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# Learning Surgical Skills with Simulator Training: Residents' Experiences and Perceptions

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## Abstract

Simulator training is becoming a more integral part of surgical psychomotor skills training for video-assisted operating techniques, which need to be practiced repeatedly and systematically. Studies concerning the implementation, realization, and potentiality of simulator training programs for hospital surgeons are needed. Also, trainees' expectations of training, and the feasibility of combining such training with their hospital work, remain rather unknown.

This paper presents important theoretical factors that influence surgical skills learning through computer-based simulator training. The curriculum and the study of learners' training experiences are presented. Statistical analysis on participants' questionnaire answers before and after training shows that the residents were confident with their progress and skills development, and felt that working in the operating room was easier after the training period. Residents' expectations before simulator training, and the skills experience gained afterwards, were consistent with the curriculum objectives. Then again, expectations of individual opportunities to practice were somewhat overestimated. The residents also reported not having reached their anticipated skill level during simulator training, which might indicate that a loose, voluntary training schedule alongside hospital work is insufficient for reaching the requisite skill levels. The implications of this research could be exploited when designing and implementing curricula for surgical residents.

**Keywords**: Surgical skills learning at hospital, computer-based simulator training, curriculum, learner experience, self-assessed skills development

## Introduction to Changes in Surgical Skills Learning

During university studies, medical students are provided with basic medical knowledge and skills. However, surgical skills cannot be achieved solely by reading. After graduation, intending surgeons need to do hospital residency work for a further 5–6 years to become specialists in Finland. University teaching is thoroughly planned, but the six years of postgraduate hospital specialist training does not include a detailed curriculum. Instead, it is dependent on the varying circumstances of individual hospitals. The traditional way of acquiring operating skills is the apprenticeship method of observation and practice with more experienced colleagues.

However, video-assisted operations, especially abdominal area operations (laparoscopies), have proved to be technically challenging for both experienced and novice surgeons (Sandor, 2010). So far, only a few video-assisted procedures have become routine—cholecystectomy and appendectomy. The adoption of more procedures is extremely slow. There are two reasons for this: 1) the complex nature of the new video-assisted operating methods; and 2) insufficient traditional means of teaching and training healthcare professionals and students (Silvennoinen, Mecklin, Saariluoma, & Antikainen, 2009). The major advantages of video-assisted operations are that they are performed with smaller incisions compared to those of open surgical techniques, resulting in less pain and fewer days of sick leave for patients. From the surgeon's point of view, the laparoscopic technique requires various skills including integration of muscle function, strength, speed, precision, dexterity, balance, and spatial perception (Khan et al., 2004; Moorthy et al., 2003). This has increased the learning demands of this technique and the time needed to learn new procedures.

The complicated circumstances in video-assisted operations is changing the teaching and training of laparoscopic operations (Silvennoinen, Mecklin, et al., 2009). Coincidently, it has been found that traditional resident education—apprentice training and skills learning in OR—is insufficient in the acquisition of laparoscopic complex motor skills, which require repeated practice (Ericsson, 2004; Reznick & MacRae, 2006). The traditional apprenticeship way to learn laparoscopic skills is no longer an adequate method, as is the case with traditional open surgical techniques. While video-assisted techniques such as laparoscopy stay complex they must be learned in a more effective way.

Simulator training has been introduced as one solution to help solve the problem of reducing the time needed to practice complex laparoscopic skills (Cosman et al., 2002; Schjiven et al., 2005). Other high-risk professions such as nuclear power personnel training, and flight simulators for pilots, astronauts and the military, have already successfully incorporated simulation technology into their training and assessment programs (Scalese et al., 2008). Closely related to safety issues are important ethical questions about the appropriateness of "using" real human patients as training resources, even though patients should be protected whenever possible (Ziv et al., 2003; Scalese et al., 2008). The use of cadavers or animals as practice tools also raises ethical concerns. Simulator-based learning can help ease the ethical tensions. During simulator training, trainees can make mistakes and learn to recognize and correct them, without fear of harming patients (Ziv et al., 2003). Simulators are also beneficial to specialist surgeons as tools to provide help in developing psychomotor abilities and skills self-assessment and maintenance (Sandor et al., 2010).

