A Hybrid Operating Room in the Making

Coordinating the Introduction and Use of New Technology

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To Matilda and Lillstrumpan

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ABSTRACT

New technologies are often introduced hoping to achieve cost reductions, efficiency improvements, and product/service quality increases. Early researchers have often focused on these hopes and how existing organizational design and function are shaped. However, recent researchers have started to explore why it is that when many of the currently emerging technologies are employed in practice, they can also bring unintended consequences to the workplace, even having the potential to fundamentally change how work is organized and coordinated. Making these new technologies work in practice thus presents a major challenge. These dynamics are especially prevalent, and important to study, in the healthcare context, traditionally organized functionally, i.e. around discipline-based specialization, but which is now largely being reorganized around multidisciplinary departments and teams. One important part of this reorganization is technological advancements, which have often been treated as if fulfilling promises to achieve increased and improved healthcare delivery, as long as these technologies are better and more expensive. However, as technologies are frequently not just integrated into existing and traditional practices or ways of working, but can also potentially challenge or disrupt work practices and coordination, more is required than simply having excellent properties built into these technologies, or individual brilliance or heroism, to make them doable in practice.

This study further builds on and explores these insights and dynamics by adopting a longitudinal field-study, between 2015 and 2019, of both the introduction and use of an iMRI Hybrid OR, a novel technology used in neurosurgery and enabling the combining of intraoperative high-resolution MRI images taken *during* surgical procedures, which was impossible before. As this new technology accommodates the traditionally-separated healthcare practices of neurosurgery and MRI, new configurations of technological tools and healthcare professionals need to be aligned and integrated. Thus, the following question was asked: How is the introduction and use of technology coordinated during conditions of merging two previously-separated healthcare practices?

This study found that making the new technology doable was not about greater skills, superior resources, or top-management support, but about the copious amounts of time and energy that the healthcare professionals involved spent on aligning various interdependencies, i.e. coordinating. The study shows how the introduction and use of technology was coordinated through the reconfiguration of the social setting and the physical space, which brought and required a new kind of coordinating, i.e. *coordinating as an overlapping professional domain*, where an *in-depth common understanding* and a *spatial awareness* proved important. In demonstrating this, the study makes a number of contributions; to the literature on coordination, to the literature on professional work and the introduction of technology, and to practice.

Keywords: coordination, professions, healthcare professionals, new technology, introduction and use, social setting, physical space, coordinating as an overlapping professional domain, in-depth common understanding, spatial awareness

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It would be strange not to reflect on what is happening in our society right now. I could never have predicted that the Coronavirus pandemic would be spreading all over the world while worrying that the major demolition work at the university would interfere with my concentration toward the end of writing this dissertation. Given the severity of the Corona pandemic, it was not easy for me to finish my writing. I was often distracted by following the latest updates, and my thoughts often wandered, being overwhelmed by the severe consequences affecting so many people. Things were put into perspective, and I had the chance to reflect on what matters in life. Despite the difficulties of staying motivated toward the end, I managed this, and I am very glad, and proud, that my dissertation is now complete.

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Daniel Tyskbo
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CHAPTER 1

INTRODUCTION

> If you look at what we're doing within the [surgical] wound, it's not that different. That's not what's intensive or difficult, it's all the new technological tools and staff that need to function together. For example, with the safety nurse and all the preparations and additional checks done before MRI scanning. These things are new and challenging, and we need to match the different requirements, and make things happen as a team (surgical nurse).

The surgical nurse in the quote above expresses the general experience of the healthcare professionals involved with regard to what was different and challenging when making a newly-introduced technology doable. As can be seen, it was not the individual achievements that mattered, but making it all work together and aligning interdependencies, between new configurations of technological tools and healthcare professionals. Understanding how people work together and coordinate their work, specifically in relation to technology, is a fundamental question in organization and management research, and one which will be the focus of this study.

Studies of new technologies have long been of key importance in organization and management research, with early researchers often focusing on the hopes of these technologies, e.g. cost reduction, efficiency improvement, and increasing product/service quality, thus viewing technologies as a means of shaping organizational design and function (Galbraith, 1973; Thompson, 1967). In this way, technologies have often been studied from the perspective of how they can automate and inform existing organizational processes. However, recent researchers have started to explore the way in which many of the currently emerging technologies, e.g. AI, algorithms, digital technology, and sophisticated medical technologies etc, which are all occurring at an accelerating rate, extend far beyond the automating and informing of existing processes (Leonardi & Barley, 2010). Once employed in practice, these technologies often also become associated with unintended or unexpected consequences in the workplace, and even have the potential to fundamentally change and challenge how work is organized and coordinated (e.g. Barley, 1986; Bechky, 2003; Edmondson et al., 2001; Sergeeva et al., in press; Timmermans & Berg, 2003). Because legitimacy is not inherent in new technologies either, we would expect that making them work in practice presents a major challenge (Anthony, 2018).

These dynamics are expected to be especially prevalent, and important, in the healthcare context, which is currently being put under pressure to change, and in which technological advancements constitute an important issue. Traditional healthcare (at least in most industrialized countries) is characterized by a functional organizational structure (Liberati et al., 2016), with stratified and divided occupational groupings (Finn et al., 2010; Wilson et al., 2013). Healthcare is thus organized around discipline-based specialization (Lega & DePietro, 2005; Liberati et al., 2016), and this fragmented and specialized professional division of labor also means that each professional has a distinct role to play (Finn et al., 2010; Lindberg et al., 2012). Health providers with similar expertise are grouped into departments where patients are admitted and come under individual medical professionals (Gittell & Weiss, 2004; Finn et al., 2010; Martin et al., 2009), *"who either 'own' them or transfer them to the care of another clinician"* (McKee & Healy, 2002, p. 220). This can be illustrated by a situation in which a patient visits the emergency department (ED) with stomach pains. She is assessed by the ED physician and is then referred to a general surgeon. After having been transferred to the surgical ward, she is then assessed by members of the surgical team, who request an MRI scan of her abdomen and pelvis. The MRI scan is performed within the next two days, and this indicates a deep infiltrating endometriosis. The surgeon then refers the woman to the gynecologist for additional investigation, subsequently leading to surgery. In this not uncommon scenario, the patient is moved between different departments and clinical divisions (Division of Medicine, Division of Surgery, and Division of Radiology and Diagnostics), thus illustrating the independent and fragmented ways in which traditional healthcare often is organized.

However, with new demands, both managerial and clinical, e.g. cost reductions and quality improvements, and conditions, e.g. new technologies, healthcare is constantly being put under pressure to change (Currie et al., 2008; Dougherty & Dunn, 2011; Leathard, 2004; Nicolini, 2006; Thakur et al., 2012). One important part of these new demands and conditions is technological advancements derived from both advanced features and clinical needs, but often based on the overall notion of, and requiring integrated care across, institutionalized professional boundaries (Finn et al., 2010; Randell et al., 2019), by attempting to reorganize healthcare around multidisciplinary departments and teams (Barrett et al., 2012; Irvine et al., 2002; Liberati et al., 2016; McKee & Healy, 2002; Rodriguez, 2015). For example, new genomic technologies make it possible to determine not only if a breast cancer tumor will recur, but also how it will react to treatment. However, to make use of these technologies, experts from various and often separate domains, e.g. clinicians, biologists, technological specialists, are required to manage and align diverse kinds of interests and information (Bourret et al., 2011; Bourret & Cambrosio, 2019). In similar ways, the introduction of new health information technologies often both requires and mediates multidisciplinary relationships among professionals who usually work in isolation (e.g. Bergey et al., 2019; Dent, 1990; Tjora, 2000). Thus, these technologies challenge the traditional way of organizing healthcare as they are not just integrated into existing and traditional practices, and ways of working. Profound requirements as well as consequences of and impacts on the organizational arrangements of medical practice and professional work, including how healthcare professionals interact and coordinate tasks, are thus expected to accompany the introduction of these technologies (Apesoa-Varano, 2013; Irvine et al., 2002; Leonardi & Barley, 2008; Petrakaki et al., 2016; Wright et al., 2019). Understanding how such requirements and consequences shape the ways in which healthcare professionals work and coordinate is especially important because these can also have consequences for the patients (Valentine & Edmondson, 2015).

An intriguing and contemporary technological advancement exploring these dynamics further, and additionally the focus of this dissertation, is provided by the introduction and use of *hybrid operating rooms* (Hybrid ORs). These rooms are designed and built in order to treat patients without having to move them between departments within the hospital. The hybrid operating rooms therefore need to entail a combination of multiple methods of diagnosis and treatment, for the benefit of high-risk patients[1] with complex complications (Hudorovic et al., 2010; Urbanowicz & Taylor, 2010). In this way, hospital staff and resources are instead expected to be organized around the patient, and the new room, instead of being determined by the traditional separation of, or distinction between, medical professions (e.g. radiologists and surgeons). During hybrid procedures, eight to 20 individuals including anesthesiologists, nurses, surgeons, technicians, device experts, and so forth, may be needed at the same time and in the same room (Hudorovic et al., 2010). The multidisciplinary teams that will work in the hybrid rooms require intensive collaboration among their team members (Hudorovic et al., 2010; Smeltzer et al., 2014). In the medical literature, it has been argued that it is not enough for these various professionals to bring with them their specific knowledge or competence; however, there is an emergent need for them to develop new knowledge, competencies and ways of working (e.g. Gandhe & Bhave, 2018; Hemingway & Kilfoyle, 2013). Thus, the focus of this new knowledge and competencies is no longer just specific organs or body parts, as in traditional healthcare, it also centers on the new technology and how to align different understandings and interests.

New technologies, e.g. the hybrid operating rooms, thus seem to be promising advancements in the healthcare industry in that they are assumed to increase the

[1] Defining high-risk patients is dependent on the context. For the purposes of this dissertation, it is viewed as patients with a high mortality, in need of combined radiology and surgical procedures, often with a history of comorbid disease and sometimes even classified by healthcare professional as inoperable in traditional operating rooms (see Babaliaros et al., 2014).

quality of the healthcare delivered and to decrease costs. With medical practices becoming more and more technologically intensive, promises about achieving more and better healthcare, and the intended outcomes, are generally perceived to be realizable as long as more and better technology is introduced (Mesman, 2008). Traditional explanations of how the introduction of new technology succeeds also frequently focus on the inherent properties of the technology itself, as well as on individual brilliance or heroism (Edmondson et al., 2001; Nicolini, 2010). However, and as already mentioned, since these technologies, and the hybrid operating rooms in particular, are complex and differ from traditional ways of doing healthcare work, and involve many different actors who usually do not work together, there are also major challenges as regards how to make them work (Ferlie et al., 2005), including the organizing of emergent and complex work practices that encompass these technologies (Lindberg et al., 2017; Nollert & Wich, 2009; Schroeck et al., 2018). Thus, it is particularly interesting to study a Hybrid OR in the making, focusing not only on the new technology as such, but also on the new configurations of healthcare professionals, e.g. surgeons, radiologists, anesthesiologists, nurses, technicians, and physicists. Studying a new technology in the making in the healthcare context, with a combination of strong professions and multidisciplinary approaches, has societal relevance. Not only because it can contribute insights benefitting healthcare professionals themselves, and ultimately patients, but also because it helps us understand the introduction and use of new technology in professionalized settings more broadly in society at large.

1.1 Introducing the Coordination Perspective for Studying the Introduction and Use of New Technology

In previous studies, it has been shown that the introduction and use of new technology which does not match with existing scripts regulating relations and workflows (Zetka, 2001), or which deviates from the institutional order (Barley, 1986), is complex and difficult. This is especially the case when aspects, e.g. professionals and practices, which have traditionally been kept apart are combined (e.g. Barrett et al., 2012; Lang et al., 2005; Schakel et al., 2016). Thus, new dependencies are created as interactions among previously-separated members are required (Barley, 1990), and existing differences in meanings, assumptions, interests, and contexts are often difficult to align (Apesoa-Varano, 2013; Beane & Orlikowski, 2015; Kellogg et al., 2006; Nicolini, 2010). The difficulty is rooted in the integration of different understandings and realities into a co-existence (Mol, 2010; Suchman, 1994), indicating that the introduction of such a technology not only makes *coordination*[2] particularly salient, but also requires the accomplishment of coordination efforts to make the new technology work (Edmondson et al., 2001; Nicolini, 2006; Zetka, 2001). Coordination

[2] Despite how the verb "to coordinate" has been used to shift the focus toward the dynamic nature of coordination (e.g. Jarzabkowski et al., 2012), the terms "coordination" and "coordinating" are used interchangeably in this dissertation.

is thus a relevant perspective when it comes to studying how a new technology is introduced and used, being defined here as "a temporally unfolding and contextualized process of input regulation and interaction articulation to realize a collective performance." (Faraj & Xiao, 2006, 1157). Input regulation involves decisions about who is responsible for doing what in specific situations, while interaction articulation involves agreement regarding a sequence of actions and how interactions are to occur in order to achieve what collectively needs to be done. This definition further allows an emergent and situated understanding of coordination.

The concept of coordination has been used to study a variety of phenomena, e.g. knowledge work (Beane & Orlikowski, 2015; Ben-Menahem et al., 2016; Faraj & Xiao, 2006), managerial work (Bouty & Drucker-Godard, 2018; Friesl & Silberzahn, 2017), responses to changes (Jarzabkowski et al., 2012), and flexibility (LeBaron et al., 2016). However, research has not paid enough attention to the link between highly-professionalized contexts and coordinating across disciplinary boundaries (Pine & Mazmanian, 2017); thus, we know little about the link between coordinating processes and occupational approaches to doing work (Bechky & Chung, 2018; Zetka, 2001). Adding to this understanding is especially important since professional and occupational groups often have different understandings and interpretations of how to do their work and what duties to perform; when attempts are made to narrow these differences, coordination challenges often increase (Barrett et al., 2012; Beane & Orlikowski, 2015; Zetka, 2001).

Many coordination studies also fall short of adopting a processual and dynamic view of coordination (Beane & Orlikowski, 2015; Jarzabkowski et al., 2012). This is the case because studies tend to focus on already-established aspects of work, e.g. routinized practices or existing technologies, without paying enough attention to foregoing coordination during prior work before settlements are reached (Beane & Orlikowski, 2015). However, as coordination follows a history of previous actions and interactions which necessarily constrain and enable future action (Faraj & Xiao, 2006), it becomes vital to consider both the past and the present in order to truly understand how coordination unfolds. Thus, despite how studies emphasize the emergent and situated practices that make coordination possible, the temporal interdependence and interconnectedness of such practices with prior work is seldom explored (Beane & Orlikowski, 2015). Thus, one way forward is to study the interconnectedness of the substantive work performed both prior and during the focal coordination, including the traditional patterns of behavior, interaction and understandings in use before, for example, a new technology is introduced, instead of using the coordination concept to solely explain an already-introduced technology or established practice. Doing so is critical because it has been shown how previous work shapes subsequent work (e.g. Barley, 1986; Barrett et al., 2012; Black et al., 2004; Edmondson et al., 2001; Nelson & Irwin, 2014); when taking this into account, we can advance our understanding of how temporality makes a difference to how coordination unfolds in practice (Beane & Orlikowski, 2015).

Moreover, many studies of coordination tend to downplay the material enactment of coordination (Beane & Orlikowski, 2015; Okhuysen & Bechky, 2009); when material arrangements are considered, these are often treated as a passive medium through which coordination processes unfold. However, paying more attention to how these material arrangements are also intertwined with coordination processes is important when it comes to advancing our understanding of how coordination unfolds in practice. For example, the notions of differentiation and integration, rooted in the coordination literature, denote a spatial element. Moreover, the implications of material arrangements are especially important to consider in knowledge-intensive settings, especially in healthcare, whereby work is centered on and largely defined within material configurations, e.g. physical space, objects and bodies (Barrett et al., 2012; Nicolini, 2006).

1.2 This Study

Based on the discussion above, I have been following, in a longitudinal study between 2015 and 2019, both the introduction, including planning and preparatory work, and the initial use of a specific technology, i.e. an intraoperative magnetic resonance imaging hybrid operating room (iMRI Hybrid OR) which is used for neurosurgery, in particular, at a large university hospital in Sweden (subsequently referred to as SweHos). The world's first introduction was in 2006 (Matsumae, 2007), and only three previous installations exist in Europe. This technology is described in the medical literature, in the media, and by the involved healthcare professionals themselves, as unique and novel, in that it enables the combining of intraoperative high-resolution MRI images *during* surgical procedures, thus accommodating the traditionally-separate practices of neurosurgery and MRI. However, merging neurosurgery and MRI practices, which have traditionally been kept apart in both time and physical space, is not straightforward. The practice of neurosurgery is characterized by a rigid professional hierarchy, with the surgeon traditionally being perceived as the key and leading actor. Various metallic instruments and tools are used in the OR, an environment that needs to be a highly sterile. To avoid surgical site infections, the surgical staff are meticulous in their aseptic and sterility routines. The practice of magnetic resonance imaging (MRI) has its own professional hierarchy, with the radiologist traditionally being perceived as the leading actor. In contrast to neurosurgery, MRI-related procedures are often described by the staff themselves as "dirty". The main concern here is instead MRI safety issues, due to the strong magnetic field and the force of attraction. This means that various magnetic (often metallic objects) can be drawn into the magnet. Given the potential danger that ferromagnetic objects *"may turn into dangerous missiles when brought near the magnet"* (Weishaupt et al., 2008, p. 143), the MRI Unit has traditionally been organized as an isolated practice, both in time and physical space, especially in relation to surgical procedures. Given the differences and seeming incompatibility of the two practices, and the change in the traditional configuration of healthcare professionals, material arrangements as well as the physical space, we would expect the new technology to be associated with requirements for new ways of working (Kirkpatrick et al., 2014; Lindberg et al., 2017), jointly making it particularly interesting to study the making of a hybrid operating room.

Thus, the purpose of this study is to describe and analyze how the introduction and use of new technology is coordinated and made doable in a professionalized context, when two previously-separated practices are combined. The following research question is asked: How is the introduction and use of technology coordinated during conditions of merging two previously-separated healthcare practices?

1.3 Outline of the Dissertation

Chapter 2 provides the theoretical background, including an overview of the previous literature on professions and the introduction of technology in professionalized contexts, as well as a review of the literature on coordination. The rationale regarding why the coordination perspective is particularly well-suited to studying the introduction and use of new technology in a professionalized context is also presented. Opportunities for further research in order to make important contributions to the coordination literature, which also served to justify this study, end the chapter.

Chapter 3 presents the research setting in which the study took place and the methods by which the research was conducted. A background is first provided of the hospital and the new center where the new technology was introduced, followed by a short explanation of how the new technology works. The genesis of the study and the overall research approach are then presented, followed by a description of the generation and analysis of the field material. Finally, the ethical considerations are presented.

Chapter 4 is the first of four empirical chapters and describes how work is traditionally performed at the Neurosurgery Department, covering the time period prior to the introduction of the new technology.

Chapter 5 describes how work is traditionally performed at the MRI Unit, and covers the time period prior to the introduction of the new technology. This chapter also includes interactions and collaborations with staff from the Neurosurgery Department.

Chapter 6 describes the planning and preparatory activities leading up to the initial use of the new technology. The focus is on how previously-separated groups of healthcare professionals, as well as material arrangements, are planned and prepared for being brought together.

Chapter 7 describes how work was done and coordinated once the new technology had been introduced. The focus is on new ways of working, as well as on the aspects that proved important in making the new technology and practice doable.

Chapter 8 is the discussion chapter in which the research question is answered. This is done by discussing the findings on a more theoretical level. The reconfiguring of the social setting and the physical space is discussed first, and what the implications for coordination are, followed by a discussion of how a new kind of coordinating, i.e. *coordinating as an overlapping professional domain*, emerged and was required.

Chapter 9 presents the study's contributions to the literature on coordination and to the literature on professional work and the introduction of technology. The practical implications are also discussed, followed by the boundary conditions and limitations, which provide suggestions for future research.

CHAPTER 2

THEORETICAL BACKGROUND

This study draws on the literature on coordination, which will be reviewed. First, an overview of the previous literature on professions and the introduction of technology in professionalized contexts will be presented. This is done because situated negotiations regarding professional work itself, and especially during times of change, e.g. when new technology is introduced, involve coordinating challenges and require coordinating efforts (e.g. Barley, 1990; Barrett et al., 2012; Beane & Orlikowski, 2015; Black et al., 2004; Edmondson et al., 2001). Focusing on new technology in a highly professionalized context also offers a rich setting for understanding coordination in practice.

2.1 Research on Professions and the Introduction of Technology

Professions[3] have been of interest to scholars from various disciplines, particularly among sociologists, who have tried to understand how they arose, how they change, and what role they play. Early views of professions described these as "*occupations with special power and prestige… Professions have special competence in esoteric bodies of knowledge linked to central needs and values of the social system*…(Larson, 1977, p. 5). In line with this, professionals are seen as having, for example, special competence and knowledge, and

[3] The concept of the profession is related to the concept of the occupation, and there has been a variety of perspectives on their differences and similarities (see Etzioni, 1969; Hodson & Sullivan, 2012). Hughes (1958), for example, regarded the differences between professions and occupations as differences of degree rather kind. What can be concluded, however, is that the traditional approaches used in the sociology of the professions neither accounted for nor covered the shift in professional work toward organizational settings (Muzio et al., 2013). Abbott (1988) wrote that he used the concept of the profession very loosely, largely ignoring the issue of when groups can legitimately be said to have coalesced into professions. In line with contemporary organization and management research, this study is not confined to the traditional professions, nor is it particularly concerned with policing the boundaries of the concept of "the profession" or excluding occupations that do not qualify (see Anteby et al., 2016; Gorman & Sandefur, 2011). Thus, I use the concept of the profession more broadly, and include a variety of occupations, e.g. nurses, hospital technicians, MRI physicists etc, because the important thing is to focus on professional work, i.e. knowledge-based expert work, the link between workers and their work, how they view their work, and what they do in practice.

these trait approaches are based on a general static view, with professionals being seen as something to become and remain by means of certain qualifications. Thus, professional and occupational groups have often been portrayed as resistant to change (Zetka, 2001). However, later views have instead stressed that these groups are neither stable nor static, but subjected to continual transformation during every-day work practices, especially since professional work has largely shifted toward organizational settings (Fenwick et al., 2012; Muzio et al., 2013).

The static and objective nature of knowledge, training, and work is thus not as relevant as situated and ongoing accomplishments when the aim is understanding what work is performed by professionals, and how, and what it means to these (Freidson, 1970). Thus, it is more useful to focus on what professions do in practice. In practice, professionals may seem rather rigid and stable, but they are always open for contestation and negotiations (Abbott, 1988; Freidson, 1988; Larson, 1977). Professionals themselves are also seen as active during the professionalization process. This also questions the view of professionals as mere receivers of ready-made identities, encouraging researchers to pay attention to work practices, rather than structures (Abbott, 1988), and to bring professionals into view as active agents during these processes (Abbott, 1988, Freidson, 1984; Larson, 1977). Being a professional thus becomes more than just a means by which the individual navigates the organization. It involves taking on an ontological location whereby, for example, the surgeon, nurse or radiologist are all existentialized through the particular narratives and discourses which accrue with and around that identity position.

As more than just material loss or gain is at stake for professionals (Dent & Whitehead, 2013), it is understandable that one of the major elements of becoming a professional is securing jurisdiction over a specific field of work (Abbott, 1988), or framing occupational jurisdictions (Bechky, 2003). Jurisdiction is understood here as the link between a profession and its work, i.e. the control exerted over an area of work. Jurisdictional claims can alter both relations between professional groups and the boundaries of their core domains, i.e. task and practice areas that often are strongly bounded to specific disciplines (Abbott, 1988; Bechky, 2003). Boundaries between professions are negotiated (Thomas & Hewitt, 2011) as professions attempt to construct, defend or contest these (Abbott, 1988; Lawrence, 2004; Suddaby & Greenwood, 2005). Since boundaries are constructed sites of difference, meanings and identities are then constituted during the act of drawing them (Abbott, 1995). In line with this and the dynamic perspective, an increasing body of research is thus starting to focus on the dynamic nature of professional and occupational work, including how professionals' work, boundaries and identities are negotiated during times of change, e.g. when new technology is introduced (Ibarra, 1999; Langley et al., 2019; Pratt et al., 2006).

From prior research, we know that individuals not only defend their boundaries, identities and work roles, they also expand these (Larkin, 1983). For example, from this, we might therefore expect professionals not only to protect their existing identities, but also to incorporate new ones as they become part of new professional groups. One example of this is horizontal substitution (see Nancarrow & Borthwick, 2005), whereby individuals start to undertake roles normally done by other professions, and whereby these substitutions imply negotiated boundary changes. Various professions may also affect the extent to which individuals within the profession are able to alter or manage their boundaries and work roles. Part of this is what Pratt and Foreman (2000) call plasticity, which may vary depending on which profession is under consideration. Greater plasticity means that jurisdictional change is less contested and more easily legitimized. It thus becomes important to investigate the rhetorical strategies generated within the profession itself (Goodrick & Reay, 2010).

It is important, however, to understand that these substitutions may involve contested jurisdictional disputes (Abbott, 1988). For example, Liberati et al. (2016) demonstrate how nurses learn skills that fall outside their formal jurisdictions and domain of practice, but have become a key part of their new professional roles. This was rejected, however, by other professionals who perceived these skills as belonging exclusively to the medical jurisdiction. It is also important to understand that these changing demands may lead to doubt and anxiety among professionals (Sveningsson & Alvesson, 2003). For example, if individuals experience that learning skills that lie outside their jurisdictions is fragmenting their work, they may also experience their identity as becoming fragmented (Sveningsson & Alvesson, 2003). Changing work situations may thus be seen as a situation filled with tensions and threats (Lutgen-Sandvik, 2008), possibly *"prompt[ing] feelings of confusion, contradiction and self-doubt, which in turn tend to lead to examination of the self"* (Brown, 2015, p. 25). Barley (1986), for example, showed how medical professionals experienced anxiety when an inversion of the intuitional order was perceived due to role reversals. Possessing dual or multiple identities may thus be complicated, as negotiating roles and identities in ways appropriate to new contexts becomes problematic (Gilardi et al., 2014).

Understanding how professionals, in practice, are neither rigid nor stable, but open to contestation and negotiations as regards, for example, boundaries, identities and duties, especially during times of change, then becomes highly important when trying to understand how new technology is introduced and used, and with which implications in professionalized contexts. Furthermore, and more generally, given the increased emphasis and reliance on objects and technologies in professional work (Barley, 1990; Leonardi & Barley, 2008; Orlikowski & Scott, 2008; Timmermans & Berg, 2003), there have been multiple calls to pay more attention to the role these aspects play in how professional and occupational groups perform their work and secure their jurisdictions. Responding to these calls is important since the use and control of these material arrangements is integral to how professional work is performed, and to how domains of practice are established and maintained (Petrakaki et al., 2012). This is especially the case when it comes to professional work done in healthcare, which is material in the way it involves dealing with people and their bodies (Petrakaki et al., 2016), but also in the way it involves working with material artifacts in terms of, for example, technological devices. Thus, the context of healthcare is not isolated, but rather closely connected to the advancement of technoscience. In other words, we need to incorporate the interactions occurring between technology and healthcare professionals in practical use (Håland, 2012; Petrakaki et al., 2016). The extant literature on professions would predict that the introduction of technology is likely to be accompanied by professionals experiencing changes in their workplaces, e.g. a change in traditional patterns of behavior, interaction and understanding, and by means of changes concerning the technology itself, through existing contestation and negotiations. This is, perhaps, especially the case when there is a divergence between existing patterns or scripts in the workplace and the new technology.

New technologies often derive their legitimacy from promises of cost reduction, efficiency improvement, and increasing product/service quality. However, from previous studies of how new technology is introduced and used in professionalized contexts, we know that technology, in addition to having these intended consequences, also frequently becomes associated with more unintended consequences in the workplace (e.g. Barley, 1986; Edmondson et al., 2001; Timmermans & Berg, 2003).

Numerous studies have documented how the introduction of new technology, that requires changes in traditional ways of working, instead leads to sustained arrangements, including patterns, scripts, boundaries, relations, identities and divisions of labor. Further boundary demarcations and reproductions of already-existing practices and boundaries are often triggered in order to preserve the status quo (Fenwick et al., 2012; Finn, 2008; Liberati et al., 2016; Martin et al., 2009). Thus, boundaries that are intertwined with existing arrangements between professions are renegotiated (Thomas & Hewitt, 2011) as professions attempt to construct, defend or contest these (Abbott, 1988; Lawrence, 2004; Suddaby & Greenwood, 2005). This is often explained in terms of how one of the major elements of becoming and being a member of a professional group is securing jurisdiction over a specific field of work (Abbott, 1988), or framing occupational jurisdictions (Bechky, 2003), and how the introduction of new technology often intensifies this great power that professionals have to sustain and reproduce traditional ways of working (e.g. Currie et al., 2012; DiBenigno & Kellogg, 2014; Reay & Hinings, 2005). For example, Leonardi (2012) shows that computer-mediated communication tools allow the reproduction of existing practices, role relationships and power dynamics among automotive engineers. Burri's (2008) study of the introduction of visualization technologies, e.g. MRI, also highlights how existing professional arrangements, including authority, identity and duties are reproduced. As these studies show, staying the same also requires effort or active work (Fournier & Grey, 2000), with insights thus being provided into how the introduction of new technology can become consequential by triggering the reproduction of existing arrangements.

Research has also highlighted how new technology can be associated with a change, rather than a reproduction, of existing arrangements, including patterns, scripts, boundaries, relations, identities and divisions of labor and coordination among professional members (e.g. Barley, 1986, 1990; Barrett et al., 2012; Beane & Orlikowski, 2015; Bergey et al., 2019; Dent, 1990; Eriksson-Zetterquist et al., 2009; Nelson & Irwin, 2014; Sergeeva et al., in press; Tjora, 2000; Zetka, 2001). For example, in a study of renal units, Dent (1990) shows how the introduction of a computerized patient data system means a change in the division of labor, whereby nurses start undertaking tasks previously under the medical jurisdiction. Similar consequences emerge among medical specialisms in the study by Lang et al. (2005) of the introduction and use of a novel technology to treat carotid artery stenosis. Carotid angioplasty and stenting mean changes in terms of which specialism performs which type of medical work. Lindberg et al. (2017) show how the introduction of a Hybrid OR, similar to the one in this study, makes boundaries between nurses visible, and how solutions entail the renegotiation and spanning of disciplinary boundaries. Sergeeva et al. (in press) show how the introduction of a surgical robot requires team members to engage in coordinative adaptations, e.g. redistributing tasks and accommodating new dependencies.

The above-mentioned literature often shares certain assumptions. For example, technology is seldom treated as ready-made and arriving in professionalized contexts black-boxed. Instead, existing arrangements often play a role in how the introduction and use of technology takes shape. For example, Dent (1990) shows how relations between doctors and nurses shape the ways in which the computer system is used. The different arrangements and relations between radiologists and radiological technologists play a role in how the identical CT scanners are used differently and lead to different outcomes at two US hospitals (Barley, 1986). Zetka (2001) also shows how the structure of relationships between gastroenterologists and general surgeons influences the new technological introduction of gastrointestinal endoscopy. Another shared assumption is that the work, efforts and negotiations of members of occupational and professional groups, either to reproduce or change existing arrangements, hinge upon competition, conflict and disputes. Although studies sometimes hint at how interactions and collaborations exist, the main focus is still on the perceived "fights" or contestations occurring among professions in the workplace (Langley et al., 2019; Wright et al., 2019).

Despite the important advancements made in the literature as regards how new technology is introduced into professionalized contexts, there are still specific opportunities for further study. For example, arguments have moved away from treating technology as ready-made and predetermined toward viewing it instead as dynamic and processual. However, many studies still only tend to examine the introduction and use of technology long after it has begun. Neglecting the activities occurring prior to introduction and use becomes problematic (see Nelsen & Barley, 1997), because numerous studies have stressed how the time leading up to a new technology arriving, including preparatory and planning work, as well as existing status differences (Anthony, 2018), has important implications for how that technology is introduced and used, and thus also plays an important role in terms of making that new technology work (e.g. Barley, 1986; Barrett et al., 2012; Beane & Orlikowski, 2015; Edmondson et al., 2001; Nelson & Irwin, 2014; Nicolini, 2006; Wright et al., 2019). This neglect can to some extent attest to methodological shortcomings arising from a lack of longitudinal studies (Nelsen & Barley, 1997); arguments have thus been made for the importance of employing longitudinal methods during extended periods of time if we are to understand how technology is introduced and used in practice (e.g. Barley, 1986, 1990; Barrett et al., 2012). This neglect can also attest to how previous studies have limited both their focus and understanding to how only situated practices seem to matter in making the introduction and use of technology possible, in doing so not exploring the temporal interdependence of these practices on prior work (Bailey & Barley, 2019; Beane & Orlikowski, 2015).

Another important area for further research concerns the simultaneous focus on a wide variety of professional and occupational groups. Previous studies of the introduction of technology in professionalized contexts have often focused on individual professional and occupational groups, and the work they do (e.g. Korica & Molloy, 2010). Lindberg et al. (2017), for example, included what they call "key respondents", e.g. nurses and doctors; however, in their findings, the perspectives and understandings of doctors were nowhere to be seen. Professionalized contexts are rarely constituted, however, by single professional groups, often including multiple ones and thus being most likely to also entail multiple interests, values, norms, competencies and practices (Beane & Orlikowski, 2015; Lindberg et al., 2019; Zetka, 2001). Each occupational and professional group often acts in different ways, embracing different definitions and understandings of new technology (Dent, 1990; Van Maanen & Barley, 1984; Zetka, 2001). Much of the studies included here tend to focus on the medical profession only, but given the increased emphasis on multidisciplinary workplace collaboration, with interdependent duties, which often accompany new technology in professionalized contexts, it becomes especially important to go beyond separate groups and to focus instead on in-between groups (Barrett et al., 2012; Comeau-Vallée & Langley, 2019). Few tasks are independent and, since changes in one person's work are likely to influence the work done by others (Barley, 1990; Zetka, 2001), local collaborations between healthcare professionals and collective efforts are required when introducing and making a new technology work (Bergey et al., 2019; Lang et al., 2004; Nicolini, 2010). Thus, in their encounters with new technology in practice, the broad spectrum of professionals involved will likely face increased dependence on, and coordination with, each other (Barrett et al., 2012), resulting in a reconfiguration of the existing work practices, including the clarification of who does what (Nicolini, 2006).

From the review above, it becomes evident that studying how new technology is introduced, used and made to work in professionalized contexts requires the tracing of how multiple occupational and professional members act and interact, both during prior and subsequent work, in order to realize collective accomplishments. Thus, the coordination perspective is particularly well-suited to such an endeavor as the focus is on the reconfigurations necessary to realign actions, interactions, roles, and material arrangements through a combination of both formal means and situated and emergent processes.

2.2 Research on Coordination

The research interest in coordination has increased over the past two decades, shifting its focus away from what can be called an *organizational design perspective* toward one that can instead be called a *practice perspective* (Okhuysen & Bechky, 2009). Before reviewing these two perspectives, a brief historical background to coordination will first be presented.

Coordination has been a key aspect of organization theory for a long time (Faraj & Xiao, 2006) and can be traced back to the seminal works of Taylor (1911), Fayol (1949), and March and Simon (1958). The traditional notion of coordination is 'the integration or linking together of different part of an organization to accomplish a collective set of tasks' (Van de Ven, Delbecq & Koenig, 1976, p. 322). Differentiation, i.e. breaking down tasks into subtasks, and integration, i.e. bringing these tasks together into a collective whole, are thus important aspects of the notion of coordination (Heath & Stuadenmayer, 2000; Lawrence & Lorsch, 1967). The historical background to coordination can be seen in one early example of coordination demands, visible as far back as the nineteenth century, when some of the first large-scale organizations of modern times were emerging (Chandler, 1962). Massive both in size and in terms of complexity, the railroads were in need of large-scale coordination to make sure that loading of passengers, delivering freight, and avoiding crashes could be managed. One way to coordinate these organizations was using printed timetables, allowing certain parts of the tracks to be owned at specific times to avoid collisions. Railroad standard time also helped to coordinate passenger, freight, and other trains by replacing the over 300 local time zones existing in the US at that time (Okhuysen & Bechky, 2009). Instead of having multiple time zones, one standard time zone facilitated synchronization.

Another example of this was the emergence of large-scale manufacturing during the late nineteenth and early twentieth centuries. The quest to maximize output led to the notion of specialization and the reduction of waste. Scientific management involved examining the work being done and dividing it up into basic elements (Schachter, 2010). Taylor and the Gilbreths were prominent thinkers in this rationalization of manufacturing through specialization (see Wren & Bedeian, 2009). This thinking led to increased demands for coordination as the various inputs from specialized tasks needed to come together and to be integrated in order to deliver output. There was thus a need for integration activities (Okhuysen & Bechky, 2009).

Compared to these perspectives on coordination that centered on the design of work, later scholars followed a different perspective on coordination and focused on the design of management systems. Henry Fayol, for example, stressed the importance of having the right management system in place. Some of the key aspects of this system included the unity of command, centralization, and the subordination of individual interests. Moving away from the notion that there is one single best way to organize to achieve coordination (Argote, 1982), the focus was on how to design organizations in the best way to meet the contingencies arising due to the environment (e.g. Lawrence & Lorsch, 1967; Thompson, 1967).

Although differences exist in how these early scholars viewed coordination, e.g. focusing on designing either work or systems, there are also some similarities. The thing that the approaches advocated by these early scholars, e.g. Taylor, the Gilbreths, Fayol and others active in organizational design and contingency, had in common was the aim of planning systems to produce coordinated activity (Okhuysen & Bechky, 2009). The significance was that, with just enough effort, organizational systems could be designed with enough specificity and precision to allow coordinated work (Wolbers et al., 2018). These approaches thus suggest a contingent view of coordination: The environment is stable, or at least predictable, enough to define existing interdependencies, and to design predetermined mechanisms for various contingencies (Isabelle et al., 2012). This early coordination research thus primarily attended to the role of structures and planning (Bechky & Chung, 2018). Research that followed this understanding of coordination could be said to subscribe to the *organizational design perspective*.

However, times have changed and organizations are facing work of a different nature (Bechky & Chung, 2018). For example, there has been a shift away from manufacturing toward services, rapid technological developments, multi-disciplinary work and more uncertainty in general (Okhuysen & Bechky, 2009; Isabelle et al., 2012). With increased specialization more and more work needs to be coordinated across expert or professional domains (Bruns, 2013). As a result, the interdependencies between different aspects of the work by professionals may be uncertain or challenging to identify. The interdependencies between processes, structures, and actors are thus difficult to anticipate, and to pre-define and plan; thus, the design perspective does not fully capture how coordination has been unfolding during recent times. Another limitation of the design perspective is its inability to capture coordination as it unfolds on the ground in organizations. How coordination is generated by actors themselves, regardless of organizational design, has thus largely remained unexplored (Okhuysen & Bechky, 2009). Recent research on coordination has thus proposed a *practice perspective* (e.g. Ben-Menahem et al., 2016; Jarzabkowski et al., 2012)

In line with the broader practice turn in organization and management research (Nicolini, 2012; Schatzki et al., 2001), a practice perspective on coordination focuses on the situated and ongoing accomplishment of work (Okhuysen & Bechky, 2009). It is less interested in finding an optimal structure for a given environment, instead approaching coordination as it happens. This also means that people in organizations need to coordinate their work regardless of organizational design. Jarzabkowski et al. (2012) argued that this means a shift in analytical focus, away from coordinating mechanisms as reified toward coordinating as a dynamic social process, something which allows insights into the micro-processes involved in coordination. This view of coordination as emergent (Bechky & Chung, 2018) means that ongoing interactions aimed at managing uncertain outputs are in focus. In line with this recent research attention on examining what people actually do to coordinate (e.g. Bechky, 2003; Faraj & Xiao, 2006; Jarzabkowski et al., 2012; Kellogg et al., 2006), coordination is in this study defined as "a temporally unfolding and contextualized process of input regulation and interaction articulation to realize a collective performance" (Faraj & Xiao, 2006, p. 1157).

In moving the coordination perspective forward, Okhuysen and Bechky (2009) proposed the coordination of collective work *within* organizations as a combination of design and emergence, while further presenting a compelling framework of how coordination is achieved by means of three different integrating conditions: i.e. accountability, predictability, and common understanding.

Accountability clarifies who is responsible for the specific elements of a task (Okhuysen & Bechky, 2009), and thus aligns responsibility. Actors make clear which elements they are performing during the final production of work, while also making other actors accountable for theirs. Accountability can be created via both informal and emergent action (Wolbers et al., 2018), e.g. ongoing dialog and via designed coordination based on formal means, e.g. predetermined plans, rules and role descriptions. For example, the duties of healthcare professionals often follow a hierarchical structure through which their responsibilities as regards specific elements are spelled out. However, the responsibilities of healthcare professionals may also be clarified via ongoing interactions and emergent needs (Faraj & Xiao, 2006), when specific actions cannot be specified or predefined, e.g. when things are not going right or when it is not obvious what to do. On these occasions, it has even been illustrated how the violating of protocols can be due to medical reasons (Faraj & Xiao, 2006). Ben-Menahem et al. (2016) for example studied how a multidisciplinary group of specialists coordinating work in early-stage drug discovery, and showed they let go of their domain-specific standards of excellence to achieve accountability.

Predictability makes it possible for actors to anticipate how the elements of a task are performed by means of familiarity with the involved elements and the timing of other actors' task performance (Okhuysen & Bechky, 2009). Actors thus formulate expectations regarding how their tasks fit into the collective whole, both over time and when the various elements are pieced together. Predictability enables an understanding of what the elements of the tasks are, and when they occur. Predictability can be created via formal workflows in protocols and checklists, or can unfold during the performance of tasks when actors enact and familiarize their roles and tasks in order to fit with those of others (Wolbers et al., 2018). For example, in hospitals, plans are used as formal protocols (Faraj & Xiao, 2006) that establish the timing of both the activities conducted in an operating room and the time when patients are to be transported to different departments, depending on the progress of the their treatment.

Common understanding provides a shared perspective on the collective whole and how actors' work fits within this whole, including the goals and outputs of work

(Okhuysen & Bechky, 2009). Actors create this common perspective on, and orientation to, the elements and the unfolding of a collective task by drawing on some common knowledge, knowledge which is explicated, contested and developed while the task interdependencies are being managed. While common understanding has been described as the shared perspective of a whole task, some scholars have argued that this does not require shared and similar interests, norms and meanings. Kellogg et al. (2006), for example, show how groups in a fast internet advertising agency coordinate by enacting a 'trading zone' (Galison, 1999), in which they just have to make their work and commitments visible to each other. Furthermore, as with accountability and predictability, common understanding can be created through both formal and planned mechanisms, e.g. plans and schedules prepared in advance, or can emerge as work unfolds and through ongoing interactions of managing interdependencies. Familiarity may play an important role here (Okhuysen, 2001) as it is assumed to enhance relationships, encouraging actors to disclose their interdependence (Claggett & Karahanna, 2018; Gittell, 2002; Okhuysen & Bechky, 2009). Thus, coordination does not occur in a relational vacuum, but through relationships (e.g. Gittell, 2002; Gittell et al., 2010), including aspects such as respect for the work of others, shared goals and knowledge, which all are believed to increase the quality of the communication between the participants in work processes, thus also contributing toward making coordination possible (Gittell et al., 2008; Gittell, 2001). This relational dimension is generally attributed to work roles and tasks, rather than personal relationships (e.g. Gitell, 2002; Okhuysen & Bechky, 2009). Thus, studies showing the importance of relationships during the coordinating of work (e.g. Ferris et al., 2009) add an important element to the integrating condition of common understanding.

These three integrating conditions are thus the means by which individuals collectively perform their interdependent tasks, in turn being created by coordinating mechanisms, defined as the organizational arrangements that allow individuals to realize a collective performance (Okhuysen & Bechky, 2009). Individuals enact different mechanisms that help in creating the integrating conditions for coordination; as can be seen above, examples of these mechanisms involve plans and rules, objects and representations, roles, routines, and proximity. Based on the review by Okhuysen and Bechky (2009), we thus start to understand not only how these three integrating conditions create coordination, but also that coordination can involve both a formal, i.e. planned, dimension as well as an informal one, i.e. an emergent dimension (Isabelle et al., 2012; Pine & Mazmanian, 2017).

Building on these ideas, research has provided substantial support for how coordination mechanisms influence the development of coordination, but it has rarely paid attention to how coordination enables the enactment of coordination mechanisms (Gittell, 2006). As only one direction in the relationship between the coordination and coordination mechanisms has mainly been in focus, with the study by Claggett and Karahanna (2018) serving as an important exception, the interplay regarding what is likely to be a bidirectional relationship is not theorized. This also applies to the potential, but underexplored, dynamic nature of planned and emergent coordination mechanisms, because structure, too, is to be understood as an emergent property of ongoing action (Barley, 1986). Moreover, despite how Okhuysen and Bechky (2009) describe the three integrating conditions to coordination being interrelated, little is generally known about how the conditions are realized in practice, and, more specifically, how they change over time or in different contexts, as well as how they shape the form of coordinating that is being achieved (Pine & Mazmanian, 2017). Bechky & Chung (2018) further suggest that integrating conditions are closely related to the nature and extent of occupational embeddedness. For example, they suggest that accountability is likely to be in the foreground if the emphasis is on organizational control and on common understanding if the emphasis is instead on occupational or professional control and freedom of action. One notable exception, exploring the nature and dynamic of the three integrating conditions, is Pine and Mazmanian's (2017) study of how doctors and nurses at a hospital obstetric unit were required to use an electronic health record (EHR) system. This introduction changed the ways in which healthcare professionals coordinated, away from artful coordinating, where there was a productive disconnect between formal means and situated actions, toward contorted coordinating, where an unproductive disconnect emerged between the same. However, common understanding remained the most important integrating condition in both kinds of coordinating, albeit only being able to produce accountability and predictability in the former. One explanation for this is how the healthcare professionals had to work around the formal means, which blurred accountability and, in particular, predictability.

As mentioned above, the traditional notion of coordination is about *integration* (Heath & Stuadenmayer, 2000; Lawrence & Lorsch, 1967; Van de Ven, Delbecq & Koenig, 1976), while the general consensus among practice-based scholars, too, is that coordination is achieved through integration (Okhuysen & Bechky, 2009). A few scholars have provided an alternative perspective, in which fragmentation is also recognized. Wolbers et al. (2018), for example, argued that incoherence and contradictions are also important mechanisms of coordination practices, rather than merely being seen as deviations. Harrison and Rouse (2014) similarly proposed a model of elastic coordination, in which both deintegration and reintegration are important elements that are involved in how group members reach a collective and final outcome. More specifically, the study of Wolbers et al. (2018) of the field exercise coordination of emergency management officers (officers from the police, fire department, and medical services), illustrated that integration was difficult to achieve, and that there was a fragmentation approach to coordination which could endure. Beane and Orlikowski (2015) similarly showed how provisional settlements were important mechanisms in facilitating coordination during night rounds in hospitals.

In addition, and despite the recent advances in the coordination literature, there are also additional opportunities for further research to make important contributions. For example, the link between emergent coordination processes and professional and occupational approaches aimed at accomplishing work needs more research attention

(Bechky & Chung, 2018). For example, Bechky and Chung (2018) argued that we need to focus on how professional and occupational members are embedded in organizations to fully understand how coordination unfolds in practice. In their study of two types of organizations, one semiconductor equipment manufacturer firm and a film production company, the authors showed how emergent coordination processes were evident in both settings, since the existing organizational control, via formal and pre-determined organizational systems or mechanisms, could not fully enable integration during the actual complex production processes. However, due to the contrasting degrees of occupational control over the coordination process, emergent coordination dominated in the latter setting but operated in the background in the former setting. At the semiconductor manufacturer, occupational control was latent, and the organization as a whole neither acknowledged nor supported it. This made the members pay close attention to the formal systems, just coordinating emergently when the formal organizational systems could not fully specify integration. In this way, emergent coordination processes remained largely unnoticed by the organization and driven by the occupational members' normative expectations. At the film production company, occupational control was overt and largely supported by the organization as a whole, which allowed members to exercise their discretion based on their professional expertise and shared understanding, as regards how to get work done. As a result of this great latitude that the organization gave to its occupational and professional members, this freedom of action was exercised in order to coordinate emergently most of the time.

In addition to the implications regarding the organizational acknowledgement of occupational control of integration and coordination, Bechky and Chung (2018) also highlight the importance of focusing on the interdependence between occupational and professional groups. The authors argue that the extent to which occupational control enables emergent coordination may also stem from how the existing arrangements, including hierarchical relationships, the distribution of authority, and the jurisdictional boundaries between groups, are played out in practice. Organizations with multiple occupational or professionals groups might have problems coordinating due to jurisdictional conflicts arising from the existence of too big a differentiation between groups and an unclear understanding of how roles are related. The important thing is for members to be on a more equal footing and to develop strong relationships, as well as a shared understanding of, for example, roles, work practices, and existing expertise (Bechky & Chung, 2018). This was also shown in the study by Lindberg et al. (2019) of how learning occurs when new medical technology is introduced, thus requiring various experts to coordinate their activities. One important aspect of this was how, despite the experts being high-status actors, they all accepted novice roles in relation to the particular setting of the new technology, making them more open to experimenting and accepting of negotiating their competence, which facilitated interaction and coordination.

Apart from the studies above, coordination research has generally not paid enough attention to professional embeddedness, and links between highly professionalized settings and coordination across disciplinary boundaries (Pine & Mazmanian, 2017). Taking this into account is important because it has been shown that coordinating both influences and is conditioned upon the practices and structures of organizations (Barley, 1986, 1990; Zetka, 2001). Thus, when studying contexts such as healthcare, it is of major importance to incorporate existing traditional arrangements, including the frequently well-established demarcations, status-differences, and traditional scripts regarding how to organize work. This is the case because these occupational and professional approaches to accomplishing and organizing work most likely influence, and are themselves shaped by, coordination processes. This idea is further supported by previous studies showing how the introduction of new technology hinges upon the coordination of multidisciplinary work, and how existing coordination arrangements are reproduced, including further boundary demarcation and the maintaining of already-existing boundaries (e.g. Fenwick et al., 2012; Liberati et al., 2016; Martin et al., 2009). As such, highly professionalized and hierarchical settings, e.g. healthcare, are not just interesting contexts in which to explore how coordination across disciplinary boundaries unfolds, they are also contexts that need to pay explicit attention to well-established practices, hierarchies and status differences (Anthony, 2018). Thus, we need to consider the existing occupational and professional approaches, including how statuses are intertwined with coordinating processes, e.g. how status differences have the potential to shape the interactions between individuals, as well as how these differences may become shaped by how coordination unfolds. The general consensus among coordination scholars, is that when status-differences between members of occupational and professional groups are salient, coordination with one another is made difficult (Anthony, 2018; Barrett et al., 2012; Edmondson et al., 2001; Faraj & Xiao, 2006; Valentine & Edmondson, 2015). For example, in a study of the introduction of minimally invasive cardiac surgery, Edmondson et al. (2001) shows how salient status difference present powerful barriers to implementation and interactions, e.g. in the way nurses are not feeling comfortable to speak up.

Another opportunity for further research is not only focusing on already-established practices, but also addressing the foregoing coordination during prior or preparatory work. The general lack of studies exploring prior and preparatory work means that, in spite of coordination having been acknowledged as a dynamic process, a processual and dynamic view of coordination has not been taken seriously (Beane & Orlikowski, 2015; Jarzabkowski et al., 2012). This is the case because coordination follows a history of previous actions and interactions that necessarily constrain and enable future action (Faraj & Xiao, 2006). Thus, "history is not just an event in the past but is alive in the present and may shape the future" (Pettigrew, 1990, p. 270).

However, there are some exceptions. For example, Beane and Orlikowski (2015) studied complex, distributed knowledge work performed either by telephone or using a telepresence robot during night rounds at a post-surgical intensive care unit. The authors focused on how nurses, residents, and attending physicians engaged in interconnected practices, i.e. preparation work, night round work, and overnight care work, over time and how this impacted the coordination of work. The study shows that the extent to which and in which way preparatory practices are performed has important implications for the coordination of subsequent work. For example, when healthcare professionals prepared extensively, collaboratively, and at their workplace, differences in interests and understandings decreased, thus facilitating coordination. In contrast, when only preparing to a lesser extent, and away from their workplace, differences increased instead, thus challenging coordination. Indeed, this study clearly illustrated how preparatory work was both highly important to and shaped subsequent coordination, thus concluding that coordination processes rely on prior activities. In addition, the study by Barrett et al. (2012) also points to the importance of acknowledging the role of planning and preparation in how subsequent coordination emerges. While these authors focused on boundary relations, they showed that the planning process, including what gets decided and by whom, for the introduction of a robotic innovation was highly consequential as regards how the technology later also influenced coordination among the workers. For example, pharmacists and technicians were included in the planning process and could, in doing so, inscribe their interests and hierarchy into the technology, which later shaped how work was coordinated once the technology had been introduced. A study by Venters et al. (2014) also shed light on the temporal embeddedness of coordination processes by studying how computing specialists were involved in the development, introduction, and use of a computing grid infrastructure. The authors showed how multiple and divergent interpretations of the past, present, and future were intertwined, shaping how the computing specialists coordinated their work. For example, when future infrastructure models were being built and coordinated between specialists, they were largely being conditioned by social and material inertias from the past, e.g. conventions of practice, disciplinary agency, history of tools and equipment use, and previous installed bases of software. These few existing studies, highlight in different ways the interconnectedness of the temporal dimension of coordination.

Apart from the exceptions given above, and despite how prior research stresses the situated and emergent nature of practices that realize coordination, little is still known about the temporal interdependence between these practices and prior work, and focal coordination processes are influenced (Beane & Orlikowski, 2015). This is especially the case when it comes to the introduction of new technology and the difference this makes to the coordination of work. The planning and preparation work carried out, as well as the time during the run-up to a technology even coming into place in an organization, is often neglected (with the exceptions mentioned earlier). Instead, frequently, the focus is not on the situated coordination processes until technologies have "arrived" at organizations. Building on the aforementioned arguments, one important opportunity for further research, thus, is to explore in detail how individuals' alignment of the past and future is entangled in emerging coordination processes, and especially when new technology is introduced. This is based on a broader critique of traditional research on technology, work, and organization, which in turn is based on the argument that we need to admit that the implications (e.g. for coordination) of a new technology are not always the result of ongoing actions at the point where people are using technologies. The interests, goals and perspectives of those who make or influence decisions about design and introduction also shape the outcomes of technological change. Thus, we cannot go on viewing the implications of new technologies in terms of merely being situated, contextual and emergent (Bailey & Barley, 2019).

A third opportunity for further research is considering materiality during the study of coordination (Beane & Orlikowski, 2015; Okhuysen & Bechky, 2009). The roles of material arrangements, e.g. objects and proximity, in how coordination unfolds, have indeed been given more attention. For example, studies have explored how boundary objects may become useful for solving issues occurring between groups (e.g. Barrett & Oborn, 2010; Carlile, 2002; Majchrzak et al., 2012; Nicolini et al., 2012), and how proximity may shape visibility and thus act as a coordinating mechanism (e.g. Claggett & Karahanna, 2018; Kellogg et al., 2006). However, these studies tend to focus on the material arrangements as a passive medium through which coordination processes unfold, e.g. how materiality can either enable or constrain coordination. The emphasis is often additionally on how changes in materiality serve as occasions for the reproduction or disruption of coordination processes. This is especially the case when it comes to physical space, where the meaning that individuals and groups assign to this aspect, and how this matters to their social process (Gieryn, 2000) of coordination is seldom considered. The material arrangements intertwined with coordinating processes, and how physical space and coordination mutually shape, is thus underexplored (Sayegh & Faraj, 2016).

A few studies have moved beyond conceiving materiality as a passive medium through which coordination is done, to show how materiality is directly implicated and intertwined with coordination processes. These studies often share a view of the social and the material as being constitutively entangled in everyday life, and that of a practice only existing as it is materialized in specific physical spaces, artifacts, bodies and so on (Orlikowski, 2007; Orlikowski & Scott, 2014). One such exception is the study of Barrett et al. (2012) of the introduction of a pharmaceutical dispensing robot and its implications for the work, interests and relations of three occupational groups. By focusing on how this technology materially reconfigured boundary relations, the authors also illustrated how the physical spaces within the pharmacy were influenced, and what the consequences were. The dispensing robot was a large object, which visibly demarcated and separated work, in turn influencing how the three occupational groups interacted and coordinated to get work done. For example, assistants working at the back-end were allowed less floor space than pharmacists and technicians working at the front-end. The assistants' work became more isolated and had less visibility, with the materiality of the technology not only serving as a barrier to interactions, but also becoming intertwined with how the assistants increased both their dependence on and their coordination with the other two occupational groups. Another exception is the study by Beane and Orlikowski (2015), who examined what difference a robotic telepresence made to the coordination of night rounds at a post-surgical intensive care unit. The authors illustrated how performing night rounds using the new technology intensified the level of coordination both positively and negatively, depending on how this coordination was materialized in practice. More specifically, coordination was substantially facilitated by the material enactment of the new technology allowing provisional settlements to be understood and accepted. Coordination was, on the other hand, severely challenged when the material enactment of the new technology allowed provisional settlements to be either unclear or not fully understood. As such, it is not the distinct properties of technologies that matter to how coordination unfolds. Instead, these authors highlight how materiality, e.g. a new technology, cannot be separated from situated practice, instead always being constitutive of the coordination of work.

Clearly, there are opportunities to further develop knowledge of how materiality is intertwined with coordination. This is especially the case given the scant attention paid to the analysis of physical space in the coordination literature. The implications of material arrangements in general and, in particular of physical space, are especially important to consider in knowledge-intensive settings, especially in healthcare, where work is centered on material arrangements like physical space, objects and bodies (Håland, 2012; Petrakaki et al., 2016). This is especially prevalent in the way healthcare has traditionally been organized, being characterized by a functional organizational structure in which health providers with similar expertise are grouped together, and thus relying on the co-presence, proximity and mutual visibility only between similar healthcare professionals (Nicolini, 2006). However, the changing healthcare landscape, including the introduction of new technologies based on multidisciplinary departments and teams, may have the potential to not only disrupt the traditional way of coordinating healthcare, but also to fundamentally change how such coordination is materially enacted in practice.

Questions regarding how existing traditional professional arrangements influence coordination, how the temporal interdependence of coordination is embedded with prior work, especially when a new technology is introduced, and how coordination is intertwined with materiality in practice all warrant further research attention. These questions have justified the current study and will help in addressing the research question posed. In sum, theories of coordination are crucial to understanding how the introduction and use of new technology, in practice, becomes associated with changes to roles, responsibilities, interactions, and alignments of actions.

CHAPTER 3

RESEARCH SETTING AND METHODS

This chapter presents the research setting in which the research took place, and the methods by which the research was conducted. A brief introduction of SweHos and its new center, as well as the new technology, i.e. the iMRI Hybrid OR, will be presented first. A background to the study will then be presented, followed by a description of how the field material was generated and analyzed.

3.1 Research Setting

SweHos is a major public-sector university hospital in Sweden. Its organizational structure is functional and it has six divisions, whereby one section director is directly subordinate to the hospital CEO. For each division, there are certain operational sectors grouped by discipline.

As far back as 2006, together with its associated county council, SweHos initiated a joint effort to construct a new Centre for Imaging and Intervention (CII). Setting up this new center was a way of fulfilling the long-term strategy of enhancing the hospital's field of imaging and intervention, in doing so also achieving the overall aim of meeting new demands for diagnosing and treating patients, becoming the motor of the region, and taking an international lead in terms of research and development. After intensive and lengthy discussions back and forth, the CII, with floor space exceeding 21,000m², was inaugurated in late 2016. The new center was constructed in stages. The final stage of having the entirely new building in complete clinical use was achieved at the end of 2017. The center is one of the regions' most expensive investments, at about SEK 2 billion. When counting all activities as up and running, approximately 600 healthcare professionals from different disciplines work at the new center.

The center is eight stories high, of which three are only for technical equipment, e.g. ventilation and electricity. Six stories are above ground level while two are below it. The building is located directly adjacent to the existing central complex at SweHos. The five different spheres of activity at the CII are: a sterility unit, a radiopharmaceutical center, clinical physiology, radiology, and hybrid and intervention operations. The whole center was mentioned in the media and talked about by hospital employees as fascinating and an enabler of the delivery of world-class healthcare; however, it was the so called Hybrid Operating Rooms (Hybrid ORs) that stood out. Developing and setting up the Hybrid ORs was described, by hospital managers and clinical healthcare professionals alike, as an integral part of the long-term strategy of the hospital, in enhancing their field of imaging and intervention. These rooms are part of the hybrid and intervention operations and are located on the fourth story of the new center.

As briefly described in the introduction, one of the overall aims of the Hybrid ORs is to be able to combine sophisticated imaging with surgical procedures in one single room. This also means that patients are treated without having to be transported between different departments within the hospital. A standard Hybrid OR is generic, i.e. designed to be used by different medical specialisms, and equipped with the advanced medical imaging device called the CT scanner. Medical professionals can see, using this form of intra-procedural X-ray imaging, objects and anatomical structures inside the patient during an intervention, thus making invasive surgery as minimal as possible. This differs from how traditional X-ray imaging is used in healthcare, with examination and intervention commonly being separated. In these rooms, there is also an enormous amount of other technical equipment and devices. Procedures applied in these standard hybrid rooms often involved 8 to 20 individuals, including anesthesiologists, anesthesia nurses, surgical nurses, radiology nurses, surgeons, technicians, physicists, device experts, and administrative personnel.

