lack of information about the patient when the planning for the examination takes place. Previous studies about patient care in radiography indicate that there are difficulties in tailoring for person-centred care due to time pressures (Hayre et al., 2016; Bleiker et al., 2016; Bolderstone et al., 2010). The findings presented in Paper II, in accordance with Munn et al. (2014), show that there are organizational aspects such as poor or missing information about the patient before the examination that affect the ability to plan for person-centred care. There is a need for new routines and structures to interconnect radiography practice with nursing practice.

Bleiker et al. (2016) stated that there is a need for an evidence-based definition of compassionate care in radiography. The findings presented in Paper I show that radiographers judge the patient's physical and psychological status in relation to being able to undergo the examination. Radiographers then adapt the technology in use to the individual patient. It was also considered important to judge and take into account the patient's communicative capacity during the planning of the examination. The findings reported in Paper I illustrate that these judgements and tasks were performed both for the patient's wellbeing and also to prevent image artefacts on the images. Patients' experiences of undergoing examinations in medical imaging have been investigated in a review article (Munn & Jordan, 2011). The results showed that patients need the support of staff to undergo the unusual experiences of being examined with CT and/ or MRI. This is in line with the findings presented in Paper I about radiographers' judgements and tasks to ensure the wellbeing of the patient during the examination. Munn et al. (2011) showed that, for the patient, it was important to be able to complete the examination, even though some parts of the procedures were uncomfortable for them. Some patients wanted information ahead of time from different sources; others did not want any

information. Carlsson & Carlsson (2013) claim that the information given to patients about their MRI examination, both written and verbal, needs to be based on patient participation and their specific needs if it is to be useful. From the patient's perspective, in order to be able to cope with the unusual experiences during MRI examination, a trustful dialogue with the radiographer who performs the examination is important (Carlsson et al., 2013).

Radiographers' work with image production with CT is pre-planned and visible through written comments in materiality in practice, such as prescriptions in the referral notes made by the radiologist, method descriptions and pre-planned protocols (Papers II & III). This is in accordance with findings showing that radiographers' work becomes more technologically deterministic when working in a digital workflow compared to analogue imaging techniques (Fridell et al., 2009; Larsson et al., 2008). This makes radiographers' actions easier if this path can be followed (Paper II). An interesting finding in this thesis is how patient safety is secured in radiography practice, which to our knowledge has not been shown in previous studies. Patient safety risks in medical imaging were identified by Wallin, Gustafsson, Anderzen Carlsson & Lundén (2018), including risks related to the usage of radiation and medical drugs. These authors also pointed out that there are risks relating to delayed examination and diagnosis which affect patient safety (Wallin et al., 2018). There are similarities with the findings presented in Papers II & III. However, the findings reported in Paper III show that patient safety is ensured both through individual professional actions and also as a result of interconnected tasks and projects between different practices. Patient safety is secured both in relation to the medical and radiation safety risks of undergoing the examination and also in terms of attaining diagnostic certainty and good image quality. Collaborative work in the interconnections is about the content and quality of two artefacts: the referral and the image. The introduction of digital imaging has led to the responsibility for judging image quality being transferred from radiologists to radiographers (Fridell et al., 2009; Larsson et al., 2007). The findings given in Paper III highlight that there is occasional collaborative work between radiologists and radiographers relating to image quality to ensure diagnostic certainty in the workflow with imaging. The interconnections in this workflow with imaging and the development of methods for image production are also potentially related to patient safety. These interconnections were seen as vulnerable due to pressure related to demands for productivity in practice (Paper III). This can be seen from a practice theory perspective. In practice, there are embedded visions about how the practice should be carried out (Kemmis, 2005; Kemmis, 2009; Gherardi, 2015), but the arrangement of a given practice can either enable or constrain the activity that actually occurs (Schtazki, 2002; Feldman et al., 2011).

The responsibility for judging image quality in the workflow with image production was transferred from radiologists to radiographers when digital image production was introduced (Fridell et al., 2009; Larsson et al., 2007). The findings presented in Paper III indicate that there is occasional collaborative work relating to image quality. Viewing this from the definition of role extension and role expansion (Murphy, 1970), the shift of responsibility for judging image quality can be seen as role extension without any theoretical education for new responsibilities. Mount

(2016) showed that there are differences between radiographers' and radiologists' perceptions of acceptable image quality. Radiographers had a lower tolerance for "not perfect images", meaning a higher incidence of rejected images. The higher rejection rate among radiographers can also, as described by Strudwick (2014), be understood in terms of image quality being an important part of radiographers' professional work. The interconnection between radiologists and radiographers in terms of image quality is important for diagnostic certainty and can be strengthened through collaborative work and interprofessional learning about diagnostic image quality. In educational programmes in radiography, this is an important issue to take into account.

