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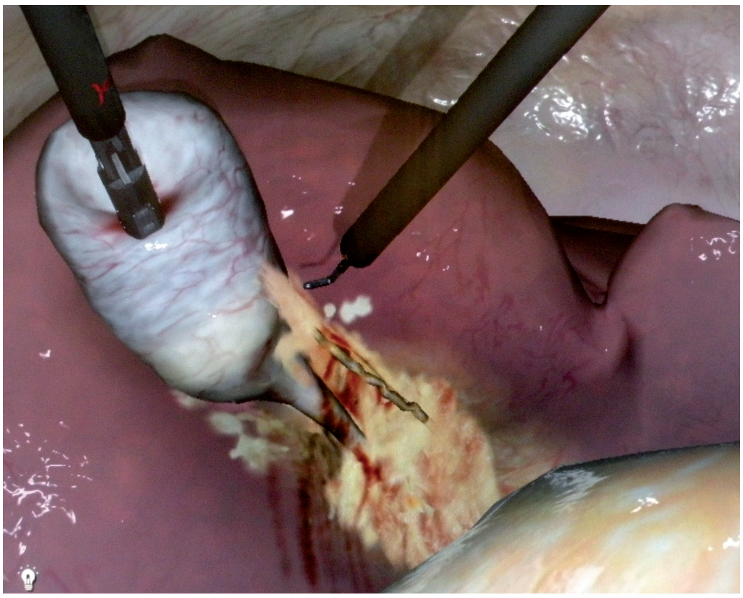
Minna Silvennoinen

Training Surgical Skills in a Simulated and Authentic Environment

Expertise Challenges in Development of Surgical Laparoscopy Practicing



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Cover picture: simulated laparoscopic cholecystectomy, picture taken from the simulator screen. Photo by Minna Silvennoinen.

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ABSTRACT

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This is a study of surgical skills practice and expertise development within the two contexts of simulation-based training (SBT) and authentic operating theatre (OT) environments. Its *purpose* is to gain a deeper understanding of how to develop minimally invasive surgical (MIS) training and practice methods at Finnish hospitals for these to respond better to today's expertise demands. The *overall aim* is to gain an understanding of what MIS expertise is how operating skills learning and training occurs, how the expertise and skills involved develop during the resident education, and what causal factors are involved. This study creates a model of the resident's skills to contribute to the discussion and practices on developing workplace learning. The study addresses four main *research questions*: (1) What are the main characteristics of surgical expertise?, (2) How do the challenges of expertise and skills development in laparoscopy lead to failures?, (3) What factors affect surgical residents skills learning and training with simulators?, and (4) What are the requirements for implementing surgical operating skills education utilising simulation-based training?

The *data* consist of video recordings from OT and SBT, surgeons' interviews, simulator logs, and questionnaires administered to residents. The data analysis is mixed and multi-method, combining both qualitative and quantitative approaches. The *findings* suggest that: 1) characteristics of surgical expertise should be seen as the needed resources and preconditions for educating surgical professionals; however, more attention needs to be paid to the development of non-technical skills; 2) the challenges of skill and expertise development manifest directly contributing to failures seen in OT work; 3) the factors that affect surgical residents' SBT and learning are organizational, individual and social and enhance or restrain learning at work; furthermore, the hospital's support for workplace learning seems to have the greatest influence on the success of SBT; and 4) the practical requirements for implementing SBT are committing both organization and workers to planning and implementation and providing them adequate resources for these tasks. The success of implementing SBT requires major changes to the surgical learning and training culture at hospitals, which highlights the meaning of education design.

Keywords: surgical skills training, surgical expertise development, simulation-based training, operating theatre, surgical education, failure prevention, learner experience.

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When I started my PhD research in 2006, I was a member of the INSKILLS research team and didn't actually have any knowledge of the work of surgeons because I have a non-medical background. During these years, I have most enjoyed participating in multidisciplinary research and education design projects and the possibility to learn from others with different specialties. Especially, my part-time job in the Center of Medical Expertise (Tietotaitopaja) during these years as a PhD student has offered me inspiring opportunities to cooperate with the doctors and residents, from whom I have learned a lot. I would first of all like to thank the two surgeons who innovatively set in motion this whole research and development effort and have maintained it ever since, Teuvo Antikainen and Jukka-Pekka Mecklin. I would also like to express my gratitude to all the doctors and residents who gave their time to participate in this study.

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4. Silvennoinen, M. (2011). Learning Surgical Skills with Simulator Training: Residents' Experiences and Perceptions. In E. Cohen (Ed.), *Proceedings of Informing Science & IT Education Conference (InSITE) 2011* (pp. 545-566). Santa Rosa, California, USA: Informing Science Institute.

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Author's contribution to the included articles: In 1., the author was mainly responsible for the theoretical background and carried out most of the work with the second author who mainly co-contributed to discussion. The third author co-contributed to theoretical background and discussions and fourth author co-contributed to discussions. In 2., the author was responsible for the major part of the work such as data collection and analysis and the author was also mainly responsible for the theoretical background, reporting and discussion on results. The second and third authors co-contributed to introduction and discussions. In 3., the author was mainly responsible for the theoretical background, empirical design, reporting and discussions and solely responsible for the data collection. Statistical analysis was executed by the second author who also co-contributed to theoretical background, reporting and discussions. The third author co-contributed to theoretical background and fourth author co-contributed to empirical design and discussions. In 4. and 5., the author was the sole author.

FIGURE

TABLES

CONTENTS

1 INTRODUCTION

This is a study of surgical skills practice and expertise development within two contexts: simulation-based training (SBT) and authentic operating theatre (OT) environments. The roots of surgery lay deep in our history. The word surgery comes from the Greek word kheirourgos, in which cheir means hand and ergon means work. In the old cultures, the people who cured diseases were divided into internal and external disease curers. Those who cured internal diseases with herbs or magic were compared to priests, and those who cured external diseases with knives were compared to craftsmen and craftswomen (Roberts & Aarnio 2004). The craftsmen, surgeons, were greatly respected and even feared authoritarian leaders in operating theatres (OTs) at least until the middle of the 20^{th} century. Still, today the role of a surgeon in OT is to lead the multi-professional operating team. Therefore, surgeons' skills and knowledge have an essential role in patient safety and in the success of an operation. This central role of a surgeon is described in the Finnish article concerning the co-operation between the anesthesiologist and the surgeon in which a quotation of an anesthesiologist is presented: ”no treatment or medicine can save the patient from a bad surgery”(Roberts & Aarnio 2004, 43).

Today the surgical traditions are confronted with the need for radical changes. The method of teaching and learning surgery has been for centuries the apprentice model in which surgical residents follow specialist surgeons and learn and develop their skills with the “see-one, do–one” method. The residents' learning opportunities are extremely workplace- and situation-dependent. Each learning situation depends on each hospital's working culture and the responsible supervising senior's guidance and work assignments. For decades, this apprentice training model has become incorporated into each hospital's everyday routines. Now, the new skill requirements of video-assisted surgery have challenged this historical tradition of learning, and the master-apprentice model has proven insufficient for developing the required skills for several reasons (Gallagher & O'Sullivan 2012, Reznick 2006).

Surgical education has not been able to keep up with the speed of the technological development of surgical instruments, operating techniques and training equipment innovations (Gallagher & Sullivan 2012, 5). For example, the development of surgical computer-based simulators has been rapid during the recent decade. These pieces of equipment are not, however, used systematically in surgical training, even though they might significantly increase the efficiency of skills learning (Reznick 2006). Also, continual savings are being pursued by the hospital administrators. It is known that surgery is responsible for consuming a major share of all healthcare expenses; even more expensive events than planned and successful operations are unnecessary surgical complications causing extra repair costs and most of all immeasurable suffering for the patients. Therefore, it would be more than logical to invest into error-preventive actions. However, even though the skill and learning demands of surgical residents seem to be increased, at the same time the valuable residency time at hospitals has been shortened. This is partly a result of the implementation of the European Working Time Directive, which radically shortened the surgical training time (Bleakley 2011). Many surgeons and senior residents think that shortened hours lead to situations in which residents are not gaining appropriate experience of surgical conditions, and there are concerns that graduating residents are not fully prepared for independent work (Britt et al. 2009). In addition, Finland is the only European country in which the residency period also contains a nine-month period of training in general medicine, which does not enhance surgical skills. The surgical residents have therefore approximately five years' time to develop their specialised expertise. These issues raise ethical questions concerning the sufficiency of patient safety in surgery. The Finnish Medical Association has also had concerns, and though the lengthening of the surgical specialisation period has been suggested several times, there have been no results. The last time it was suggested was in the report of the Ministry of Social Affairs and Health 2011 (Erikoislääkärikoulutustyöryhmän loppuraportti. 2011). However, other countries such as Sweden have acknowledged the problematic combination of the organisational changes resulting in more wide-ranging healthcare professionals' expertise demands and the shortage of investments to meet these requirements through training (Ellström et al. 2008). So, what is the state of Finnish surgery today from the educational and safety perspective, and what is expected in the near future? These problematic issues need to be discussed though the changes to both surgical education and working methods should be considered also.

Several high-quality studies have been conducted to understand learning from experience and the nature of workplace performance and factors affecting it. It is known that workplaces are only rarely structured with learning in mind and that local workplace culture, with its various norms and values, shapes the learning and expertise development when workers engage in cooperative work and tackle challenging tasks (Eraut 2004, Tynjälä 2008). However, only a few studies have investigated how physicians learn in the workplace (van de Wiel et al. 2011), and in the context of surgical OT practice, expertise and learning research is practically missing (Norman et al. 2006). Van de Wiel et al. (2011) suggest that research on workplace learning by both residents and experienced physicians needs to be expanded to explore the activities they engage with at work. Studies on both observing the learning and supervision in medical practice as well as studies implementing and testing interventions that focus on promoting medical professionals' learning at work are needed (van de Wiel et al. 2011). There is also a need to understand more of how surgical skills are learned during residency. There are several different views on how resident education at hospitals should be arranged optimally. Arguments favorable to simulator training are increasing worldwide (Aggarwal et al. 2004 & 2006, Kneebone et al. 2004, Ahlberg 2007), but there is no consensus on where and how particular surgical skills should be learned. The empirical evidence on both implementation of systematic simulator training and optimal ways to use the simulators as learning tools for residents are scarce, and the current guidelines for educational use of these pieces of equipment remain varied and even controversial (Hammoud et al. 2008). This is at least partly caused by the fact that the general quality guidelines for surgical simulators concerning methods, settings, and data interpretation are missing (Schout et al. 2010). Therefore, the opportunities, benefits and limitations of enhancing surgical resident education and skills learning should be explored. The implementation of simulator training into surgical education and learning at hospitals in Finland is still relatively rare. More information on the current methods of surgical training and practice is needed, and new innovations should be compared to these current methods in order to find the best solutions and combinations for educating residents today (Kneebone et al. 2004).

Detailed knowledge is lacking also concerning OT work challenges and error management in relation to surgeons' expertise and skill development. Also, more understanding of common failures occurring during surgical procedures is needed as well as educational suggestions for their prevention. Surgical errors should be studied more openly, in a prospective manner, and the knowledge gained from these studies should be used for learning purposes to enhance patient safety (Etchells et al. 2003). Many error studies in surgery are targeted solely on technical errors, and the holistic view of surgeon's expertise is missing also in relation to error studies. Dexterity or technical proficiency are seen as a paramount feature of surgical skills (Moorthy et al. 2003), and researchers also suggest that there should be more focus on curricular design and the development of methodologies, particularly for surgical technical skills training (Sweet et al. 2010). On the other hand, from the patient safety view, technical skills are seen as important for safe surgery, but they are not seen as sufficient to maintain expertise, like non-technical proficiency (Yule et al. 2008, Yule & Patterson Brown 2012). There are different views on how surgical experts should be trained and a lack of studies on how the different expertise areas should be taught.

In other high-risk professions such as aviation or nuclear power, both skills training, following the Crew Resource Management (CRM) principles as well as development of error-preventive work practices were launched several decades ago; this development still seems to be in a more advanced level and the risks considerably more controlled compared to medicine and surgery (Flin, O'Connor & Mearns 2002). The awareness of the challenges in learning and practicing abdominal area video-assisted, e.g., minimally invasive surgical (MIS) procedures and laparoscopies, has made it topical target for research. Despite the special attention focused on the development of MIS training simulators, the complication rates of laparoscopic gallbladder removal, laparoscopic cholecystectomies (LC) have not diminished desirably. This operation procedure is a very common treatment for gallstones. Therefore, laparoscopic skills learning and training manners seem to need special attention. Trere are researchers who have recently suggested, the human factor research for inventing solutions for enhancing patient safety in this particular area of surgery (Charness & Tuffiash 2008; Gawron et al. 2006; O'Connor et al. 2010).

In this thesis, I pursue a better understanding on how to develop minimally invasive surgical (MIS) training and practice methods in order for these to be able to respond better to today's expertise demands and challenges. Therefore, this thesis aims to understand what MIS expertise is, how operating skills learning and training occurs and how surgical expertise and skills involved are developing during the resident education at hospitals and what causal factors are involved. Though surgery is a diversified area of medicine, this phenomenon is considered through the case example of laparoscopy. This is one of the most rapidly developed areas in modern surgery and has also had quite recently plenty of educational attention concerning the development of computer-based, virtual reality (VR) skill training simulators. This thesis explores laparoscopic surgery practice within two different contexts: simulation-based training utilizing VR simulators and authentic practice at work in operating theatre (OT).

Multidisciplinary views to explore this area seem to be necessary, and therefore this thesis combines knowledge from various disciplines: surgery, cognitive science, education and psychology. Multidisciplinary research methods are needed. For example, both educational and user-psychological research is required to analyse human factor effects in OT and also the human-technology interaction during simulator training.

The purpose of this thesis is to contribute to designing efficient and systematic surgical skills education and training methods that respond to the present demands of surgical competences. In order to clarify the motivations of this thesis in more detail, I describe the problems and inconsistencies of surgical education and working methods today as well as the requirements for making changes.

This thesis is organized as follows. The theoretical background is provided in chapter two. Research objectives and methods are presented in chapter three. Research aims and questions are presented in more detail in chapter 3.1. Methodological approaches including both qualitative and quantitative means are introduced in chapter 3.2. Summary of the findings of the sub-studies is given in chapter four. Discussion and answers to research questions are presented in chapter five as well as reflections on methods and assessment of trustworthiness of this study. Chapter five also presents implications for future research as well as practical conclusions.

2 BACKGROUND AND RELATED LITERATURE

This chapter provides an overview of the theoretical issues related to surgical skills development and practice. Surgery is a unique profession as it requires considerable psychomotor skills as well as critical thinking and decision-making skills to perform diagnostics, a tremendous amount of knowledge to recall and apply (e.g. from human anatomy and physiology), an ability to react to rapidly changing situations and also social skills and an ability to lead the medical team, etc. In order to investigate operating skills training and learning, we need knowledge on the particular skills and specific demands required from the surgeon as well as knowledge on how to become skilled and how to achieve surgical expertise. In the following chapter, the theoretical background of laparoscopic surgical skills learning and requirements to become skilled and achieve expertise in this profession are presented. In order to understand the problems and challenges of surgical education today, information is needed on learning and practicing surgery in two integrated contexts, authentic operating theatre (OT) and simulation-based training (SBT). The final section, 2.5, summarises the theoretical background of this research context.

2.1 Laparoscopy - a challenge for surgical resident education

In modern surgery, there are various techniques to perform operations. Traditionally, a common abdominal area disease, gallstones, has been treated by removing the gallbladder from the abdomen with an open surgical operating technique for over a hundred years. The laparoscopic technique became a standardized method for gallbladder removal during recent decades, and a great majority of these procedures, cholecystectomies, are performed today with this technique. Laparoscopy is an abdominal area surgery performed with the MIS technique through small, 0.5 – 1cm wounds with thin, long instruments causing minimal blood loss and tissue damage. The popularity behind this technique is the short sick leave, only 7-10 days, and most of the patients are able to go home on the same day as the surgical operation (Satava 2011).

However, the laparoscopic technique also has its flip side. When the MIS surgery revolutionized surgical practices in the late 1980s, it led to changes in the research field concerning both the motor and the cognitive skills in surgery. It was then noticed that training in MIS is more demanding and time-consuming than the training for open surgical techniques (Villegas et al. 2003, Madan 2003, Soper, Brunt & Kerbl 1994, Subramonian et al. 2004). The video-assisted technique means that the surgeons are observing their operation from a monitor's video picture that comes from a small camera inserted inside a patient's abdomen through one of the small (5-10mm) skin incisions. Also, other long and thin LC instruments are inserted through these skin incisions. While operating using video-assisted techniques, surgeons have limited information available compared to the open surgical technique where the incision is larger, the visual field is normal and they can touch and feel the tissues with their hands (Ericsson 2006, Villegas et al. 2003). In laparoscopy, the ends of the instruments actually move to the opposite direction compared to the surgeon's hands (Levy & Mobasheri 2014). The latest research has fortunately focused attention on safety and new aspects of the skills needed in MIS such as: perception, dexterity and ergonomics (Levy & Mobasheri 2014, Heemskerk et al. 2006). MIS techniques, such as laparoscopy, require special skills to be integrated; such skills include muscle function, strength, speed, precision, dexterity, balance, and spatial perception (Khan et al. 2004a, Moorthy et al. 2003a). To learn laparoscopy, strengthening the specific spatial and perceptual motor skills is essential. The MIS technique has proven prone to ergonomic problems when a large amount of equipment must be present in OT, limiting space and restricting movements (Berguer et al. 1999, Van Veelen et al. 2003), and therefore issues such as adjustments of the patient table, optimal placement of the monitor and clarity of the visual view should be taken into account.

If today's medicine and surgery were described with one word, it would be change. Studies on surgical skills learning emphasise considerable changes that need to be conducted in order to respond to requirements and challenges of modern day and to guarantee surgeons' increased competence and better patient safety in the future. An awakening factor was the introduction of MIS, which had an eminent effect on medical educators' beliefs that surgical education needed a radical change (Gallagher & O'Sullivan 2012, Scott 2006). The learning demands of the MIS technique revealed that both time and traditional educational methods for learning new video-assisted procedures were insufficient. Soon, MIS training courses organised by the equipment manufacturers began to emerge, and it was during that time when the surgical community first seemed to realise the increased importance of human factors and ergonomics in training and education (Gallagher & O'Sullivan 2012).

Due to these increased demands, it is therefore rather contradictory that surgical residents must learn to perform LC already in the beginning of their residency time in hospitals. The reason for this is the commonness of the gallstone disease. Surgical trainees actually learn most of the operating techniques and skills during their residency time while working in hospitals. It is notable from the point of view of education and learning that this obviously very important period includes no structured curriculum. While LC will stay complex, it is important to pay attention to the surgical resident's education for enhancing possibilities to learn it in an optimal way. Acquiring expertise in medicine has been one specific interest area of expertise research. Researchers are hoping to be able, through expert performance investigations, to demonstrate the possibilities to develop skill-sensitive education for bringing novices to high levels of performance efficiently through facilitating skill acquisition (Charness & Tuffiash 2008).

