The Impact of PACS on Radiologists' Work Practice

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This paper identifies and analyzes how the implementation and use of picture archiving and communication system impacts radiologists' work practice. The study is longitudinal from 1999 to 2005 and have a qualitative perspective were data were collected by structured interviews in a total of 46. The interviews were transcribed, analyzed, and coded using grounded theory as an organizing principle. In radiologists' work practice, three main categories were defined: *professional role*, *diagnostic practice*, and *technology in use*. The changing trends within the professional role indicated that radiologists moved from a more individual *professional expertise* to become more of an *actor in a network*. The diagnostic practice changed, as reading x-ray films was seen as an *art form* in 1999, requiring years of training. Once *everyone* could view digital images, including 3-dimensional technology, it was easier for other clinicians to see and interpret the images and the *skills become accessible to everyone*. The change in technology in use *as a result of the shift* to digital images led to an *increased specialization of the radiologist*.

KEY WORDS: Radiology information systems, organization and administration, trends, professional practice, health care, PACS

INTRODUCTION

The introduction of a new technology tends to loosen occupational boundaries in affected professions.[1] Hence, it is of interest to study how the professions within radiology are influenced by the introduction of picture archiving and communication systems (PACS). Cabrera[2] remarked that it was not until PACS had been introduced that people saw the need to reform their work practice. "If we took away my computer, my colleagues, my office, my books, my desk, and my telephone, I would not be a sociologist writing papers, delivering lectures, and producing 'knowledge'. I'd be something quite other—and the same is true for all of us."[3]

Revolutionary technological innovations such as magnetic resonance imaging, computerized tomography, and ultrasound have all affected the ways in which radiologists work, and have contributed to the changing pattern of activity discussed in this paper. But the introduction of PACS is considered as possibly the most clinically significant innovation[4,5] for many years. The aim of this study is to analyze and illustrate how the use of PACS affects radiologists' work practice. PACS can be described as the applications for electronic storage, retrieval, distribution, communication, display, and processing of data associated with medical imaging. These applications create new possibilities for distributed radiology workflow. This paper will not focus on an analysis of the extent to which the various technologies have contributed to change. Instead, a holistic approach to technology innovation and work practice development will be discussed.

In this paper, a work practice is defined as a radiological occupation, ie, a community of practice with defined tasks and a set of relations

between them. New radiologists learn by conducting the defined tasks and also through the interactions and relationships within the community. In this study, PACS function in a hospital-wide electronic network connecting different image production modules, archives, printers, diagnosis and reporting work stations, and work stations in other units within the hospital. Several manufacturers sell PACS. Most PACS products are based on the global medicotechnical standard "digital imaging and communication in medicine" (DICOM). Digital imaging and communication in medicine is based on the idea that there will be one homogeneous image technical network of uniform design, so it is perhaps not surprising that the conformance statements of DICOM impose stringent design constraints.

Related Research

Many studies of PACS address technical issues, such as technical descriptions of clinical applications: PACS, Web technologies, teleradiology solutions, 3-dimensional and multimedia applications, image acquisition and hospital information system/radiology information system/PACS integration.[5–7] These articles record that there has been continuous growth in clinical implementation of PACS, and that this is a trend that is expected to continue internationally. However, PACS are complex and costly. To select a system that best meets customer requirements, purchasers of PACS equipment need to be aware of the key characteristics and different features of the various products. Mobile products used for other purposes are now sufficiently effective to be linked to PACS. It is likely that handheld personal digital assistants will soon be in use in radiology, will become an important platform for image review and reporting, and will enhance communication with referring clinicians. So the technology is not in itself a limitation to innovation in work practices. However, the technical standards, ie, High Level-7, KithXML, Dicom Structured Reporting, and XDS, remain elusive in most health care environments, even those with new systems. But the prospect of applying the "gold standard" appears to be on the horizon.

Bramson and Bramson[8] have an organizational perspective on PACS. They argue that the ability

to view organizational issues related to changing how people do their work, from multiple organizational perspectives, is equally important in the determining the success of PACS projects. They suggest (1) the involvement of system users in design implementation, (2) training and ongoing support of users, (3) the importance of building persuasive cases for change and development to support change, and (4) creation by management of opportunities that encourage users to let go and look ahead.