Two levels of strategy for learning professional tasks relating to digital image production were identified by Larsson et al. (2009) and Larsson et al. (2013). Previous knowledge led to a more holistic approach, but when the radiographers were learning about previously unknown tasks, they read and understand different manuals and/or method descriptions. The findings given in Paper IV illustrate that, when students learn about knowing related to the technology in practice, it is through the identification of words and utterances from their theoretical studies about the materiality (machines). They also observed how the technology was used before they started to act by themselves. Descriptions of professional learning strategies when tackling unknown tasks (Larsson et al. 2009; Larsson et al., 2013) indicate that learners are dependent on following descriptions in order to perform tasks. Larsson et al.'s (2009 & 2013) findings are also in line with the findings reported in Paper II; because of the rapid development of methods, radiographers have to constantly read and update themselves via documents and method descriptions. Viewing this in relation to the findings about students' development of knowing in practice about technology (Paper IV), there seems to be a need for radiographers in practice to learn about new technology both theoretically and practically. This need is in line with the recommendations of the SFR (2014) for education at an advanced (master's) level for radiographers in Sweden, and can be seen as role expansion to fulfil the need for new knowing in practice (Murphy, 1970).

The radiography students' learning about knowing in practice consisted of an individual reconstruction of prior embodied knowing from the theoretical parts of the curriculum (Paper IV). There are similarities here with the findings of Aura et al. (2016), who described how simulating practical tasks in scenarios facilitates the learner in reconstructing prior knowing in practice. The findings presented in Paper IV show this in relation to the practical doings with the patient before image production. This approach might also be useful for learning about the practical handling of technology before clinical placement.

The findings reported in Paper IV show the importance of repeating actions for the development of embodied knowing in practice, as described by Gherardi (2000). The relational aspect with other persons in practice is shown in the findings presented in Paper IV, for the development of both embodied knowing through repeated actions and language-as-work. Students need to be able to build relations with others in practice that facilitate learning; therefore, the organization and planning of clinical placements are important.

Phenomenology was useful in Paper I for the description of radiographers' general tasks and responsibilities within image production. In order to learn about how technological advancement impacts upon the professionals' tasks, responsibilities and interconnections with other practices, a practice theory perspective was suitable because it takes both human and non-human actors into account. A practice theory perspective was also constructive for investigating how radiography students make sense of professional knowing in practice. For understanding these learning processes in practice, the metaphor "Becoming a professional" was valuable for investigating how the students make sense of professional knowing in practice.

Methodological considerations

Questions one and three in the interview guide for Papers I & II could have been formulated differently. The questions were: 1) Describe an ordinary situation that you have experienced when your knowledge as a radiographer was important. 3) Describe an ordinary situation when your professional knowledge was important for taking care of patients. The word "knowledge" might have made the interviewees to feel that they had to verbalize their professional knowledge and not talk about their professional tasks and responsibilities. It would have been better to formulate the questions as: 1) Describe an ordinary situation that you have experienced when what you did as a radiographer was important! 3) Describe an ordinary situation when it was important that you as radiographer took care of the patient!

The method chosen for Paper I, interpretative phenomenology (Colazzi, 1978; Szklarski, 2004) consists of six steps. The sixth step is verification of the findings. Colazzi (1978) suggested member-checking and Szklarski (2004) recommended focus-group interviews. In Paper I, the first five steps of the method (Colazzi, 1978; Szklarski, 2004) were used, which might be seen as a weakness because the findings were not verified with the informants. Instead, the data analysis was discussed at research seminars and reflective writings were made during the research process.

In Paper II, practice theory was useful for analysing the codes from the inductive analysis. The first inductive analysis resulted in a description of the changed practice related to technological advancement. Analysing the data within the codes from a practice theory perspective made it possible to identify the causes of the changed practice. The code "the image" was found not to fit into the final analysis. When scrutinizing the analysis during the writing of the thesis, it was seen that this code could have fitted into the theme: "Changed materiality makes the practical actions easier". This might have affected the credibility of Paper II.

LL's pre-understanding of the practice can be seen as a weakness. Bracketing was used in Paper I and memo writing during conduction of all Papers. Discussions within the research team and at seminars might have strengthened trustworthiness.

CONCLUSIONS

The main features of radiographers' work are: adapting the technology in use to the individual patient, ensuring patient safety while undergoing the examination and securing diagnostic certainty on the images.

Technological advancement in relation to the switch from conventional techniques to CT leads to radiographers' tasks and responsibilities with image production becoming more focused on patient safety issues during the planning phase before the image production, instead of the actual image production itself.

Interconnections in medical imaging with other practices for ensuring patient safety are about common shared tasks and projects related to two artefacts: the referral and the image.

Radiography students' learning in practice for becoming professionals is embodied, linguistic and relational mediated.

FUTURE STUDIES

Radiographers' ongoing learning about technology in practice needs to be further investigated in order to obtain knowledge about how to design courses at advanced (master's) level for radiographers in the future.

Studies are needed about inter-professional collaboration and learning in medical imaging to gain more knowledge about how and when the different professions learn together. This is important for ensuring patient safety and good image quality in medical imaging. A case study might provide in-depth knowledge about this subject.

How does distributed practice, when the radiologist in charge is at the other side of the world, affect the activities in medical imaging and in referring physicians' practice? It would be useful to design a case study in different locations; for example, a university hospital, a middle-sized hospital and a small hospital.

Studies are needed that focus on referring physicians' perspective on referring patients to medical imaging and the process of justifying the need for examinations. It would be advantageous to first conduct a case study that could be used to help formulate questions for a questionnaire that can be distributed nationally.

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