2.2 Expert surgeon today - skills and professional requirements

From a skills point of view, a person is skilled or an expert if she is able to reach an exceptionally high level of performance compared to other people (Ericsson & Lehmann 1996). From a psychological point of view, expertise in medicine is on a general level like expertise in any other domain. However, expertise in medicine involves also special features that make it different compared to other fields of expertise though it requires joint mastery of various knowledges and skills, such as motor, cognitive and interpersonal (Norman et al. 2006). The medical knowledge base is also different compared to many other fields and is extensive and dynamic at the same time. This forces medical experts to keep themselves up to date in relation to new medical innovations, treatment methods and drugs, etc. so that their knowledge and performance does not decline (Choudhry, Fletcher & Soumerai 2005). Recently it has been acknowledged that besides the technical skills, also the cognitive and interpersonal skills, such as teamwork, communication, leadership, and decision making, should be highlighted while discussing surgical expertise (Yule et al. 2006; 2008). The detailed knowledge of surgical decision making during operating is still rather scarce.

Nevertheless, it is known that expert performance is heavily dependent on domain-specific knowledge rather than advantages of general abilities that enable experts to anticipate upcoming actions superiorly (Charness & Tuffiash 2008). The domain-specific knowledge in medicine can be broadly divided into biomedical knowledge, which forms the basic theory of medicine, and practical knowledge about treatments and the way they should be done (Van De Wiel, Boshuizen & Schmidt 2000). These knowledge types can be intertwined in many ways; for example, biomedical knowledge is needed for interpreting appropriately complex treatment cases (Boshuizen 2003). Expert knowledge can be categorized into three components, which are 1) formal, explicit declarative knowledge; 2) practical, tacit and procedural knowledge; and 3) self-regulative knowledge, which is metacognitive by its nature (Eteläpelto & Light 1999) and is related to self-monitoring ability (Eva & Regehr 2011). Investigations have categorised medical knowledge slightly differently in I) causal knowledge, which medical students learn at school for understanding basic mechanisms of diseases, and two forms of knowledge that are gained through patient exposure, II) analytical clinical knowledge of signs and symptoms and III) experiential "constructive" knowledge, which accumulates as a storage of prior experience and cases (Norman et al. 2006). Expertise in medicine thus involves coordination among multiple kinds of knowledge that each may be used to greater or lesser degrees depending on the situation (Norman et al. 2006). In medical diagnostics, for example, the factors leading to variation in performance appear to be multiple, and therefore the general problem-solving principles do not seem to fit in medical diagnostics, since the success in one problem is not simply predicting the success in another problem (Norman et al. 2006). However, expertise in medicine demands high problem-solving and reasoning abilities that enable one to identify essential elements underlying cases (Charness & Tuffiash 2008), a kind of pattern recognition.

More research is still needed to better understand all the aspects of medical knowledge and diagnostics. Medical knowledge, however, is composed from thousands of patterns, rules and principles, which medical students need to learn for the aim of making diagnosis and conducting treatment (Boshuizen 2003). Boshuizen (2003) argues that the learning processes are critical factors in expertise development to be assured that this knowledge can be easily retrieved and applied. It seems that the experts' possess large memory "chunks" (based on the original chunking theory of Newell and Rosenbloom 1981) and their superior memory manifests as an index of rapid pattern recognition in relation to exposure to several patient cases (Norman et al. 2006). Various investigations have also shown that medical experts show greater diagnostic accuracy with forward reasoning compared to novices (Norman et al. 2006) and that the experts are selective in their verbal or written explanations even if their knowledge is encapsulated (Schmidt & Boshuizen 1993). This refers to the fact that experts possess a great deal of scientific knowledge in an encapsulated form which seems to release extra capacity for problem solving and other simultaneous tasks.

2.2.1 Surgical expert performance

Although quantitative studies comparing expert and novice surgeons' technical performances on simulators has been conducted for training validation, there are still a quite few studies relating to expertise and skill in surgery and virtually no studies to assess expert surgical performance (Norman et al. 2006). However, in the surgical domain the meaning of the psychomotor skills involved in expertise is important. The question of how to become an expert surgeon should be considered from all of these aforementioned multiple skills points of view. One special feature in the process of becoming a surgical expert is reaching the mastery of technical skill which from a learner's point of view is highly resource consuming. Even though one might believe so, surgical technical talent is not actually unique and it can be acquired with practice through training with required tasks. The whole process of how humans acquire complex motor skills is not fully understood; however, researchers in expert performance have documented that it takes often a minimum of ten years of practice to achieve the highest skill level in a particular sensomotor task (Ericsson et. al, 1993). Surgery has been in several occasions compared to learning to play violin. Violin playing and surgical expertise are similar in the sense that the general knowledge and skills are not enough, because the cognitive processes and domain-specific knowledge has a central meaning in both of these forms of expertise (Norman et al. 2006). The acquisition of complex motor skills, such as playing a string instrument, takes considerable time, and the optimization of joint coordination patterns is a prolonged learning process, with expert performance levels requiring approximately 10,000 hours or 10 years of intense practice (Ericsson et al. 1993, Konczak et al. 2009). Vickers et al. studied one very complex procedure, radical prostatectomy, and found out that it takes at least 1500 operations to achieve the best surgical performance level (Vickers et al. 2008).

Naturally, most of the specialized surgeons performing laparoscopies are not in the extreme level of skill; however, they are still perfectly capable of conducting these operations successfully with minimal risks. However, in surgery the number of times a surgeon has completed a certain procedure has been demonstrated to predict surgical outcome for complex and challenging procedures, with quite similar features as laparoscopy (Ericsson 2011). Therefore, the particular skills should be practiced also during surgical training as intensively as possible to guarantee the best possible result. The level of expertise development on perceptual and motor skills seem dependent on amount, but also on the quality and length of deliberate and repeated practice of movement patterns and rigorous information processing, which also require considerable time and full concentration while practicing (Ericsson 2004, Schmidt & Lee 1999). It is therefore tempting to argue that the more operations a surgeon has conducted, the better outcome it guarantees for the patient.

As a consequence, the deliberate training and practice experience results in changes of the task-relevant knowledge representations (Charness & Tuffiash 2008). It is then noteworthy that surgical performance and expertise on one task is not generalisable to other tasks, even to apparently similar surgical task, since the technical component needs a cognitive component in order for a surgical task to be a success (Norman et al. 2006). The transfer of learning across surgical tasks is therefore not straightforward. The most important aspect that correlates to surgical performance seems to be hand motions referring to visual-spatial abilities, what surgeons call a "steady hand" (Norman et al. 2006). However, one is not born to be an expert surgeon; this exceptionality is created through systematic education and training (Sadideen et al. 2013). Surgical expertise thus does not seem to need innate technical skill abilities, though these might aid the skills training, especially in the beginning. Among experts, the acquisition of technical skills might actually be dependent on experience alone. The efficient hand motion during surgery seems to be more closely related to cognitive skills, such as planning and preoperative visualization, than technical ones, such as motor control (Norman et al. 2006). This gives an opportunity to speculate on setting the right learning aims and gives an idea that reinforcement of surgical skills should be implemented in a way that stresses, for example, planning and preparation processes. Surgical trainees are developing towards expertise within the period of apprenticeship in hospitals through workplace learning according to a hospital's rules and possibilities. This learning phase should highlight the importance of learning cognitive skills such as decision making, creative problem-solving thinking and proper preoperative planning in combination with intensive technical skill training in order to produce highly skilled surgeons. We know that surgical excellence is needed also in other skills such as communication and leadership, not only concerning technical performance. However, surgical training today is too concentrated on mastering technical skills, with little regard for the importance of non-technical skill education (Aggarwal et al. 2004). Also, the hospital routines and rules are not necessarily supportive of changes within resident education that has remained unchanged for centuries. This argument is supported by the study of van de Wiel et al (2011), which indicates that learning opportunities for expertise development are not utilized optimally by the young physicians at clinics. Instead, learning is directed according to practical experience and patient care, and opportunities for enhancing competence are not deliberately sought (Van De Wiel et al. 2011). The next chapter discusses this highly topical issue on surgical expertise development at work.

2.2.2 Surgical expertise development through learning at work

Alan Bleakley (2011) presents some theoretical models in terms of socio-cultural learning theories that can be used to explain surgical learning at work. He claims that this phenomenon can be partially seen through the model of communities of practice by Lave and Wenger (1990), as participation in a highly context-situated and dependent work-based activity, such as surgery in OT. The importance of situated learning ideas for surgery is highly relevant, especially for helping to understand and integrate better ways for team- and inter-professional work (Fry 2011). However, this theory does not explain how expertise is constructed. Bleakley (2011) sees the actor-network theory by Latour (1996) and activity theory by Engeström (1987) as more appropriate for discussing this matter. The actor-network theory focuses on analysing people in complex work environments where actors and artefacts (actants) such as surgical instruments are in "dialogue", more appropriately in interaction with surgeons and in which surgeons' learning and expertise development is more like the development of adaptability and sensitivity to material (Bleakley 2011). The advantages of activity-theory in the role of explaining surgical learning is that Bleakley (2011) sees that the dynamic nature of learning activities, an activity system (like OT team), is focused on achieving the same goal but still conflicts can be produced, which in this context mean that OT teams are unstable and in states of transformation (Bleakley 2011). The evidence bears out this view, although it has been found that the teamwork in OT often involves conflicts of interests: individual vs. group; and it is also affected by the system-level problems and therefore further strengthening and developing OT practices, especially inter-professional teamwork through education, is needed (Collin, Paloniemi & Mecklin 2010). OT is then one complex within another complex hospital system and therefore in order to understand functions and problems occurring within OT and surgical teams, we would first need to understand the functions of a hospital and OT and then start looking at the behavior of an individual (Masiello 2012). The social theories of learning seem important in the surgical context although they focus on the OT as a learning environment and impact of the team in the learning process (Fry 2011).

Today's surgeons need to keep up their skills while learning new methods and techniques throughout their whole career. Making workplaces effective learning environments is a common interest in many fields today, not only in medicine. In medicine, learning at work, however, lacks deliberate efforts, and therefore meaningful opportunities should be created more intentionally, by better facilitating skills and knowledge development (Van De Wiel et al. 2011) Opportunities for planning and preparation before the learning experience should be arranged, as well as adequate feedback; all of these have an effect on reflection on experience, which further results in the quality of knowledge constructed through learning (Boshuizen 2003). However, materializing this goal of making workplaces effective learning environments needs a clear understanding on how learning within each workplace should be best realized (Billett 2000). Complex skills like laparoscopy, which require intensive practice, would benefit from good teachers who help to adopt the best training methods. Being a good teacher, however, involves an understanding of at least some key educational ideas and the capability to make rational educational choices (Fry 2011). It is possible to be a teacher also without this understanding, but there are many interacting variables that do not react in predictable ways. Without pedagogical knowledge, it will be difficult to analyse learning situations, what went wrong and how to make corrections (Fry 2011). The direct guidance or supervision by more experienced co-workers is also valuable for mediating what is taking place during workplace activities (Billett 2000).

The characteristics of workplaces, in this case the hospitals, influences the contents of workplace learning; for example, through different working cultures (Tynjälä 2008). Another important issue in workplace learning is that interaction between novices and experts is crucially important in it. This means in surgery that the residents interact with their supervisors and work under the guidance of more experienced surgeons, observing operations, taking part in the job tasks together – in other words, participating in the communities of practice (Lave & Wenger 1991). What Tynjälä (2008) highlights in her review on workplace learning also is that workplaces vary a lot in how they support learning, which has major effects on learning opportunities and execution. The potentiality for learning at work depends greatly on the extent the workplace is designed not only to produce service of care, but also how it supports learning and competency development; how it enables or constrains learning (Ellström et al. 2008). Ellström et al. (2008) present the two types of learning readiness, individual and organizational, as complementary factors. The particular organisations that foster so-called 'expansive learning environments' provide the best possibilities for both organisational and individual development as well as their integration (Fuller, Munro & Rainbird 2004). The organisation is responsible for creating a favourable learning climate and opportunities for skills development (Tynjälä 2008). The list of features expressing that organisations are fostering an expansive workplace learning approach to workforce development are presented in the following table 1.

TABLE 1 Features of organisations fostering an expansive workplace learning approach (merged from Fuller & Unvin 2004 & 2010)

Workforce development is used as a vehicle for aligning the goals of developing the individual and organisational capability
Organisational recognition of and support for workers as learners—newcomers (including trainees) given time to become full members of the community (gradual transition); Vision of workplace learning—career progression, chances to learn new skills/jobs, access to range of qualifications. Concrete 'workplace curriculum' highly developed (e.g. through documents, symbols, language, tools) and accessible to apprentices
Managers given time to support workforce development and facilitate workplace learning and individual development
Skills and knowledge widely distributed through workplace—multi-dimensional view of expertise; valuing expertise, high trust
Workers given discretion to make judgments and contribute to decision-making
Participation in different communities of practice inside and outside the workplace is encouraged—job/team boundaries can be crossed, cross-boundary communication encouraged and identity extended. Primary community of practice has shared participative memory: cultural inheritance of workforce development
Planned time off-the-job for reflection and deeper learning beyond immediate job requirements

In a context of this study, fostering surgical expertise development at a hospital would require a vision and development of both organisation and individuals through workplace learning. As an example, this would mean a curriculum developed for the surgical residents to progress towards laparoscopy expertise within the residency program. It would also mean hospital organisations and managers recognition of and support for surgeons as learners not just as a workforce, making commitments to chances and organising time for skills development and reflection both on- and off-the-job during the courses, high appreciation towards expert laparoscopists, but still fostering cross-boundary communication within surgical teams.

The findings concerning medical knowledge and expertise show that there is still a shortage of research on how the medical experience and learning at work should be structured to enhance skills and knowledge development optimally (Norman et al. 2006, Van De Wiel et al. 2011) Based on an empirical study of care work, Ellström et al. (2008) suggest that learning at work is not an automatic process and that workplaces should be designed to promote learning. Employees should be provided opportunities to acknowledge and utilize the learning situations at work, and the managers should be provided with adequate competences to organise and lead workplace learning (Ellström et al. 2008). Learning at work in fact has two types of processes, informal and non-formal; informal learning can be described as unplanned, everyday learning at work, which occurs spontaneously, and non-formal learning refers to all education taking place outside school but having an organised nature and learning objectives (Kyndt, Dochy & Nijs 2009, Gijbels et al. 2012). According to research on workplace learning, laparoscopy training conducted as a formal or non-formal (according to Kyndt et al. 2009) learning task or curriculum-based learning assignment within hospital alongside the resident's normal work, resembles significantly what Tynjälä calls on-the-job learning (Tynjälä 2008). She states that when conducting successfully this kind of learning activity, at least the following three issues should be acknowledged:

- Theory and practice cannot be separated from the development of vocational and professional expertise, which is a holistic process.
- When learners are solving problems in, for example, simulated contexts (during SBT), they need to be provided with conceptual and pedagogical tools to enable the integration of theoretical knowledge and practical experiences.
- Participating in real-life situations (such as OT work) is not solely sufficient for the development of high-level expertise, because it requires deep integration of theoretical, practical and self-regulative knowledge.

According to Tynjälä (2008), in professional expertise these three basic elements, theoretical-, practical-, and self-regulative knowledge are closely integrated. Education of medical professionals should also be structured and combine all three elements. Medical expertise can be described as a stage when a person has sufficiently understood the fundamental structure and functioning of the human body as well as the ways of malfunction and knowing what can and should be done when having been able to detect and understand the causes of problems. The mediating tools in the surgical education context in hospitals could be seen as enhancing metacognitive and reflective skills, such as creating possibilities for supervisor-learner discussions and self-assessments. For improving workplace learning, Kyndt et al. (2009) sees as the most crucial contribution to support the condition of "feedback and knowledge acquisition". This means creating situations for receiving feedback, such as enhancing teamwork practices, debriefings or peer feedback possibilities (Kyndt, Dochy & Nijs 2009).

The so-called self-directed learning orientation is a personal characteristic, which seems to predict work-related learning behavior; self-directed employees are able to "identify learning opportunities, show learning initiative, undertake learning activities, and persevere in overcoming barriers to learn"(Gijbels et al. 2012, 420). Self-directedness is not an entirely stable personal feature, although it can also be stimulated through coaching and direct instruction (Gijbels et al. 2012). The current research on continuing education of health professionals tends to promote research-based pedagogical self-assessment in professional development, to help physicians become better informed about self-assessment and more skilled monitors of their own practice (Sargeant 2008). Self-monitoring is one aspect of self-assessment, a metacognitive process that is necessary to manage in order to sustain adequate situational awareness, one important key to expert performance (Epstein, Siegel & Silberman 2008, Eva & Regehr 2007, Eva & Regehr 2011, Moulton & Epstein 2011). According to Billet (2000), not all workplace experiences are appropriate; wrong or even dangerous working methods might be learned. Achieving high expertise in surgery, similarly as in other critical safety professions, is, however, particularly important when there are human lives at stake. Therefore, the physician's capacity for concurrent moment-to-moment self-monitoring is an important aspect of professionalism that seems to form the basis of the early recognition of cognitive biases, technical errors and facilitating self-correction and self-questioning (Epstein, Siegel & Silberman 2008). The one difference between an expert and novice is that an expert makes fewer mistakes. The next chapter discusses how safety issues and errors are handled and managed today in surgical work.

2.3 Error management and safety promotion at surgical work in operating theatre

It has been estimated that as much as 40-45% of medical errors occur in the operating theatres (Flin et al. 2006, Tang et al. 2004). The risks involved in laparoscopies are also known in the surgical literature. The rate of complications remains higher compared to open surgeries. Laparoscopic cholecystectomy (LC) is a very commonly conducted procedure although it has serious risks. Bile duct injury is the most often reported severe, even fatal complication of LC, which often remains undetected during surgery (Soper, Brunt & Kerbl 1994, Tsalis et al. 2003). The incidence rate is actually much higher (0.4–0.7% vs. 0.2%) with the laparoscopic technique compared to the open technique (Ikonen et al. 2012, Gawande 2003).

Handling of errors is a delicate subject in surgery even today. The historical background has been preventing any discussions on that matter for decades, and only recently the medical society has realized that they do need to develop more effective methods for human error prevention. Medication errors on the other hand have been systematically researched since the 1960's, to categorize and define them as well as to develop reporting systems to detect the issues and paths leading to adverse medication incidents (Flynn & Barker 2000). Errors in medication seem to be somehow more acceptable in discussions than errors in surgical practice, even though in both situations it is a matter of human behaviour. Even today, the culture of medical practice socialises surgical professionals to strive for an error-free practice. Especially in surgical culture, the powerful emphasis on perfection, competitive climate, and fear for malpractice charges emerges (Luu, Leung & Moulton 2012, Luu et al. 2012, Flynn & Barker 2000). It is unreasonable and unrealistic,however, to expect medicine to function without errors, and worst of all this mindset has erroneously led the medical society to assume that an error cannot exist without negligence (Leape 1994). These general attitude problems towards medical errors has delayed and impeded the development of error research culture in medicine and has decelerated the adoption of the philosophy that learning from mistakes and errors is an important element in safety-critical work environments. The knowledge gained from errors, mistakes and close calls has not been utilised sufficiently or at all in the physician's workplaces. Instead, lessons learned are shared privately and defectively, and external debriefings are not conducted to share the valuable knowledge even though all physicians are aware that mistakes are inevitable (Leape 1994). The research from workplace learning suggests that it is possible to adopt a learning-oriented error culture in organisations; however, this requires a participation of both employees and management to jointly negotiate common values and goals regarding errors as well as common strategies for error prevention, error management and learning from errors (Bauer & Mulder 2013).