However, not all the hybrid rooms were planned to be identical and, even if all the hybrid operating rooms were talked about with great interest and fascination, it was still the room containing MRI (iMRI Hybrid OR) that stood out. This room was often described by those involved as unique and special. The iMRI Hybrid OR was unique due to being Sweden's first and only MRI scanner in a surgical context and due to being the fourth installation in Europe. It was also the most expensive of all the Hybrid ORs, with an estimated cost of about SEK 50 million. A major difference between the iMRI Hybrid OR and the other Hybrid ORs is the possibility of additionally using magnetic resonance imaging (MRI), which differs from the radiation scanners (e.g. X-rays and CT scanners) used in the standard hybrid rooms.

The idea behind the room is to be able to use magnetic resonance imaging (MRI) *during* surgery, by means of having a movable MRI scanner mounted in the ceiling. This intra-operative imaging makes enormous demands as regards safety since MRI involves strong magnetic fields. As the movable MRI scanner weighs approximately 14 tons in total, of which the magnet itself weighs approximately 7, major demands and special considerations were also involved as regards how to construct such a room, making it durable enough as regards these concerns, and how to accommodate the scanner. The solution was to install 15 tons of iron beams, above the ceiling, which would support the MRI scanner, something which also had consequences for the numbers of stories in the new building. As can be seen in Figure 1 below, the large number of iron beams installed resulted in the new building having fewer stories, seen to the left, compared to the older building, seen to the right.

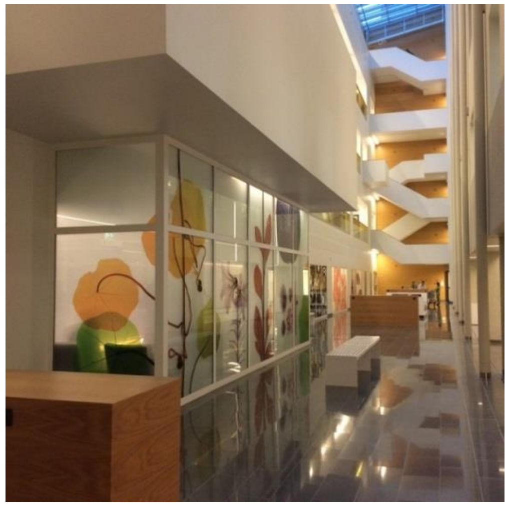

Figure 1. Difference in numbers of stories between the buildings.

The magnet (as seen in Figures 2 and 3) was lifted into place by a large crane off a truck and up through the air, and then into the magnet room on the fourth story.

Figure 2. The crane just about to lift the magnet.

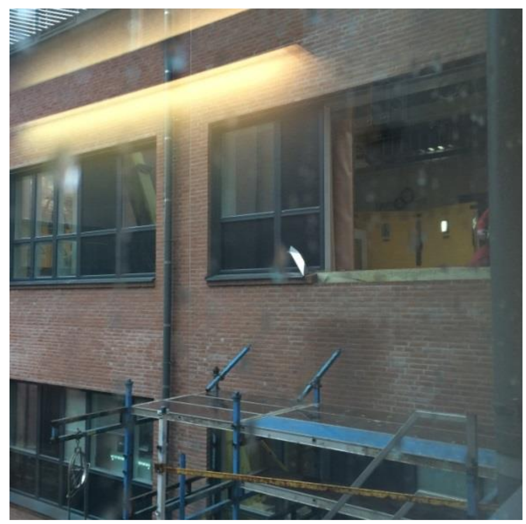

Figure 3. The opening into the magnet room.

Put simply, the procedure carried out in the room includes the patient remaining on the operating table while the MRI scanner moves towards him/her from an adjacent room, called the garage. Thus, it can be thought of as in terms of the entire Hybrid OR needing to be quickly transformed from an operating room into an MRI-compatible room. To enable this transformation, a special operating table is used from the start. This table is MRI-compatible table, which is somewhat different from what most surgical staff are used to. All the tools and instruments need to be carefully counted, and not taken out of the room without being documented. Whenever it is decided, during surgery, to carry out an MRI examination, all the tools and instruments that are not MRI-compatible need to be counted again, and taken away, both from outside and inside the patient. All the MRI-compatible technological devices, except for the anesthesia machines, need to be switched off. Surgical staff also need to leave the hybrid room. It is not until the doors are locked that the MRI scanner mounted in the ceiling can enter the Hybrid OR.

Since the MRI scanner only reaches as far as a certain point inside the iMRI Hybrid OR, and since the operating table is fixed, it has thus far only been possible, and appropriate, to examine the head and neck areas. In my study, the new technology has been used in neurosurgery and for brain tumor resection, in particular. The key difference between how brain surgery is traditionally performed and how it is performed using the new technology is *how* and *when* the MRI examination is done. Traditionally, the surgeon needs to completely close up the patient and finish the procedure in the OR, and then have the patient transported to the MRI Unit for examination within 48 hours, all in order to check whether or not the entire tumor has been resected. At the MRI Unit, the MRI images are produced and then interpreted by a radiologist who communicates the results to the surgeon. If tumor remnants are detected, the entire surgical procedure will be repeated, or a series of radiotherapy treatments, with commonly severe side effects, are will be performed. However, using the new technology, it is possible to perform an MRI examination *during* the surgical procedure, without having to completely close up or move the patient. This means that, whenever the neurosurgeons experience that they have sufficiently resected the entire tumor, they can request an MRI examination in the OR to verify if their judgment is accurate, and to update their navigation system with real-time images if an additional resection is needed. As neurosurgery is inherently delicate and highly uncertain, the new technology offers important improvements (Litofsky et al., 2006). For example, due to the so-called phenomenon of "brain-shift", i.e. brain structures moving during surgical procedures, there is inaccuracy of up to 10mm in the preoperative MRI images (images produced prior to the surgical intervention) (Gerard et al., 2017; Kuhnt et al., 2012; Roberts et al., 1998). As a result, the neurosurgeons face high levels of uncertainty in relation to their orientation within the surgical cavity, and in relation to whether they have affected healthy tissue and whether their tumor resection has been sufficient. All in all, the new technology offers immense improvements to both surgical outcomes and patient safety. Surgeons can navigate inside the brain with more precision, and verify the extent of tumor resection using real-time images, as well as engage with the radiologists during the immediate interpretation of images, with the risk associated with patient transportation also being reduced.

In this way, the new technology (iMRI Hybrid OR) seems to be a straightforward and promising technological development in the healthcare sector. However, organizing such new technology is complex as it requires new ways of working, new configurations of healthcare professionals, and the emergence of a new practice, changes which all need to incorporate the requirements of two seemingly incompatible and previously-separated healthcare practices (neurosurgery and MRI), in addition to being accommodated in the same physical space. This makes it particularly interesting to study a Hybrid OR in the making, and thus tracing how the introduction and use of the new technology is coordinated.

3.2 The Genesis of the Study and Research Approach

It was not clear from the start that this study would be about how the introduction and use of the new iMRI Hybrid OR[4] had been coordinated. This focus emerged during the research process. What was clear from the start, however, was the empirical context, i.e. the new imaging and intervention center and its surroundings, built at SweHos. In 2015, after an initial interview with the HR manager responsible for competence and knowledge development at the center, I was invited to participate in seven full days of training sessions. What I observed during these days will be described in subsequent empirical chapters, but it was here I first heard about the combination of surgical and MRI practices. It was also during these sessions, when I first met the physicist responsible for the MRI part of the iMRI Hybrid OR. This specific part of the new center was, as previously mentioned, generally described as unique and special, being the fourth of its kind in Europe. It was talked about as highly technologically intensive, making fantastic medical advancements possible, but it was also described as challenging and demanding. There were utterances and reflections about uncertainty and newness, regarding how two distinct and separated practices would need to come together, and this puzzled me. The physicist's intriguing and almost captivating description probably also affected my decision to study how this specific technology was introduced and used. It turned out that the chosen site was ideal for the study as I had access to how a multidisciplinary group of professionals engaged and interacted over time, in order to introduce and use the new technology.

This is a longitudinal study in which I have followed the planning, introduction and initial use of a specific Hybrid OR at a major university hospital in Sweden. The Hybrid OR is still a relative new and developing healthcare phenomenon, and this is especially the case when it comes to iMRI Hybrid ORs, not being established anywhere in the world until 2006 (Matsumae, 2007), and with only three previous installations in Europe. As it is a novel research context wherein few theoretical frameworks have been defined, lending themselves to detailization and careful empirical texting, an open research approach is very appropriate (Corbin & Strauss, 1998; Eisenhardt & Graebner, 2007). Furthermore, because little theory has been developed regarding how coordination unfolds in practice, when considering the

[4] The iMRI Hybrid OR is the new technology featured in my study. *iMRI Hybrid OR* and *technology* are two terms used interchangeably throughout the dissertation when referring to my specific study. I do not intend to develop a singular or definitive definition of technology as this is inherently problematic (Orlikowski & Scott, 2008). Instead, I have followed what the informants in my study experienced as the new technology. The iMRI Hybrid OR, with its new arrangement, was what the informants undoubtedly mentioned and described as the new technology, knowing the name of it and being able to point to an instance of its use (see Barley, 1990).

material enactment, the temporal dynamics, and the link with occupational approaches to work, an inductive approach to studying this problem is justified (Edmondson & McManus, 2007).

I strive to provide a fundamental understanding of the coordination of the introduction and use of new technology, and how it unfolds in practice; thus, in order to generate a grounded theoretical understanding, ethnographically-inspired methods become particularly relevant. In this way, I have followed a series of "events" at the studied hospital. The ideas regarding the field material are interpretations of the phenomena targeted (Alvesson & Sköldberg, 2009; Steier, 1991), and I do not claim to produce generalized results, nor field material mirroring some objective reality. Instead, the interpretative approach used has guided me toward focusing on the level of meaning.

3.3 Generating Field Material

The field material was generated between October 2015 and November 2019, and includes data from formal and informal interviews, observations, photographs and documents. To establish a baseline regarding the way neurosurgery and MRI was performed and coordinated before the new technology had been introduced, I spent a considerable time in the field before the technology had been planned for, introduced and used. This before-and-after approach (Barley, 1986) was also a way to take the processual and dynamic view of coordination seriously. This study was approved by the regional Ethics Committee (www.epn.se), and informed consent was obtained from the informants.

Figure 4 illustrates a basic timeline regarding the planning, introduction and use of the new iMRI Hybrid OR, with the data generation plotted alongside this. Interviews were conducted throughout the entire timeline, with a focus on the traditional practices, as well as the planning and preparatory activities taking place during the period 2016-2017, with a focus on the situation concerning the new technology during the period 2018-2019. I conducted observations during all the events plotted on the timeline. In addition, I also observed traditional surgical and MRI procedures, mainly during the period 2016-2017. Documents were collected throughout the entire timeline. Managers were interviewed throughout the entire timeline, but mainly at the beginning of the study.

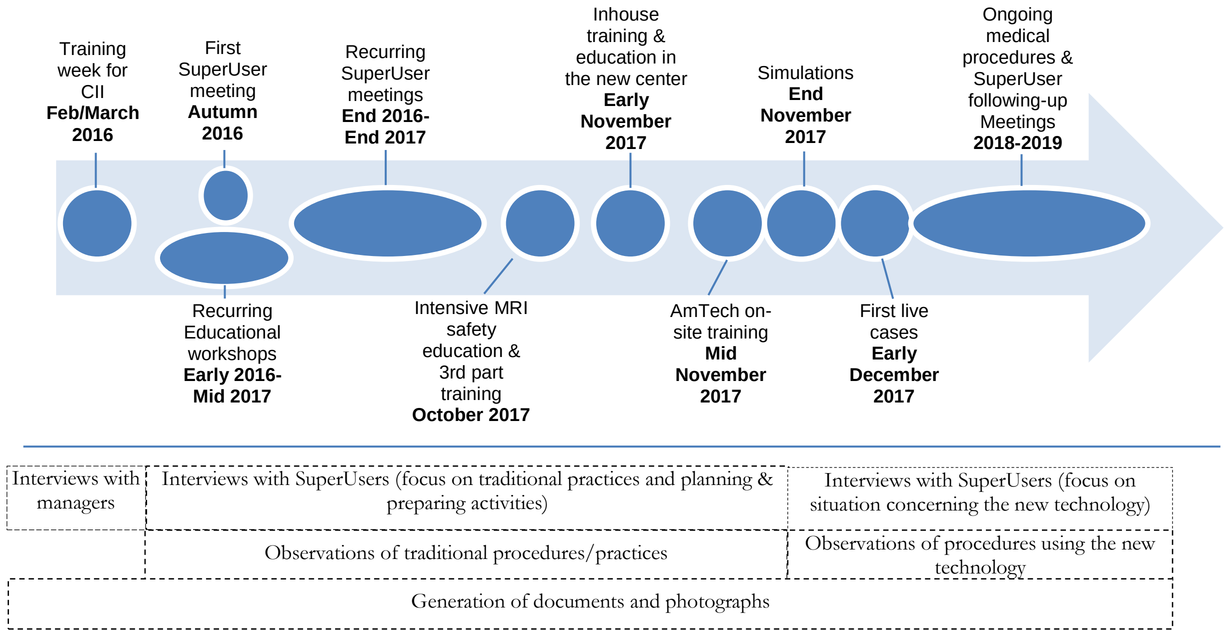

Figure 4. A basic timeline of the new technology and the time period for data generation.

3.3.1 Interviews

I have conducted 87 interviews, of which 57 were formal interviews and 30 were informal (see Table 1 for an overview). The formal interviews were all semi-structured and open-ended (Kvale, 1996; Silverman, 2011) in order not to steer them, instead allowing the interviewees to talk freely about their work and letting them manage the performance and impression (Czarniawska, 2014). The interviews lasted between 60 and 120 minutes, which I felt was enough time to acquire the interviewees' accounts. Even though notes were taken during the interviews to act as a reminder about issues needing to be further explained (Czarniawska, 2014), the focus was on listening and trying to understand the interviewees' accounts. The majority of the formal interviews took place at the interviewees' workplaces, being recorded and transcribed verbatim.

Table 1. Occupations of interviewees and numbers of interviews.

Occupation	No. Formal Interviews	No. Informal Interviews	Total No. Interviews
Doctors	16	7	23
Nurses	17	10	27
Physicists/technicians	6	4	10
Technological/application experts	4	1	5
HR personnel	6	4	10
Construction specialists	2		2
Section managers	6	4	10
Total	**57**	**30**	**87**

I purposely started interviewing individuals in a managerial position, in order to legitimize myself and my project. This was a way to negotiate access, not only for potential occasions to observe, for example, meetings and workshops, but also for contacting further individuals to interview. These individuals were section managers, HR managers, competence and development managers especially involved in planning and preparing for the new iMRI Hybrid OR. I firstly asked them questions regarding their work in general, what duties they were involved in, how long they had been working at SweHos, and so on. After reaching a greater understanding of their ordinary working situations, and the context they were part of, I asked them to tell me about the new iMRI Hybrid OR, what it was, and what it meant, as well as how it was connected to their work. The contribution of these interviews was an understanding of which knowledge and competence was seen as important for working with the new technology, and how training and developmental sessions were planned.

Starting from the top and then moving downwards within the organizational hierarchy has both its advantages and disadvantages. One advantage, as previously mentioned, was the legitimizing aspect, whereby I as a researcher, and my project, were accepted by management, and this can be considered an obligatory passage point, as a necessity for coming even closer to non-managerial employees. This is especially important, perhaps, when studying inside a hospital, often considered a protective environment, which makes obtaining access difficult. Starting from the top can also be problematic, e.g. if it becomes a power game, where the researcher is unintentionally seen as taking a managerial stance, and where non-managerial interviewees may thus experience an uncomfortable pressure to participate in the study. It is thus highly important to reflect upon, and to be aware of, these issues. I have thus made it clear to the individuals I interviewed that I was not taking sides, instead representing myself and my university. This still means that I bring with me certain expectations, and that the informants may have ideas about my purpose. During my presence (both during interviews and observations), I have presented myself as a curious researcher interested in how those involved make the technology work within the room. I strived distinctly to disclaim any judgmental prerogatives likely associated with a research role (Van Maanen & Kolb, 1982). For example, I explained that I was not present to evaluate how they did their work or tell them how to work. From the informants' responses, I get the sincere feeling that they also viewed me as such, a curious researcher.

The majority of the formal interviews have been conducted with the healthcare professionals planning and preparing, as well as working in, the iMRI Hybrid OR. These were physicists, technicians, doctors, and nurses belonging to different disciplines, e.g. surgery, radiology, and anesthesia. They were directly involved in the planning and establishing of what procedures to perform in the room, how to do these, and what equipment was needed. They were the so called 'SuperUsers' or 'Champions', thought of as being the first ones working in the new iMRI Hybrid OR. I started out asking general questions about their background, education, experience and then about their current role, what they do, whom they work with and so on. I then asked questions about the new iMRI Hybrid OR, e.g. what it meant to be a part of the so called SuperUser group, how they became involved, what they expected the new technology to be like, how it would affect their work, how they prepared for it, and so on. These interviews have, for example, contributed a broad understanding of what is expected of the new technology, how the preparation work is performed, and how it differs from traditional duties. I interviewed all the SuperUsers twice, during two different interview periods. The first period was before the new technology had been introduced, mainly during the period 2016-2017. The second period was after the new technology had been introduced and was in use, mainly during the period 2018-2019.

I have also conducted 30 informal interviews, or talks, similar to what Barley and Kunda (2001) called "real-time interviewing", with a wide variety of healthcare professionals. These occasions, compared to the formal interviews, were generally more spontaneous, shorter (up to 30 mins.) and less structured. They took place wherever and whenever possible, e.g. in control rooms, hospital corridors, seminar rooms, locker rooms, restaurants, and on the phone. They covered both general topics and emerging topics raised during, for example, workshops, educational visits, educational sessions, and SuperUser meetings. Examples of these topics concerned the traditional ways of performing neurosurgery, including patient transportations to the MRI Unit, and the use of technical equipment. They also concerned planning and preparatory activities, including training in the new technology, and new ways of working with the new technology, including general reflections on it and whether it had turned out as expected. The author's jotted down field notes were later elaborated upon on a computer almost the same day. These interviews thus generated additional field material and provided a more complete understanding. They also helped me to verify and clarify information I had generated during the formal interviews and observations. It is important, for reasons of clarity, to mention that these informal interviews were generally different from chat during observations. As described in more detail later in this chapter, the latter were directly related to what was happening in a given situation. Since these talks were occurring while the healthcare professionals were doing their work, less time was generally allowed for follow-up questions or further reflections.

Interviews are not, however, an unproblematic method of generating field material, with Atkinson and Silverman (1997), for example, highlighting that, in our interview-based society, we rely pervasively on face-to-face interviews, often without critically reflecting upon their shortcomings. A general drawback with interviews has been put forward by Czarniawska (2014), who argued that interviewees may be concerned with saying the "right things", or putting either themselves or their organizations in a good light, thus being tempted to answer the questions in a way that pleases the interviewer rather than shares what they do. Saying the "right things" and aiming to show oneself in a good light are also, however, aspects of organizational work and should therefore not be mitigated. These aspects however need to be concerned with reflection and critical thinking, in a way that prevents a naïve view of the interview and the data it yields (Atkinson & Silverman, 1997). The experience gained from this study's interviews in particular contrasts with the notion of pleasing the researcher, instead leaving me with a sense of honesty and openness. It was not, for example, uncommon for interviewees to criticize how work was planned for, e.g. the lack of clear instructions and guidelines, not to mention time. Adding to this was also how the interviewees were able to comment during the interviews that they had to stand up for themselves, whenever they said something that could be considered critical.

Another important concern with interviews is the often neglected asymmetrical power distribution, whereby the researcher often takes the dominant position (Kvale, 2006). I have not, however, experienced any signs of power concerns. I have reflected upon these methodological and ethical concerns, and my aim has been to make these issues transparent whenever they arise, so that the reader can ascertain the potential effects of these issues on the knowledge reported (Kvale, 2006).

3.3.2 Observations

While interviews are useful for studying points of view and meaning, such techniques are less than adequate for studying work because most *"work practices are so contextualized that people often cannot articulate how they do what they do, unless they are in the process of doing it"* (Barley & Kunda, 2001, p. 81). Watson (2012) argued that no methods can replace close involvement with people in their 'natural' setting, but they can considerably enhance the richness of the insights which can be generated. Thus, in order to strengthen what I interpret and experience, I have, as already mentioned, included several methods of generating the field material (e.g. Silverman, 2011; Spradley, 1979). In addition to interviews, I have also observed over 200 hours of various occasions (see Table 2 for an overview). Doing observations mitigates the potential shortcomings of interviews, but it also corresponds to my research aims and my view of how to gain knowledge.

Table 2. Types and durations of observations.

Type of observation	Duration
SuperUser meetings	20hrs 45 mins
SuperUser training	61hrs 10 mins
Educational work-shops	17hrs 30 mins
Training week	56hrs
Educational visits	11hrs
Medical procedures	78hrs 30 mins
Total	**244hrs 55 mins**

In order to understand how the introduction and use of the new technology is coordinated on the ground, in practice, I needed to interact at close-hand, with the people and the things I wanted to understand. By observing meetings, workshops and development courses for competence and knowledge, and medical procedures, I was able to construct my own account of how this played out in vivo, close to the point of origin (Van Maanen, 1979a). Thus, I view observations as occasions when I can gain insights, at close-hand, into how people act, and how practices are performed, but also as occasions when I can legitimate myself as a researcher. Legitimizing seemed especially important in the hospital context, in which it can be difficult to be just "hanging around" (Feldman et al., 2004). This became evident during the seven full days of training sessions (Training week in Table 2), which I observed at the beginning of 2016. These sessions, which included parts especially focusing on hybrid operating rooms, were meant as an orientation for healthcare professionals who could end up working in the new center. I participated in the same sessions as the healthcare professionals, but I also had the chance to eat lunch with the participants and chat with them with no formal agenda. This made it possible to observe relationships in a natural setting. I gained relevant knowledge of how hospital management trains and develops the various medical professionals that are supposed to work with the new technology, and in the hybrid operating rooms. The individuals I was observing were also given a face, and my name could now be related to a face and not only to an email address or signature. These observations thus led to the legitimizing of my presence, something that would be important since access is a constant negotiation process (Czarniawska, 1998). Uncertainty regarding how the new technology was to be introduced, the technological intensity, and how diversified the duties and knowledge of the various professionals were, were aspects reoccurring during these observations, enabling me at close hand to encounter the everyday work lives of the relevant actors (Watson, 2011).

In addition to this training week, I also observed the so called SuperUser meetings that started in the autumn of 2016, and continued throughout my field work. These were held on a regular basis, with the SuperUsers meeting to discuss, plan and prepare for the introduction and use of the new technology. Moreover, SuperUser training sessions, where the SuperUsers gathered to perform various kinds of training and simulation activities regarding the new technology, were also observed. I also observed and participated in various educational visits, some of which involved SuperUsers when visiting, for example, the new room that would contain the new technology, while other visits were dedicated solely to my own understanding of, for example, the new material arrangements and the MRI Unit. These observations were extremely important for various reasons, e.g. in order to understand the physical layouts and their implications for how work was to be performed and coordinated. Medical procedures, both before and after the introduction of the iMRI Hybrid OR, were observed in order to get as close as possible to coordinating on the ground. I also acted as a test patient on numerous occasions, while the staff worked at learning and improving the technology.

On all these occasions, my role was mostly that of a passive observer. I took notes and wrote field stories based on these notes (see Schwartzman, 1993). I divided my notebook into three columns: i.e. the first for time and actors, the second for notes, and the third for my immediate comments or thoughts. At the end of each day, I reread my daily notes and expanded them with additional comments and supplementary notes. At the end of the observations, I started to write memos about my impressions, and how I could interpret what I had observed.

Doing observations also means talking to participants (Green & Thorogood, 2013), and thus I participated in numerous ethnographic conversations (Emerson et al., 2011) while observing, for example, medical procedures, training activities and educational visits. These talks were directly related to the current situation, and involved participants explaining what they were doing and me asking them what they were doing and why. The work demands of the healthcare professionals I engaged with were so great and so pressing that I was such a relatively unimportant figure in their world. In that they got used to me, I felt that my presence did not affect the coordination processes in any significant way, if at all.

3.3.3 Photographs and documents

During both interviews and observations, the informants often mentioned and engaged with the objects and spaces involved in their work. After spending some time in the field, I thus decided to include visual methods, specifically the use of photographs (Meyer et al., 2013; Ray & Smith, 2012; Warren, 2002). In total, I took over 300 photographs, with the main purpose of capturing visual 'field notes' in a documentary sense (Meyer et al., 2013) regarding the material things that seemed important to the informants. I was thus able to more holistically document my observations, compared to just using verbal field notes. In addition to playing an important role during the research process itself, photographs were also used when presenting the findings and insights. This was the case because I sometimes found it difficult to present and discuss my empirical findings using words alone, thus photographs enriched the data from other sources and enabled a more sensorially complete presentation of the empirical story (Meyer et al., 2013).

The use of photographs as a visual method involves data that are static in nature (Hatch & Schultz. 2017), but still hold great promise for following change over time (Ray & Smith, 2012), as photographs visually account for changes (Meyer et al., 2013). In this way, the photographs thus enabled me to compare the various physical layouts in which the traditional way of both performing and coordinating neurosurgery was taking place, and in which the new way of doing it was unfolding, but also how the new room was physically changing over time. This included, for example, various pieces of technological equipment and objects and their positions, as well as the lining and covering of the room. However, as I only decided to use photographs after having spent some time in the field, fewer were taken in relation to the traditional way of performing neurosurgery and MRI, compared to the new practice and the new room. The cover of this dissertation, for example, is a fusion of an MRI image of my own brain and a photograph illustrating how the SuperUsers met in the iMRI Hybrid OR to plan and prepare for its introduction and use.

Adopting visual methods requires numerous considerations to be made. For example, "a photograph is not taken, but rather is made" (Ray & Smith, 2012, p. 290) and, since I adopted a documentation technique, and took the photographs myself, these will thus always reflect my own judgment and preferences, and thus also play a role in the framing of these photographs (Schwartz, 1989; Warren, 2002). Moreover, ethical considerations are often emphasized when using visual methods, especially when it comes to the sensitivity of people appearing in photographs (Ray & Smith, 2012). One important aspect was thus preserving patient integrity and protecting the anonymity of my informants. Before taking any photographs, I always asked for the consent of those in the current situation. Neither did I take any photographs when patients were involved (with the exceptions of healthy test patients), and I made sure no faces were recognizable whenever photographs were taken in which healthcare professionals could be captured. The photographs I used when presenting my findings were thus directly affected by the ethical considerations mentioned. I thus only made partial progress in my use of visual methods, as discussed by Wagner in these terms; "In the first place, there are too few visual studies of people acting in natural settings. We simply have not seen enough of what people do and the physical contexts in which it is done" (1979, p. 286).

Furthermore, the collection of the field material for this study has also been done by gathering various documents. Documents like PowerPoint presentations, equipment lists, and descriptions of equipment, policy documents and checklists were all mentioned and discussed during both interviews and observations. I have collected these in order to acquire an understanding of how they are used and what they stand for. Furthermore, since some of the interviews involved stories of events that took place prior to my arrival, various documents, memoranda and reports were gathered in order to identify and analyze some of these events. To also understand how these documents had been translated, I asked for earlier versions as well. I am also aware of the notion that for whom and by whom these documents are intended affects both their content and structure (Silverman, 2011). These organizational documents have not only provided me with important background information about the hospital, the new center as such, and the specific technology, they have also functioned as a complement to the interviews and observations. Access to these documents was valuable because many of the coordination efforts involved textual objects (e.g. plans, guidelines, check-lists), not only as mechanisms for coordinating, but also as the results of these coordinating efforts. I have also been on the email list which was occasionally used by the SuperUsers to communicate their reflections on aspects brought up during the planning and preparatory phase.

3.4 Analyzing the Field Material

The analysis process consisted of different steps; however, as I was inspired by a grounded theory approach (Glaser & Strauss, 1967; Martin & Turner, 1986; Strauss & Corbin, 1990), the field material started being analyzed even during its generation. This was done by generating, sorting and coding the field material, whereby coding means attaching labels that could depict each fragment of material (Charmaz, 2006).

I started out with a broad and guiding interest in whether and how new ways of working would be needed with the new technology, and how the new technology would be made doable. However, while in the field, I realized quite early on that, in order to understand any changes, I would need to begin by establishing a baseline regarding how work had traditionally been done. This was both sensible and possible as the new technology had not been introduced and would not be ready for use until the end of 2017. Thus, my initial field material focused on the way work was done before any changes had been made, including existing and traditional practices, norms, values and understandings. Once I understood how work had traditionally been done, I started focusing more on how the new technology was being planned and prepared. At this point, I also realized that understanding how work had traditionally been done was not only important as regards tracing potential differences and similarities both before and after the new technology, but also as regards understanding why any differences and similarities would be present, since past actions entail future changes. The alignment and fitting together of the various aspects, e.g. material arrangements, actions, interactions and roles, emerged as an issue prevalent among the informants. Finally, my field material focused on how work was done once the new technology had been introduced and started to be used.

During the first step of analyzing the field material, I started by transcribing the first set of interviews, coding and categorizing them into relevant concepts line-by-line, by hand, on pieces of paper. There were many codes attached to the field material, which is no surprise as interviews often end up with a large amount of data and, as discussed by Martin and Turner (1986), perhaps too many concepts and themes can arise during the initial stage. I divided the field material into three temporal brackets – Neurosurgery and MRI practices prior the new technology, Planning and preparatory activities – Introducing the new technology (iMRI Hybrid OR) – and then developed lists of what distinguished these phases in terms of practices, rules, norms, values, and physical spaces. In the beginning, the second and third temporal brackets were forward-looking. To understand how neurosurgery and MRI practices were performed prior to the introduction of the new technology, I identified multiple first-order concepts that would later enable thick descriptions of what characterized these practices (see Table 3). For the practice of neurosurgery these concepts included for example: lengthy experience, sterility, doing our own thing, and technology. For the practice of MRI these concepts included for example: changes, isolated, division of duties, others visiting us. For the planning and preparatory activities these concepts included for example: selected, building something from scratch, unclear, working as a team. For the temporal bracket of introducing the new technology these concepts include for example: new relationships, us doing it together, doing duties together, in the same space, and respect for safety nurse.

Table 3. Second-order themes, descriptions of what they describe, and examples of first-order concepts.

	1st order concepts	2nd order themes & descriptions
Neurosurgery practice	Experienced, feeling safe, colleague nearby.	*"At home"* Informants had lengthy experience, felt safe both with colleagues and the surrounding physical environment and knew what was going on.
	Knowing what to do, doing it the same way, sterility, counting, discipline.	*"Order and control"* Well-established procedures and preparations, including counting and sterility requirements.
	Doing our own thing, divided, division of duties, dependent on each other.	*"Working alone together"* Healthcare professionals were working closely together in teams and dependent on each other, while also largely doing their own thing.
	Multiple tools, dependent on technology, function together.	*"Technologically-intensity & interdependence"* Multiple technological tools were absolutely necessary and needed to work together.
MRI practice	Narrow expertise, additional MRI scanners and examinations.	*"Continuously evolving".* Dynamism including increased specialization, technological advancements
	Isolated, remote, to ourselves, MRI safety, ignorance, accidents.	*"Fort Knox"* MRI is potentially dangerous due to the strong magnet. MRI safety is important and the MRI Unit is isolated.
	Division of duties, we do this and they do that, not treating patients.	*"Clearly-defined responsibilities".* Work at the MRI Unit was specialized and clearly separated between the MRI staff, progressed from being treatment-based to becoming diagnosis-based.
	Others coming to us, known to us, we are in charge.	*"Interactions with guests".* Work practices and collaborations with non-MRI staff, interactions that include a small group of staff, and largely being dictated by the MRI premises.
Planning & Preparatory activities	Regularly meetings, small group, building something, up to us, and designing.	*"Authority and privilege".* SuperUsers an exclusive group of healthcare professionals with an interest in building something from scratch, and with the right to make important decisions.
	What to do, how to do it, how is the new room designed, and how to fit together duties?	*"Uncertainty".* Lack of clarity regarding who is doing what and the timing and sequencing of duties, what the role of the safety nurse would entail, and regarding the new physical space.
	Need to plan together, all of us, getting to know each other.	*"Making it work together".* Incompatibilities between the previously-separate practices. Training proved important for exposing and reducing differences in interests and understandings.
	Over there, up there, new room, not at home.	*"Home vs away".* New relationships and ways of working, but also a physical re-location.
Using the new technology (iMRI Hybrid OR)	Teamwork, us doing it together, matching requirements, thinking for each other.	*"Doing it together".* New dependencies and relationships largely based on mutual reliance.
	Dividing duties, participating, splitting between us, not just me.	*"Shared responsibilities":* Many duties were shared among multiple professional groups (e.g. duties as regards counting and maintaining MRI safety).
	In the same space, the same room, co-presence, the hatch, MRI safety.	*"The physical space".* The new technology means changes in the material arrangements (e.g. the hatch, the MRI stickers, and locked doors), and increased proximity between the healthcare professionals.
	Respect, compliance, discipline, following rules, must be present.	*"Safety nurse compliance".* Including respect for the role and how sequences of duties were largely dictated by this role.

I continued using a similar open coding (Strauss & Corbin, 1990) approach for additional interviews, and observations, and the various documents collected and photographs taken. The large number of concepts from all this field data could be described as first-order concepts and as the "facts" of an ethnographic investigation, consisting of both the descriptive properties of the studied scene and the member interpretations of what underpins the properties (Van Maanen, 1979b). These concepts, in which I strived to faithfully adhere to the informants' terminology, were later imported into Excel together with representative quotes and extracts to produce a systematic management of the data. During the second step of analyzing the field material, I compared more intensively the first-order concepts with each other in order to search for connections. In this way, I was able to cluster first-order concepts together, into second-order themes that were closely related to the first-order concepts mentioned, but with a broader scope and a more analytical and abstract meaning underpinning them. See Table 3 for examples of first-order concepts, their connections to second-order themes, and descriptions of what the second-order themes describe.

During the third step of analyzing the field material, and with the identified second-order themes, my analytical strategy shifted toward axial coding (Strauss & Corbin, 1990), where I discovered, based on a more constant comparison of the material, relevant theoretical concepts that were useful to address in my study. During this stage, and when examining who actually did what and under what circumstances, I had realized that the ways in which the practices of neurosurgery and MRI were performed, in some ways were similar, yet in other ways were different. For example, and as will be described in more detail in the empirical chapters, they were both highly specialized practices, with experienced staff who knew clearly who was doing what. There was a clear division of labor and generally little overlap in terms of duties. However, at the same time, these were two practices that required interactions and the alignment of inputs in order to realize collective performance. Differences concerned how the neurosurgery practice was all about sterility and featured various metallic objects, while the MRI practice was all about MRI safety and was instead considered by the MRI staff themselves to be dirty. Many of these seeming incompatibilities between the two practices led the healthcare professionals to feel that alignment and integration were the main concerns regarding the new technology. Thus, I started to identify concepts based on theories of coordination as being useful to my study; especially since this literature often focuses on the integration of inputs from diverse specialists. Insights were thus provided into the dynamics of how coordination was unfolding before the new technology had been introduced and brought into use.

When analyzing the field material, I also started to realize not only the importance of social interactions, but also that of the material arrangements regarding how work was performed. This was especially evident when the new technology was being planned and organized, (as will be described in Chapter 6) as it would mean an altered physical space. Much of what was kept isolated and physically distant was now being brought together in more or less one room. The new technology thus required new ways of working, which differed in certain respects from the traditional ways of doing things. In addition to new ways of working, new artifacts were also needed, and often in different arrangements than before. New demands regarding knowledge and competencies also emerged, which meant that tasks and roles needed to be integrated in different ways. The integrating and aligning of various activities, technologies and practices were aspects often discussed by the healthcare professionals involved, as they met to plan and prepare for the new technology.

As will be described in Chapter 6, during the planning and initial use of the iMRI Hybrid OR, the particularities of the previous isolated healthcare practices, with their distinct specialisms, were raised. These interdependencies, with staff from different specialisms and disciplines, had traditionally been kept apart, but as already mentioned, they now needed to be negotiated and integrated with new technology, as well as previously-established routines and workflows. The informants thus directed me towards the understanding that making the new technology work depended on coordination between multiple groups. The coordination perspective puts a focus on the reconfigurations necessary to re-align the mentioned actions, interactions, and roles, as well as the material arrangements. From the uncertainty and changes regarding who was supposed to perform what duties and when, using the new technology, as well as how healthcare professionals were no longer able to just do their own thing, a crucial analytical step here was to identify the three integrating conditions for coordinating (accountability, predictability, and common understanding). One way to integrate the previously distinct and separated practices was by formulating formal guidelines, checklists and protocols. This was similar to what is described as formal coordinating mechanisms in the coordination literature. When introducing the new technology and when new ways of working started to emerge, the use of these predefined mechanisms was supplemented by more emergent mechanisms, e.g. ongoing negotiations and interactions, often related to jurisdictions. Here, it also became evident that work done prior the new technology had largely been defined and organized according to a well-established hierarchy and status structures. Who was doing what was largely based on a distinct division of labor, with jurisdictions being clearly defined. This led me to the literature on the sociology of professions, and the work of professionals in particular. I thus started to become more confident that the concepts identified from theories on coordination and professions were useful to my study. This iteration was further strengthened by the notion of how new tasks and roles had the potential to blur jurisdictions. In this way, I proceeded to abstract from the field material by developing an explanation of how coordination emerged following the introduction and use of the new technology.

Organizing and connecting the field material with theoretical concepts as during step 3, is also a way of moving up in the level of abstraction (Martin & Turner, 1986). While, during the first two steps and at a lower level of abstraction, I included data as it was presented to me, here I moved to higher levels of abstraction by focusing on themes that took on a more theoretical meaning (Martin & Turner, 1986). Van Maanen (1979b) described these second-order themes as "theories" an analyst uses to organize and explain the facts. Many of the initial codes identified during the first steps were thus reduced by the introduction of theoretical concepts. After an intensive and iterative analysis, back and forth between my field material and theory, I ended up with the understanding that the social setting and the physical space were important to how work had traditionally been coordinated. Changes occurred alongside the ongoing efforts of continuously stabilizing the social setting and the physical space, which implicated and facilitated coordination. Thus, when changes to the social setting and the physical space were occurring, I realized this would have profound implications for coordination. On the basis of these changes, I later theorized a new kind of coordinating which was based on a different interrelationship between, as well as degree of, the integrating conditions.

The generated field material allowed me to identify various narratives, and I recognized that these narratives could at times be seen as competing. Some of these competing narratives included, for example; how important MRI safety and sterility were, what the new technology meant, how planning and preparation ought to be done, how uncertainty was managed, what the various roles entailed, and the level of respect for the safety nurse. As suggested by Czarniawska (1997), I did not attempt to narrow these differences, instead trying to understand how they arose and the role they played. I hope to allow the story to unfold as multi-sided, and to allow the reader to make different interpretations regarding what the case concerns (Flyvbjerg, 2006). This way of refusing settlement, in the way interpretations are left open, is often used by Karl Weick. The reader is challenged to identify and figure out, together with the author, how things connect and what they might mean. Van Maanen (1995) expressed this as displaying ideas with enough coherence to make them intelligible but not dressing them up with an alluring but false sense of finality. In line with these ideas, the findings section is therefore presented in a rather descriptive way to also include some of these contradictions.

When presenting the findings, I was inspired by ethnographic writing and the use of thick descriptions (e.g. Geertz, 1973; Holliday, 2007). The intention was to put my data in a wider context in order for the reader to explore and understand the various meanings behind it. That way, I was able to showcase the richness of my data and to transport the reader into my informants' experiences. Thus, while I have decided to present the findings in a rather descriptive way, to faithfully adhere to the informants' experiences and interpretations, I addressed the pending "So what?" question by including summary sections after each empirical chapter (see Berends & Deken, 2019). In these summaries, I retell part of the empirical story, or its patterns, in more theoretical terms to foreshadow the theoretical concepts that will later on be introduced in the discussion section. Thus, the discussion section is written to reflect a more intensified iteration between field material and theory, in order to increase the level of abstraction.

3.5 Ethical Considerations

Throughout this chapter, I have mentioned various ethical considerations relevant to this study, and how I dealt with them. Here, I will expand on the discussion on ethical considerations. As already mentioned, this study was approved by the Regional Ethics Committee (www.epn.se), and informed consent was obtained from the informants.

In the application for an ethical review, and throughout the study, I have been required to relate to a number of specific ethical considerations. In the application, and during my field study, I clarified that, although patients could potentially be present when I was generating data, they were never my focus, which was rather the healthcare professionals and how they work. I also had to describe the research project, the generation and nature of the data, and how the data was to be documented. This meant, among other things, that I had to give written and verbal information to all the potential informants prior to their participation, and to inform them that participation was entirely voluntary. A direct consequence of this was the fact that, despite how my research project had been presented, and guaranteed access by the relevant managers who approved which studies could be conducted, access still had to be continuously negotiated. Healthcare professionals are extremely busy and I had the utmost respect for their work, so I always tried as far as possible to adapt to their schedules as regards the timing of interviews and observations. This sometimes meant changing both days and times, but I was never prevented from conducting either interviews or observations, and my informants were generally willing to share their thoughts and experiences. Recording interviews was only allowed after each participant had approved this, and I guaranteed these participants that I was the only one transcribing the interviews. Moreover, a direct consequence of the ethical review was that my institution had to buy a new safe that was fire-proof, in which I kept the consent forms and transcribed interviews. Also, I had to guarantee the participants' right to integrity, which led to my decision to unidentify the informants by not using their real names, instead using either fictive names or their professional roles, and by not numbering the various informants in the empirical chapters. As a consequence, I was also unable to state specific dates when interviews or observations had been conducted. In one way, the ethical considerations meant I had to compromise with regard to contextualization (Saunders et al., 2015), but I still tried to provide enough detail regarding the research context etc, in order not to entirely decontextualize the empirical story.

CHAPTER 4

PERFORMING WORK AT THE NEUROSURGERY DEPARTMENT

In this chapter, the organization and experience of working at the neurosurgery department will be described, focusing on what characterizes the practice of neurosurgery. Neurosurgery is a practice that includes healthcare professionals belonging to different professions and disciplines, and therefore hinges on multidisciplinary work.

4.1 Introducing the Neurosurgery Department

At the neurosurgery department, teams of doctors (surgeons, specialists in anesthesia and intensive care), registered nurses (general nurses, and specialist nurses in anesthesia and surgery), and assistant nurses work together to perform surgical procedures on the brain and spinal cord with the purpose of treating tumors, bleeding, or vascular malformations and epilepsy. In addition, the department also receives patients requiring acute hand and eye surgery.

Even if neurosurgery is one of the surgical specialties, it is still clear that neurosurgical procedures constitute an integrated part whereby many specialties and healthcare disciplines take part in clinical neuroscience collaborations. This group of healthcare professionals thus consists of members belonging to different professions and disciplines and possessing different knowledge, experience and training. In what follows, I give a brief description of what characterizes these disciplines and their respective roles in general, but mainly in terms of neurosurgical procedures[5].

Surgeons and *specialist doctors* first have to graduate from medical school (five and a half years), which gives them broad competencies in relation to preventing, treating and alleviating disease and illness. In addition, they also do a minimum of 18 months of general training, with specialist training continuing for another five years. There are

[5] This is by no means an exhaustive description of what healthcare professionals within these disciplines do or what their roles consist of, which often differs depending on both context and procedure.

approximately 45 different specialist areas, e.g. surgery, psychiatry, internal medicine, children and adolescent medicine that doctors can specialize in (e.g. Swedish Government Report 2017:21).

During brain surgery, neurosurgeons are the ones who resect the actual tumor. They are also involved, however, in positioning the patient on the operating table, and putting him/her in a head fixation device. Before the tumor can be resected, the surgeon first opens up the patient's head so as to turn the bone flap (a specific part of the skull that is removed in order to access the brain underneath), then opening the dura (a protective covering of the brain) and finally starting to resect the tumor. Surgeons are also responsible for the closure of the patient; in effect suturing the incisions. One of the anesthesiologists' roles is to sedate and reawaken the patient undergoing surgery. Before initiating sedation, they first need to decide on the best way to sedate the patient (based on, for example, the patient's history and the surgical procedure to be performed). Since anesthesiologists are responsible for multiple patients undergoing surgery at the same time, they often leave the operating room after the patient has been sedated. They are then on-call and within close distance of the operating room, in case something unexpected happens or if the monitoring anesthesia nurse needs assistance.

All *registered nurses* graduate from nursing school (three years), providing them with broad competencies in healthcare and authorizing them to work as registered nurses. Patient care is the registered nurse's specific competence, and is often described in relation to six core competencies, person-centric care, interacting within teams, evidence-based care, improvement knowledge and quality development, safe care and informatics, and leadership and educational efforts in nursing work (Swenurse, 2017). Specialist nurses also have to do the one year specialist program, which focuses on one of the eleven specific competence areas (e.g. anesthesia, surgery, psychiatric care, and so on). Surgical nurses are most often specialized in perioperative care, and are responsible for patient care before, during and after the surgical procedure or examination.

During surgery, they engage in specific tasks, e.g. assisting procedures, verifying and preparing material and instruments, and handling tissue samples. They also have extensive training in sterility and aseptic techniques, and are thus responsible for these aspects in the operating room. Anesthesia nurses are specialized in anaesthesiological care, requiring extensive knowledge of both nursing science and medicine. They engage in the administration of anesthesia, independently inducing, maintaining and concluding general anesthesia with some support from anesthesiologists. The usual location is during surgery, where they engage in tasks such as preparing medicine, administering precise dosages, and controlling and monitoring the patient. Together with the surgical nurse they also help with positioning of the patient.

Assistant nurse is one of the most common occupations in Sweden (Statistics Sweden, 2018), and has been subject to much debate, e.g. whether or not it should be a protected title (Swedish Government Report 2017:21). Today, it is not a protected title and thus not a certified occupation; consequently, the training that is needed has not been determined exactly. Instead, it has very much been up to the employer to decide what qualifications and experiences are needed. A common educational background here, however, is a three-year high school diploma in health and social care, and there are also various specialist and additional courses for assistant nurses, e.g. anesthesia, surgery and acute care (see Swedish Government Report 2017:21).

Assistant nurses in surgery are 'unsterile', aiding the surgeon and the surgical nurse during operations. They also help the surgical nurse to make the table and prepare the operating room. This includes assembling and monitoring many of the tools to be used during surgery. Assistant nurses in anesthesia work closely with anesthesia nurses and anesthesiologists. During surgical procedures, they engage in preparing equipment, medicine, and also in connecting the patient up to ECG and blood pressure monitoring equipment.

4.2 Preparations Before a Surgical Procedure Begins

What struck me over time, as I was observing surgical procedures and interviewing healthcare professionals, was how much preparation is needed before an actual procedure can begin. Thus, before neurosurgery can start, as with many other operations, there are various, and sometimes lengthy, preparations that need to be done by and synchronized among the various healthcare professionals involved. These preparatory activities seemed even more important and prevalent in neurosurgery than in other surgical disciplines. As two surgical nurses explained:

> What I know is that we generally have very long procedures here. We have lengthy preparations, where it takes a long time to make the table, position the patient and so on. If you compare us to other places.

> Doing surgery on a brain tumor can differ substantially depending on what type of tumor it is and where it's located. So, I think that is why we have much lengthier preparations, and why it never gets like an assembly line in that sense. And some people may experience that as slow.

Experiencing neurosurgery as slow was something residents from other specialties mentioned. They often related how they could perform three, or even more, operations on the same day, with complex neurosurgical procedures that allowed one or perhaps two operations on the same day. The nature of neurosurgery, with tumors being located differently from patient to patient, however, meant that every patient was different. The informants thus said that neurosurgery could not get like an industrial assembly line, with this also serving as an explanation as to why neurosurgery involved both lengthy preparations and lengthy operations.

These lengthy preparations occurred at different points in time, and were evident even before the patient arrived at the surgical department. One anesthesia nurse explained these initial preparations as follows:

> We firstly put everything in order, and prepare for the patient's arrival. With medicine and prepare the equipment and make sure we have everything we need to hand.

When preparing for the patient's arrival, the anesthesia staff were mainly in a room close to the operating room. This was a room in which all their medicine was stored, as well as the tools needed for their preparations. While anesthesia staff were preparing their medicine and equipment, the surgical staff were in the operating room making the table and performing other preparations. As one surgical nurse explained:

> We have a certain time that we need for our preparations. Gathering the things together and then making the table. And during that time, the anesthesia staff usually prepare their medicines and so on. It usually doesn't take them so long, so they often have time to meet the patient and then come back to prepare their medicines and then sedate the patient.

Furthermore, before the patient is sedated, there are additional preparatory activities that need to be performed. One surgical nurse commented on how some of these occur at a point of time upon meeting the patient:

> Many of my colleagues and I usually try to meet the patients when they arrive in the mornings. Or when they arrive, because we have certain things we want to know about them. For example, we ask if they have any allergies or are sensitive to certain things. We want to know if they have any implants. We're mainly concerned here with implants made of metal, because then it might be problematic if we want to use electrical cutting equipment. And then all patients have washed themselves with this descutan soap or descutan wash sponge which also contains this chlorhexidine stuff which makes the skin cells on the body decrease. So we ask the patient about that as well.

The following situation further illustrates some of these and other preparatory activities that are performed before the patient arrives at the surgical department, and before he/she is sedated. I quote from my field notes at length here because this situation illustrates, not only which preparations are coordinated, but also how:

> Karin, a surgical nurse, and Linda, an assistant nurse, had been working since 06:30, and were almost finished with their preparations in the operating room. They had prepared the room in accordance with the surgery notification letter hanging outside the doors leading into the room. This was a handwritten note from the surgeon, from last night. The note just contained the patient's diagnosis. After having worked at the department for over ten and thirty years, respectively, Karin and Linda were experienced, and knew just by reading the diagnosis how they would prepare the operating room. They even referred to the department as their 'home' and they knew where to find what they needed. This was not, however, the case for inexperienced nurses who had to look through various catalogs in order to figure out which devices were needed and how to prepare the operating room for the specific type of surgery at hand.

Preparations involved turning on computers, connecting up various machines, e.g. navigation systems, and controlling them. The correct grids and a drilling tray, for making holes in the skull bone, were gathered together. All disposable materials were written down and, when they felt satisfied with their preparations, they got dressed and the surgical nurse washed herself to become sterile. At this time, they were ready to start making the table and setting up the sterile field. This included picking up all the sterile instruments and materials needed for the specific surgical procedure and placing them, in order, on the instrument table. After all the instruments and materials had been counted, written down and placed in order, the table was then covered with green sterile drapes. Technology, like the surgical microscope, was also covered with sterile drapes. The process of making the table and setting up the sterile field took approximately 30 minutes (but can take up to 50 minutes depending on the surgical procedure at hand).

While Karin and Linda were finishing off the making of the table, and then grabbing a chance to have breakfast, Beatrice, an anesthesia nurse, and Arne, an anesthesiologist, were preparing their medicines and devices and placing them in order in a room close to the operating room. Arne had prescribed which medicine they were going to sedate the patient with, but they prepared that medicine together. Beatrice also prepared the intubation trolley, with its various tools and devices that might be needed. The process of intubation consists of inserting a tube (endotracheal tube) into the patient's mouth and then down into his/her airway. This is done so the patient can be connected to a ventilator and provided with assisted breathing. Even though intubation is a standard procedure, often done by doctors or nurses in anesthesiology, it can still be difficult or critical, especially if the patient has difficult airways. When they were done preparing the medicine, and the other instruments, they were ready to enter the operating room. First, however, they needed clearance from the surgical staff that they had finished their preparations of the room. This was very important as success in making of the table and setting up the sterile field required the surgical and assistant nurses to be alone in the room. Restricting movements in the operating room, during these preparations, reduced the risk of contaminating the sterile field. Following routinized ways of preparing, the surgical staff were fast at finishing their preparations, and they had also informed the anesthesia staff of their approximate finishing time. This information could easily be disseminated due to the shared location, which allowed surgical and anesthesia staff to keep track of what the others were doing. One way of doing this was sending and receiving information through the hatch in the operating room door, enabling communication without the risk of contamination that the opening of doors is associated with. On receiving clearance from the surgical staff, Beatrice and Arne entered the operating room. They now started positioning the operating table and re-positioning the anesthesia equipment and tables (intubation and medicine tables) accordingly.

A while later, Beatrice and Arne said hello to the patient as he was being pushed in his hospital bed along the corridor at the neurosurgery department. These healthcare professionals quickly noticed and attended to the patient upon entering the operating room. The surgical nurse entered the operating room and joined in as the patient was being asked some questions. These questions involved, for example, how many times he had washed himself with the descutan wash sponge (disinfection soap), whether or not he had any allergies, and so on. Satisfied with the answers, the anesthesia staff then started inducing their medicine, in doing so initiating the sedation phase. Meanwhile, the surgical staff were waiting to start on their final preparations, followed by the actual surgery.

In addition to how the situation above illustrates various preparatory activities, performed before the patient arrived at the department and was then sedated, it also indicates how healthcare professionals from different disciplines (surgery and anesthesia) interact during these activities. At times in the operating room, they prepare together, while at other times, they are alone in that room preparing activities specific to their disciplines. Anesthesia and surgical staff also take turns waiting for each other, in order to continue with their preparations, something which in turn requires ongoing coordination efforts in time and space. This was accomplished by relying on established sequences of activities to be performed. It was, for example, always the surgical nurses who started preparations in the operating room. Despite the anesthesia staff being able to prepare medicines in a room close by, it was not until the surgical preparations had been finished that the anesthesia staff were able to start their operating room preparations. By following these sequences, the staff could observe the progress made on the overall preparation tasks.

Preparatory activities do not stop once the patient has been sedated, instead continuing. For example, the anesthesia staff continue preparing the patient for surgery:

> We have quite a lot to do before surgery starts. We administer antibiotics and so on. We set coarse needles if we think the patient may going to bleed, we connect up the medicine that's required to keep the patient pain-free and sedated. We check the respirator, and the anesthesia drugs, the heating, and whether the patient is lying in a comfortable way. We sometimes also turn the patients around so they're lying on their stomachs (anesthesia nurse).

As can be seen, there are many preparations that the anesthesia staff need to perform before surgery can start; these include using both equipment and their own and other bodies. Many of these activities also need to be performed and be completed before the surgical staff can continue with their preparations:

> Sometimes, when we have very advanced procedures, it may take a very long time for anesthesia to prepare the patient before the surgical staff can do their part. This has to do with needing many different kinds of equipment, such as the monitoring machine, and also the different

> catheters need to be in place, urinary catheters, infusion lines, that we have to put in place. So, the start-up time for anesthesia can vary to a large extent, from just 10 minutes to up to two hours (anesthesiologist).

Thus, taking between ten minutes and two hours, the surgical staff patiently need to wait and to time their additional preparations. These divided activities thus need alignment in both time (following sequential preparations) and space (sharing and negotiating space in the operating room). This was not, however, experienced as an uncertainty as they were often able to predict, from experience, when they could continue. Responding to each other's contributions and aligning tasks was thus seldom problematic or uncertain for the staff. The integration of tasks was facilitated by their lengthy experience of neurosurgery and how they had also worked with each other before, leading to an established way of preparing and working.

Moving on, the assistant nurse helps the anesthesia staff to put a catheter in the patient, before the patient's head is shaven just where the surgeons are planning to cut him open. The patient is then washed with a specific descutan wash sponge, which he should also have done himself multiple times before arriving at the hospital. Additional preparations are explained by one surgical nurse thus:

> We put a crown (a head fixation device) on the patient, where you secure and then screw or insert clamps right into the skull bone, and then fasten it when the patient has been sedated. When we're done with that, we usually take time out, according to the WHO [World Health Organization] checklist, when we check that everyone knows each other in the operating room, that we have the right patient, that the patient has a side mark, and that the patient is positioned correctly. We also check that we have the MRI images, that the patient has been given antibiotics, and thrombosis prophylaxis to prevent the occurrence of blood clots. They're often given an injection the night before. Whether there's a need for any specific technology, that wasn't thought of before. Whether there's a risk of bleeding and so on. We go through a few aspects that are on a checklist.

The timeout mentioned in the quote is a preparatory activity done before the incision is made. It is most often initiated by the surgeon, and sometimes also by the anesthesia nurse. It is a standard procedure, and all staff in the operating room engage in this checklist; however, it is mainly the surgeon and the anesthesia nurse who talk and interact.

Following this, and as indicated in earlier quotes, these preparatory activities are not often done in isolation, instead needing to be synchronized among and between the various healthcare professionals involved. For example, and as shown, some of the anesthesia-related preparations need to be done before surgery can continue, which indicates the need for timing during the preparations relevant to the discipline. In addition, there was also a need for joint preparations before surgery could start, "Before a surgical procedure, we need to do a check, making sure it is the right patient, the right side, and that everyone knows each other on the team" (Neurosurgeon). Checking and making sure that everyone knows each other, at least in terms of name and role, were preparatory activities that all healthcare professionals, regardless of their discipline, engaged in. Having healthcare professionals jointly engage enables them to familiarize themselves with the elements and the timing of both their own and others' execution of tasks, with a preferred and agreed upon way of preparing and working being in evidence. These significant preparatory activities would also come to shape the coordination of subsequent collaborative work, something that characterized much of the practice of neurosurgery.

4.3 Working Together

Many of the informants described how performing neurosurgery meant working closely in multidisciplinary teams. This close team-work collaboration, present in the operating room, also seemed enjoyable to many of the informants. As one surgical nurse commented:

> One of the biggest reasons for choosing this job, which I may have realized in retrospect or when I started on the training, is teamwork. It's very satisfying and amusing to work in teams the way we do. There are four or five of us in the operating rooms in general, who work very closely with each other. And I also appreciate, or find it interesting, to reflect on why certain things work and certain things don't in teams and so on. We're very dependent on being able to work well together. With good team communications and so on. So our close teamwork is one of the advantages, or one of the most fun things about being a surgical nurse.

Similarly, one anesthesiologist said how neurosurgery involved both performing your own tasks and working in a team, centred on the patient:

> Our duties aren't only about administering anesthesia, they're also about communicating, and working together with anesthesia nurses who work with the anesthesia side. Then you also have the surgical side, with many different professions, like surgical nurses and assistant nurses, and then the operator comes, and sometimes also an assistant operator. This means we're a team, a team working around the patient.

These two quotes further illustrate how the staff involved are dependent on each other, and the importance of working well together in order to make the teamwork flow. As one surgical nurse put it; "The relationship between those of us in the operating room is extremely important." One surgeon also mentioned the importance of the relationships between the staff in the operating room:

> Knowing each other and knowing about each other are very important. It's easier to get a flow going with people you know already. It's also about matching personalities.

In this way, familiarity was not just about having knowledge of other people's task-related expertise, but also about the people per se. Working in teams and knowing each other was not just about getting a flow going, it also meant that neurosurgery operations could not be performed independently of each other, or if someone was absent, indicating that all the independent roles contribute toward coherent performance. By stressing the importance of her own role, one surgical nurse also points to how all roles, regardless of professional title, are valuable:

> We are, in fact, a team, and they can't do anything without me, nobody can do anything without someone else. If I bring a doctor into a dark operating room in the morning, he won't be able to start operating because he won't know where to look, or where to turn on the lights. It's that level that we're on. I think it's about mutual understanding and having respect for each other.

An individualized approach to neurosurgery, thus, is insufficient when it comes to treating patients efficiently and smoothly. Role substitution, by means of determining who has the expertise needed to replace missing actors, is thus impossible. This has to do with how the knowledge needed to perform neurosurgery is situated within multi-disciplinary domains. As one surgeon noted:

> I see it very much as teamwork, that we're in some way solving a problem. We have a problem, a tumor in the brain, and we have to resect it as smoothly as possible. To accomplish this, the patient needs to sleep and be positioned in the best possible way. We also need to do a sterile wash to maintain sterility, and we need to have all the things to allow it to flow. This is needed to make it as smooth as possible.

Thus, performing neurosurgery can be seen as resolving a key problem, i.e. curing the patient by removing a tumor in his/her head. Removing the actual tumor is always done by the surgeon as he/she possesses the specialized knowledge required. However, doing this in a satisfactory way requires them to work together. For example, the patient needs to be positioned on the operating table, and anesthetized in a way that ensures comfort and dignity. Performing this work and knowing how to, are mainly the responsibility of the anesthesia staff, in collaboration with the surgical nurses, and of the surgeons who help to position the patient. Another example concerns sterility (which is elaborated on further later on in this chapter), which is a responsibility shared by all the operating room staff in order to prevent patient infections. Although this is a shared responsibility, most of it rests with the surgical nurses who, for example, wash themselves and the patient to achieve sterility and who check the level of sterility during surgery.

Different domains of knowledge and expertise thus become evident in the operating room and, as shown, the informants often express the importance of having these present. Staff recognized that achieving complete understanding of each other's work tasks was neither possible nor desirable. This would have taken too much time and attention from the main purposes. Interestingly, at many times during my observations, the tasks being done in the operating room also seemed quite separate, in terms of having staff from different disciplines performing their work in isolation. The surgical staff, e.g. the surgeon, surgical nurses, and assistant nurses, worked very closely with each other. In simple terms, the surgeon was assisted by the surgical nurse, who in turn was assisted by the assistant nurse. They seemed to form a smaller group within the larger team, working very much around the patient's head; however, the assistant nurse moved around in the entire operating room. The anesthesia staff, however, most often worked within and around their workstations, located close to the foot-end of the patient. This workstation was even sheltered from the operating staff by the anesthesia arc/frame, upon which a sterile drape is attached, so as to protect the anesthesia staff from moving into the sterile area.