Studies of clinical organization have uncovered a range of meanings associated with the use of PACS in medical work. In a study of the impact of PACS on medical work, Lundberg[9] points out that the new tools used, ie, PACS, are not isolated artifacts but social and material parts of medical work; when PACS are introduced this intervention creates new activities and responsibilities. This implies that the use of PACS leads to change in the radiologist's working practice. Lundberg concluded that the radiologist was not equipped in the same way as before using PACS. From her study it may be concluded that in 1999 the changes in work practice were very limited.[9] Studies of the changes of social and organizational issues related to the use of PACS are limited. We were unable to find any such work after 1999 on this subject. This is possibly because such studies require interpretive qualitative analysis over a longer period of time, for example, using interviews or observations. These methods are not commonly used in studies of technological change within the medical field.

Medical work is complex, partly because of the unexpected contingencies, which frequently arise. According to Berg, "...medical personnel are engaged in a never-ending process of ad hoc rearticulations."[10,11] This may be because of the delivery of an unexpected x-ray diagnosis or a new supervisor who disagrees with the policies of the previous one, etc. Medical staff are continuously working, managing with odds and ends, to perform their tasks in keeping the patient's trajectory on track—while concurrently reconstructing its course.

We focus on how diagnostic practice changes over time using PACS. In this process we highlight changes in radiologists' profession, diagnostic practice, and technology in use from 1999 to 2005.

METHOD

One reason for choosing a qualitative method is its potential to make diagnostic work visible. The opportunity that the interviews provide to elucidate medical settings and to illustrate the activities of radiologists has been crucial in this study. The interviews were structured, ie, all interviewees were asked the same questions in the same order. However, they were open-ended in the sense that follow-up questions were permitted in the interviews. The questions covered three areas: (1) technology in use, (2) practice related to technology in use, and (3) professional skills and learning processes. All interviews covered the following questions: (1) How did you prepare yourself for the transition from x-ray film to digital images using PACS? (2) How were you educated in the new technology? (3) How were the groups divided during this training? (4) How has your work practice changed? (5) How has it changed in relation to the interpretation of images, professional skills, image processing, prestige in work? (6) Has the professional radiology paradigm shifted in relation to either threats or opportunities? (7) How has learning and diagnostic knowledge changed? (8) What trends of changes in diagnostic practice might be identified? (9) Why have these changes occurred? (10) What were the indicators of change?

A senior administrator at Lund University Hospital, who also had strong connections at the other three sites, selected the participants for the study from the total of 57 radiologists at the four participating hospitals. He contacted the majority of the radiologists, and asked if they had experience of the implementation of PACS, and, if so, whether they were willing to share their experience in an interview. He then planned and booked all interviews. Different numbers of respondents, and individuals were available for interview on the different occasions at Lund University Hospital. However, at Ystad Community Hospital, Landskrona Hospital and Simrishamn Hospital in Sweden, all the radiologists on duty agreed to be interviewed on each occasion.

The sites chosen for the empirical study were the departments in the Skane region using PACS in work practice at that time (see Table 1).

On the first occasion, in 1999, 12 radiologists were interviewed. Of these, 11 were specialists, including 2 who were also managers, while the 12th was a subspecialist. On the second occasion, in 2000, 12 were interviewed; all were specialists, and 3 of the specialists were also managers. On the third occasion, in 2002, 12 were interviewed; 1 was a resident and 11 were specialists (1 specialist was also a manager). Finally on the fourth occasion, in 2005, 10 radiologists were interviewed; all 10 were specialists and 3 were also managers. In total, 24 interviews were conducted in Lund, 10 in Ystad, 8 in Landskrona, and 4 in Simrishamn. PACS was introduced in Lund, Landskrona and Ystad in 1998 and in Simrishamn in 1999.