The research on medical errors belongs in the area of human factor research. The most known researcher in the human error field is James Reason, who has also investigated surgical errors and developed accident models that can be applied to the healthcare system as well. Reason (1990) defines an error as the failure of planned actions to achieve their desired goal. He presents the following ways in which a failure can occur: 1) the plan is adequate but the actions do not go as they were intended. These failures of execution are defined as *slips and lapses*. Slips mean the observable actions associated with attention failures and lapses instead are more internal and caused by the failures of memory. Slips and lapses occur during the largely automatic performance of some routine task and are typically associated with expert failures (Reason 1990; Reason 2005); 2) If, then, the actions goes as planned but the plan is inadequate, the failure is defined as a *mistake*.

In medical error research, the human factors view too often fails to take account of patient and procedural variables, and too often medical research fails to consider human factors. Therefore, more accurate and holistic methods combining these views should be developed to investigate medical errors (Carthey, de Leval & Reason 2001, Carthey et al. 2003). Human factors engineering has the potential of significantly reducing medical errors and increasing safety by offering expertise for analysing systems, human needs and their mismatches and helping to implement IT systems by involving personnel to redesign their work tasks and environment (Gawron et al. 2006).

Even though error research has been conducted in the surgical field and also within sociology since the 1970's, the research concerning errors' causality and the systems approach is still in a very early stage (Calland et al. 2002, Moray 1994). Reason (2005) categorized errors in OT as active versus latent failures, where active failures are unsafe acts (errors and violations) committed by, for example, surgeons or other individuals of the surgical team whose actions may cause immediate consequences. Latent failures are more hidden and caused by the result of decisions or actions taken by the hospital organisation at a system level. The recent, although still relatively mild changes in attitudes towards surgical errors are fortunately directing more attention from blaming individuals for their mistakes towards a culture and systems approach for investigating errors and their causes from a wider perspective (Cuschieri 2006, O'Connor, Papanikolaou & Keogh 2010, Aggarwal et al. 2004). System vulnerability influences adverse events' occurrence, while this vulnerability makes the system more prone to errors; therefore, it is the whole system, not just a single individual or team that must be considered (Greenberg et al. 2006). The surgical community has only recently begun to acknowledge that exploring the problems in OT enables the identification of both active (clearly visible errors made by the practitioners during surgery) as well as latent errors/failures (circumstances that predispose practitioners to errors) within the system as well as the background mechanisms of errors and failures, for example (Cuschieri 2006, Calland et al. 2002). This detection of weaknesses within the surgical processes could be then utilized in both error prevention and efficacy promotion of surgical working methods (Catchpole et al. 2008). The systems approach should be made multiprofessionally by focusing on the system design—human factors, data management, redesigning and training (Calland et al. 2002, Gawron et al. 2006). One interview study of error reporting in surgery revealed that systems factors contributed in 84% of adverse event cases (Gawande 2003).

In OT the so-called near misses are not uncommon either. By studying these so-called 'close call' events occurring during surgery, many unsolved or surprising errors might actually have a logical explanation. Therefore, in addition to error analysis, more research on surgical near misses is needed to gain a deeper understanding on the processes and mechanisms of errors and also to gain important information concerning chains of near misses that might escalate to errors. However, the concept of near-miss is difficult to define, and therefore the evaluation of occurrences might easily be subjective and incomparable (Carthey, de Leval & Reason 2001).

Today, the critical incident and near-miss/close call reporting systems have been developed in medicine for gathering a knowledge base and to explore and learn from these adverse events and close calls. However, there are significant problems with the use of these reporting systems for several reasons.

The fear of punishment when admitting making an error, lack of awareness on how to report or to analyse the reports and lack of constructive feedback derived from the reports creates reluctance to use these systems (Mahajan 2010). The discussions of errors and close calls, however, should be further enhanced to utilise information sharing for both individual and organisational learning purposes, and to promote both patient safety as well as general safety culture within a hospital organization (Reason 2000, Musson 2009). In addition, it has been realized that the research methods for studying operating room safety needs to include more qualitative approaches, since understanding operative safety is not entirely possible with traditional quantitative medical research approaches (Greenberg et al. 2006, Flin & Mitchell 2009).

Recently, the SBT has risen to the discussions among surgeons in Finland while they are trying to find solutions for diminishing complication rates and aiding learning (Ikonen et al. 2012, Kössi & Luostarinen 2009). Most residents began their 5-6 years period of their residency at a hospital without any manual skills in laparoscopy. However, the complexity of this procedure, skills deficiencies in the beginning of training, diminished residency time at hospitals (meaning also the reduced time for rehearsing skills with seniors) are all factors that might add risks of procedure complications. In addition, organisational changes leading to the new practice requirements produced by the fast development of the OT technique and equipment are constantly increasing the need for extra training. The next chapter presents the current knowledge on SBT training methods available for surgical residents today.

2.4 Learning surgical skills through simulator training

Today it is not appropriate or ethical to use human patients as training resources; also, human cadavers or live animals as practice tools raises ethical concerns (Ziv et al. 2003, Scalese et al. 2008, Satava 2011). As a result of the awareness of medical error occurrences and the need to improve patient safety, a major increase in the use of simulators for both teaching and assessment in medical education has occurred worldwide (Scalese et al. 2008). Simulations are one form of increasingly employed technology within medical education amongst others like digital assistants or teleconferences (Scalese et al. 2007). Both non-computer-based box trainers and computer-based virtual reality (VR) simulators have been invented to enable surgeons to practice for example LC safely without risking patients (Cosman et al. 2002, Gallagher et al. 2005, Schijven 2003, Gallagher & O'Sullivan 2012). Current knowledge of VR training has proven that these pieces of equipment are important and ethical tools providing unrestricted practice opportunities for skill-based training and performance measurement (Ahlberg 2007, Cosman et al. 2002, Ikonen et al. 2012, Gallagher & O'Sullivan 2012).

However, the clinical impact of virtual reality training is still unknown (Nagendran 2013), and there are also many open questions relating to suitable manners, amount and execution of SBT during the period of surgical residency (Gallagher & O'Sullivan 2012, Gallagher et al. 2005, Schijven et al. 2005, Kneebone 2003). Although a lot of validation studies have been conducted on surgical simulators, there is a lack of consensus on their guidelines, methods, setting and data interpretation, which concerns also the development and validation of training programs based on training needs (Schout et al. 2010). Other high-risk professions such as aviation, space programs, nuclear power and the military have already successfully incorporated simulation training into their education programs for training and testing skills (Scalese et al. 2008, Schout et al. 2010). Training needs and program requirements analysis in a training program design are methods used by designers of military simulation programs (Schout et al. 2010). Compared to other high-risk professions, surgery is still in a very early stage, and SBT is seeking its place in surgical education. There is unfortunately also a lack of research on trials comparing different forms of VR training, and there is also a high risk of bias in these trials. Researchers tend to measure only operating time and operative performance as outcomes, not the real clinical impact (Nagendran 2013). Although simulation has been acknowledged to improve skills, there is no guarantee that simulation is used in an optimal way in healthcare education programs due to the lack of guidelines or instructions. Simulation is not working automatically; instead it needs to be implemented with careful considerations. Development and validation of training should be multidisciplinary involving both users and designers; specialists as teachers, residents as learners, educationalists for teaching the teachers, and industrial designers and HCI experts for designing and providing teaching facilities that enable optimal learning transfer from virtual to real environments (Schout et al. 2010; Stone 2011). Therefore, in order to reform the traditional surgical education, and even changing the whole culture of educating surgeons to meet the skills requirements of the modern day, more research and development work is needed (Van Dongen et al. 2011, Van Dongen et al. 2008).

As mentioned earlier, the traditional resident education—apprentice training in OT—is not an adequate or patient-safe method in the acquisition of video-assisted complex motor skills, requiring repeated and intensive practice (Ericsson 2004, Ericsson 2006, Reznick 2006, Ziv et al. 2003). In addition, surgical residents' possibilities to educate themselves in day-to-day work with patients have been reduced. Therefore, deliberate practice opportunities need to be arranged systematically, but not in expensive OT time with real patients. In surgical SBT research, the skills transfer between VR training and operating room performance has been confirmed. This indicated that VR training could be utilised to reduce the time needed for mastering these skills instead of using expensive OT time for training the basics of MIS (Ahlberg 2007, Sturm et al. 2008, Haluck & Krummel 2000, Seymour et al. 2002, Schijven et al. 2005). Due to the safety demands and to the critical nature of laparoscopic surgery, VR simulators have been suggested both to rehearse procedures and to demonstrate competences prior to entering in OT (Gallagher et al. 2005, Gallagher &

O'Sullivan 2012). It is known from skills research that by focusing on the weaker aspects of performance, with deliberate practice and defined learning goals, improvements towards expertise is faster (Ericsson 2011). For example, trainees should be given adequate feedback about their errors and weaknesses, and they should be made aware of corrective actions as well. The meaning of instructor feedback during laparoscopy simulation training has been proven efficient in reducing time and repetitions needed to reach the predefined proficiency in complex operating tasks (Strandbygaard 2013). Simulators should offer individuals opportunities to set personal goals and receive adequate feedback relating to performance on demand. However, there is also the opposite finding that instructor-controlled learning is not as efficient as training alone from a study where a basic laparoscopy task was rehearsed (Snyder 2009). However, if the simulator practice lacks adequate instruction, an external one is required. Self-guided access to instruction has been demonstrated to be efficient in learning surgical technical skills through SBT, but only when the goal setting is related to the process, not the outcome (Brydges et al. 2009). The instruction and feedback features should be designed by exploiting HCI research, especially for paying attention to the needs of the end users (Stone 2011). The SBT technology should accommodate the individual learning needs and learning styles, not the opposite (Windsor et al. 2008).

Simulators are suggested to be used as training tools within formal residency curricula, which would integrate SBT into surgical residents' other daily work routines (Kneebone 2003, Kneebone et al. 2004, Sadideen & Kneebone 2012, Van Dongen et al. 2008). Practicing opportunities should be organised systematically and periodically within longer interval periods in order for the requirements for expertise development in complex skills like laparoscopy to be fulfilled (Ericsson 2004). The core function of hospitals is, however, patient care, and therefore the possibilities for organising SBT within working hours might be problematic. Amongst the public health sector employees, several prohibiting reasons for participation in formal learning activities have been identified. The younger generation, like residents in this study, could be discouraged by the 'required investments' such as distance, costs, time, or writing assignments relating to the learning activity; also, younger employees are more likely to have young children, who tend to demand time and prohibit extra working or training hours (Kyndt et al. 2011). More experienced employees, such as surgeon supervisors in this study, might have deficits in attitude towards learning (for example, learning to use the new simulators); they might feel that they are not good at learning new things, and they do not feel like going back to school (Kyndt et al. 2011). Simulator practice should, however, especially while realized in early residency, boost efficacy in skills learning and guarantee the maintenance of training motivation (Kozlowski et al. 2001). It would also be important to get the senior surgeons involved in training, although simulator practise should always contain tutoring, assessment and corrective feedback for enhancing learners' evaluative reflection processes (Kneebone 2003, Carter et al. 2005) (Epstein, Siegel &

Silberman 2008). There are a lot of demands placed on a surgeon; however, there seem to be a lot of demands placed on simulation technology and methods for using it as well. The near future will show what happens to traditional apprentice learning and how technological revolution affects it.

2.5 Summary of the theoretical background

In this chapter, an overview of the theoretical background, the issues known and further required for learning and practicing minimally invasive surgical procedures (MIS), especially laparoscopies, are presented. Table 2 reveals that the factors contributing to surgical expertise development and skills learning in the contexts of authentic surgeries as well as simulation-based training are manifold. Therefore, for example, laparoscopy training and practicing can't be observed or analysed as separate pieces of issues, but should rather be seen as a whole. Errors and expertise development issues should be reflected against new training options and surgical education requirement changes.

TABLE 2 Summary of what is known in the subject and what is required for further understanding the phenomenon

Key issues addressed in the previous literature	What is required to increase understanding further?
Laparoscopy is challenging a)Error management research and attitudinal change needed (errors are sensitive issue)	Awareness on **Errors;** Perspective from individual to system approach and solutions on how to learn from errors and how to prevent them.
b)Expertise development is time and resource consuming ➡ more training…	**Training challenges in OT**; Knowledge needed on skills development, complications, and failures.
	Facilitating **expertise development;** Knowledge needed on practicing, learning, supervising, feedback etc.
c) Simulators available for training ➡ educational solutions for effective implementation lacking	**Simulator training;** Options or complementary training methods and knowledge on skills development, human technology interaction.

Adopting the holistic view and all of these various elements involved in surgical practice justifies that the diversified approach and multi-professional collaboration should be utilised for exploring, designing and implementing new innovations and solutions into this field.

3 RESEARCH OBJECTIVES AND METHODS

Surgical resident training has been performed for centuries according to the master-apprentice model controlled by each hospital's own rules and policies, until the MIS –surgery revolutionized surgical OT practicing. Thus, it really seems to be a need for investigating how this technological development has affected the prospects for developing and maintaining surgical expertise. There is a clear need for research on surgical laparoscopy expertise, errors at surgical work and skills in new training possibilities, as well as the demands placed on a surgical trainee education. Challenged by this, this study focuses on these issues. This section introduces the research aims, the overarching research questions and research methods used in this thesis.

3.1 Research aims and research questions

This study investigates the phenomenon of operating skills learning and training in authentic OT and within the simulator environment. The *overall aim* is to understand what MIS expertise is in the case of laparoscopy, how operating skills learning and training occurs and how surgical expertise and skills involved are developing during the resident education at the hospital and what causal factors are involved. In addition, this research aims to create a model for educating laparoscopy. So this study also aims to contribute to the discussion and practices on developing the resident's workplace learning through the new education and training methods. The research task was to understand surgical laparoscopy expertise and skills development as well as the training and learning possibilities and challenges inside the hospital's two different practicing environments, authentic OT and simulation centre.

Within this issue, it is important to understand both skill development processes as well as various other factors such as contextual, cultural and even technological, which all influence the success and failure of learning and practicing.

The aim of this dissertation is to understand and interpret the challenges and influencing factors in the context of laparoscopy practice. Understanding this phenomenon, the characteristics, prospects and learning requirements relating to these skills is a main focus of this research. The first and second research questions address the development of expertise and skills in laparoscopic surgery. The third and fourth research questions aim at investigating surgical operating skills training and learning with simulators. The overarching research questions can be specified as follows:

RQ1: What are the main characteristics of surgical expertise?

RQ2: How do the challenges of expertise and skills development in laparoscopy lead to failures?

RQ3: What factors effect on surgical residents skills learning and training with simulators?

RQ4: What are the requirements for implementing surgical operating skills education utilising computer-based simulator training?

The following five articles form this thesis. 1 Review on expertise and skill in minimally invasive surgery, 2 Video-assisted surgery: suggestions for failure prevention in laparoscopic cholecystectomy, 3 Learning basic surgical skills through simulator training, 4 Learning surgical skills with simulator training: Residents' experiences and perceptions, and 5 Towards technology-supported surgical training.

Each of the five sub-studies seeks to contribute to the research task in order to gain a holistic view of the overall research topic. The research aims of the sub-studies in relation to overarching research questions are presented in Table 3.

TABLE 3 Research aims of the sub-studies in relation to overarching research questions.

Sub-studies	Aims	Relation to overarching research questions
1 (review)	To provide understanding of the multifaceted characteristics of laparoscopic skills and expertise development.	*RQ1 & RQ2*
2 (failure prevention)	To investigate surgical work and operating skills learning and challenges from the viewpoint of failures occurring in OT during LC's. To suggest an approach for investigating and evaluating surgical work and failures during LC.	*RQ2*
3 (basic skills simulator training)	To elaborate understanding of simulation-based laparoscopic skills training and learning with virtual reality simulators and to explore human technology interaction within the context. To address the possibilities for expertise development during simulation-based training.	*RQ3, RQ4 & RQ1*
4 (residents experiences and perceptions)	To investigate factors that have an effect on simulation-based laparoscopy training and learning. To suggest an educational approach for utilizing computer-based simulators at the hospital for laparoscopic operating skills training and learning.	*RQ3 & RQ4*
5 (metods approach)	To suggest triangulated research methods for investigating and understanding surgical operating behaviour and learning and training laparoscopy in OT.	*RQ1 & RQ2*

All of these sub-studies contribute to a more elaborated understanding of the requirements and the state of learning and practicing laparoscopy at the hospital. The research task requires comprehensive analysis and familiarisation of the cases and untangling factors that have an effect on surgical working and skills learning both in OT and within simulation-based training (SBT). In the first sub-study, the aim was descriptive in terms of gaining a picture of surgical expertise. In the second sub-study, the aim was to empirically investigate this phenomenon through observing surgical working and master-apprenticeship training in OT. The viewpoint was the failure investigation, and this study also applied the existing method of surgical failure classification to the context of LC. In the third sub-study, the aim to investigate operating skills learning and training has been taken to another context; the SBT environment and human-technology interaction has been added as an additional angle to this overall phenomenon's exploration. The same SBT context is the focus also in the fourth sub-study, which aimed at exploring the phenomenon from the viewpoint of the trainees, the surgical residents. In this fourth sub-study, the method for training LC skills within the systematic curriculum is elaborated and assessed.

In the fifth sub-study, the aim is different from all these other sub-studies. The fifth study is methods procedure, and it gives an overview of the methods applied in empirical data gathering, settings and analysis in the OT context. It further specifies the research methods contributed and used through this thesis in the context of surgical operating and producing knowledge from the behaviour as well as skills learning and training in the OT environment. The aim of this fifth sub-study is also to discuss and evaluate the suitability of the data collection methods for this purpose.

3.2 Method approaches

In this section, the method approaches used in this study are addressed. The main emphasis is on describing the method choices and how they have been supporting the knowledge construction throughout the study. First, the starting points of this study, the study process and researcher's position during this process are presented. Second, the data and data collection processes are introduced. Third, the method choices used in collecting data from surgeons' work in OT are presented in relation to the fifth sub-study. In addition, the method choices in exploring the simulator training are described. Finally, methods chosen and applied in this study are evaluated.

3.2.1 Researcher's position and research process

This dissertation originates from the multidisciplinary research project (INSKILLS), which provided a starting point for this surgical skills research in 2005. The project combined knowledge from education, medicine, psychology and cognitive science. Most of the sub-studies in this dissertation are concluded with the other members of the original INSKILLS; Saariluoma, Mecklin and Antikainen. The methodological choices made in this thesis are also generated as a result of the multidisciplinary project's purposes to gather information from surgical expertise and skills learning from two different contexts.

One important characteristic of this study is that the position of the researcher is actually both a researcher as well as education designer. During the years 2008-2012, the researcher worked part-time in the Central Finland Central Hospital's simulation training center (The Center of Medical Expertise, in Finnish Tietotaitopaja). This working period is seen as having a significant value in developing an understanding from the study's context. The dual position has provided an extended opportunity to get familiar with surgical working and learning environments and has also made possible the valuable co-operation with the physicians, especially with surgeons and gynecologists, in various training interventions relating to laparoscopy. This work position has also enhanced the opportunities to observe closely the residents' training possibilities and supervision at the hospital even more widely than this dissertation reveals. Both the theoretical and empirical research processes have therefore had an extra perspective from the reflection through the researcher's experiences and knowledge gained while participating in various education tasks in the simulation center. This dual position can be seen as an advantage that had helped the researcher to understand better, for example, surgical working culture and resident training and supervision traditions. However, it has also been challenging at times to keep the two roles, education designer and researcher, separated; for example, during the data analysis and reporting. Figure 1 presents the process of conducting this study and how the researcher's role is seen in this process.