Although many of the tasks done in the operating room seemed quite separate, in terms of staff from different disciplines performing their work in isolation, there was still a need to integrate these separate activities. Work is thus being done both independently and together at the same time. As one anesthesia nurse commented:

> It's fun to collaborate with surgery, surgeons and anesthesiologists. You work quite independently in many ways, but you also need to collaborate at the same time, in order for everyone to be satisfied, the patient, the surgeon and the surgical nurses.

One example of this integration concerns how staff from different disciplines collaborated to perform certain activities, e.g. the already-mentioned and important tasks of maintaining sterility and positioning the patient. The surgical and anesthesia nurses often helped each other when positioning the patient. For example, the anesthesia nurse's main concern is securing the oxygen tube, which is keeping the patient alive, while the surgical nurse's main concern is positioning the patient in a way that suits both the surgeon and the specific surgery being performed. This was seldom problematic as positioning was expressed as belonging to both groups of nurses' jurisdictions, and they thus acknowledged each other as having the relevant understandings. The staff had also routinized how to position the patient, from lengthy experience of working together and using similar surgical procedures. They had learned how to position the patient in a way that met the considerations of both the surgery and the anesthesia staff, thus developing a form of shared understanding.

Another example was how the separated or isolated activities needed to be synchronized, in terms of both time and space. The following account given by an anesthesiologist, when speaking of how access to the head is negotiated, is representative of this:

> Because, sometimes, we negotiate access to the same part of the patient. It's that way here at neurosurgery, where we operate on the head, so we need to agree. We can't just say, okay now it's our turn. At the start, it's our turn with the head you can say, but then we have to let it go, and then the surgery staff start working with their stuff on the head, and we need to get finished. We can't go back to the head because it will be totally covered with drapes.

Synchronizing activities like this meant that integrating and coordinating the inter-disciplinary domains of knowledge and expertise required that the healthcare professionals continuously communicate what they are doing with each other, and jointly agree so that everyone is satisfied. One anesthesiologist commented that his/her work is not only about sedating patients, but that it also entails interacting with others:

> The anesthesiologist not only needs to know how to sedate the patient, he/she also needs to know how to collaborate and communicate within the team. It's a challenge every time, doing what we're supposed to do, while at the same time communicating whatever needs to be communicated to the others.

During one observation, one anesthesia nurse elaborated on this by explaining that it is very important, as regards the notion of working together, that there is good communication with the surgical staff, especially since what they do affects the status of the patient. This nurse commented; "What hurts will increase the patient's heartrate and blood pressure for example" (field notes). Communicating thus works as a way to integrate the interdependencies between the staff of the operating room, in doing so creating some form of shared understanding. This also works the other way round, what anesthesia staff do affects the work of the surgeons, and thus requires communication:

> If there's a lot of pressure on the brain, and if there are skull injuries, or if there's some bleeding on the brain, then you'll have to think a little bit differently… There are some things, the carbon dioxide level in the body is lower, during neurosurgery, and then you have a more ventilated patient. We blow out more carbon dioxide on a neurosurgery patient, and that's because lower levels in the body mean less of a flow up to the brain. And then the brain becomes less swollen, and it'll be easier for them to perform the surgery. Also, there'll be less pressure on the brain, so we control that a bit. Otherwise, it depends on how things look (anesthesia nurse).

Thus, depending on how much the anesthesia staff ventilate the patient, the swelling of the brain increases or decreases. The surgeons preferred a highly-ventilated patient as a less swollen or more relaxed brain would make their work easier. Optimizing brain relaxation, to improve the conditions in which the surgeon was operating, was not as easy, however, as simply ventilating the patient to the maximum. Despite being a valuable and effective tool, hyperventilation also entailed a risk to the patient due to reducing the cerebral blood flow, something which concerned the anesthesia staff. Thus, this required ongoing communication between the surgeons and the anesthesia staff, in a way that monitored the beneficial and adverse effects.

For the most part, the operating room staff seemed satisfied with how communication between them played out. There are, however, times when this is not the case, as one anesthesia nurse explained during a surgical procedure:

> The surgeons don't always communicate what they're doing, and this is especially so with new teams, or if someone is new on the team. It can

> thus be difficult for the anesthesia nurse to follow both where they are in the surgical procedure and what is hurting the patient (field notes).

Communication between the operating room staff, and across the disciplines, can thus be related back to the previously-mentioned importance of having relationships. As a result of being less knowledgeable about each other, and not knowing the elements of the surgical procedures, as well as when these happened, new teams, or teams with partially new members, seemed to face more difficulties maintaining satisfactory communication, thus also indicating less integrated interdependencies. Communicating and recognizing the stages of surgery were thus very important as regards coordinating the practice of neurosurgery. To sum up, the teamwork seemed to be characterized, on the one hand, by separation and isolation, while on the other, by a dependence on a shared understanding and smooth communication. This isolated dependency is further illustrated in how sterility was maintained.

4.4 Maintaining Sterility

The informants often explained how operating room infections, for all the surgical disciplines, entailed serious negative consequences, including economic and environmental costs, and patient suffering. Postoperative infections, after neurosurgical procedures, were described as even more serious as these are often associated with a high rate of morbidity and life-threatening consequences. One neurosurgeon explained the consequences of an infection, for neurosurgery, as follows:

> For our part, you remove a brain tumor, make a hole in the scalp, and the skeletal hatch is put next to the patient while you're trying to find and resect the tumor. Then you put it back and sew up. However, if you get an infection, you'll often need to open up the scalp again, and then the patient may live with a gap, maybe sunken, and may look cosmetically bad for six months. And then there will be a new operation because then you'll do a new reconstruction. So it'll be a half year of suffering for the patient, plus you'll have two extra operations then. One when you take out and one when you replace. So an infection will have very major consequences. So, you want to do everything to avoid it. And do you count what the cost of an infection would then be with the number of extra days of care and you might order, if you have a complicated piece of skull that's taken out, then you can send it to have it custom made, and that could cost twenty, thirty, forty thousand. Just the artificial part. And then you have a number of days of care, and two extra ones.

Keeping the operating room sterile and clean in a way that prevents infections in the patient was thus very important, and was achieved by following rigorous routines and by ongoing efforts. This 'aseptic and sterile technique' was often mentioned as the responsibility of all members of the surgery team. Many of the activities performed during surgery and around it are thus grounded in sterility thinking. One surgical nurse even argued that; "Sterility is everything, it's extremely important". Another assistant nurse concurred similarly about the importance of sterility; "I think sterility is the most important thing". Despite the shared responsibility expressed, it was the surgical nurses who bore the main responsibility, and who recognized and corrected breaches in sterility, both when preparing for and during surgery. Many of the surgical nurses I interviewed and observed explained how they were the ones responsible for sterility, and that they possessed extensive and specific knowledge in this regard:

> Yes, they could contaminate. And then it's my responsibility to counteract that. And to look after it, and of course to prevent it from happening. But if something happens, I'll need to say it. That's my responsibility (surgical nurse).
>
> It is, of course, that which is my main responsibility, and I have much more knowledge than anyone else in the operating room, really. I'm expected to have more knowledge than everyone else in the room, including the surgeon, because they don't have as extensive training in that as we do. They don't focus on what we do. So that's my main responsibility (surgical nurse).

Maintaining sterility was evident before, during and after surgery. For example, surgical nurses worked together with the Central Sterile Department (CSD), where the large autoclave chambers are located. These autoclaves sterilize medical instruments by heating them to high temperatures (above boiling point). This work entails both receiving sterile instruments from the CSD and sending unsterile ones back to the CSD. As one assistant nurse explained:

> We prepare trays of instruments and other stuff that's supposed to be taken in, sterile clothing and all. You go to the packaging area, where the clean instruments are, and which will be re-packaged according to grid drawings and other things. Then we also send the stuff into the autoclaves and back to the sterile center again, where we can take it back for the next surgical procedure.

However, before the instruments are sent to the CSD, the nurses wash them in the dishwashers, located in their own department:

> We take the dish and put it in the dishwasher, and when it is cleaned then it comes out to the packaging area. And when it's been cleaned, it's packed and then sent to the autoclaves for sterilizing (assistant nurse).

In addition to explaining how the nurses engaged in maintaining sterility, the nurse in the quote above also indicates that there is a difference between clean and sterile. Clean means it has been washed in the dishwasher in the department, while sterile means it has also been sterilized in the autoclaves at the CSD. This distinction was not always understood by others, since nurses and doctors sometimes thought clean instruments were also sterile and that they could then be used during sterile procedures. These examples also illustrate, thus, how bacteria and germs are invisible, and how maintaining sterility requires ongoing efforts.

Collaborating with the CSD seemed quite unproblematic. The crucial point, when receiving sterile instruments, is getting the right instruments, at the right amount, and in time. Nurses also need to make sure that instruments already received remain sterile. One assistant nurse explained how they controlled the sterility of the instruments despite their coming directly from the CSD:

> When preparing for an operation, and when establishing the sterile field, there are these boxes, and even if they contain sterile instruments, we do check the paper we use to package the instruments before they're sterilized in the autoclaves. We check these papers when we unpack the instruments in a way which ensures the date is correct and that they're still sterile, and which also makes sure the instruments aren't broken

After ensuring the sterility of the instruments, and before surgery begins, thinking and acting in terms of sterility was also visible when the surgical nurses were washing themselves and the patient for sterility, and making the table by covering surfaces like instrument tables with sterile drapes. Two surgical nurses elaborated on this:

> I wash the patient for sterility with a special chlorhexidine alcohol, as it's called. Then we put sterile drapes, we put sterile tissues and so on over the patient (surgical nurse).

> I need to wash. First, the assistant nurse will wash everything using HiBiScrub [antiseptic agent]. This is a special descutan soap [antibacterial agent]. She'll wash twice, for 30 seconds, in the target area. Then I'll wash with alcohol and put on a surgery drape and a tape, and then it's considered sterile (surgical nurse).

As the quotes above show, it is mainly the surgical nurses who perform the various activities related to sterility. As this formed part of their expert knowledge, it was seldom called into question who should engage in these activities. There were, however, occasions when other healthcare professionals experienced the benefit of taking part in sterility activities. One such occasion was during a surgical procedure when surgeons expressed the benefit of taking part in a specific sterility activity, namely sterility draping the patient, especially the wound. This is illustrated by the following conversation between two surgeons in the operating room:

> S1: I know that in other countries surgeons are engaged in sterility draping the patient before surgery, but not here in Sweden.

> S2: Yes I know, but I'd like to get involved in that because sometimes it isn't done the way I want it to be, and the area I've marked out also gets draped and so on.

This conversation could indicate that the surgeons' concern for sterility would make them want to become involved in additional sterility activities, which traditionally fall under the nurses' jurisdiction. This seems, however, to be more about engaging in sterility activities to make sure that their own main purpose, i.e. dissecting the tumor, is not made more difficult.

Regardless of the reason, having surgeons engage in sterility draping the wound was not generally welcomed by the surgical nurses without sterility considerations. Sterility was not a part of the surgeons' knowledge and expertise as they did not have as extensive training in that as the nurses did. Suddenly, having surgeons present while nurses were sterility draping the wound would thus mean an increased risk of contamination. This increased risk was present, even though the shared body of tacit expertise, in the way that the importance of sterility is well-known among the various healthcare professionals involved in surgical procedures, because it is also something that is continuously being maintained and coordinated. For example, surgical nurses "sometimes need to keep close tabs on the surgeons in case they don't know what they're doing" (surgical nurse). These sterility breaches may also occur when students, and other staff not trained in sterility, come to observe surgical procedures. As one surgical nurse explained:

> I think sterility is the most important thing. Everyone in the room has to respect it. Sometimes, there are clashes. We have, for example many students and other staff who want to come and have a look. They're in training and not used to moving around in a sterile room. Then there is the risk that they stand and lean against my table or walk or run into the microscope. There are different aspects like this, but the assistant nurses are really good at this as well. We help each other to keep it as sterile as possible.

The risk of sterility breaches due to having people who are inexperienced in sterility moving around in the operating room was also something I noticed during one of my observations in the operating room. In the present case, there were two medical students observing the same surgical procedure I was observing. As one of them moved closer to the surgeons (to see how they were dissolving the brain tumor), he was just about to walk into the sterile microscope. The surgical nurse, however, spoke up quite loudly and harshly and told the student to back away. As the student remained silent, it seemed as if he did not understand what he had done wrong. The nurse then explicitly told him that the microscope was sterile and should not come into contact with anyone except the surgeon and the surgical nurse. It seemed like the student was unaware that it was not just the area around the wound that was considered sterile, but also the equipment positioned further away from the surgical area.

It was not only students who posed sterility risks, but also the healthcare professionals themselves. For the most part, sterility was something that staff from all disciplines working in the operating room seemed to think about, and act in accordance with. However, the surgical nurses indicated that non-surgical disciplines seemed more prone to breaching sterility. One such example is illustrated by the following quote, given by a surgical nurse:

> Just the other day, I was washing a patient's throat before doing a tracheostomy, where you put a tube straight down the trachea, through an incision in the throat. This is done on patients who may need respiratory treatment for a long period of time, and for other reasons as well, but it was for that reason in this case. The anesthetist wanted to do something at the same time with the tube inserted into the throat. So, the anesthetist was about to do something with the tube that was in the patient's mouth, while I was washing the patient's throat for sterility, and there's a very short distance in between. And then he was a bit careless, he was moving his hands within the area I'd just washed. Then I needed to point that out; you've just contaminated my sterile area so now I have to do it all over again. And that's something you need to say at times like these, and that's what happens.

As with the surgical nurse in the quote above, many other informants were also easily able to recall situations where sterility had been threatened. Thus, even if they had commented, on the one hand, that the staff in the operating room most often understood the importance of sterility, had been acting in accordance with it, and were thus sharing a body of tacit expertise, they were also, on the other, indicating that sterility was something to be continuously maintained by means of ongoing efforts. These efforts do not form part of any formal mechanisms, e.g. written protocols or rules, rather they form part of the emergent coordination processes, e.g. interactions and negotiations, which ensure that surgical procedures are error-free, or that appropriate action has to be taken when errors do occur. In the case of sterility, it was the surgical nurses who had a broader and deeper knowledge base regarding sterility and who thus needed to remind others of their expertise; however, seldom had to justify their opinions as the importance of sterility was a common understanding.

Two interesting ways regarding how maintaining sterility during surgical procedures was undertaken involved how material objects were used during collaborative efforts. The first way was by using a small hatch (see Figure 5) in one of the operating room doors, instead of using and opening the entire operating room doors themselves. This was expected to have minor effects on particle concentrations in the room, compared to opening the entire doors, thus decreasing the risk of patient infections.

Figure 5. Hatch in the operating room door.

During my observations in the operating room, I was able to notice the use of the hatch on all occasions. It was used by both surgical and anesthesia staff to exchange information, receive tools and instruments, and to deliver blood samples and tissues. When asked about the hatch and why they used it, many of the informants mentioned patient-care quality, referring to studies showing the correlation between opening the doors and the effects on particle concentrations in the operating room. Using the hatch instead of opening the doors was a generally accepted way of maintaining sterility at the department. A second way regarding how material objects were used in maintaining sterility was the use of the anesthesia arc/frame. A sterile drape was put on this steel arrangement, in doing so isolating the anesthesia staff from the sterile surgeon and surgical nurse. As the object of this was to stop the anesthesia staff from getting into the sterile area, it thus worked as a referent object around which the surgical and anesthesia staff aligned their work. This further facilitated a shared meaning concerning sterility.

To sum up, the ongoing sterility efforts described in this section consisted of paying meticulous attention to small details. Constant controlling and monitoring was evident, and was something I illustrate below as also being manifested in the activities of counting and writing down.

4.5 Counting and Writing Down

One of the most important aspects for the surgical staff is performing a constant counting and writing down of the material, instruments and so on. This was, for the surgical staff, an absolute necessity as it ensured nothing was left inside the patient's head (or other body parts), thus preventing the risk of patient infections and other serious complications. Maintaining patient safety was done both by documenting all materials and instruments used, and by control counting against what was unused just before closing the patient. As one surgical nurse explained, "Before the surgeon closes the dura, we need to count everything so as to ensure that all the patties, strips, and such have been taken out of the brain".

Being of great importance, many of the activities performed in neurosurgery were thus related to this counting and writing down, with one surgical nurse even commenting that she was writing things down all the time:

> I write everything down on the computer. During the actual surgery too, all the time. From arriving in the morning until leaving in the evening

As indicated by the nurse, this counting and writing down was not designated any specific time in relation to the surgical procedure, instead being performed before, during and after surgery:

> Everything should be checked. It should be counted before and after surgery or at the end of it so that everything's correct (surgical nurse).

Counting and writing down were not always easy to do, especially during surgery as no additional time was allotted; instead, it had to be performed simultaneously with other tasks. One surgical nurse expressed this difficulty as follows:

> And it isn't always easy. There's no extra time set aside for us to do it. But it should be done while the surgeons are operating and getting their stuff. So, we need to count in the meantime.

Apart from time, ensuring that nothing was left inside the patient was considered both easier and more difficult in the case of neurosurgery, compared to other surgical disciplines. It was easier since surgical wounds are smaller, making it more difficult to leave larger instruments and tools inside:

> You'll see pretty soon if there's something missing. Things are quite easy for us at neurosurgery because we have small incision areas where it's difficult to forget something. It's difficult to put something in. You can't put in a 20 centimeter long forceps and just leave it there, but that's something you can actually do during more large-scale surgery such as abdominal surgery. But the checking system is the same… and it's important that you follow that. So, even if the incision area is small, it's still very important that we do it, which is also part of our quality control or whatever you call it (surgical nurse).

At the same time, small surgical wounds also meant that smaller materials were used, which in turn were more difficult to keep track of. One surgical nurse explained how this consequently complicated counting and writing down:

> We count the brain patties, strips, and compresses. The compresses are, however, difficult to get inside the head, now we're talking about the brain. But, we're also in the stomach at times, where we put floatings, these are for pain-relief, and then you are in the vicinity of the stomach,

> and then it becomes even more important to also count the compresses. These are not, however, as difficult to keep track of as the small brain patties, because they can easily attach to the scrub and get away. It's very important that we count these and check them, so that we get everything out.

During my observations, I also became aware of how not only the strips, compresses, and small brain patties were counted and written down, but also the larger instruments and tools. The nurses often commented on how they counted and wrote down everything that they were either about to use or had used, e.g. all the instruments and packages. The following quotes, given by three nurses, further illustrate and are representative of how both smaller and larger things were counted and written down:

> I have to write down and count all the grids and so on. I write down catheters and how we've filled the cuff. All the disposables and compresses need to be counted and written down. We need to have control. We also need to write down a PAD [Pathological-anatomical diagnosis] referral as we send all the tumors in a jar to the pathologist for analysis. So, that's also written down on a large sheet of paper (assistant nurse).

> We write down all the material we've unpackaged, which instruments are used, all the different grids, various loose-packed instruments, and so on. This is done in a way that documents what you've unpackaged and later on also helps in making sure that everything is out as well (assistant nurse).

> We have small patties, micro pads that are 1mm times 3mm, they're tiny. Then we have clips and small brain patties that need to be counted. They come in tens on their small cards, and we count them like that (surgical nurse).

As the last quote indicates, these materials, instruments, tools and so on were not counted and written down using any imaginable method; rather, the nurses counted and wrote down using specific methods. As illustrated by two surgical nurses thus:

> Yes and then there are small receipts, especially for the cloths. I'll take one receipt, which I keep sterile in the surgical area or on my table which is sterile, and one that's non-sterile which the assistant nurse in the room takes and sticks on the wall. We have small boxes, you can call them, which have five compartments, and in these I put the used compresses, one in each compartment and then I count them. Then you'll see quite soon if there's anything missing.

> For the instruments, we have a list of each grid, as we call them. On each box that contains a certain number of instruments, it's listed exactly what they're called. Needles, we put in a box that has compartments with numbers. Then we put them there, on a foam rubber plate, into which we push the needles. Surgical wipes and these small brain patties are labeled with X-ray wires in order to find them, if you notice something is missing.

> Then you can use a C-arm to find them. There you count every compress and every patty you put them into, how can I explain it, into a kind of cash register. You count them five by five, because they come five by five, and then you see that the X-ray thread remains. It's my responsibility in the end, but as I told you, we help each other, but I'm the one who signs off on everything being correct. I'm responsible.

In explaining the specific methods of counting and writing down, using something similar to a cash register, the surgical nurse also indicates how they use objects such as boxes. This also facilitates small things being made recognizable. Moreover, what is indicated here is also the fact that the main responsibility, and the final say as regards counting and writing down, lies with the surgical nurse. This pronounced responsibility is in spite of the fact that the surgeon is the one using the instruments, the materials, and so on in the surgical wound, but not taking part in the counting and writing down. This is, as mentioned, the pronounced responsibility of the surgical nurses instead:

> No, as it is today, we have no part in that [i.e. counting and writing down]. And it's the instruments, we use many very small strips and similar stuff, and they also need to be counted to ensure nothing is forgotten. But it is the surgical nurse who's responsible for that and keeps track of it (surgeon).

However, in practice, this is instead a partly-shared and collective accomplishment as the assistant nurses help out and take part in collaborations. One surgical nurse commented thus:

> Counting things is my responsibility, but I work with the assistant nurse. But it's my responsibility at the end of the day that everything's correct.

Particular disciplinary foci lead to differences in counting and writing down behaviors in the operating room. Counting and writing had a different meaning and role for the anesthesia staff. As they did not have anything inside the patient (at least not in the surgical wound), they did not need to worry about leaving/forgetting something there. As a result, performing activities related to the counting or writing down of materials and instruments was not part of their work. The anesthesia nurses often said; "We're not counting anything today" (field note). This was in spite of using multiple tools and materials, such as needles and syringes:

> But we do use those needles and we don't count those needles or anything like that. On the surgical side, everything is counted because they're afraid that things may get left in the patient's stomach or head. But here on the anesthesia side, we use our stuff like this instead [showing with the hands how they throw things around] (anesthesiologist).

As can be seen above, the differences between the disciplines regarding counting and writing down were noted by the healthcare professionals. One surgical nurse further reflected on these differences:

> No, they [anesthesia staff] don't count in the same way. For them, it's more about counting drugs and what they've injected. They don't have any materials that they count.

Despite being reflected upon, these differences were seldom problematized since they did not interfere with other people's work, and thus did not prevent surgical procedures from proceeding smoothly. In contrast to what the surgical staff engage in counting and writing down, and how, the anesthesia staff performed counting and writing down activities that were mainly related to medicine and the patient's vital parameters. As described earlier, the anesthesia staff had to engage in extensive preparations before surgery could start. One part of this was preparing the right type of medicine and the right quantity, which was then counted and written down. During surgery, too, it was important to count and write down the exact quantity of each medicine that was given to the patient. In addition, the anesthesia staff also kept track of the patient's vital parameters, writing down, for example, the blood pressure curve indicated by the monitoring and surveillance technology every five minutes. Counting and writing down was thus achieved by interacting with the technology. Next, how neurosurgery involved technological interactions is further developed.

4.6 Interacting with Technology

When asked what distinguishes neurosurgery, many of the informants described it as very technology-intensive. The nurses, for example, often said that they "have so many pieces of equipment", and that "neurosurgery is very technologically-oriented". During one interview, when describing what neurosurgery was like, one clinical manager also stressed the technological intensity:

> It's all the technology, large instruments and lots of instruments. A lot of technology, everything from small clips, small screws, where we have small clips that are meant to be placed in the brain and to cut certain veins.

The informants thus highlight the existence of the many and varied technological elements which in turn make neurosurgery a complex environment. As one surgeon commented during an interview; "It's a complex environment, a complex technical environment, absolutely. There are many different parts."

Thus, given the nature of neurosurgery, as a particularly technology-intensive surgical discipline, it was no surprise that one of the first things I noticed, during my observations of real-time surgical procedures, was the various pieces of technological equipment involved when activities within and around neurosurgery were being performed.

For example, during one of my observations in the operating room, I noticed the 'anesthesia workstation', where the staff were continuously using machines such as the anesthesia machine, the monitoring system, and the syringe infusion pumps. Before the patient was due to arrive, the staff were checking these machines and positioning them in their appropriate locations. These technological machines were 'permanently' in the operating room, as they were needed for all surgical procedures. From lengthy experience, they were also used and positioned in almost the same way for each specific surgical procedure. When the anesthesia process started, they were then connected up to the patient using cables and wires. In order to monitor the patient's condition, these machines were also used during surgery. Additional machines that can be used by the anesthesia staff during surgery included, for example, a machine for blood and fluid warming and one for the perioperative warming up of the patient. When observing the physical arrangements of the OR, it was evident how the surgical staff used various machines, e.g. the surgical microscope, the tower (rack of devices), and the navigation system. As with the machines used by the anesthesia staff, the surgical technology also had its specific use and position in the operating room. The type of surgery and the surgeon's decision regarding the patient's position determined the location of much of the technology, as well as the positions of the OR staff. These decisions regarding how to use, or where to position, the technology were neither called into question nor debated. As described earlier, it was mainly the surgical nurses who prepared these machines, turning them on, checking them, sterility draping them, and positioning them. The surgeons would then use them during surgery to perform the various parts of the surgical procedure. Thus, when asked to describe their work, many of the informants mentioned the use of technology; some of these pieces of technological equipment included, for example, the following:

> You can use the navigation system, which is like a GPS with a map of the head, and then connect it to the brain or scalp of the patient, and then point on the monitor and the picture and then on the tumor to see where in the head that is. We can find things better this way (surgeon).

> We have many different tools that are important. The most important thing is probably the drill, so we can get into the patient's head. But it must be possible to drill and then saw and then the bone flap should be put a side (surgical nurse).

> Then there are different tools, for example, we often use the microscope as a technical tool. There are different additions to that, which we can use differently. We can also illuminate a tumor using different fluorescence, which is another technical thing that needs to be harmonized with filters and other things like that (surgeon).

The microscope mentioned in the quote above enables the surgeons to illuminate and magnify deeper parts of the brain. By means of also illuminating tumors using different fluorescence, surgeons can reveal a clear-cut borderline between tumors and normal brain tissue. The microscope is a technological tool that makes neurosurgery different from many other surgical disciplines, both in terms of how the operating room is configured and in terms of how the work is performed. The microscope occupies a substantial part of the floor space and is mostly positioned close to the patient table. The position of other devices and tools, as well as other operating room staff, is very much decided by the position of the microscope. For example, weighing approximately 360kg and reaching (with a movable arm) up to about 2.7 meters in height, the microscope is a large technological tool that also entails constraints regarding where other devices and tools can be positioned and used. Also, the microscope is sterility draped meaning that other technological machines and devices need to be positioned far enough away, so as not to risk breaching sterility. In addition, throughout most of the surgical procedures, the surgeons' eyes were fixed on the oculars. I observed that the surgeons could at times stare into the oculars, with no interruption, for up to 10-12 minutes. This dependency on the microscope leads to deep immersion in the ongoing surgical procedure, but it also means constraints on interactions with other staff members, and with other technological elements. As the surgeons' eyes are busy using the oculars, they have a limited view of the other technological instruments, which may pose a challenge to important interactions.

The various pieces of technological equipment were not only expected to function in isolation, their different parts were also expected to work together in a synchronized manner. The importance of synchronizing the technology was explained further:

> Yes, there's so much technology that needs to function, IT systems for images and image transfer. And then it also needs to work together with the other tools and the software of various other manufactures (surgeon).

> It's very important for each part to work well, but also that everything works together. Having an understanding that we have to have an anesthetic machine, even though it may feel it is in the way with the cables and so on. That everyone gets their part to work, but also that they work together. That all parts can be put together later. Separately and then it has to come together (anesthesia nurse).

In using the terms "we", "everyone", and "together", the healthcare professionals were acknowledging the shared nature of synchronizing technology. One important aspect of realizing collective performance, thus, is synchronizing the various technological elements, and thus making the staff integrate.

Having the technological equipment run smoothly and efficiently was most often taken for granted as the staff had learned the technology well enough. They knew how to start, control and operate the various technological elements in a satisfactory way. However, there were times when this was not a given, and something needed more ongoing effort. This was especially evident in the comments made by the informants regarding technological complexities:

> Sometimes, some technology doesn't work. So, there's often something wrong with the technology. For example, the drill may not work, or there's something else that isn't working, or something may be missing (surgical nurse).

> But then the drill may start acting up. Or the bone in the head, the skull bone, is so porous, and then the drill wont' get through it because it'll stop

> drilling. The drill will stop drilling when it becomes porous. And then we need to put in a new handle [instrument] and mill the hole instead. Then you'll have to saw with a cranial perforator and then it may lock up because it gets too hot and doesn't work. And then you have to change the handle for the cranial perforator (surgical nurse).
>
> It happens rather often, but 95% of the time, this is user error. Not because people are negligent really, it's a bit like how it is with computers. To make it as user-friendly as possible. And many of the systems we use are not user friendly in the way a modern mobile phone is. It isn't intuitive that way. But often, it can lock up and it can often be software where there's a built-in security device that you have to do that step beforehand. Otherwise, it won't let you proceed, you'll get stuck. It can also be simple things like there's a bad connection in a cord. That you have to restart one device in order for it to recognize another one. Lots of things like this, which you can troubleshoot and usually find a solution to. But sometimes, there's simply something wrong with it, or that you can't figure out what it is (surgeon).

Occasionally, performing neurosurgery thus meant more visible cooperation and ongoing efforts with the technology, thus including both troubleshooting the technology that was not working and exchanging this for functional technology. Coordinating work during these technological problems was facilitated by the co-location of technology and colleagues. In close proximity to the operating rooms, the surgical and anesthesia staff had organized various storage rooms, from which they could fetch tools, devices and suchlike when needed. As colleagues were frequently moving around in the corridors just outside the operating rooms, they could also assist in providing technology, as it was generally undesirable for the operating room staff to leave the room. The physical co-location of both technology and colleagues thus contributed to surgical procedures progressing appropriately.

Interestingly, the surgical staff seemed to experience more technological problems than the anesthesia staff, who generally seemed to experience few technological issues. As one anesthesia nurse put it; "Normally it works, 99% of the time, the technology works". Even though the anesthesia staff seemed satisfied with their interactions with the technology, they also experienced certain technological problems. One anesthesia nurse gave an example:

> It can fail. Sometimes, it can happen that the POCs [Portable Oxygen Concentrators], which measure the oxygen, aren't working properly. Either we check with another device, we use these portable ones that we can double check with. But it isn't often there's a failure.

Additionally, one anesthesiologist, during a surgical procedure, uttered the following as a reaction to a patient's sharp increase in blood pressure, followed by a decline (from over 200 to under 80); "I don't trust the machine. I don't trust it at all" (field note). The anesthesia staff went on to give additional examples of other technological problems which, perhaps, did not occur very often; however, when they did, they could have serious consequences:

> Mmm, heart rate, blood pressure and so on. The heart rate may sometimes unexpectedly start to count double. Like this, the patient has 50 but 100 is being indicated. For some reason, and then it reads something that doesn't exist or something less distinct in the heart that makes it count double. But then I can detect this error, either by taking the heart rate manually, or if I can see it myself that it isn't 100 like it says it is. You can count the ECG rate. And then it can also be the case that the patient has very cold hands and very poor circulation there. And it may be the case that the oxygen saturation, which it's supposed to measure, the POCs, may not be able to measure that adequately either. It may be showing lower than what it really is. But then I can use the blood gases instead, and see if the patient has enough oxygen (anesthesia nurse).
>
> It has been the case that the patient's temperature has suddenly increased drastically. He/she may have 36.5 degrees when starting sedation, with it then increasing very fast up to 39.5, on the monitor. But if I touch the patient, I can feel that this is not the case, he/she isn't that hot. This is very serious because if your temperature increases drastically, this is one of our most frightening complications, malignant hyperthermia. Which some, but extremely few, people have, and that means they can't tolerate anesthetic gases, and then they develop a deadly increase in their body temperature. Then you get very scared when the temperature increases drastically and reaches 39 degrees in like ten minutes. But then you have to be like, is this really correct? And then you touch the patient and no he/she doesn't feel that warm, and then you have to disconnect the cables and go and get some other cables and connect them up again. And then you can see that it wasn't correct. It's been a normal temperature all along. So, yes it can fail and then you always need to be critical and ask yourself if this is really correct. If not so many of the aspects are pointing in the same direction (anesthesia nurse).

Much of the technology was not optional, or to be used as and when; however, the staff were, in fact, dependent on it. The importance of the technology, for example, meant that the anesthesia staff could not perform their work at all without their machines. One anesthesia nurse explained that she could not work without her machines:

> The technology is very important to us. We have a monitor checking the patient's heart rate, blood pressure, and oxygen, and this gives me a lot of information about him/her. Whether the patient is stressed or not, whether he/she is sleeping well or too deeply. Then I also have the anesthesia machine, which I couldn't work without. It's almost the most important one, as it shows whether or not oxygen is getting into the patient, and how much the patient is getting. We get an indication of whether this is enough by checking how much carbon dioxide he/she is

exhaling. Then, we have the syringe pumps, which administer medicine and so on. I couldn't do without any of these machines.

This was even more important in the discipline of neurosurgery, since the anesthesia staff seldom had access to the patient's head. During surgery, the head was 'occupied' by the surgical staff instead as they were operating on this area. This also meant that the head was inside the sterile area, and that the anesthesia staff could not breach sterility. Thus, instead of checking the patient's physical changes, e.g. assessing eye position and pupillary reflex activity (so as to check for anesthetic depth), and observing the movement of the chest (so as to assess respiration), the anesthesia staff were more reliant and dependent on the technology. As explained by two anesthesia nurses:

> Because we don't have access to the patient, we use the monitors and the equipment instead. It isn't so much about the physical side, well we can feel if one of the patient's hands is sticky or whatever. And I can also feel his/her heart rate, but that's something I can see very well on the monitor.
>
> I look at the monitors to a greater extent, they become even more important. They're the only things I have.

It was not only the anesthesia staff who relied and depended on technology, but also the surgical staff. One surgeon even said that they were entirely dependent on a lot of technology, and that they could not operate without it:

> It's very technical, a lot of information that we're entirely dependent on. For example, we're entirely dependent on having a picture, an MRI image or a CT image. And that's also a vulnerability, the IT system. It happens, it's happened a number of times that the image display system is down. In the worst case scenario, I can't start operating, or I may even need to wake the patient. You can't perform surgery if you don't have a picture showing where the tumor is located. You can't guess your way there.

As this surgeon mentioned, being able to perform neurosurgery entails a reliance on technology, and this also means interacting and collaborating with healthcare professionals not working at the neurosurgery department. The most common example of this is how the use of MRI images required the staff at the neurosurgery department to interact with the staff at the isolated and far-away MRI Unit, in order to bring about a joint effort. This is further described in the next chapter.

4.7 Analytical Summary

In what follows, I summarize and discuss how the practice of neurosurgery was performed and organized before the introduction of the new iMRI Hybrid OR. The healthcare professionals were engaged in stabilizing the social setting and physical space, which are in turn implicating and facilitating coordination processes.

4.7.1 The stabilizing of the social setting

In the ways neurosurgery is performed, the knowledge and skills necessary are situated within multiple disciplinary domains, with all individual roles and actions contributing to a coherent performance. All the disciplines stress their importance and comment on how they can speak up if necessary. Notwithstanding this multidisciplinary approach, work at the neurosurgery department is, at the same time, performed in accordance with well-established social dynamics, including roles, responsibilities and interactions, a social setting largely based on the traditional hierarchy and status differences existing in healthcare (Barley, 1986, 1990; Zetka, 2001). Authority rested with and was based on professional status and the knowledge and skills within the professional domains. For example, surgeons and the surgical discipline per se were attributed with high status, in the way that surgical requirements were generally associated with high levels of respect and an influence on how work was performed and integrated. During the preparations performed before a surgical procedure, there is a timeout. This timeout is required before an incision can be made and is most often initiated by the surgeon (sometimes also initiated by the anesthesia nurse). This timeout not only has a coordinating function, by getting everyone on board, it also means the surgeon can exert control and authority over what the others are doing, by getting the attention of all the healthcare professionals in the OR. Another example of this is the way in which the microscope dictates the position of the other devices. With well-understood status-differences and duties, complying with a hierarchical authority through which the responsibilities for specific elements have been spelled out and little overlap exists, accountability is facilitated by the way in which it is clear who does what.

While the well-established roles and responsibilities prove functional in terms of coordinating work, the integration of work does not occur in a relational vacuum, but through relationships (Gittell, 2002). This relational dimension proves important in developing predictability and a shared understanding, being attributed to professional roles and duties, and to personal relationships. For example, during a surgical procedure, the duties performed by the anesthesia staff and the surgeons directly influence each other. The main duty of the anesthesia staff is to check, monitor, and stabilize the patient's vital parameters. This work is directly affected, however, by the surgical interventions being performed by the surgeons. Another example of this is how the preparations before a surgical procedure are made to work in such a way that the involved healthcare professionals need to align their activities. This is largely made possible by them familiarizing themselves with the elements and timing of both their own and others' execution of duties. Thus, in-depth knowledge and understanding of each other's duties is not crucial, but an awareness of the overall duty and how separate duties are to be aligned and integrated. In this way, coordinating work at the neurosurgery requires respect for, and alignment with, the work of others.

Personal relationships also show themselves to be important to the integration of interdependencies and the ongoing coordinating of knowledge and expertise unfolding without too much tension or conflict. The staff have lengthy experience of their own disciplines, and have worked with each other before. Based on training, discussing and experiencing, they have developed, not only knowledge and an understanding of who is responsible for the specific elements, and what is needed and when, but also a 'liking' of each other. This positively contributes toward developing a shared perspective (treatment of the patient), and bringing about an important 'flow' inside the OR. Thus, being dependent on relationships between the diverse groups of experts is not only in relation relative to familiarity with others' task-related expertise, but also relative to personalities. In sum, despite how neurosurgery is a highly complex and dynamic practice, the healthcare professionals perform their duties largely based on traditional hierarchy and status differences existing in healthcare, which contributes to the enactment of stabilizing the social setting.

4.7.2 The stabilizing of the physical space

The meaning the staff assign to the neurosurgery department, by calling it their "home", matters to how work is performed and integrated (Gieryn, 2000). The physical co-location of both technology and colleagues contributes to staff feeling safe, and knowing where to find what is needed. Feeling at home is also important as the practice of neurosurgery is intertwined with a highly dynamic and complex physical space. For example, the practice of neurosurgery hinges on multidisciplinary work, with the neurosurgery department thus being a physical space that a variety of healthcare professionals negotiate and enact when performing their work. In this way, in order to make neurosurgery happen and healthcare professionals carry out their duties, a shared physical space is essential. This space provides the context that enables and constrains what the healthcare professionals do, and how they interact, thus becoming intertwined with the accomplishment of work (Barrett et al., 2012).

For example, during the preparations ahead of a surgical procedure, the anesthesia and surgical staff take turns waiting for each other both inside and outside the operating room. As these groups share and negotiate the physical space, the work they perform is materially enacted in spatial configurations of the OR and its immediate surroundings. Another example of this is how the healthcare professionals are engaged in maintaining sterility, a duty that is highly intertwined with material arrangements (Barrett et al., 2012; Beane & Orlikowski, 2015). Maintaining sterility is accomplished by materially enacting the space, e.g. making use of the hatch and the anesthesia arc to negotiate and make clear that everybody and everything is in the right place.

While functioning as a shared physical space, the neurosurgery department is not randomly utilized; the material objects and the healthcare professionals themselves are most often continuously arranged in specific ways. They have, or come to have, their specific places in specific points in time. For example, while anesthesia and surgical staff sometimes negotiate the same space, e.g. when balancing requirements regarding securing the endotracheal tube with ensuring the best possible surgical entry, they are mostly working in separate locations both inside and outside the OR. Inside the OR, the anesthesia staff mostly work and move around in the areas surrounding the patient's feet, while the surgical staff mostly work and move around the patient's head. Outside the OR, the two disciplines have their own rooms for medicines and equipment. While this, on the one hand, reproduces traditional and discipline-related arrangements and causes coordination processes to become fragmented (Harrison & Rouse, 2014; Wolbers et al., 2018), it also contributes to the arrangement of a shared physical space in ways to be productive. This is the case because the material enactment of coordination, especially in relation to spacing, helps to clarify not only who does what, but also where.

Given the different backgrounds, in terms of experience, training, and competencies, the multidisciplinary work performed at the neurosurgery department is fragmented and separated. However, since duties and individual achievements are highly interdependent, and since how the duties of a specific discipline often directly influence the work of another group, an ongoing need exists for individual achievements to be integrated and aligned, in both time and space. Realizing this collective accomplishment relies on well-rehearsed and well-orchestrated sequencing patterns. For example, during preparations, the staff were not always able to occupy the same space and then had to take turns waiting for each other, requiring the alignment of both duties and physical presences. With their lengthy experience, the staff rely on established sequences of activities in order to observe the evolution of each expert group's progress and movements. Furthermore, as sterility is a responsibility shared among all the healthcare professionals, they generally understand the strict rules and know where they are able to move around freely. If necessary, the surgical nurses check and prohibit staff from breaking these rules, but this is seldom the case as the well-rehearsed sterility routines are well-understood.

Furthermore, many of the various pieces of technological equipment involved in neurosurgery not only have to function separately, but also in relation to each other in a synchronized way. One example of this is the anesthesia machines, and how they are enmeshed in how the surgical and anesthesia staff coordinate their expertise and work. More specifically, exactly how much the anesthesia staff ventilate the patient, using the machines, directly affects the work of the surgeons in how the brain becomes either more or less swollen. A less swollen brain is preferred by the surgeons, but can be problematic for the anesthesia staff due to hyperventilation and a reduced cerebral blood flow. As such, in spite of how the staff and the technological equipment occupy different spaces inside the OR, they are directly interdependent and require alignment. As the machines act as intermediaries between the two expert groups' work, the alignment and integration of the material arrangements present in a shared physical space is required. Having the technological equipment function properly and efficiently, and in alignment with each other, is accomplished by drawing on the lengthy experience that the healthcare professionals generally had. They had learned the separate technologies well enough, and they also knew how to perform together. For the same type of surgical procedure, the positions of the devices and tools, as well as the members of staff, are almost identical, following a specific layout largely dictated by the position of the microscope. In sum, despite how neurosurgery is a highly complex and dynamic practice, the healthcare professionals engage with the physical space largely based on traditional organizational arrangements, which contributes to the enactment of stabilizing the physical space.

CHAPTER 5

PERFORMING WORK AT THE MRI UNIT

In this chapter, the organization and experience of working at the MRI Unit, and how this also involved interactions with staff from the neurosurgery department will be described. Studying work practices related to the MRI Unit further illustrates the broader social trends and relations that form part of producing MRI in practice.

5.1 Introducing the MRI Unit

The MRI Unit comes under the Department of Radiology, which includes all adult radiology, including mammography at SweHos. Neuroradiology is a specific clinic focusing on Magnetic Resonance Imaging (MRI) examinations of the head and neck areas, as well as contrast examinations of the brain's blood vessels, and computed tomography (CT) examinations. The MRI Unit was established in 2007 when the hospital decided to increase its MRI capacity with two additional MRI scanners. To ensure the new systems would be easily accessible, it was decided to add another storey to the already-existing hospital complex adjacent to radiology. Unlike the "ordinary radiology department… where conventional examinations and elective coronary interventions, CTs and so on are performed" (radiology nurse), the MRI Unit only contained MRI scanners as its imaging technology.

In and around the MRI Unit, teams of, mainly, doctors (radiologists), radiology nurses, hospital physicists, and technicians work in various ways toward making sure that MRI images are produced and interpreted, as safely as possible and in as high quality as possible. In what follows, I give a brief description of what characterizes these roles.[6]

Radiologists, as with all medical doctors, first graduate from medical school (five and a half years), which gives them broad competencies in preventing, treating and

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[6] This is by no means an exhaustive description of what healthcare professionals working in and around the MRI Unit do or what their roles consist of, which can differ depending on context.

alleviating disease and illness. In addition, they also do a minimum of 18 months in general training, and then their specialist training in radiology for another five years. The specialism of radiology is characterized by diagnosis, the staging of diseases, making prognoses, treatment, and the exclusion of diseases and the evaluation of therapy with the help of morphological imaging and functional methods. The mechanisms of origin and progressions of diseases thus form part of the radiologists' competence areas. The result of this work is then communicated to clinicians and affects patient treatment. Neuroradiologists, in addition to their five years of special training, also perform another two years of specializing in the central and peripheral nervous systems, as well as the spine and the ear, nose, throat (ENT), and neck areas. This training includes fields such as imaging and functional medicine, neurology, neurosurgery, and neuroradiology.

In their day-to-day work, and in terms of MRI, neuroradiologists interpret the images produced by radiology nurses using diagnostic imaging technologies. This can mean interpreting both images produced at the hospital but also those from other hospitals needing a second opinion. Usually, more images than the radiologist has time to interpret are produced, thus much of their day-to-day work is occupied by sitting inside dimly-lit reading rooms, in front of computers, and by looking at, interpreting, and dictating as many images as they can. Often, they are not present during the actual scanning, but are easily accessible if radiology nurses need their advice, e.g. in terms of clarification of which images to produce, or when making sure the produced images are satisfactory. Another important part of their work is showing the produced and interpreted images to clinicians and medical students during major rounds and tumor conferences. The outcomes of these occasions shape the ongoing treatment of the patient.

Radiology nurses (sometimes referred to as nurse radiographer outside Sweden), up until 2001, did not receive any formalized training, instead often being recruited among general nurses and undergoing training at the department. The profession has undergone various changes in terms of training. In January 2001, Sweden's government and parliament (Higher Education Ordinance 2001:23) decided to introduce a vocational qualification for radiology nurses who had undergone, and passed, the radiology nurse training program. Today, it is a three-year program with radiography as its main subject. The training objective is to develop the competencies required to carry out different examinations and treatment methods, with a diagnostic and treatment objective, using morphological imaging and functional methods. This training is also aimed at providing competencies and knowledge in patient care, before, during and after radiological examination or treatment.

In the MRI Unit, the work performed by the radiology nurses is highly technical. They produce the images using MRI as a diagnostic imaging technology, which means they conduct the actual MRI scanning. During scanning, they sit in a control room, directly adjacent to the examination room, where they run through the predetermined protocol in accordance with how the radiologist has prioritized the examination. There is, however, more to it than just pushing a button and allowing the scan to be automatically conducted. Radiology nurses need to stay focused as they adjust various parameters, and the relationships between these, e.g. contrast and field of view, meaning in which part and at which angles the patient is examined. For example, they need to compromise between field of view and contrast, since they want to examine an area that is big enough, but without losing too much signal and running the risk of ending up with poor images.

An MRI examination protocol is built up by different sequences after each sequence, radiology nurses need to make sure these are optimal and that the image quality is satisfactory. Image quality is directly affected by patient movement, and thus one important task for radiology nurses is motivating patients into lying still. This also means that much of their work, in addition to being technical, is also related to patient care. The radiology nurses, for example, are the ones who welcome the patient to the MRI Unit, informing him/her about the procedure and making sure he/she has been MRI-screened (a safety procedure). As mentioned, in order to ensure that high quality images are produced, radiology nurses often need to motivate patients into lying still, especially since it is generally not perceived as comfortable to be in the scanner. Another aspect of patient care concerns the number of patients having claustrophobic experiences with MRI; thus, radiology nurses often have to calm them down, for example by explaining the procedure and that it is harmless.

Hospital physicists undergo a five-year university program, leading to their registration as hospital physicists. This program is simultaneously a Master's program called Master of Science in Medical Physics. The program aims to provide physicists with broad competencies and knowledge relating to radiation safety, radiation physics, and measurement technology etc. The program combines knowledge of physics, mathematics and radiation physics for use as a tool in medicine. The first two years focus on basic physics, mathematics, and programming. The third year focuses on medical radiation physics, while the fourth year is more clinically-oriented, involving, for example, radiation physics, magnetic resonance physics, and ultrasound physics. The final year consists of mainly clinical hospital practice and concludes with a degree project. After their training, it is common for hospital physicists to focus on a specific field of competence, e.g. radiation therapy, nuclear medicine, and radiology (including, for example, MRI and CT).

Hospital physicists are often seen as problem-solvers, helping doctors and nurses with their day-to-day physics problems in the diagnosis and radiotherapy of patients. In radiology, and in terms of imaging technology based on ionizing radiation, the physicist's work is regulated to ensure that the best possible image is obtained at the lowest possible radiation dose. They also work at determining radiation doses during radiation therapy against cancer. In terms of MRI, the hospital physicist's work is not regulated, instead being determined on the basis of what the different hospital departments need. This often includes work that is related to safety, image quality, training and the procurement of MRI equipment. They are also frequently involved in various projects of implementing already-existing methods, as well as the development of new diagnostic methods. As the physicists are the experts on the parameters underlying the MRI technology, and know what various changes to the technology mean, much of their work thus consists of optimizing and developing MRI protocols for patient examinations. Another part important part of their work is to translate information exchanged between, for example, surgeons, radiologists and radiology nurses. For example, if a surgeon wants to achieve better contrast in images then the physicists will be the link with the radiology nurses, knowing what to change in order to meet the surgeon's requests. Physicists are thus sometimes present during the actual scanning as they consult with the radiology nurses in their work.

Technicians work with a wide variety of tasks, often related to some kind of medical technology. They can have different educational and professional backgrounds, but a common educational background is being a university-trained engineer. The training for engineers focusing on medicine often includes subjects such as medical technology, medical IT, clinical technology, physics, chemistry, computer and network technology, electro technology and so on.

Technicians make sure equipment is working properly and safely. They thus need to check how the technology is being used, and the methods being adopted. When healthcare professionals decide to implement a new clinical practice that involves technology, the technicians are the ones who perform a technical evaluation of these methods. During procurement processes, technicians are also involved in deciding what technology to procure, then checking and testing it post-purchase. In the MRI Unit, technicians are usually only present during installation work, for example when new MRI-related equipment is being tested and implemented, or when it is in service, such as when existing equipment needs to be fixed or adjusted.

In addition to these professionals groups, there are also others who perform work in and around the MRI Unit. One example of this is the anesthesia staff, where both anesthesiologists and anesthesia nurses are involved whenever sedated patients undergo MRI examinations. This happens often because many of the neuro patients are indeed sedated when being examined. Another example of this is how neurosurgeons engage in both the production and use of MRI. Interactions between both MRI and non-MRI staff are further described in the section on work practices and collaborations.

As indicated in these descriptions, the MRI Unit involves a division of labor that assigns each profession different responsibilities. At the same time, the actors in the MRI Unit are also engaged in the highly-integrated task of producing and interpreting MRI images. This collective responsibility means they are directly affected by each other's work. In what follows, I will first provide a brief description of what MRI is and how it works, before presenting its broader changes and trends. This is followed by descriptions of the work practices and interactions that produce and coordinate MRI in practice.

5.2 How MRI Works

As the detailed physical and biological principles underlying MRI go beyond the scope of this dissertation, a more simple or layman's description will be given of what MRI is and how it works.[7] Put simply, MRI is a technology consisting of a strong magnetic field and radio waves, which are used to produce images of the body's various organs and functions. The magnetic field is generated by a strong magnet, with a strength typically ranging from 0.1 to 3.0 T (Tesla, which is the unit measuring magnetic field strength) in medical MR imaging. The most common field strength in medical MR imaging is 1.5 T, which is about 30,000 times stronger than the earth's magnetic field and about 100-1,000 times stronger than an ordinary refrigerator magnet (Westbrook & Talbot, 2018).

The human body contains water molecules distributed all over it, and it is the hydrogen atom, specifically the hydrogen nuclei (the small part at the heart of the atom), that generates the MR signal that the MRI scanner can detect. The hydrogen nucleus has a magnetic moment, as it is known. These are, under normal conditions, oriented randomly; however, when an external magnetic field is applied, such as when a patient is placed in the bore of the MRI scanner, many of these magnetic moments will align in the direction of the external magnetic field, adding up to a net magnetisation of larger than zero, called longitudinal magnetisation. Then, using a special radiofrequency (RF) coil, energy is produced in the form of a rapidly changing magnetic field, often called RF pulses. The hydrogen nuclei absorb this energy and then start to change their orientation, thus increasing their energy and resulting in a magnetization that is perpendicular to the applied external magnetic field, known as transverse magnetization. The RF pulse is stopped, whereupon the recently-energized hydrogen nuclei go back to their previous state and release their energy in the form of radio waves, resulting in a lowering of the transverse magnetization. This recovery on the part of the hydrogen nuclei, and this lowering of the transverse magnetisation, differ in duration between tissues, being called the relaxation time. Specific receiver coils placed in close contact with the patient detect the transverse magnetisation in the form of an electric current. Image formation occurs due to the MRI signal being received by the coils being transformed into images by means of computers dealing with complex mathematical processes. As such, MRI images are computer-generated visual reconfigurations of physical data, with MRI differing from X-rays in that no ionizing radiation is transmitted through the body; instead, non-ionizing RF electromagnetic radiation is used to generate the MR signal emitted by the body.

MRI is often considered, both by the media and by healthcare professionals themselves, to be the gold standard of imaging technology. This is often explained by its advantages over other radiological technologies, e.g. X-rays and Computed Tomography (CT) scanners. Some of the advantages often mentioned include MRI not involving the damaging ionizing radiation of X-rays, producing a large dataset

[7] For a more detailed and elaborate description of MRI, and how it works, see Chavhan (2013), English & Moore (2012), McRobbie et al., (2017), and Westbrook and Talbot (2018), for example.

from which any anatomical plane can be reconstructed, and offering superior soft-tissue contrast. Next, changes and trends in MRI are described.

5.3 Changes and Trends in MRI

Certain changes and trends in MRI, and in radiology per se, both on the broader (national legislation) and local levels (within the studied hospital), were often mentioned as affecting the work of the MRI staff. For example, in Sweden, neuroradiology is considered the only subspecialism of radiology that is left; some years ago, there were more subspecialisms, e.g. children's and adolescent radiology. This was the result of an evaluation made by the National Board of Health and Welfare, whereby subspecialisms of radiology were reduced in number in order to, for example, stimulate the breadth of the radiology staff. Breadth is, however, in stark contrast to current changes and their technological advancements, towards constant development and specialization, which many radiologists themselves are experiencing and being confronted with. One radiologist said:

> Yes, the National Board of Health and Welfare did an evaluation a couple of years ago, whereby they wanted to reduce the number of specialisms. I think they had some kind of idea that people should broaden their skills, so people could work on call anywhere. However, the trend is, in fact, toward more specialization, and when we heard about this, we worked very hard to keep our specialisms. We succeeded in this, but due to the children and adolescent specialism missing the fact that this was coming, they just disappeared. So, this specialty doesn't exist as a formal program anymore. I think that they got all of this wrong, because at university hospitals at least, it doesn't work being broad and mastering everything. It isn't possible as the trend, particularly in radiology, is toward greater specialization.

Technological advancements allowed more and more specialization, with neuroradiologists resisting attempts to erase their subspecialism. They argued that being a generalist was in direct contrast to the current trend. The current trend was present in the overall practices involved in radiology, characterized by technological advancements which, according to radiologists, require more narrow and specific knowledge and competencies. These changes were particularly visible in the case of MRI, and especially so during the last couple of years. One radiology nurse commented; "MRI has never stood still. It's been developing all the time, especially recently. It's an enormous technological development."

Technological advancements meant that it was possible to do more and to do it better. For example, the areas potentially examinable were expanding. When introduced, MRI technology was mainly used to diagnose the areas around the brain and spine, but it has now developed to become capable of visualizing, for example, the heart, thorax, liver, abdomen, and arteries as well. In addition, it is now also possible to examine sicker patients as the manufacturers of medical devices have progressed towards developing more MRI conditional implants.

As new applications were arising, this also meant an increase in specialization as certain specialists would mainly do specific examinations. One radiologist described this as follows; "and then they are the only ones doing that type of examination". This specialization was also noticeable within narrower areas of examination, e.g. within neuroradiology as a subspecialism, as one radiologist continued:

> We've also become sub-specialized. We've focused on specific parts. Some of us are better at certain aspects. There's a certain level of sub-specialization among us, with some people being better at, for example, head-neck tumors, and who then focus on that.

In addition to these new applications, advancements also made it possible to obtain better quality images due to the development of better coils, and the introduction of high magnetic field scanners. One MRI expert explained the benefits of high magnetic field scanners thus:

> You get a better signal and can scan at a higher resolution and you get higher resolution images. In terms of quality and for examinations, you get a very nice resolution with very detailed structures.

Thus, using a stronger magnet, a higher resolution and better quality images were possible. MRI staff had the possibility to see more and more and at greater detail. However, looking through all these details, sorting them, interpreting them, and in doing so also taking advantage of these advancements, required even greater knowledge and experience. One radiologist explained how higher magnetic field scanners set new and higher requirements:

> It's great to have accessibility, but it puts great demands on the person handling the images. What's interesting, which details are essentials, and what am I going to show? And what are the things I can just discard? It'll all be better and better or worse and worse depending on how you see it. If you think of the MRIs, which, for example, were rated perhaps at 0.1 Tesla in magnetic strength initially. They had this strength at the beginning and then they increased to 0.5T and then 1T and then 1.5T, and now they're 3T.

One way to deal with the increasing level of detail was by specializing the work of the radiologist even further. One radiologist explained how the detail would need to be reduced to a particular field of expertise in order to make use of the current trend. Related to the technological advancements mentioned, swaying MRI work towards greater specialization, there was also an increased focus on production and efficiency. On the national level, the use of MRI grew by almost 100 percent between 2005 and 2015 (Nysam, 2015). This production increase was also noticeable at the studied hospital, where there was an increase in both the number of MRI scanners and the total number of examinations performed.

For the studied hospital, this meant shifting away from a small number of MRI scanners, with the staff having relied on four scanners for quite a long time, towards a steady increase in the number of scanners. Typical phrases used by the MRI staff, when describing this evolution of MRI and their own practices, included; "It's been developing from a very small function with only one scanner from the beginning, to adding two scanners and upwards", and "MRI's increasing all the time. Supply and demand, it's like that".

The demand for more MRI examinations is constantly increasing, thus more scanners are being installed. The increasing demand for MRI was partly to do with the technological advancements mentioned, additional areas of the body for examination, and providing higher quality images than before. Thus, in addition to new applications of the technology, this increase in the number of scanners and examinations was also to do with how MRI was generally experienced as superior to other diagnostic methods, e.g. Computed Tomography (CT) and conventional radiation techniques:

> And of course, you shouldn't have to first undergo CT and conventional radiation and then MRI, when you can do MRI directly. When you know that MRI is the best diagnostic method (radiology nurse).

In line with how MRI is often portrayed in the media, the general view among healthcare professionals themselves was that MRI is the gold standard of imaging technology. This meant that MRI was used because it is believed to both add accuracy and provide better treatments for patients. As a result, prescribing doctors are starting to request MRI examinations at an earlier stage than before:

> MRI is being introduced earlier than before. Perhaps not as early on as DT, but still very early. We haven't been involved in the first stage, if you're talking about those who are admitted via the emergency department. Then it's very rare to do an MRI, because a CT or something else is done first. But MRI is often introduced during the second stage (radiology nurse).

The general view among the healthcare professionals I interviewed and observed was that MRI is now the "main technology" used in diagnostic work. As mentioned, this has thus influenced the demand for more examinations and brought about the installation of more scanners.

The increasing numbers of scanners and examinations performed had consequences for the staff at the MRI Unit. One of these consequences was the demand for more MRI examinations also putting more of a focus on production and efficiency. The radiology nurses I observed and interviewed were pressured into increasing the volume of patients scanned. As one radiology nurse explained:

> Every year, we face increased efficiency requirements and demands for cutting costs. Of course, this comes from the top and filters down to the respective functions. So, every year you have to save a certain percentage. And of course, we notice this. We already run a lean business as it is.

Operating with an already tight budget and a lack of human resources, additional pressures regarding efficiency requirements were putting the MRI staff in a difficult situation. In their day-to-day work, the MRI staff thus had to work under tight schedules, during which they tried to minimize downtime, as is evident from the following excerpt:

> It took approximately 20 minutes for MRI [staff] to complete the previous patient. Marcus, the anesthesiologist, was thus unable to start sedating, or he didn't want to start it in a way that would minimize the sedation time for the patient. I asked Marcus if this was to do with a lack of communication, he didn't confirm that but explained instead that MRI is on a tight schedule and so he prefers having the anesthesia team waiting than vice versa.

Matching the schedules of the MRI staff with the anesthesia staff was subject to rules allowing the former to dictate how activities are placed on the "temporal map". By means of overlapping schedules, the MRI staff were thus able to reduce downtime, which was one way to deal with the increased focus on production and efficiency. Another way was how the MRI staff had started to work in a more repetitive and specialized manner. One example of this was by continuously optimizing their examination protocols in order to scan more patients:

> Our work has become more and more production-focused, where you need to optimize the protocols so that more people can be scanned. Production and numbers seem to be the way to go (radiology nurse).