The interviews were transcribed, analyzed, and coded using grounded theory as an organizing principle. The grounded theory method has recently become more widely recognized as a research technique within the health care field.[12–16] Health care researchers studying information technology implementation and use have also applied this theory.[17–20]

The interview data were viewed from different perspectives by different people to elicit a range of meaning from the basic textual material. Immediately after each interview, each researcher read through the data material to gain an initial impression of the collected material. The analytic method used in this study is called open coding, as

Table 1. Respondents and Sites (Hospitals) from 1999, 2000, 2002, and 2005

	1999	2000	2002	2005
Lund	7 (3)[a]	5 (3)	7 (3)	5 (3)
Ystad	2 (2)	4 (2)	2 (2)	2 (2)
Landskrona	2 (2)	2 (2)	2 (2)	2 (2)
Simrishamn	1 (1)	1 (1)	1 (1)	1 (1)

[a]In Landskrona and Simrishamn the same radiologists were interviewed on all four occasions. In Ystad two of the four radiologists were interviewed on all four occasions and in Lund three of the radiologists were interviewed on all four occasions

described by Strauss and Corbin.[21] At first an open coding is done. This requires a careful reading of the transcript of the interviews. The analysis started by breaking down the interview text and taking it apart, like a sentence, and giving each part a name in the open coding/classification; this is called conceptualizing. The process is intended to identify the concepts/groups and the smallest parts in the analyzing process. This is the first step in the reduction of data. The next step is to group related concepts. The process of grouping concepts that seem to pertain to the same content is called categorizing. The final stage of the analysis is the making of categories (see Fig. 1). The researchers performed the process first individually and then jointly. The process is continued until the researchers have agreed on common categories (compare Giorgi[22]). The process of categorizing was conducted three times in this study. The three main categories were defined as: *professional role*, *diagnostical practice*, and *technology in use*.

RESULTS

Changes in the Radiologists' Work Practice from 1999 to 2005

The results in this study show trends of central changes in the radiologists' work practice, translating from reading x-ray films to reading digital images on computers. These changes are summarized in Figure 1.

Threats and Opportunities in 1999

Professional Role

Radiologists described the x-ray film image and the content of the image as strongly related to *professional expertise*. The skill lies in the ability to discern the relevant diagnostic information, sometimes from a very extensive base of material. A central issue concerning the radiologists was how the translation from analogue x-ray films to digital images would be carried out in practice. In the analysis, the age of the radiologists could be identified as a factor associated with the range of opinions. Fear of change was noticeable among the senior radiologists, in contrast to the junior radiologists, who identified improved possibilities to offer new and better services in the future. The junior radiologists were early adopters of the new technology. This in turn had an impact on tutoring and they become "superusers", ie, expert users. The junior radiologist became the senior radiologist's tutor in the digital environment. The interviews indicated that the radiologists' professional role was strongly related to the individual's professional expertise and performance.

Diagnostic Practice

In the world of analogue technology, x-ray radiologists are accustomed to handling x-ray film as a physical material, and it has not been possible to manipulate the content of the image, "...you could feel, smell, and touch it" as one of the
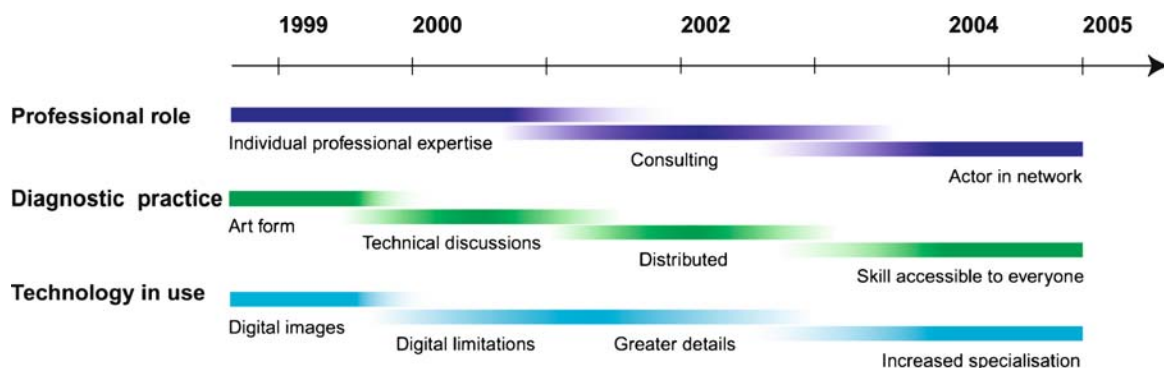