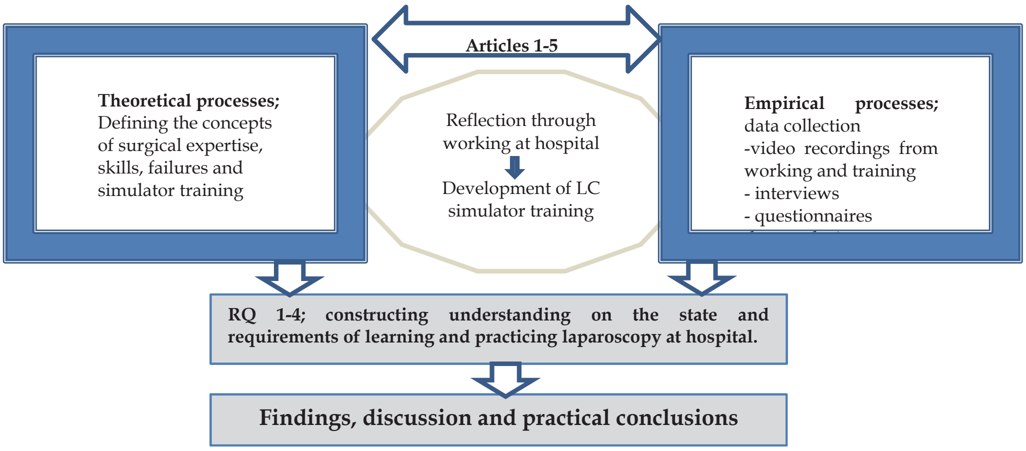

FIGURE 1 The process of conducting this study

The theoretical and empirical processes are inevitably affected by the reflection through the working period at the hospital. Simultaneously with research work and data collection, the researcher has been developing a laparoscopy training program that was also based on the gained research results. While the understanding of this phenomenon of surgical expertise development and skills learning has been constructed, it has affected also the training intervention design. The simulator training has also been explored and further developed based on research results. The data collection as well as methodological choices have been made for the most part during this intertwined research-development process. I will now present the data collection process performed within both contexts, first in OT and thereafter in the SBT environment.

3.2.2 Data and data collection

The data for this study are collected from the two different contexts in which the supervising surgeons and surgical residents performed LC's during the research. Relating to the first context, OT, the aim was to elaborate understanding of authentic surgical work and special features involved in practice. The common procedure LC was chosen to be the case to investigate.

The data collection relating to surgical work in OT as well as methods to investigate and evaluate performance and challenges related to it are the main contents of the methodological sub-study 5. The data were collected for both sub-studies 2 and 5 during which video data from 12 elective LC operations performed in a day surgical unit were captured simultaneously with four separate cameras. The length of the operations captured altogether was approximately 14 hours. In each operation, the surgeons were working in pairs, where one was the so-called main operator and the other one an assistant. Two of the surgeons were experts specialized in gastroenterology; one was an intermediate level resident and three were novices residents, all from the same aforementioned area of specialty. All of the operations were teaching sessions in which either an expert or the intermediate level surgeon was teaching the procedure to the novice. The combination of surgical team (surgeons and nurses) varied between the operations. The four video cameras were separately capturing the actions of the operator and assistant, one from the front, second from the hand motions above the operating table, third as a panoramic view of the whole surgical team (4-6 persons) and fourth directly from the laparoscopic camera as a view inside the patient. The total amount of video material collected was 56 hours. For the analysis, all four views were synchronized as simultaneous actions and edited as one display with four video windows.

After video data gathering, several interviews were performed. At first, all of the six surgeons were interviewed by two researchers. Interviews were conducted with a stimulated recall method, which means that video recordings of the operation were watched during the interview. The main responsible interviewee was a third author in the third sub-study. This interview material is not used directly in any of the sub-studies presented in this dissertation. However, the author of this thesis was acting as a co-interviewee and took notes, which obviously affected the researcher's knowledge construction and therefore also the findings and interpretations during the research process.

Secondly, four surgical experts were interviewed in 2007 in the session where the researcher showed them the video-recorded procedures. In these open-ended interviews, each of the four surgeons watched and commented on three to five operations from a total of twelve. This way, each video was commented on by more than one surgeon. In the interview session, the experts were instructed to comment on events on the videos in detail from the viewpoint of risks and performance difficulties, as well as to offer solutions for possible problems reported. The interviewer also asked questions concerning some vague situations, and the events on videos were further discussed with experts rather informally. Each interview lasted longer than the actual procedure, from one to two and half hours, though the discussions continued even further after the video ended. If there was any need for elaborating incidents, the video-recorded procedures were paused or re-wound by the researcher. The interviews were audio recorded and transcribed by the researcher. The total amount of the interview recordings was 19 hours and 25 minutes.

In the sub-studies 3 and 4, the focus was on simulator training in a simulation center. The study investigated the newly developed LC training program, and all the residents who participated in these studies worked in the hospital. Participation in the training program was voluntary. In the third sub-study, we studied the technical performance of 13 surgical residents' training with the Lap Mentor™ VR simulator. Seven were at the beginning of their residency, while the others were either in the middle stage or further on. Participants included eight men and five women, all between 26 and 38 years of age. The investigated simulation task was a camera navigation training period of nine sessions, and the studied items were a set of six primary performance parameters (total time, total path length of the camera, average speed of the camera movement, number of correct hits, total number of camera shots, and accuracy rate), which the simulator automatically logs. In addition to these parameters, we administered questionnaires before and after training to collect additional information. The questionnaire items selected for this investigation concerned prior experience in laparoscopy and computer gaming. Finally, the first and last resident-training sessions, supervised by a specialist surgeon, were also video-recorded.

In the fourth sub-study, the participants were 14 surgical residents who had completed the first part of training sessions with the simulator. Participants included seven men and seven women with an average age of 31 years, all between 26 and 38 years of age. Six of the participants had no laparoscopic operating experience, although some of them had made preparative actions and wound closures and had acted as assistants under senior supervision; eight participants had performed at least part of a laparoscopic operation under senior supervision. This first simulator training period lasted approximately 1 to 4 months and contained five basic skills exercises. In the study, we administered questionnaires both before and after the basic skills exercises training period. The data were collected with questions relating to participants' background, training experience and exercises. The questionnaires presented residents with Likert-type scales, ranging from 1 to 5, to rate their current assessments or perceptions. The questionnaires included questions about learning expectations (before the course) and learning outcomes (after the course). After each training period, the residents also filled in self-assessment forms designed to help them to reflect on their performances and learning. I will now present these data collection methods used in both of these study contexts' in more detail.

3.2.3 Methods used in the analysis of data

The data analysis was multi-method. Literature review was used in the sub-study 1. Thus, understanding context was essential for gaining a holistic perspective (Patton 2002a). In the sub-study 2, data were collected through interviews and naturalistic observations taking place in the field, in the OT surroundings. The data were analysed using qualitative methods in triangulation. Methodological triangulation was thus used here to acquire information on surgical errors using multiple methods to increase the credibility of the results (Patton 2002a). In the sub-studies 3 and 4, the data derived from SBT environment were analysed with mixed methods combining qualitative analysis of simulator training observations and quantitative analysis concerning both simulator user data and surgical resident's training experiences and perceptions. The majority of the research methods used in the sub-study 2 are described in detail in the sub-study 5. Objectives of the fifth sub-study were to describe an exploratory way of gathering data by combining video material with interviews and creating a valid study design for investigating surgical working and learning processes. This sub-study highlighted the importance of detail familiarisation within the research subject and context environment prior to developmental interventions by arguing that it is necessary to construct detailed knowledge about the surgeon's everyday working and learning situations and the issues that affect surgical performance. This method of deciding seemed justified, because using qualitative methods increases the depth of understanding of situations like OT surroundings and produces a lot of detailed information (Patton 2002a). This sub-study clarified how the occurrences in OT can be recorded and enriched the way it enables a detailed and credible understanding of surgical processes from both educational and professional angles. It suggests that the surgical OT work can be investigated comprehensively by combining video data, participant interviews and expert interviews. This kind of method and data triangulation was used for enhancing the credibility (Patton 2002a).

The fifth sub-study suggests various possibilities to utilise the research data for analysing teamwork, learning, supervision and surgical failures. Actually, the significance of paying attention to surgical risks and failures was emphasised as the data analysis proceeded. It became evident that this knowledge gained could further be used in exploring the ways to eliminate risks and reduce incorrect working methods, as well as aiding learning. The qualitative analysis of LC and failures from the video data was conducted first with the general task and behaviour analysis, in which the detailed notes of events, activities, and communications were written in the Excel sheets together with the timeline. Secondly, the interviews with four expert gastroenterology surgeons were conducted. The experts were instructed to observe and evaluate operations aloud, and to concentrate on highlighting the risks and errors occurring in the procedures. The task and behaviour analysis was completed with the information gained from the expert interviews. Thirdly, the failure identification was made based on this combined information gained from video analysis and interviews. The identification method applied was based on the failure source models presented by Catchpole et al. (2006) and Catchpole (2009). The failure analysis is described in the article reporting the sub-study 2.

In the third sub-study, a quantitative analysis of the residents' performances through a nine-session training period of laparoscopic camera skill training was conducted. Skill development was at first investigated in terms of changes in performance when contrasting the beginning of the training period (i.e., calculated as an average of the first two sessions) to the end (an average of the last three sessions). Thereafter, multiple two-way analyses of variance were used to compare the overall average performance of residents with and without experience in two skill-relevant types: laparoscopy and gaming experience. Secondly, a qualitative evaluation of simulator training was conducted, in which resident's performance models were registered from the video-recorded data and simulator performance feedback received after training was analysed.

In the fourth sub-study, the quantitative analysis of responses to the questionnaires administered for the resident's both before and after simulator training period was conducted. It aimed to untangle the learners' experiences and perceptions on training and exercises and whether their views had changed during the training period experience. Training period selected for analysis was training period of basic skills instrument manipulation. Together, 14 surgical residents working in the hospital, including seven men and seven women with an average age of 31 years, were studied. The training period lasted approximately 1 to 4 months and contained five different exercises that needed to be repeated until the performance became fluent. Analysis of the responses was investigated in terms of distribution of prior experience. The participants were divided in two groups: Group 1 (n = 6) was characterized by minor experience and that they had experienced only on preparative actions, wound closures and senior assistance concerning LC operations. Group 2 (n=8) was characterized by experience also in some laparoscopic operating, such as performing at least part of a laparoscopic operation with senior assistance and under supervision. The experiences and perceptions during simulator training were investigated within four themes: 1. Training and learning expectations and perceptions; 2. Learning confidence and self-assessed progress; 3. User experience; and 4. Advantages gained from training. A nonparametric Wilcoxon signed-rank test was used to assess improvements or change within the groups; a Mann-Whitney U-test was used to evaluate differences between the two groups.

3.2.4 Methodological considerations

The multi-method approach applied in this study is based on an aim to understand the phenomenon of surgical practicing and possibilities to gather knowledge as widely as possible from it. It is also based on practical needs for inventing solutions to enhance and promote surgical education in the target area of laparoscopy during hospital residency. The motives for methodological choices are thus extremely practically driven. One can say that in this study the purpose was to select information-rich cases for studying them to acquire in-depth understanding, which Patton refers to as *purposeful sampling* (Patton 2002b). There is not only one truth of what are the best research designs to be used; the answer is highly case-dependent and affected by the study purpose, the users' interests (in this case hospital education needs), the resources available and the interests/abilities/biases of the researchers (Patton 2002b).

The research methods in this thesis are mixed, including both qualitative and quantitative methods. According to Johnson and Onwuegbuzie (2004), mixed methods research means that the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study. It can be seen as a complementing element for the traditional qualitative and quantitative research genres in which key features are methodological pluralism or eclecticism (Johnson & Onwuegbuzie 2004). There have traditionally been two separated schools, quantitative and qualitative, and the strong supporters of each of these have argued that these two should not be mixed. However, this "paradigm war" has mostly been the result from concentrating solely on the differences between these two methodological traditions (Johnson & Onwuegbuzie 2004). Instead, the supporters of mixed methods argue strongly for the advantages of mixing, which is seen to cover points in the middle area between these two traditions, to draw their benefits and diminish their weaknesses for conducting more effective and reliable research (Johnson & Onwuegbuzie 2004). Because qualitative and quantitative methods involve differing strengths and weaknesses, they make divergent alternative, although not reciprocally exclusive research strategies (Patton 2002a). Johnson and Onwuegbuzie (2004) further argue that the goal of understanding as such leads to the examination of different phenomena that are holistic and detailed involving both qualitative and quantitative data. Therefore, I argue that by using multiple analysis methods, one might be able to open completely new possibilities to combine pieces of information drawn from the data.

Johnson and Onwuegbuzie (2004) also suggest that especially in educational phenomena research, pluralism should be promoted, and researchers should be making choices based on what research approaches are most helpful and how they should be mixed or combined. Within the context of this thesis, the research field is multidisciplinary and mixed methods is therefore a reasonable choice that can be seen also as a way for promoting collaboration between differing fields of science. The mixed methodology approach allowed various manners to be used, such as testing cause-and-effect relationships, investigating change as well as in-depth case-based exploration (Patton 2002a). Using the mixed methods in this study is also seen as a great opportunity to test and learn to use all of these different research methods.

4 FINDINGS OF THE SUB-STUDIES

This section provides a summary of five research articles included in this dissertation. These sub-studies are introduced with respect to their role in and contribution to the thesis. The following five sub-studies are; 1 Review on expertise and skill in minimally invasive surgery, 2 Video-assisted surgery: suggestions for failure prevention in laparoscopic cholecystectomy, 3 Learning basic surgical skills through simulator training, 4 Learning surgical skills with simulator training: Residents' experiences and perceptions and 5 Towards technology-supported surgical training.

4.1 Sub-study 1: Expertise and skill in minimally invasive surgery

The objective of this sub-study is to selectively review the theoretical basis of minimally invasive surgical (MIS) skills learning and surgical expertise. The motivation of this study was to gather knowledge on the specific demands placed on a skilled MIS surgeon and to present an overview of studies from the areas that are seen as important for surgical training today and in the future. In addition, the motivation was to find the relevant research problems for empirical investigations.

The aim of this first sub-study was to build knowledge and offer background information for further sub-studies of this thesis. The theoretical issues presented in this review covered the following three main areas; 1) Expertise and skill development in medicine and surgery, 2) Special characteristics related to conducting MIS procedures and 3) Available learning and training options for MIS surgeons.

The findings of this literature using scientific data show that the general characteristics of medical expertise prove to be applicable in surgical expertise as well, such as issues related to thinking, memory and social skills (Ericsson & Lehmann 1996, Patel et al. 2001, Yule 2006). Reasoning strategies are the core component in many medical tasks, as well as in surgery, including clinical problem-solving, decision-making and text interpretation (Patel et al. 2001;2005). During surgical performance, continuous problem-solving and decision-making are needed, especially if the case is complex or urgent. Outside OT expertise in surgery means also, for example, the ability to avoid unnecessary surgery, to co-operate with the healthcare community and to weigh economic issues concerning the high costs of surgical treatment.

Second, the review results show that surgical skills have become more complicated and difficult during recent decades and this seems to be continuing. MIS has had major effects on surgical practices since the late 1980s, which has also affected the research concerning the skills involved, such as perception, spatial ability, hand-eye coordination, dexterity and ergonomics (Khan, Widdowson & Tiernan 2004, Moorthy et al. 2003, Gallagher et al. 2001, Moorthy et al. 2005). The research on skills required during MIS operations has today been increasingly directed from a sole focus on motor aspects towards a broader focus on psychomotor and cognitive aspects. However, there are still very few studies concerning, for example, ergonomic problems and ergonomy education, even though the physical, perceptive and cognitive problems are encountered not only by surgeons, but the entire medical team during MIS operations (Van Veelen et al. 2003).

The third main issue that this review points out is the lack of proper learning and training possibilities available for surgeons. It seems that the traditional “see one – do one – teach one” method does not guarantee adequate skills in MIS (Roberts, Bell & Duffy 2006, Rogers, Elstein & Bordage 2001) and changes in continuing training and alternative educational options are needed, especially for shortening the early skills learning period (Park et al. 2007). Although the potential of new technologies has been investigated for surgical skills training for several decades, clearly the implementation has not been optimal. It was already in 1991 when Satava created the first virtual reality simulator for abdominal surgery, which was based on the technological research concerning flight simulators and 3-D graphics (Satava 1993). Today, various surgical simulators with various techniques and features are continuously developed. These equipment’s are argued to have a central meaning for surgical education, providing patient safety training possibilities (Schijven et al. 2005, Schijven 2003). However, the results from this review indicate that even though there is a general agreement that simulators should be used in teaching complex skills like MIS, the reality is that these possibilities have been utilised in a very limited fashion. In order for a computer-based simulator training to succeed, for example, at hospitals, it is vital not only to have the necessary equipment, but also to organise training conditions with proper techniques by including curriculums with working culture and organisational processes. For example, the structure of training and assessment measures and processes requires careful consideration of many aspects (Kneebone 2003, Van Dongen et al. 2008, Sidhu et al. 2006). This review leaves open questions concerning how laparoscopic skills are learned today at Finnish hospitals and how these aforementioned technological training possibilities, simulators, are utilised.

This first sub-study concludes that the nature of surgical expertise and skills, maturation and development should be seen holistically in a larger context. The issues considered in the research involving surgical MIS skills should acknowledge the various specific elements such as motor, ergonomic and spatial demands in addition to general requirements placed on an expert surgeon, such as skilled problem solving, familiarising oneself with complex situations and the non-technical and managerial skills required in teamwork. In investigating surgical skills, MIS needs extra attention. The educational possibilities also need to be explored, especially concerning the latest available technological training innovations. It is obvious that the utilisation of simulators adds extra challenges in education implementation and therefore these should be conducted with careful planning and preparation.

Restrictions of this literature review are that it is selective, not systematic, and the amount of literature found needed to be minimised. Therefore the selection of the literature is subjective and is based on the researcher's interpretations on its relevance. In sum, this paper's role and contribution for the study is a versatile literature review, which apart from giving answers also opens up new questions and suggests issues to focus on in empirical investigations.

The arguments presented in the review encouraged the researcher to make plans for further empirical investigations, which should concentrate both on the obvious challenges related to achieving expertise in MIS and the manifestation of learning and training. These issues should be investigated in the natural environment where the learning and training occurs, in OT. Afterwards it would be possible to try to find the best patient safety manners for learning and training operating skills.

As presented in chapter 2, skilled surgical performance is much more than just technical talent. There are various mental processes involved and surgeons need alertness concerning risks end errors involved in these procedures and also skill in monitoring their own skills and progress (Moulton & Epstein 2011). Way (2003) argues that deficiencies in knowledge and technique are never the only cause for surgical errors, though a surgeon's capacity to maintain concentration and a serious attitude towards work and a correct identification of the current evolving situation— what is called situational awareness—is also important. In the next chapter, the safety aspects of surgical learning and operating as well as possibilities for failure prevention are considered from both technical and non-technical viewpoints.