Optimizing protocols meant developing standardized methods as a way of cutting examination times. The MRI staff were working towards developing "smoothly-functioning protocols that are speeded up, and finally achieving great examination modules for something that may have been really difficult to implement beforehand" (radiology nurse). They had also developed a routinized way of positioning the patient. As described by one radiologist thus; "the patients are always positioned in the same way, on their backs and head first." By doing this, they could easily center the patients along the ISO center of the MRI scanner, and position the different coils in order to receive as much signal as possible. "Today they only lie on their backs and then we know how to position the coils etc." (radiology nurse).

In addition, and also so as to accomplish and maintain routinized ways of working with standardized methods, the MRI staff, both the radiologists' and the radiology nurses' work, was geared towards more specialization, relying on what they call specific areas of knowledge. The MRI staff, however, were not willing to give up their broader competencies, whereby radiologists, for example, still considered themselves able to master various diagnostic methods, e.g. DT, MR, and different functional areas such as the brain, the lumbago area, the head and neck area, tumors, and for different specialisms. However, they often viewed themselves as experts on specific areas and they also seemed to prefer certain diagnostic methods or specialisms to others. In their day-to-day work, the MRI staff even considered themselves specialists in specific scanners, as described by one radiologist thus; "a specialist is a neuroradiologist responsible for a specific magnet [scanner]".

This was also the case for radiology nurses, who also called themselves MRI nurses, despite the absence of a formal title including that name. However, and similarly to the radiologists, they neither wanted to give up their broader competencies in radiology:

> It's something you call yourself. But fundamentally, we're all radiology nurses. You don't say you're a CT nurse, but a radiology nurse. You don't say you're a musculoskeletal nurse. Our main competence is within radiology and we're trained radiology nurses. That's our title. That [MRI nurse] is something we call ourselves (radiology nurse).

The MRI staff thus expressed how the ongoing changes, mainly ascribed to technological advancements, were leading to increased specialization. This specialization was not purely being greeted by excitement since they also wanted to preserve their broader knowledge and competencies within the larger domain of radiology. The technological advancements were also leading to more MRI scanners and more examinations, making it possible to advance production and efficiency requirements. These requirements in turn strengthened the shift towards greater specialization even more.

The focus on production and efficiency, however, also encountered some skepticism and caution. For example, the MRI staff stressed the importance of not sacrificing image quality and patient care for speed, arguing that patients should in no way suffer due to the shift in focus towards production.

According to the MRI staff, however, this was not the case everywhere. Smaller, often private, healthcare providers were described more as image factories adopting assembly line processes, under the mantra "Get them in, get them out, and get them in" (radiology nurse). With the focus on minimizing costs and maximizing revenue, patients at these places were described as being more like bodies than patients. The MRI staff often stressed, therefore, the mismatch of comparing the production measures of these image factories with a hospital like SweHos:

> The problem we had before is when comparing production, how many patients we examine in one day using MRI here at SweHos, and looking at how many patients Hospital C [pseudonym for a private hospital] examines, which has many more. And then they miss out on the fact that patients here come in with severe illnesses, transported on beds, while at Hospital C, or at other places, the patients walk from home and lie on the diagnostic table and are lively and happy. That isn't comparable. You shouldn't compare SweHos with Hospital C, but with other similar university hospitals, if you want a fair picture. That's something we have to keep saying. Because otherwise, it's easy for the ones planning and administrating to count and compare and go oops! (radiology nurse).

Different circumstances thus made the situation different at SweHos. One noticeable example of this was how older and sicker patients, in general, were examined at the studied hospital compared to other healthcare providers. In recent years, this was even more so, especially since technological advancements had made it possible to examine sicker patients. This had not been possible before due to long examination times making it unbearable for older and sicker patients to stay in the scanner. One radiology nurse commented positively; "You see the trend in the way that we can take care of much sicker patients than we were able to do before". Thus, the decrease in examination times mentioned was not only described as a result of production and efficiency pressures, but also as means of increasing patient comfort, and thus the quality of patient care. One radiology nurse commented; "It's just that we've crept down in examination times that are sensible for the patients". Enabled by technological developments, the decrease in examination times was thus also described by the MRI staff as benefitting the patients.

However, despite shorter examination times being in line with pressures to produce more, and also for the benefit of sicker and older patients, taking care of sicker patients also required greater efforts from the MRI staff. One radiology nurse said that; "because they're sicker, they're also heavier to examine". Thus, decreasing the examination time itself was one thing, but preparatory and finalizing activities also had to be considered. These activities were often especially demanding when sicker and older patients were taken into account. Part of this involved how sterility was not considered to be of the utmost importance regarding how MRI practices were performed, as is noticeable from the following excerpt:

> I spent some time with the radiology nurses at the MRI Unit. We sat in the control room, from where the radiology nurses were running and controlling the ongoing examination of a patient in the adjoining room [examination room]. I noticed how they were all dressed in scrubs but didn't have any surgical caps or masks. Also, I couldn't spot any disinfection, something I was so used to seeing in other places (for example the neurosurgery department). How did sterility come into play during their work practices?

The MRI Unit and the magnet itself were considered "dirty", which was in stark contrast to other places, e.g. the neurosurgery department. As one of the radiology nurses put it:

> It's like all patients who are recumbent, well perhaps we can't directly compare this, but a Neurosurgical ICU-patient, for example, they almost never want to leave their hospital to undergo an examination. Because the patient is very well off in that environment, but as soon as you change their environment, and when they come down to dirty radiology, then the parameters change and they get worse and so on.

One MRI physicist added; "in terms of sterility, the magnet will always be considered dirty because we have no control over what's inside it". The MRI staff themselves thus considered their workplace dirty. What is of interest here is the fact that this "dirty" environment most often functioned properly; for example, there were no problems with infections, but things became somewhat problematic as sicker patients underwent examinations. This required more effort on the part of both anesthesia and MRI staff as the vital parameters of these patients could often change. Thus, despite how the MRI staff experienced the trend towards being able to examine more patients and other types of patients as something satisfying, they also raised concerns as regards how additional requirements were incompatible with the production and efficiency targets.

To be added to this was how sicker patients were often inpatients, thus arriving at the MRI Unit with many foreign medical objects from their respective wards. This would also require additional efforts on the part of the MRI staff. They needed to engage in prolonged safety procedures in order to maintain MRI safety. This is further described in the next section.

5.4 Maintaining MRI Safety

Work practices at the MRI Unit relied on the shared understanding of maintaining MRI safety. This became evident not only during observations at the MRI Unit, but also through interviews with various healthcare professionals. During workshops and training sessions, descriptions were often given of MRI itself, serving to help us understand why safety was important.

As mentioned, in contrast to other radiology techniques, e.g. Computed Tomography (CT) scanners, MRI does not involve the damaging ionizing radiation of X-rays. However, an MRI scanner is always active, or on, compared to radiation techniques that are only active while being used. This means that other types of safety concerns apply to MRI than to CT, mainly as regards reducing the radiation doses that patients and staff are exposed to. Safety concerns did not, however, involve the risk of being exposed to magnetic fields or how to reduce this as much as possible. The general opinion among the MRI experts I interviewed and listened to, during workshops and training sessions, was that MRI did not pose any exposure risks, neither in the short- nor long-term. I could not, in fact, recall even one instance of exposure to MRI being problematized as potentially dangerous.

Despite being considered safe in terms of exposure, there were still a number of safety concerns related to the use of magnetic fields. As already mentioned, one consequence of the strong magnetic field during MRI is the force of attraction, which causes various magnetic objects to be drawn into the magnet, often described as ferromagnetism. This force differs with the strength of the magnet and the object, and usually increases as the distance to the geometric center of the main magnetic field (also called the iso-center) decreases. One potential danger of the force of attraction is that ferromagnetic objects "may turn into dangerous missiles when brought near the magnet" (Weishaupt et al., 2008, p. 143).

This potential danger has important consequences for safety considerations, also being a prevalent concern often talked about during the meetings and workshops I observed. The importance of maintaining MRI safety was shared by the MRI staff, but it was the radiology nurse who had the main responsibility during day-to-day operations. To illustrate this, consider the following statement from a radiology nurse, who has been trained in the importance of applying safety thinking whenever MRI is involved:

> A lot of it's about safety thinking. Safety is a major thing here at the MRI Unit. It's very important, and there are many safety issues to think about, and to figure out how to deal with.

5.4.1 Restricting ferromagnetic objects

One of the many safety issues is preventing all external ferromagnetic objects from entering the MRI diagnostic room. All people, including both patients and staff, entering the room need to leave metallic objects such as bags, wallets, cellphones, keys, watches, hair clippers, forceps, pens and so on outside the room. Outpatients are assigned lockers where they are obliged to store all their metallic objects, and they have to wear a special smock. In spite of the fact that the patients were given these instructions, they were still scrutinized by the radiology nurses before entering the room; "If you're an outpatient, everything needs to be taken off, and we also check the patient to make sure no hairclips and so on have been missed. You have a critical eye." (radiology nurse). To facilitate the prevention of ferromagnetic objects being taken into the examination room, MRI safety warning signs adorn the doors both into the MRI Unit and into the actual examination room. These signs indicate the dangers associated with strong magnetic fields, and include stop and warning symbols and information such as; "The magnet is always on!", "Warning, strong magnetic field", and "No pacemakers, no metallic implants, no neurostimulators, no loose metal objects".

Most of the time, these signs were not very helpful when it came to the inpatients, as these were generally in a worse condition and being pushed around in hospital beds. At first sight, it could be assumed that it is easier to maintain MRI safety regarding the inpatients as these would not have any personal belongings with them in the same way as the outpatients. This was not, however, the case as these patients were often brought with many foreign medical objects from their respective wards. The MRI staff, mainly the radiology nurses as these are usually the ones present in the MRI Unit, thus end up in difficult situations where they firstly need to locate these foreign objects and secondly find out if they are safe to be in the MRI or not. Exactly how the MRI staff need to deal with situations like these is further illustrated by the following quote:

> So it's become a much more important aspect to consider when accepting a patient. Especially for the inpatients, who can have a plethora of different things with them. A sedated patient, who can come here with a strange tracheal tube that you've never seen before. Then, I'm faced with that situation, standing in front of it and wondering what it is. The anesthesia staff ask me if I can see that tube, and I answer yes I can see it. Then they ask what it is, and I say I've never seen it before. And these patients will be entering the room, so I need to make a decision about

whether I dare to let them in or not. In this particular situation, I said no I don't dare to, because it feels strange. It looked like there was metal around the tube, and the question then was whether it was magnetic or not. In this particular situation, they had one of these things at the surgery department, so they came down with one and we tested it. And it got pulled into the magnetic field. If we'd put the patient in the magnetic field and started scanning, the coils would have generated heat and been able to change their position and so on. Then the mucous membranes in the trachea can get heated up too much, and it can be harmful. So that's the way it is, many things to consider (radiology nurse).

As mentioned, restricting external ferromagnetic objects was something that applied to the healthcare professionals themselves as well. Thus, the staff often reminded both themselves and others of the terrible accidents that had happened, not where they were, but in other hospitals, and that people had been severely injured on being hit by, for example, forceps, or had even died from being hit by larger ferromagnetic objects such as oxygen tubes. One general and oft-repeated saying among the staff usually working at the MRI Unit, e.g. radiology nurses and MRI physicists was; "it's still imprinted on our minds that nothing is to be taken into the room, everything should be removed before entering". A routine pocket check was mandatory, whereby the staff needed to check and empty all of their pockets before entering the room.

In addition to how objects could cause direct injury to patients and staff, there is also another important reason for preventing smaller objects from entering the MRI diagnostic room. This is due to the risk of objects being attracted and stuck to the magnet of the scanner, leading to image quality reductions caused by, for example, signal losses and homogeneity problems. Even a small object like a paperclip can drastically reduce the quality of the image and the magnet's homogeneity:

> Then it can be small things, which can be seen as ridiculous things but which can have serious consequences. A hairpin, for example, might not cause an accident if a patient is lying there, but it may penetrate somewhere underneath. Under a table or inside a little seam where you can hardly see it, but you'll end up with poor images because of the magnetic field being disturbed. We've had that, I think it was someone from anesthesia and there was just a smack, you heard it. We were thinking, what was that noise? Then we realized that something had been pulled away from her body, but we didn't find anything. We had to lift up the table top later on and finally found a little hairpin stuck there. Trivial in one way but not in another, you get image disturbances and there's a negative impact on the magnetic field, giving you poor images (radiology nurse).

Ending up with "poor images" may be seen merely as a quality issue and not directly related to safety concerns. However, the MRI staff explained that, although it happens very rarely, it is possible, in theory, that poor images can lead to false diagnoses as a result of disturbances to the images. This is similar to what radiologists, radiology nurses and physicists call artifacts, something that is more common as the result of internal ferromagnetic objects.

Concerns over safety were not only about preventing objects from becoming missiles, but also about considering "what is put into the patient". Major safety concerns were thus related to ferromagnetic objects as well. Smaller metallic implants and other foreign objects, which may be found in patients' bodies, are a common group of artifacts. Artifacts are shapes that appear in an image, and are not perceived as useful when trying to understand the patient's condition. An artifact is often referred to as an anomaly, something appearing in an MRI image that is not present in the original object under study. It was mainly metallic objects near the regions of interest that were bothersome. As mentioned, artifacts are not only about reductions in image quality as a result of, for example, signal losses, but may also pose a safety risk as they may be confused with pathology and may potentially lead to a false diagnosis.

One way of maintaining MRI safety thus concerned the patient's arrival at the MRI Unit. Before the patient is allowed to be scanned, a special MRI patient checklist needs to be filled out and signed by both the patient and the radiology nurses. In addition to the patient's name, personal ID number, height and weight, the elements making up the checklist consist mainly of a number of yes/no questions. The first couple of questions concern implants and objects inside the patient. One question asks the patient whether or not he/she has any implants, e.g. a pacemaker, medicine pump, neuro stimulator, hearing implant, or other electrical or battery-driven implants, and if so which. Another question asks the patient whether or not he/she has any implanted objects that may consist of metal, e.g. vascular clips, objects such as tracheal tubes, screws, shunts, prostheses, and so on. A follow-up question asks the patient whether or not he/she might have any hidden metal objects internally, e.g. metal splinters, shrapnel, pellets, or gunshot residue. The final questions concern whether or not the patient is pregnant, breastfeeding, undergoing dialysis, or claustrophobic. All the questions need to be answered; if the patient answers yes to any of them, the MRI Unit will need to be contacted in advance of scanning for further clarification.

These safety concerns, regarding when patients are allowed into the MRI Unit, had become part of the mantra of the MRI staff, whereby expressions such as "check the checklist" and "the patient needs to be screened" were common. Highlighting the importance of the checklist, one radiology nurse commented; "you have to check the checklist, if it's okay to let the patient in", thus indicating that the checklist is strictly mandatory, and something always needing to be considered.

The importance of checking the checklist can further be understood in terms of how metallic objects are not only able to cause artifacts, but also how implants themselves can malfunction or even break. Making sure that implants inside, mainly, patients are compatible with the magnetic field was thus a predominant concern. If this is not taken seriously, implants may then start generating heat and cause tissue to burn, as well as stop working, leading to, in the worst-case scenario, potentially life-threating situations. This is especially so when it comes to pacemakers, which have traditionally not been allowed at all in or around the MRI Unit. As manufacturers have started developing pacemakers and other implants that are considered MRI-compatible, patients with these implants are now also being considered for MRI scans:

> There's a lot of that. Which implants patients have, and so on, it comes back to the safety issues. There are plenty of implants, and we have a thick book where you can search for all kinds of implants, such as aortic flaps, biological, mechanical and shunts in the brain, umbrellas in the aorta. They're inserting so many of these things today. It changes with time as well, and implants can become compatible. One such example is the pacemaker, which is possible to scan today. The manufactures have now developed compatible pacemakers, but it's not just a matter of allowing a patient in because a pacemaker is considered compatible (radiology nurse).

As the radiology nurse in the quote above highlights, despite the development of new MRI-compatible implants, much more has to be considered than merely accepting the patient for scanning. Safety concerns regarding interactions between a specific implant and the magnetic field now also require consultations with other healthcare professionals; for example, neurosurgeons in the case of neuro-stimulators or cardiologists in the case of pacemakers:

> Now there are more pacemaker patients, and we always said no to them before because it was too uncertain. But now there are some MR-compatible pacemakers, and sometimes we scan them anyway after having consulted cardiologists, with cardiologists or nurses in-situ who can monitor the patient as regards his/her pacemaker and heart rate. So, after doing all this, we can now actually scan these patients (radiology nurse).

Safety concerns regarding magnetic field interactions with implants are important, not only to the patients, but also to the healthcare professionals themselves. It is not uncommon for staff to also have implants, something which requires safety considerations and is not always thought of:

> I myself had a colleague, I remember when they'd built the new MRI Unit, located outside of the main hospital complex. Then I know we didn't think of the fact that this colleague had implants in her ears, and her implants broke. And they couldn't be redone (radiology nurse).

The quote illustrates not only how MRI safety is important to both the staff and the patients, it also points to how maintaining MRI safety requires ongoing efforts. Staff at the MRI Unit found it quite easy to recall situations where safety had been breached. These situations often seemed to have one thing in common, namely the involvement of healthcare professionals from non-MRI disciplines:

> It's still the case that some people don't take all their stuff off when entering the MRI room. For example, anesthesiologists who have been trained but still don't follow the rules. Phones, yes you know, keys, there are still people who hang onto their stuff (radiology nurse).

Thus, despite the various MRI safety precautions and procedures in place, breaches in safety still occurred. Thus, this suggests ongoing efforts rather than friction-free functioning when maintaining MRI safety. This was especially so during emergency situations:

> I just stand there and I'm focused on the patient, and they come in with stethoscopes, which they're not allowed to do of course and I'm expected to stop them. But you're so focused on sorting out the table and you're standing with your back to them. Just things like when emergency situations occur, then safety can be breached. It's a big issue. It's easy to say that the patient always has to be taken out, and that no people are allowed to enter the room. But when many people are in circulation, and there is staff rotation, then it's a little tricky (radiology nurse).

In emergency situations, the main focus of the staff is trying to save the patient from severe injuries, or even dying, leading to the potential loss of focus on other MRI safety concerns. In addition to this, there are also many frequently different people usually answering the emergency calls; thus increasing the potential for safety breaches further.

Despite the occurrence of safety breaches, the general opinion among the MRI staff was that safety was respected and maintained. Maintaining safety was not, however, something that was self-achieving, it needed ongoing efforts and accomplishments. This was partly achieved by isolating the MRI Unit, and by restricting access to it to only a few healthcare professionals, something that is further elaborated on in the following section.

5.4.2 Organizing to be like Fort Knox

As seen in the previous section, one of the main topics discussed in relation to MRI was the need for safety thinking. One way of dealing with the ongoing efforts to maintain MRI safety has been isolating the MRI Unit, and restricting access to only a few healthcare professionals. Safety issues can thus been seen as shaping the organizing of the MRI Unit into an isolated practice.

It was common among the MRI staff to describe and talk about the MRI Unit as the "MRI bubble". It was a rather old, dark and secure area on the second floor of the central hospital complex. Even though the MRI Unit functioned well in terms of getting the work done, e.g. by making the MRI scanners easy to handle and having radiologists sitting close by reading the images, it was described, however, as neither patient- nor worker-friendly. For example, despite being connected to the main hospital building, it was, in one of the nurses' own words, located "quite remote", requiring patient transports from other departments. A few chairs in the hallways were used as the waiting room, while the hallway itself was described as boring and with no artwork, also being dark and having no windows, either there or in inside the various connected MRI rooms. One radiology nurse described the MRI Unit as follows:

> Closed in, dark and boring. It worked really well from the point of view of doing your duties, but it was dark and you couldn't see daylight. You didn't see anyone other than those you worked with, so if there were four of you, then you only saw them every day.

In addition to being described as secure, the MRI Unit was also considered to be a world of its own, as one radiology nurse explained; "The MRI bubble has been very much like a small secure environment and like a closed world". One way to maintain this secure environment was by putting various warning signs and notices on the doors leading into the MRI Unit. These included warning symbols and said things like; "No access to unauthorized persons", and "Warning, magnetic field". These material arrangements thus contributed to the organizing of the MRI Unit as secure, and thus facilitated the maintenance of MRI safety.

When describing the MRI Unit, some MRI staff even used Fort Knox as a metaphor. Similarly to how this U.S. military reservation consisted of a maximum security and bombproof structure, with mechanical security devices, the MRI Unit was described as a secure environment and a closed world:

> It can sound a little odd, maybe some people think it sounds silly to have locked doors and zones, but we've noticed that it's good to have things like that. It's like Fort Knox, you have to identify yourself here, and not everyone is allowed to enter. You need to have authorization. This is very good because the people who are authorized have been trained in MRI safety, and are then given permission and access to the zone inside the locked doors (radiology nurse).

As mentioned in the quote above, and similar to Fort Knox, the MRI Unit did not allow general visitors, instead only granting a few selected people permission to visit. As one of the MRI physicists described it; "MRI is taken place inside locked doors and there's a very small group of staff who move around there. You've then shut everyone out and it's worked really well." This also meant that everyone knew each other and, if someone unknown were to enter, he/she would easily be noticed: "Today, we're like a small island, shutting out everyone else. We are even closing to the extent that you'd react if someone came in that you didn't recognize" (MRI physicist).

Noticing unknown people was something I got a sense of during one of my observations at the MRI Unit. I was following and observing the visiting anesthesia staff as they were sedating a patient for an MRI scan. As we passed through the locked doors and through the final zone just outside the MRI rooms, the MRI staff already present greeted the anesthesia staff gladly, while simultaneously giving an accompanying person a somewhat inquiring look. The MRI staff asked who this person was and what he was doing there. The anesthesiologist introduced the person, whereupon the MRI staff also asked whether an MRI screening had been done. This situation illustrates that the staff working at the MRI Unit know each other, and that a trained response to unknown people is to firstly question their presence and secondly make sure they are MRI safe.

It was also common among the non-MRI staff to describe the MRI Unit as isolated, secure, and allowing access only to MRI-trained staff. As one surgical nurse commented:

> Have you been down to MRI? It's secure where they sit now. Now it's almost only those who know MRI who are down there with the MRI scanners. And then, anesthesia will come down and help out with the patient. They know exactly what they can and can't do down there.

When describing the MRI Unit, one surgical nurse pointed out that the neurosurgery department is also locked and not considered a "public space", while simultaneously emphasizing the MRI Unit as even more private and secure:

> They're described as being by themselves. Just because not everyone has access, you can't enter the MRI Unit just like that… And I think that makes you think they're secure. Not everyone can access our department either. There's no public space there, and you need to have clearance on your card to get in here and so on. But at MRI, it's even more like that, and I think most people knows that which further creates a sense of them inhabiting their own little world. Just because it is, not everyone has access there. I can't just go there. I can go to another surgical department and ask if I can borrow things. But going to the MRI Unit, I wouldn't be able to enter. I can't just walk in there (surgical nurse).

Generally, no other individuals than the MRI staff were present at the MRI Unit, and the physical space thus did not function as a shared space. The non-MRI staff described the MRI Unit as isolated and locked, also seeming to have become used to this; "The others are probably quite used to how we lock ourselves in. You often hear that you MRI people are on your own. And then I answer yes but there are reasons for that." (MRI physicist)

Even though the non-MRI staff I interviewed and observed did not always understand why, due to asking, for example, why the MRI-staff locked themselves in, there was a general acceptance that the MRI Unit was isolated and secure. As healthcare professionals in general were used to this, it was seldom something that was questioned or challenged. There were, however, occasions when the MRI staff were asked why they locked themselves in:

> But I can hear when I'm sitting here, because the MRI Unit is right outside or the doors are close to the coffee room, so I often hear that there are many people asking why it's locked in there. Many people are satisfied with the answer; it's the MRI Unit, where they always lock themselves in. Then they answer yeah okay. So there's some kind of acceptance that we do what we do (MRI physicist).

The MRI staff were not striving to uphold what they themselves called some kind of mythical reasons as to why the MRI Unit was organized the way it was, or making others believe they were locking themselves in just for the sake of it. As already mentioned, exactly why the MRI Unit was organized as "isolated", "closed", and a "world of its own", and what this meant, was instead something that was often expressed by the MRI staff thus:

> Some people think it sounds silly with locked doors and zones, but we´ve noticed that it´s good to have it like that. It´s very good, because the people who have authorization have been educated and trained in MRI safety, and are then given the permission and access to the zone after the locked door (radiology nurse).

The general opinion among the staff working in the MRI Unit was thus that isolating and securing the unit was good, especially since it ensured that the people in there were trained in MRI safety. Thus, in contrast to how Fort Knox was mainly about protecting the United States' gold reserves and the original copy of its Constitution and Declaration of Independence, the major safety concerns of the MRI Unit were not about stopping something from being stolen, but mainly about protecting people, e.g. preventing staff and patients from getting hurt:

> That's based on safety, to protect people so they don't just go in and inflict damage on themselves or others. It's because of this that we have these safety concerns. And the stronger the magnetic field - the stronger the magnet, and the more important it is to have safety and safety training. So as to protect everyone from just intruding (MRI physicist).

As mentioned, everyone working at the MRI Unit knew each other; they had worked with each other before. Visiting non-MRI staff, e.g. anesthesiologists and anesthesia nurses, consisted of a small group, something enabled by a non-rotational schedule. MRI safety was thus maintained by restricting people's access to the MRI Unit, and by not rotating visiting staff. Maintaining MRI safety was achieved by relying on the familiarity of the staff working there, as described thus by one MRI physicist; "We have been very confident as regards knowing that everyone who works here knows each other.". Knowing each other thus seems to be about trust. The MRI staff therefore relied on their confidence that others possessed MRI safety knowledge. Knowing that non-MRI staff had the required understanding and knowledge helped operational activities to proceed without tensions.

So, restricting access to just a small group of people allowed the MRI staff to maintain MRI safety. This also served to explain why a larger group of people had not been trained in MRI safety:

> Not so high I'd say, but it's also because we've been restrictive about not training any more people than those who need it. Entirely because we want to escape the risk of having people who think they know MRI, but maybe don't. Perhaps it was a very long time ago they did their MRI training, maybe 15 years ago, and a lot of things have happened since then. Things change and they still think they're on top of it. I think that's a dangerous group of people. So, we've been bad at making training available slightly on purpose (MRI physicist).

So, by not training more people than necessary in MRI, it is possible to reduce the number of people who lack knowledge and awareness of MRI safety, but who still think they do. One MRI physicist explained; "Safety is a very important issue and it's very dangerous having untrained staff there [in the MRI Unit]." This was especially important since the general level of MRI knowledge and awareness of hospital staff is considered quite low. This was evident, for example, in the "uninformed questions" often put to MRI staff:

> You still get people saying; "I can go in because it's not on right now". They've thus failed to understand that there's a constant magnetic field and that it can't be switched off (MRI physicist).

In addition to how the MRI staff considered the general level of MRI knowledge and awareness of other hospital staff to be low, they also divided non-MRI staff into two groups. People in the first group did not understand MRI, perhaps, or the various safety concerns, but at least they respected it, realized it was dangerous, and were sometimes even afraid of it. The second group involved what MRI staff called 'ignorant' people who think MRI safety is over the top. One MRI physicist described these two groups thus:

> There are two camps. There are those who are a bit afraid and understand that they're not on top of this and it can be very dangerous. And then there are those who don't think at all, who think that we're a bit ridiculous and exaggerate.

Common to those in the first group were expressions like; "I have a lot of respect for the MRI environment" (anesthesia nurse), and "I'm not afraid, but I have respect for it and I know that strong forces are involved." (surgical nurse)

During a training session, it became evident which people the MRI staff associated with the second group. It was during a session on MRI safety, when the MRI staff were informing the attendees, especially prescribing doctors and transporting nurses, about the importance of letting them know what implants patients have. One doctor commented on this by arguing that there was no point writing down whether a patient, for example, had a pacemaker or not if other parts of that patient were being examined. This doctor continued by arguing that it was unnecessary and would just use up time. One MRI physicist recalled the following situation in which a doctor ignored important MRI safety concerns:

> There was a doctor, during the training blocks, who argued that because they were only examining the brain they wouldn't see, or get any images of, the patient's pacemaker. So, there he thought it would just be to ignore the fact that the patient had a pacemaker, and just pass it through completely. But if we're unlucky, or something, if something happens, we might actually kill the patient. And that's an example how people don't really respect the skills and professions of others. So, I got quite mad at him. But there are people like him, who think they know everything, that it's safe just because there are MRI-compatible pacemakers. But then you

> haven't considered that, for a pacemaker patient, this requires collaborations with various people. You bring in the cardiovascular team who reprogram the pacemaker before the MRI examination, and who check it afterwards to make sure it's still fully functional. And they're present and prepared during the examination if something were to happen. So if you think that, just because there are MRI-compatible pacemakers, we can just go ahead and scan the patient, and don't even write it down and document it for us, because it just means extra work, then you're too ignorant.

Interactions like this, between the MRI staff and other healthcare professionals, over MRI safety concerns, contributed to upholding the notion of not training more people than necessary in MRI. There were times, however, e.g. during parental and sick leave, when new or additional people were needed to work in an around the MRI Unit. Since this did not happen often, or to any great degree, MRI training was often offered without much planning or organizing, as one MRI physicist explained; "Today, we maybe train someone when he or she is new; can you do it tomorrow?, Yes, then we'll do it tomorrow morning, so we meet up and sit down at a computer and go through this training." Having less organized and more personal MRI training can be seen not only as a result of doing it to a minor extent, but also as a means of controlling it. As already mentioned, the MRI staff relied on familiarity to a high degree when maintaining safety. They all knew each other in the MRI Unit and adopting less formalized and more personalized training was one way of upholding this.

Thus, it was in the way the MRI Unit was organized, with little sense of a shared space, intertwined with an isolated and secure practice, with restrictions regarding who could visit, and also more personalized MRI training, that the MRI staff were able to maintain MRI safety. Only people who had undergone MRI-specific training, and who thus possessed adequate MRI knowledge, gained access to the MRI Unit. This was, however, something that could be seen as challenging, especially since using MRI included, and often even required, collaboration with other (non-MRI) healthcare professionals. Work practices and collaboration at the MRI unit are described next.

5.5 Introducing Work Practices and Collaboration at the MRI Unit

The collective performance of making neurosurgery possible relied on the production of MRI. To produce MRI in practice required collaboration among various healthcare professionals. This collaboration included interactions among both MRI staff and other non-MRI staff, e.g. anesthesia staff and surgeons.

5.5.1 Work practices and collaboration among MRI staff

At the beginning of this chapter, the work performed by the MRI staff, and how their work was connected, was briefly described. In this specific section, I will elaborate on this by illustrating typical workflows at the MRI Unit.

For a non-sedated patient, a typical workflow at the MRI Unit starts with patients being remitted to the MRI Unit by surgeons, and then prioritized by neuroradiologists. It is in accordance with this prioritization that the radiology nurses choose an appropriate examination protocol. However, before scanning can start, the patient needs to be subjected to extensive checklists to make sure MRI safety is maintained. Dressed in two-tone scrubs (white bottom and blue top), the radiology nurses are usually the ones meeting the patients as they arrive at the MRI Unit. After being declared safe, the patient can enter the examination room, in which the MRI scanner is positioned. The patient goes onto a platform, where an important part of the radiology nurse's work is making sure the patient is positioned "in the right way". The right way often means as close to the iso-center as possible, in order to make sure as much signal as possible is received, and in doing so also increasing the chances of producing images of high quality.

When the radiology nurses are satisfied with the position, the patient is slid into the actual MRI scanner. The radiology nurses then leave the examination room and enter an adjacent room, called the control room. This room consists of various computers which the radiology nurses use to conduct the actual MRI scan. To help them see the screens better, this room is typically dimly lit. Most of the radiology nurse's working day consists of sitting alone, or in pairs, operating the technology in these rooms.

There is, however, more to conducting an MRI scan than just pushing a button and allowing the scan to be automatically performed. For example, the radiology nurses need to stay focused as they are adjusting various parameters, and the relationships of these, e.g. contrast and field of view, meaning which part of and at which angles the patient is to be examined. "Patients can come in different sizes" and the nurses, for example, need to compromise between field of view and contrast since they want to examine an area big that is enough, but without losing too much signal and risking ending up with poor images. The radiology nurses were often described as "the ones running and doing things", meaning they are the ones sitting and scanning during the MRI examinations. One MRI physicist described them as being the best at "buttonology", indicating how they were the experts at operating the scanner, doing this better than anyone else. The radiology nurses thus had extensive training and expertise in the technology and equipment.

The radiology nurses were directly responsible for producing the images; "We have the responsibility for producing images of high quality." To fulfill this requirement, they need to stay focused and cannot just lean back, which means they prefer not to be surrounded by a lot of people while working. As one radiology nurse commented:

> When you're working, you don't want to have a lot of people around you. You need to do a good job, and it's a workplace. You can't have a lot of noise or a buzz going on around you.

Most often, the radiology nurses were alone in and around the examination and control rooms, but there were occasions when other MRI staff were there too. The physicists, for example, also knew how to scan and operate the magnet, but it was the radiology nurses who were the experts at this. Instead, the physicists had expert knowledge of the parameters underpinning the MRI technology, and thus knew what changes entailed. One MRI physicist reflected upon this as follows:

> But then I have more knowledge of what happens 'behind' the parameters, whenever they change something. If they change a parameter, what does that really mean? And if the surgeons say they want better contrast between this and that, then I'm the link who understands what we need to change to make it better for them.

Acting like a "sounding board", physicists were thus translating information flowing between the surgeons and the radiology nurses as a way to create a common understanding. Furthermore, there were rare occasions when technicians were also present in the MRI Unit. It was mainly during installation work, for example when new MRI-related equipment was being tested and implemented, or serviced, such as when existing equipment needed to be fixed or adjusted. The technicians' work was often referred to as "going through" and "running in" the technology, meaning that they were making sure the new technology passed all checks and tests.

As already mentioned, in addition to the technical part of their work, the radiology nurses also had what they themselves called "the softer" side of their work. For example, an examination protocol is made up of different series; after each series, the radiology nurses need to make sure these are optimal and that the image quality is satisfactory. Since image quality is directly affected by the patient's movements, one important task of the radiology nurses is thus to encourage the patients to lie still. Encouraging them to lie still requires ongoing efforts and can sometimes be difficult, especially since it is generally not perceived as comfortable to be in the scanner. This is done by communicating with the patient via a microphone, both during an exam and between series. The radiology nurses try to run the scan as prioritized by the radiologist, but there are times when the radiology nurses struggle to get the patients to lie still, or when they run into technical issues forcing them to adjust the current MRI examination. They can change to shorter series or even skip certain ones if this is deemed appropriate to the current situation. The radiologists were also accessible if the nurses needed their help, e.g. to clarify which images had been requested, but also in terms of social intercourse. One radiology nurse described how relationships with radiologists involved close interactions:

> Down in the MRI Unit, there's a doctor sitting in a reading room so they're easily accessible. And we have amazingly good doctors, in terms of their knowledge, but also in the way they care for us. And the social part as well.

Another aspect of patient care is how many patients have claustrophobic experiences with MRI, thus radiology nurses often have to calm these patients down, for example by explaining the procedure and that the examination is harmless. Thus, much of the work performed by the radiology nurses unfolds during the initial parts of MRI being produced in practice. Their work practices seem technical in nature, but as illustrated above, patient care also plays an important part. Much of their work also seems isolated, with their work days indeed often being spent in dark control rooms and with their preference of not being surrounded by a lot of people. Their relationships with the radiologists, however, are often described as involving close interactions, despite the fact that the radiologists' main work activities unfold after the actual scanning has been done.

When the scan has been done, the patient is then escorted back to the dressing room. It is now that the work performed by the radiologists intensifies. Images produced by the radiology nurses, using the MRI scanner, are then sent to radiologists in an electronic format. Most often invisible to their patients, the radiologists work in so called "reading rooms", where they sit in front of computer screens interpreting and modifying the images produced by the radiology nurses using the MRI scanners. In the MRI Unit, these reading rooms were positioned on the opposite side of the corridor from the MRI scanner. This meant there was a physical distance between the radiologists and the radiology nurses, with these two occupations thus having their own areas in which to work. The radiologists were not involved very much in the scanning procedure itself as they expected the radiology nurses to perform these particular actions. Instead, and as mentioned, the radiologists' work intensified after the scanning had been done and finished.

The images are the main focus of their work, with the radiologists often describing their current work in terms of "only looking at images". Looking at various images, e.g. the ones taken within the hospital and the ones from other hospitals in need of a second opinion, thus takes up most of their work days. As the radiologists look at the images, they are also simultaneously transforming them into verbal and written records. This is done by analyzing and preparing a report summarizing their findings and impressions, which is then communicated to the referring physician.

For the radiologists, it had not always been a case, however, of only looking at images, their work had instead been developing in this direction over the years. The radiologists often expressed how their work had changed away from being more "hands-on" and performing, for example, patient examinations, towards basically only looking at images. One radiologist reflects on this thus:

> I still think it's fun to have some craftsmanship, and there was more of that when I started working here. Then we were doing angiographs here, and when we were going to treat the patients, we had a special intervention section that did the treatment. But now they also do the examinations. So, now we don't really have anything like that, we just look at images.

Other radiologists shared this view, with many thus seeming to miss what they called "the craftsmanship" of their work, e.g. meaning examinations and closer relationships with their patients. This was not only due to how this kind of work was considered "fun", but also because it was aligned with the training medical doctors underwent:

> The thing is that during your entire medical training, you learn how to treat patients and if you're working with intervention here, then you're also treating the patients. But if you're only looking at images, you're not really treating anyone. It's diagnostics and a bit of detective work (radiologist).

Thus, with this change, it was generally felt by the radiologists that they were now only looking at images. Some of this was explained by the increased number of MRI images being produced, and the increased specialization among the radiologists. More images than the radiologists were able to interpret were being produced, described by one radiologist thus; "… and then I look at everything on MRI, that much I can manage. Because they're producing so much, I can't catch up with it. You just have to do the best you can". This increased volume in combination with the general lack of radiologists meant both an increased workload per radiologist and a shift in the work being done towards focusing on looking at images. Along with the increase in volume, ongoing technology advancements were increasing the complexity of the examinations. New technology makes it possible to obtain a higher resolution and quality, which means that radiologists can see greater detail in the images. To make use of these developments, the work of the radiologist had shifted towards greater specialization and a reduced field of expertise. Despite how the radiologists still considered themselves as having mastered various imaging technologies, and for different parts of the body, they still frequently focused on one technology and concentrated on a specific part of the body. In their day-to-day work, the radiologists were often responsible for a specific MRI scanner, and were thus also considered specialists, on that particular technological equipment too.

As seen from the descriptions above, the MRI Unit involves a division of labor, which assigns each profession different responsibilities. For example, the radiologists' duties were distinctive and isolated, with formulated role descriptions, when compared to those of the radiology nurses. The radiologists read and interpret the images, while the radiology nurses produce them. Most of their working day is spent within their own spaces. The radiologists and radiology nurses are also aware of when their respective actions can be expected, especially since they follow a specific sequence. However, their relationships were also expressed as involving close interactions and some sort of "closeness". Staff at the MRI unit are thus also engaged in the highly-integrated task of producing and interpreting the MRI images. This collective responsibility means they are directly affected by each other's work. This was even more the case when it came to the neurosurgical patients, who also required collaboration with non MRI-staff, which will be described next.

5.5.2 Work practices and collaborations between MRI and non-MRI staff

A university hospital is sometimes the last resort. For the MRI Unit, this meant, for example, trying to deal with difficult cases that other local hospitals had not been able to deal with, or taking care of specialist cases such as brain tumors and neurosurgical patients in general. The majority of all the MRI scans done at SweHos are performed on neurosurgical patients. This is the case not only because SweHos is a university hospital, and thus assigned these patients, but also because many of the neurosurgery patients generally need to undergo MRI examinations. One neuroradiologist described how a large proportion of all MRI examinations consist of neurosurgical patients:

> Most of the work done on the magnet is Neuro… It's like 65% percent Neuro and the rest are a little bit of gastrointestinal and some orthopedic cases, and thorax is perhaps the least common… But most of all, MRI examinations are neuro [examinations].

The use of MRI in diagnosing and treating neurosurgery patients meant collaborations between not only MRI staff, e.g. radiology nurses, radiologists, physicists, and technicians, but also with non-MRI staff, e.g. anesthesiologists, anesthesia nurses, and neurosurgeons. This collaboration between healthcare professionals had certain commonalities, but also played out differently depending on the type of neurosurgical patient and the procedure that had been decided upon.

One such commonality was the high degree of involvement of anesthesia staff. Almost all the neurosurgery patients and procedures involving MRI included patient transportations between the neurosurgery department and the MRI Unit. As the majority of all neurosurgical patients were sedated, this transportation was always carried out by the anesthesia staff. Thus, there was almost always some interaction and collaboration between the MRI staff, mainly radiology nurses, and the anesthesia staff, regardless of which neurosurgical patient and procedure had been decided upon. "Anesthesia within neurosurgery has always been involved in radiology" (anesthesiologist); in terms of MRI, this involvement was similar from case to case, with just minor variations.

When it is decided to transport a patient from surgery to the MRI Unit, the anesthesia staff disconnect the ordinary anesthesia equipment in the operating room. The patient is then moved from the operating table onto a specific table for transportations, and connected to equipment designed for transportation. For example, during transports, the patient is ventilated using either a transport ventilator or manually, with the help of a bag valve mask (BVM). The lack of a shared or co-located facility means that transports between the neurosurgery department and the MRI Unit need to use public spaces, e.g. corridors and elevators. The anesthesia staff thus make sure to bring with them the medicine and instruments that might be needed in case emergency situations arise during transportation.

The anesthesia staff were used to transporting patients as they did this often. Many of them did not worry about the associated risks, mainly because they had never experienced an incident while transporting a patient. At the same time, there was a general understanding, however, that transporting patients between the neurosurgery department and the MRI Unit was not unproblematic. Even though accidents rarely occurred, patient transportations were, for example, associated with elements of risk, e.g. lifts and changes of anesthesia equipment. One anesthesia nurse described some of the associated risks thus:

> When pushing the patient out into the hallway and into an elevator, the pumps shake and may raise the pressure. Thus, there's a potential risk associated with transporting the patient through corridors and so on. And then when you reach the MRI, you have to switch to another respirator, and it's always good to keep them [patients] on the same respirator, because of their lungs. When we help patients breathe with a balloon during transportations, the respirator always keeps a negative pressure, so the lungs will never be completely sealed outwards, instead always keeping some pressure. And these bubbles, where the gas exchange happens, easily collapse if you're lying down. But then we have a little bit of suppression, which keeps them tense, but if you then start breathing with the tube [a bag valve mask], many of them will collapse then, and then the gas exchange in the lungs will worsen.

The following is a vignette from the field notes that illustrates one occasion when these risks became noticeable. As mentioned, since the MRI Unit and the neurosurgery department are physically located in different spaces, the transportation of patients is needed, which may pose certain risks. It also shapes the way in which the work is coordinated:

> During transportation to the MRI scanner, it acts up. The patient's blood pressure is unstable, high and low. The anesthesia staff stop in the hallway and then later on in the elevator as they sense something is wrong. As they start adjusting the devices, they seem to think something's wrong with the equipment, or that some cables have tangled. An increasingly stressful and worrisome situation emerges. Many of the cables are also hanging in a higgledy-piggledy way. The machines and the patient's bed are continuously bumping into floor transitions [due to height differences]. The anesthesiologist says he wants to mix invasive and non-invasive drugs because the indications given by the equipment are incorrect or appear to be wrong.

The above situation thus illustrates how these patient transportations are associated with certain risks. I later had the chance to ask the involved anesthesia staff about this particular occasion; from my field notes:

> Researcher: Because when we went down to the MRI, something happened with the patient's blood pressure?
>
> Anesthesia nurse: It jumped around a lot right? We still thought that his blood pressure was correct, but we don't really know why it got like that.

> And it was the same thing when we went back, but then it was slightly less stressful. It seemed like he got stressed when we transported him, but he was well sedated. We didn't really have a good answer for that.
>
> Researcher: But did you think the indicators corresponded to how things were?
>
> Anesthesia nurse: Yes, we did, because we can also double-check. That was arterial blood pressure and we often take manual blood pressure to check. And then that was high too. So, we actually thought it was high but we didn't really know why. If he just got stressed, or if he had nor-adrenaline, that will raise your blood pressure. It may have been the case that shakings during transportation added a little extra. We don't really know what it was.

Taken together, occasions like this thus make the anesthesia staff aware and reminded of the potential risks of transporting patients. In addition, transporting patients was not only seen as problematic due to the risks involved, but also with regard to patient integrity:

> We need to transport the patient through the coffee room sometimes, where people are sitting and watching. It's not really a good environment from that point of view. Even in the MRI Unit, even though it works, it's not good for patient integrity, and it would be better if that wasn't needed. Today, well it's not the end of the world, sure, but there are still people sitting and looking at our patients while they are lying there sedated. You can have your own opinions about that (anesthesia nurse).

Making sedated patients visible to the "public" was thus experienced as problematic in terms of patient integrity. However, the anesthesia staff had no choice, since the lack of a shared or co-located facility meant that transportations between the neurosurgery department and the MRI Unit needed to use public spaces.

Upon reaching the MRI Unit, it is noticeable how the timing of the work practices done by the anesthesia staff, in terms of collaborations at the MRI Unit, is dictated by the MRI staff. It is the MRI staff who decide the schedule and the workflow; as a result, the anesthesia staff often have to wait in a preparation room near the examination room before being allowed to enter. The anesthesia staff are thus unable to foretell exactly when the MRI staff will be ready. The MRI staff, on the other hand, are able to predict when to expect the actions performed by the anesthesia staff, as they will have decided when the anesthesia staff are allowed to enter the examination room with the patient.

In addition, upon reaching the MRI Unit, the anesthesia staff need to change all their anesthesia equipment to what they call, "special technology that can withstand MR". This is the case because the ordinary equipment used by the anesthesia staff in an operating room is metallic, which is strictly prohibited at the MRI Unit, which has a strong magnetic field. One anesthesia nurse explains; "We have to change all the equipment then. The stuff we have is not compatible, all the equipment we have is magnetic. In all the other operating rooms. So, we have to change it all then." Some of the equipment they change to is similar, in terms of appearance and function, to the equipment used in the operating rooms; "The monitoring equipment is the same, blood pressure and ECG. It's probably similar." Other equipment was different; "Then we have a different anesthesia machine and it doesn't look the same… then it's wireless down there, pulse and ECG". The equipment that the anesthesia staff were used to and familiar with was considered easier to use and made them feel more confident. In contrast, unfamiliar equipment was considered more difficult to use, often giving rise to "hassle" that required ongoing efforts. One anesthesia nurse explained; "The monitoring equipment is quite simple to use, but the anesthesia machine is difficult and complicated. It's probably also simple, but I'm not as good at it as I am on this [ordinary machine]." When asked what was perceived to be troublesome, this nurse responded; "I think it's really complicated and gives us hassle. It brings up alarms and keeps on beeping. But maybe it's just me that doesn't understand it." Other anesthesia nurses experienced the same thing, with one of these also raising serious concerns:

> It brings up alarms for various pressures, high airway pressures. Especially for children, where it shows other volumes than our other instrument does. So, I don't know what's right. Because it's quite a big difference for the lungs to have, especially for a small child, then 50ml can be their entire lung volume and then it's really bothersome if differs so much.

Moreover, it was not only the equipment that needed to change and required ongoing efforts when anesthesia staff worked at the MRI Unit. The cables connecting the equipment to the patient also needed some adjustments and trying out. As one anesthesia nurse explained:

> We need to change the cables and hoses for the syringe pumps because we have, when we stand by the patient's bed in an operating room, we can make do with 1.5 meters. But at the MRI, we need to extend them to double or triple length. We need to get it as far away from the patient as possible, because anything close to the magnet causes poorer images, thus it can cause poorer image quality. So, we try to get all the equipment as far away from the patient as possible, and then you need long cables and hoses from the syringes. That's something we're trying to solve in various ways.

When working at the MRI Unit, the anesthesia staff thus had to change their ways of working. This change was often described using words such as "trying out" and "tinkering", indicating the occurrence of emergent and ongoing efforts. These efforts were performed in collaboration with the MRI staff, e.g. radiology nurses.

The anesthesia nurses were the ones using the equipment and were thus experts on usage; however, it was the radiology nurses who were responsible for MRI safety, and who knew the consequences of the magnetic field on this equipment. The equipment used during MRI examinations is therefore positioned and connected to the patient jointly by the anesthesia nurses and the radiology nurses. For the radiology nurses, the main objective was to strive for as high a quality as possible in the images, while the anesthesia nurses' main objective was to ensure safe and comfortable sedation during the examination. These interdependencies, in terms of knowledge, expertise and objective, affected how they wanted to position the equipment, thus requiring ongoing and emergent interactions between the two groups. These interactions were to a large extent, however, dictated by the MRI scanner itself. Weighing approximately 4 tons and being about 1.5 meters in length (excluding the length of the dockable table), the fixed scanner requires a minimum floor space of about 30m². In addition to being a large piece of technological equipment, it also involves a magnetic field extending out from the magnet three-dimensionally. All the other technological equipment, such that used by the anesthesia staff, thus need to be positioned in accordance with this magnetic field.

There were additional activities at the MRI Unit which also required ongoing and joint collaboration. One such activity was positioning the patient. As mentioned, the radiology nurses' main concern is positioning the patient close to the iso-center, so as to ensure as much signal as possible and, in doing so, increasing the chance of producing images of high quality. For the anesthesia nurses, the main concern is positioning the patient in a safe and comfortable way, by securing the oxygen tube and making sure there is enough padding. Both groups of nurses thus had a say in how to position the patient, with this activity thus being considered part of their domain of authority.

Putting the patient in a supine position (on his/her back) was the joint preference of both groups of nurses. For the radiology nurses, this meant complying with their standardized way of positioning, enabling them to place the coils in ways that ensure as much signal as possible. For the anesthesia nurses, being supine was better than being prone (on his/her stomach), in terms of having "free airways". Moreover, staff churn was low, which meant the nurses also had lengthy experience of working together. They had learned how to position the patient in a way that satisfies both groups of nurses. Taken together, the radiology and anesthesia nurses shared a common understanding of how to position the patient, and thus this was seldom experienced as problematic. However, positioning the patient and maintaining this common understanding also required ongoing efforts and interactions. The following is an excerpt from my field notes that illustrates this:

> Once at the MRI, and when we've entered the examination room, it feels like the situation is somewhat stressful. When the patient is to be lifted onto the MRI table, his/her blood pressure changes and the anesthesia machines begin to beep. The MRI staff continue to position the patient and prepare their coils, they don't act on the beeping. The anesthesia staff tell the MRI staff they need to interrupt their preparations, because they need to instead focus on stabilizing the patient.

Despite how both groups of nurses share a common understanding of how to position the patients, on certain occasions it also becomes noticeable how the existing interdependencies require ongoing negotiations. Thus, on the one hand, integrating the nurses' separate fields of knowledge with their objectives was seldom problematized, as a common understanding was created most of the time. On the other hand, maintaining this common understanding required ongoing efforts and interactions.

In addition to collaborations between the radiology nurses and the anesthesia nurses, the use of MRI in diagnosing and treating neurosurgery patients also entailed collaborations with neurosurgeons. These collaborations are dependent on the type of neurosurgical patient and the type of procedure decided upon.

One common procedure is Deep Brain Stimulation (DBS), which is a neurosurgical procedure that is commonly used for various types of motor disorders, e.g. essential tremors and difficult cases of Parkinson's disease. The procedure involves implanting electrodes in the brain that are connected to a battery, similar to that in a pacemaker, which is placed beneath the skin on the patient's chest. The battery then generates electrical pulses that are sent to the electrodes, entailing that electrical stimulation inhibits the nerve signals causing the unwanted motor pattern.

The procedure starts off with the surgeon identifying the specific target areas in the brain. Doing this requires millimeter precision so as not to interfere with sensitive areas. To be able to do this, the neurosurgeon uses MRI and computerized systems to aid his/her work.

> For example, if we're going to the MRI Unit, we have some surgical procedures, such as DBS, where you sedate the patient, preparing a special crown [a head fixation device], that then goes down to a few coordinates. Once you've done that, you transport the patient to the second floor to the MRI Unit, where you perform an MRI scan. We then calculate, because we need to enter the patient's head in a specific angle in order to reach a specific area inside the brain, where to insert an electrode. The patient is taken back to the neurosurgery department again and into the operating room, where we go in and perform the surgical procedure. Afterwards, we check that everything is correct, so we go back to the MRI Unit and perform a second MRI scan. Then we transport the patient using the elevator back up again, and insert the device as we know the electrode is in exactly the right position (surgeon).

As seen in the quote above, DBS procedures require MRI scans, and often even multiple ones during the same day. This also meant collaboration between MRI and non-MRI staff. For example, neurosurgeons performing DBS procedures are always present at the MRI Unit because they want to "guide how the examination is done":

> It's because we want to be there deciding which images to take, in order for us to calculate the coordinates. And we don't want to hand that over to someone else, we want to do it ourselves. And that means we're in the MRI Unit much more than most of our other colleagues (surgeon).

In this way, neurosurgeons perform part of the work normally done by the radiologists and radiology nurses. This was seen during observations in the control room, where the radiology nurses sit in front of their computers conducting the scan, with the neurosurgeons sitting behind them telling the radiology nurses how to scan and which angles to include. The surgeons were thus closely involved in the MRI examinations, even deciding which images to produce. This collaboration between the surgeons and the staff of the MRI Unit was quite unique to the DBS procedures, however, in comparison with the other surgical procedures. As reflected upon by one neurosurgeon as follows:

> I'm pretty used to MRI because DBS is one of the few niches in which we participate at the MRI Unit. We sit there and decide which images to take and so on. That's the case with DBS, but you don't do that with almost any of the other niches. So, I'm in the MRI environment and we're always present down at the MRI Unit, moving the patient and so on.

Thus, being at the MRI Unit deciding which images to produce, and even interpreting them, was specific to DBS procedures. Other neurosurgical procedures, however, entailed collaborations unfolding differently. One of the most common procedures, brain tumor resection, generally did not include a post-MRI scan the same day as the operation. Thus, the neurosurgeons were often absent during the actual scanning:

> No, they aren't. The patients I'm thinking of are the neurosurgical ones, and they usually come down to us and then we do the examination. Sometimes, the neurosurgeon is present to get a quick look and so on, but they're usually not involved. It's the anesthesia staff then, and then maybe they'll call if they've been told to call the surgeons when the examination has been done. But they're not present while we're conducting the actual examination, usually not. I guess they have something else to do, of course (radiology nurse).

The neurosurgeons interacted instead with the radiologists during major rounds and tumor conferences, as they are known. Major rounds, which take place twice a week in the mornings, entail neurosurgeons visiting the MRI Unit, where the radiologists show them the produced images and give a presentation of their interpretations of these images to the neurosurgeons. Exactly when these images are produced varies, but they are often from the week before. The images can also be from other hospitals, who often turn to SweHos for expert help. One radiologist explained that the objectives during these rounds concern finding out; "What is it then, has something happened, and has it become better or worse?" The radiologists and neurosurgeons discuss particular patients and how to progress in their diagnosis and or treatment. These rounds were often said to be of major importance because the neurosurgeons attend these in the morning before doing their operations, and because how they perform their operations later on is highly dependent on what has been discussed and decided during the rounds.

In addition to these rounds, there are also tumor conferences one afternoon a week. Various clinicians and a radiologist meet up to discuss and make decisions about specific patient cases. Before the conference starts, the radiologist goes through all the patient cases, looking through the images and deciding upon a preliminary diagnosis, or progression. The radiologist also needs to decide which images to show to the clinicians. The conference starts with the radiologist showing images and making a presentation of his/her interpretation of what the findings may be, or how a tumor is progressing. The clinicians can then comment, ask questions, and discuss what seems an appropriate next step for a particular patient. One radiologist says:

> There are a lot of diagnostics; it can be a matter of the treated tumors we need to look at, what's happened, and has it gotten better? Has it gotten worse? How has the medicine helped? There are a lot of conferences with a lot of specialists involved, when we jointly make decisions about how to treat the patient. We sit there showing the images, and telling them [surgeons] how it looks. It's growing here and there and it's spreading here and there.

During these conferences, interactions take place between healthcare professionals, e.g. radiologists and neurosurgeons. Instead of being present at the MRI Unit during scanning, the neurosurgeons attend these rounds and conferences to be able to progress their examination and treatment of their patients.

Interactions between neurosurgeons and MRI staff are somewhat different when it comes to brain tumor resections in children. The most common primary brain tumor in children is malignant, requiring maximal resection. However, highly malignant tumors often grow without a clear-cut border with healthy tissue. It is thus particularly difficult and delicate to carry out a total resection without affecting nearby healthy structures, and protecting children from severe complications such as significant neurocognitive impairments. Being aware of these complications, surgeons are often unwilling to "push" the resection too far, or to be too "brave" during the initial operation, especially not since the navigation system they are guided by uses "old images":

> We have a kind of navigation system to find our way around the brain. It's currently based on old images, on images taken before the operation. And then, when you've been operating for a while, everything can move. It can move a couple of centimeters actually, if it's a big tumor. And it's like driving with a poor GPS, where you risk ending up going wrong (surgeon).

Structures "moving" in the brain was referred to as "brain-shift", meaning a distortion of intracranial structures as a consequence of craniotomy procedures. The preoperative images, in which intracranial pressures have not been modified, do not, thus, accurately depict the structures after this displacement. Thus, neurosurgery is inherently delicate, highly uncertain and centred around the clinical judgment of surgeons. The surgeons order a post-MRI directly after the operation for all children. By doing this, they get an updated image of the child's brain, making it possible to find out whether the resection of the target lesion has been complete, or if additional operations are needed due to tumor remnant, in that case being able to "navigate from an updated map".

Sedating children was generally perceived as more difficult and potentially harmful. Keeping children in one and the same sedation phase during initial surgery, MRI scanning, and then, perhaps, also during any additional surgery was thus preferable. When it came to children, the neurosurgeons were sometimes present at the MRI Unit during scanning, mainly because they wanted to get immediate indications of whether the tumor was still there, and whether there was any bleeding, thus requiring additional surgery. In this case, the neurosurgeons sit behind the radiology nurses who are conducting the scan in the control room. The radiologists turn up when the images are being produced and immediately start interpreting. Most often, the neurosurgeons decide not to continue with surgery as it is considered difficult to "start over again", for example because the patient has already been "closed", entailing that the patient had been sutured and stabilized. One neurosurgeon describes why they perform an immediate post-MRI scan, and why they most often decide not to continue with surgery:

> Yes, it's unusual for us to go back and operate again, because it's pretty complicated. So, it's partly to see that there isn't a hemorrhage, and whether we have to go back and operate. But also to map the tumor, whether it's been removed and how it looks. And, because you have to do it [perform an MRI scan] within 48 hours of surgery, and because they're already sedated, we can do it right away.

However, during what the surgeons and radiology nurses call "the worst case scenario", the child needs to be transported back to surgery again. The potential risks associated with transporting an anesthetized patient provides another reason not to continue with surgery.

To sum up, in order to make neurosurgery possible, there was a reliance on the production of MRI. MRI was produced, in practice, by collaborations between the MRI staff as well as between the MRI staff and the non MRI staff. These healthcare professionals often performed varying tasks, but were also reliant on ongoing interactions with each other to coordinate their work.

5.6 Analytical Summary

In what follows, I summarize and discuss how the practice of MRI was performed and organized before the introduction of the new iMRI Hybrid OR. From the findings, work related to MRI appears to be continuously evolving, with technological advancements and increased specialization occurring. These dynamic features are, however, unfolding alongside a continuous process of stabilizing the social setting and the physical space, which are in turn implicating and facilitating coordination processes.

5.6.1 The stabilizing of the social setting

In spite of the fact that MRI constitutes a mostly dynamic field, ongoing effort of continuously stabilizing the social setting existed. When the underlying arrangements, including interactions, status and hierarchy, are not challenged, this in turn facilitates coordination.

As described in this chapter, work at the MRI Unit is traditionally organized using a distinct division of labor. Put simply, the radiology nurses are responsible for operating the machines and producing the images, as dictated by the radiologists, who interpret these images once they have been produced. The radiologists then communicate and interact with the neurosurgeons during formal rounds and conferences. Technicians and physicists provide guidance and assistance whenever it is deemed necessary. With a distinct division of labor and expertise within well-established occupational jurisdictions (Bechky, 2003), there is generally little overlapping of or role substitution during duties (Nancarrow & Borthwick, 2005), and thus little need to understand each other's work. However, despite coordinating work through isolation or fragmentation (Wolbers et al., 2018), there is still a continuous need for interaction and alignment as regards separate duties. Producing and interpreting images does, in fact, require collective accomplishment in the way the isolated duties directly affect each other. A prevalent need for interaction and the alignment of distinct and isolated duties was also evident with regard to the non-MRI staff. For example, the anesthesia nurses transport the patient from the neurosurgery department to the MRI Unit, but this specific duty is both dependent on and conditions the duties and the timing of the tasks performed by the radiology nurses. Another example is the fact that the anesthesia nurses are experts in using MRI conditional ventilators but that the radiology nurses are experts in, and responsible for, the impact of the magnetic field on this equipment.

This way of dividing up expertise and labor, and structuring interactions, is a part of constituting the MRI Unit's traditional arrangements, which were not threatened by the technological advancements and associated specialization occurring. Instead, these arrangements were sustained and reproduced through even greater specialization, with the MRI staff being responsible for a narrower field of expertise. Professional groups working in and around the MRI Unit viewed themselves more and more as experts within specific and narrower fields. This increased specialization also contributed to a further and more distinct division of labor, whereby each professional group is assigned specific responsibilities and distinct duties.