Simulator training requires investments in both the equipment and time required for training (Gerald et al., 2004). However, it has already been confirmed that simulator practice has improved the performance of novice surgeons—especially within curriculum-based training (Aggarwal et al., 2006)—as well as the skills transfer between simulator and operating room (Seymour, 2002; Ahlberg et al., 2005 & 2007, Sturm et al., 2008 ). A structured simulator training program is needed in hospitals. However, this paper also argues that training surgical skills with simulators still requires further exploration. In the prior study of Silvennoinen, Helfenstein, Ruoranen, and Saariluoma, 2011, the quantitative analysis of residents' simulator performance from training (from onset to completion) produced mixed results in basic level laparoscopic camera skills. It revealed both improvements and declines, depending on the analyzed parameters. In other studies as well, the learning has been difficult to assess from the simulator metrics (Andreatta et al., 2008). According to van Dongen et al., 2011, the optimal implementation of a simulator into a surgical skills curriculum is still open for discussion.

There is an overall need for research into the experiences of systematic or guided simulator training in surgical skills learning. This study also adds the learner's view to the existing surgical simulator training study field, by presenting one model of a simulator training program and its results on residents' experiences.

The paper is organized as follows: The theoretical grounds are first introduced and thereafter a model of the simulator training program is presented. Presentation of the training program is followed by analyses of the results concerning learners' perspective on simulator training. The results are discussed, with mention of the challenges that emerged in the study. In addition suggestions for the future research are introduced.

# Factors Influencing Surgical Skills Learning with Simulators

How could a simulator training program for surgical residents be designed to take advantage of learning and training theories in order to achieve optimal learning results? The following theoretical review presents the interacting factors of complex surgical skills learning within systematic long term computer-based simulator training.

## *Complexity of Laparoscopic Technique*

Video-assisted surgery has introduced major changes to surgical techniques, although new and even more challenging complex motor skills are needed to practice it. Laparoscopic surgical technique means performing operations through small incisions in the abdominal cavity using long instruments and a camera. The paradox, a spatial challenge, is that two-dimensional pictures are presented on a video monitor from a three-dimensional operation area. Video-assisted skills highlight the importance of visuomotor and perceptual skills as well as motor coordination. Perceptual information in laparoscopy is highly restricted. The operation area cannot be seen directly, or explored with hands, and therefore spatial abilities involved in laparoscopy correlate with surgery performance (Hegarty et al., 2007).

It has been suggested that training novices specifically in instrument manipulation is important, so that their psychomotor skills can become automated before entering the operating room (Jordan et al., 2000). Studies conducted by Keehner et al., 2006, show that interindividual variations diminish with practice. All participants attained laparoscopic skills, but some individuals required considerable practice. However, individual spatial capabilities also have an effect on these skills after a considerable amount of training, probably because users are facing heavy memory loads resulting in errors (Saariluoma & Sajaniemi, 1989; Hegarty et al., 2007). It should similarly be realized that surgical skill is obviously more than just perceptual ability (Hegarty et al., 2007). Perceptual motor skills development is connected to higher cognitive skills development—such as memory, decision making, and problem solving—in addition to visually guided movements training (Ericsson et al., 1993). The complicated sensomotor control environment combined with perceptual challenges has created pressures for changing teaching and learning methods.