4.2 Video-assisted surgery: suggestions for failure prevention in laparoscopic cholecystectomy

The objective of this sub-study was to untangle the challenges that surgeons and residents encounter in OT while engaging in practicing and learning video-assisted procedures at work. The study was motivated by a need to investigate the sensitive issue of failures, mainly for two reasons: 1) investigating human factors in relation to surgical failures needs more research as well as methodological development (e.g., Carthey, De Leval & Reason 2001), 2) error research culture in surgery needs to be enhanced in order to adopt the thinking model that learning from mistakes and errors is an important element in safety-critical work environments such as OT. The literature on medical errors strongly emphasises the need for untangling the sources of medical failures and the error mechanisms involved. The need for systematic research concerning not only errors but also so-called near misses is acquired (Carthey, De Leval & Reason 2001). The investigation of accidents in medicine is often superficial unless malpractice is suspected, and therefore failures not leading to errors are rarely examined (Leape 1994).

This sub-study had three aims. The first aim was to find out the types and sources of threats and errors in a typical LC procedure. This was accomplished by gathering at first procedure data through video recordings from a hospital day surgical unit. The total of twelve LC procedures was performed by both residents and their supervisors. Thereafter the recordings were explored by the author with the help of four expert surgeons who commented on the video recorded performances in an interview situation. Then video and interview data was merged and the identification of failure types and sources were derived from this data set by applying and modifying the failure source models presented earlier by Catchpole et al. (2006) and Catchpole (2009). The second aim of this sub-study was to illustrate the nature of the LC procedure. This was done through a procedural list, which described the phases of the video recorded procedures in relation to the current literature instructions on conducting the LC operation in a correct manner. The third aim was to go beyond failure identification to find the phases of LC that are associated with multiple failures and contain the most risky sequences. This was done by combining the procedural list of LC phases with the identified failures, which then enabled the researchers to see the whole profile of LC and to assess whether some phases in it were more risky or challenging and associated with multiple failures. This failure profile of LC also enables the evaluation of differences between the amount and extremity of failures within and between the operating phases. It, for example, showed in sequence how the occurrences in OT lead to failures, for example how the resident surgeon's unsupervised and un-optimal placement of trocars in the beginning of an operation seemed to have a major influence on the decreased fluency of the procedure, and later on the incorrectly inserted trocars combined with insufficient lighting used caused ergonomic problems to both operating and assisting surgeons. The causalities and accumulation of failures were seen throughout operations and typical novice and expert failures could be pointed out.

The analysis applying the failure source model produced 20 various failures, which were categorised either as errors or threats. Failures were related either to cultural or organisational issues, the patient, work tasks or working environment. The associated errors were categorised either in relation to technical or non-technical aspects or in relation to judgment. The results showed that the LC procedures were multidimensional and challenging for the surgeons to perform. These analysed operations resembled rather well the way that these procedures are presented and instructed in the current literature. However, some dissimilarities were found; compared to the literature instructions the meaning of working principles as well as the role of ergonomics were highlighted in our data analysis, unlike in general literature instructions. The deficiencies concerning preparation and planning were found in the instructions; these were also seen in the OT work as lack of orderliness. The analysis of the failure profile produced a detailed description of failures within each operating phase. The wide diversity of safety aspects, a total of 205, was identified, indicating at least some risk of errors and complications. However, these results are not divergent as compared to the findings of other studies derived from other procedures, for example of orthopedic or heart surgeries. From the LC profile it could be seen that the failures were accumulating into two main operating phases and three sub-phases, indicating that these were clearly more challenging than others.

The results of this study reinforce the conclusions that there are several failures occurring during surgical procedures and too many of these remain without the needed attention. In some cases the denial of failures or risks, such as effects of stress or fatigue, may originate from the surgical working culture of covering up one’s own mistakes (Aggarwal et al. 2004). This sub-study argues that errors and failures are not unambiguous; rather they are products of chains of events and a combination of several background factors. Therefore, the assessment of individual surgeons’ skills and competences are not unambiguous either. The issues relating to organisation and culture, the patient, the task and the environment as well as individual abilities, should be acknowledged as significant issues impacting success or failure of surgery. While analysing errors in these kinds of safety-critical contexts, the wider system approach needs to be highlighted, instead of blaming individuals or pointing out narrow details (Reason 2000). Reasons for the surgical failures leading to safety threats and complications can be found from various factors, such as emerged increased learning challenges, including technical demands, lack of theoretical knowledge, or non-technical skill shortages such as communication problems among the surgical team. Other reasons for failures could include problems with alertness or ergonomic circumstances, with OT technology or distraction during the procedure. In MIS procedures it has been reputed that the significance of the functional and competent team works together with the competences of the operating and the assisting surgeons, which is emphasised in the accomplishment of high quality treatment results. (Gawande 2003, Van Veelen et al. 2003).

In relation to expertise development and skills learning, this empirical investigation of failures contributes eminently in developing an understanding of how both senior and novice surgeons behave and work in OT. To be able to understand why errors occur, we need to understand the behavior of expert and novice surgeons when confronting difficulties. This sub-study enhances the knowledge related to both failures as well as learning within the study context. It argues that workplace learning in surgery will benefit from the failure source knowledge and system-related view while aiming to enhance patient safety in OT, and that we could benefit from further acknowledging the issues that affect working, teaching, learning and team work behavior in OT, such as distractions, external time pressures, and enabling adequate supervision and training possibilities. The information on the tide of operations, such as the LC profile, enables to see the causalities and accumulation of failures. Therefore this type of demonstration could be used in resident education to acquire knowledge on procedures and protocols. It may also be applied as the framework of a checklist or assessment tool when teaching or evaluating performance. During operating the sustainability and monitoring of skills need more attention. It has been acknowledged that medicine is far from aviation where, for example, periodical testing of performance is ongoing. This kind of system–based thinking should be enhanced within surgical work culture as well (see also, e.g., Leape 1994). Learning from mistakes in practice should be possible; however, preventing these errors from occurring should be the primary aim because it is ethically unacceptable to ignore the risks of failures in patient care. With simulators, error situations could also be practiced both ethically and safely. Learning basic skills in the hectic OT environment is hardly beneficial; it is risky and costly as well. The pros and cons of other opportunities for practicing and learning should therefore be investigated and promoted systematically. When designing training curriculums, a detailed profile of an operation offers information on phases and aspects that need special attention during training. One weakness of this investigation might have been that the view of the residents has not been taken into account in this analysis. For example, in validation studies, novices' experiences are considered equally important as those of experts (e.g., Schout et al. 2010). It was, however, a conscious choice made by the research team to concentrate on expert analysis, though in future studies residents' perceptions on failures will also be important to hear.

This sub-study concludes that based on the results obtained from the LC profile, before entering OT, surgical residents should have comprehensive knowledge and skills at least in patient anatomy and physiology, requisite knowledge on equipment types and their handling, mastering of ergonomics and other work environmental issues as well as various non-technical skills. The next sub-study investigates how skills learning occur with simulators and what contextual issues need to be taken into account while implementing systematic surgical skills training for pursuing optimal learning outcomes.

4.3 Sub-study 3: Learning basic surgical skills through simulator training

The objectives of this sub-study were to explain how laparoscopic skills training with the simulator affects to surgical residents' performance and what kind of feedback the user can retrieve from the simulator. The study motivations included a need to untangle laparoscopic performance development as well as factors that affect, enhance or complicate learning. The sub-study had two central aims. Its first aim was to explore the performance levels and skills development of differently experienced learners. Performance levels were explored concerning prior operating and computer game playing experiences and whether these have an effect on surgical residents' skills development during simulator practise. The second aim of the sub-study was to explore the feedback received from the simulator by learners after completing basic skills training tasks and whether this information could be utilised for skills development or performance evaluation.

First, a quantitative analysis of selected performances was conducted. The performances were analysed through a nine-session training period of laparoscopic camera skill training. Skill development was first investigated in terms of changes in performance. Thereafter the overall average performance of residents with and without experience was compared in two skill-relevant types. Second, a qualitative evaluation was performed in which both residents' performance models from the video-recorded data was analysed and simulator performance feedback received after training was examined.

Results from the skill development analysis showed that both prior operating and gaming experience contributed to significantly higher training scores. Prior gaming experience appears to benefit simulator training at the beginning, but it may also have negative effects on surgical skills training, because game playing highlights specifically the significance of speed. Retrospective parameter changes offered inconsistent results while the developmental profiles of the participants' training results were very heterogeneous: some residents made considerable improvements, whereas the performance of other residents declined.

Results from qualitative feedback analysis indicated that the simulator parameters are objective measures, but they lack qualitative information, which a surgeon in training needs in order to beneficially self-evaluate one's skills development and to make corrections. Video analysis of performances showed that the lack of appropriate feedback was problematic during training. Therefore, a suggestion was made to add new parameters to the simulator measurement in order to receive more information on performance quality. The information provided by the simulator seemed to be difficult to utilise for performance improvement, and therefore it was suggested that especially novice residents should not use simulators without the possibility to share their learning experiences with a competent specialist supervisor. Based on these qualitative evaluation findings, the conclusions and suggestions for constructing effective feedback systems and new educational methods for the future were suggested.

This sub-study argues that the possibility to evaluate performance and skills development during training is an important feature that promotes successful learning. Therefore, it might be beneficial to transform the parameter information into inspiring and motivating recommendations or visual presentations on how to carry out the tasks to improve performance. Also the possibility to compare learners' performances to optimal (expert) performance levels might offer target goals to strive for (Gauger et al. 2010). The results of this article are consistent with the earlier arguments that feedback on skill level and skill development as well as cues for further improvement should be available during training (Ericsson 2004, Ericsson 1993, Kneebone 2003). Restrictions of this sub-study are first the small sample size, which emphasises the preliminary character of our findings and conclusions. The second restriction is that the training intensity and the duration of practice period varied greatly among the residents.

This sub-study concludes that simulators may ease and support surgical skills learning and assessment at least at some level, but they are not adequate tools for replacing the supervision offered by senior surgeons. Neither can simulator practice be directly compared to authentic work in OT. Billet (2000) argues that workplaces should be made more effective learning environments through engaging new workers (residents) more in authentic workplace activities though the direct guidance or supervision of more experienced co-workers. This increased interaction and supervision could also be increased through more formal learning activities like simulator training. Senior surgeons should then be intensively involved in resident training as role models and teachers to mediate learning. However, this form of participation with senior co-workers is not a guarantee for the development of expertise (Tynjälä 2008).

During simulator training, residents should receive content-based feedback and guidance from their supervisors on how to practise better and develop skills needed for expertise development (Ericsson 2008, Patel et al. 2005) and in particular the quality of practice should be highlighted (Kozlowski et al. 2001, Ericsson 2008, Ericsson 2006, Dennen & Burner 2008). The user-interaction issues related to surgical simulators should also be acknowledged. The next chapter presents a sub-study presenting one way of implementing the simulator training program as a formal learning activity for surgical residents and it also evaluates the success of this program through participants' experiences and perceptions.

4.4 Sub-study 4: Learning surgical skills with simulator training: residents' experiences and perceptions

The objectives of this sub-study were to represent the training program developed for surgical residents to learn laparoscopy and to explore factors that influence participants' skill learning during the program. Study motives were fairly similar to those in the previous sub-study, to untangle factors affecting laparoscopic skill learning and training. In this sub-study this was conducted both by exploring previous literature as well as learners' experiences and perceptions on simulator training and exercises they conducted during the laparoscopic curriculum.

The first aim was to review factors that could influence, either by restraining or promoting, surgical skills learning. The second aim was to address the developed curriculum, and the third aim was to explore participating residents' training experiences and perceptions relating to this new education method and whether their views had changed during the training period.

At first a literature review on influential factors of complex surgical skills learning within systematic long-term computer-based simulator training was conducted. Second, the training curriculum, which was launched at a hospital in March 2008, was introduced. It included three short, approximately one-hour sessions with a specialist instructor, and two longer independent self-training periods. During the self-training periods, specialist surgeons gave lectures on laparoscopy and presented other material such as videos for the learners. This training program implementation was reflected in relation to the previously presented literature. Thirdly, a quantitative analysis of residents' questionnaire answers before and after the selected training period was conducted. The first part of the training included an instructive session with a specialist supervisor and the basic skills instrument manipulation exercises. The residents' learning experiences and perceptions were investigated within four themes: 1. Training and learning expectations and perceptions; 2. Learning confidence and self-assessed progress; 3. User experience; and 4. Advantages gained from training. The answers were investigated in terms of distribution of prior experience.

The results gained from the selective review of previous literature showed that many issues should be taken into account while implementing and designing training programs utilising simulators. Learning objectives and the nature of skills to be practiced, learners' individual characteristics, supervision and resources as well as environmental factors should be taken into account. The educational choices made during the implementation process of this training program were discussed in relation to the previous literature. It showed that learning was supported through supervision, feedback, equipment instruction and guided self-assessments. Also motivational aspects were taken into account by allowing freedom of choices made, for example, those related to one's own training intensity.

Results from the questionnaire analysis showed that learners had realistic expectations in the beginning of the training. As the training proceeded, the residents' views had changed as follows: 1. Decreased willingness to practice simulator exercises outside working hours; 2. Perceived difficulties of finding time for training; 3. Slightly decreased motivation. However, simulator training was seen as necessary as well as beneficial. Residents acquired confidence, and according to self-assessed progress the significant positive skills development in LC related skills emerged. However, the rush to accomplish the training session occurred within both groups. Self-assessment of skills was experienced as difficult, which supports the results gained from sub-study 3, arguing that simulator feedback is hard to exploit. Surprisingly, the satisfaction concerning the simulator and exercises was rather high and the simulator was considered relatively easy to use, even though 1/3 of participants reported plenty or quite a lot of functionality problems in each acquired task. The advantages gained from training, according to the residents, were the various skills learned and transferred to OT. The residents found simulator training beneficial, especially concerning the confidence gained in instrument manipulation. Also the readiness to operate and assist in OT was considered to have increased.

The negative side was that the residents' expectations towards their individual opportunities to practice with the simulator were overestimated in the beginning of training. Therefore, the allocation of training and working schedules at the hospital must be managed more systematically in the future.

This sub-study supports earlier studies, which have proven that practicing laparoscopic skills with a simulator makes assisting and operating in the OT easier, that simulator training creates a feeling of confidence, especially among novice trainees, but also for more experienced ones, and that skill transfer to an authentic situation does occur (Windsor et al. 2008, Huang et al. 2005). However, this sub-study only demonstrates that skills were learned according to the trainees' own reported experiences, which are not alone a valid measure for skills learning. The limitation of the sub-study thus was that the objective measure of residents' performances was lacking. The basic skills development during this training program was, however, already proven in sub-study 3. Both learner experiences and perceptions are still important factors in explaining motivation, training activity and success of the training program implementation.

The conclusions of this sub-study are that implementing laparoscopy training programs at hospitals requires careful planning and preparations and that it should be based on the theoretical guidelines of skills learning, also considering a wide variety of other factors that influence the success of implementation, such as organisational issues. Similarly, van Dongen (2011) argued that at least allocating and coordinating residents' time resources and aiming at goal-oriented practicing should be recognised. In addition, the ability to assess one's own performance—critical in surgery—is important throughout one's working career and should be supported. Restrictions of this study are that it is a relatively small sampling and that not all participants followed the training till the end of the entire program. The instructor assessments were also excluded from this study, which could have added more value. The contribution of this sub-study is that it suggests computer-based simulator training as a valuable resource and sees it as a great possibility for enhancing laparoscopic skills learning during surgical residency in the hospital. It shows that this type of training intervention is effective and the trainees feel positive about it. They also experience the training as being important for their skill development. It also reveals both pros and cons in executing the systematic training within the hospital.

The fifth sub-study is different from the other sub-studies. It is formed on the construction of method investigation.

4.5 Sub-study 5: Towards technology-supported surgical training

The objectives of this sub-study were to explain the special requirements for selecting a method approach for investigating surgical work and surgeons' performance during laparoscopy operating in OT. The study motivations included a need to find suitable research methods to gather all the information needed to understand the phenomenon of surgical working and expertise development as well as issues that influence surgical performance in OT. The first aim of this sub-study was to specify a proper model for comprehensive surgical performance familiarisation, which is able to reveal factors that affect surgical performance in OT. The second aim was to evaluate the suitability, advances and shortages of this method for gathering data for this purpose. This sub-study describes an exploratory way of gathering data by combining video material with interviews.

The role and contribution of this sub-study for this thesis is that it offers common ground for the OT related sub-studies and a starting point for developmental suggestions to be discussed and alternatives explored. The limitations of this sub-study are that it was written several years ago in the beginning of this study process. It reveals in part the inexperience of the author as both scientific researcher and writer. However, it is also an important tool to describe the initial phases of this whole study and how it all started. The contribution of this sub-study is further elaborated in chapter 3.

5 DISCUSSION

During this period of major changes in surgical education, what is needed is the knowledge on efficient skills and professional development as well as educational and working life demands relating to surgery. Laparoscopy involves extra challenges and is therefore a suitable subject to study this phenomenon. Cognitive science as a discipline enables the combination of various research methods and background theories to be used in untangling the problems within this context. This thesis aims to benefit from the advantages of applying a multidisciplinary viewpoint. It offers viewpoints to contemplate and discusses operating skills learning and training within both OT and SBT environments. In this section, the key findings are summarised and briefly discussed. First the answers to overarching research questions are provided. Secondly, the reflections on strengths, limitations and trustworthiness of this study are considered. Thereafter further studies and implications are reflected in the light of this thesis's results.

5.1 Surgical expertise and skills development in relation to failures in OT

This chapter elaborates surgical skills training and learning in the context where LC is practiced by the surgical residents and their supervisors in the hospital. For untangling the preconditions of patient safety enhancement in surgical skills learning and training, two issues are needed. First we need knowledge on expertise development—how to gain expertise in laparoscopy. Secondly, an understanding on what really occurs during surgery in OT is required. The knowledge gained from challenging situations at work, such as failures during operations, offers valuable information on factors increasing risks and restricting learning. This knowledge gives further insights on how to deal with errors, learn from them and prevent them. The following sub-chapters address the findings of the first two overarching research questions.

5.1.1 The main characteristics of surgical expertise

The first overarching research question is focused on the characteristics of surgical expertise. Surgical expertise research is in this thesis constructed by combining the general knowledge from expertise, knowledge from medical and surgical expertise, and surgical skill demands. The research concerning surgical expertise in particular is still rather scarce, even though there is some high quality expertise research done by, for example, K. Anders Ericsson (Ericsson 2004;2011). In order to reveal surgeons' skill demands, the knowledge of surgeons' expertise is used in this study not only to understand the supreme performers in this profession but also issues related to how to become an expert in this field. In general the characteristics of an expert surgeon are constructed from various technical and non-technical abilities. When one sees a surgeon in action, it is likely easier to point out the technical aspects from that performance as opposed to non-technical skills.