Work done at the MRI Unit was also embedded in status and hierarchy structures, which influenced interactions and coordination. As the radiologists were thought to possess respected and prestigious expertise, and to also be controlling others' duties, e.g. dictating MRI examinations, they were constructed as high-status actors by the MRI staff. In addition to the respected expertise of the radiologists, the radiology nurses were also constructed as high-status actors in that they possessed formal authority related to maintaining MRI safety. Although it was a responsibility shared by all the professional groups present, maintaining MRI safety during day-to-day activities was ultimately the main responsibility of the radiology nurses. The MRI physicists had the greatest in-depth knowledge and expertise regarding magnetic fields and their related MRI safety concerns, but they were seldom present at the MRI Unit. Instead, it was generally known by all the professional groups that the radiology nurses were the ones knowing the details of MRI safety, and that they should thus be deferred to. These differences in terms of possessing expertise in MRI, the authority accompanied by it, and its salience during interactions and coordination were not threatened by the dynamic features characterizing MRI work. Despite how additional scanners had been installed and additional parts of the body were being examined, the MRI staff continued to have more or less unrestricted access to the MRI Unit and its resources, while the non-MRI staff were being restricted more. The radiology nurses made sure checks were made on both the patients and the staff, as well as restricting potentially dangerous equipment from getting too close to the magnet. Thus, they had control over task distinctions and resources. In addition, whenever ambiguities emerged regarding MRI safety, e.g. whether or not a specific duty could be performed at the MRI Unit, or whether or not a specific piece of equipment was safe to use, it was the voices of the radiology nurses that were given greater weight.

Moreover, with technological advancements, additional implants and other related tools were introduced to the duties performed at the MRI Unit. However, the maintaining of MRI safety continued to be managed by means of the radiology nurses controlling and dictating how technological equipment in use at the MRI Unit needed to be positioned, in order to meet the requirements of the MRI scanner and the magnetic field. For example, being able to examine sicker patients often required the increased use of anesthesia machines, but as these not only ran the risk of malfunctioning, but also interfered with the images if placed too close to the MRI scanner, the radiology nurses maintained a great deal of authority in dictating the position of these machines.

Based on these findings, we start to understand how status differences are intertwined during coordinating processes (Anthony, 2018). The organizing and coordinating of the work done at the MRI Unit was informed by the salience of the status and hierarchy structures. Who was doing what and how was largely shaped by the status differences between the professionals groups. We know that coordination does not unfold in a relational vacuum, but through the entanglement of relationships (Gittell, 2002); while others have stressed how status differences work to pose significant obstacles to coordination (Anthony, 2018; Gittell, 2001; Okhuysen & Bechky, 2009), the findings in this chapter show how status differences and hierarchy structures may also facilitate coordination. By sustaining and reproducing the social setting, the advancements occurring were made to work and thus coordination proceeded accordingly. As such, it is not only a question of how the social setting, including status and hierarchy structures and interactions, changes or not when faced with the introduction of new technology, but also of how the existing social setting, which shapes the nature of the coordination that exists before a technology is introduced, may influence that technology's consequences as regards work.

Furthermore, we also know that professionals tend to reproduce and sustain traditional arrangements when new technologies or innovations are introduced which will potentially disrupt the social structure (Van Maanen & Barley, 1984). However, at the MRI Unit, the social setting was mainly stabilized to reproduce and strengthen the existing smoothly-functioning coordinative arrangements.

Overall, MRI is a most dynamic field where technological advancements and increased specializations occur. However, these dynamic features occur in a largely stable social setting, including status and hierarchy structures, and interactions. This is the case because the dynamic features do not threaten the underlying arrangements, but it is also the case because healthcare professionals actively work toward sustaining the arrangements. This means that, despite being considered a stable social setting, the stabilizing is not to be treated as static, because structure, too, is an emergent property of ongoing action (Barley, 1986).

5.6.2 The stabilizing of the physical space

As described above, MRI-related technological advancements are occurring at an accelerating rate, making it possible to perform better and faster examinations, as well as examinations on previously unthinkable patients and less explored parts of the body. Given the general experience of MRI as the 'gold standard' of all diagnostic methods, more scanners are being installed and the number of examinations is continuously increasing. Associated with these technological advancements, there is also greater specialization, through which MRI staff are responsible for a narrower field of expertise. While MRI constitutes a mostly dynamic field, the stabilizing of the physical space in which these advancements are occurring and deployed, as well as used, is materializing. This stabilizing means arrangements being sustained, in turn facilitating coordination processes.

As described in the findings, maintaining MRI safety was one of the most important concerns of the MRI Unit. Despite how the technological advancements, including, for example, stronger magnetic fields and the possibility of examining additional patients with implants, pose potential MRI safety risks, the ways in which MRI safety was managed were sustained. The traditional material arrangements continued to be involved, e.g. how certain objects that could potentially be dangerous continued to be restricted. In practice, this was often facilitated by incorporating material objects in various ways; warning signs adorned doors and floors to indicate the danger associated with so called ferromagnetic objects being in a strong magnetic field. Checklists and protocols could still be used to make sure no unknown metallic objects inside patients were brought into the magnet, or to prevent occasions when implants malfunctioned or hurt patients. Moreover, the MRI Unit, and the duties performed there, continued to be organized in a similar way to Fort Knox, i.e. physically isolated and secure. The MRI Unit was positioned as 'quite remote'; doors were locked, access restricted to a small group of people, and signs warned that it was not allowed to access the unit, thus prohibiting it from functioning as a physical space shared by various healthcare professionals.

In addition, despite the greater level of specialization, the work performed by the MRI staff continued to be performed in isolation, as regards both time and space. The radiology nurses are present in close proximity to the examination room when operating the machines and producing the images and, once the images have been produced by the radiology nurses, the radiologists interpret these in the reading rooms. The radiologists communicate and interact with the neurosurgeons during major rounds and conferences, as the neurosurgeons are typically absent during the production or interpretation of the images. The overall changes occurring do not challenge the seemingly functional and traditional coordinative arrangements, including the performance of work within the expert practices (Bruns, 2013), and the traditional division of expertise and labor in terms of being isolated in time and space, which jointly contribute toward clarifying who does what and where.

In this way, work at the MRI Unit continued to be defined largely in relation to physical space. Coordination at the MRI Unit is materially enacted in space, something which was not threatened by the advancements occurring, with the healthcare professionals also worked toward sustaining this traditional way of coordinating their work. Thus, the stabilizing of the physical space is a combination of how the advancements are allowed to be introduced, without threatening the underlying arrangements, and the efforts healthcare professionals make to sustain these, jointly facilitating the coordination processes. As the stabilizing of the physical space motivates and enables the healthcare professionals to maintain the coordinative arrangements, space emerges both as the way and the outcome of the coordination processes it recursively organizes. Based on these findings, we start to understand how the MRI Unit, as a physical space, not only contains the coordination processes, but also how the coordinating of the work done at the MRI Unit is highly intertwined with the material arrangements (Barrett et al., 2012; Beane & Orlikowski, 2015).

CHAPTER 6

PLANNING AND PREPARATORY IMRI HYBRID OR ACTIVITIES

As seen in the previous chapters, work at the neurosurgery department and the MRI Unit is based on well-established coordinative arrangements, including role boundaries, accountabilities, and material arrangements. When introducing the iMRI Hybrid OR, multiple and previously separated groups of healthcare professionals, such as neurosurgery staff and MRI staff, as well as objects such as the microscope and the MRI scanner, are brought together. With this novelty, achieving integrated action is predicted to be more difficult, as it confronts the traditional arrangements and involves greater uncertainty regarding how interdependencies will contribute to collective performances (Carlile, 2004; Wolbers et al., 2018). Responsibilities for organizing local courses of action (Jarzabkowski et al., 2012) are now expected to move closer together to form a collective approach, and the emergence of new ways of organizing work is thus expected. In this chapter, the planning and preparatory activities leading up to the initial use of the new technology will be described.

6.1 Selecting the Team of SuperUsers

As mentioned, in contrast to the neurosurgery department and the MRI Unit, with their traditional and well-established teams of healthcare professionals, the iMRI Hybrid OR required a new constellation of healthcare professionals. Thus, an important task was to select the so-called SuperUsers, i.e. a group of healthcare professionals designated to prepare, plan and work in the new room from the start. This selection was done with the guidance of AmTech (a pseudonym), a US-based medical technological company specializing in systems combining MRI with surgical environments. As will be described later, AmTech not only delivered the technological system, it was also responsible for formal training and so called readiness action planning. AmTech provided the hospital management at SweHos with a worksheet upon which it had described what was meant by a SuperUser, listing the appropriate composition of specialties and disciplines each SuperUser would represent. A

SuperUser was described as "someone with an in-depth understanding of the workflow within this environment".

Healthcare professionals had the chance to show their interest in working in this specific setting; operations managers together with an MRI physicist (also the local coordinator of the SuperUser group) then decided which candidates to nominate. When selecting the SuperUsers, SweHos followed the suggestions made by AmTech, with some adaptations. The local coordinator explained:

> Some roles originating from AmTech did not fit with our context, with how our organization looks. We don't have all the roles that a US operating room has, not in a Swedish operating room. So they made a list of these roles, and then we put names to the ones who have these roles, and who should be included. We've added some roles, and for some roles we didn't write any names, either because they don't exist or we didn't think they'd be involved in an operating room like this.

Examples of roles not relevant to SweHos included various grades of surgical nurses who do not exist in the Swedish healthcare system, as well as IT support and cleaning staff, who could not be assigned specifically to this room. In addition to, and partly in contrast with, what AmTech had suggested, poignantly advocating "starting with a core group of people who will work in the new room", SweHos also decided to include more SuperUsers for each role. This was a way to cover for staff sickness and schedule constraints, as explained by one surgeon:

> It's better if more people are part of this training, AmTech wants fewer people, a small group. (…)I think it's important that many people are part of it right from the beginning. Because, as we work, if you run an organization, it's not possible to base it on only a few people.

Given this awareness of how a small group of people would create vulnerability, more healthcare professionals than the number suggested by AmTech were thus included, with the final SuperUser group consisting of neurosurgeons, registered surgical nurses, assistant nurses, radiology nurses, technologists, anesthesiologists, anesthesia nurses, radiologists, and MRI physicists (also the local coordinator of the SuperUser group).

Apart from having lengthy experience of working with neurosurgery, and possessing particular skills, the SuperUsers also shared technical interests and the desire for 'something new' and to 'build something from scratch'. When asked why they joined and had been nominated, common responses included; "I've always been interested in technical stuff, technical development, so that's probably why I ended up in this project" and "It's exciting when something new happens, which didn't exist before. Being involved in this and building it up. It'll be fun to be part of something right from the beginning". As such, the selection of a team of SuperUsers was made deliberately and based on what AmTech recommended, but with local adaptations. Following selection of the SuperUsers, it was time to plan, prepare and train for the introduction of the iMRI Hybrid OR.

6.2 Planning, Preparing and Training

Many of the SuperUsers experienced the introduction of the new technology as uncertain and a long way into the future. One anesthesia nurse, for example, said; "It's still a bit remote". This general experience also shaped how planning and preparing were performed. The same nurse continued:

> There isn't so much talk among my colleagues, the anesthesia staff, because it's a long way off as yet. It feels like several years away, but it isn't. It's just six months away.

Nurses from surgery shared similar experiences, "It's taken such a long time", thus being planned and prepared as they went along. "We take one day at a time, we take one week at a time and we see what's happening". The emergent and ongoing planning and preparing was not only explained in terms of being due to time, but also in terms of being due to the uncertainty that was experienced and the major restructuring that the new technology would actually entail:

> So, it's a totally new organization that will need to be developed over there. And, as we said during a meeting yesterday, we know we'll have certain things. But many things we'll only notice when we're there. What works and what doesn't. Much can be done beforehand but some things need to be taken on an as-and-when basis. It's difficult to know right from the beginning, even if you have the drawings and know the exact measurements. It's still difficult to know. An incredible amount of stuff, like materials and equipment has also been bought. And that's what's in the pipeline and not even here yet (assistant nurse).

However, many of the SuperUsers gradually started realizing there was actually more to be done and that many aspects remained uncertain, which seemed to give rise to a need for a more thorough level of engagement in planning and preparing. One surgical nurse said:

> Step by step, you realize there's a little bit more that needs to be organized. We haven't really received any directions or orders about what we're supposed to do. We've been noticing that more and more. What we should be doing. We'll certainly take care of that too. But we don't really know so much.

Thus, despite the fact that the new technology and the room were still under construction, and that the initial use was experienced as a long way into the future, many activities related to training and planning still needed to be performed. Many of these activities were related to a training program that had been procured.

One way to plan, prepare and train for the new iMRI Hybrid OR was by engaging in structured training and readiness activities. The hospital had not only procured the technological system to be used in the iMRI Hybrid OR but also a training program, from AmTech. A clinical application specialist in operating room workflow and a clinical application specialist in MRI were in direct contact with SweHos. As many of the SuperUsers were not preparing so much in advance of the program, they were passively waiting for it to start; "So far we haven't prepared a whole lot, but it's what they'll be suggesting, how they propose that we'll be working, so we can learn from that" (anesthesiologist). The program mainly consisted of a series of formal and structured meetings, when SuperUsers gathered in conference rooms, going through action plans designed by AmTech.

In addition to the SuperUsers themselves, the two clinical application specialists from AmTech (via Skype), and frequently also the related operations managers, were also present during the formalized meetings. It happened more than once that doctors were busy treating patients and thus could not attend the meetings. As these occasions were beneficial in terms of training together, and in doing so creating a common understanding, any absences proved to be unfortunate. The following was raised during one SuperUser meeting:

> The SuperUser group discusses how the work flows and processes are going to be in the new room. One anesthesia nurse says; 'it would have been good if we had our doctors here', referring to how doctors not only have important knowledge that has to be considered, but are also medically responsible, and thus important when formulating policies and method cards (field note).

SuperUser meetings were also beneficial in terms of getting to know each other. This was especially the case for those not working together previously. One radiology nurse explained:

> We're working really well already with the anesthesia staff in neurosurgery, and the surgical nurses we'll be getting to know now. You get to know them when you go to these meetings, they don't have to be grand meetings, it's enough to meet up and talk a bit about general stuff too. Then you get a bit more feeling, you know who the people are and so on. It's good to have these meetings, you get to see who the person behind the voice or name is.

With few exceptions, many of the SuperUsers from the different disciplines had not worked together before:

> We hadn't worked together before. We [the surgical nurses] had no workplace relationship with them [the MRI staff] before starting with this [introducing the new technology]. I knew who one of them was, I don't know from where, maybe from a course or something. But we had met previously (surgical nurse).

Many of them had not met at all before; 'No, the first time I ever met them was basically when we gathered for the meeting, so not until this point no' (anesthesia nurse). The goal of the formal training and structured meetings was to train the SuperUsers to "optimize the independence of the hospital with respect to maintenance and the training of individuals to work safely and efficiently within the iMRI environment. SuperUsers are to be able to independently train future employees" (clinical application specialist). To accomplish this, ways of maintaining MRI safety in the new environment emerged as one of the most important issues needing to be discussed and planned first.

6.3 Maintaining MRI Safety in an Environment Full of Metallic Objects

Discussing and planning for how MRI safety could be maintained was especially important for several reasons. The new technology meant a room that would be full of various metallic objects most of the time, such as surgical and anesthesiological devices and equipment, thus posing serious risks regarding MRI safety. The technology would also mean more, different, and new healthcare professionals working in an MRI environment, being in stark contrast to how the MRI Unit was traditionally organized in order to maintain MRI safety.

6.3.1 Introducing the role of the safety nurse

One way to maintain MRI safety in the iMRI Hybrid OR was to introduce a new role, namely the safety nurse. The idea for a safety nurse stemmed from AmTech and was described as "a cross functional role whose primary responsibility is to maintain a safe iMRI Hybrid OR". Exactly who would take on this new role was not obvious, but the local coordinator and managers had an idea:

> I don't know what we've decided, but we think it's better if it's a nurse from surgery who has this role. They already have knowledge and experience of working in an OR. They're also highly disciplined and accustomed to counting their stuff. They're more comfortable in that role. It will then be a smaller step to train them in MRI safety than getting a radiology nurse to be comfortable in a role in an OR.

Although the local coordinator and managers had an idea, it was important that the SuperUsers themselves discussed this question too. The local coordinator continued:

> I have talked to both of the unit managers, and after that the heads of departments will discuss what they think. And then we'll have a meeting with the heads of departments and the SuperUser group. This is because they [SuperUsers] are the ones who have the most practical opinions about how this should be.

The safety nurse question was thus experienced as entailing the most practical implications for the SuperUsers, but this question was not only a matter of what the role would include. It was also a question of resources, turning into a 'budget war issue':

> But then the person needs to be replaced by someone else who does what he or she normally does, and then the question is whether more resources will be needed, and more people will need to be hired. So, even if we have

> a candidate who's suitable as a person, surgery may not want to let that person go. Then there'll be a kind of budget war. (Local coordinator)

Thus, at the initial SuperUser meetings, during which the safety nurse question was a major issue for discussion, unit managers and heads of department were present. As the local coordinator explained:

> The safety nurse role becomes an important issue not only regarding what the role should mean, but also organizationally. Should the person be employed under radiology or surgery? The heads of department thus wanted to attend these meetings when they were told that a safety nurse would be appointed.

The SuperUsers themselves had little understanding of what a safety nurse was. One assistant nurse from surgery commented; "Then, on the SuperUser list, it said safety nurse, what's that? Who's that? Who's going to do that? We didn't get it all". One way forward in reaching a decision on the safety nurse was clarifying what the role would entail. During one of the initial SuperUser meetings, AmTech thus showed a PowerPoint slide, in which a number of bullet points were used to describe the role, and these included the following:

Textbox 1. Bullet points describing the safety nurse role.

- Ensures a team approach to safety in the iMRI Hybrid OR
- Performs counts with Anesthesia and Scrub Person
- Monitors movements of staff in and out of the OR
- Performs all the extra safety functions outside the normal assistant nurse duties
- The assistant nurse, while equally responsible for safety, should not have to take time out from his/her role in patient care
- Maintains the checklists
- Trains and orients new staff to the iMRI Hybrid OR.
- Prepares room for magnet entry

The SuperUsers at the meeting read these bullet points and their immediate reactions included a combination of curiosity and doubt. The role of safety nurse was, for example, completely unknown in Swedish healthcare, as commented on both by a surgical nurse; "We've never had this role before", and by a head of department; "We can conclude that it's a new role that includes duties that we haven't had before". Discussions among the group members quickly turned from what the role would entail to who should take that role. As mentioned, it was far from clear whether it was going to be someone from anesthesiology, radiology or surgery. As one assistant nurse said; "Are we supposed to take on that role, or will it be the surgical or anesthesia nurses? We thought, help what does it mean". One way forward lay in comparing the new role with existing knowledge and duties. For example, the anesthesia staff argued that they were not suited to taking on this role, especially because they were unfamiliar with the surgical devices and equipment, as one anesthesia nurse commented; "I don't even know the names of three percent of your stuff, your instruments and so on". They were also going to introduce new ways of working, something which was considered difficult enough, and thus adding a new role would be considered too much. One anesthesia nurse commented:

> We've been thinking about who this safety nurse should be and we realized quite quickly that he/she couldn't be anyone from anesthesia. We don't know about any of the material and equipment used by the surgical staff. In addition, we'll need to work in new ways ourselves when, for example, we have to count all our own stuff. A surgical nurse would fit well, but there's a huge lack of surgical nurses.

The anesthesia staff were thus suggesting that assistant nurses would suit the safety role particularly well, especially since they often had a broad set of skills from surgery and anesthesia, and sometimes even radiology.

In an attempt to move forward, the group discussed with AmTech how it had done things in other hospitals that already introduced an iMRI Hybrid OR. One assistant nurse asked; "but how are things done in other places then?" The local coordinator, who had been on various educational visits to other hospitals, answered; "Where I've been on educational visits, there's been a person from MRI who made it his/her *own baby*". The clinical applications specialist from AmTech similarly explained that, in the US, "it has often been a nurse or technologist from radiology, especially since they've already been trained in MRI safety". However, just taking the concept of the safety nurse from other contexts, and then adopting it into the Swedish context was not seen as satisfactory:

> What we've realized is that [AmTech] cannot just tell us what to do, we need to shape things [the role of safety nurse] in ways that fit with us and our practice. They may not do things the same way that we do in the US (assistant nurse).

The role of the safety nurse thus needed to be adapted to the local context. The group discussed how the iMRI Hybrid OR had been designed, using a combination of MRI and surgery procedures, with the safety nurse thus needing to master issues from both these practices. A common understanding among the group members was that, in a Swedish context, it made more sense to have a nurse from surgery taking on this role. Because this differed the least from how they worked traditionally, it was considered easier to train a surgical nurse in MRI issues than to have a radiology nurse learn surgical issues.

One of the heads of department summarized what the group had discussed during one of the initial SuperUser meetings thus; "I can then conclude from our discussions that all of us seem to agree that it should be an assistant nurse from surgery". After it had been decided that an assistant nurse from surgery would take on the role, the SuperUser group had to decide on a specific person. In deciding on this person, they referred back once again to what the safety nurse would do. During the meeting, the local coordinator explained the role thus:

> This is a person who owns the checklists, keeping track of the patient but also of what goes into the room and what goes out. When the MRI staff are going to use the MRI, this person needs to make sure it's safe. This means being involved all the way from preparations to the the last part after the surgery.

The important thing was thus to ensure MRI safety before, during and after surgery, including "having control over what goes into the room and what goes out, but also checking the people who are entering the room". One radiology nurse added; "The safety nurse will ensure that the room is safe for me to bring in the MRI scanner. Consequently, before the disco lights can be turned on, and before we release the smoke". However, the role not only involved securing the room in order for the MRI scanner to be deployed, it also involved maintaining MRI safety while the scanner was parked in the 'garage'. The MRI physicist replied to the radiology nurse thus:

> But now we not only have the patient to think about and make sure is safe, but also the room itself. Even when the doors are closed, part of the magnetic field is still present in the room.

Thus, while the MRI scanner was not needed in the operating room, it was going to be parked in a room nearby, often described as the 'garage'. But even if the MRI scanner were to be parked in the garage, with closed doors, this would still mean that a magnetic field was active inside the iMRI Hybrid OR. This stray magnetic field was indicated by a line on the floor, becoming an important part of the role of the safety nurse. Located almost in the center of Figure 6, the dark blue line is seen as almost surrounding the open doors leading into the MRI garage.

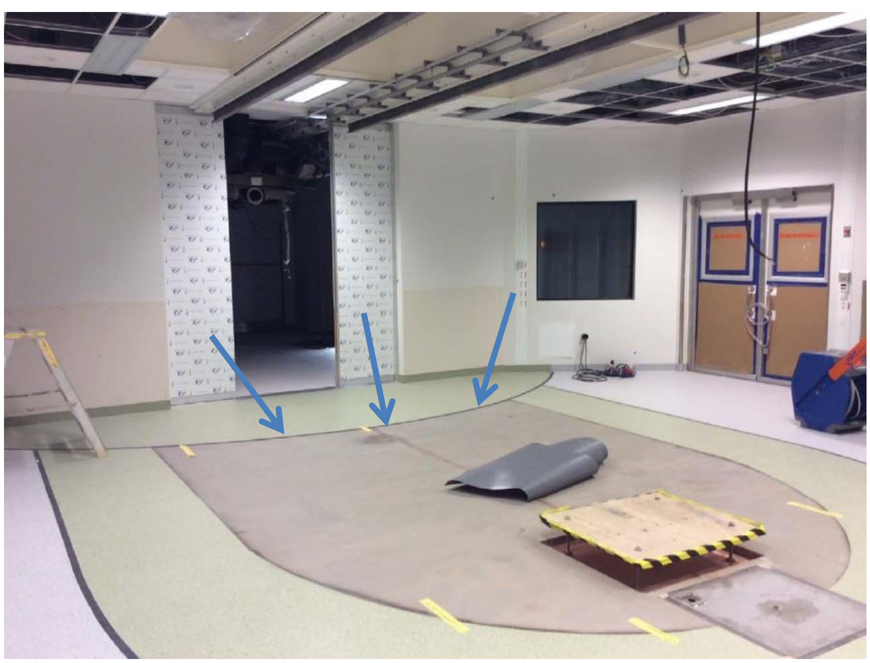

Figure 6. The iMRI Hybrid OR under construction.

An important task performed by the safety nurse was thus to safeguard this line, to be a 'defender' of it. Individuals without a security clearance or who were not authorized could not cross this line. The role of the safety nurse was described using many nicknames, and could be summarized in terms of someone possessing great authority and courage. The group decided that this nurse had to be almost cocky. As one anesthesia nurse said, "Yes, someone with courage who thinks like a rugby player, a terrier able to protect the line". The local coordinator agreed and added, "This person must be able to confront those entering the room, and to be comfortable asking who they are. Is it ok for you to be here? What training do you have?" After the SuperUsers had started comprehending what was actually required from the role of safety nurse, a shared understanding emerging was that a specific assistant nurse in the group seemed the most suitable. One surgical nurse even commented that this person was the only one who could be the safety nurse, "I think Linda's the only one who can have that position". The assistant nurses, however, decided they needed to train at least two people to become safety nurses. As one of them commented:

> We decided that us two assistant nurses would learn both things. Becoming both an assistant nurse and a safety nurse in the new room, so both of us would need to be there for all the cases. So, that we could learn both roles.

What the role of the safety nurse would entail, and who it would be, thus became clearer after the first couple of SuperUser meetings. The safety nurses themselves, however, continued to express concerns regarding what they had agreed to, and what was expected from them. During interviews they said, "Now, Karin and I will be safety nurses, whatever that means. We've tried to find out what it means", and "Help, what have we got ourselves into? When we were told about this safety nurse thing, we didn't really know what it meant, we had no clue". The assistant nurses who were designated as safety nurses were thus requesting; "to know more about what the role entails". During upcoming SuperUser meetings, the role of the safety nurse continued to be an important topic. This was not only the case because the designated safety nurses themselves were uncertain, concerned and searching for more clarity, but also because of what the SuperUser group would later decide on regarding emergency situations related to the new technology.

During certain emergency situations, often called 'crash calls' or 'code blues', the patient is in need of immediate medical attention due to respiratory problems or cardiac arrest. It was common among the healthcare professionals, who I talked to, to describe how a situation like this becomes chaotic quite quickly as other healthcare professionals are responding to the alarm and rushing into the relevant room. This is usually a code team, consisting of physicians, critical care nurses, and a variety of other medical specialists, e.g. anesthesia doctors and nurses, whose primary objective is to attend to the critical patient. SuperUsers also told me that, in addition to this code team, a bunch of other hospital employees also respond to these alarms. These people carry with them various pieces of equipment, e.g. a defibrillator, oxygen cylinders, and crash carts with medicine, in order to save the critical patient. However, this would pose a serious risk to MRI safety, and thus a major topic during SuperUser meetings was discussion around how emergency situations were especially critical and complex in relation to the new technology. In line with this understanding, the SuperUser group often discussed, during its meetings, how it would need to change and develop new routines for emergency situations. One anesthesia nurse explained:

> What will need to change is what happens during emergency situations, and how to keep people away. When you have crash calls, a whole bunch of people come, and then we need to stop them. They can't come in if the scanner is there. Because they'll be carrying all kinds of magnetic things, phones, ID cards, bank cards, scissors, forceps, and everything else you can imagine.

The SuperUser group firstly discussed how both the code team and other responding healthcare professionals could smoothly be MRI-screened during emergency situations. It was not only a matter of having them leave all their metallic objects outside the room, but also about ensuring that the staff did not have any vulnerable implants themselves. After intense discussions back and forth, however, they decided the following; "instead of screening all responders, during crash calls, the safety nurse will need to secure the room and the line". This was a decision that affected the role of safety nurse since; "this person will become extremely important and critical" (local coordinator). Despite the fact that the group realized that the current routines for emergency situations needed modification, reliance on the safety nurse meant that the SuperUsers "wouldn't have to change the emergency routines entirely".

The new routines were divided up between crash calls when the scanner was being deployed and those when it was not. The former routine would include the attendant anesthesia nurse performing immediate CPR while the radiology nurse was removing the MRI scanner. The safety nurse would put up a plastic chain or warning/barrier tape to protect staff from walking into the 0.5mT field (the blue line mentioned and illustrated earlier). Only when the MRI scanner is parked inside its garage, and the doors are closed, can the operating room doors be opened and the code team allowed to enter. Thus, the sole focus of the safety nurse is to protect the blue line. The latter routine would include the safety nurse putting up a plastic chain or warning/barrier tape to protect the blue line, and then letting the code team in, with the safety nurse then focusing on protecting the line.

As already mentioned, the SuperUsers' decision to develop the emergency routines in this way had major implications for the role of safety nurse. The SuperUsers discussed this thus:

> Anesthesiologist: Even when the MRI scanner is not being deployed, the safety nurse will still need to be there and secure the room. The safety nurse will need to stay inside the room.

> Surgeon: Okay, but what about during the scan? How far can the guardian of the line go? He/she must be able to reach the room before the code team gets there. Maybe to the coffee room here, but not back home [the neurosurgery department].

> Anesthesia nurse: Yes, during the MRI scan, which goes on for about an hour. Then this person can't leave the room like we usually do. He/she can maybe take a break close by, or take a chair and sit with me and the MRI staff.

After further discussions, the local coordinator summarized what the group had decided on and what implications this would have:

> Local coordinator: The safety nurse will need to be present even during non-MRI surgery. In any case, the role needs to exist and to be well-defined. The safety nurse can't leave the MRI area, not even during the MRI scan itself.

The implications for the safety nurses were not straightforward, instead creating some anxiety. One of the safety nurses said; "The safety nurse then actually needs to work there!" The other safety nurse added; "But how will it be for us then? It all seems uncertain. Won't we ever go back home? Should we make ourselves at home in the new room?" In the light of these uncertainties, many of the assistant and surgical nurses decided to regularly meet outside of the formal SuperUser meetings to discuss and plan for their specific roles. They often met to discuss, for example, what it meant to be a safety nurse and what duties this would include. Additional aspects they planned and prepared included what instruments and materials were to be stored in the new room.

6.3.2 Rethinking MRI safety training

Another way to maintain MRI safety was to rethink MRI safety training, and to make it more formalized and structured. Previous MRI training had been rather unstructured, given on an ad hoc basis to only a limited number of individuals who were required to work at the MRI Unit. However, as the new technology would be located closer to the clinicians, in fact within a surgical department, and because more, different, and new healthcare professionals would be working in the MRI environment, new routines for MRI safety training were needed. All individuals working in and around the new technology would now need to undergo some form of MRI training.

From the SuperUser group, it was mainly the local coordinator, and also the MRI physicist, who jointly engaged with a specific MRI safety group to develop these new routines. It was important, however, to also involve the other SuperUsers in discussions related to MRI safety. They were the ones who would be working in this environment right from the beginning, and they would be directly involved in emergency situations and develop procedures to deal with, for example, code blue alarms, crash calls, and so on.

How the new MRI safety training would be designed had not yet been determined. During one of the first SuperUser meetings, one of the surgeons asked; "What MRI training is required in order to work in the room? Are all disciplines working in the room required to have MRI safety training?" The MRI physicist explained that the following; "Jointly with the MRI safety group, I'm in the middle of developing new guidelines and requirements for this. But everyone at this department will at least need to do some basic training in MRI safety".

At a later SuperUser meeting, the MRI physicist explained what they had come up with thus far after their initial discussions. It had been decided to structure the training on different stages or levels (see Figure 7). The idea was to align levels with access and jurisdiction, meaning that a higher level would allow an individual to engage in more activities both within and around the new technology. No training meant no access, being intended for students, interpreters and security staff. Typical routines for accompanying staff would be applied. Level one would give access to the department, but not to the new room. It would provide knowledge enabling someone to work in a department that has MRI, but not inside an MRI room. Training would be repeated annually. This level is intended for people from construction companies, departmental staff working with appointments, and general surgical staff. Level two would give access to the MRI room, and provide knowledge enabling someone to work independently in the room, but only when no scanning was in progress. This needs annual repetition and is intended for medical technology engineers and cleaning staff. Level three would give access to the MRI room and the authority to act as a guide to others. This level would provide knowledge enabling someone to work independently in the room during scanning too. This training is to be repeated annually, and if no work has been done in the MRI environment for six months. It is intended for MRI engineers. Level four would give access to the MRI room and the authority to act as a guide to others. It would provide knowledge enabling someone to work with patients in the MRI room during scanning. This training is to be repeated annually, and if no work has been done in the MRI environment for six months. It is intended for anesthesia staff. Level five would provide access to the MRI room and the authority to act as a guide to others. It would provide knowledge enabling someone to run the MRI scanner in vivo. This training is to be repeated annually, and if no work has been done in the MRI environment for six months. It is intended for radiology nurses, MRI physicists, and MRI radiologists.

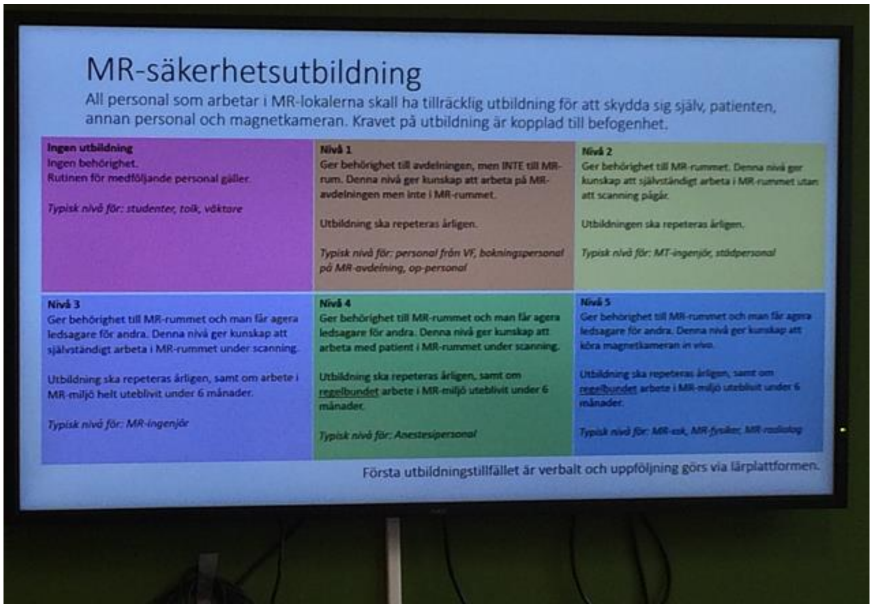

Figure 7. MRI training consisting of different levels.

When the MRI physicist presented the initial draft of these levels to the SuperUser group, there was both discussion and disagreement. It was not clear what level the different disciplines within the SuperUser group would need, and there were also disagreements about which level the SuperUsers themselves felt they needed. As illustrated in this field note from a SuperUser meeting:

> Surgical nurse: What level do we need?
>
> MRI Physicist: You and the safety nurses will need level two at least, or maybe four.
>
> Anesthesia nurse: But how are things being done today at the MRI Unit?
>
> Radiology nurse: We have no levels, and we've been against training everyone. Because it can easily turn out that you' were trained several years ago and then maybe you haven't been working in the MRI environment for a while. And then you might forget things, but still think you know everything
>
> Surgeon: Yes, but we can't be locked out. I will not open a patient's head and then leave the room unless I know that I can come back into the room again at any time.

Surgeons, for example, were not comfortable having a level that does not give them access to the MRI room at all times. Other SuperUsers questioned whether or not they really needed to undergo any MRI training at all since they had already been trained in MRI. These discussions led to new potential adjustments for the consideration of the MRI physicist and the MRI safety group. The final structure, however, was similar to the one first presented, but with minor corrections regarding whom to place on the various levels. For SuperUsers in general, it meant either level four or five. Anesthesia staff and surgeons were placed on level four, and MRI staff on level five. Giving all SuperUsers a level of four or higher was considered a safe bet, as one MRI physicist explained; "Giving all SuperUsers a level four or higher means being on the safe side, they'll actually be getting more knowledge than they need".

Training included access processes, theoretical lectures, educational visits, annual repetitions/checklists, and reading the safety manual. When the instructor asked the trainees whether or not they were used to the MRI environment, it became apparent that the different SuperUsers had varied levels of knowledge and experience of MRI. The radiologists expressed being both confident and knowledgeable with regard to MRI, while the anesthesia nurses expressed something similar. This was not, however, the case for the surgical nurses:

> No, we're not used to it at all. We don't work in this environment at all, which the anesthesia staff do. You develop a respect for it. It's even really frightening (field note).

MRI training was designed to account for this varied level of experience of MRI by including both basic and advanced levels of knowledge. In addition to theoretical lectures, which included topics such as terminology, the MRI environment layout, MRI symbols, MRI wording, and the MRI labelling of objects, it also included an educational visit to the MRI scanner. This was meant to make the staff "more comfortable in their new environment", and to "increase their level of confidence". During the educational visits, all the participants visited the new room, gathering inside the garage where the magnet was parked. The information given during the theoretical lecture was then applied in practice, too. For example, a pair of forceps attached to a cord was handed to the participants, who were then able, one by one, to use it to feel the magnetic field. A soda can made from aluminum was also used; it was not pulled in toward the magnet but floated in the air instead. Resulting from these practical exercises, one general comment made was how strong the magnetic field really was and how much it pulled the forceps. One of the participants even accidently let go of the forceps so that it went slightly into the exterior of the scanner.

When the staff completed their MRI training, including the theoretical lectures and study visits, an application for access needed to be sent to the most immediate manager, who then sent it on to the head of the radiology department. However, this was considered to be "basic" training, at least for the SuperUsers, who also needed this in addition to the training provided by AmTech. As will be described later, the additional training given to SuperUsers included more specific MRI safety issues, e.g. workflows using the new technology, emergency procedures, counting and so on.

As already mentioned, all healthcare professionals who were going to work in and around the new iMRI Hybrid OR now needed to undergo MRI safety training. This meant that there would be an increasing number of individuals to monitor, especially when compared to the restricted group of people who had been working at the traditional MRI Unit. Along with how "the MRI scanner is now in the middle of a surgery department" (surgical nurse), there was thus a prevalent need for a developed and structured monitoring system to keep track of all healthcare professionals who had done the required MRI training.

An initial step consisted of aligning training with personal ID badges, in a way only allowing access to authorized staff. In addition to electronically allowing or restricting staff, stickers showing colors and numbers for each level were also planned. So, instead of relying on familiarity and personal relations, as was the case at the MRI Unit, the coordinating of MRI safety was now more dependent on formalized and structured routines, including objects such as keycards and safety signs. One MRI physicist explained:

> Up there [in the new iMRI Hybrid OR], things won't be as they were at the MRI Unit. You might not recognize all the people working there, or you might not know them by name. For example, the surgical nurses who we aren't used to working with. Or the anesthesia staff who might also be on a rotating schedule. Then we'll need to rethink MRI safety. We need to do more as regards following up and keeping track, via an annual update, which will be done and registered using a computer, so we can tell who's done the training. And it'll also be linked to the personal ID badges, so if you haven't refreshed your training, you won't be allowed access to the room.

As maintaining MRI safety could no longer be performed simply by relying on familiarity, because the MRI staff would not be able to assume they knew everyone working there, it thus became obvious that MRI training now needed to become more detailed, structured and formalized than previously. For example, when informed about the new MRI safety training, one surgical nurse in the SuperUser group asked the MRI physicist; "But what about the educational package that we did, it included MRI. Doesn't that count?" The MRI physicist answered; "No, it doesn't count. It was more of a general orientation in MRI safety". This was no surprise, perhaps, as surgical nurses seldom work in an MRI environment. However, the new MRI training was not just more extensive, it also required more formalization, monitoring and maintenance. One surgical nurse commented; "But you [anesthesia nurses] are working in an MRI environment already, don't you already know this then?" One anesthesia nurse answered; "Yes but we don't have a diploma". A newly-appointed MRI physicist added; "Yes because anesthesia and MRI staff already have MRI training". Another MRI physicist, who had been at the iMRI Hybrid OR right from the start, replied; "Yes, but it's a new room and it requires new knowledge, it's a new concept so it needs to be documented on paper. They [anesthesia nurses] don't have it on paper right now".

Thus, it was important for the new MRI safety training to be both more in-depth and formalized, something which was not always greeted with acceptance. One radiologist asked the question; "Is it really important that we have it on a piece of paper, formally?" The consequences of not having it on paper, however, were so drastic that it did not become an issue for further discussion. As one unit manager poignantly pointed out; "Yes, if you haven't done the training and had it registered, you won't be able to enter the room. You won't get the right clearance on your card".

6.3.3 Counting and writing down

One additional way of maintaining MRI safety was to change the coordinating routines of counting and writing down, as commented on thus by one surgical nurse; "The counting is extremely important, it's not just about knowing MRI". The purpose and common understanding as to why counting and writing down were performed had partly changed. In the traditional operating room, surgical nurses performed counting and writing down so as to prevent things from being left in the patient's body, and to prevent infections and severe complications in patients. However, in the iMRI Hybrid OR, this would also be performed so as to avoid metallic objects from being missing, thus preventing them from becoming missiles when the scanner was deployed. It would also mean that new things needed to be counted and written down, e.g. pencils and scissors, which were previously considered too large to be left in a patient's body and would normally not form part of a surgical procedure, but which now posed risks to MRI safety. One surgical nurse explained:

> You really have to count everything. All the instruments and things we use. Everything now needs to be counted.

Counting more things, and doing it with extreme accuracy, also shaped how nurses interacted. Instead of the surgical nurse directing and performing the counting, mostly alone, as done at the ordinary neurosurgery department, increased MRI safety concerns now required that two nurses perform the counting. The surgical nurse was now to be assisted by the safety nurse:

> When we count things in the room today, we don't do it with the safety nurse. But the new room requires two of us to count. The safety nurse is with us (surgical nurse).

Just how this counting, with its new interactions, was to be performed became visible during simulation training. The surgical nurse was standing inside the sterile field counting which instruments and items were being unpacked out loud. The safety nurse was assisting by standing just outside the sterile field and double checking what the surgical nurse was counting against a checklist. The nurses were thus helping each other by sharing the responsibility for the counting. In addition to assisting the surgical nurse, the safety nurse also, on occasion, questioned the counting. For example, during a simulation session, one safety nurse said the following to a surgical nurse:

> It's not enough to just look through it quickly. There may actually be something missing, things getting lost.

As the safety nurse was now majorly responsible for maintaining MRI safety when using the new technology, questioning and counter-checking was an important part of his/her accountability. Interaction between the nurses was thus affected, both in the way the counting was performed, by two nurses in collaboration, and with regard to who was directing the counting.

The checklist used for counting and writing down was designed as a counting sheet and provided by AmTech, being a checklist that the nurses could use as a starting point when modifying it for their own context. As the purpose of counting and writing down had partly changed, or at least expanded, the checklist would also serve multiple purposes. Not only would it account for any objects left inside the patient, it would also maintain MRI safety. Developing a checklist for multiple and shared purposes was not easy. One of the application specialists from AmTech reflected upon this sheet and the amount of time counting required; "It can require up to 15 pages and it takes time. But it can also be cut down slightly if prepared well beforehand. Deciding carefully what is needed and so on".

After the first couple of simulations, the nurses began commonly experiencing counting as complicated, and as taking longer than usual. One way to speed up the process, and to make it more convenient and reliable, was using parts of already existing checklists. One surgical nurse explained how they were updating and modifying the formal checklists:

> I thought that, since we'll be using the same instruments as today, my idea would be to also count as we do already, against our old checklists. And to then check it and add the additional things according to the new sheet.

Including already-existing elements of counting was a way for the nurses to increase their familiarity with the process. This was formed of the nurses' general comments regarding how they preferred changing their duties as little as possible.

In addition to how the counting and writing down had changed, in terms of how it was to be performed and by whom, the timing also changed. In traditional neurosurgery, counting was performed before the procedure started, in order to set a baseline, and then again after the procedure in order to be sure nothing had been left in the patient. The new technology would, however, require counting to be performed on an additional occasion, namely before MRI scanning. The timing as regards when counting was to be performed was not, however, always clear and predictable, as indicated by the following question asked by a surgical nurse during a simulation session; "Am I supposed to count now before we do the MRI scan?" The clinical application specialist seemed surprised to have been asked this question as her answer was; "Yes, of course. You'll always have to do the counting before the scanner can ever be deployed."

Thus, the combination of partly new checklists and additional occasions of counting and writing was not always straightforward, sometimes creating confusion and uncertainty. During one simulation session, counting was, for example, performed in the wrong order, as one surgical nurse put it; "It was very confusing and things were counted in the wrong order. We need to update the checklists." As indicated, the nurses were not satisfied with the formal counting sheets, expressing an urgent need to modify and adapt the checklists as they continued training and simulating.

In contrast to a traditional operating room, in which meticulous counting and writing down was performed solely by the surgical staff, the new technology would also require anesthesia staff to perform counting and writing down. This was a major change that affected how the anesthesia staff would need to work, especially since they were currently "not counting anything" (anesthesia nurse). These changing requirements and duties were reflected upon by an anesthesia nurse thus:

> We use needles and we don't count needles and things like that at all. On the surgical side, they count everything because they're afraid of forgetting things inside a patient. However, on the anesthesia side, we use our things like this [throws her hands around to illustrate]. And it'll be different because we can't forget things, we need to count and write down every needle we've used, so it won't disappear into the scanner, because it's magnetic. So, it'll be different.

Counting everything meant they could not even throw away the small covers for the needles, which they usually just threw away. Counting and writing down, for the anesthesia staff, also meant needing to rethink how their trolleys were filled and prepared. Many of the instruments and supplies used by anesthesia were carried on trolleys, one for medicine and one for instruments, which with the new technology also had to be counted. The clinical application specialists suggested that they; "cut down to the minimum, for example needles and only having maybe five instead of 15". The idea was to make counting more convenient and smoother by only having to count what is absolutely necessary for a specific procedure. This was different from how they usually filled their trolleys, partly contrasting with what it meant to be an anesthesia nurse or anesthesiologist. A major part of their role was based on knowledge and expertise relating to the anticipation and management of complications and unexpected events. Part of this involved "carrying" with them more than they needed, for example as regards needles, medicines and other instruments that might be needed for a change in direction. However, the new technology, with its requirements of counting and writing down everything, made the anesthesia nurses more averse to the thought of bringing into the operating room any more than they needed. Thus, the anesthesia staff carefully discussed and prepared both what and how much to include on their trolleys.

However, since counting and writing down were not part of the traditional duties performed by anesthesia staff, there was no past experience to draw upon. This also meant that they needed to practice and to try out managing these new and additional concerns. They knew they had to start counting but they were not sure about how to perform that. As one anesthesia nurse said during an interview:

> We'll need to count everything, needles and so on. When we intubate, we'll also need to count oxygen masks and laryngoscopes because they're metallic, like all our other equipment. Whether we'll have to replace much

> of it [the equipment] completely for non-metallic, or whether we'll have to take it out into the hallway, I don't know yet. I don't know how it'll actually be. So it's good to develop routines for this.

Similarly, another anesthesia nurse explained how they were not sure about how counting and writing were to be performed:

> We have to bear in mind that no magnetic objects are allowed in the room. In that case, I don't know how to do it, whether we can't bring anything at all, or whether we'll just have to make sure that nothing's still there when the scanner comes in.

Given this uncertainty, the anesthesia staff had to try out different ways of counting, something which became apparent during a SuperUser meeting when an MRI physicist asked the anesthesia staff how they would be counting:

> MRI physicist: How will you do the counting then?
>
> Anesthesia nurse: We haven't completely decided yet. But we will have to count the needles at least.
>
> Anesthesiologist: Yes, we'll try various ways of solving this. When we take a needle, for example, we'll need to put it in a specific place. We'll learn how to count, because we'll also need to count everything now. We won't be able to work as we do today.

Additionally, when complying with the new requirements as regards filling their trolleys, the anesthesia staff lacked previous experience and thus needed to make an effort and to try out different ways. It was not obvious what keeping things to the minimum meant. The anesthesia staff carefully discussed and prepared what they thought were absolute necessities; however, as their training went on, during simulation sessions for example, a need for modification emerged. As one anesthesia nurse commented:

> This is totally new to us and something we've never done before. We'll thus need to change the checklist as we go along, because we'll need to add things that may be necessary, and so on.

In addition to trying things out, another way of including counting and writing down in the duties performed by anesthesia staff was seeking help from the surgical nurses, especially the safety nurse. As the clinical application specialist reflected:

> The anesthesia staff need to count all their stuff, but as this is new to them, they'll need help doing this. The surgical nurses are used to counting so it'll be a good idea for them to help, maybe the safety nurse.

During the training sessions, the surgical nurses thus shared their method of counting with the anesthesia nurses. Sharing knowledge and developing a common understanding of counting meant consequences for the way in which the anesthesia staff were able to work. One example of this was how they needed to handle needles in the operating room. Traditionally, the anesthesia staff throw all their used needles and syringes into a sharps bin, a yellow plastic box usually placed on the medicine trolley. This is used for the safe storage and disposal of sharp objects, e.g. in order to prevent needle jabs and the ensuing risk of secondary infections and exposure to the contents of needles. With the new technology, however, it was not possible to use a sharps bin at all, since all needles and syringes had to be counted and written down. As explained by one anesthesiologist during a training day:

> We won't have a sharps bin inside the operating room, because everything needs to be counted and written down. Instead we'll put them in a special box. And then we'll have the sharps bin outside the room instead.

Since the anesthesia staff traditionally do not count their instruments, neither did they have any existing aids for that purpose. The surgical nurses suggested that the anesthesia staff use "a special box", similar to what they were using for their counting. This box also seemed to work for the purposes of the anesthesia nurses: "We'll use a box with numbers, similar to what the surgical nurses use, and in which we'll put our needles on a specific number". Figure 8 illustrates how the box looked, and how the anesthesia staff practiced part of their counting. Next, how sterility would be maintained in a dirty environment is described.

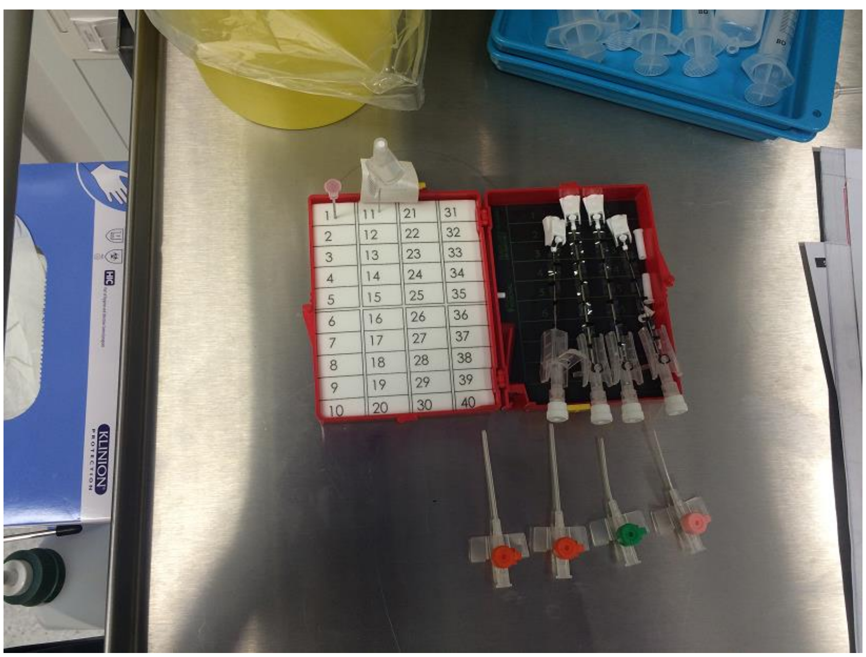

Figure 8. Box used by anesthesia staff when counting.

6.4 Maintaining Sterility in a Dirty Environment

As described in Chapter 4, neurosurgical postoperative infections were very serious as these were often associated with a high rate of morbidity and life-threatening consequences. Keeping the operating room sterile and clean was thus very important.

However, as the new technology would mean the hybridization of an operating room with an MRI room, maintaining sterility would be especially challenging. A traditional MRI room was described by the MRI staff themselves as dirty, with the MRI scanner being described by one MRI physicist as always being dirty. A major concern of the new technology was thus how to maintain sterility in this "dirty" environment. One radiology nurse reflected upon this concern thus:

> It'll be different now when a dirtier environment, in MRI, will be combined with a non-dirty environment, in surgery. We'll work together, you can say. So sterility is a major issue that needs to be planned for.

6.4.1 The (non-)existence of a hatch in the door

Bearing these sterility concerns in mind, many SuperUsers were both surprised and shocked during an educational visit to the new iMRI Hybrid OR upon noticing that no hatch had been placed in the door leading into the room (see Figure 9). This small opening, or window, was traditionally used in order to exchange things like blood, instruments or medicines, or information; in doing so, obviating the need to open the doors themselves. Restricting the door openings to a minimum is believed to prevent cross-contamination and to reduce the incidence of wound infections during operations. Thus, since the OR environment must be as sterile as possible, the noted absence of a hatch into the new room caused some intense reactions.

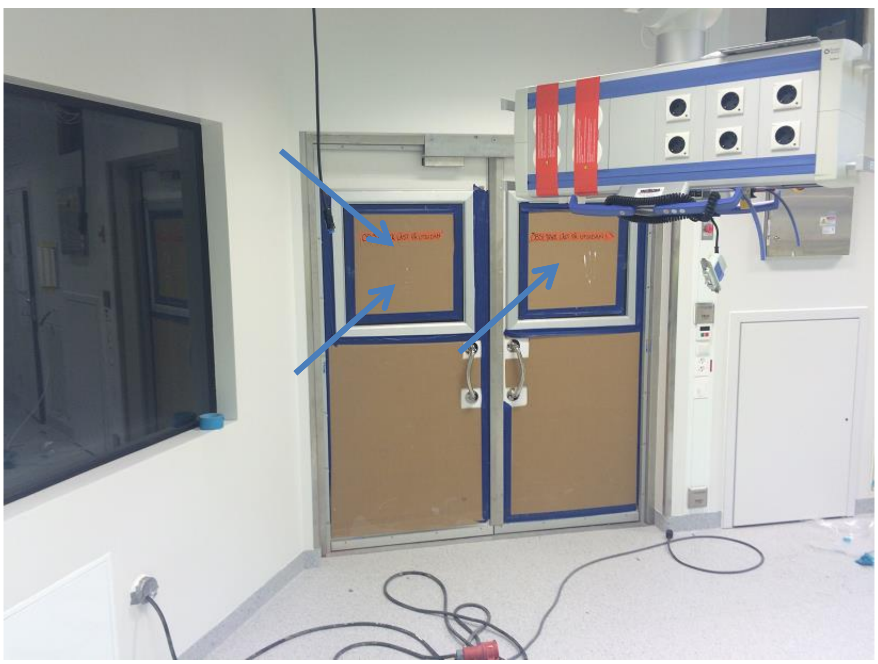

Figure 9. Lack of a hatch in the door leading into iMRI.

During a SuperUser meeting, many of those present raised their concerns and frustration over not having a hatch. They could not believe that a modern and expensive room like this could be built without them, and they thus started questioning this. The following discussion unfolded during the educational visit to the room:

Anesthesia nurse: There is no hatch in the door leading into the operating room! This'll create a lot of irritation, especially among the surgical staff. We'll have to be opening the doors the whole time. The air pressure will change. Then I don't want anyone glaring at me. Us anesthesia staff use the hatch all the time. And that goes for you too [talking to a surgical nurse], you get a lot of stuff through the hatch. We'll be disrupting the air pressure and flow, making the particles move around the whole time. However, it feels a bit late to be cutting an opening in the door for a hatch now.

Surgeon: Yes, but it's better to do it now than in two years' time.

MRI physicist: I can say that thinking about having a hatch in the door is gone now.

Surgeon: Why?

MRI physicist: It wasn't in the product catalog. It wasn't possible to have them, because it wasn't on offer from the manufacturers of the copper shielding system.

Surgeon: Yes okay, I'm not arguing against that but pointing out that it'll result in an extreme number of door transits.

Anesthesia nurse: Yes, talking about the infection risk!

Anesthesia nurse: We'll need to bring in a whole lot of stuff, like blood gas, blood, and medicine. Every time a bunch of anesthesia people come, and we might need to open the doors like 20 times during one surgical procedure.

Surgeon: Yes, this isn't just a minor issue!

Surgical nurse: Yes, this is totally new.

The MRI physicist, also the local coordinator of the group, replied that she had heard what they were saying and that she would take these concerns to the technology suppliers and project leaders. After the educational visit to the new room, the plan was to start discussing and planning for MRI safety training. However, concerns over the hatch were raised once again. The following discussion ensued:

Surgical nurse: Then it's this business of the absence of a hatch. I can tell that he [surgeon] is really concerned. We can't be opening the doors like that. The infection risk would be catastrophic.

Anesthesia nurse: Yes, you can just imagine how many times we'll be opening the doors.

> Anesthesia nurse: Will there be windows in the doors leading out into the corridor?
>
> MRI physicist: Yes, there will be windows.
>
> Anesthesia nurse: Okay, then we'll need to hold up notes describing the things we want to bring in.

The conversation once again turned to why a hatch was not possible:

> MRI physicist: We looked at them, the drawings, and concluded that it wasn't possible.
>
> Surgeon 1: Nothing is impossible.
>
> MRI physicist: The room is RF shielded.
>
> Surgeon 2: The idea was to not run around, to not be in and out of that room so much, but that we'd be self-sufficient.
>
> Surgeon 1: Yes, but why can't they make a hatch in the door now then?
> MRI physicist: It's technically impossible.
>
> Surgeon 2: There's only one manufacturer in the world making this door, so there weren't a whole lot to choose from. It's not like you can buy this door at *Hornbach* [a common DIY store].
>
> Surgical nurse: It'll destroy the laminar flow, and the whole idea behind it.

Following many of the SuperUsers' strong points of view regarding the hatch, the local coordinator raised this issue with the manufacturers, suppliers, and responsible managers. After internal discussions, a potential solution was offered that included the possibility of modifying the existing controller of the double swing door leading into the room. The new suggestion was to provide for one push button to open a primary door leaf, and a separate button to open both door leaves. The response of the SuperUser group was that it would be good to be able to open just one door, since opening two doors is frequently only needed when transporting patients. However, they still insisted on having a hatch in the door. These two adjustments were once again forwarded to the responsible managers.

During interviews, many of the SuperUsers repeatedly raised their concerns over the hatch. As one radiology nurse told me:

> I think this thing that came up, it's a very practical detail, but I understand the surgical staff and all this stuff connected with the hatch. It might sound trivial when you come from outside, but when you understand how they work, and you know how they work and you're told how they work, you'll understand it's very important.

When asked about the reasons why a hatch had not been put in the door, somewhat different explanations were given and discussed. Some of the SuperUsers seemed to accept the reasons given by the MRI physicist; i.e. that, due to the technical complexities of RF-shielding, it was technically impossible:

> It must have been because of the magnetic field somehow. That it was something to do with safety that was so important that it wasn't possible to have a hatch (surgical nurse).

Others seemed to have a somewhat different understanding, as one surgical nurse explained:

> I think they didn't have this aspect in mind during the initial procurement and planning phase. They discussed it, as I understand things, early on to try and solve it, but it wasn't possible at that time. Since the room must be shielded the issue was probably forgotten. We weren't part of the planning process at that stage, it was several years ago. We weren't part of the construction stage either. I don't know, but I think they didn't have enough knowledge of sterility, why it's so important etc. Or at least the fact that nobody was pushing for that (surgical nurse).

One surgeon had a similar understanding:

> I can only interpret it in such a way that it's because the people who planned and designed this room are not the same people who'll actually be working in the room during surgery. For someone who works there, as you've noticed, all those who are part of the group [SuperUser group] are basically those who work with these things every day, and they think this is something that's obvious. But I have difficulty believing that any of them have been planning this room right from the very beginning. Thus, the knowledge and experience connected with these things hasn't manifested itself in the planning group.

Due to pressure from the SuperUsers, especially doctors, who even sent internal emails referring to studies showing the correlation between numbers of door transits and the increased infection risk, having a hatch shifted away from being impossible toward being possible. During upcoming SuperUser meetings, the local coordinator repeatedly stated; "It'll be difficult to get a hatch". One alternative suggestion was to create a different kind of hatch in a different place, as explained by one surgical nurse thus; "We've talked about having the hatch inside an electrical cabinet. The idea is to go inside the electrical cabinet, and talk through the hatch". This solution was perceived to be better than none at all, as one anesthesia nurse commented; "Having a hatch inside the electrical cabinet, below the electronics, might be better than not having a hatch at all." This solution would mean, however, having a hatch at knee height, located among electronics, something which did not make the solution self-evident (see Figure 10). However, a turning point was looming.

Figure 10. Inside the electrical cabinet, as a suggested location for a hatch.

One radiologist curiously asked, during a later SuperUser meeting; "What has happened with the hatch, any changes?" The local coordinator replied:

> We have a solution, or we've been given two alternatives. We can have a hatch in the door. The head of department has been told to take this with her to the management meeting because it'll cost about 160,000 SEK. However, we want to get the answer earlier than the management meeting because the manufacturers will soon be coming and, if we wait even longer, it'll cost another 60,000. (…) Alternative two is only having one primary door leaf being opened. So, it's a matter of functionality versus money.