Fig. 1. The trends of changes in the radiologists' work practice from 1999 to 2005 using PACS.

radiologists stated. Many describe this work of analyzing the x-ray film images *as an art form* demanding considerable time and experience. The occupational skills involved can therefore also be difficult to describe. Nevertheless, the way in which radiologists experience the environment in which analysis work takes place, and their interaction with the material examined, is important. Could PACS threaten this core competence? No evidence to suggest that this might be the case was found in the present study. It became clear from the interviews that the diagnostic practice at this time was strongly related to the physical object and the art of reading it.

Technology in Use

As x-ray films became *digital images*, they also became distributed in the sense that there was no longer one original x-ray film. Digital images could be accessed in as many "originals" as might be wanted. This in turn gave the clinicians in other disciplines the opportunity to read the images themselves. As the radiology's x-ray film ownership dissolves, would the demand for their services decrease? How can the services of radiology remain attractive in the future?

The interviews showed that with digital technology and the PACS, the technology in use was no longer strongly related to the physical object, and hence could be communicated in many new ways.

Problems and Opportunities in 2000

In the second interviews, conducted after 1 year had passed, the radiologists had all gained experience of PACS. It was possible to categorize changes in their comments that were traceable back to the original interviews concerning the expectations that professional groups had for PACS and for their occupational activities. The general finding of these interviews was that the radiologists' professional role was still strongly related to the individual's professional expertise and performance.

Professional Role

Radiologists described the core of their skill as being able to discern the relevant information in the image, and being able to understand how the image is produced and manipulated. Because the skill of professional expertise is only acquired through long experience, the respondents were not able to see any significant changes at this early stage. The interviews indicated that this was the first time a real shift of focus was identified, as the diagnostic material changed the practice shifted from having the art form in focus to having intense and necessary technical discussions.

Diagnostic Practice

The fact that digital images have considerable potential for manipulation was a feature of the new technology, which radiologists had not yet learned to exploit. There are two main explanations for this. One is that it takes time to learn to use this facility, and the other explanation is that the radiologists may have been unable to recognize the value inherent in this option. This was expressed in the view that technology takes too much space, and that there was a risk that the focus had shifted from diagnosis to *technical discussions*. "Previously the most interesting element was the content of the image, but now we have training on how to use the technology rather than on interpretative diagnostics..." The interviews showed that the quality of digital images had become a central focus. The contextual framework of diagnosing images had been changed.

Technology in Use

The radiologists described the image itself as important in the way it was presented to the observer. The way in which the presentation of the image is received can naturally make it easier to focus on the content of the image. It is therefore unsurprising that radiologists were critical of changes from analogue to digital image format, and they complained about the *image limitations*: "...the radiologist takes the x-ray film from the light box, holds it up, and turns it to examine it from different angles. This is not possible on a 21-inch monitor." The analysis first involves a general overview of the image material available. When this facility is changed, important conditions also change. Changes in the mental approach in the interpretation of the digital examination

were, in themselves, a challenge. Things could not be done as before. Again, the key finding of the interviews in this respect was that the quality and the practice linked to the digital images was of central focus. The contextual framework of diagnosing images had been changed.

The Winds of Change in 2002

Professional Role

A significant feature of the professions and their development is the learning process, which hones the skills of the professional while also ensuring that skills are maintained and developed. In the first study, the radiologists described their occupational skills as an art form, which meant that it took a long time to learn, requiring both knowledge and experience. In 2002, a generational difference becomes apparent between the senior and junior radiologists concerning their view of the new workflow. The junior radiologists do not experience the new workflow as threatening, and are able to formulate a vision of the future in which they see potential in the new workflow for the simplification of *consulting*. They recognize that, with rationalization of activity, closer contact with the customer/clinicians can be achieved. Senior radiologists, on the other hand, see the new technology as presenting a threat to both their skills and their independence. "I won't be able to do my job in three years' time. I will be sitting at a computer..." The interviews indicated that the radiologists' professional role had shifted, becoming more of a consulting role, with a discussion and focus on new services to be offered by the radiology department.