As referred to in chapter 2.2.1, the one special feature, highlighted in the surgical skill and expertise literature, is reaching the mastery of technical skills, such as complex motor skills. However, the acquisition of technical abilities might actually be dependent on the amount of experience alone and therefore mastery is reached only through deliberate and repeated practice over time. What is also known is that a technical component needs a cognitive component to go with it (Norman et al. 2006) and that the efficiency of hand movements during surgery is more closely related to cognitive skills, such as planning and preoperative visualisation, than technical ones, such as motor control (Norman et al. 2006). Surgical training is reputed to concentrate too much on mastering technical skills, with little regard for the importance of non-technical skills education (Aggarwal et al. 2004). It therefore makes sense to examine how the technical and non-technical components of laparoscopy expertise manifest in this study. This examination offers further understanding of these two complementary skill categories within the context of surgical expertise development. It seems, based on the results of this study, that learning and reinforcing surgical skills should concentrate even more on non-technical, cognitive oriented skills development alongside technical training. Excellence is needed in surgery in decision-making, metacognitive skills, feedback utilisation, communication, leadership and other team working skills, and learning should be supported by a high motivation for one's own professional development.

The main characteristics of surgical expertise in the area of laparoscopy are gathered as a very concrete list in Table 4. This list presents the components of surgical expertise in a way that could also be applied as a basis for listing the needed resources and preconditions for educating professionals with the highest knowledge and skills in laparoscopy.

TABLE 4 The main characteristics of a surgical expert laparoscopist

T / N	Laparoscopy expertise characteristics T=technical N=non-technical	Described in the Article /Introduction
T	accurate and controlled movements, exceptionally fine motor skills, balance and dexterity	1
T	highly developed spatial abilities and motor coordination skills related to depth perception	1
T	highly developed haptic abilities to identify objects and their consistency through laparoscopic instruments	1
T & N	ability to apply awareness in ergonomy for gaining optimal posture as well as safe and minimally straining working environment during operating	1+2
N	highly developed reasoning and memory strategies (clinical problem-solving, decision-making and understanding texts), large memory "chunks" and exceptional pattern recognition, e.g., wide variety of formulated "illness scripts" based on the knowledge from surgical cases	1+3
N+T	capability to effortlessly perform simultaneous motor and cognitive tasks	intro +2
N	automatic or effortful situation awareness during operating	intro
N	regular use of metacognitive skills; moment-to-moment self-monitoring for facilitating self-correction and self-questioning	intro + 4
N	excellent teamwork skills, such as abilities to lead the surgical team and enhance communication and cooperation between team members	1+2
N	proficient coordination of multiple kinds of specialised knowledge concerning laparoscopic surgery	1+intro.
N	enthusiastic attitude and high motivation towards constant development of own professionalism and skills, capability to utilise feedback, to learn from mistakes and from other members of work community	2+3+intro

This study has shown that there are in fact a large amount of non-technical skills that actually control the technical part of the performance. The findings suggest that besides the technical skills, an even greater amount of attention needs to be focused on the non-technical skills of laparoscopy surgeons. The factors that create a surgeon's "steady hand" are part of a much more complicated process than one can see at first sight. The characteristics of an expert surgeon are in this study mostly covered in the first sub-study and partially also in sub-study 3, and complementary notions are also presented in literature in chapter 2.2. What this study also highlights is the fact that the development towards expertise in surgery is initially dependent on both knowledge and skills learned in medical schools, but the majority of the professionalism in laparoscopy is developed through working at a hospital and participating in everyday work tasks, such as treating patients in OT. Metacognitive and reflective skills used during working mediate this learning process. This expertise development in surgical work is not a simple process without any risks. There is always patients' well-being at stake, which also creates particular stress factors. The next chapter answers in more detail the question of the challenges that surgeons encounter during their OT work.

5.1.2 The challenges of expertise and skills development in laparoscopy leading to failures

The second overarching research question is focused on how the challenges of expertise and skills development in laparoscopy may lead to failures. Research on failures was conducted in sub-study 2, where the knowledge gained through video observations and expert interviews was merged as an understanding on special demands and risks involved in this particular procedure. The expertise challenges were formulated based on the main characteristics of surgical expert laparoscopist and listed in the previous section 5.1.1.

The research on surgical failures has previously concentrated too much on immediate life-threatening errors, since only recently have researchers also acknowledged the importance of paying attention to the threats and minor failures as well (e.g., Carthey, De Leval & Reason 2001). In my knowledge the LC procedure has previously not been explored in such a specification as in this study, and the failure identification and procedural list combination is therefore seen as a new approach to study operations. I see that in order to understand all the risks involved and to develop a more rigorous understanding of the many phases and sub-phases of operations and their specific contents and requirements for surgical teams, this detailed analysis is needed. The in-depth understanding is required, especially for such an operation, which is very common and part of all surgeons' basic training, such as LC. The knowledge here is applied for not only understanding how to avoid failures and enhance patient safety, but also to build an understanding of how we should educate surgical residents in the future, and whether OT is an optimal place for conducting resident training. The main challenges and failures that emerged in sub-study 2 are listed here in Table 5 to show the correspondence between challenges and failures.

This study emphasises that the challenges of skill and expertise development lead quite straightforwardly as failures seen during LC. This list of challenges is summed up based on the findings from sub-studies 1, 2 and 3. Even though the non-technical skills form a substantial part of expertise in surgery, the amount of technical failures were especially high in those operation parts where various errors were actually cumulated. These parts of the operation seemed to be particularly challenging for the surgeons, both from the technical and non-technical perspective.

TABLE 5 Expertise- and skill-related challenges in relation to failures presented in sub-study 2 during LC

The challenges of expertise in laparoscopy	**Failures during LC**
Technical skill challenges - deliberate practice opportunities needed for developing; • fine motor skills, controlled movements, balance and dexterity • haptic abilities for object manipulation and identification • spatial abilities, depth perception, coordination patterns	Technical skill failures; • novice surgeons' technical skill difficulties and psychomotor related errors such as uncontrolled instrument movements and instrument handling problems
Ergonomic challenges - to apply awareness on ergonomy; • for gaining optimal posture • to ensure safe and minimally straining and stressful working environment during operating	Ergonomic failures, e.g.; • nonoptimal working positions caused by disadvantageously placed tools and equipment • general lack of focus on working conditions
Challenges relating to acquired specialised knowledge	Working against guidelines, lack of knowledge on how to use the tools
Cognitive challenges; • to develop adequate reasoning and memory strategies (for problem-solving, decision-making, etc.) • to adopt formulated "illness scripts" based on the knowledge form surgical cases	Cognitive failures relating to memory or reasoning; • decision related errors • awareness failures
Team working challenges; • e.g., leadership, communication and cooperation skills	Errors in team working, e.g.; • coordination, communication & resource management failures
Metacognitive challenges; • constant development of own professionalism and skills • motivation and capability to learn from mistakes and from others	Errors related to situational awareness and own skills assessment; • unnecessary risk taking • wrong judgments and nonoptimal choices • overconfident actions and proceeding with known risk

It seems that the increased requirements of technical skills might be burdening the thinking and memory processes, which leads to difficulties in concentration on motor tasks. This creates a loop of challenges for novice surgeons who have verifiable problems of simultaneously performing the multiple tasks required by laparoscopy (Zheng et al. 2010). Nevertheless, this study argues that the solution for preventing this accumulation could be found from training options. The best place for rehearsing surgical technical skills is definitely not in OT, not least for the patient safety reasons, but also for the trainee's requirements, indicating that this basic, so-called deliberate skill training should be provided elsewhere to optimally enhance skills development and reflection. The answer to the next overarching research question deals with these alternative training and learning possibilities.

5.2 Operating skills training and learning with simulators

The first two overarching research questions in chapter 5.1 concern defining surgical expertise and safety issues in OT. This chapter continues to elaborate laparoscopy expertise development by answering another two overarching research questions on laparoscopic skills learning and training. The context, however, is simulator training in a simulation learning center. The focus is more on skills learning in the workplace and its preconditions to resident education in the hospital, but not particularly in OT. For untangling the issues of promoting and restricting learning we need to add another element to this former contemplation relating surgical expertise: How to support and facilitate the skills and knowledge development process during surgical residency? The knowledge and answers for these latter two overarching research questions are now specifically explored, deriving from sub-studies 3 and 4 and partially from the literature review, sub-study 1. All these sub-studies discuss surgical training programs utilising simulators for laparoscopy practice. The points presented here are also to be read as suggestions for developing surgical resident education.

5.2.1 The factors affecting surgical residents skills learning and training with simulators

This third overarching research question concentrates on factors affecting surgical residents' skills learning and simulation-based training. This environment is, however, not understood here as a completely isolated place outside the normal surgical workplace. Instead the fact that the location of the simulation center is at the hospital where surgeons work makes it a part of their working environment. Therefore, the simulator training is also affected by some of the conditions that normally affect learning at work. It is also affected by the common individual and social factors that enhance or restrain learning.

The working culture of the workplace, in this case the hospital, has an important meaning for workplace learning (e.g., Tynjälä 2008) as well as the supervision and guidance given by expert physicians within a master-apprentice arrangement (e.g., Billet 2000), which is also noticed in sub-study 3. A hospital's organisational support for workplace learning probably has the greatest influence on the success of surgical simulator training. In chapter 2.2.2, I presented a list of features of organisations fostering an expansive workplace learning approach in Table 1 (merged from Fuller and Unvin 2004 & 2010). Similar issues could be found from sub-studies 3 and 4. I collected these results and formulated them according to Fuller & Unvin's concepts. This list is now refined and complemented with the empirical findings as well as background literature. These factors were found to influence complex surgical skills learning within systematic long-term computer-based simulator training. The summary of all these various factors is presented in Table 6.

TABLE 6 The factors that affect surgical residents' skills learning and training with simulators

Factors affecting surgical residents' skills learning and training with simulators	Described in the Sub-study
1. Workplace culture-related factors affecting skills learning and training	
• Hospital's recognition of, and support for employees as learners;	4
• Enough planned time off-the-job for SBT to maintain training intensity & enough possibilities to learn new skills	
• Hospital's recognition of, and support for employees as teachers/mentors;	3 & 4
• Enough planned time off-the-job for instructors of SBT for facilitating learning and developing their own competences.	
2. Individual factors affecting training and learning	
• Prior skills, experiences and knowledge from similar tasks; prior laparoscopic experience and prior gaming experience	3
• Motivation and willingness to learn, attitudinal factors	4
• Learning skills – metaskills (self-assessment), individual learning style, goals, speed and habits	4
• Managing one's working hours and capability to maintain training intensity	4
• Learning requirements; the gap between the task demands and existing skills	4
3. Training and learning facilities – planning, organizing and supporting	
Pedagogical design;	3 & 4
• Structure of training (curriculum, etc.)	
• Learning objectives	
• Learning support during training; instructions, feedback, supervision, enhanced reflection	
4. Special characteristics /constraints of the simulation environment;	
• Simulator's usability and efficacy: realism, interactivity, received feedback, potential to enhance skill transfer	3 & 4

The hospital's support for residents as learners and supervisor surgeons as learning facilitators seem crucial for the success of training. However, this support as well as the administrative role in resident education in the LC training curriculum is still searching for its final form. A hospital's learning culture and workplace demands directly influence simulator training implementation and in a very concrete way the organisation of skills training at the simulation center. The evidence of this was seen in sub-study 4, e.g., in problems with time allocation and some surgeons' lack of commitment to the training.

It is also possible that the training commitment and learning outcomes are different due to individual factors. For example, the evidence for prior experience effect was clearly demonstrated in sub-study 3. These other individual factors were elaborated in the fourth sub-study's literature. Further issues are presented in Table 6, such as training and learning facilities; planning, organising and supporting emerged from both sub-studies 3 and 4. These issues also highlight the meaning of education design and arranging the training facilities optimally for enhancing learning. It is stated that in all simulation training facilities there should be a team of personnel to design simulation training together, which involves an expert in medical education, a human factor expert and healthcare personnel (Masiello 2012).

Since efficient skills learning requires feedback and continuous evaluation and monitoring of skills and performance (Eva & Regehr 2011, Eva & Regehr 2007, Ericsson 2008), in sub-study 3 we addressed the requirements of learning support, e.g., content-oriented qualitative feedback, by examining simulator feedback and possibilities for monitoring skills development during training. In sub-study 4, the senior surgeons' supervision was highlighted within the training program; instructors were encouraged to give verbal and formal feedback to residents during instruction/training sessions.

The simulator training environment challenges learning and training in many ways. One special characteristic is naturally the equipment and user interaction with it. Human factors research can be utilised to better guarantee the skills transfer from simulated to authentic by focusing on end users' abilities and limitations during design (Stone 2011). Surgical simulators are still rather complex and with many limitations and therefore these issues need to be known, and they need to be addressed with extensive user support, at least until their development proceeds. Investigation and proposed decisions for usability problems are also needed to inform the manufacturers on how to enhance skills learning and training further (Silvennoinen & Kuparinen 2009). After explaining these various issues that affect surgical residents' skills learning and training success in a hospital's simulation center, I will conclude this study by formulating the requirements for implementing simulator training for surgical residents. The following section could also be read as my suggestions for developing surgical resident education.

5.2.2 The requirements for implementing surgical operating skills education utilising simulation-based training

The fourth overarching research question is related to preconditions for conducting surgical resident education involving simulator training. As mentioned in chapter 2.2, Tynjälä (2008) presents three conditions for learning and expertise development at work that need to be fulfilled in order for surgical laparoscopy education to succeed optimally. In the present study the preconditions for implementing resident education utilising simulator training were considered first in terms of expertise development and what is needed to develop surgical expertise. Secondly, this study aimed at identifying the characteristics of learning and training this particular skill, laparoscopy, and the specific demands related to LC. Thirdly, this study highlighted the meaning of safety and failure prevention in the second sub-study. Based on this sub-study it can be stated that the meaning of patient safety and meticulousness towards safe working conditions should be highlighted more during surgical resident education. Increased professionalism gained through individual and teamwork skills training as well as good ergonomics increases the wellbeing of employees and safety of operations (Bharathan 2013). The increased system safety is likely to bring work efficiency and even though measured evidence for cost-effectiveness is scarce it is highly possible (Sturm et al. 2008; Bharathan 2013). This study presented one model for laparoscopy training implementation and also evaluated the successes and shortages of this model. In the implementation it is also crucial to evaluate outputs critically and make required changes for improvement. As was stated in the introduction of this study, the surgical traditions are confronted with needs for radical changes, since technological development is rapid in this field. Surgical techniques as well as simulators are developing fast and new equipment and models appear non-stop. Therefore the SBT implementers also need to keep up with this speed of development, to be ready for the upcoming changes. However, there are also basic elements and principles of adult learning that stay the same and that should be applied when designing medical education. Also there are plenty of other core elements and requirements that will be needed in the future for education implementation within surgical and also other medical training contexts. I have collected these practical requirements as a list presented in Table 7.

TABLE 7 Practical requirements for successful implementation of surgical residents' simulator training program in the hospital

Practical requirements for surgical residents' simulator training implementation		
A	**Full commitments from organisation and workers for putting training into practice**	
	• Are the hospital leaders and surgical department management committed? • Are all trainers and trainees committed? • Are other parties committed; secretaries, education designers, IT support, etc.?	Written commitments (e.g., e-mails) are important and could be one way to guarantee that all parties are seriously involved. It is also a way to guarantee equal training possibilities for all residents and make sure they are aware of their obligations as well.
B	**Plan and placement of training**	
	• Is the training a mandatory part of surgical resident education? Is it in the right training phase? Is it documented with certificates, log book etc.? • Is the training idea/ model reasonable and functional in our situation?	Decisions of how to place the training and how to document accomplishments – some recommendations are presented in the literature. Choosing the suitable model and possibly editing it for one's own purposes needs careful consideration.
C	**Resources and tools for training and learning**	
	• Is there enough space and time allocated for instruction, training and facilitating? • Are simulators appropriate and up to date? • Are there enough professional personnel involved? • Are there other types of expertise available besides surgical? (Pedagogically qualified instructors, professionals for education design and pedagogically meaningful realisation user support/ IT management for maintenance.	Simulators are only one part of the resources and alone they are useless. Pedagogical and HCI know-how is seen here as essential for gaining optimal learning and skill transfer outcomes. Simulators also require various actions; they are, after all, computers with similar features and challenges.
D	**Pioneers with innovative attitude and determination for project realisation**	
	• Are we capable and willing to succeed? • Are we evaluating circumstances, our results and accomplishments? • Are we capable of making changes?	Implementation of new ideas requires pioneers in the beginning who start the project by giving their full attention to it and are willing to compromise even with their own working schedules. Proper planning and ensuring points A, B and C increases the likelihood of success and diminishes the pioneer's workload. Pioneer commitment is important in arranging A-C and thus guaranteeing continuity of the education. In the future, the critical evaluation of actions and accomplishments is important. Success requires often major changes from both surgical workplace learning and training culture as well as hospital organisation.

I argue that taking into account these issues when organising surgical resident training in the hospital means that the training will most likely succeed. This list can also be used when evaluating current education and seeking possibilities for enhancing and emphasising current learning and training. It is also a practical tool to use when detecting the reasons for possibly emerged problems and finding solutions for them.

As I stated in chapter 2.1, surgical residents must learn LC in a very early stage of their residency and therefore the most suitable time for conducting laparoscopy training with simulators is the hospital stage of residency. However, I see no reasonable obstacle why training could not start even earlier, before the hospital stage, already in medical school. What is seen as equally important in other studies as well is that the laparoscopy training is structured as a part of a curriculum, and it is not separated from learning through work in OT (Kneebone 2003, Aggarwal et al. 2006). The primary aim of these curricula should be to enhance patient safety in OT by accelerating skills and expertise development of young surgeons.

5.3 Methods reflections to strengths, limitations and trustworthiness of this study

Today the tendencies in methods approaches seem to have shifted towards creativity, thus various diverse approaches and the importance of using mixed methods have been emphasised (Patton 2002b). Patton (2002b) sees that the researchers are challenged by the task of appropriately mixing methods, which is seen as a valuable skill and also the recognition of various ways of using methods is more appreciated. Because judging the quality of a study requires criteria, the strengths and limitations of the methods and analytical processes used in this study are addressed in the following table, Table 8, in terms of Patton's traditional scientific research criteria for judging the quality and credibility of qualitative inquiry (Patton 2002a). These criteria are; Objectivity of inquirer, Validity of the data, Systematic rigor (accuracy) of fieldwork procedures, Triangulation (consistency of findings across methods and data sources), Reliability of coding and pattern analysis, Correspondence of findings to reality, Generalisability (external validity), Strengths of evidence and Contributions to theory. These quality assessments in turn form the basis for judging credibility (Patton 2002b). The strengths and limitations are also considered here with relation to the quantitative credibility of this study. These same criteria are used to evaluate the trustworthiness of this study further in the following chapters.