During a SuperUser meeting about five months later, the local coordinator announced how the impossible had become possible: "There will be a hatch, and it's even being put in place as we speak". Next, how training and preparing took place also within disciplinary domains will be described.

6.5 Training and Preparing Within Disciplinary Domains

One of the ideas underpinning the formalized and structured training and readiness activities, purchased by AmTech, was to engage all the SuperUsers together. As one anesthesiologist noted:

> The idea is that we're supposed to do a whole lot together, because we need to learn and practice where others have their things and issues, it's not enough for me to know about my own issues and how I solve them. (…) So, that's why we're training together and showing where we believe there are issues.

However, the SuperUsers still had to engage in individual exploration, by means of planning and preparing within disciplinary domains. This was the case because specific issues and elements, which were more related to specific disciplines or subgroups of the SuperUser group, had emerged. In effect, the SuperUsers were breaking the larger group into sub-groups. For example, the MRI staff needed to engage in specific training related to the new scanner; "Us MRI people need to go through our training on the scanner itself. It's a two-week MRI application training" (radiology nurse). Their major concern was how to learn the new MRI scanner, which had a different user-interface and software than they were used to. I observed how radiology nurses sat for hours in front of their monitors optimizing protocols and sequences (see Figure 11). One radiology nurse commented on the challenge of the new machine thus:

> There's so much extra you need to do. Today, we had an application specialist from the company here. I tried to do this myself and succeeded to about 50%. Then he had to assist me with a lot of things. He also thought it required a lot of effort and extra work to get to where we wanted to go.

Figure 11. MRI staff during MRI application training.

The anesthesia staff also needed to train within their disciplinary domain, as new MRI-compatible machines were to be used in the new room. It was due to changing and to incompatible material arrangements that the iMRI Hybrid OR would not be allowing traditional anesthesia machines to be used, with nurses thus having to master new machines. One anesthesia nurse explained:

> We'll have to be very good at using the new anesthesia machines, so we can teach people about them too. Because today we're not that good at using them. I can cope with it but I wouldn't be able to go through it, with all the details. We have to make sure that we can and do become confident with it, otherwise we won't be able to pass on the knowledge if we really don't understand it.

Since it was mainly nurses who would be using the new machines, the anesthesiologists largely handed over the responsibility for planning and preparing to them. As a result, the anesthesiologists were rarely present when anesthesia nurses met outside of the formal SuperUser group to learn how the new machine really worked. Gaining increased knowledge of and expertise in the new machines required considerable effort and interaction. For example, anesthesia nurses were in contact with the supplier of the machine, even bringing the machine with them and using it during traditional surgical procedures.

Surgical and assistant nurses also gathered outside of the formal SuperUser group to plan and prepare for issues that were specific to their disciplinary domain. Many of these issues were related to practical details that were considered absolutely necessary in order for safe and efficient surgical procedures to be performed. Nurses described these issues as "all the practical things that many others have no idea about", thus triggering planning activities and interactions. One example of this was arranging patient positioning and padding to optimize surgical conditions, promote access to the surgery site, and protect anatomical structures. As one assistant nurse said:

> Traditionally, we have two different adjustable pillows of different materials for the abdominal position, so that you build up [increase the height of] the patient quite a lot. This is done to make the legs fall in the correct direction when positioning the patient. It makes the brain fall in the right place, that's to say downwards. In the new room, however, we can't have thick pillows or mattresses because then it will not fit into the scanner. So, several bouts of irritation and contacts with different companies have been necessary to finally get a custom-made cushion containing these two materials in one and the same cushion. This was very tricky, and part of all the little things that are extremely important to us and no one else knows or understands. Who could think that the position of the knees is so important?

Other examples were related to the formulating of checklists and routine documents, and the organizing of operating room storage in order to provide control and instant access. All these activities and interactions required considerable effort on the part of the surgical and assistant nurses. As described by one nurse; "We've been working round the clock, pretty much living with this. We even went to work in the evening and organized and thought it through." Another nurse summarized it thus; "We've been working like dogs."

Meeting independently of the SuperUser group like this was important to the surgical and assistant nurses because they were the ones with the knowledge and expertise required to prepare and plan for the specific needs of their domains. The nurses argued that, otherwise, it would be easy for this to disappear into the shadows of the overarching goal.

> We [the surgical and assistant nurses] know about all the things needed for a surgical procedure, and how to use these things. As we know the procedures by heart, we can also plan accordingly. If we hadn't been actively involved, or if someone else had planned it, then either it would have been forgotten or they wouldn't have understood how all these details contribute to the whole (surgical nurse).

With increased specialization, the SuperUsers engaged in planning and preparatory activities within their disciplinary domains rather than purely focusing on aspects that applied to the whole group. The need for integration and alignment would also bring changes to activities and elements within expert and disciplinary domains, and thus enable the reconciliation of differences in the emerging contributions. Thus, prior to the initial surgical procedures, it was important for the SuperUsers to prepare and plan, both as a team and broken down by discipline. However, and as will be presented in the next chapter, many of the separate duties that were planned and prepared for in isolation still required alignment and integration once the new technology was in place.

6.6 Analytical Summary

In what follows, I summarize and discuss how the planning and preparatory activities leading up to the initial use of the new technology were performed. The SuperUsers were engaged in organizing a temporary social setting and an imaginary physical space, which had implications for the coordination processes.

6.6.1 Organizing a temporary social setting

Introducing the iMRI Hybrid OR was generally experienced as novel and how new ways of coordinating work, new roles, new responsibilities, and new interactions, were required. In envisioning these important changes and realizing the collective action needed, a deliberately exclusive group of so called SuperUsers were engaged in planning and preparing activities, which became intertwined with the organizing of a temporary social setting.

These designated SuperUsers had a formal and visible status, gathering for regular meetings taking place within the hospital, but at a distance from their day-to-day workplaces (i.e., operating rooms, MRI Unit) in conference rooms. These structured meetings allowed the healthcare professionals traditionally separated in locations to meet and focus their attention on the overall goals and requirements of the new technology. Collocating separated actors from different locations thus provided new interactions; enabling discussions and understandings of the collective accomplishments rather than regards discipline-specific requirements only. The SuperUsers engaged in deciding on who did what, when and how, and how these separate tasks were to be integrated. This collective engagement proved important because the alignment of the various separate elements required that the different healthcare professionals familiarized themselves with each other, creating trust and common understanding. For example, as maintaining MRI safety and sterility in the new room would become a shared responsibility, this would also require the various healthcare professionals involved to bring about collective accomplishments. In addition, as the duties of the safety nurse would directly influence the duties of the others, as well as how these would be integrated, all the SuperUsers had an interest in taking part in decisions related to what the role of the safety nurse role would entail. On the other hand, more localized planning and preparatory activities, involving less diverse groups, also proved important. In contrast to integrating, the SuperUsers were separating, in this way, the various elements and activities of the overall collective accomplishments (Harrison & Rouse, 2014; Wolbers et al., 2018) by breaking up into smaller groups according to their disciplines. For example, the anesthesia staff and the MRI staff often trained on new technological equipment separately and independently. This separation was important when it came to managing the specific issues and elements related to the different disciplines involved.

Furthermore, it would not always prove easy to change the ways of working, with the SuperUsers at times tending to revert to traditional performances. The training and readiness activities, including what roles to involve and how to perform duties, and who would do these, were all designed by AmTech, but were locally adapted in order to match how work was traditionally carried out and coordinated. For example, counting and writing down were now needed, not only for sterility reasons, but also due to MRI safety concerns; however, the way in which it had been decided that this counting would be done largely reflected and matched the traditional way of counting. By including already-existing elements of counting, as little as possible needed to be altered. Another example of this was how the role of the safety nurse was introduced. A nurse working in surgery was designated to take on the role of safety nurse, especially because of this role's incompatibility with the SuperUsers who were unfamiliar with surgical devices and equipment. Adding to the designation of the role itself, the responsibilities of the safety nurse, especially the tasks performed during emergency situations, meant the SuperUsers did not have to change existing emergency routines entirely. Instead, they were able to rely more heavily on the safety nurse ensuring that the new MRI safety requirements would be met once the new technology had been introduced. A final example of this was the hatch and how it was intertwined in how work was traditionally performed and coordinated. Despite its impossibility, a hatch was preserved and insisted on in the door leading into the new room, too. Taken together, these examples illustrate how previous work becomes important in terms of shaping the enactment of subsequent work (e.g. Barley, 1986; Barrett et al., 2012; Black et al., 2004; Edmondson et al., 2001; Nelson & Irwin, 2014), in that the organizing and coordinating of the work that the healthcare professionals aim to enact in the future becomes reflected in and influenced by traditional arrangements, including roles, responsibilities and interactions.

However, the success of the new technology would depend on the integration of changes to individual duties and elements with new coordinative arrangements. As such, the most critical planning and preparing activities still consisted of the collective endeavor in which the insights of the different healthcare professionals were combined. On these occasions, particular types of interactions took place, contributing toward a temporary social setting emerging. The interactions between the healthcare professionals were perceived as less hierarchical than usual and traditional status differences were in some regard even reconfigured, jointly enhancing the potential for generativity (Anthony, 2018).

During planning and preparatory activities, it was not uncommon for doctors to be absent. Nurses sometimes expressed a preference for having doctors more involved as important decisions were being taken and consequential planning was being done. The doctors' knowledge and expertise were considered important to problem solving, and their involvement was also important to knowledge sharing and the creating of a common understanding. The absence of doctors was explained by them being occupied treating patients, with the other SuperUsers attributing their absence to pressing needs rather than a lack of interest. Yet, the occasional absence of doctors still indicates how planning and preparatory activities take place within a relational context. Differences exist with regard to who participates and when, as well as what pressing needs there are, something which is influenced by interactions among the occupational members. These differences and the nature and extent of the interactions thus seem to be informed by differences in status. At the same time, this also meant there was a potential for the traditional hierarchical and status structures to be separated and suspended.

To begin with, being the local coordinator, a role taken on by an MRI physicist, meant being in direct contact with the subcontractors, and having the authority to dictate at meetings. The direction and content of the meetings thus reflected the in-depth knowledge and understanding that the MRI physicists had in terms of MRI safety. More specifically, depending on their level of training, the SuperUsers were to be authorized to perform different types of duties, and in different places. Regardless of professional role or level of seniority, no training at all would still mean no access to the room. One surgeon resisted this by insisting on gaining a higher level in order to have access to the new room at all times, which could be understood as if traditional status differences were being used to insist on gaining a higher level (Anthony, 2018). However, an alternative interpretation here is that MRI safety training becomes consequential, in some ways redefining what status means. Instead of relying on disciplinary expertise and seniority, knowledge of MRI and MRI safety per se is given a significant role to play in how work is organized.

Moreover, in being able to integrate and align previously separated healthcare practices, the role of the safety nurse was experienced as very important. Being responsible for aligning the activities and duties traditionally performed in the separate practices of MRI and neurosurgery, the safety nurse emerged as a new occupational role. This role was described as 'cross functional', requiring broad competencies and at least some experience and knowledge from all three disciplines, i.e. surgery, anesthesia and radiology. With narrow expertise and specialized knowledge generally being valued, the role seemed to be attributed a low status, and few SuperUsers were willing to take it on. However, in that the underlying coordinative arrangements for future performances had been decided on, including the safety nurse largely controlling and dictating the duties of the others, it was to be enacted in the future as a high-status actor.

Thus, the emergence and organizing of a temporary social setting was the result of how the planning and preparatory activities had been performed as well as the means by which the coordinative processes had been envisioned or were to be enacted in the future.

6.6.2 Organizing an imaginary physical space

During much of the planning and preparatory period, no new physical space had as yet been constructed. This absence of a physical space contributed toward the SuperUsers experiencing the introduction of the new technology as abstract. It was also a long way off in time and uncertain in terms of how the work would be done. However, the SuperUsers gradually realized that what was being planned and organized would have important consequences regarding how the work would be performed and coordinated once the physical space had materialized. As a result of these alternative possibilities, they started engaging in imagining and conceiving of the physical space they were about to use, i.e. organizing an imaginary physical space. Imagining and conceiving of the space also gave the SuperUsers various possibilities. They could start inscribing their interests and understandings into the embodiment of the representation of the space, thus also shaping the material enactment of coordination (Barrett et al., 2012; Beane & Orlikowski, 2015). However, this was not always straightforward as different intentions came together.

Maintaining MRI safety, despite the presence of a variety of healthcare professionals and metallic objects, and maintaining sterility despite the presence of an MRI scanner considered dirty, had to be represented in the new physical space. In aiming to maintain and represent the MRI safety requirements in the new physical space, various ways were conceived of and revealed during the planning and preparatory activities. An initial example of this was the role of the safety nurse, and the way in which the role was planned and prepared for would emerge as requiring not only specific knowledge, but also significant bodily doings in a pre-specified space. First of all, the safety nurse would have to 'actually work there', i.e. in the new room with the new technology, thus stressing the importance of a considerable physical presence. Additionally, being a 'defender of the line' would mean confronting people and physically hindering them from entering the area where there was a strong magnetic field. Thus, the safety nurse would have to rely on her body to orient the presence of others, and on her physical ability to keep objects and people away. These sanctioned bodily doings of the safety nurse were important additions to the safety protocols. The body of the safety nurse thus plays an important organizing and coordinating role in the imaginary physical space, by means of dictating what, and in which manner, tasks would be performed. As such, the SuperUsers' representations of the space would mean requirements to use their bodies to enact the role of the safety nurse, in order to realize intentions and interests as regards maintaining MRI safety.

In addition to the importance of the bodily doings of the safety nurse, other ways of maintaining MRI safety would also need to be materialized in the imaginary physical space. One such way was using stickers showing colors and numbers on keycards, representing the different levels of MRI training. Another way was strictly following the rules as regards having documented MRI training and knowledge over and above

MRI knowledge. As such, the intention was to partly replace the role of familiarity with material arrangements in order to realize the coordinating and maintaining of MRI safety. Other material effects of the attempts to represent the maintaining of MRI safety included the tasks of counting and writing down. Specific counting sheets and numbered boxes were to be used by both the surgical and the anesthesia staff to materially manifest obedience. Additionally, the anesthesia staff were no longer allowed to throw small needle covers around, and would have to start filling their trolleys to the bare minimum.

Another important intention, or interest, that needed to be embodied in the representation of the imaginary physical space was the maintaining of sterility. One way to materialize this was by having a hatch in the door leading into the operating room. However, this would prove difficult in the new room due to the changing material arrangements, and clashes with intentions and interests concerning the maintaining of MRI safety. To prevent external electromagnetic radiation from distorting the MR signal in the new room, and to prevent electromagnetic radiation generated inside the room from causing interference to nearby medical equipment, the magnet room had to be radiofrequency shielded by means of having the entire room shielded by copper. In the opinion of the MRI staff, a hatch was an impossibility as it would increase the risk of RF leakage, and thus it had not been initially planned for the imaginary physical space. The absence of a hatch was also possible as no consistency or cohesiveness is required in the imaginary physical space. However, as soon as the imagined physical space started to become visible, e.g. during educational visits to the room, the interests and understandings of the surgical staff were revealed, and a considerable discussion arose during meetings. Here, the future-imaginary physical space is enlivened by drawing on the past, thus making both previous work and traditionally coordinative arrangements important in shaping subsequent work (e.g. Barley, 1986; Barrett et al., 2012; Nelson & Irwin, 2014; Venters et al., 2014). Traditionally, the hatch was used in order facilitate coordination, including the exchange of blood, instruments, medicines, and instruments, without having to open the doors entirely. As this was believed to prevent cross-contamination and to reduce the prevalence of wound infections, the SuperUsers insisted on also having one installed in the door leading into the new room. Solutions, e.g. a hatch in an electrical cabinet at knee height, and the possibility of opening just one primary leaf, were attempts to mediate between the imaginary physical space of the MRI staff and that of the surgical staff, thus also managing the interests and understandings related to MRI safety and sterility. Differing interests, understandings and intentions coming together during the organizing of the imaginary physical space revealed divergence in how the physical space was being conceived of. With regard to the hatch issue, the sterility and surgical representation would, however, come to dominate, as a hatch was installed later. These examples illustrate how, in their attempts to organize and represent the imaginary physical space, the SuperUsers engage in a material enactment of coordination by creating references to things like objects and bodily doings (Barrett et al., 2012; Beane & Orlikowski, 2015).

CHAPTER 7

PERFORMING WORK WITH THE NEW IMRI HYBRID OR

In this chapter, how work was performed and coordinated once the iMRI Hybrid OR had been introduced will be described, focusing on new ways of working, and aspects that proved important in making the new technology doable.

7.1 Performing Work in a Different Spatial Layout

As explained in the previous chapters, the new technology meant a departure from the spatial layout used when performing traditional neurosurgery. Instead of the surgical and MRI practices being performed in separate places, they are now combined and co-located. Thus, the iMRI Hybrid OR must accommodate the space and objects needed for both surgery and MRI, something which created both challenges and opportunities. An overview of the new spatial layout can be seen in Figure 12.

An initial consequence of co-location was that the operating table now had to integrate both surgical and MRI requirements, which proved to be a challenge right from day one. There had been an intense couple of weeks leading up to the initial use of the iMRI Hybrid OR. In mid-November 2017, the SuperUsers had engaged in multiple days of training, organized by AmTech. During the week prior to the first live cases, simulations requiring a fully-gathered surgical team and all their equipment and supplies had also been performed. After intensive training and media attention, the day of the first live case had finally come.

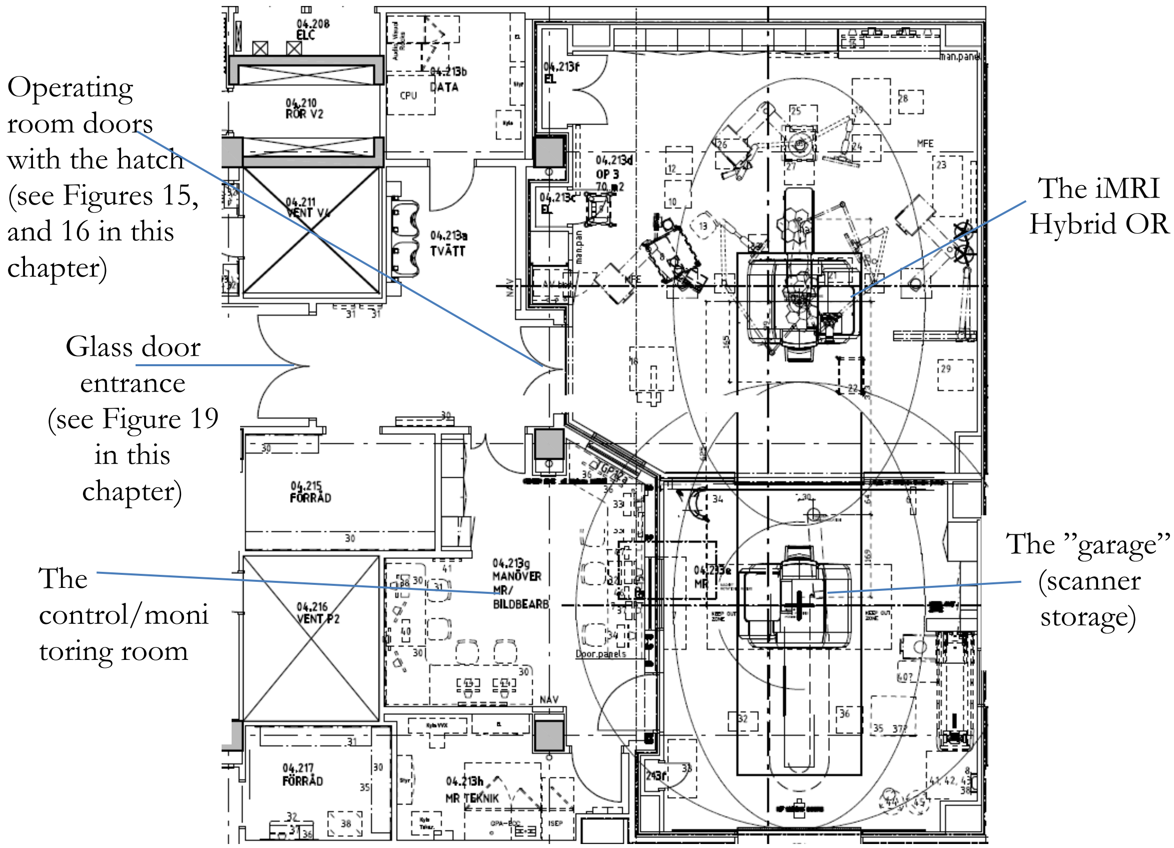

Figure 12. Overview of the spatial layout.

It was early December 2017, and the time was about 6.45 am. Based on utterances such as, "We're stressed and nervous", I could sense a generally tense mood among many of the SuperUsers. Part of this was a problem with the operating table, as explained by one of the clinical application specialists from AmTech:

> We tested the table overnight by placing a weight of approximately 20kgs on it and noted some drift. It's just a few centimeters but still important to talk about.

Despite a tilt only being as small as a few centimeters, it would still be large enough to be an important issue that had to be dealt with. This was mostly the case because the surgeons are very meticulous about having the patient in the exact same position during surgery as even minor movements could affect their work in serious ways. There were, however, no other tables to switch to and a temporary solution was needed. The adopted solution was to close the hydraulics by turning off the valves under the table, which meant that the table could neither drift nor be adjusted.

While the problem with the operating table on day one may appear to be merely a technical error, it also indicates the complexities of a co-location in the merging of the surgical and MRI practices. First of all, the table could not just be replaced with any other operating or MRI table as it needed to integrate the requirements of both practices. Furthermore, the SuperUsers not only described how "there [had] been some technical issues with the table", they also indicated how the incompatibility between the surgical and MRI requirements was creating challenges. For the surgical staff, as described by one surgical nurse; "the most important part is from the shoulders upwards" as "neurosurgery requires you to be able to raise just the patient's head". Thus, having the possibility of tilting and raising specific sections of the table to the desired angles was of major importance. For the MRI staff, however, a standardized position (most often the supine position) was important for ensuring image quality and fitting into the scanner. Thus, besides the possibility of lowering and raising the entire table, so it can slide into the MRI scanner and thus ensure usability for both patients and staff, as few table adjustments as possible was the general preference. As "there are not that many operating tables compatible with an MRI scanner" (MRI physicist), integrating the requirements was complicated and compromises had to be made. Specific sections of the table could not be adjusted, and the surgical staff were "very dissatisfied with it", with some even saying; "it's not a table, it's a bunk" (surgical nurse). To cope with this situation, and to sustain the traditional way of working, some surgical and assistant nurses had accessories custom-built, e.g. padding materials and surgical cushions.

With the introduction of the new technology, staff traditionally working physically distant from each other were now also brought together. One example of this was how the radiology nurses, radiologists and surgeons were now physically co-located in one and the same room; i.e. the control/monitoring room. As one radiology nurse described this:

> Now we're in the same room and it wasn't like that before. Before, we we're never close to each other like this. And not with the radiologist either. Then, we took the images and then the radiologist looked at them quite quickly and later they called the neurosurgeons, so they could take a look at the images at a workstation in some other place. They were barely in the room at all. It was only during emergencies, or while on call, really special when everyone was in the same room.

Thus, merging surgical and MRI practices required a novel spatial layout, a physical space that was not only about a modification of the aesthetics, but also about being consequential as regards how neurosurgery was performed and coordinated.

For example, at the traditional MRI Unit, despite being under pressure to increase the number of scans performed, the radiology nurses often experienced having time to optimize the protocols in order to get as good quality images as possible. This was partly the case because the nature of their work and the physical distance between the MRI Unit and the neurosurgery department meant that it was not expected that the patient would undergo more surgery the same day. Thus, the timing of the radiology nurses' duties did not directly impact the duties of others. However, this changed with the new technology, as both the radiologists and the surgeons directly relied on the timing of the radiology nurses' duties. This increased dependence on and visibility of each other's duties had implications for how neurosurgery was performed and coordinated. One example of this was the way in which the radiology nurses performed their work partly changing. Instead of trying to get as good quality images as possible, without reflecting much on the timing, they were now trying to get images that were good enough while trying to decrease the examination time and the order of the images. As one radiology nurse explained:

> What's changed is the order, and what's most important to start with, so they get information about what other things you need to look for. If you start with a series of images, where you can see the tumor very clearly, then we can think about whether we need any additional images. Because no one wants to keep on scanning for too long and take many series, but they want to start with the target images right away here. At the MRI Unit, we have a more standardized way of running the scanner. Here you need to start changing in accordance with what type of patient and surgery you have, which we don't do there [MRI Unit]. So, we've tried to shorten the examination time a little bit here. You don't need to scan for nothing. At the same time, we need to spend time on the scan to get good images.

The changing order of how the images were produced (starting immediately with the target images) was also initiated by the radiologists, whose work also became affected by the changing spatial layout:

> Before, we examined the patient the day after surgery instead, when they were back at the department. The questions now are roughly the same but they want an answer right away so that they know if it's done or not. Shall we continue? So, there are more disturbances in the images and a bit more urgency to get a correct answer as soon as possible (radiologist).

The neurosurgeons were sitting in the same room waiting for the images to be produced and interpreted, so that they could decide if they were going to continue with surgery or not. Changing the spatial layout thus resulted in increased urgency regarding how fast the radiologists had to read and interpret the images. As the radiologists faced increased pressures to work faster, they could not 'ponder' as much as they did before, instead having to make up their minds faster; "You have to make up your mind faster about what you think" (radiologist). Changing the order of the images was one way for the radiologist to also speed up the process. This was evident at the end of one of the first live cases:

> The surgeon announced the scan one hour ago by saying out loud; "If nothing drastic occurs, we can do the scan in one hour." It's now been about six hours since the first healthcare professionals entered the operating room this morning. The surgeon says that he feels satisfied with the amount of tumor he's been able to remove. The assistant surgeon, however, says; "But then we have something yellow here, but it doesn't feel like tumor." The surgeon then replies; "No, and it's a totally different thing to close up here, we can just suck it out again and it'll take 5 minutes". The surgeon closes up the patient while the nurses start turning other equipment off and positioning it outside the strong magnetic field. Sterility is protected by a plastic cocoon, which is put on like a cover on

> the patient. MRI is deployed and the first images start popping up on the radiology nurses' computers. The radiologist, who is sitting just behind the radiology nurses at another workstation, is waiting for the images to be transferred so that interpretation can start. The surgeons are looking over the radiologist's shoulder, impatiently waiting for a pronouncement about whether the entire tumor seems to have been resected, or if anything remains. This is a pronouncement that pretty much determines whether the entire staff can expect to go home in about one hour, or about 4. After stating that the entire tumor seems to be gone, the radiologist comments; "Maybe we should change the order of the images, with the decision-making images coming first. There's some pressure on us to quickly make our pronouncements."

As can be seen, this changed way of performing and coordinating work was due to the physicalities. Having the radiology nurses, the radiologist, and the surgeons sitting in the same room made their respective duties more interdependent in terms of timing, something which also increased the need for predictability. The timing of the other's task performance was thus made more visible and salient.

Physical co-location also resulted in new ways of learning and knowing. One radiologist explained what it meant for image interpretation to be sitting in direct proximity to the neurosurgeons:

> During one surgical procedure, when I was sitting interpreting the images, there was a signal I was really wondering about. I said out loud that it looked really strange, while upon the surgeon while pointing to the images commented, but there I have put some blood-curing material into it. This was something I found out at that time, then. Then you know, yes, it looks like this, once you've tried to stop bleeding during surgery. At first it looked like a signal that I wondered about. It wasn't there before. So, is it a small part of a tumor lying there, or what is it?

Thus, physical co-location enabled the radiologists and neurosurgeons to more closely communicate when interpreting images. This had important consequences, for example, for when the radiologists had to deal with uncertainties in the images. They could then directly ask, or the neurosurgeons could describe the surgical procedure, e.g. how it went, if there was a lot of bleeding, and if something was still inside the patient. One radiologist added the following:

> That's what's so good now, about having them here, the fact that we can ask. Have you been all the way up there and resected something, or why am I seeing it like this? Then we can talk to each other."

This way of communicating and discussing was thus directly enabled by the change in the spatial layout. How their respective duties were integrating and affecting each other was thus being materially enacted. When compared with the traditional way of performing and coordinating their work, this was even more evident:

> No, then it was more like, they wrote the referral beforehand, saying; "grateful for postoperative examination, operated on for Glioblastoma" and so on. But we didn't know if it was difficult during surgery, or if there was bleeding or if they had to leave something. That wasn't written in the referral because they didn't know this before surgery. And then, we had to sit and ponder, thinking about whether or not they had to leave just that little bit. Haha, sometimes it's like that, you can't resect the entire tumor, and I mean, it could be the case that we called the neurosurgeon to ask, but you have a threshold when you know they're exhausted and have been operating all day long. So, you might not call them to ask how it was. But when we're up there [the new room], then we can ask them directly. Did you have to leave a small edge there, or what do you think about that? (radiologist).

Another way in which the change in the spatial layout affected the ways in which work was performed was positioning the patient. This was considered extremely important for both the surgical staff and the MRI staff. At the traditional neurosurgery department, it was the surgeons who decided the position of the patient, as this directly affects how the tumor can be resected. Patient positions that varied with the location of the tumor were thus common. At the MRI Unit, it was the radiology nurses instead who decided the position of the patient. They always tried to have the patient, and especially his/her head, as straight and as well-centered as possible in order to optimize the image quality. However, the new technology meant that the surgeons and radiology nurses were co-located, with this physical co-location resulting in the surgeons and radiology nurses needing to negotiate and interact when positioning their patient. One way for the radiology nurses to make sure the patient position matched the requirements of the MRI scanner was using a specific patient position verification device (see Figure 13). This device has the exact contours of the scanner, as well as the exact height of the bore of the scanner, in order to make sure the patient fits into the scanner when it is deployed.

Figure 13. Patient positioning device.

Despite how the positioning of the patient was planned and prepared for, as commented on by one radiology nurse thus; "It was something we knew right from the start", it still required ongoing efforts; "We need to put a lot of energy into it." This was especially the case when there was no common understanding of why the positioning of the patient was important to both the surgeons and the radiology nurses. Consider, for example, the following situation during a surgical procedure:

> The surgical procedure has just started and the surgeon is sitting above the patient's head trying to fix it using the Mayfield support [a head fixation device]. The radiology nurse is standing close by and says that this position won't work. The radiology nurse continues questioning this position by explaining that they won't have the room to put the coils in place. The surgeon just looks at the radiology nurse uncomprehendingly; there are no issues with this. Insisting on keeping the position, he comments that this is how they always locate the head fixation device. When the scanner is deployed later on, it suddenly stops moving as it gets close to the patient. As something is in the way, and is touching the moving scanner, a safety alert has been triggered. Positioning needs to be redone, requiring more time and effort.

Positioning the patient is now a shared responsibility, with more people being responsible for this specific duty. Exactly how this element is performed directly affects the subsequent elements of the surgeons' and radiology nurses' duties. A common understanding is thus vital in order for the new practice to be coordinated.

This common understanding was most often achieved whenever the SuperUsers were working together, because they had been part of the planning and preparatory activities. During these activities, the different healthcare professionals' needs were made salient, negotiated and interacted. However, when newcomers made their entrance into the new room, this common understanding was sometimes disrupted or lost. As one radiology nurse explained:

> As I say, those who've been involved from the start, they position the Mayfield support straight in these two dimensions. And if you do that as straight as you can, of course you can't put it exactly straight as it depends on how thin the bone is in the head where you insert the screws. But if you do it like those who've been involved from the start do it, then there's a click and you always have room for everything. However, if they haven't done this correctly, it'll be problematic and then you'll need to check them all the time. No, that won't work, so you'll have to get it straighter, and you'll have to put it like that. You have to positions it that way.

The radiology nurses thus had to monitor and check the positioning of the patient:

> Then you might have to be on your toes, and sometimes you have to help them position the patient. You have to be like a hawk, standing and looking at the midpoints when they position the support. You have to be there all the time, especially until they finalize fixation using the Mayfield support, then you really have to see, that it's not like that or not like this (radiology nurse).

The importance of positioning the patient as straight and as well-centered as possible had been communicated and discussed during formal meetings and training sessions. It was even part of the designed protocols and checklists. However, these predefined mechanisms were not enough while work was unfolding. Thus, one way of helping the radiology nurses to center the patient's head, while also facilitating a common understanding of why this was important, was drawing a physical line with a dot at one end on the floor (see Figure 14). This line on the floor thus serves as a material indication of the importance of correctly aligning the patient. In addition to the importance of aligning the patient, maintaining sterility would also emerge as an important aspect.

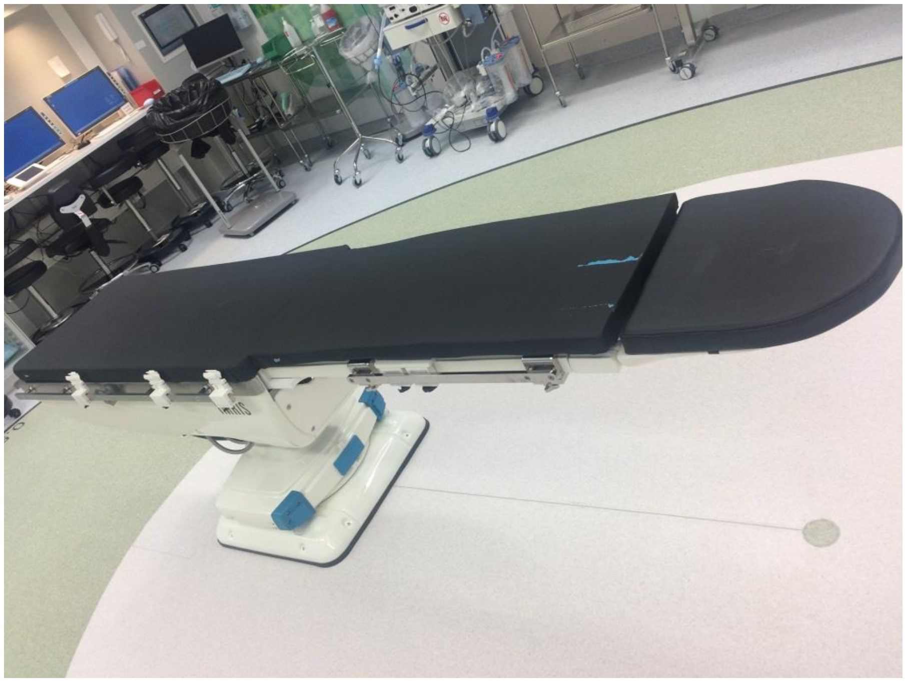

Figure 14. Operating table with a physical line and dot underneath it, indicating a straight and well-centered patient position.

7.2 Maintaining Sterility

As described in Chapter 4, maintaining sterility was very important to the surgical staff, in order to prevent infections. In the traditional neurosurgery department, the staff working in the operating rooms were used to the rules and behaviors that mainly the surgical nurses applied in order to maintain sterility. As the new technology would require a room combining the strict requirements of sterility with a "dirty environment", in the words of the MRI staff themselves, significant efforts were expected. One situation was especially illustrative of this:

> The surgeon had just finished resecting the tumor and was closing the patient up temporarily. The surgical nurses and the assistant nurses started to cover the patient. An MRI scan was to be performed in order to see if the entire tumor had been removed, or if traces of it were still there. The radiology nurses enter the operating room to put their coils in place, enabling the magnetic field signals to be transmitted and received, when they suddenly touch the green sterile drapes placed on top of the patient. They have to touch parts of the patient at some point in order to put their coils in place, and they thought that now was the time to do it. However, the surgical nurses had not finished positioning the outer layer of plastic covers needed in this new room. As a result, the surgical nurses needed to redo some of their duties, like doing additional washing and draping for sterility.

This situation was exceptional, but it clearly illustrates how the new technology requires different, and sometimes significant, coordinating efforts to maintain sterility. Traditionally, the radiology nurses are not present in an operating room and thus not used to the sterility requirements. They had, however, received some training in sterility since part of their role in the past included interventional procedures as well, but these only required what they called, "radiological sterility". As one radiology nurse commented:

> We're used to sterility since we were working with vascular interventions before, so we have a sense of it even though that was a while ago. However, some people ironically say well that was radiological sterility. It's not real sterility.

When maintaining sterility in the new room, thus, the coordinating efforts were not only more significant, they also played out differently. The surgical nurses were not used to having other people around the patient's head, except for the surgeons. This had to change when the new technology was introduced as the radiology nurses needed to be around the patient's head when putting their coils in place. One way of performing this new way of working, and integrating duties, was to rely on open interactions and negotiations. One radiology nurse explained this as follows:

> The surgical staff told us where we can stand, and that we shouldn't get too close. If possible, we should be outside there, this specific area where there's clean air. There has been very good communication in the room I think. The fact that we speak a lot to each other kinda, does this work for you if I do this? Yes definitely. So, we've had very good and open communication. There haven't been so many prima donnas among the different staff groups. Everybody wants to reach the same goal.

7.2.1 Using the hatch in expected and unexpected ways

As the hatch had become a topic of considerable discussion during the planning and preparatory activities, it was of particular interest to follow up how it was actually being used after the iMRI Hybrid OR had been introduced. As described in the previous chapters, the hatch in the operating room doors had traditionally served an important function with regard to maintaining sterility. By opening what looked like a small window, instead of the entire doors, the risk of infection due to contamination decreased. During their first visit to the new room, a heated debate thus arose when the SuperUsers noticed, and realized, that a hatch was not present in the doors leading into the new room; they were later told, moreover, that it would not be possible to install one afterwards. After intensive discussions and negotiations back and forth, the impossible was later made possible and a hatch was built and installed (see Figure 15), but this was not cheap. I was told that its approximate cost was an additional SEK 160-200 k. Once installed, the hatch turned out to be used in both expected and unexpected ways.

Figure 15. Hatch into the operating room in the open position.

As expected, the hatch proved to be important for maintaining sterility in various ways. Starting with the first live cases, the hatch was used multiple times and by different healthcare professionals. For example, consider the following situation:

> The surgical nurses and assistant nurses are present in the room preparing the operating tables, instrument tables, and the other instruments and materials. As they're preparing sterile instruments, they generally prefer being alone in the room in order to reduce the risk of breaching sterility. While they're performing their preparations, the hatch opens and an anesthesia nurse asks the surgical nurses for an approximate time for patient intake. One of the surgical nurses answers, around 8.45, at which the anesthesia nurse says that it's good to have an approximate time, because they also need to ask the patients some questions, which may take time, before they enter the operating room.

As can be seen in the situation above, during the time running up to surgery, it can be difficult for both the surgical nurses and the anesthesia nurses to keep track of each other's activities. The time it takes for surgical nurses to perform their preparations is longer than they are used to, and they are not really sure themselves about the amount of time they need. In addition, the surgical and anesthesia nurses are not physically co-located during their preparations, making them less visible to each other. Timing each other's activities is, however, very important, especially since the surgical nurses' preparations need to be done before some parts of the anesthesia nurses' activities can be performed, e.g. taking the patient into the operating room and starting sedation. The situation above thus illustrates how the hatch is used by the nurses to facilitate communication, communication that helps to either integrate or time their respective activities. The hatch thus plays an important role in making the interdependent activities predictable. The surgical nurses know when others are expected to enter the room, and the anesthesia nurses know when they are allowed to enter it, and they can thus plan their activities accordingly. The hatch was also used for other reasons, as explained by one anesthesiologist:

> If I don't want to talk on the phone, and maybe see the results from tests or something like that. Or sometimes it might be nice to just talk face-to-face with people without having to enter the room. Then I can open the hatch and wave a little bit.

Thus, in addition to making interdependent activities predictable, and meeting clinical aims, e.g. getting results of blood tests, the hatch also seemed to play a relational role. Seeing each other face-to-face through the hatch was experienced as satisfying, thus indicating the potential importance of familiarity when performing one's duties. The hatch was also used for research purposes. For example, during one surgical procedure, a researcher opened the hatch in order to ask for tissue samples. Consequently, instead of having the researcher entering the room, it was possible for an assistant nurse to provide the sample through the hatch. Using the hatch instead of opening the doors was poignantly assigned by many of the surgical nurses, as they did not see the need for the researcher to enter the operating room. Research purposes were also used, ironically, to justify the additional costs associated with the hatch, as one surgical nurse put it; "In the end, research might even be able to pay for the hatch. The cost of the hatch starts to decrease with increased usage".

As shown, the hatch proved important in maintaining sterility in various ways. However, despite the general importance attributed to it, there were still differing opinions regarding its use and relevance in practice. The majority of the healthcare professionals working with the new technology seemed to attach great importance to the hatch. As one anesthesiologist commented:

> Yes, it's used because, according to our sterility guidelines, it's good that we have the hatch and don't need to open the doors completely… Here we even count the number of times the door is opened, the surgical nurses count the number of times.

However, despite some SuperUsers arguing how they could not work without it, "It wouldn't work, no no no it wouldn't work" (surgical nurse), others were still mildly skeptical about the importance of the hatch, and even thought this was slightly exaggerated:

> It's used but not so much I think, but it is used, yes. But that's not really so often… I'm a bit surprised because there was a lot of discussion about that hatch… I can say they open the doors a lot back and forth. But maybe there's something I don't really understand here. But as it seems, they open the doors so much that it makes me wonder if the hatch was really needed. I feel they might as well open the doors and stand there to receive something. That's how I feel, but again it's something I'm not really across, this business of airborne infections and how long doors should be open and closed for, and so on. But maybe the hatch is a bit

> over the top. But, as I said, I'm not the right person to answer that. I do however think the doors are open quite a lot during surgery (radiology nurse).

> I worked in another operating room before, and I found that the hatch was used quite frequently, but I don't think it's used so much here. The doors are opened a lot too. So, maybe the hatch might not have such a huge part to play actually (MRI physicist).

Thus, there were different opinions about the importance of the hatch, with most of the people using it considering it to be an absolutely necessity, while others who were not using it felt mildly skeptical. This skepticism was, however, expressed in a humble manner since those raising these concerns did not generally use the hatch themselves and perhaps did not understand the logic underpinning it.

One possible reason why the hatch was not used to such a great extent was the new room being located at a distance from the traditional neurosurgery department and the MRI Unit. The SuperUsers were not able to store all the materials and instruments they needed in the new room, instead having to continuously go in and out of the room with what they needed. One anesthesia nurse explained:

> Instead of using the hatch, we opened the doors more than I thought. You went in and out of there quite a lot; I did after a while too. So, this idea of restricting the number of times the door was opened was not put into practice as much as I thought it would be. The doors were opened a lot because we had to go and get things and bring them into the room, as well as other people entering.

Another conceivable reason why the hatch was not used to a large extent was the hatch itself. One anesthesia nurse explained what it meant for the hatch being experienced as "not the best one in the world":

> The difficult thing is that you can't really see if it's open or closed properly. So you don't know, so sometimes you hear someone trying to push it open, and then you realize okay, someone wants to get in or something, but then the locking hasp is closed. So, it's not the best hatch in the world exactly. In our department, it's so easy to just open the hatch and look in. Here, it's a bit more difficult, but it's been great to have it. (anesthesia nurse).

Compared to the hatches used at the neurosurgery department, this hatch was not as easy to open and, since the locking hasp was located on the operating room side, it was also difficult to see and hear if someone wanted to open if from the outside. One way to improve use of the hatch, and prevent people from trying to force it open, was putting up a sign stating that the hatch opens inwards (see Figure 16). As such, the functionality of the hatch constrained its use in daily practice.

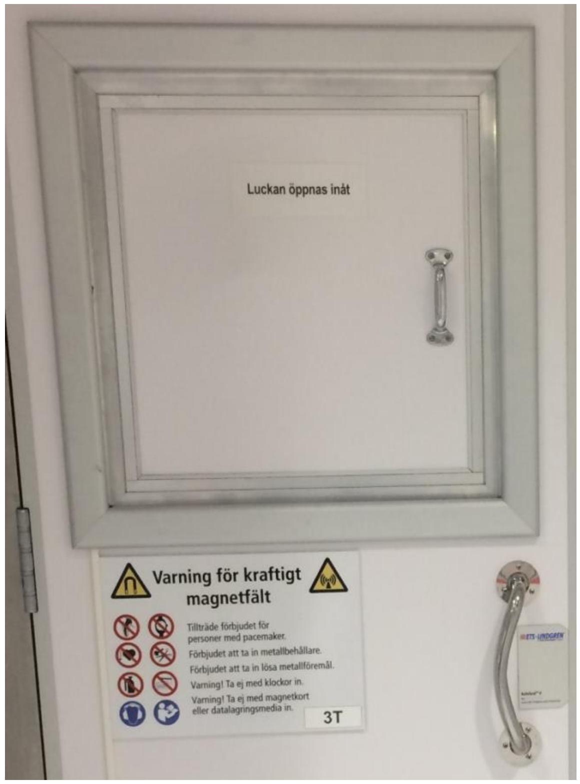

Figure 16. Hatch showing sign stating that it opens inwards.

To sum up, despite how the hatch proved to be important in maintaining sterility in various ways, it was still given less importance than what had been expected. However, it also turned out to play other and more unexpected roles, which were not always related to sterility. As can be seen in Figure 17 below, all phones and alarm beepers had to be left outside the operating room due to the presence of a strong magnetic field.

Figure 17. Lockers used as storage for metallic objects, e.g. phones, alarm beepers and pens.

Inside the room, phones and alarm beepers did not work as the whole room was copper-shielded, resulting in no signal. The only chance of getting a signal was by opening the operating room doors, something which was not possible due to the increased risk of infection. This was totally different to other operating rooms, into which multiple phones were brought and used continuously. One anesthesiologist explained:

> In other operating rooms, they all have their own phones, but our phones won't work here if the doors are closed. They only work if a door is open. Because the room is so shielded, and our phones use IP telephony, they won't get a signal.

This isolation of the room also meant it was soundproof, thus ringing phones or alarming beepers left outside could not be heard from inside it. However, there were times when these phones and alarm beepers needed to be heard, e.g. during late-day procedures when the hospital was generally short-staffed. One anesthesia nurse explained:

> The doctors need to leave their phones, and sometimes you might get help from the staff on call, and then we use the emergency phone. Then they can't bring the phone with them in, and even if the scanner isn't there, the phone still won't get a signal anyway so it doesn't matter. And you might also have a small alarm beeper that receives alarms and so on. Then you need to have it outside the room and to leave the hatch open. Because then you might hear it, you hope you'll hear it. So, that's the difficult thing inside the room. You get a bit isolated.

An open hatch thus made it possible to hear ringing phones and alarming beepers, serving multiple purposes, and thus also serving as a mechanism for integrating MRI safety precautions with surgical activities.

> Interviewer: So, it means the hatch enables you to hear the phones?
>
> Anesthesia nurse: Yes, exactly, and then we open the hatch to be able to hear them [the phones]. Because the doors automatically close, we can't hear anything. It's very soundproof there, so you won't be able to hear anything.

As there was an incompatibility issue between the copper-shielded iMRI Hybrid OR and the functionality of the alarm beepers and cellphones, the hatch turned out to play an unexpected, albeit important, role when the new technology was introduced. Next, how MRI safety was maintained is described.

7.3 Maintaining MRI Safety

7.3.1 MRI training

As the MRI scanner had now been located at a surgical department, rethinking MRI safety training was an important aspect of maintaining safety. The more in-depth and formalized MRI training was different to how things had traditionally been organized, and it was not always met with acceptance. The following section thus describes how MRI training was realized, and some of its related consequences.

The various operational managers decided which healthcare professionals to enroll in training. Their decisions were based on whether or not these professionals would be working with the new technology. The MRI physicists were responsible for training, and often stressed the importance of physically experiencing the magnetic field:

> We make sure they actually get to feel the magnetic field, because things are so much clearer if you're actually there and get to see how it works and see how strong the magnetic field is (MRI physicist).

One radiology nurse also stressed the importance of physically feeling the magnetic field, in addition to just reading or being told about it:

> There are many people who think it's great, that it doesn't just include sitting in front of a PowerPoint screen but that you also get see how it looks in the room. We explain for them how it looks, and they can also feel how strong the magnetic field is. For them, they're complete beginners, starting from scratch, those who come. They don't know anything, and if you haven't understood how strong a magnetic field is or whatever, then it'll be difficult to get an understanding of why it's so important. But if you've felt a magnetic field, how strong it is, then you'll understand the safety routines.

After completion of their MRI training, the attendees' most immediate managers send a request to the radiology manager who checks their names against the attendance lists and then grants them authorizations on hospital keycards.

7.3.2 Stickers as a supplement to familiarity?

The old MRI Unit, as described in Chapter 5, was isolated, and only a small group of hospital employees were allowed access. The radiology nurses thus knew more or less all the people working there, and could rely on this familiarity as a way of maintaining MRI safety. They would immediately react to 'outsiders', asking them who they were and what they were doing there. However, the new technology entailed less isolation, as it was located at a surgical department, as well as more people circulating around the MRI scanner, as the new procedures would require the presence of more and different healthcare professionals. One way of maintaining MRI safety was thus to supplement familiarity using other visible mechanisms.

After the staff member's most immediate manager had granted him/her authorization on his/her hospital keycard, stickers showing different colors and numbers, indicating the level of MRI training, were then put on his/her keycard to indicate eligibility (see Figure 18 below).

Figure 18. Keycard showing MRI sticker.

The potential ability of these stickers to facilitate the maintenance of MRI safety was questionable, however. During work, the stickers were small and thus seldom noticed or differentiated between as regards color or number:

> Radiology nurse: Everyone has got one of these symbols on his/her keycard
>
> Researcher: Okay, how are the symbols used?
>
> Radiology nurse: It's probably different. It's quite small, so is it green or blue? It's a bit like that you know. So things will actually be slightly relaxed as regards the symbol… But whenever we've been unsure, we've been able to ask and check what level the person had.

One MRI physicist had a similar explanation:

> I think it gives a sense of security to the staff. That they've actually done the training and feel they can actually do this. And then they have something to show then. I think that's good. But I don't know if it serves its purpose, to be able to check if the people entering there actually have the training. Because I don't think you look so closely at the keycards. But if you're in any doubt and if someone you don't recognize comes in, you can always ask, have you done the training, and then you can double-check it on the card, so that's good.

Thus, on the one hand, the stickers were too small to allow the staff to notice the difference between the colors and levels, while on the other, being used if the staff were unsure or just wanted to check the level of MRI training. The stickers thus seemed to play a certain role, particularly for some people who seemed to associate them with status and confidence. This was also evident during one interview when an

MRI physicist received a phone call from another healthcare professional reminding him that he had undergone MRI safety training and thus wanted to have his sticker on his keycard. In addition to this, other SuperUsers also mentioned, and showed, their stickers during interviews, as one radiologist said; "We' did the MRI safety training and we got this little sticker [shows sticker on keycard]", and as one anesthesiologist also said; "We had MRI training and gained level four, it says here somewhere [shows keycard]." As many healthcare professionals actively searched for their stickers, and had no problem showing them, this attributing of status to these stickers has implications for how MRI safety is maintained.

7.3.3 MRI training becoming consequential

As MRI safety was important, MRI training became, in various ways, consequential. For example, the consequences of not undergoing the training were immediate:

> If they haven't undergone training, they won't be granted authorization, and thus they won't be let into the department. Well, into the surgical department anyway, but not past the final set of glass doors (MRI physicist).

Figure 19. Final set of glass doors leading into the iMRI Hybrid OR area (viewed from inside).

One situation where this was especially evident was when one of those responsible (Margret) for the deployment of the new surgical department in its entirety was denied access. In describing Margret as experienced, knowledgeable and autonomous, among other things, many healthcare professionals expressed their respect. With almost unlimited access, Margret normally moved freely throughout the hospital. However, during the visit involved in the training being done at the entirely new department, which included an educational visit to an MRI scanner, Margret and the members of the supervised group all lacked clearance on their keycards; thus, they were unable to pass through the glass doors (see Figure 19). Despite Margret suggesting deviating from the rules, the MRI staff did not let them in, as explained by one radiology nurse thus; "The ongoing training on floor four includes an educational visit to an MRI scanner, but I didn't let them in. She [Margret] wasn't happy, but I didn't care."

The situation above illustrates not only the immediate consequences of MRI training, in the way staff who lacked it were not let in, but also how the importance of MRI safety makes changes to who gets to do what and where. As a result, these consequences may explain why there generally seemed to be very few compromises regarding how MRI safety was taught and complied with. One exception to this, however, was the yearly repetition, which was later changed to every third year. This was initiated, surprisingly, by the radiology department managers, who thought repeating MRI training annually was too often. The MRI physicists did not agree and continued to stress the importance of continuity:

> Yes, apparently they thought it was too much to have it every year, but we have kept this repetition for those who haven't worked there for six months, which we think is good.

Thus, one compromise was the annual repetition, but the MRI physicists managed to keep the requirement that healthcare professionals redo their training if they have not worked in the room for six months.

The general opinion among both the MRI physicists, who were training healthcare professionals in MRI safety, and the other SuperUsers, was that aligning this training with keycard authorization had worked. They were aware that it was still possible to be let in by someone else, or to sneak in with someone who has access, but they did not recall this ever actually happening. Thus, having all the healthcare professionals who were supposed to work with the new technology doing MRI training did not seem to be an issue for negotiation. Other issues requiring ongoing interactions, however, seemed to arise, in which the safety nurse came to play an important role.

7.3.4 The contested role of the safety nurse

The way in which the SuperUsers had decided to handle emergency situations, together with how the safety nurse was the one mainly responsible for MRI safety in the new room at all times, both meant that the role was considered extremely important and critical. When reflecting on how the role of the safety nurse played out during the introduction of the new technology, a common response was as follows;

"It's been working very well and things have felt safe". Two SuperUsers further described this as follows:

> Yes, it's worked very well. The role has earned people's respect. There have been two of these safety nurses… But I think the role has worked well. There have been clear guidelines and checklists for the two who have been responsible. It's something that has worked well having these hard stops and control checks [MRI safety routines]. You go through and then they go through all these checklists. We haven't had any kinds of incidents or anything (radiology nurse).

> Yes it [MRI safety] has been maintained, and they [safety nurses] are always there. I think the role has worked really well. They're very good at following the rules and being disciplined. So, the role has been adhered to very well (anesthesia nurse).

In the quotes above, it is apparent both that the role had been functioning well and that the other SuperUsers felt a sense of security in the safety nurse being responsible for MRI safety. This seemed to be attributable to how the safety nurses were good at following rules and maintaining order, and had thus strictly followed the checklists for the new room. Moreover, the role of safety nurse could be assumed by either of the two assistant surgical nurses, and was in accordance with how they had planned it, with both nurses being trained into the role.

Another explanation as to why the role had worked so well was how it had been generally experienced that there was a lack of issues related to hierarchy and status. As one anesthesiologist commented:

> Yes, I think the role has worked well, because we don't have any big problems with respect for the nurses and so on. We see that these are important functions, so it's worked out well.

The lack of a distinct hierarchy being experienced made it easier for all occupational groups to respect the role. The role was even given some 'extra importance':

> I think it's worked well. They were given a task they would do. That is, it was an upgrade for those assistant nurses that we had. They probably enjoyed it quite a lot. Getting a bit more importance quite simply (anesthesiologist).

One surgeon even thought the safety nurses should receive formal recognition in terms of monetary compensation:

> I also think that they [the safety nurses] should get something extra, I mean a rise in salary, but that's my personal opinion.

However, there was no salary increase, and neither was the role completely problem-free. For example, the safety nurses themselves sometimes felt they were not being recognized for their efforts:

> No cred, at all. No negotiations about salaries or anything. We've worked like slaves, really, setting up a very nice operating room for a hospital that doesn't even know who we are.

Not only did they experience a general lack of appreciation for what they had done to make the new technology work, they also saw the MRI safety rules sometimes being observed loosely:

> It was a bit sloppy, very sloppy, and then we weren't so popular so we took a lot of crap. I shouldn't say crap, but we felt we were being seen as the angry and picky ones. But we stood up for ourselves; we have no problem doing that (safety nurse).

The safety nurses were acting strictly and harshly in order to maintain MRI safety. This also created a misunderstanding, i.e. that they were the 'annoying ones', something they did not agree with:

> Then we became the bitches me and Karin, and we were thought of like that for a pretty long time there. People considered us to be pretty angry and impolite, but we weren't. We were just tough and determined (safety nurse).

Thus, the safety nurses testified that they had often been perceived as tough, grumpy, and even angry, something they did not identify with. They felt this was unfair, but they also stressed they had no problem per se questioning or correcting both people and duties that might jeopardize MRI safety.

As mentioned, MRI safety breaches did occasionally occur, which complicated the role of the safety nurses as it was during these situations that this role was important. For example, despite having both training in and experience of other MRI scanners, some healthcare professionals still breached some of the safety procedures. One situation when this happened was described like this by one anesthesia nurse:

> It was probably one of the anesthesiologists who came in there with a lot of things and so on. And she had received the information and knew that it was an MRI room, and had even been at MRI before, working on MRI and so on. Yes, there was a bit of irritation there.

Despite the situation above not involving any of the SuperUsers, but someone new who had been brought in, the anesthesiologists themselves did not generally experience the new technology as very different from the other MRI scanners; since they were used to sedating patients in these other MRI environments, they felt comfortable working in ways they had always used previously:

> I don't think we work that much differently. The thing is that for us anesthesiologists, there's not so much that's new to us. We've sedated patients in MRI environments and we know what we're doing when the MRI scanner is taken in. Well, as long as the scanner has gone back into the 'garage', you can do almost anything you usually do. Just make sure

> that, when the scanner enters the room, everything will need to be moved (anesthesiologist).

However, having experience of other MRI scanners was not always perceived by everyone to be an advantage because the new technology had a different kind of magnet and was located in a different context. One MRI physicist explained:

> Well, they [anesthesiologists] are more experienced, they know from before that unless the scanner is in the room, there is no direct risk. But the thing is that they don't think about how the scanner will actually enter and that if they then drop something, it'll go straight into the scanner once it's entered. And they haven't really understood this yet.

Thus, when the original group of SuperUsers, who had been part of the overall planning and preparatory activities right from the beginning, was working, this was generally experienced as safe and smoothly-functioning. As one MRI physicist commented:

> The SuperUser group is very much like that, they think very much about safety. I mean those who've been involved from the beginning, and things feel safe in their hands. The safety nurses, the ones who work as safety nurses, they're very strict and things feel safe in their hands too. That you can keep it like that all the time, so it won't get more relaxed with time. I hope it'll stay as strict as it is now.

However, as time went by, more colleagues were trained in the new technology because the SuperUsers needed to be interchangeable. Some of the SuperUsers felt that this rotation created problems. This constituted one important topic during a SuperUser meeting held in mid-January 2018, that focused on following up on the procedures using the new technology. The following discussion unfolded:

> Safety nurse: The safety rules must be followed. We must respect them, there will be a safety risk otherwise. Things are done in a special way here, but not in other places. We have this kind of thinking in the SuperUser group, but others who haven't been a part of it from the beginning don't.
>
> Radiology nurse: Yes, those of us from MRI also agree with that.
>
> Safety nurse: Our roles and tasks have been questioned by anesthesia. They ask us why we do things the way we do, and they say, no that's not how we've been taught and no one has told us why it has to be like that. These are the new anesthesia staff, outside the SuperUser group.
>
> Anesthesia nurse: Which of the anesthesia nurses have disputed you?
>
> Section manager: We don't need to name anybody here and now. It would be better if you came to me if it happened again, then I'd raise it with that person or persons. That's my role as a manager.

> Safety nurse: Okay, but we feel violated, questioned and oppressed. This doesn't feel good. We're being questioned as regards why we do things the way we do, why we correct them and so on. There must be a change, we need to get our act together.

There was some silence… and then the safety nurse went on:

> Safety nurse: The honeymoon is over. People can have anything on them, phones, forceps, pens and so on. They say that when the scanner is out, there's no danger. They roll their eyes. But we've decided that we'll hold on to these rules and routines and not let them go. It doesn't matter whether the scanner is there or not. Because I don't want to get forceps in my eyes. Just the other day, we found a pair of forceps that someone had taken in and put on the floor, and also a paperclip. If we don't follow these rules and routines strictly right from the start, it'll get sloppier and sloppier, and that's a safety risk.
>
> Anesthesia nurse: Those of us from anesthesia don't think it's been particularly nice to be working there either. You haven't been so helpful.
>
> Safety nurse: We understand that. We certainly didn't contribute to a pleasant atmosphere either. But that's because we always need to be a little impolite and point things out, so they understand. And that's because we're thinking about safety.

As can be seen in the discussion and read from interviews, a tense and anxious situation had emerged. The safety nurses thought some of the safety procedures were being violated, and thus had to correct things and speak up whenever this happened. These issues seemed to occur mainly in relation to whenever healthcare professionals outside the SuperUser group were being introduced to the new technology. Bringing up the MRI safety violations during meetings like the one described enabled the safety nurses to share their knowledge of non-compliance with other SuperUsers and to thus create some form of peer support, as further illustrated by the following two quotes:

> Of course it's an important aspect. They were safety nurses and I understand it was their duty to keep track of this. So, I still think it was correct of them to seek a confrontation. But then you can also say it in a good way, I think. But that's how it was and I think it got better after this as well (anesthesia nurse).
>
> We support the safety nurses in trying to get others to obey them when ensuring that all staff follow the routines which are, in fact, specific to this room (MRI physicist)

7.4 Counting

Counting and writing down had traditionally been important aspects of surgery, but only to the surgical staff. This was the case because counting could prevent things from being left inside a patient and could thus prevent serious infections or complications. With the new technology, however, counting took on additional meanings and also involved another group of people, i.e. the anesthesia staff. As already mentioned in previous chapters, with the new technology, counting was also performed in order to make sure no metallic objects were missing, thus preventing them from becoming missiles whenever the scanner was deployed. This new meaning of counting had implications for how it was performed and coordinated, and how this played out is described next.