## *Learning through Experience*

Insights to computer simulations vary according to learning theories. Training with computers can be seen as an experiential learning activity, meaning that the learner can manipulate learning environment and experience, and visualize learning situations within a dynamic environment (Kolb, 1984; Feinstein et al., 2002). The training technology should therefore accommodate individual learning needs and learning styles (Windsor et al., 2007). Both constructivist and experiential learning approaches highlight the meaning of interactivity and learner control (Mantovani & Castelnuovo, 2003). Current learning theories highlight that new learning experiences are constructed from an individual's former learning, which contributes to the learning of new skills. Learners construct knowledge out of their own experiences, through their own actions, through the evaluation of those actions, and through acquired feedback (e.g. Duffy & Jonassen, 1992; Jonassen, 1999). Kolb, (1984), created a model of experiential learning through four abilities:

concrete experience (CE); reflective observation (RO); abstract conceptualization (AC); and active experimentation (AE). This means that learning occurs through experiencing and doing rather than listening or reading. According to Kolb, experiential learning involves no teaching; however, the learner must be active in processing and reflecting the experiences by themselves in order for learning to occur.

Individuals acquire skills and competence through stages, developing from beginner or novice level towards expertise (originally Dreyfus & Dreyfus, 1980). Patel & Groen, 1991, have similarly described stages of skills development in medical expertise. Motor skills learning is affected by several influential factors such as observing others' focus of attention, feedback after trials, and self-controlled practice with model demonstrations (Wulf et al., 2010). There are also individual differences in learning speeds (Boshuizen et al., 2004). Individually different learning styles affect skills learning. Some are more watcher-oriented and like to learn by watching, whereas doers learn best through active experimentation (Kolb et al., 2001, p. 228). In computer-based learning, knowledge is gained through practice and situational interaction. Learning through experience has been proven to increase student motivation and participation activity (Feinstein et al., 2002).

## *Learners' Time Resources*

Performance improves through training and experience. Complex motor skills training requires deliberate and repeated practice. Learning new movement patterns might require considerable time to process the information (Ericsson, 2004; Schmidt & Lee, 1999). Even though the process of how humans acquire complex motor skills is still not fully understood, researchers in expert performance have documented that it may take years of practice to achieve the highest skill level in a particular sensomotor task (Ericsson et. al, 1993). The acquisition of complex motor skills, such as playing a string instrument, takes considerable time, with expert performance levels requiring approximately 10,000 hours or 10 years of intense practice (Ericsson et al., 1993). The study of Konczak et al., 2009, on violin playing, provided further evidence to support previous studies that optimization of joint coordination patterns for complex fine motor skills is a prolonged learning process that may last years. The level of skills learning and expertise development on perceptual and motor skills is dependent on the quality, length and the amount of experience and training (Ericsson, 2004; Schmidt & Lee, 1999). Since these skills need to be practiced repeatedly and intensively, the simulator is a useful interface for training (Jordan et al., 2000; Kneebone, 2003). Therefore, it should be essential to organize complex skills training systematically and periodically within longer intervals of training. Hospitals are mainly organized to take care of patients; the training of personnel often becomes a secondary task when allocating resources. Therefore opportunities to learn laparoscopic skills with simulators can be expected to have limitations.

## *Simulator as a Learning Tool*

In skills training, simulator functionality has an important influence on user experience, even though surgical simulator studies usually emphasize technical standards and validations (Karaseitanidis et al., 2006; Stone & McCloy, 2004). The potential to enhance learning and offer support and feedback to learners should be underlined. Managing simulator-based learning must be an active process, and simply providing sophisticated equipment will not guarantee a successful learning outcome (Jonassen, 1999; Kneebone, 2003).

Learning has been proven to intensify alongside virtual realism, when learners are able to make meaningful first-person experiences, feel (emotionally and cognitively) present in the situation and fail in a safe environment (Mantovani & Castelnuovo, 2003). They connected this sense of presence in learning environments into four areas: perceptual features; individual factors; content characteristics and interpersonal; and social and cultural context. In order to enhance the feeling of realism, a good simulator should also: offer haptic feedback; an anatomically realistic view; and must interact realistically with the surgeon's actions (Schijven & Jakimowiczm, 2003). This feedback is important, although surgeons trust greatly in the information from tactile sense and through laparoscopic instruments (Brydges et al., 2005).