Diagnostic Practice

Negative attitudes were changed over time. At the third interview, an assimilation of the new workflow has begun to emerge. This is true of radiologists at both smaller and larger clinics. At smaller clinics they see the potential for professional exchange through rapid access to radiologists and specialists by *distributing* the images and then discussing them over the telephone, as both parties are able to have the image in front of them at the same time. "...in a couple of years we will be going out from the x-ray department, and

having the clinical meetings at the wards." The finding from the third round of interviews was the focus on change management in diagnostic practice related to the distributed diagnostic opportunities, which had become available.

Technology in Use

At the larger clinics, the clinical meetings have taken on new dimensions. This is probably because of the fact that the examination images are accessible to everyone present at conferences. It is not surprising to find respondents expressing appreciation of the changes, which give them the option of manipulating images infinitely, showing *greater detail* in the images, and which improve the level of communication with their colleagues' in other disciplines. In the previous system, the x-ray films were shown in their original form, which often meant that they were far too small to be seen by those without a front row seat. These interviews showed that at this stage the radiologists had more fully realized the opportunities provided by digital technology, for instance, the processing possibilities and the new opportunities for using digital images as visualization at clinical meetings.

Growing Demands in 2005

Two years had passed since the last round of interviews. The system had been updated several times and had become more stable and reliable. The radiologists felt more secure using the system, but at the same time, they felt that the system could be more flexible and thus more responsive to new ways of working. Their conclusion this time, however, was that the advantages were greater than the disadvantages.

Professional Role

All of the professionals, namely, the radiologists and other clinicians, are closely engaged in a large and heterogeneous sociotechnical work practice with numerous actors. Although the junior radiologists were quicker learners of this new workflow, the more senior radiologists had caught up over the years. Previously, they worked more as individuals in the health care organization; radiologists were not as involved as they are today in the treatment of patients. The use of

PACS has led to a reconceptualization of the clinical workflow, allowing for a deeper understanding of the interaction between technology and organizations, which transforms the individual in an organization into an *actor in a network*. The new network functionality offers a promising way of enabling more concrete relationships between people and objects in organizations. It was concluded from these interviews that the radiologists' professional role had shifted toward being more of an actor in a network, and a more actively engaged discussion partner for the clinicians in the ambition to find the correct diagnosis.

Diagnostic Practice

The radiologists identified three features that have affected clinical practice: easy access to images, new capacity to show the images to clinicians over the Internet, and the 3-dimensional tool that has made it possible to interpret and show large image materials in volumes instead of as separate images. As the technology is refined, and images can be viewed as images in a "stack", *the skills and the reading and interpreting of the images are available to everyone in clinical practice* accessing this new distributed radiology workflow, enabled by PACS and other network technology. The interviews showed that the new focus of diagnostic practice was the technology's penetration on all levels among users outside of radiology, making the diagnostic practice available to everyone at any time, through the radiologist's various techniques of presenting their findings.

Technology in Use

The easy access to images that has been made possible by the changes in technology means that clinicians can do some interpretations themselves. This creates opportunities for the radiologists to engage in more complex diagnostic problems, and supports an *increase of specialization* within radiology. An increase in services offered to the clinicians has also become apparent because of the new workflow. The provision of easy access for clinicians to new and previous radiological examinations improves the quality of the radiology service. The clinicians' access to images also allows more detailed questions to be posed to the radiologists. This has made the radiologists feel more engaged in the overall treatment and diagnostic care of the patient. In general, the radiologists were pleased with the way their profession had developed.

The interviews indicated that, as the technology became more widely distributed, the clinicians in other disciplines could undertake the "easy readings" while the radiologists could focus on more complex methods and findings, thus becoming more specialized in their work.

The summarized conclusion of these interviews was that different phenomena comprised the central focus of the radiologists' practice over time. This does not mean that the earlier priorities disappeared from the radiologists' work when a new role emerged as the central one. Generally, the old priorities were still relevant, although less central. Over time, a phenomenon could shift from being the most important to become more peripheral, to become more central again. The central focus in radiologists' practice over time is illustrated in Figure 1.