TABLE 8 The strengths and limitations of the methods and analytical processes used in this study and how these complete each other. (Assessed according to Patton 2002a)

Methods and analytical processes	Strengths	Limitations	Completion of the other method choices
Literature review (sub-study 1)	Helps focus the study subject and gives attention to the aspects of a phenomenon that need special attention or lack research.	Might bias the researcher's thinking and reduce openness to all emerging issues in the field.	Offers theoretical knowledge for reflecting the past and present and methodologies applied in the context.
Qualitative simulator performance analysis; video-recorded sessions from participants using the simulator (sub-study 3)	Data was collected in naturalistic simulation training settings to describe this complex task in question. It provided individual level case information on how the training occurs.	Results might not be generalisable to other trainees. Data collection and analysis were time consuming. The results might be biased by the researcher's personal interpretation of situations, since no participant interviews were conducted.	All these two qualitative and two quantitative methods are completing each other as they all are used to gather knowledge on the same phenomenon in order to understand in detail the aspects of simulator performance and factors affecting to it.
Qualitative simulator feedback analysis; the information received by the trainee during practice (sub-study 3)	Individual case information collected from a naturalistic setting, which can be used to demonstrate the process of trainees receiving feedback.	Results might be biased by the researcher's own understanding on the meaning of feedback.	
The quantitative analyses of residents' simulator performance averages. Changes in performance by contrasting the beginning and end of the training period (sub-study 3)	Study is relatively easy to replicate. Analysis was not time consuming due to use of SPSS software. The results are relatively independent of the researcher.	Results were based on a relatively small sample size, the size defined by the voluntary resident participants and the rather small amount of exercise repetitions the participants chose to perform, each within varying time periods.	
The quantitative analysis of residents' questionnaire answers before and after the simulator training period. (sub-study 4)	Easy to replicate the study and the results independent of the researcher. Personal viewpoint of the participants untangled.	Relatively small sample size diminishes generalisability. Naturalistic setting and not standardized groups, very heterogeneous.	

(continues)

(TABLE 8 continues)

Video observations; participants working in OT (sub-study 2)	In depth and detailed rich description of cases and complex phenomena of surgical performance as it occurs in natural contexts. Analysis of causes and effects of occurrences was possible.	Extremely time consuming research method, results might be influenced by the researcher's personal biases and attributes. Difficult to do any quantitative readings. Difficult environment to study due to ethical and privacy concerns.	Interviews provided personal viewpoint of the experts, which completes the video analysis results and diminishes the bias of the researcher's interpretation of events.
Expert interviews based on the safety issues evaluation. (sub-study 2)	Provides understanding and description of specialists' personal experiences of the phenomena.	Rather time consuming data collection method and analysis time consuming as well. Data analysis limited to experts view. The novice participants' experiences and reflections on their performances would have added a second angle to the results and would have completed the results gained from sub-study 4.	

The literature review in this study helped to focus the study subject and build a theoretical framework from surgical expertise and skills learning as well as familiarise the researcher with the whole focus area of this research. Qualitative investigation on residents' performance models during task execution, together with quantitative performance analysis, offered essential information on the nature of the simulator performance, which was further investigated from another angle by analysing the participants' own views and expectations related to this training model. Therefore the simulator training was able to be discussed in both sub-studies 3 and 4 from the point of view of enhancing and restraining factors concerning the surgical residents' skills practice and learning.

Furthermore, the methods investigating OT work, the video observations, and expert interviews were supported with the understanding gained during sub-study 5. The failure investigation based on both interviews of the experts and the results of the researcher's video analysis adds to the trustworthiness of the results.

While further addressing the trustworthiness of this study according to Patton's (2002a) criteria, the objectivity of an inquirer is highly dependent on the assumptions and biases that I as a researcher might have and how well I have been able to describe the data, methods, procedures and the whole research process. All of these issues I have tried to explicate as much as possible to the reader of this study and I have also tried to critically review the choices made during this research process. A researcher is an instrument of inquiry who affects the way findings are received (Patton 2002a). Patton (2002a) states that the researcher should report all issues that might have affected data collection, analysis and interpretation of the findings. During this study I have openly expressed, for example, the funding for this work and my personal connections and experiences as well as competences that I've had or have not had.

To assess the generalisability of this study I first need to argue that it was not the primary goal of this study; instead, the intention was to elaborate the phenomenon through case analysis. There is no common or generalisable definition of validity in educational or social research; however, the validity has sometimes been defined as the truth of a research study (Winter 2000). The truthfulness of the study should be considered through the whole research process, not only by exploring small pieces (Winter 2000). In evaluating the trustworthiness or truth of this study it is quite possible, even probable, that the position of the researcher has affected interpretations of the presented results. However, I have provided detailed and accurate descriptions on how the study has been conducted, how the results have been analysed and how I have reached the conclusions.

Validity can be seen as different for each methodology and indicates whether the research has measured, with accurate measures, what it was intended to measure (Winter 2000). In quantitative studies the reliability of the study requires that its repetition is enabled by the possibility to measure exactly the same thing all over again. The validity of questionnaire analysis results, however, might be distorted if all respondents will not understand the questions in the same way. The validity of the qualitative inquiry, however, can be seen as the richness of the cases selected and the observational or analytical capabilities of the researcher (Patton 2002a). The strengths of evidence should be discussed critically because the samples in all studies were relatively small, especially for the purpose of quantitative studies. Yet the limitations of individual analysis were compensated with multiple studies exploring the same phenomenon from various viewpoints.

Concerning the trustworthiness or credibility of data and analysis, a few general issues need to be highlighted. In the studies of OT work and errors, a relatively large amount of data was gathered; the transcriptions and video edition were made meticulously. The analysis process was multiphase, and I was trying to prevent data interpretation errors by using the expert surgeons as informants in the interviews, a research triangulation. Therefore I can say that the richness of the data was considerable. Reliability of coding and pattern analysis was reinforced by selecting rigorous methods such as the failure analysis model recommended and used in other surgical behavior studies.

I also had surgeons as co-authors in several sub-studies and this compensated my lack of surgical knowledge. This was extremely important, especially in the beginning of the study. The process of data gathering and analysis are in this study also described in detail in chapter 3. I see the systematic rigor of fieldwork procedures better in the OT studies compared to simulation-based training (SBT) exploration. Within the SBT context the rigor was distracted by the delays and difficulties for gathering data since the surgeons were appearing at the simulation center to practice, instruct and fill out the forms quite surprisingly and usually without prior notice.

Patton (2002) encourages a researcher to also ask if qualitative findings can be generalised or extrapolated and what is their transferability. Findings from experimental and naturalistic settings should be valued differently. Concerning possible practical generalisability of the surgical training across Finnish hospitals, I see that it is possible that many of the detected issues would apply within our country. However, generalising the conclusions of this study to other countries would require a comparison of the surgical teaching and learning cultures and medical school traditions. The video-assisted surgery and LC was chosen as a case example of this study, because it was seen as the best representation to investigate the issue. It is the first MIS procedure to be taught to resident surgeons in education programs worldwide and the basic skills should be acquired by this procedure. It also captures the problematic nature of surgery in many ways. The recommendations to focus on this particular procedure came from the surgeons, who were involved as co-authors of the sub-studies.

The main purpose of this study was not to contribute to the theoretical issues of learning surgical skills and expertise. The purpose of this study was to gain better understanding on how to develop minimally invasive surgical (MIS) training and practicing methods at Finnish hospitals, in order to be able to respond better to today's expertise demands and challenges. This purpose would have enriched the analysis of residents' perceptions concerning authentic operating and expertise development. The findings of this study within Finland might also be transferable at least to other MIS procedures and many findings may also be transferable even to other kinds of surgical procedures. Findings concerning SBT would quite easily be transferable to other surgical simulator training settings. I would also suggest that the naturalistic settings of this study also ensure the correspondence of findings to reality, since no artificial settings were created for this study.

In the studies concerning SBT, the decisions of data collection and analysis were made mostly based on what was seen as important issues to investigate within the training program experiment and what kind of data was produced during the program, such as participant questionnaires and parameter data from the simulator. As discussed in chapter 3, both qualitative and quantitative data were gathered and analysed and these processes were seen to complement each other well. Therefore I also see that the consistency of findings across methods and data sources increased trustworthiness, since there were no significant contradictions between results of various sub-studies.

One could, however, argue that this was a rather disorderly realisation and sometimes I was also experiencing confusion within all these variable data sources and analytical processes. However, I see that it was both surprising and rewarding to conduct these studies in a naturalistic hospital environment without the possibilities to control the elements of the study. To add to the trustworthiness of the study, I see that in order to conduct studies within small hospitals involving few participants, it is important to acquaint oneself well with the international research conducted in this field and reflect one's own findings to them in a versatile manner.

5.4 Practical conclusions and future research

In these five sub-studies the phenomenon of surgical laparoscopic operating is addressed from several viewpoints. This research gathers the knowledge gained into a holistic understanding of the requirements and preconditions for training surgeons at hospitals in Finland. Many of these issues are connected to the practical implementation of SBT-related education. The findings of this study offer valuable information for both researchers and practitioners in the field of medical simulation and training. The practical conclusions are presented here in relation to some issues worth addressing in the future for education implementation and research.

The changes in surgical resident education are inevitable and the near future of surgical education will most definitely be different than the current situation (Mecklin, Silvennoinen & Scheinin 2013). This study is offering knowledge and concrete tools for hospitals and surgical education designers to be better prepared for this upcoming change. It seems that there is a need to be concerned at the lack of educational curriculums utilizing SBT in surgical training in Finland. Simulation can be used more comprehensively, not solely for technical motor skill training, but also as part of a structured curriculum. It should be used increasingly for teaching cognitive skills such as decision-making as well as ergonomics and other teamwork skills such as communication. More solutions concerning future training models' implementation and incorporation of these curricula into surgical work practices are still needed. The findings of this study support the earlier findings, which suggested that we should aim to solve emerging resource and administrative problems so that learning and teaching at hospitals using surgical simulators will become more systematic and efficient (Van Dongen et al. 2008, Aggarwal et al. 2006, Kneebone 2003). Laparoscopy training with VR simulators should, however, not be the only SBT method for educating surgeons. The comprehensive OT skills training should also involve regular training in a simulated OT environment. This would have a lot of potential for reducing the occurrences of adverse events. Simulated operating room training would widen skills practice from restricted technical skills acquisition to the much needed non-technical skills training. This integration of technical and non-technical skills would allow for surgical education to take into account the whole surgical team and a more intensive application of systems approach, leading to increased possibilities of identification of sources of errors and understanding of the multifactorial perspective in surgical performance and decision-making (Aggarwal et al. 2004, Vincent et al. 2004, Sevdalis, Jacklin &

Vincent 2009). With the aid of SBT, surgical resident training is on the way to ethically approved and acceptable training methods and better patient safety. In addition to training simulations, education should aid the learner with the best possible manners to develop error management strategies and to learn from mistakes (Bauer & Mulder 2013). We should not forget the meaning of workplace learning and senior supervision in authentic situations. On the contrary, SBT should also contribute to traditional master-apprentice training, by introducing new tools for promoting interaction between novices and experts working together in surgical wards. There is also a shortage of studies concerning teaching in OT; it seems that teaching and learning in OT needs to be reorganised as well (Lyon 2003). The quality of training should be highlighted, and more experienced workers should be utilised to help the novices to practice better and develop skills that will lead them to expertise (Dennen & Burner 2008, Ericsson 2004, Ericsson 2006, Ericsson 2008, Patel et al. 2005, Kolozsvari et al. 2011, Van De Wiel et al. 2011). The knowledge gained from participating in SBT should be seen as a support for the teacher-learner interaction situation in OT and a way to enrich it with more structured manners concerning guidance and reflection.

The findings of this study indicate that there are many issues that should be further explored. Further research is obviously still needed to investigate the efficacy of surgical curricula in teaching laparoscopy and other MIS skills. At some level the technical skill transfer from SBT to OT has already been demonstrated (Ahlberg 2007, Sturm et al. 2008, Haluck & Krummel 2000, Seymour et al. 2002, Schijven et al. 2005). Nevertheless, the meaning and efficiency of various pedagogical interventions, such as senior guidance, instructive feedback or reinforced self-reflection of trainees, remains unexplored in this context. The perceptions and experiences of residents working in OT should also be utilised in education design. The learner's view also completes the knowledge gained from expertise development during surgical operation. Validating the curricula, enhancing surgical skills and expertise development would require longitudinal studies to evaluate the educational effects for patient safety and complication rates. High quality studies on SBT impact on clinical outcomes should be conducted (see also Nagendran 2013). We need knowledge on medical expertise and adult learning to be able to develop better and more effective training models and curriculums utilising simulations that are comprehensive and still cost-effective (Eteläpelto, Collin & Silvennoinen 2013). The results from this study show that there are issues that could be further improved for enhancing patient safety.

5.5 Concluding remarks

More people are dying today due to medical errors than from motor vehicle accidents. Increased availability of information on adverse medical events through the media and easy access to these issues on the Internet has drawn the attention of the general public towards practitioners' competences. Citizens are more concerned about their personal health and demand information on the quality of healthcare services. This trend requires that healthcare organisations exercise more openness and transparency about their procedures, treatment protocols and medical professionals' competences and education. The relationships between patients and their doctors are significantly different from those in past decades. The dominancy of physicians as decision makers in practice situations as well as respect for their professionalism has weakened (Gallagher & O'Sullivan 2012).

Today, the perceptible promotion of patient safety and patients' emphasised role as active clients and as consumers of health care services, rather than passive recipients, are central objectives of modern healthcare. In Finland, according to Valvira's (National Supervisory Authority for Welfare and Health, Finland) "patient's charter", patients can choose their healthcare providers, which also creates a healthy competition between the provider organisations. As a result the patients as educated consumers want to know as much as possible about the quality of treatments and the expertise of the specialists they choose. Healthcare providers need therefore to actively and prospectively enhance their quality of care as well as invest noticeably in training and education of their staff. Surgical educators need now more than ever to ensure the efficiency of learning at work. Understanding of the issues related to the acquisition of surgical expertise is required for enhancing improvements in surgical care. Understanding the development of expert practitioners should encourage the design of surgical education programs that produce even more competent physicians. This progression should further enhance patient safety. Systematically implemented education, such as simulation-based training, is one ethically approved method that enhances patient safety when applied adequately. It is an investment for better patient care even though it has been noticed, as this thesis has also shown, that training involving simulation introduces new educational and organisational challenges. Making the investments in more effective training possibilities is, however, an important step towards improving healthcare professionals' education. On the other hand, transparency of healthcare treatment processes should be promoted through open discussion concerning the state of healthcare and treatment results, which further strengthens the valuable atmosphere of trust between patients and healthcare organisations.

YHTEENVETO (FINNISH SUMMARY)

Kirurgisten taitojen harjoittelu simuloidussa ja autenttisessa ympäristössä, asiantuntijuuden kehittymisen haasteet laparoskopiaharjoittelussa.

Tutkimuksen tavoitteena on lisätä ymmärrystä siitä, miten tähystyskirurgian koulutus- ja harjoittelutapoja suomalaisissa sairaaloissa voidaan kehittää, jotta ne vastaisivat paremmin nykypäivän asiantuntijuuden vaatimuksiin ja haasteisiin. Tutkimuksessa tarkastellaan sitä, mitä tähystyskirurgian asiantuntijuus on, miten vatsan alueen tähystyskirurgian eli laparoskopian harjoittelu erikoistuvilla lääkäreillä tapahtuu, miten taidot kehittyvät ja mitkä tekijät näihin vaikuttavat sairaalaympäristössä.

Kirurgin rooli leikkaussalissa on johtaa moniammatillista tiimiä, siksi kirurgin taidoilla ja tietämyksellä on keskeinen merkitys potilasturvallisuudelle sekä leikkauksen onnistumiselle. Perinteisesti kirurgiaa on opetettu sairaaloissa oppipoikamallilla, jossa erikoistuvat kirurgit oppivat työn ohessa seuraamalla kokeneempia kollegojaan. Kirurgikoulutus ei kuitenkaan ole pystynyt täysin vastaamaan uusien leikkaustekniikoiden, erityisesti tähystyskirurgian sekä leikkaussalivälineistön nopeaan kehitykseen. Samalla kun erikoistuvien osaamisen haasteet ovat kasvaneet, on erikoistumisaikaa sairaaloissa lyhennetty. Nämä ristiriitaisuudet herättävät kysymyksiä hyvän potilasturvallisuuden ylläpitämisen mahdollisuuksista. Näistä haasteista on tarpeen keskustella sekä kirurgikoulutuksen että työkäytänteiden näkökulmasta. Myös teknologian käyttöönoton lisäämistä koulutuksessa tulee pohtia, sillä leikkaustaitojen harjoitteluun on saatavilla simulaattoreita. Potilasturvallisten tietokonepohjaisten leikkaussimulaattoreiden käyttö koulutuksessa on Suomessa edelleen kovin vähäistä, osin siksi, että niiden käyttösuositukset ovat puutteellisia tai vaikeaselkoisia. Toisaalta sairaaloiden toimintakäytänteet eivät nykyisellään tarjoa riittäviä mahdollisuuksia toteuttaa työtehtävistä irrallaan olevaa harjoittelua täysipainoisesti.

Tässä tutkimuksessa käsitellään kirurgien työskentelyä ja tähystysleikkaustaitojen oppimista kahdessa ympäristössä, leikkaussalissa ja simulaatioympäristössä. Lisäksi tutkimuksessa arvioidaan kirurgikoulutuksen muutostarpeita ja -mahdollisuuksia. Esimerkkinä on laparoskooppinen sappikivileikkaus, joka on yksi yleisimpiä tähystyskirurgisia toimenpiteitä ja jonka kaikki erikoistuvat joutuvat oppimaan jo erikoistumisen alkuvaiheessa. Lisäksi tutkimuksessa esitetään laparoskopiataitojen koulutuksen malli ja keskustellaan erikoistuvien työssä oppimisen tehostamisesta uusien koulutus- ja harjoittelukäytänteiden avulla.

Tutkimuksen pääkysymykset olivat seuraavat:

(1) Mitkä ovat kirurgisen asiantuntijuuden tunnusmerkit?
(2) Miten laparoskopiataitojen asiantuntijuuden kehittymisen haasteet näkyvät virheinä tai riskeinä leikkaustyössä?
(3) Mitkä tekijät vaikuttavat erikoistuvien kirurgien simulaattoriharjoitteluun ja taitojen oppimiseen?

(4) Mitä simulaatioharjoittelua hyödyntävän leikkaustaitojen koulutuksen toteuttaminen edellyttää?

Tutkimusaineisto koostuu videoiduista tähystyssappileikkauksista, jotka erikoistuvat kirurgit ja heidän ohjaajinaan toimineet seniorikirurgit suorittivat päivystyskirurgisella osastolla. Lisäksi haastateltiin neljää kirurgian erikoislääkäriä, jotka katsoivat videot sekä esittivät kommentteja leikkausten virheistä ja riskeistä. Simulaatioympäristöstä kerätty aineisto sisältää erikoistuvien kirurgien videoituja harjoituksia sekä kyselylomakkeilla kerättyä tietoa heidän harjoittelu- ja oppimiskokemuksistaan. Lisäksi aineistona ovat simulaattoreiden tallentamat tiedot leikkaussuorituksista. Aineistot analysoitiin sekä kvantitatiivisia, että kvalitatiivisia menetelmiä käyttäen. Lisäksi tutkimuksessa esiteltiin menetelmä, jolla leikkaussalitapahtumia voidaan tallentaa ja rikastaa siten, että se mahdollistaa yksityiskohtaisen ja luotettavan käsityksen muodostamisen kirurgian prosesseista sekä ammatillisesta, että koulutuksellisesta näkökulmasta.