7.4.1 Surgical counting

The surgical staff were used to counting; however, due to the specificities of the new technology and the new room, this counting had partly changed. Previously, the surgical nurse counted things by herself in the traditional operating room, but she now needed some assistance from an assistant nurse. This was explained in terms of being due to the number of additional things needing to be counted, and due to the counting itself needing an extra pair of eyes. Just how this differed from the traditional way of counting was visible during the first live case. Consider, for example, the following situation:

> The surgical nurse and the assistant nurse are collaborating to prepare the operating room for surgery. They're unpacking and placing various materials and instruments on the different tables close to the operating table. The surgical nurse asks the assistant nurse whether they should do the counting together. The assistant nurse answers; "Well, it's up to you to decide how you want things."

The two nurses later recalled that the whole idea was to actually do the counting together. The situation thus serves as an example of how the new ways of working had not yet become fully-established or self-evident. This was also evident during one situation when counting was performed after the patient had been closed up:

> The surgeon has just closed up the patient and flushed the wound one extra time in order to reduce the risk of bacteria leading to an infection. The surgical nurse starts counting the instruments together with the assistant nurse. The assistant nurse calls out the names of the instruments to be counted, some of which are missing. They realize that some things have already been put on the trolley to be taken to the autoclave for sterilization, and they need to go there to count them.

Thus, despite the overall technique of counting being well established among the surgical staff, and the fact most of the time there were no issues, these new demands made the nurses continuously aware, however, of counting and how to do it. In addition, despite it being the surgical nurse and the assistant nurse who did the surgical counting, their work was directly affected by the other people in the room. Consider, for example, the following situation:

> At one point, there was a surgeon who didn't belong to the SuperUser group who came up and did do the surgery. He lacked understanding of

> the importance of routines and so on in the new room, but we guided him quite well. But when we'd sterility washed and draped the patient, and were about to start counting, we found a needle was missing, one of ours on the surgical side. We realized it was a needle used for local pain relief that was missing, because you use that on the skin before starting. We shave the patient's head, sterility wash and then the surgeon gives local pain relief. We never received that needle and we couldn't find it. So we needed to search for it quite a lot there. Then the surgeon had taken, you know because they're so used doing what they always do, the needle with him like he always does, and he had it on him and no one saw it. But then I saw later, when he was on his way over to the anesthesia side, and was just about to throw it into their bin or their box over there. So, it was about 2 seconds away, good that I saw him just about to put it down.

In this situation, it is apparent how healthcare professionals at times were relapsed into old habits. However, many of the traditional ways of doing things could not be sustained, and the new technology thus had implications for how people needed to work. In order for the surgical nurses to do their counting successfully, they now needed to also check other people more intensively. As a result, the counting done in the new room also put greater demands on the safety nurse to actually have the courage to speak up if something was missing. As one safety nurse explained:

> For example, if a pair of forceps is missing, then I'll need to be tough and say STOP, we can't proceed. To have the courage to say that and to stand up for it. Because, then the surgeon might say, well it's not so important, it's not in the patient's head at least. But, no we can't proceed. And there are a lot of people in the room, so you can't be unsure of yourself, that's just not a possibility.

While counting in the new room meant nurses needed to work differently and engage in new ways of working, little generally changed for the surgeons regarding their surgical technique. One exception to this was how they needed to stop using the sewing technique called 'snatching', as this often caused needles to be thrown on the floor, and thus had to be abandoned due to the risk of them becoming missiles in the new room. Despite the surgeons saying that they strove to work as they had traditionally worked, counting still had consequences for how they worked. As mentioned, they could no longer, for example, place needles or other instruments wherever they wanted. The importance of counting and following checklists also meant that the surgeons were not always able to do what they wanted at any time, as illustrated in this field note:

> It's 9:30am and the staff are still doing all their preparations before surgery can begin. The lead surgeon is walking toward the doors leading into the Hybrid OR when the safety nurse stops him, exclaiming; 'Where are you going?' To which the surgeon responds; 'I'm on my way to the toilet! Am I allowed to go there?' The safety nurse responds decisively; 'No, not now because we're about to do the checklist!' While the surgeon is slowly

> moving back to the center of the Hybrid OR he mumbles; 'It takes such a long time, I could have had time to go to the toilet and buy a croissant'

7.4.2 Anesthesia counting

Counting was new, and also very important, to the anesthesia staff. One nurse described the seriousness of counting and how it emerged as important to the work done in the new room:

> We have to count the needles and the metallic objects and the other equipment. We need to have that under control. And sometimes something is missing, and then the whole process stops. The surgical procedure can't go on until we've found a needle, for example. And this happens sometimes, but we always find it. But then we need to stop the flow completely because there's a needle missing (anesthesia nurse).

Despite its novelty, the general opinion was that the anesthesia staff had handled the task well, and managed to incorporate counting into their traditional work patterns. The safety nurse commented:

> It's been great; they've been really good at it. Absolutely, they took it seriously. They tried to minimize their stuff and take up as little as possible, with needles and so on. Otherwise they can use three or four or more needles at the same time and just chuck them around. Now they're very careful and have a specific place for counting where they can gather everything together and count it. So, they've taken it seriously (safety nurse).

To make counting possible, the anesthesia staff still had to make an effort and some sacrifices. For example, they decided to reduce the numbers of needles and materials on their trolley. This was done to make counting faster and easier, but also as a way of reducing the risk of metallic objects going missing and thus posing a safety risk. Reducing the number of needles and other materials on their trolleys worked well, and the anesthesia staff quickly got used to it. At the same time, they said that this change was partly different to what being an anesthesia nurse traditionally meant. Anesthesia nurses are known as airway experts; however, in addition to their duties of ensuring proper breathing and circulation, they are also specialists in managing the entire respiratory system. Being an anesthesia nurse goes beyond preventing critical incidents, it also entails being prepared for the unexpected to happen and, when it does, needing to act immediately. Anesthesia nurses often described needing "to find solutions all the time and to be prepared and always have a plan B". I was told that filling up their trolleys to the max was part of this as it could provide a sense of security and serve as a backup during critical incidents. Although it did not pose a risk to the patient, instead being more a feeling that some had, this changed with the new technology. In the new room, if something goes missing or runs out, the staff can "go and get it", but the supplies were still experienced as "being scattered and taking longer to collect" (anesthesia nurse). Counting generally worked well as long as the patients were stable, but once they became unstable, it became especially challenging:

> We can have either a completely stable patient, where we can be very much involved in the counting and all that, but we can also have a patient that we feel is not sleeping terribly well or is in pain. Then our focus needs to be changed to concentrate on the patient's wellbeing, and not on counting things. Here we need to be very clear and say that the patient is not feeling well, so we can't count right now or move on with the checklist. If we don't clearly communicate this, the surgical staff won't understand, and irritation arises. They may think I'm not following the counting routines etc. (anesthesia nurse).

Thus, when a patient is unstable, it becomes difficult for the anesthesia nurses to divide their attention between multiple tasks and physically engage in both counting and safeguarding the patient's airways. On an occasion like this, they have to change their focus to what they consider to be most important, i.e. the patient, clearly communicating this to others in order for the SuperUsers to have a shared understanding. Developing a shared understanding was something that the SuperUsers cultivated over time, partly due to changes in the fabric of their relationships, in turn facilitating a more integrated approach to doing their work. This is further described next.

7.5 Working Together and Changing Relationships

The SuperUsers commented that, over time, they had been 'getting into the new ways of working' more and more. When reflecting on what made the introduction and use of the new technology work, the SuperUsers tended to explain how they had been able to work together more closely and 'really felt like a team'. As one surgical nurse further described this; "If we talk about us SuperUsers, who have been part of it and developed it right from the beginning, we've developed very good teamwork". Working together more meant that the SuperUsers 'really help[ed] each other' (surgical nurse) by seeking and giving advice; as one radiology nurse explained; "It's worked very well in that we can ask them [the surgical staff] how to do this and that. And they can also ask us." One specific example of this was related to patient positioning, a duty now requiring the active involvement of multiple occupational groups. As one surgical nurse explained; "We position the patient together. We see if his/her position is good or not, and sometimes we have to readjust it, but it's something we do together." Thus, the SuperUsers not only had shared responsibilities for their duties, they also started to "help and remind each other of what is important" (radiology nurse), in turn requiring a shared understanding. Working this closely together was different to how things were traditionally. As one surgical nurse explained:

> We were collaborating before as well, but even more so here. It's really us doing this for the patient. We did that before as well, but it was much more split, with us doing our own thing. Here more of us are involved,

> such as with MRI, and all the parts now need to match up. Anesthesia needs to locate the tube in a specific way so as not to take up too much space and risk not fitting into the scanner, and MRI needs to know they'll have space for their stuff, and we need room for our navigation system and so on. All these parts need to be aligned and match. And then the situation is much more about us needing to think for each other. Thinking both of each other and for each other. We collaborate in a better way, it's more us.

Thus, instead of doing their own thing and then aligning their separate duties, the SuperUsers were now even participating, to some extent, in each other's tasks, thinking both of and for each other. Developing this more integrated approach to working was facilitated by and facilitated the emergence of a shared understanding. Here, the changing fabric of the relationships also played an important role. The general view among the SuperUsers was that they had "gotten to know each other really well", which, according to one radiology nurse, meant that they; "Can have fun with each other, but also be serious, so the relationships have turned out great." Besides just enjoying each other's company, the changing fabric of the relationships also played an important role in facilitating a shared understanding and working in a more aligned way. As one surgical nurse described it:

> I think it's been important getting to know each other during the planning phase. It feels as if we have very good cohesion within the group, and this has made the work easier to do. If you know each other, it'll be easier to communicate and sometimes you can just send a text message saying; 'How are we going to do things tomorrow? And what time are we going to do that, and what do I do if something acts up? So, the threshold for making contact is much lower if you know each other. There's no strangeness in asking. It's made our work flow very well (surgical nurse).

7.6 Analytical Summary

In what follows, I summarize and discuss how work was performed and coordinated once the new iMRI Hybrid OR had been introduced. Making use of the new technology required the emergence of a new social setting and a new physical space, which in turn contributed toward new coordination challenges arising, as well as new ways of managing these challenges.

7.6.1 The emergence of a new social setting

Making use of the new technology required new social dynamics, including roles, responsibilities and interactions. This emergence of a new social setting in turn contributed toward a number of coordination challenges arising.

First, challenges arose as regards how a number of duties required full responsibility on the part of the SuperUsers, while only granting them partial authority. One such duty was patient positioning, and how multiple professional groups had full responsibility for making it work, while at the same time only partially controlling and dictating it. Similarly, maintaining sterility was a responsibility shared by all the SuperUsers, but it was mainly the surgical nurses who had the authority to control and dictate what was done. Second, challenges arose in connection with changes in authority and the knowledge this rests on. Traditionally, authority rested with and was based on professional status, and the knowledge and skill existing within the professional domains. However, once the new technology had been introduced, authority was largely based on the responsibility and knowledge regarding the new physical and technical environment. One example of this was how MRI, and knowledge of it, became the means through which status positions were afforded. For example, the safety nurse, a role occupied by assistant nurses, emerged as a new occupational role with considerable authority over traditionally high-status actors. This created challenges, especially when high-status professionals outside the SuperUser group resisted changes in authority. For example, by being less strict with MRI safety rules, e.g. insisting on wearing and bringing metallic objects into the iMRI Hybrid OR. Thus, by exhibiting neglect of and non-compliance with the dictates of the safety nurse, these higher status professionals were reasserting their dominant position in the hierarchy and reinforcing status differences, in turn impeding the accomplishment of collective work efforts. Third, and related to the challenges above, an insider/outsider dynamic emerged which became associated with coordination challenges. While the SuperUsers became part of an insider group, allowing them to develop a shared understanding, the newcomers became part of an outsider group instead, with their own interests and understandings of how work was to be done. For example, surgeons, being outsiders, did not generally entirely understand why patient positioning was important to the MRI staff too. They had not been part of the planning and preparatory activities, during which the SuperUsers had decided that the head fixation device needed to be placed in parallel. Instead, the surgeons argued that the way in which they carried out their work did not need to change to any large extent, thus striving as much as possible to work the way they always did. However, as new interdependencies emerged, this was not always possible, e.g. how even throwing a needle into a bin disrupted the counting performed by the nurses, thus impeding collective accomplishments. Another example of this was how some anesthesiologists, who had not been part of the SuperUser group, were less strict about surrendering all their metallic objects before entering the room. They were used to working in an MRI environment, referring to the traditional ways of maintaining MRI safety when arguing that it is safe to bring metallic objects into the new room as long as the scanner is not being deployed. However, as they had not been part of the insider group, they lacked training on the potential dangers of such behavior when using the new technology. Thus, these insider/outsider relations resulted in integration difficulties and counteracted the desired flow in the OR.

The findings regarding the emergence of a new social setting, and its associated coordination challenges, illustrate how the changes in terms of who was doing what, i.e. accountability, not only followed predetermined role descriptions but also ongoing interactions (Faraj & Xiao, 2006). It has been argued that, in healthcare settings, the responsibility for duties often follows hierarchical authority. The findings of this study also show how the responsibility for duties does not have to be equal to complete authority of the same duties, which contributed to coordination challenges. Thus, separating responsibility from authority is important when it comes to understanding how coordination unfolds in practice, and with what consequences, in turn bringing important nuances to our understanding of coordination as a dynamic process (Jarzabkowski et al., 2012).

The findings also illustrate how status differences are intertwined during coordinating processes (Anthony, 2018). The safety nurse took advantage of opportunities when well-established disciplinary demarcations were in a state of flux, and emerged as a high-status actor in the new social setting. The nature, or basis, of how to attribute status and authority was changed, with the traditional roles of seniority and expertise partly being replaced by the responsibility and knowledge regarding the new physical and technical environment. Thus, while the existence of a professional hierarchy, and the deferential status accorded to the healthcare professionals in different disciplines, is very pronounced in healthcare settings (Friedson, 1970; Nembhard & Edmondson, 2006), the findings of this chapter show how both status differences and authority are ongoing and constantly emerging as part of the situated coordination processes. At the same time, the findings of this chapter also show how certain high-status actors resisted the changing nature of authority and status, thus pointing to the influence that well-established traditional arrangements have on coordination (Anthony, 2018), and how occupational and professional approaches to accomplishing and coordinating processes are mutually shaping (Bechky & Chung, 2018).

The findings regarding insider/outsider relations provide important insights into how a shared understanding is developed, as well as the contribution it makes to coordination. The planning and preparatory activities functioned as formal coordination mechanisms through which the insiders had the possibility of developing a shared understanding of how work was to be performed, and why, in the new room. In addition, informal mechanisms, including the situated performance of work, and the familiarity and relationships that insiders developed over time, also contributed toward interdependencies becoming included. The shared understanding developed by the insiders was partly contested, however, by the outsiders, who instead adhered to the traditional occupational approaches, including well-established hierarchies, demarcations and scripts, when working. Thus, planning and preparatory work, in addition to the traditional occupational approaches, influence how coordination unfolds in practice, and this is explained by how coordination follows a history of previous actions and interactions (Faraj & Xiao, 2006).

7.6.2 The emergence of a new physical space

Making use of the new technology also required a different spatial layout; a physical space combining multiple duties, material objects as well as configurations of healthcare professionals, traditionally separated. This emergence of a new physical space in turn contributed toward a number of coordination challenges arising.

First, challenges regarding timing arose; the sequencing dynamics of separate duties were rendered unclear. It was more difficult to predict how duties were bound up with each other, and these also became more interdependent on each other. One such example was challenges related to how the duties performed by radiology nurses and radiologists had a more immediate impact on and implications for the work of the surgeons than had traditionally been the case. Second, challenges regarding spacing arose; the locating of duties was negotiated. It was more difficult to realize the requirements regarding the performing of multiple duties in the same physical space. One such example was patient positioning, a responsibility shared by the surgical, anesthesia and MRI staff, who all performed their duties in the same physical space, and with specific requirements that needed to be aligned and integrated. Third, challenges regarding control arose; the maintaining of safety was made complicated. Examples of this include the maintaining of safety as regards sterility and MRI. In a new physical space, it proved difficult to combine the surgical sterility requirements with a dirty MRI scanner, and the strict MRI safety rules with all the metallic objects used during surgery.

The findings regarding the emergence of a new physical space, and its associated coordination challenges, illustrate how material arrangements are intertwined with coordination (Barrett et al., 2012; Beane & Orlikowski, 2015). For example, while physical proximity has been described as facilitating coordination processes (Barrett et al., 2012; Espinosa et al., 2007), the findings of this chapter indicate how it can also complicate coordination processes. Based on these insights, the challenges arising are not solely to be understood in terms of whether materiality is acting to facilitate or to complicate coordination, they are also to be understood in terms of how the material enactment of the technology unfolds in practice. As such, performing work using the new technology became complicated due to how coordination was materialized in practice. More specifically, coordination challenges emerged in the way the material enactment of the new technology allowed the timing to be unclear, the spacing to be negotiated, and the control to be complicated.

7.6.3 Ways of managing new coordination challenges

A number of ways of managing the new coordination challenges emerged. First, the SuperUsers assumed a mediating role throughout the development of a shared understanding, shared responsibility, and collective authority. Second, the material arrangements eased the bridging of the restraints of timing, spacing and control.

As mentioned before, the SuperUsers became part of a team of insiders in relation to the new technology, for which planning, preparing, training and knowledge of the new physical and technical environment acted as conditions of membership. The actions and interactions that took place during the planning and preparatory activities affected how the subsequent work was coordinated in various ways. Based on the extensive planning and preparatory activities, the SuperUsers had the chance to inscribe their interests into the technology and ways of working, thus developing a shared understanding of how work had to be performed. The planning and preparatory activities meant the SuperUsers had developed a rather strong relationship with each other, with this familiarity also leading to informal communication channels being developed, something which facilitated the alignment and integration of duties. As such, the differences in interest and understanding decreased due to the extensive planning and preparatory activities The SuperUsers engaged in planning and preparatory activities, which in turn facilitated coordination, through the development of a shared understanding, shared responsibility and collective authority.

The SuperUsers developed a shared understanding of why work had to be organized differently with the new technology. For example, in terms of sterility, the surgical nurses explicitly made known which specific areas were okay to move freely within and why. In terms of MRI safety, the safety nurses were observant and controlling, but they also advised and spoke up regarding why breaches and acts of neglect were dangerous. In terms of timing and sequencing dynamics, the SuperUsers understood why separate duties sometimes had to change to facilitate a collective accomplishment, e.g. how the radiology nurses and radiologists changed the order in which the images were produced, and how they also had to speed up the process of producing and interpreting the images. The SuperUsers also developed shared responsibility for many of the duties performed in the new room. For example, patient positioning became a responsibility shared by healthcare professionals from different disciplines, and for this work task it was not enough with planning for all requirements being met separately, but ensuring the alignment and integration of all the requirements. The SuperUsers also developed collective authority, deciding on and controlling the acceptable ways of working in the new room. For example, one way forward, when the safety nurses were experiencing resistance, was to engage in the tactic of making announcements to the SuperUsers, by which means they disseminated knowledge during the SuperUsers' meetings about the non-SuperUsers' non-compliance. In this way, the SuperUser meetings functioned as a shared information space; by raising MRI safety violations on these occasions, a form of peer knowledge was created. Given this awareness, the SuperUsers generally supported and endorsed the safety nurses, something which, in turn, could exert an influence on the higher-status professionals, and in doing so facilitate coordination.

In addition to the mediating role of the SuperUsers, material arrangements also served to bridge the coordination constraints. For example, instead of mainly relying on familiarity and informality when maintaining MRI safety, more systematic and structured MRI training served the purpose of physically and unconditionally controlling who had access to the new room. In addition to keeping out unauthorized staff, stickers on keycards also created a sense of comfort and trust in both the MRI staff and the safety nurse, regarding the fact that the staff moving in and around the new room actually had the right qualifications and adequate MRI training. Managing the issue of patient positioning was accomplished by making use of material objects. A patient positioning device and a physical line with a dot underneath the operating table reminded the healthcare professionals of MRI requirements. Furthermore, while the hatch proved to facilitate, as expected, the maintenance of sterility in various ways, it also played an unexpected role in relation to managing MRI safety. The room was copper-shielded, due to the MRI safety requirements, which meant material objects, e.g. cellphones and beepers, would not work in the iMRI Hybrid OR. This incompatibility with changing material arrangements enabled the hatch to be used for dealing with emergency situations and days of staff shortages.

Taken together, when introducing and using the new technology, it proved important for the SuperUsers to strive towards more collective engagement in, as well as alignment of, various duties. The SuperUsers developed accountability, predictability and a shared understanding by means of gaining knowledge of each other and each other's duties. The SuperUsers explained how they had started to work more as a team, rather than just doing their own thing. This became evident in how, in addition to making it easier for others to perform their own duties, some SuperUsers even started to do work for each other.

CHAPTER 8

DISCUSSION

This study sets out to answer the following question: How is the introduction and use of technology coordinated during conditions of merging two previously-separated healthcare practices? The findings revealed that the introduction and use of technology was coordinated through a reconfiguration of the social setting and the physical space, which brought and required a new kind of coordinating, i.e. *coordinating as an overlapping professional domain*.

Importantly, this dissertation did not reveal a story of greater skill, superior technological resources or top-management support. Instead, it turned out to be a story about *coordination*. Because, in making the new technology doable, the multiple healthcare professionals involved were required to spend copious amounts of time and energy aligning various interdependencies, and even managing the disruption of traditional arrangements which had largely been shaping how work was traditionally performed. Following healthcare professionals over the course of several years made it possible to do justice to the 'invisible work' (Allen, 2014; Star & Strauss, 1999), which in prospect would most likely have been considered minor, but proved to be of major importance when the new technology was being introduced and made to work. Thus, it was the new kind of coordinating, emerging, brought and required by the reconfiguring of the social setting and the physical space, which proved important in the introduction and use of technology being coordinated during conditions of merging two previously-separated healthcare practices.

Reaching this understanding first required an in-depth understanding of how the two previously-separated healthcare practices were performed prior to the introduction of the new technology. This is the case because professionalized contexts, healthcare organizations in particular, are based on well-established disciplinary demarcations, rooted in taken-for-granted norms, values, understandings, and power relations, which has implications for how work is performed and how changes unfold (Abbott, 1988; Barrett et al., 2012; Lawrence, 2004; Suddaby & Greenwood, 2005). Thus, the way I first set out to understand the established and traditional arrangements of the practices of neurosurgery and MRI, and how these were traditionally performed, not only provided a more grounded explanation, it was also necessary to be able to discuss how the new technology accompanying the merging of these two healthcare practices was introduced and made doable. Drawing on the coordination literature is particularly useful as it enables tracing of how coordinative arrangements emerge following the introduction of the novel technology, directing attention toward the reconfigurations required for re-aligning actions, interactions, roles, and material arrangements.

The findings illustrated changes in the social setting and the physical space as two analytical categories[8], how they occurred and how these changes proved important to coordinate once the new technology had been introduced. Healthcare professionals needed to (re)orient themselves both in a reconfigured social setting and in a reconfigured physical space. In line with this, I have divided this chapter according to these categories. Thus, I will start by discussing the reconfiguring of the social setting and the implications for coordination, followed by the reconfiguring of the physical space and the implications for coordination. Furthermore, the implications for coordinating brought by the introduction of the new technology, together with new coordinating challenges, produced and required a new kind of coordinating, i.e. coordinating as an overlapping professional domain. This kind of coordinating was based on the *in-depth* common understanding of each other's work, as well as of the new physical space, which the healthcare professionals had developed over time. Following this, I end this chapter by discussing the emergence and nature of this new kind of coordinating.

8.1 Reconfiguring the Social Setting and Implications for Coordination

As shown in Chapters 4 and 5, neurosurgery and MRI are two highly complex and dynamic healthcare practices. Various healthcare professionals with different disciplinary backgrounds and various technological equipment were present, with technological advancements and increased specialization also occurring. With clear interdependencies between duties and technologies, there was also a prevalent need for alignment and integration to realize collective performance. However, this complexity, dynamism and need for integration were still largely bounded by the traditional arrangements, including well-established roles, responsibilities and interactions. In this way, the social dynamic was grounded in the ongoing work of continuously *stabilizing the social setting*, which not only facilitated coordination but also shaped how it unfolded. Thus, despite the fact that, on certain occasions, there was a need to adapt and shape action around the specifics of the situation at hand, there was generally little need for ongoing coordinating efforts to realize collective performance.

[8] While it is possible to analytically separate the social setting from the physical space, in practice, they are much more deeply intertwined.

However, with the introduction of the new technology, new ways of working were required, which included defining responsibilities for duties and deciding the alignment of these, anew. These changes would entail the disrupting of many aspects of the traditional arrangements, including hierarchical and status structures. As shown in Chapter 6, this was made possible and could go on without too much friction or resistance during planning and preparatory activities, as the SuperUsers mainly had to envision the changes through the organizing of a *temporary social setting*. Once the new technology had been put in place and started to be used, however (as seen in Chapter 7), the *emergence of a new social setting* became associated with a number of coordination challenges, which triggered novel ways of managing these challenges.

Making sense of these findings, and starting to understand how the reconfiguring of the social setting shaped how coordination unfolded in practice, involves the starting point of making use of the compelling framework regarding how coordinating is achieved, as proposed by Okhuysen and Bechky (2009). This framework explains how multiple mechanisms are brought together to achieve the three integrating conditions (accountability, predictability, and common understanding), which then result in coordinating. Accountability is about who is responsible for specific elements of a task, predictability is about knowing what the elements of a task are and when they occur, and common understanding is about knowing how work is to be performed, how it is to take place, and the goals of that work (Okhuysen & Bechky, 2009). This compelling framework, with its emphasis on the three integrating conditions, is particularly useful as regards explaining my findings because it resonates with the definition of coordination adopted in this study; input regulation, i.e. decisions about who is responsible for doing what, and interaction articulation, i.e. agreement regarding a sequence of actions. In addition, the work done in this study was performed by highly diverse and specialized healthcare professionals who were part of multidisciplinary teams; as these professionals were interdependent on each other, their contributions needed to be integrated. Thus, in order for coordinating to be realized, these professionals needed to define, clarify and understand who was accountable for performing a given task, how sequences of activities should proceed, and how their work fitted into the whole. Attention is thus directed at how coordination is made possible in practice, despite the seemingly opposing need for integration and specialization.

While in most situations combinations of all three integrating conditions are present simultaneously, work contexts differ with regard to which conditions are at the forefront of coordinating (Okhuysen & Bechky, 2009). Thus, exploring how the integrating conditions for coordinating are achieved, both before and after the introduction of the new technology, is vital to understanding how coordination unfolds in practice during conditions of merging two previously-separated healthcare practices. The following sections are divided accordingly; I first discuss accountability before and after the new technology; secondly, I discuss predictability before and after the new technology; and finally I discuss common understanding before and after the new technology.

8.1.1 Reconfiguring the social setting and implications for accountability

In terms of *accountability,* prior to the new technology, it was clear most of the time who was doing what and who was responsible for a specific part of a certain task. This was largely grounded in the ongoing work of continuously stabilizing the social setting, which facilitated accountability and shaped how it unfolded. For example, the distinct division of labor, and how authority was well-understood by being rested on professional status and knowledge skills, within professional domains, helped to clarify responsibilities. In addition to how responsibilities for specific elements were spelled out, there was little evidence of what Nancarrow and Borthwick (2005) call overlapping or role substitutions of duties, which jointly contributed to achieving accountability. Nancarrow and Borthwick (2005) described in their conceptual paper that the overlapping of roles is one of the ways through which professionals in the healthcare workforce are changing. However, this was not evident in my study because, with clearly defined duties, it did not make pragmatic sense for professionals to share responsibilities (Nancarrow & Borthwick, 2005). On this basis, we start to understand not only whether accountability was achieved or not, but also how. Achieving the condition of accountability is made possible by different coordination mechanisms (Okhuysen & Bechky, 2009); prior to the new technology, in neurosurgery and MRI practices, these included, for example, roles, rules and routines. These mechanisms were largely based on traditional and well-understood arrangements, including status-differences and hierarchical authority. For example, formal plans, rules and role descriptions defined responsibilities for many of the tasks, and made the healthcare professionals aware of both their own and others' responsibilities. While these formal mechanisms largely defined and dictated who was doing what, accountability was still not solely being channeled through assembly lines, instead requiring ongoing social interactions and being enacted through, for example, relationships, familiarity and trust. Trust was developed among both healthcare professionals at the MRI Unit, as regards following MRI safety requirements, and in the OR, as regards following sterility requirements. Trust was not only about knowing that others had the requisite training and expertise to perform the tasks they were responsible for, but also about familiarity as regards to personal relationships. This type of relationship had arisen through working closely together over many years. In addition to intra-practice, achieving accountability across neurosurgery and MRI practices was mainly important when the staff from the two practices jointly engaged in work practices and collaborations (see Chapter 5). On these occasions, it was clear who was doing what, especially since the healthcare professionals' jurisdictions and areas of autonomous professional expertise were clearly defined and little plasticity existed (Abbott, 1988; Pratt & Foreman, 2000), something which, however, would change with the new technology.

With the new technology, new ways of working were required, and responsibilities for many tasks had to change. Thus, one important aspect of this was to clarify and define how work was to be performed, and who was to do what. Achieving the condition of accountability was not straightforward, instead requiring SuperUsers to invest considerable time and effort in planning and preparing activities. Accountability was no longer a given as it was not clear who was doing what, and who was responsible for a specific part of a certain task. Many of the healthcare professionals involved did not even fully comprehend their own intra-disciplinary responsibilities. During planning and preparatory activities, initial attempts at defining responsibility relied on formal coordination mechanisms, e.g. role descriptions provided by the supplier, and traditional arrangements, including existing hierarchical authority and status differences. For example, there was a division into smaller groups, whereby discipline-specific responsibilities were clarified and defined, making healthcare professionals able to control their own responsibility.

These findings are partly in line with previous research highlighting fragmentation or de-integration in terms of being important for coordination (see Harrison & Rouse, 2014; Wolbers et al., 2018). However, while moving closer to the first live cases, working within domains, or as Bruns (2013) called it 'alone together', could not fully contribute toward achieving accountability. Instead, integration, by means of fitting together activities and aligning understandings and actions, became more and more important as the technology was used, supporting the general consensus that coordination is achieved through integration (Argote, 1982; Heath & Staudenmayer, 2000; Okhuysen & Bechky, 2009). Standing in contrast to this general consensus, however, is the study by Wolbers et al. (2018), for example, of coordination among emergency management officers (officers from the police, fire department, and medical services) during field exercises. These researchers found that integration was difficult to achieve, and that there was a fragmentation approach to coordination, which could endure. This was partly explained by experts having clearly-demarcated responsibilities for duties, allowing them to work simultaneously on the same problem and thus making it possible for interdependencies to be put on hold. Beane and Orlikowski (2015) similarly argued that provisional settlements can be important mechanisms in facilitating coordination. However, the conditions for the medical workers in this study were again ones of low-level uncertainty regarding accountability. In contrast, the findings from this study suggest that, when new technology is introduced during conditions of merging two previously-separated healthcare practices, and when real-time operations not exercises are to be performed, a fragmentation approach to coordination will only be allowed initially, but will need to progress toward an integrative approach, especially when responsibilities are unclearly defined and shared across expert groups.

As certain duties, e.g. positioning the patient and maintaining sterility, would become shared responsibilities distributed across disciplinary groups, it was even more important to move towards an integrative approach, in which clarifying where the responsibilities of interdependent parties lie, and defining the contributions made to the collective overall task was of principal concern. This meant that, instead of a distinct division of labor, there was an overlapping of duties, preventing the responsibilities for many tasks from being clearly defined. Added to this complexity was how the responsibility for duties did not always mean that healthcare professionals would also be able to control and dictate how the same duties were to be performed. With greater interdependence, the duties performed by one disciplinary group directly affected the duties performed by another. Thus, the healthcare professionals needed to ensure that the ways of working were up to the quality standards of their own practice, and to others'. This is in contrast to how accountability is achieved in other contexts (see Ben-Menahem et al., 2016), in that compromises regarding domain-specific standards of excellence were not allowed when it came to meeting overall requirements. Ben-Menahem et al. (2016) studied the coordination of a multidisciplinary group of specialists at a global pharmaceutical company, when engaging in knowledge creation through early-stage drug discovery. When clarifying who should do what, some specialists either "relaxed" or had to let go of their domain-specific standards of excellence to allow an effective resolution of the overall team's collective objective. This is, perhaps, possible in contexts where less severe and pronounced risks are attached to such actions, e.g. in drug discovery, which is characterized by a high degree of knowledge work, but not in contexts with a more direct impact. As in my study, not only would actions be less integrated, coordination directly complicated, and progress put at risk, patients would possibly also lose their lives if healthcare professionals were unaware of or disregarded the requirements and responsibilities of others.

In addition to how some duties became a shared responsibility spread across disciplinary groups, other tasks were redistributed among individual healthcare professionals. For example, once the new technology had come into use, the safety nurse started to increasingly assume ownership of it from the radiology nurses, with regard to being in control of maintaining MRI safety. In this way, the safety nurse, a role taken on by an assistant nurse, was expanding its jurisdiction (Abbott, 1981; Freidson, 1988). Following this role expansion, the safety nurse in possession of the new technology also developed the formal authority and power to question and dictate to other traditional high-status actors (e.g. anesthesiologists, surgeons and ward managers) whenever MRI safety was at risk. Claiming responsibility for duties traditionally outside the assistant nurses' jurisdiction entailed the role of safety nurse being constructed as a high-status actor in the new context. This was further observed in the way that the authority and mandate to perform duties, and in which workspace, was largely based on training and knowledge of the new physical and technical environment, rather than on professional role or level of seniority, as is most often the case in healthcare settings. Thus, achieving accountability when traditional arrangements are disrupted, or well-established disciplinary demarcations are in fluctuation, can be shaped by and in turn be shaping status-differences (Anthony, 2018), e.g. how lower-status actors can take advantage of opportunities. One way of understanding the possibility for lower-status actors to take advantage of opportunities is how this possibility can be reinforced by how the organizing of a temporary social setting was generally attributed with low status. In my study, traditionally high-status actors did not engage with the same level of interest and motivation as traditionally low-status actors, thus to some extent failing to guard their interests. These findings are both in line with and in contrast to the findings of Barrett et al. (2012) in their study of the introduction of dispensing robots into hospital pharmacy work in the United Kingdom. These authors also found that planning and preparing activities, through which the actors involved could inscribe their interests and intentions, taking place prior to the introduction of new technology, had important implications for how roles, interactions and alignments unfolded once the new technology had come into use. However, in this study, it was only high-status actors (pharmacists and technicians) who were involved in what they called the "tuning" process of the new technology, due to their ongoing aim of increasing legitimacy and professionalization in the healthcare field. In contrast, the traditionally high-status actors in my study did not experience new technology as an opportunity to reproduce the authority of traditional roles (Zuboff, 1988), or to expand their areas of jurisdiction. This made them less interested in participating and contributed toward a more open involvement of all the stakeholders, which also afforded low-status actors the opportunity to imagine alternative futures and roles. Importantly, the new and expanding responsibilities of the safety nurse were later also manifested and formalized in protocols and guidelines, and rewritten to ensure that procedures could not be performed in the absence of the role. Over time, and once the new technology had come into use, the more formal mechanisms proved incapable of fully achieving accountability on their own, and the means of achieving accountability progressed toward a greater reliance on emergent and situated action, e.g. interactions during meetings and an emergent dialog (Bechky & Chung, 2018; Faraj & Xiao, 2006; Okhuysen & Bechky, 2009). This proved important as all healthcare professionals were now involved and the specifics of the situation at hand required continuous adaptations.

As has been shown, prior to the new technology, accountability was high and largely defined and clarified by means of a clear division of labor, which was based on traditional and well-understood arrangements, e.g. status-differences, hierarchical authority, and formal plans and role descriptions. With the new technology, accountability was initially low. New ways of working rendered the responsibility for many duties unclearly defined, and that they required shared responsibilities for some specific duties and redistributed responsibilities for other specific duties. Over time, healthcare professionals managed to achieve accountability anew using a combination of formal means and emergent actions, which were largely disrupting the previous reliance on traditional arrangements. Next, the integrating condition of predictability is discussed, something which turned out to be interrelated with accountability in different ways both before and after the new technology had been introduced.

8.1.2 Reconfiguring the social setting and implications for predictability

In terms of *predictability*, prior to the iMRI Hybrid OR, healthcare professionals most often knew the various elements of the task and when they happened. Although work was not entirely repetitive, many of the elements occurred sequentially and could thus be prepared and planned for. Exceptions existed, of course, such as when unexpected things happened during a surgical procedure or during an MRI examination, thus making work less predictable. Anticipating task-related activities was developed through both formal plans and ongoing interactions. For example, a surgical timeout works to specify not only who does what but also the sequencing of tasks that must take place. In this way, we also begin to understand how status-differences and well-established roles help in achieving predictability, thus facilitating rather than just complicating coordination, as many previous researchers have argued (cf. Anthony, 2018; Edmondson et al., 2001; Okhuysen & Bechky, 2009). As shown in Chapters 4 and 5, ongoing work of continuously stabilizing the social setting was occurring. This was also making the sequences in which duties were performed rigid, as high-status actors (e.g. surgeons during surgical procedures, and radiologists and radiology nurses during MRI examinations) were dictating tasks and resources. Thus, while in situations requiring a substantial change in how work is performed, e.g. when routines are disrupted due to the introduction of new technology, status differences can hinder coordination in some respects, e.g. how lower-status team members are not willing to speak up in the OR due to feeling psychologically unsafe (Edmondson et al., 2001), status-differences can also facilitate coordination, in more stable situations, in terms of achieving predictability.

The strict division of labor and the workflow descriptions used at the MRI Unit also helped to develop predictability by specifying who does what and in what order. Anticipating when others did their work, and were thus able to fit their own tasks into the whole, was also achieved by means of repeated interactions and ongoing negotiations. The timing and sequencing of MRI examinations and surgical procedures were largely dependent on achieving a flow, made possible by the familiarity developed by healthcare professionals. From the knowledge they had of each other, they could start using each other's preferences to guide the performance of the task in hand (Okhuysen & Bechky, 2009). As such, it was important to think like the others as this enabled these healthcare professionals to predict what was to come. Achieving predictability across neurosurgery and MRI practices, compared to within them, was not as important since the two practices were mainly sequentially performed and less reliant on each other time-wise.

With the new technology, predictability was substantially undermined since how and in what order duties were to be performed was no longer well-understood. Merging neurosurgery and MRI practices would mean new configurations of duties, and duties not being performed as sequentially as prior to the introduction. In this manner, the healthcare professionals could not fully anticipate what their colleagues would do in various situations, something which would then have implications for the timing and sequencing of their work. Achieving predictability was no longer possible just by relying on well-rehearsed routines, traditional roles, or repeated interactions. Thus, during planning and preparatory activities, the SuperUsers had to engage in deciding on how and when their duties would be performed, as well as how separate duties would fit into the whole and would be fitted together. The SuperUsers adapted and negotiated potential sequences during which action could be expected to unfold, and they even modified their ways of working; making predictability largely engendered through emergent and ongoing interactions. Here, power and legitimacy were granted to the healthcare professionals who were managing to think like all the others, and who knew what would happen in a given situation. Important ways of achieving predictability relied on relational coordination (Gittell, 2002), i.e. frequent, timely, and problem-solving communication, by having healthcare professionals develop informal communication channels. This was the case because many of the formal means of communicating, e.g. surgical planning systems, local coordinators and referrals, proved insufficient when trying to integrate and anticipate actions. Then, using personal cellphones and social media helped the healthcare professionals to match their schedules and update each other about what a specific procedure would involve.

Another way included how the role of the safety nurse not only expanded its jurisdiction, but also emerged as a new occupational role that largely dictated and controlled how work progressed. While roles as a useful means of coordinating work have been identified by scholars before (Okhuysen & Bechky, 2009), this has most often been in relation to the integrating condition of common understanding (Barley, 1996; Gittell, 2002), which will be discussed below. However, the findings of this study also provide support for how predictability can be created by specific roles. By being in charge of aligning previously separated duties, and dictating the order of these and keeping control of how to proceed in any given situation, the role of the safety nurse would thus work to make interdependencies visible, and allow others to rely on it to create predictability. The importance of the role of the safety nurse in achieving predictability was based on that role's knowledge and expertise regarding the new physical and technical environment. In this way, predictability was largely achieved differently than it was prior to the new technology, as the distinct division of labor was partly replaced by the emergence of a new occupational role. Achieving predictability through roles rather than the division of labor, then, requires much more interaction and negotiation during work practices. Thus, as it was no longer the traditionally high-status actors who were dictating tasks and resources, the previous reliance on traditional disciplinary expertise and status-hierarchies, as regards achieving predictability, was disrupted. Furthermore, while predictability was largely achieved through ongoing and situated interactions, it would also be formalized through the development of formal and standardized delineations of the work process. The timing and sequencing of duties was documented in protocols, checklists and workflow documents.

As has been shown, prior to the new technology, predictability was high and largely based on traditional and well-understood arrangements, e.g. status-differences and well-established roles. In this way, predictability was also supported by accountability. However, with the new technology, predictability was substantially undermined and could not be supported by accountability that was initially low as well. New ways of working made the timing and sequencing of duties less clear. Healthcare professionals could no longer rely on traditional arrangements, instead having to actively engage in emergent actions in order to achieve predictability. Relationships and the emergence of new occupational roles, i.e. that of the safety nurse, proved to be important mechanisms. Next, the integrating condition of common understanding is discussed, something which turned out to be supported by accountability and predictability before the new technology had been introduced, but not after its introduction.

8.1.3 Reconfiguring the social setting and implications for common understanding

In terms of *common understanding*, prior to the introduction of the new technology, the healthcare professionals had a shared perspective of the entire tasks of either diagnosing or treating patients. Relationships were important in order to bring a flow to the work, and it was not only about having knowledge of each other's task-related expertise, but also of the individual. However, since the knowledge and abilities of healthcare professionals were overlapping considerably, it was most often possible to replace a specific individual with another with the same role. Furthermore, since there was a reliance on traditional arrangements, including a distinct division of labor and well-established status and hierarchy structures, it was clear who should do what and when, which brought generally little need to develop a common understanding in terms of in-depth knowledge of the nature and dynamics of each other's duties, both as regards intra- and inter-practice. This is similar to what LeBaron et al. (2016) described as coordinating through interrelated actions, rather than common understanding, whereby healthcare professionals create the conditions to move forwards with a joint task. Even though separated duties needed to be aligned, healthcare professionals performed work by 'doing their own thing' to a large extent (Wolbers et al., 2018), and were thus demarcating their expertise by having specific individuals with specific expertise assume the responsibility for certain tasks. Knowing clearly who should do what also supported an understanding of when tasks were to be performed. Thus, in addition to how accountability and predictability supported each other, as described above, they also jointly contributed toward negating the importance of common understanding. Healthcare professionals were using accountability and predictability to navigate a shared perspective on the goals and outputs of work. Thus, common understanding was neither critical nor the focal integrating condition (cf. Pine & Mazmanian, 2017) when coordinating alongside the ongoing work of continuously stabilizing the social setting, with practices being separated. This is in contrast to Pine and Mazmanian (2017), who found that common understanding was, in fact, the central integrating condition when doctors and nurses engaged in the practice of ordering. However, they focused on emergency or non-routine situations, in which accountability and predictability are logically undermined, making it impossible for these conditions to be a substitute for common understanding.

With the new technology, common understanding was initially low, especially during planning and preparing activities. As previously-separated healthcare practices using healthcare professionals with different backgrounds, assumptions and interests were now being brought together; this also meant that differences existed with regard to knowledge and expectations of the work that was to be done, how it should take place, and the goals and objectives of that work (Okhuysen & Bechky, 2009). Healthcare professionals did not fully understand the overall goal, or how their individual duties would fit within the whole. Developing common understanding was, however, important for a number of reasons. First, and as described above, accountability and predictability were also initially low, and it was not possible for healthcare professionals to rely on these integrating conditions as a substitute for common understanding. Second, even later on during the period, when the new technology was being used, and when accountability and predictability would be achieved, many aspects of the traditional social setting were still being disrupted. This jointly contributed to a new social setting emerging; in turn triggering a need to develop a common understanding. While the SuperUsers, initially during the planning and preparatory period, were separating various elements and activities forming part of the overall accomplishments (Harrison & Rouse, 2014; Wolbers et al., 2018) in order to manage disciplinary-specific issues and elements, they had to be actively involved in developing an in-depth common understanding of both the overall task, which was now both diagnosing and treating patients, and how individual work was to fit within the whole. This was achieved both through formal, planned mechanisms and by emergent interactions. Structured meetings and training sessions made the healthcare professionals not only familiar with the ways in which their work fits together, but also knowledgeable about the nature and dynamics of each other's tasks. Here, we also start to understand how the SuperUser group was granted significant latitude (Bechky & Chung, 2018) by the hospital in developing common understanding and thus making the new technology doable. The occupational or professional control processes the SuperUsers drew on were acknowledged and, to some extent, supported by the hospital, which was important because it enabled the SuperUsers to exercise discretion in coordinating emergently to decide on how to get work done using the new technology. Furthermore, coordinating emergently was important because the organizational control, in the form of pre-determined mechanisms (e.g. formalized training sessions, workflow documents and role lists from the supplier), of how the healthcare professionals were to plan the introduction of the new technology, and later do their work once the technology had been introduced, did not take into account the necessary reconfiguring of the social setting, and was thus unable to fully specify common understanding (Bechky & Chung, 2018). To protect their latitude in achieving common understanding, the SuperUsers exercised occupational control through a strong relationship, and through an informal hierarchy in which the safety nurse was attributed great respect.

In the way the role of the safety nurse was attributed great respect, it also emerged as an important role in strengthening and spreading a shared understanding across disciplinary groups. This proved important as highly divisive distinctions pose challenges to the creating of a common understanding. The safety nurse was updating the ways in which and in what order tasks were performed; e.g. for example by calling out various healthcare professionals to make them inform her about what tasks they were performing at a specific point in time, and by updating the separate tasks to match them together into a collective performance. By making evident and clear what tasks remained to be performed, information was both provided and translated across the disciplinary groups, and the requirements of the different groups were translated (Okhuysen & Bechky, 2009). In this way, creating a common understanding among the diverse group members was mediated by the role of the safety nurse, in turn enhancing coordination.

Turning the role of safety nurse into one spreading a common understanding was made possible by the breadth of experience and expertise the assistant nurses had developed (de Vries et al., 2014). While the majority of healthcare professionals involved had narrow in-depth disciplinary knowledge and expertise, the assistant nurses taking on the role of safety nurses had been working with both surgery- and anesthesia-related tasks. In this way, it became easier to relate to the understandings and values of the members of the various disciplinary groups. This may also explain why the role was not, as suggested in the literature, enacted by a traditional group leader (Richter et al., 2006), but rather by traditionally low-status actors (however, this, in and of itself, increased their status vis-à-vis other actors). Those who can be considered leaders in a highly-professionalized context often have in-depth expertise and knowledge within a rather narrow area, which thus hinders them from mastering the breadth of experience needed to span disciplinary groups. The emergence of the role of safety nurse was the result of both formal and emergent mechanisms. Formal guidelines and description lists were provided by the supplier, but with extensive clarifications and adaptations, during the periods of both planning and preparing the activities and during live cases; this emerged through ongoing interactions and negotiations. The expectations associated with the social position being represented by the role of safety nurse were negotiated through the intensive interactions the SuperUsers engaged in during the planning and preparing activities. Over time, when the new technology had come into use, the SuperUsers had also learned the tasks and expectations associated with the particular role of safety nurse. Thus, by interacting and changing during the course of action, common understanding was also achieved through bottom-up approaches. Furthermore, continuously reminding each other of the broader context in which their work was being performed, i.e. making the new technology work and thus benefiting the patients, helped to keep all the healthcare professionals focused on common task outcomes. Thus, the healthcare professionals were aware of and constantly reminded that a form of holistic thinking, going beyond their own respective practices, was absolutely necessary.

As has been shown, prior to the new technology, there was no prevalent need to develop an in-depth common understanding. The reliance on traditional arrangements made it clear who was doing what and when, and thus a common understanding was partly substituted for by accountability and predictability that were both high. However, with the new technology, there was a prevalent need to develop an in-depth common understanding. Both accountability and predictability were initially low and thus unable to be a substitute for common understanding. Even when accountability and predictability were achieved, they were still unable to be a substitute for common understanding as many of the traditional arrangements had been disrupted. A combination of formal mechanisms, e.g. meetings, training sessions, and role descriptions, in addition to emergent actions, e.g. live cases and ongoing interactions related to the role of the safety nurse and the broader context, proved important to the SuperUsers in developing a common understanding.

To summarize, all three integrating conditions were, more or less, simultaneously present both before and after the introduction of the new technology. However a changing social setting would mean different work contexts, and thus differences regarding which conditions were at the forefront of coordinating. Prior to the new technology, accountability and predictability conditions were at a high level and could partly be a substitute for a low level of common understanding. During planning and preparing activities, all three integrating conditions were at a low level. Over time, and once the new technology had come into use, the accountability and predictability conditions were achieved, but not at the same level as before the new technology, and they could not be a substitute for common understanding in order to produce coordinating. With a new social setting emerging, common understanding instead proved to be both critical and the focal integrating condition of the new context, instead working to support the other two integrating conditions. In addition to (the reconfiguring of) the social setting, (the reconfiguring of) the physical space would also prove important for implicating, and in turn being implicated by, the three integrating conditions, and thus also as regards how coordination is produced in practice. Thus, the reconfiguring of the physical space and its implications for coordination are discussed next.

8.2 Reconfiguring the Physical Space and Implications for Coordination

The previously-mentioned complexity and dynamism of neurosurgery and MRI practices also applied to material arrangements. As seen in Chapters 4 and 5, technological advancements were occurring at an accelerating rate and various healthcare professionals, from different disciplinary backgrounds, both patients and objects, were moving, and being moved, in and out of the physical space. With clear interdependencies between the elements of the material arrangements, e.g. how pieces of technological equipment needed to function together, and how healthcare professionals were dependent on each other's presence and absence, there was a prevalent need to align and integrate in order to realize a collective performance. While, this was done by adapting and shaping the material actions around the specifics of the situation at hand, it was still largely bounded by the traditional material arrangements. In this way, the material dynamism was grounded in the ongoing effort to continuously *stabilize the physical space*. Furthermore, coordination processes across the neurosurgery department and the MRI Unit were separated in both physical space and time. The alignment of duties was not time-critical, and task performances were largely sequential. As a result, the two separated healthcare practices could unfold rather independently of each other and in a stable and predictable physical space; there was generally little need for any extensive and explicit coordinating efforts. However, with the introduction of the new technology, radical changes to the traditional material arrangements were needed; interests and understandings concerning two previously-separated healthcare practices now needed to be inscribed and embodied in a shared physical space. Since a practice only exists as it is being materialized at specific times, and in physical spaces, artifacts, bodies, infrastructures and so on (Beane & Orlikowski, 2015; Orlikowski & Scott, 2014), changes to this material enactment become deeply consequential. Thus, through the co-existence, in both time and physical space, of two seemingly incompatible practices, a highly dynamic physical space emerged which implicated and required extensive coordinating efforts. Discussing this is important because limited attention has been paid to how technologies materially reconfigure groups' coordination processes (Barrett et al., 2012). Many of the changes needed would imply the disrupting of many aspects of the traditional material enactment of coordination. As shown in Chapter 6, this was made possible and could go on without too much friction or resistance during planning and preparatory activities, as the SuperUsers mainly had to envision and conceive of the changes through the *organizing of an imaginary physical space*. Thus, in terms of disrupted traditional ways of coordinating, there was a clear advantage in not yet having an existing physical space. Once the new technology had been put in place, and started being used, however, coherence was needed and the *emergence of a new physical space* contributed toward a number of coordination challenges arising, which triggered novel ways of managing these challenges.

As discussed above, the ways in which work was performed, both before and after the introduction of the new technology, and especially how the reconfiguring of the social setting implicated how coordination would unfold, all provide support for the importance of the three integrating conditions for coordinating (accountability, predictability, and common understanding). Here, in the same way as above, I will discuss how the reconfiguring of the physical space had profound implications for coordination, especially in relation to the three integrating conditions. In addition, I will also discuss the importance of adding a spatial dimension to these conditions.[9] Previous studies of the introduction of new technologies into professionalized contexts, and the coordinative reconfigurations required, have emphasized the importance of social dynamics, e.g. physiological safety and leadership for making a new technology doable (e.g. Edmondson, 2018; Nembhard & Edmondson, 2006).

[9] I am not adding a new condition but rather a new dimension to the existing conditions.

Even though materiality has been given more attention in the coordination literature, and even though Okhuysen and Bechky (2009) note that people's physical proximity to one another supports coordination, an analytical emphasis of the spatial dimension is seldom in focus (Sergeeva et al., in press). Drawing on the past work of Barrett et al., (2012) and of Beane and Orlikowski (2015), who stress the material enactment of coordination, I conceptualize the spatial dimension of two of the integrating conditions, i.e. accountability and predictability, by showing the importance of also clarifying who is doing what *where*, and when work is getting done *where*. Making this addition is important because, as has been shown in the empirical chapters, much of the work performed at the neurosurgery department, the MRI Unit, as well the work performed using the new technology, is largely defined and enacted in physical space. With the new technology, the healthcare professionals were required to comprehend a holistic view; it was not, for example, possible under any circumstances to sacrifice sterility or MRI safety by sequentially dividing the physical space, or by assigning these responsibilities to designated locations in the workspace. This is an important difference from many other studies of new technology and coordination; in that it was not possible to modify the materiality with regard to MRI safety and sterility. As important aspects of the new technology could not be modified, neither could specific healthcare professionals take advantage of any flexibility in order to further their own interests. This was the case in the robot study by Barrett et al. (2012) in which technicians and pharmacists had the capability and authority to develop material workarounds in order to accommodate their interests and, in doing so, overriding the technology's normal mode of operation, which had implications for how occupational groups interacted and coordinated. Similarly, in the study of Lindberg et al. (2019) of a Hybrid OR with a robotic X-ray, doctors were seemingly able to balance their ambitions, i.e. to produce the "best possible" image, with the requirements of medical physicists as regards radiation safety. Thus, we start to understand how differences in the way in which work is materialized in practice become deeply consequential (Beane & Orlikowski, 2015). The following sections are divided accordingly; first, I discuss accountability before and after the new technology; second, I discuss predictability before and after the new technology: and finally, I discuss common understanding before and after the new technology.

8.2.1 Reconfiguring the physical space and implications for accountability

In terms of *accountability*, and as discussed above, most of the time it was clear who was doing what and who was responsible for a specific part of a certain task. This also proved to be largely grounded in material arrangements, and especially the stabilizing of the physical space, which facilitated accountability and shaped how it unfolded. As many duties were materially enacted, the spatial configurations and material arrangements were critical constitutive aspects of how work was performed. Although not functioning as shared physical space, the neurosurgery department and the MRI Unit were still physical spaces enacted and negotiated by healthcare professionals from different disciplinary groups when doing their work. These physical spaces were not, however, randomly utilized or arranged; instead, material objects and healthcare professionals were largely arranged and positioned according to traditional arrangements. For example, at the neurosurgery department, the positions of both devices and staff were largely dictated by surgical needs and the position of the microscope; however, at the MRI Unit, it was needs relating to MRI and the position of the MRI scanner that dictated this positioning. Here, we start to understand how the enactment and negotiation of the physical space is shaped by salient status differences (Anthony, 2018), and how these patterns also shape the way in which accountability is achieved. Healthcare professionals from different disciplines were also mostly working in separated locations. Both formal mechanisms and emergent actions enabled it to be made clear that healthcare professionals and other objects were positioned accordingly in the physical space, e.g. with the help of objects like the hatch, anesthesia arc, MRI warning signs, and through the well-rehearsed and well-orchestrated movement patterns that healthcare professionals had developed from their lengthy experience. Thus, the stabilizing of the physical space provides the context that enables and constrains what the healthcare professionals do, and how they interact (Barrett et al., 2012; Beane & Orlikowski, 2015). While the ongoing work of continuously stabilizing the physical space helped in clarifying who was doing what, it also reproduced traditional and disciplinary arrangements. However, in contrast to, for example, the study by Barrett et al. (2012), in which barriers to coordination emerged as the result of a physical separation of workers and the ensuing accentuating of the division of labor, coordination opportunities were to be found instead in my study. This also meant that, in order to change this way of achieving accountability, a tremendous amount of work and negotiations would be needed over time. Highlighting how material arrangements are intertwined with the accomplishment of work, and how the elements are interdependent, also makes it evident that adding a spatial dimension to the accountability condition is important. Physical spaces cannot be randomly arranged, and it is vital to define and clarify not only who is doing what, but also who is doing what *where,* i.e. achieving what I call *spatial accountability*. As will be discussed next, when paying specific attention to the material enactment of coordination, it becomes evident that three integrating conditions, as proposed by Okhuysen and Bechky (2009), are not enough for coordinating work in situations where there is a reconfiguring of the physical space.

The new technology not only required new ways of working but also a new physical space for accommodating the needs and requirements of both the neurosurgery and MRI practices. Merging two previously-separated healthcare practices that had been largely defined and enacted in physical space disrupted the previous ongoing work of continuously stabilizing the physical space. As the physical space both influences and is influenced by how work is carried out, and who does what, the traditional ways in which the material arrangements had been facilitating and shaping accountability would now be affected. This was especially the case since it was no longer clear who was doing what and who would have the mandate to perform work in specific locations in the physical space. As the reconfiguring of the physical space had become associated with accountability challenges, one important aspect, thus, was to define and clarify, in relation to the physical space, how specific duties were to be performed, and who would do what. Achieving accountability during the planning and preparatory period was, on the one hand, difficult as the new physical space did not yet exist, and different interests and understandings now had to come together, while on the other hand, it was facilitated by consistency and cohesiveness not being fully required in an imaginary physical space. Similar to what have been described as "experimental spaces" (see Langley et al., 2019; Zietsma & Lawrence, 2010), the SuperUsers were temporarily relieved from their day-to-day activities to experiment with assigning responsibilities for specific duties. One of the advantages of an experimental space was that their experimenting did not have to cohere, allowing multiple interpretations and understandings to flourish, which later played an important role in developing an understanding of how to coordinate work using the new technology. Initial attempts at achieving accountability included healthcare professionals inscribing their interests and understandings into the imaginary space, largely by drawing on traditional arrangements. Similar to what has been described above, healthcare professionals were initially engaged in de-integration (Harrison & Rouse, 2014; Wolbers et al., 2018), by focusing on clarifying and defining discipline-specific responsibilities. This finding is partly in line with the few existing studies going against the general consensus that coordination is achieved merely through integration (e.g. Bruns, 2013; Harrison & Rouse, 2014; Wolbers et al., 2018). For example, the modern dance group rehearsals studied by Harrison and Rouse (2014) required members to proactively separate to find expressive and new movements. More specifically, these dance groups repeatedly de-integrated in order for members to develop divergent ideas deriving from specific insights, then coming together to collectively build on the specific member's work to form a final solution. However, and as hinted at in the study by Harrison and Rouse (2014), the findings of this study show how this integration is both more plausible and relied on at a specific point in time, namely at the outset of a change or during the initial points of disruption. Divergence and de-integrating can go on, especially since the physical space is still being organized as an imaginary space, where coherence is not yet to be required.

Furthermore, the healthcare professionals commonly referred to the old ways of doing things. For example, the surgical staff intended to position themselves and their tools as largely dictated by surgical needs and the position of the microscope, which was in accordance with how it was traditionally done. Similarly, the MRI staff invoked traditional arrangements by letting the MRI scanner dictate accountability, and by conceiving of the physical space as isolated and thus preventing general entry. Thus, the future-imaginary physical space and the planning for spatial accountability were enlivened by drawing on the past, thus supporting the findings of several studies highlighting how previous work and traditionally coordinative arrangements shape subsequent work (e.g. Barley, 1986; Barrett et al., 2012; Beane & Orlikowski, 2015; Nelson & Irwin, 2014). For example, the study of Venters et al. (2014) of the development, introduction and use of a computing grid infrastructure showed how coordination is configured by the past, arising not only from social but also from material inertias, in their case consisting of the history of tools and equipment use, and the already installed bases of software.