DISCUSSION

The study illustrates trends of central changes in the radiologists' diagnostic practice, in the shift from reading x-ray films to reading digital images on the computer. These changes are summarized in the next sections.

Professional Role

It has taken time to discover and reflect on how the new distribution radiology workflow has changed the radiologist's professional role. In practice, the flow of images has taken new routes, thus creating new relationships between the actors in the network. In 1999, when clinicians met with the radiologist in clinical meetings, the radiologist was the professional expert with experience in reading x-ray films. However, over time, as the clinicians obtained access to images, their ability to read images improved. In this process of change, the radiologist received more questions from the clinicians as their interest in and ability to view digital images and reports increased. This is how the radiologist over time became more of a consultant to the clinical decision-makers. From

this we could say that the radiologists' and clinicians' roles are defined through their use of technology.[3] Hanseth and Braa[23] confirm this way of thinking, as they indicate that neither the human factor nor technology should be considered as pure, isolated elements, but rather as linked heterogeneous networks. "When any actor (human or non-human) acts, this very actor is always such a network, not a single element."[23] Actors, such as radiologists and clinicians, are not defined by their "internal" functions in a network, but rather by their relationships to other elements in the network. Also, Foster[1] notes that new technology can dramatically change the conditions and roles for certain occupational groups. Lundberg[24] also confirms the impact of PACS on radiological work and roles. The study illustrates how the radiologist's work became more distributed and physically isolated, and how they, in their role as professionals, were less well "served" by ancillary staff: The radiologists became their own assistants, secretaries, and archive personnel. In practice, certain activities therefore became more time consuming for the radiologist.

Diagnostic Practice

The radiologists stated that the practice of reading x-ray films used to be an art form. Becoming a skilled "artist" takes time. However, the introduction of digital images viewed on a computer shifted practice toward more technical work, where the focus was on technology rather than on the skill of reading images. Suddenly, the radiologists' learning shifted to a greater exposure to technology courses rather than interpretative diagnostic techniques. The increasing technical focus created insecurity because radiologists were worried that they would become less skilled readers of images because of the shift in focus from diagnosis to technological learning. However, the technology improved access to images for distributed radiology, and it became possible to access a greater number of comparable cases as well as any previous examinations of a specific patient. For example, the technology allowed clinicians to keep in more frequent contact with radiologists, and to derive second opinions in a dialogue whenever needed. Thus, the changes in workflow were important for the clinical practice. Being an actor in a network, in combination with

the ability to give everyone access to the basic interpretive skill through technology, has changed the scope of the radiologist's profession. Gale et al.[25] writes that many PACS require too many "clicks on the mouse" for the work to be performed at the computer by radiologists, which results in a significant loss of efficiency with the use of software in which these links are not made automatic.

Technology in Use

As physical objects, x-ray films have different properties from digital images; in 1999 radiologists could hold x-ray films, feel them, and know that they were looking at the whole image. This allowed them to be relatively confident in the opinions they expressed because no extra information could be obtained from the image. In 2004 digital images are "objects without properties"[26]: A digital image allows a wide scope of functionalities/properties for subsequent manipulation in a dynamic pattern of interactivity. It took a long time for the radiologists to cut the umbilical cord linking them to the x-ray film. The new workflow has allowed wider scope for manipulation of the image, making the radiologist insecure. This insecurity had to be dealt with and the process of getting used to the technology took time. This study shows that it took about 4 years. Reger et al[27] confirm what a time-consuming process it is to change the users' attitude to digital images. They described in detail how mental barriers can make the adjustment more difficult. Ramirez[28] use the term "reconfiguration" when discussing the development of new attitudes and concepts in a translation process. They highlight how significant and encompassing the reformation of occupational attitudes can be in practice, and how difficult it is to describe these "invisible" changes. In the present study, an important factor in developing a new mental framework for the new workflow was the emergence of a greater insight into the advantages of the functionalities made possible by the new technology. An important feature of the new technology is its superior ability to illustrate anatomic details in the images by 3-dimensional reconstruction. Using x-ray films, the radiologist could create computer images, but 3-dimensional reconstruction images were less informative. Using digital images, it is

possible to increase the illustration of details, eg, one could illustrate the acoustic nerve for the neurosurgeon in its full length. In this way the radiologist has became, for instance, a new and important advisor in discussions with the neurosurgeons. It is likely that there will be a development of increasing expertise in subspecialist areas, leading to better quality of care, for instance, in developing from a general neuroradiologist to a neuroradiologist specializing in the acoustic nerve. We predict that increased specialization is the future for radiology.