Tutkimuksen tuloksina todettiin, että 1) kirurgisen asiantuntijuuden tunnusmerkit tulee nähdä edellytyksinä ja resursseina, jotka vaaditaan tiedollisesti ja taidollisesti tasokkaan laparoskopia-asiantuntijuuden koulutukseen. Tutkimus osoitti, että 2) asiantuntijuuden ja laparoskopiataitojen kehittymisen haasteet ilmentyvät selvästi virheinä tai riskeinä leikkaustyössä, erityisesti niissä leikkauksen vaiheissa, jotka olivat kirurgeille sekä teknisesti että ei-teknisesti haastavia. Tutkimuksen tulokset osoittavat lisäksi, että 3) erikoistuvien kirurgien simulaattoriharjoitteluun ja taitojen oppimiseen vaikuttavat sekä organisatoriset, yksilölliset että sosiaaliset tekijät, jotka rajoittavat tai edesauttavat työssä oppimista. Merkittävimmäksi simulaatioharjoittelua tukevaksi tekijäksi tutkimuksessa nousi sairaalan tarjoama tuki työssä oppimiselle. Tutkimus osoitti, että 4) käytännön edellytykset simulaattoriharjoittelua hyödyntävälle leikkaustaitojen koulutukselle ovat henkilöstön ja organisaation sitouttaminen koulutuksen suunnitteluun ja käytännön toteutukseen sekä riittävien resurssien ja välineiden tarjoaminen.

Tutkimuksen käytännön johtopäätöksinä esitetään, että simulaatioharjoittelun toteuttamisen onnistuminen sairaaloissa vaatii merkittäviä muutoksia kirurgian oppimis- ja harjoittelukulttuuriin. Lisäämällä tietämystä leikkauksissa vaadittavan asiantuntijuuden erityisvaatimuksista ja leikkauksiin liittyvistä riskeistä ja virheistä, voidaan edelleen lisätä potilasturvallisuutta ja ymmärrystä siitä, kuinka kirurgeja tulevaisuudessa tulisi kouluttaa sairaaloissa. Tältä pohjalta voidaan kehittää virheitä ja läheltä-piti-tilanteita ehkäiseviä toimintamalleja sekä koulutusta. Koulutussuunnittelun tärkeyttä tulee korostaa, sillä koulutusmallien luominen työpaikoille on haastava tehtävä. Simulaatioharjoittelun suunnittelijoilla ja toteuttajilla tulisikin olla ajantasaiset tiedot paitsi tarjolla olevasta koulutusvälineistöstä, myös tietämystä aikuisen oppimisen periaatteista. Tutkimuksen tuloksena syntynyttä käytännön vaatimusten listaa voidaan käyttää arvioitaessa nykyisten koulutusmallien toimivuutta, suunniteltaessa uusia oppimista ja työskentelyä tehostavia malleja sekä hakemalla syitä ja ratkaisuja ongelmatilanteisiin.

Simulaatiokoulutusten toteuttaminen Suomessa on vielä verrattain vähäistä ja sen määrää voisi huomattavasti lisätä. Uusien koulutusmallien käyttöönotto on kuitenkin vaativaa ja resursseja vievää ja asettaa haasteita terveydenhuollolle. Jokainen investointi laadukkaaseen koulutukseen on kuitenkin askel kohti entistä parempaa potilasturvallisuutta.

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ORIGINAL PAPERS

I

EXPERTISE AND SKILL IN MINIMALLY INVASIVE SURGERY

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2009

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II

VIDEO-ASSISTED SURGERY: SUGGESTIONS FOR FAILURE PREVENTION IN LAPAROSCOPIC CHOLECYSTECTOMY

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III

LEARNING BASIC SURGICAL SKILLS THROUGH SIMULATOR TRAINING

by

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IV

LEARNING SURGICAL SKILLS WITH SIMULATOR TRAINING: RESIDENTS' EXPERIENCES AND PERCEPTIONS

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V

TOWARDS TECHNOLOGY-SUPPORTED SURGICAL TRAINING

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Towards technology-supported surgical training

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Abstract

Technology offers alternatives for training surgeons with patients and also possibilities to take part in surgical learning from afar, outside the operating room (OR). Simulated and other technical training tools provide opportunities to practice surgical skills in undisturbed learning environments. In order to implement effective educational methods and create new environments for learning, we need to find out what skills a surgeon must learn and what are the elements affecting surgical performance.

This paper describes a study designed to investigate surgical processes and presents an exploratory way of gathering data by combining video material with interviews. The suitability of triangulation as a method of data collection for the development of technology–supported surgical education is then evaluated and discussed.

The triangulation method provides data which benefits technology-supported surgical education. Advantages include a more accurate and detailed knowledge obtained from surgeons' actions, surgical procedures and learning.

Key words: *Surgical education design, operating room environment, evaluation of research method, technology supported education*

1. Introduction

Surgical learning traditionally takes place in the operating room (OR) through master-apprenticeship training. Today the complexity of surgical equipment, the fast development of new surgical techniques [1] and the need to intensify the learning and working processes, for saving expensive time in the operating room, is leading towards more technology oriented learning environments [2,3]. There are also growing ethical concerns towards teaching and learning surgical skills on live humans and animals. New technology, like operating simulators, offers possibilities to learn important basic surgical skills and complex working methods outside the operating room [4,5]. In addition, there is a growing interest in studying technological equipments that support surgical training [6,7,8,9].

Simulation-based education offers interactive technology for practicing the skills needed when performing surgical operations. These include motor skills, visual-spatial skills, decision-making skills and team working skills [7,10,11]. New learning environments and laboratories are equipped with modern technology, such as surgical simulators and training torsos. Simulators can also be used in assessing skills and surgical performance [12,13,6].

Even if simulators seem to offer important individual skills training, surgeons and residents are not necessarily actively spending time with this equipment spontaneously, and do not prioritize simulator practice [10]. Therefore, merely providing simulators to surgeons for practise is not a sufficient way of responding to the educational challenge [4]. We need to approach the teaching of surgical skills holistically, through a comprehensively validated curriculum which offers the advantages of new technology for the use of surgical training to both resident and special surgeons and integrates this equipment logically to their working and learning environments.

For the purposes of developing effective surgical training in simulated environments, it is necessary to acquire detailed data from surgeons' authentic everyday working and learning situations. It is important to examine and become familiarized with surgeons' actions, issues that affect surgical performance and the operating room as a workplace and learning place.

The aim of this paper is to introduce and evaluate research methods used in investigating and considering operating room surroundings and surgical work in the operating room environment.

The paper is organized as follows. The research methods are presented in the following section. After that, the suitability of the methods for gathering and producing data for technology-supported surgical education is evaluated in section three. The final section draws conclusions of the main findings and makes suggestions for future research.

2. Method for investigating surgical work and skills learning

Understanding surgeons' actions when operating requires comprehensive analysis and familiarization with the surgical procedure and factors that affect surgical performance in the OR. The research method presented in this section is developed for a project which combines knowledge from education, medicine, psychology and cognitive science. Research means arise from the multidisciplinary research group's interest in obtaining information about surgical skills, learning of surgical skills and elements that relate to surgeons' actions in operating room surroundings. Laparoscopic cholecystectomy was chosen as the observed operation. It is a typical procedure that all specializing surgeons must learn to perform and simulators have been developed for practicing it.

2.1. Videotaping the surgical procedures

To learn about surgeons' actions in the operating room, 12 educational laparoscopic cholecystectomy operations were captured. Either expert (senior) surgeons or novice (specializing) surgeons performed the operations. In each operation, two surgeons were present and the data consisted of operations where another, more experienced surgeon or resident acted as a tutor or teacher to the less experienced surgeon (master-apprenticeship training). Their status profiles were in operations 1-6 senior and specializing surgeon, in operations 7-9 both specializing surgeons and in operations 10-12 senior and specializing surgeon.

To get detailed information about the events and actions in the OR, several cameras with different angles were used. Four video cameras were used (see Figure 1) to capture 1.) actions of the operator and assistant from the front, 2.) manual operations from above the operating table, 3.) panorama of the whole surgical team (4-6 persons) and a view from the OR, and 4.) the laparoscopic camera inside the patient. The different scientific interests of our research group formed these four video angles and perspectives as follows:

- The first video camera was used to record the co-operation and communication of the novice and senior –surgeon in the teaching-learning situation. In addition, the video camera offered an ergonomic view of the posture and position of surgeons.
- The second video camera was used to capture the ergonomic movements of surgical instruments and surgeons' hands, and to get a view from the instrument entrance hole and suturing.
- The third video camera recorded a general view of the OR and the posture and position of the surgical team. It provided information about individuals who were present in the OR and their behavior. In addition, important data about the placing of the equipment such as the patient table, monitors, and instrument tables was recorded.
- The fourth video camera was the laparoscopic camera, which was held and directed mainly by the assistant surgeon. The camera captured the view of the operation inside the patient, where the accuracy of movements of the camera and instruments as well as the progress of the operation could be observed.

The video data-collecting phase of the research was finished in late 2006. Each of these videos showed a small separate view from the events in the OR. To combine data from the video recordings, they were synchronized as simultaneous actions and edited as one display (Figure 1) with four video windows.

Figure 1. Combined display with four views to the OR.

As a combined view, four video recordings could give a more holistic view, and produce data for the multidisciplinary project's interests. However, there were questions which could not be answered solely based on the videotapes. These concerned surgeons' experiences, learning, guidance and understanding the surgical procedure from the performer's point of view. Therefore, the next phases of data gathering were designed to answer these questions.

2.2. Interviewing participant surgeons performing and assisting on videos

In order to gain deeper insights into the videotaped surgical processes, all six operating and assisting surgeons were interviewed. Interviews were conducted by stimulated recall, which means that video recordings of the operation were watched during the interview. The interviewee could freely describe the operation and his/her thoughts and actions on the video. If necessary, the interviewer asked focused questions related to the learning, challenges, guidance and interviewees' performance in the operation. Semi-structured interviews were recorded and transcribed.

All 12 operations were divided into three phases: Preparation, Operation and Suturing. The phases and their performers, specializing surgeon or senior surgeon, were listed (Table 1) to see the distribution of surgical work in these educational operations. Table 1 shows that the preparation and suturing phases were most often carried out by the specializing surgeon. The operation phase was mainly performed by the specializing and senior surgeons working together.

Table 1. Performer status in 12 laparoscopic cholecystectomy operation phases.

Performer	I Preparation phase	II Operation phase	III Suturing phase
Specializing surgeon	8	4	10
Senior surgeon	4	2	0
Specializing and senior	0	6	2
Total	12	12	12

The data acquired from participants' interviews included verbal descriptions of their own performance and actions or the co-operating surgeon's actions in the videotaped operation. Some of the comments related to other surgical team members, such as scrub nurses, who organize equipment for the surgeon. The interviews provided data on surgeons' own thinking when operating or assisting the main operator. Surgeons told about possible difficulties and challenges of work. Also general knowledge and information considering the learning process of the particular type of operation was obtained from participants' interviews.

In order to gain a precise view of these procedures, video material was divided into detailed work descriptions. All 12 operations with three phases were divided into lists of individual surgical actions in a chronological order. Each action of the main operator and assistant, and for example some of the case relevant actions of nurses, were registered. This was not an easy task, because there were still deficiencies in the data. The solution for the unsolved questions was found in the expert interviews presented in the next chapter.

2.3. Interviewing the surgical experts

When classifying the data to form a precise description of these 12 operations, many new questions emerged. The participating surgeons had commented on some of the surgical actions on the videos. Still, there were data missing concerning the specific explanations for these actions and events, which could help understanding the meaning of choices, possible failures or success.

Errors and risks have a crucial role in medicine and surgery [14,15,16], and naturally surgical education is heading towards performance that is completed with less errors and risk situations. Several features of surgery support adding the viewpoint of risks to research concerning surgical operation. These include the consequences of errors and the fact that surgery is an area where errors may occur because of single unsafe acts [17]. In medical operations, there are always risks involved and the main interest when designing medical education and effective working environments is to make operations and surgical work safer and less time- and resource-consuming.

The information sought from the experts concerned possible alternative or different actions during the operations. Possibilities to operate better or more effectively and to intensify and improve the learning of surgical performance in order to make surgical procedures safer and less vulnerable to risks were inquired.

In order to find more answers, the surgical experts were asked to give a "second opinion", and answer questions such as what was happening in these surgical operations and why. Expert interviews were conducted with the idea of considering videotaped operations from the viewpoint of difficulties and risks.

The expert interviews were performed in 2007. In these interviews, four expert senior surgeons watched and commented three to four operations each from a total of twelve. Experts were instructed to comment events on videos in detail from the viewpoint of risks and performance difficulties, as well as to offer solutions for possible problems reported. The interviewer asked questions concerning some vague situations, and actions on videos were further discussed with experts. Interviews were recorded and transcribed.

Experts insightfully analyzed the risks and errors present in these operations and commented on surgical skills learning concerning the particular operations. They gave their own recommendations for solving problems they had noticed. Experts also emphasized the importance of patient safety, good equipment and ergonomics.

3. Evaluation of method suitability

This section evaluates the suitability of the method for data gathering presented in the previous section to offer a foundation for studying surgeons' actions in operating room surroundings and to get detailed data on and description of the operation for the interests of technology supported surgical education design.

3.1. Surgical operations data

Figure 2 presents the compound data collected from videos and interviews. Material representing surgical operations contains:

- Surgeons' and other surgical team members' actions and work in the OR
- circumstances that affect surgeons' and other surgical team members' work
- stories and comments of the surgeons assisting and performing in operations
- expert surgeons' comments concerning surgeons' and other surgical team members' actions on video from a safety and risk perspective
- the duration of the operation and different actions

The communication is naturally related to various contexts, but presented here in the most observable location, Circumstances in the OR. Research data on operations consists of video material combined with the interview material of participants and expert surgeons who watched and commented on the videos.

To evaluate the suitability of the method for gathering and producing data for the interests of technology-supported surgical education, the value of the data collected (Figure 2) for educational benefit is evaluated. Based on the data, several educational benefits can be seen.

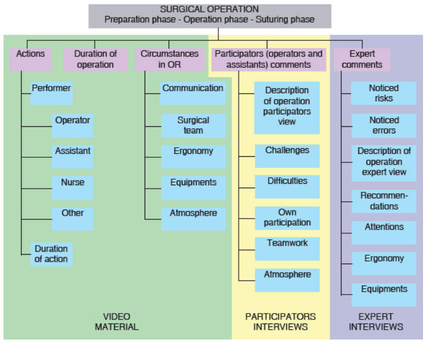

Figure 2. Surgical operation data

3.2. Multiple perspectives on surgical operation

Multidimensional data offers possibilities to investigate the actions, working and learning models of senior surgeons and residents from various perspectives. It offers a detailed description of particular laparoscopic cholecystectomy operation as well as information concerning instruments and equipment used in the operation. Surgeons' work, learning, expertise and different skills such as visual-spatial ability, motor ability, thinking, decision-making, perceptual and cognitive skills can be investigated simultaneously. In addition, the data enables studying the actions of nurses and the whole surgical team and finding out how team work affects surgeons' performance.

Surgical operation data provides information concerning learning, supervision and relationship between the learner and teacher in the OR situation, as well as data on the differences in skills between expert and novice surgeon documented and analysed. It also provides the possibility to compare the duration of actions and operating phases performed by expert and novice surgeons.

The data offers insights into surgeons' own thinking when learning and performing, concerning for example the challenges and difficulties. There is also data on the errors and risks related to surgical work and expert surgeons' recommendations for intervening in risk situations, intensifying surgical work and learning and improving circumstances in the OR.

3.3. Using data in surgical education

Information obtained from surgical operation offers material that can be used in familiarizing different audiences with surgical work and with the skills needed in operating room. Information gained can also be used in developing simulations and simulated learning environments with the necessary equipment to highlight problematic actions and behavior.

The method makes it possible to store detailed material to be used later, for example, in teaching surgical skills and presenting different ways of performing operations. The method can be used to compare skills learned in the OR to skills learned in simulated environments. The method is also suitable for providing information for supervision and feedback in the training of different surgical operating phases and actions.

Research enables finding solutions to educate surgeons by focusing the education on detectable risks, evident difficulties and challenges that surgeon's encounter in their work. A detailed mapping of risks and errors makes it possible to intervene effectively in mislearning or unnecessary risk taking. Research increases awareness of the influential elements of these risks and errors, and enables finding solutions for preventing them. It is possible to focus simulated surgical education more on risky functions and the training of particularly risky procedures and actions before entering the OR.

Surgical operation data is beneficial for educating surgeons and designing surgical education, educational equipment and environments, and naturally for surgical residents and surgeons. The triangulation method presented here can also be generalized to investigate other surgical or medical procedures.

The knowledge gained through this research is also beneficial to surgical equipment and instrument manufacturers and ergonomics specialists.

4. Conclusion

Research data was gathered in order to gain a deeper understanding of the contents and structure of surgical skills and work in order to establish a more holistic approach to surgical skills learning and grounds for educating surgeons. Research was designed to collect data from surgeons' operating room performance, surgical skills, learning and surgical work. The aim of the research was to understand what skills surgeons must learn and what issues affect surgical performance. The significance of paying attention to risks in surgery became more emphasized as the data gathering proceeded.

The data contained videotaped surgical operations and interviews of the participant surgeons and residents in training that operated or assisted in videos. The video cameras showed actions in the OR and how surgical procedures were performed. The multivideo-method makes it possible to observe surgeons' work comprehensively from several perspectives. Participants' interviews provided data on surgeons' and residents' experiences of operations and circumstances in the OR. In addition, expert interviews offered data concerning the progress of the operations, risks related to procedures, and recommendations for preventing errors and risks.

It was important to use all these methods jointly. The multimethod data gathering presented and evaluated creates three stages for building a research approach for forming an extensive view on surgeons' actions, facts that affect surgical performance and the operating room as a workplace and learning place in laparoscopic cholecystectomy operation.

Research adds new perspectives on the challenges of laparoscopy and helps to understand the nature of surgical skills, which is needed in order to understand the learning of these skills. The information gained through the research can be used in finding ways of eliminating risks and reducing incorrect working methods as well as removing hindrances of learning. It also builds foundations for developing further simulated surgical training programs for intensifying the learning of skills and eliminating risks.

The method presented here enables investigating surgical work in operating room surroundings in a holistic way. These methods produce knowledge that can be used in designing surgical skills learning environments, effective training methods, effective and safer work environments, work methods and equipments.

The present research on surgeons' work in the operating room environment focused on one typical and very common operation, laparoscopic cholecystectomy. This research offers material for investigating the actions and working and learning models of senior surgeons and residents. Investigating and describing the laparoscopic cholecystectomy operation and the operating room environment offers good grounds for also investigating other operations, especially keyhole surgery procedures. It has been shown that the research method presented in this paper is effective for gathering information for the interests of surgical education. We all share the agreeable thought that it is important to offer possibilities to practice surgical skills outside the operating room with patient simulations.

Future research should further consider experimental ways of investigating surgical work. It could offer suggestions to reduce risks and errors in laparoscopic operations and surgical work, such as more efficient technology-assisted learning environments. The information could be used in describing the challenges of learning surgical skills and designing training models for surgeons. To investigate possibilities for improving and intensifying surgical skills learning and surgical work by utilizing simulated environments and simulators is a growing interest in modern medical education. It has been found that simulation may help to reduce training times and accelerate improvements in performance [18,19]. Simulation training can also be used in reducing risks and errors [20]. This is why a deeper analysis of these risks, critical and challenging work processes and functions in a laparoscopic cholecystectomy operation will be the next step in research. There is a reason for investigating surgeons' work in the OR. Hopefully, the study will direct special attention towards introducing safe, ergonomic and effective tools for surgical teaching and work.

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