However, once the new physical space had started to manifest itself, the profound implications, which reconfiguring the physical space would have for how accountability was achieved, emerged. Initial attempts at relying on traditional and disciplinary arrangements were made difficult. For example, as patient positioning became a shared responsibility, this also meant that various healthcare professionals who had different requirements needed to work in the same physical space. In addition, when maintaining MRI safety, it was no longer possible to rely on emergent actions, e.g. familiarity and trust, to the same extent. Instead, defining how work was to be done, and the responsibility and mandate in relation to maintaining MRI safety, became largely reliant on formal mechanisms, e.g. counting sheets and numbered boxes, stickers and documented MRI training and knowledge. Achieving accountability, and especially in relation to the importance of maintaining MRI safety, would also rely heavily on the role of the safety nurse. In addition to having specific knowledge, the safety nurse would also, through bodily doings, control and confront staff with regard to their mandate to work in specific work locations. Thus, when moving closer to the actual use of the new technology, complexities arose; the accountabilities that had been planned and prepared for separately now needed to be integrated and fitted together. Here, as it was no longer clear who was doing what where, or who would have the mandate to work in specific work locations, achieving *spatial accountability* became especially prevalent. Maintaining sterility by using the hatch serves as an illustrative example. At the neurosurgery department, the hatch had traditionally been important for achieving spatial accountability by dictating who was doing what where. However, this would now clash with how spatial accountability had traditionally been achieved at the MRI Unit, with a strong reliance on isolation and shutting out. These accountability challenges were largely based on the negotiation of physical space, which healthcare professionals managed by making use of a combination of formal coordination mechanisms and emergent actions, e.g. ongoing interactions and material objects. These findings are in line with previous studies showing how the introduction of new technology has profound implications for how work is materially coordinated (e.g. Barrett et al., 2012; Beane & Orlikowski, 2015). Beane and Orlikowski (2015), for example, studied how the practice of doing night rounds at a post-surgical intensive care unit at a teaching hospital was performed differently using either a telephone or a telepresence robot, and what the consequences were for coordination. They showed how the different material enactments strongly influenced how work was coordinated. It was either facilitated or challenged, not only because of different technologies, but also depending on how interconnected practices were being performed. I add to this by showing how differences in material arrangements are consequential for the respective integrating conditions.

As has been shown, prior to the new technology, the level of accountability was high and, as the positions of the staff and tools were not random, who was doing what was largely defined and clarified through a stable physical space. With the new technology, a new physical space emerged which initially contributed toward accountability being low. It was not clear who had the mandate to work in specific locations, and initial attempts, based on traditional arrangements for clarifying and defining discipline-specific responsibilities, were not enough. For accountability to be achieved, a negotiation of the new physical space was needed through a combination of formal mechanisms and emergent actions. The way in which accountability was achieved, both before and after the new technology, further supports the importance of adding a spatial dimension to the integrating condition of accountability. This also proved important in terms of predictability, which is discussed next.

8.2.2 Reconfiguring the physical space and implications for predictability

In terms of *predictability*, and as already mentioned, the healthcare professionals could most often anticipate the various elements of the task and when these were taking place. This was not only shaped by the social setting but also by the physical space, which helped to define and clarify the elements of the tasks and when they occur. At the neurosurgery department, because of co-location and visibility, the staff could easily update themselves on task progress. For instance, without risking sterility, the staff could use the hatch to see what others were doing, get instant progress updates, and, in doing so, adjust their own work accordingly. By feeling at home at the neurosurgery department, and by having technology and colleagues co-located, the staff also felt safe and knew where to find what they needed (see Gieryn, 2000). Achieving predictability was also facilitated by healthcare professionals generally adhering to well-rehearsed and well-orchestrated movement patterns. Thus, by enacting a specific and stable physical space, and by making use of material arrangements, staff could easily keep track of what others were doing, and also make sure work was progressing smoothly. At the MRI Unit, work was more physically distributed, and while the literature presumes that this lack of co-location makes achieving predictability more difficult (Okhuysen & Bechky, 2009), this was seldom the case. As work is performed more sequentially, the spatial divide between, for example, radiologists and radiology nurses instead strengthened the strict division of labor, thus helping to clarify who is doing what and in what order. As such, predictability was supported by accountability through the enactment of the material arrangements. Also, with an MRI Unit being physically isolated and protected, non-MRI staff were not able to just show up unannounced, which helped the MRI staff to anticipate the actions of others. Here, we also start to understand the importance of not only knowing what the elements of the tasks are, and when they occur, but also where. Thus, it becomes important to achieve *spatial predictability*, i.e. knowing who does what where at what time. Anticipating how the elements of a task will be performed thus requires a spatial familiarity with the involved elements and the timing of other actors' task performance. At the neurosurgery department, knowing the elements of the tasks, and where they occur in specific locations, is especially important as regards both maintaining sterility and the preparations necessary before a surgical procedure can begin. Surgical nurses need to anticipate the location of the task-related activity of others, in order to plan and perform their own work, and to thus maintain sterility. In addition, during much of the preparation work, it is not possible for surgical nurses and anesthesia nurses to occupy the same physical space; instead, they have to take turns waiting for each other. To realize a coordinated activity, they need to anticipate when the separate duties performed by the two groups will take place in specific locations. This was largely done by relying on the established sequencing of activities. At the MRI Unit, achieving spatial predictability mainly occurred in relation to work practices and collaboration between MRI and non-MRI staff, during which spatial predictability was largely achieved by MRI staff dictating the schedules and workflows.

With the introduction of the new technology, the previously stable physical spaces, through which predictability had largely been achieved, were now disrupted. For example, while the hatch was traditionally important to the surgical staff, as regards achieving predictability, using it would initially prove difficult due to its material incompatibilities with MRI. Also, the way the physically isolated and protected physical space had helped the MRI staff to achieve predictability was now at risk as the physical space would become more accessible to a larger group of healthcare professionals. Thus, the disruption of the physical space had profound implications for achieving predictability, also making it of even greater concern. Above all, defining and clarifying the sequence and timing of duties was vital in order not to compromise the maintenance of either sterility or MRI safety. During the planning and preparing period, similar to that of accountability, the healthcare professionals attempted to inscribe their interests and understanding, (often based on traditional arrangements) in relation to sequencing and timing, into the imaginary physical space. This is in line with the study of Venters et al. (2014), in which physicists incorporated past patterns of thought and interaction in order to make new technological additions predictable. Furthermore, while we know that training and rehearsing can increase a kind of familiarity with each other's roles and responsibilities, and thus help to achieve predictability (Okhuysen & Bechky, 2009), this was not so straightforward when there was no physical space to be enacted yet. As such, there are limitations to a physical space that does not exist yet. Also, in that it was not fully clear who was to do what, accountability could not support predictability. While proximity, in terms of co-location, generally complicated predictability, there were also examples of how it supported healthcare professionals in predicting workflow. For example, the MRI staff were able to follow surgical procedures through windows, and to thus anticipate when they would be able to perform their tasks in specific locations. This is similar to the situation pharmacy workers faced prior to the new dispensing robot being introduced, as studied by Barrett et al. (2012). Here, the three occupational groups (pharmacists, technicians and assistants) worked in parallel at the pharmacy, and since the shelving area that occupied the bulk of the floor space could be used by all workers, it formed a space for contact, visibility and interaction, helping to achieve predictability. In this study, achieving predictability in the new physical space improved over time and, as pre-determined mechanisms could not fully help in achieving predictability, live cases, during which healthcare professionals worked together, proved important. During these interactions, they were able to develop a better understanding of how their duties needed to be aligned. The mentioned physical presence and bodily doings of the safety nurses, as well as how these dictated the sequencing and order of tasks, would also become important to achieving predictability.

From these findings, we are again reminded about the importance of achieving *spatial predictability*. This relates to who was expected to do what where, and when. For example, the duties performed by the radiology nurses and radiologists would have a more immediate impact, as well as implications for the work done by the surgeons. As a result, it was not obvious who should perform their duties where at specific points in time. Also, in relation to the already-mentioned duty of patient positioning, one important question concerns defining and clarifying whether the various healthcare professionals sharing this responsibility would be doing their work in the same physical space at the same time, or whether they would be dividing it up more sequentially. The healthcare professionals mainly developed this spatial predictability through emergent interactions, and would, over time, be able to better anticipate where duties were being performed at what time, supported by their co-location and physical proximity to one another.

As has been shown, prior to the new technology, predictability was high and largely based on a stable physical space, e.g. through visibility and the co-location of neurosurgery staff, and through the MRI Unit being physically isolated and protected. However, with the new technology, the previously stable physical space was disrupted, undermining predictability. Initial attempts at achieving predictability included inscribing separate interests and understandings into an imaginary physical space. However, it was through situated actions, over time, that the healthcare professionals were able to fully achieve predictability, by learning how to enact the new physical space. The way in which predictability was achieved, both before and after the new technology, further supports the importance of adding a spatial dimension to the integrating condition of predictability.

8.2.3 Reconfiguring the physical space and implications for common understanding

In terms of *common understanding*, the shared perspective that the healthcare professionals had of the whole task, prior to the new technology, was not only developed through the social setting, but also through the material enactment of physical space. The ongoing effort of continuously stabilizing the physical space helped the healthcare professionals to clarify who should do what and when. Thus, knowledge and understanding of the work that is to be done, and how it is to be done, was embodied in material arrangements, which could be used as a store of information when performing duties. Similar to what was discussed above, while this reliance on traditional arrangements proved important to getting the work done, it also meant that the healthcare professionals generally had little need to develop a more in-depth, common understanding of the nature and dynamics of each other's duties. This was further strengthened by the way in which the physical division of many duties contributed toward healthcare professionals 'doing their own thing' (Wolbers et al., 2018), and working within expert practices (Bruns, 2013). Since the knowledge and understanding that the healthcare professionals had of the physical space overlapped considerably, this also meant that it was possible for one of them to cover for another.

In the vast majority of studies of coordination, it is unilaterally argued that physical distance hinders coordination while physical proximity improves it; in particular, the integrating condition of common understanding (e.g. Barley, 1986; 1990; Beane & Orlikowski, 2015; Espinosa et al., 2007; Hinds & Bailey, 2003; Okhuysen & Bechky, 2009). For example, in the findings of their quantitative study, showing how geographic dispersion had a negative effect on team performance during software development, Espinosa et al. (2007) advanced the theory that the benefits of co-location, e.g. presence awareness, frequent communication and contextual reference, facilitate team coordination. Similarly, Hinds and Bailey (2003), in their conceptual paper, argued that co-location provides team members with clarity regarding resources and responsibilities, making it possible to reconcile divergent perspectives and overcome communication challenges, thus coordinating with fewer problems. In the ethnographic study by Barley (1986), of the introduction of CT scanners into radiology departments as a new medical imaging device, the physical proximity is again argued to facilitate coordination, in that separation between expert groups instead complicates the coordination of work since directions and input cannot be spontaneously shared. Beane and Orlikowski (2015) showed how the practice of skimming, during which preparation work was materially enacted at a distance, allowed assessment differences to increase, later challenging the coordination of overnight care work. The robot study by Barrett et al. (2012) also showed how the new technology became associated with a physical divide between the occupational groups, which served as a barrier to interaction and visibility, further accentuating the division of labor.

Thus, with these arguments in mind, the new technology featured my study, and the associated greater physical proximity from co-locating neurosurgery and MRI practices, should have unidirectionally improved coordination, through the effect of strengthening common understanding, including goal alignment between the involved healthcare professionals However, the findings from my study show a more complex relationship between proximity and coordination. As the physical space had radically been changed by the new technology, it was not possible to use or rely on existing material arrangements as a store of information when performing tasks. Having neurosurgery and MRI practices co-located also made the healthcare professionals from the different disciplines more dependent on each other, and on coordinating with each other. The emergence of a new physical space thus made it difficult to clarify and define who should do what and when. Additionally, as the knowledge and expertise of the new physical and technical environment became so important to doing work, the conditions of accountability and predictability were not able to be a substitute for common understanding. Together, this triggered a prevalent need to develop a more in-depth, common understanding in order to make coordinating possible. Thus, it is not the distance or proximity per se that matter to how coordination is implicated, but how these are intertwined with work practices and coordination processes.

In my study, it was over time that a co-location facilitated coordination, in that increased exposure to each other's duties increased the understanding of why certain tasks had to be performed in specific ways and at specific points in time. Thus, it was only over time, as healthcare professionals were working in co-located facilities, that they developed a more in-depth understanding of each other's duties, including what tasks the others were performing and why these were important. For example, by being able to observe surgical procedures directly, the MRI staff gained a better understanding of why sterility was so important, and why the operating staff performed their tasks in specific ways aimed at maintaining a sterile environment. Through this increased level of understanding, the MRI staff were thus also able to align their own actions accordingly in order to participate in maintaining sterility. The surgical staff also developed a better understanding of why MRI safety was so important, and why the MRI staff performed their tasks in specific ways aimed at maintaining a safe environment. As a result, the surgical staff were also able to integrate their own actions and, in doing so, contribute toward maintaining MRI safety. This is similar to the Beane and Orlikowski (2015) study, in which the material enactment of co-presence during bedside interactions, while preparing for night rounds, made it possible for differences in understandings and interpretations, between the healthcare professionals, to be addressed. By interacting in the same physical space, they were able to collaboratively make adjustment related to their co-present experience, and to thus stabilize their interactions. However, the Beane and Orlikowski (2015) study was situated in a context where accountability was clearly defined, and seldom shared across disciplinary groups. In contrast, the healthcare professionals featured in this study were jointly responsible for many duties, making the co-presence, over time, even more important as regards developing a common understanding. For example, in terms of patient positioning, the healthcare professionals increased their general understanding of why this had to be a shared responsibility and were then able, based on this awareness, to do their own work accordingly. Thus, the in-depth common understanding that the healthcare professionals had developed constituted conditions of accountability and increased predictability. In this way, a common understanding became both critical to and the focal integrating condition (Pine & Mazmanian, 2017) of coordinating during conditions of merging two previously-separated healthcare practices. Similar to the study by Sergeeva et al. (in press), of a surgical robot, when material arrangements change, achieving effective coordination is less about preserving traditional coordinative arrangement, or finding workarounds, and more about finding new ways of coordinating. As will be discussed in the next section, a new kind of coordinating, i.e. coordinating as an overlapping professional domain, both emerged and was required as a result of the introduction of the new technology.

As has been shown, prior to the new technology, the healthcare professionals developed a common understanding through material arrangements. The stable physical space could be used as a store of information regarding how work was to be done and where. However, there was generally little need to develop an in-depth understanding of each other's work, especially since many duties where physically divided in the physical space. However, with the new technology, the physical space changed, and there was thus no longer a store of information embodied in the material arrangements. Co-locating previously-separated healthcare practices made knowledge and expertise regarding the new physical space and the technical environment of major importance. The healthcare professionals thus had to develop a more in-depth, common understanding of each other's duties, how these were performed and where.

To summarize, in addition to the social setting, the reconfiguring of the physical space also had profound implications for coordination, especially in relation to the three integrating conditions. A stable physical space could be used as a store of information in order to achieve accountability, predictability and a common understanding. However, once the new technology had been introduced, the physical space changed, making it difficult to enact the material arrangement as it had traditionally been done. The healthcare professionals instead had to go through situated actions and learn how to both engage with and enact the new physical space in new ways to achieve the three integrating conditions. Adding a spatial dimension to accountability and predictability also proved important, because clarifying and defining who is doing what where and when, is needed for coordinating.

8.3 Coordinating as an Overlapping Professional Domain

Based on the discussion above, we start to understand how the introduction of the new technology became associated with the reconfiguring of the social setting and the physical space, which entailed changes in the nature and dynamics of the three integrating conditions, thus also implicating how coordination unfolds in practice. Prior to the new technology, accountability and predictability were high and largely based on traditional arrangements, including ongoing efforts to continuously stabilize the social setting and the physical space. In addition to how accountability and predictability supported each other, they also largely were a substitute for common understanding. With the new technology, the traditional arrangements were largely disrupted, which meant reconfiguring the social setting and the physical space. This proved to have implications for the three integrating conditions, such that, initially, these were all undermined and required the healthcare professionals, using a combination of formal mechanisms and emergent actions, to find new ways of achieving them. During conditions of merging two previously-separated healthcare practices, achieving accountability and predictability was not enough when it came to producing coordination in order to realize a collective accomplishment. Instead, an *in-depth,* common understanding would emerge both as critical and as the focal integrating condition, supporting the two other integrating conditions. By exploring how these conditions were achieved before, during and after the introduction of the new technology, it was possible to understand that the ways in which these conditions changed, together with the new coordinating challenges that were emerging, also produced and required a new form of coordinating. Thus, this new form of coordinating was both the result of and the requirement for the introduction of the new technology, being profoundly different from how coordinating traditionally occurred. In what follows, I discuss in detail how this new form of coordinating was achieved using a combination of formal mechanisms and emergent actions, as well as what this entails and some consequences.

Even though common understanding was discussed above, it will also be discussed in more detail here as it was both central and the focal integrating condition of the new kind of coordinating. Common understanding has generally been described as the shared perspective of a whole task and how an individual's work fits within the whole (Okhuysen & Bechky, 2009); however, the SuperUsers featured in this study were required to also develop a more *in-depth,* common understanding of both each other's work and the physical space. This proved to be the linchpin and informed the two other integrating conditions, in the new kind of coordinating that was emerging. Overall, by means of regularly seeing and engaging with each other over a period of several years, at meetings, during training sessions and social gatherings, as well as when using the new technology, the SuperUsers were able to increase their understandings of both each other's duties and the new physical space, and in doing so to decrease their differences in terms of interests and understandings. Exactly how common understanding can be developed was hinted at in the study by Bechky and Chung (2018) in which they argued that common understanding, as an integrating condition, would be at the forefront if occupational control were acknowledged and if occupational and professional members were granted latitude. The findings of the study in hand provide empirical support for this by showing how the significant latitude that the hospital granted to the SuperUser group, regarding substantive work, allowed mechanisms that made it possible to increase their understandings and decrease their differences. More specifically, in being granted freedom of action, the SuperUsers were able to set boundaries concerning who could perform specific tasks and how these tasks were to be performed, thus exercising control over how to coordinate with the new technology. This collective authority over the terms and content of work further allowed the SuperUsers to start identifying as members of a unified group in which they not only shared and reinforced specific expectations regarding how to do their work using the new technology, but also developed strong relationships. Developing a common understanding via the latitude the SuperUsers had been granted was not, however, something that occurred overnight, but over an extensive period of time.

In what follows, I will discuss how this common understanding, which was the result of the considerable time and effort the SuperUsers had put in over time, both brought and required a new kind of coordinating emerging, i.e. *coordinating as an overlapping professional domain*, something which was achieved through the enactment of both formal mechanisms and emergent actions.

In terms of formal mechanisms, the SuperUsers were actively engaged in structured sessions that included planning, preparing, training and gaining knowledge as regards the new social setting and the physical space. Due to the extensive actions and interactions occurring during these formal occasions, the SuperUsers had the chance to inscribe their interests into the physical space and the ways of working, and to thus develop a common understanding of how work had to be done. One important part of this was how the SuperUsers were able to use and rely on the reconfiguring of the physical space as a store of information when performing tasks. In this way, these formal occasions clearly had implications as regards how the subsequent work was coordinated once the new technology had come into use. While these formal mechanisms were important, they were not enough to fully develop a common understanding and thus to realize a collective accomplishment. Emergent actions were also needed, which will be discussed next.

In terms of emergent actions, the SuperUsers, for example, modified the material arrangements within the physical space, e.g. the hatch and patient positioning devices, over time, which allowed them to further develop an in-depth, common understanding of the physical space and to be able to use it as a store of information as regards how to perform tasks and integrate these. The physical space becomes a "site of knowing" (Nicolini, 2011); in that the specific positions of the staff and tools embed expertise and knowledge. In addition, prior to the new technology, the radiology staff, e.g. Radiologists and radiology nurses, and the surgical staff, e.g. surgeons and surgical nurses, met just occasionally and during specific situations. With the new technology, more intensive collaborations took place which improved relationships across the disciplinary groups, thus contributing to a common understanding emerging. For example, instead of relating to one another as part of a group, e.g. "surgery" or "MRI", most of the SuperUsers started to refer to one another using their first names. By getting to know each other personally, the SuperUsers were not only informed about the importance and specificities of the different groups' duties, they also developed an interest in learning more about the underlying reasons for working in specific ways. Having the opportunity to observe each other's duties further improved personal relationships, contributing to the development of common understanding. For example, the surgeons and radiologists started to communicate more directly as they were now enacting a shared physical space. Having close interactions with each other emerged as important because what the surgeons and radiologists were doing affected each other's duties to a larger extent with the new technology. The radiologists were able, for example, to ask the surgeons directly, and immediately, how the surgical procedure had gone, and whether or not they had to leave any surgical material in the wound, which would affect the interpretation work being performed by the radiologists. This kind of communication seldom took place prior to the new technology as the separated physical space did not encourage it. These emergent actions that the SuperUsers engaged in, over time, thus caused them to learn about each other's work, which helped to develop a common understanding.

The relationship the SuperUsers developed through emergent actions also helped as regards increasing their trust in each other. This was important since many of the previously separated duties now became a shared responsibility, or even shifted in terms of accountability. For example, and as discussed earlier, an important part of maintaining MRI safety was accomplished by transferring certain duties and responsibilities away from the MRI staff to the safety nurse. With a personality described by many of the other SuperUsers as authoritarian, the MRI staff explained how they both trusted and felt secure about the safety nurse performing the safety activities in the proper manner. Moreover, the way in which many surgical procedures in neurosurgery had traditionally been performed, with MRI examinations often being done a couple days after surgery, did not really require rapid and direct communication between the surgery staff and the MRI staff. With the new technology, however, this changed, and many of the formal means of communicating, e.g. through surgical planning systems, local coordinators and referrals, proved to be insufficient during attempts to integrate the previously separated activities. To facilitate coordinating the introduction of the new technology, frequent, timely and accurate communication across disciplinary boundaries was needed. To achieve this, some of the SuperUsers developed informal communication channels, e.g. personal cellphones and social media, through which they could synch their schedules and update each other about what a specific procedure involved. Realizing this was both dependent on and nurtured the more intimate and personal relationships the SuperUsers had developed. Thus, as the quality of the relationships increased, the quality of the communication did too, and vice versa. Relationships and informal communication channels were largely the result of emergent actions, which turned out not only to achieve a common understanding but also to support accountability and predictability.

Thus, the findings regarding emergent actions highlight not only situated actions, but also long-term personal connections and relationships, as an important mechanism to coordinate as an overlapping professional domain, and realizing the successful introduction of the new technology. One implication of this finding is that creating opportunities for different healthcare professionals to engage via emergent actions, as well as meet outside of work in more relaxed circumstance, is important when it comes to a group of previously separated members starting to work together, and for the new technology to be made doable.

As has been shown, it was through a combination of formal mechanisms and emergent actions that the SuperUsers developed the in-depth, common understanding of each other's work, and the new physical space, that was necessary for coordinating as an overlapping professional domain. These findings provide overall support for the general consensus that formal mechanisms and informal interactions have a complementary relationship in coordination in practice (e.g. Ben-Menahem et al., 2016; Okhuysen & Bechky, 2009; Pine & Mazmanian, 2017; Valentine & Edmondson, 2015). Furthermore, the new kind of coordinating that emerged allowed the SuperUsers to understand why work had to be carried out in new ways, including who was doing what and the timing of tasks, using the new technology. For example, they understood why specific duties had to be adapted and changed, as well as why the responsibility for specific duties had to be shared. In addition to the involvement of modifying and aligning tasks, this also involved thinking for each other. This meant that the SuperUsers started reminding each other of their own tasks, even to some extent helping out in performing tasks outside of their traditional jurisdictions. In this way, demarcation lines were drawn around the SuperUsers group (Langley et al., 2019), which is different to, for example, what Kellogg et al. (2006) found in their study of coordination among four groups at a fast-moving Internet advertising agency. Group members were coordinating by enacting a 'trading zone' (Galison, 1999) in which they did not have to transform local understandings into shared meanings and commitments. Thus, coordinating as an overlapping professional domain is different, as it does not entail coordinating across professional domains, as has been highlighted in previous research (Abbott, 1988; Bechky, 2003; Bruns, 2013), but developing an overlapping domain through deep collective engagement, and working more as a team rather than just doing one's own thing. This was not, however, fully accomplished whenever healthcare professionals outside of the SuperUser group became involved. Based on this discussion, we start understanding better the importance of planning and preparatory activities in coordinating as an overlapping professional domain. The SuperUsers shared a common purpose with the new technology, namely making it work in order to increase surgical precision and patient safety, all for the benefit of severely ill patients. As already mentioned, no explicit sub-goals were attributed to specific occupational groups, e.g. having high-status actors experiencing the new technology as an opportunity to expand their areas of jurisdiction etc. Together, this contributed toward how all the healthcare professionals, regardless of status or expertise, had been invited to participate, not only during the structured planning and preparatory activities, but also during the emergent actions, e.g. when modifying the material arrangements over time. Having all the healthcare professionals involved enabled them to collectively inscribe not only their interests and understandings, but also their roles, relationships, and interactions, thus largely inscribing ways of coordinating. As such, they were also made aware of the range of changes the new technology would introduce. For example, the SuperUsers had learned, over time, the tasks and expectations associated with the role of the safety nurse, and thus understood why they had become dependent on and coordinated with that role. This contrasts with the preparatory and planning activities reported on in the studies by Barrett et al. (2012) and by Beane and Orlikowski (2015). In the study by Barrett et al. (2012), coordination was challenged by the way in which planning and preparatory activities were being performed, as only the high-status actors were involved, with the low-status actors being left out. Beane and Orlikowski (2015) showed how, in the preparatory practice of skimming, the exclusion of important healthcare professionals meant challenging consequences for coordination. The findings of my study thus support previous research highlighting how planning and preparatory activities have important implications for how subsequent coordination unfolds (e.g. Barrett et al., 2012; Beane & Orlikowski, 2015; Venters et al., 2014), also adding insights, however, regarding what implications the inclusion/exclusion of information and individuals during planning and preparatory activities has on subsequent coordination.

The impact of including/excluding individuals, during planning and preparatory activities, on coordination became especially evident in my study, since coordinating as an overlapping professional domain became associated with team membership stability in that the SuperUsers were part of a small special team and developed as an insider group to the new technology. This proved important for the success of the introduction and use of the new technology, in that the insider group was granted significant latitude (Bechky & Chung, 2018), largely mediating the new kind of coordinating and enabling a form of transactive memory. The SuperUsers, as part of the insider group, decided and controlled the acceptable ways of working with the new technology. In that they developed the right to make decisions, to enforce obedience and to give orders to others, they developed a collective authority. Thus, as argued by Bechky and Chung (2018), the interdependence between the professional groups had important implications for coordinating. The differentiation between the professional groups decreased due to the changing arrangements, including a decrease in hierarchical relationships and the distribution of authority, making the new kind of coordinating possible.

Bechky & Chung (2018) argued that the significant latitude granted to occupational members, and to the occupational control processes they exercise when coordinating, helps to maintain work quality and practical expertise in novel and uncertain situations. For example, in that the professional members draw on a common understanding of their duties in order to allow role substitution in the absence of key personnel (Bechky & Okhuysen, 2011). My findings provide nuances in this understanding, by means of illustrating the complexities of role substitution and how occupational control processes generally did not allow interchangeability due to the risks this would bring to work quality. The fact that just a small and unified team of SuperUsers had developed the necessary in-depth common understanding made it difficult to substitute specific insiders with other healthcare professionals with the same professional role. The knowledge and abilities of insiders were not overlapping with those of outsiders. While at the film production firm studied by Bechky and Chung (2018), the junior members seemed to learn how to coordinate rather easily due to being constantly coached by more experienced members, involving newcomers in my study would be more problematic as the required in-depth common understanding could not be taught superficially. However, involving healthcare professionals other than the SuperUsers, and thus members of the insider group, was inevitable over time as staff rotations were needed. This would put coordinating, as an overlapping professional domain, at risk.

While, the SuperUsers became part of an insider group based on an in-depth common understanding, developed through a combination of formal mechanisms (e.g. planning and preparatory activities) and emergent actions (e.g. the situated doing of work and familiarity and relationships), newcomers instead became part of an outsider group as they had not been part of the planning and preparatory activities and thus generally lacked knowledge and understanding of both the new ways of working and the physical space. Outsiders had their own interests and understandings as regards how work was to be done. For example, they often focused on local issues within disciplinary groups, which hindered them from seeing the big picture of collaborating intensively with each other (Ren et al., 2008). Overall, they often argued that the way in which they did their work did not have to change to any large extent.

In that outsiders followed traditional occupational approaches to work, they largely adhered to, and sustained, the overall traditional arrangements, including the social setting and the physical space. Thus, with the involvement of outsiders, coordinating as an overlapping professional domain was often made complicated, the desired flow was counteracted, and progress in general was put at risk. This became especially evident during what I call coordination breakdowns, i.e. when the new kind of coordinating was explicitly disrupted. One example of this is how outsiders often failed to acknowledge or follow the new MRI safety routines, instead citing traditional ways of maintaining MRI safety. Additionally, the extra weight given to the assistant nurses in their roles as safety nurses, through the expansion of their roles and jurisdictions, was sometimes met with pronounced resistance by outsiders. It happened more than once that outsiders resisted the safety nurses when directing and controlling the sequencing of surgical procedures. In this way, outsiders at times defended their own professional autonomy and authority, generally striving to reinforce existing hierarchy and status differences. Importantly, coordination breakdowns were most often counteracted by the collective authority that the SuperUsers had developed as insiders. For example, insiders generally supported and backed-up the safety nurses whenever these experienced resistance.

As has been shown, the insider/outsider dynamic discussed above further illustrates the importance of an in-depth common understanding in coordinating as an overlapping professional domain, and sheds light both on what this new kind of coordinating entails and on its consequences. In addition, the findings regarding the insider/outsider dynamic also provide insights into the interplay between formal mechanisms and emergent actions for coordinating. Outsiders had access to a variety of mechanisms, identified by the literature, in order to promote coordination among a diverse group of specialists, including formal guidelines and checklists, as well as training. But these formal mechanisms did not fully address the importance of departing from the traditional arrangements. Thus, while the existing literature suggests a variety of ways in which the integration of specialized tasks is managed (e.g. Argote, 1982; Lawrence & Lorsch, 1967; Thompson, 1967), these suggestions are largely rooted in structured and predetermined mechanisms, e.g. protocols, role descriptions, and checklists, to name a few (e.g. Valentine & Edmondson, 2015). This is different to the Hybrid OR studied by Lindberg et al. (2017), in which a method card (prescribing how to work) could be used as an upscaling device in terms of numbers of people. One possible explanation for this is the Hybrid OR in their study being a generic room supposed to be used for a variety of medical procedures, thus focusing on general ways of coordinating work. However, the Hybrid OR in this study was largely discipline-specific and thus required specific ways of coordinating. In this way, this study affirms recent arguments that predetermined mechanisms (even if a result of bottom-up processes) for achieving integration are not always sufficient when it comes to realizing coordination in practice (e.g. Bechky & Chung, 2018; Okhuysen & Bechky, 2009). More specifically, this study suggests that structured and formal coordination mechanisms may not be sufficient when it comes to achieving integrating conditions, especially an in-depth common understanding, for coordination, when a new kind of coordinating is necessary for the successful introduction and use of new technology.

To summarize, a new kind of coordinating emerged, i.e. coordinating as an overlapping professional domain, which was both a result of and a requirement for introducing the new technology. During this kind of coordinating, an in-depth, common understanding was both key and the focal integrating condition, being allowed by the significant latitude granted by the hospital, and achieved through a combination of formal mechanisms and emergent actions, the SuperUsers mediated this new kind of coordinating in that they became part of an important group of insiders regarding the new technology, thus enabling a form of transactive memory. As healthcare professionals other than the SuperUsers had not been as immersed in the new technology, e.g. by taking part in the planning and preparatory activities, they often had their own understandings and interests regarding how to work with the new technology. In this way, they instead became part of a group of outsiders who often followed traditional occupational approaches to work, putting coordinating as an overlapping professional domain at risk.

In showing how reconfigurations, in both the social setting and the physical space, implicated coordination, and how a new kind of coordinating was required and had emerged, I make a number of important contributions. These contributions are presented in the next and final chapter of this dissertation.

CHAPTER 9

CONTRIBUTIONS AND FUTURE RESEARCH

In this study, the story was told of a new technology in the making, where coordination processes proved crucial in making it doable. The study of the introduction and use of new technology was conducted in a highly professionalized context, consisting of multiple and specialized professional groups who were interdependent on each other, thus offering a rich setting for making important contributions to the literature. In this way, and based on the insights derived from this study, a number of contributions are made to the literature on coordination, and to the literature on professional work and the introduction of technology, which are discussed first. This is followed by the study's practical implications, especially when new technology is to be introduced into organizations. The final part of this section discusses the boundary conditions and limitations, providing suggestions for future research.

9.1 Contributions to Research on Coordination

This dissertation makes a number of contributions to the coordination literature, regarding how coordination is materially enacted, how it is temporally embedded, and how it is linked to professional and occupational approaches to accomplishing work. First, this study contributes to our understanding of how coordination is materially enacted by empirically demonstrating the impossibility of separating the social and the material, instead showing how the social and the material were constitutively entangled during coordination processes and everyday life (Orlikowski, 2007). The distinction made between the social setting and the physical space in the discussion section was merely an analytical separation to foreshadow the important role materiality played in how coordination unfolded in this study. What becomes clear in the empirical chapters and the discussion chapter is how the healthcare professionals, and the ways in which they interacted, aligned their tasks, and thus coordinated, were different with the new technology. It would be possible to relate this to the notion of agency in the way the new technology is added as a gathering of things, including the reconfiguration of the physical space, with the possibility of influencing actions and relations. It is not a causal relationship because the agency would then be lost, instead being about how the new technology holds relations and shifts attitudes, and thus becomes consequential or even disruptive. The traditional arrangements, including hierarchical and status structures, through which much of the duties, and the alignment of the same, were usually performed, became disrupted. While previous studies have demonstrated flexibility, or the possibility of workarounds (e.g. Barrett et al., 2012; Lindberg et al., 2019; Pine & Mazmanian, 2017), this was not possible to the same extent in this study, making the disruption largely non-negotiable, which speaks of an agency that is not human-centred, and how the technology thus climbed onto the 'hierarchy ladder'. Arguments about how technologies and materialities can become consequential for coordination in the workplace are often made without empirical demonstration. Edmondson et al. (2001), for example, argued how roles and ways of sharing knowledge changed as a result of the introduction of minimally-invasive cardiac surgery; however, it was not explicitly shown how the changes traced back to the new technology. Here, I provide an in-depth field study with thick descriptions of how the consequences of a new technology vis-à-vis coordination can play out in practice. Important implications are to be expected, e.g. how shifting attitudes may turn into questions about what it is, or what it means to be, a healthcare professional. This is further in line with what was mentioned in the introduction chapter, i.e. with technological developments occurring at an accelerating rate, especially in healthcare, changes in how work is done and coordinated are likely to be followed. In this way, not only do new technologies, e.g. genetics and imaging, redefine our knowledge and understanding of the body, health, and disease, they also reform healthcare from within. The symbolic systems through which healthcare professionals and healthcare organizations provide meaning to their daily activities, as well as organize both time and space and reproduce their lives and experiences, are, as discussed in Chapter 2, traditionally based on professionalism, but are now partly shifting toward becoming more technologically embedded. This also links back to the discussion in Chapter 2, regarding how professionals in practice are neither rigid nor stable, and how meanings and identities are likely to be changed when symbolic systems are altered (Abbott, 1995; Ibarra, 1999; Pratt et al., 2006). Thus, this study makes an overall contribution to the coordination literature by responding to calls to consider materiality in the study of coordination (e.g. Barrett et al., 2012; Beane & Orlikowski, 2015; Okhuysen & Bechky, 2009). Coordination scholars have been paying increasing attention to the role of objects and tools etc., and this study adds to this by analytically emphasizing materiality. Specific attention was paid to how new technology can materially reconfigure the way in which multiple groups coordinate in practice. Thus, this study is also in line with a broader call to put materiality front and center in organization and management studies (e.g. Leonardi & Barley, 2008; Orlikowski & Scott, 2008).

This study also contributes to our understanding of coordination as materially enacted, more specifically, by discussing how proximity is related to coordination.

Extant scholarship has focused on how physical distance hinders coordination while physical proximity improves it (e.g. Barley, 1986; 1990; Barrett et al., 2012; Beane & Orlikowski, 2015; Espinosa et al., 2007; Hinds & Bailey, 2003; Okhuysen & Bechky, 2009; Valentine & Edmondson, 2015). A more complex relation between proximity and coordination is put forward in this study. What were once separated healthcare practices, in terms of not only time but also of physical space, became merged and co-located with the new technology. With this reconfiguration of the physical space, the existing material arrangements that were highly intertwined with how coordination unfolded, e.g. acting as a store of information, were disrupted and thus challenged rather than facilitated coordination. Thus, how proximity matters to coordination is not about proximity itself, but rather about how it becomes intertwined with work practices and coordination processes. I envisage various implications with this finding, reaching beyond the immediate context of this study. For example, organizations seem to be moving away from assigned offices toward open spaces, which will then likely include not only changes, but also challenges as regards how duties are done and aligned. Multidisciplinarity is often presented as the hallmark of modern organizational work, especially in healthcare. As co-location is one important aspect of this, it becomes important to reflect upon what this means, not only in terms of meanings, understandings, and interests, but also in relation to changes in the material enactment.

Furthermore, our understanding of coordination as materially enacted is advanced in the way this study contributes a new dimension to the integrating dimensions, especially accountability and predictability, addressing the spatial aspects of integration – i.e. those of *spatial accountability* and *spatial predictability*. This spatial dimension was inductively derived from this study and, while the existing literature on coordination has considered material arrangements with regard to coordination mechanisms, e.g. technologies, objects, and representations, to name a few (e.g. Barrett & Oborn, 2010; Barrett et al., 2012; Beane & Orlikowski, 2015; Majchrzak et al., 2012), none of these fully account for the required spatial awareness found in this study, that was necessary to coordinate work while largely being defined in space (Sergeeva et al., in press). The spatial dimension addresses how integration is achieved in two ways. First, by providing the opportunity to clarify who is doing what *where*, which helps individuals to be aware of their responsibilities for duties in relation to space, and thus contributes toward aligning actions. Second, by providing the opportunity to clarify when work gets done *where,* which helps individuals anticipate when the elements of a task happen in relation to space, and thus contributes toward the planning and performing of tasks. Together, the spatial dimension of the integrating dimensions becomes an important means by which people collectively accomplish their interdependent tasks in the workplace, and thus redefines and broadens the meaning of integrating conditions of coordination. While a practice only exists as it is materialized at specific times, in physical spaces, artifacts, bodies, infrastructures, and so on (Beane & Orlikowski, 2015; Orlikowski & Scott, 2014), work contexts certainly differ with regard to whether or not the spatial dimension is at the forefront of coordinating activities. The healthcare context is, perhaps, exceptional in the way it is largely defined in physical space (Barrett et al., 2012; Nicolini, 2006).

Taken together, based on the importance of materiality, given what this study has shown, one suggestion is to incorporate a more symmetrical view, i.e. giving equal consideration to humans and non-humans, in formulating a practice-based perspective of and when studying coordination. This is especially important as recent attempts to develop a practice-based perspective on coordinating have included writings similar to those of Jarzabkowski et al. (2012), "…shifting the analytic focus from coordinating mechanisms as reified standards, rules, and procedures to coordinating as a dynamic *social practice* [emphasis added]…" (p. 907).

Second, this study contributes to our understanding of the temporal embeddedness of coordination processes by not focusing on an already-established practice, or taken-for-granted technology, thus advancing the processual and dynamic view of coordination (Beane & Orlikowski, 2015; Jarzabkowski et al., 2012). While many current studies stress the situated and emergent nature of coordination, they often overlook how coordination relates to prior work and practices, thus treating coordination as if it were unfolding in a situated contextual vacuum. This is especially the case when it comes to the introduction of new technology and the differences this makes to ways of working and coordinating work (Bailey & Barley, 2019). By means of the longitudinal study, spanning several years, and also covering the traditional practices during the time before the new technology had been introduced and used, as well as planning and preparatory activities, this study highlights the temporal interdependence between past social and material inertias and focal coordination processes. This is important because coordination follows a history of previous actions and interactions which necessarily constrains and enables future action (Faraj & Xiao, 2006), and it has been shown, in adjacent literatures, that previous work and traditional arrangements shape subsequent work (e.g. Barley, 1986; Nelson & Irwin, 2014).

Here, I build on and advance the few existing studies that explicitly acknowledge the temporal embeddedness of coordination, and the interconnectedness of prior and subsequent practices in different ways (e.g. Barrett et al., 2012; Beane & Orlikowski, 2015; Jarzabkowski et al., 2012; Venters et al., 2014). I add to these studies by, for example, providing further insights into how the inclusion/exclusion of information and individuals as regards prior practices, e.g. planning and preparatory activities, matters to subsequent coordination. It is suggested that, when not just high-status actors are involved, differences in interests and understandings are decreased, which helps to facilitate subsequent coordination. The study also provides a processual understanding of how traditional arrangements, intertwined with the social setting and the physical space, matter to subsequent coordination once a new technology has been introduced, and how these traditional arrangements become reconfigured and what the implications are for coordination. While the above-mentioned studies have shown how traditional and coordinative arrangements not only shape subsequent coordination, but are also frequently sustained over time, this study suggests that this is, perhaps, only possible initially or when there is no uncertainty regarding responsibilities. This is further connected to the recognition of a fragmented approach to coordination (e.g. Bruns, 2013; Harrison & Rouse, 2014; Wolbers et al., 2018), in this study related to the traditional arrangements, which could go on only for as long as a temporary social setting and an imaginary space were being organized. However, with the reconfiguring of the social setting, and in particular the physical space, the traditional arrangements could no longer be maintained.

This study also contributes to our understanding of coordination as temporally embedded by means of discussing the dynamics of, and the interrelationships between, integrating conditions. More specifically, the study shows how the conditions change over time, how they are achieved in different contexts, how they relate to each other, and how they implicate what kind of coordinating emerges. Thus, the study adds to the comprehensive review by Okhuysen and Bechky (2009) by empirically studying the integrating conditions in-depth. This is important because much empirical work on coordination refers to the integrating conditions, but seldom explicitly accounts for how these are achieved. I add to the study by Pine and Mazmanian (2017) as one notable exception, by showing how the alterations to the social setting and the physical space, following the introduction of the new technology, had profound implications for the integrating conditions. To what degree these were achieved changed over time, and their relationships shifted. During ongoing efforts to continuously stabilize the social setting and the physical space, common understanding was peripheral. During reconfigurations of the social setting and physical space, and once the new technology had been introduced, common understanding became key, and the focal integrating condition, which also meant that a new kind of coordinating emerged. One implication of this is that the three integrating conditions, as proposed by Okhuysen and Bechky (2009), are not enough to coordinate the introduction and use of new technology during conditions of merging two previously-separated healthcare practices. Instead, a more *in-depth common understanding* is required, which emerges as key, and the focal integrating condition in the new kind of coordinating, i.e. *coordinating as an overlapping professional domain*, being produced and required. This further suggests that important degrees of common understanding exist as an integrating condition.

Third, this study also contributes to our understanding of the link between coordination and professional and occupational approaches to accomplishing work, by exploring how healthcare professionals are embedded in organizations and what the implications are for how they coordinate (Bechky & Chung, 2018). More specifically, this study contributes to the coordination literature by showing how and when a different kind of coordinating (i.e. coordinating as an overlapping professional domain) to that usually depicted in the literature emerges. Prior to the new technology, the situation was similar to that reported in various other studies (e.g. Ben-Menahem et al., 2016; Kellogg et al., 2006; Wolbers et al., 2018), i.e. there were explicit disciplinary demarcations (not static but continuously reproduced in practice), which helped in defining and clarifying who was doing what and when. While this has largely sustained professional domains (Abbott, 1988; Bechky, 2003), it has also facilitated coordination by prescribing that healthcare professionals merely relate to the explicit demarcations, and occasionally adjust their work if necessary. As Kellogg et al. (2006) have argued, rather than transforming local understandings into shared meanings and common knowledge, organizational actors instead make their work and commitments visible to others, and draw on the mechanism of a distinct division of labor in order to coordinate their duties. However, with the new technology, the responsibilities for many duties changed and became shared, which brought new requirements with regard to understanding the aspects that also concern each other's work. Given the need to make deep commitments in order to develop an in-depth common understanding and transform knowledge, the previous explicit disciplinary demarcations were made less pronounced. Boundaries were instead set with regard to who could work, and how, with the new technology, which entailed roles partly replacing the division of labor as a mechanism for coordinating. Achieving this kind of integration required much more interaction and negotiation, being made possible by the significant latitude granted by the hospital (Bechky & Chung, 2018). In terms of boundaries (e.g. Langley et al., 2019), this would resemble how boundaries are downplayed, which is different to how work was coordinated through negotiating boundaries in other studies (e.g. Ben-Menahem et al., 2016; Kellogg et al., 2006). In the study by Kellogg et al. (2006), the actors were able to coordinate by enacting a 'trading zone' (Galison, 1999), and were thus not required to share similar interests, norms, and meanings, while in the study by Ben-Menahem et al. (2016), the specialists were even able to relax their domain-specific standards of excellence to allow collective outcomes. In contrast, the healthcare professionals in this study not only had to downplay the divide between previously "us" in order to achieve "we", they also had to develop an in-depth common understanding hinging upon the considerations of the requirements and responsibilities of all groups, which is less what Kellogg et al., (2006) call a new 'coordination structure' and more what Okhuysen and Bechky (2009) call a 'coordinating activity'. In this study, the way the healthcare professionals coordinated is seen as a new kind of coordinating, i.e. coordinating as an overlapping professional domain. This makes an important contribution to the coordination literature, showing how, in what could even be seen as a traditional hierarchical organization, accountability can be distributed and work coordinated emergently in a domain that overlaps previously explicit demarcations. Occupational or professional embeddedness serves as one possible explanation here, in that the reconfiguring of the social setting and the physical space allowed embeddedness to be in flux. With this in mind, our understanding of the three integrating conditions (accountability, predictability, and common understanding), as proposed by Okhuysen and Bechky (2009), is also advanced: They seem to be relevant overall, but different contexts require their enactment to varying degrees. In this study, for example, given the introduction and use of a new technology during conditions of merging two previously-separated healthcare practices, coordinating as an overlapping professional domain required an *in-depth* common understanding.

This study also contributes to our understanding of how status differences and hierarchy structures implicate coordination. This is important because these arrangements constitute an ordinary organizational dynamic (Freidson, 1970; Nembhard & Edmondson, 2006), and cannot be neglected if the aim is to explore the link between coordination and occupational and professional embeddedness (Okhuysen & Bechky, 2009). Scholars often argue that, because occupations and professions have different statuses, it is difficult for people to coordinate with one another (e.g. Abbott, 1988; Faraj & Xiao, 2006). It is often portrayed in the literature that status differences are static and, when salient, they pose a particularly significant barrier to coordination (e.g. Anthony, 2018; Bechky, 2003; Edmondson et al., 2001; Valentine & Edmondson, 2015). High-status actors, for example, often ignore the claims made by lower-status actors (Barrett et al., 2012; Zuboff, 1988). It was demonstrated in this study that status differences are dynamic and also able to have beneficial effects on coordination. Specifically, prior to the new technology, coordination was facilitated due to accountability and predictability largely being achieved by relying on traditional statuses and hierarchical structures. Also, with the new technology, lower-status actors were able to take advantage of opportunities and to emerge as high-status actors with an important role in sharing and spreading common understanding across the disciplinary groups. This shows not only how status differences are dynamic, but also how the opportunity to take advantage was largely due to the traditional status differences and hierarchy structures: High-status actors were not as interested and motivated as lower-status actors in participating in the planning and preparatory activities, thus to some extent failing to guard or realize their interests. Thus, these findings provide an explanation as to why the current literature may have been focusing on the challenging role of status instead of the role of facilitating.

Related to the previous points, this study contributes to our understanding of how the embeddedness of professionals in organizations makes a difference to coordination by highlighting implications regarding when previously-established embeddedness starts to dissolve. It was during the conditions of merging two previously-separated healthcare practices that the new technology was introduced and used. In that, for example, role expectations were no longer clearly defined or clarified, the important and established aspects of occupational control and embeddedness started to become blurred or dissolved. In this way, it was important to establish new anchoring, and it was here the emergence of a new occupational role, i.e. the role of the safety nurse, proved important in managing new interdependencies among the occupational groups. While roles, as a useful means of coordinating work, have been identified before (e.g. Bechky, 2006; Okhuysen & Bechky, 2009; Valentine & Edmondson, 2015), the focus has mainly been on existing roles within organizations. This study extends this reasoning by focusing on the emergence of a new occupational role, amidst the flux in occupational and professional embeddedness.

9.2 Contributions to Research on Professional Work and the Introduction of Technology

This study contributes to the literature on professional work and the introduction of technology, specifically with regard to how the time before a new technology is introduced matters to its subsequent use, how collaborative interactions can be at the forefront even when a new technology that breaks with traditional arrangements is introduced, and how other professional and occupational groups, rather than just medical professionals, matter when new technology is introduced. First, this study contributes to our understanding of how new technology is introduced into organizations, and with which implications, by demonstrating how what it is that gets done during the time before the technology 'arrives' in an organization has important implications for subsequent use and work-related changes. To date, much empirical and theoretical work on the introduction of new technology, as reviewed in Chapter 2, tends to only examine the introduction and use of technology long after it has come into use, despite recent acknowledgements of the importance of also including the interests, goals, and perspectives of those involved in making decisions about shaping its design and introduction (e.g. Anthony, 2018; Bailey & Barley, 2019; Beane & Orlikowski, 2015; Wright et al., 2019). This study shows how, despite the planning and preparing activities being perceived as far from the actual use of the new technology, they still proved to have important implications in shaping the introduction and use of the technology. For example, and similar to what was discussed in the previous section, the organizing of the temporary social setting and the imaginary physical space actually also paved the way for low-status actors to have their interests and understandings inscribed.

Second, this study also contributes to our understanding of how new technology is introduced in professionalized contexts by problematizing an assumption shared by many existing studies. As seen in Chapter 2, it is often argued that, once new technology breaking with traditional and well-established arrangements is introduced, members of occupational and professional groups will be engaged in reproducing or altering these arrangements largely dependently upon jurisdictional contestations, conflicts or even fights (e.g. Bucher et al., 2016; Langley et al., 2019; Wright et al., 2019). However, this study shows how cooperative and collaborative interactions were at the forefront, rather than conflictual and adversarial interactions. While there were traces of contestation and negotiation, the overall approach to realizing a collective performance was instead characterized by collaborative relations, which is in contrast to many of the studies reviewed in Chapter 2 (e.g. Bucher et al., 2016; Comeau-Vallée & Langley, 2019; Currie et al., 2014). This is explained by how, during conditions of merging two previously-separated healthcare practices, and the reconfiguration of the social setting and physical space, demarcations are drawn around the multidisciplinary team, facilitating the development of an in-depth common understanding and coordinating as an overlapping professional domain. Adopting a longitudinal study based on a combination of observations of real-time procedures and meetings, interviews and documents, provides the opportunity to capture nuances which studies mainly relying on texts and reports (e.g. Bucher et al., 2016), or only on interviews and observations of meetings (e.g. Comeau-Vallée & Langley, 2019; Currie et al., 2014) have not been able to. Thus, partly explained by choice of method, one implication of this is that previous studies may have tended to overemphasize the conflictual nature of professional work, in doing so failing to capture how members of professions and occupations, in practice, go about getting their work done. One additional take-away is the fact that contestation and collaboration can emerge jointly, and that they are not necessarily opposing processes.

Third, this study contributes to the literature on professions and technology by focusing, not only on the medical profession that has dominated in much previous research (see Chapter 2), but also on other important professional and occupational groups. This is important given the increased emphasis on multidisciplinary workplace collaboration with interdependent duties, entailing that changes to one person's work will likely influence the work of others. As described in the introduction chapter, traditional explanations of how new technology is successfully introduced often focus on the inherent properties of the technology itself, as well as on individual brilliance or heroism (see Edmondson et al., 2001; Nicolini, 2010). However, these explanations would only have provided an impoverished story of what happened in my study, where making the new technology doable required multiple professional groups to instead work out new coordinative arrangements. In addition to recognizing the role of multiple professional groups, this study also highlights the considerable time and effort that was required, in particular, by nurses from various disciplines. Coordinating the introduction and use of the new technology, under conditions of merging previously-separated healthcare practices, was dependent on many non-clinical or non-caring tasks. It was nurses who performed the majority of these tasks, e.g. planning, preparing, and establishing checklists and workflow charts. Paying greater attention to nurses is, furthermore particularly important at a time when the scope of nursing practice and the profession are expanding (e.g. Jones et al., 2011; McDonald et al., 2009).

9.3 Practical Implications

This study offers implications for practitioners involved in the introduction of new technologies in organizational contexts. As explained in the introduction, new technologies are often introduced accompanied by promises of cost reductions, efficiency improvements, and increased product/service quality. These technological panaceas appear irresistible, despite often promising more than they can deliver. As shown in this study, once employed in practice, a new technology may also have unintended consequences in the workplace, e.g. disruptions to responsibilities regarding duties, status-hierarchies, interactions, and the coordination of work. Decision-makers and managers need to be aware, not only of the intended consequences, but also of the potential for more unintended consequences, when considering the introduction and use of new technology. Although it is difficult to plan for something unexpected, this can still be beneficial to reflect upon so that no further difficulties can hinder the successful introduction and use of new technology.

This study shows the existence of certain challenges with the new technology as such, but also that it was the coordination challenges surrounding how to work with the new technology that demanded considerable time and effort on the part of the healthcare professionals involved. While the great latitude that was granted to the healthcare professionals, when planning, preparing and adjusting the new technology, allowed them to successfully make it doable, additional organizational support could have helped in managing these challenges even further, and with fewer staff constraints. Thus, these findings raise important questions regarding organizational support in the wake of introducing technology. Given the general trend of focusing on maximizing return on investment (ROI), and minimizing support and staff costs in relation to new technology, coordination challenges and tensions are likely to be present in organizations. When new technology is to be introduced, managers and decision-makers may be better off if they also reflect, right from start, upon potential coordination challenges, challenges that are not always directly related to the technology's properties.

Based on the implications set out above, understanding the introduction and use of new technology as a dynamic and complex process, thus brings managers and decision-makers challenges. These managers and decision-makers may, for example, easily end up thinking in organizational silos or fragmented processes, and may not always be the ones who have enough knowledge and understanding of the new technology itself, or of the local prerequisites governing its introduction and use. On the basis of this study, suggestions for managers and decision-makers include making an extra effort to understand the potential consequences, as well as the local understandings and meanings, of new technology, even before its introduction. Furthermore, it is suggested that managers evaluate results and progress, not only after the introduction, but also during the process, and from multiple perspectives.

While it is generally assumed that, as long as new, better and more expensive technology is introduced, better outcomes will also be achieved, this study has shown how it required considerable time and effort on the part of the ones involved in making the new technology doable. These efforts were largely related to coordination challenges, which tend to go unnoticed once the new technology has been introduced and come into use in practice. This has been referred to as invisible work, and I am strongly convinced that without the dedicated team of SuperUsers, the introduction of the new technology featured in this study would not have been possible. Even at the cost of sounding clichéd, I would like to emphasize the importance of acknowledging all the individual contributions, and of reminding about the greater good achieved by a new technology, especially in healthcare settings. Thus, an important implication of this is not being fooled by the lure of the technology, or ascribing to traditional explanations, often focusing on the inherent properties of a new technology or on individual brilliance or heroism, as regards how the introduction of new technology succeeds. More often than not, these explanations only provide impoverished stories, not accounting for what goes in practice, and thus not being helpful when embarking on future introductions and uses of technology.

As mentioned above, this study further suggests that the invisible work, often done by nurses, needs to be acknowledged. Highlighting the important work done by nurses provides important insights that go beyond the dominant groups (e.g. doctors) that researchers often focus on. Much of the work done by nurses goes beyond their immediate professional role, and is thus nowhere to be seen in formal documents or performance reports, but that work is absolutely necessary for a new technology like the one in this study to be introduced and made doable.

Another important implication of this study is how, not only social and cognitive aspects, e.g. leadership, psychological safety and group cohesion, but also material aspects matter when introducing a new technology. The implications that the reconfiguration of the physical space had, regarding how work was coordinated, can help practitioners to acknowledge the material aspect when introducing new technology. This is especially important in healthcare settings, where work is largely defined in space. Thus, this study suggests that, when new technology is to be introduced and used, there needs to be consideration, not only of aspects related to changes to the social setting, but also in relation to the physical space. Greater attention has been paid, understandably, to socially developing the group of healthcare professionals introducing and working with the new technology. Many of the informants, however, said that educational visits to other hospitals using similar technologies, and to the new physical space when under construction, helped them in their planning and preparatory activities. Thus, it can be beneficial to give greater priority to ensuring that the individuals involved have continuous access to the reconfiguring of the physical space.

9.4 Boundary Conditions and Future Research

The emerging insights discussed in this study are tied to certain boundary conditions, i.e. the situations to which the insights are likely to be theoretically generalizable. In discussing these boundary conditions, limitations to this study are also mentioned, which provide further important suggestions for future research.

The first contextual factor that might have an important impact on whether, and how, the findings observed here will occur concerns the cultural context. Despite how hospitals are generally considered hierarchical, Swedish culture, (if there is such a thing in the first place), is on the whole frequently described, both in the literature and by employees, as rather egalitarian and collectivist (at least in the workplace) (see Holmberg & Åkerblom, 2001). We would, perhaps, expect coordinating to unfold somewhat differently in contexts based on elitism, where certain people have the right to have their opinions and preferences realized to a greater extent than others. A more elitist context would thus facilitate and encourage unequal power relations and undermine egalitarian power values (e.g. Kabanoff et al., 1995), thus having a potential impact on how coordination plays out in practice.

The second contextual factor relates to the nature and origin of technologies. The technology featured in this study was very much self-initiated, or 'home grown', by the professionals themselves (or at least some of them), as they had identified specific benefits to their duties. Thus, it is plausible to assume that the present self-interest in the technology, with the consensus to make it work, shaped how coordination played out and made the relationship more mutually constitutive (see Korica & Molloy, 2010). The introduction of other technologies initiated by management, or externally imposed, may be coordinated differently, especially in professionalized contexts with a great deal of autonomy.

In addition to boundary conditions, there are also important limitations to my study which future research could address. While a single case study enables the generation of detailed and in-depth understanding, it limits opportunities for generalization. Since hierarchy, status and other dynamics are considered permanent to the system of professions (Abbott, 1988), one suggestion for future research would thus be to also study coordinating the introduction and use of new technology in other professionalized contexts, reaching beyond the healthcare context. In addition to this more general caveat, there are also more specific limitations. First, temporality has been an important aspect of my study, which relates to my choice of not focusing on an already-established practice or taken-for-granted technology, and adopting a longitudinal approach. This can be seen as both a strength and a limitation: It is a strength in that it allowed the acknowledgement of how coordination follows a history of previous actions and interactions (Faraj & Xiao, 2006), and a limitation in that it was not possible to fully follow the new technology and coordination for a significant period of time once it had come into use. As John Van Maanen wrote; "There is always more to learn and surprise is always just around the bend. Exit from the field is then largely arbitrary, having little to do with either theoretical or empirical saturation" (2015, p. 41). Thus, the questions remain as regards whether my findings would also be similar for a time period not that close to the introduction of the new technology, e.g. once the new practice had become well-established and the new technology was being taken-for-granted. This study may, thus, have missed aspects that previous studies, focusing on established practices, have captured. It might be the case, for example, that the coordination breakdowns and the insider/outsider dynamic are less prevalent over time, and even that the new kind of coordinating is just temporary. This also links back to one aspect of my research question, i.e. merging, and the question of when this process starts and ends, and what it means for coordination. These are all questions to be answered by future empirical research taking these aspects forward. However, exiting from the field was a gradual winding down and a slow withdrawal (Van Maanen, 2015), and my impressions, having followed work with the new technology for about two years after it had been introduced, are that little had changed thus far.

Second, as a single fieldworker in a complex and embedded setting, I could not capture the organizational processes in their entirety. More specifically, the strength of this study, in going beyond separate professional groups and including multiple groups with their potential different interests, values, norms and practices, also became a limitation in that I sometimes had to opt for breadth instead of depth. I focused more on the interactions and alignments among the professionals groups, and thus studies that are more attentive to individual differences within professional groups could advance our understanding of the implications for coordinative arrangements of individual characteristics. On a similar note, all the healthcare professionals in this study had lengthy experience, and were considered more or less senior experts, which could have influenced their attitude toward coordinating. The point about how experienced healthcare professionals have developed a fuller repertoire of alternative actions, thus being less dependent on existing treatment pathways than junior healthcare professionals, points to this situation (see Faraj & Xiao, 2006; Wilhelm et al., 2019). Thus, future research could also consider less experienced healthcare professionals, e.g. junior doctors or junior nurses, in order to explore whatever differences that makes to how new technology is introduced and used during conditions of merging two previously-separated healthcare practices.

Third, and related to the previous point, my emphasis was in line with the broader practice turn in organization and management research (Nicolini, 2012; Schatzki et al., 2001), in that I focused on studying work itself, what people do at their workplaces, and how they make sense of their practice (see Orr, 1996; Yanow, 2006). For example, I traced the interactions across, and to some extent among, professional groups. However, generally less of my attention was devoted to what happened on the organizational level. This emphasis was guided by where the emergent findings took me, but with an accompanying limitation in that less attention was paid to how the local accomplishments connect with more overall organizational mechanisms, e.g. the structure of healthcare systems and budget constraints. Nicolini's (2009) point about 'zooming out', in which he argues that local practices are always immersed in a thick texture of interconnections that extend beyond the scope of the local set of practical concerns, refers to this. Thus, future research could also be more attentive to aspects on what social scientists often describe as the "macro" level, in order to acknowledge how coordinating the introduction and use of new technology, in practice, extends beyond the scope of the local set of practical issues.

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