Radiological work has changed dramatically over time. This change is likely to continue in order for radiology to stay attractive to the customers and live up to the motto "any time, any place." Of course, within the changes in diagnostic practice, there were many variations between the radiologists. However, the similarities among the majority of radiologist points out the trends that are being described. The radiologist needs to provide swift results, to be specialized, and to offer interesting as well as qualitative information to the users. He or she is a major contributor in the clinical process surrounding the treatment of the patient. Although this paper discusses the changes in diagnostic practice as directly related to PACS use and to the new distributed radiology, we are well aware that there are many other factors influencing these changes. These have, however, not been in focus in this paper and are therefore not highlighted.

The new distributed radiology may be seen as an enabler of change. How these changes will occur in the future is a question that we will explore in further research. Both through the radiologists' embracing of the new workload and technology and also through their letting go of old techniques, the tasks no longer focused on by the radiologists may disappear to other professions. This may be a way to position and to preserve the radiological profession.

In comparison to the impacts of PACS, which were noted in 1999,[9] this paper has illustrated that changes in work practice have occurred. This implies that work practice changes related to the use of new technology take time, but will gradually emerge. It is impossible to predict precisely which changes will be realized, as this depends on how the users will apply the functions of the technology.

Changes in Work Practice

PACS have properties that allow images to take new routes. As images took new routes new relations in work practice between medical actors were created. Before PACS, working with analogue films, when clinicians met with the radiologist in clinical meetings, the radiologist was the professional expert with experience in reading x-ray films. However, over time, as the clinicians obtained access to images, their ability to read images improved. This changed work practice in a way from individual to teamwork.

Working with PACS images, being electronic and not physical, translated the practice from a more art-related practice to a more technical practice. With PACS, in theory, the radiologist became a technical expert in work practice. This, sometimes, implied a feeling of insecurity for the radiologist in work practice as it was "possible" to access all previously made examinations done to the patient in a hassle-free way. The number of images included in these examinations was often of such great number as not all could be viewed, digital technology produce more images than analogue. There had to be a selection made. In this selection, an insecurity entered as how the radiologist could be entirely sure to have viewed the relevant images. The digital system allowed the work practice to become more detailed, for instance, by the use of 3-dimensional reconstructions. This translation in work practice made work more specialized and created some new subspecialization in practice.

CONCLUSIONS

To the best of our knowledge, this study is unique in both its timing and its scope. The prospective interpretative qualitative study of the consequences to radiologists of introducing distributed radiology has shown that when analogue films were replaced with digital images viewed on a computer, the radiologists' diagnostic practice also changed. The aim of this study is to analyze and illustrate how the use of PACS affects the trend of changes in radiologists' work practice. Work practice was divided into three areas: professional role, diagnostic practice, and technology in use. The changing trends within the

professional role indicated that radiologists moved from a more individual professional expertise to become more of an actor in a network. The diagnostic practice changed, as reading x-ray films was seen as an art form in 1999, requiring years of training. Once *everyone* could view digital images, including 3-dimensional technology, it was easier for other clinicians to see and interpret the images. It was also found that none of the radiologists interviewed wanted to return to the old work practice of using x-ray films. The change in technology in use *as a result of the shift* to digital images led to an *increased specialization of the radiologist*. In total this is the result of interviews with 21 radiologists. Hence, the scope of this study is limited and needs to be followed up by further similar studies to ensure the validity of the results.

The findings of this study would appear to be of some importance, as the majority of hospitals globally are planning the introduction of information and communication technologies, supporting the workflow for process-oriented treatment of the patient.

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