A key issue is the relationship between skills learned in a simulated environment and skills applied in real clinical situations (Kneebone, 2003). Cognitive science and situated learning research further supports the benefits of learning skills through active engagement in simulated situations, and to practice with similar equipment to that in the real world (Feinstein et al., 2002; Lave & Wenger, 1991). Manipulating objects is an important way to interact with the simulated environment. Also necessary are opportunities: to receive instructional feedback; to reflect and to analyze own behavior as well as modify own actions; that have been proven to enhance a sense of presence through interactivity and learning control and to promote the transfer of knowledge from the simulation context to the real one (Ericsson, 2006; Mantovani & Castelnuovo, 2003). The important aspect is the degree to which learned abilities, knowledge, skills and attitudes transfer to authentic similar contexts and situations, such as basic psychomotor skills and tasks provided in laparoscopy (Feldman et al., 2004; Newell & Simon, 1972; Singley & Anderson, 1983).

## *Skills Learning Curriculum*

The advantages of simulator training in surgical laparoscopy have been studied increasingly in past years, and it has been proven that simulator training methods must be properly embedded in the learning context of the institution in which they will be used or they will fail (van Dongen, 2011). A learning space must be provided for the student to fully engage in the four modes of the cycle: feeling, reflection, thinking, and action. The learning space needs to be hospitable, welcome, safe, and supportive—but also challenging (Kolb & Kolb, 2009). It should allow learners to be in charge of their own learning, and it should give them time for the repetitive practice that develops expertise (Kolb & Kolb, 2009).

Knowledge from a performance environment is important in curriculum design. For decades, traditional apprentice training has been subsumed into a hospital's everyday routines and has thus become nearly invisible. Therefore, it is important to construct teaching protocols that are effective and capable of being embedded within organizational processes (Reznick & McRae, 2006). Most residents begin their residency without any manual skills in laparoscopy, thus early residency should be the best point to introduce simulator training, when students are highly motivated and have not developed routine working methods (Enochsson et al., 2004; Ström et al., 2002).

To reach the required competence, simulator training for surgical residents should be connected into curricula and pedagogical practice, and should rely on the teaching skills of experienced surgeons (Ström et al., 2002). An ongoing and supervised training program is essential, though residents still need an adequate level of content-based feedback and supervisor support during training. Solely autonomous training with the simulator is not sufficient for developing adequate levels of performance (Silvennoinen et al., 2011). Through repetitive practice it has been confirmed that the performance of novice surgeons improves more when the learning concept includes distributed rather than massed training sessions (Aggarwal et al., 2006). Similarly, as in traditional surgical skills learning, simulator training should begin with observing experts and performing tasks by following their model.

Unlimited access to practice basic surgical skills with a simulator, but without any form of obligation or assessment, has proved to be insufficient to maintain their motivation and active practicing (van Dongen et al., 2008). Unfortunately, the important role of learner motivation has, until recently, been largely neglected in motor learning literature (Wulf et al., 2010). Feedback that emphasizes successful performance benefits learning due to its positive motivational effects, therefore feedback for increasing training motivation should be available (Wulf et al., 2010). The provision of especially facilitative feedback can be seen as one of the most influential factors in medical skills learning (Archer, 2010; Mann, 2011). Verbal feedback from an expert instructor has been demonstrated to lead to lasting improvements in technical skills performance (Porte et al., 2007).

To optimally enhance skills learning, the educational experience should be learner-centered instead of patient-centered, as is appropriate in actual clinical settings (Scalese et al., 2008). Individual differences in learning speed should be taken into account when designing training (Kolb et al., 2001; Boshuizen et al., 2004). Challenges and difficulties need to be carefully managed, together with learning goals (Mantovani & Castelnuovo, 2003). Structured and carefully planned curriculum-based simulator training offers opportunity to gain and assess skills through repeated practice within a supportive, learner-centered, and safe environment that includes expert feedback.

Gathered from the theoretical review presented above, Table 1 presents the factors influencing complex surgical skills learning within systematic long term computer-based simulator training.

**Table 1: Factors influencing skills learning in computer-based simulator training**

| COMPLEXITY OF PREQUISITE SKILLS | INDIVIDUAL LEARNING FACTORS | PEDAGOGICAL DESIGN | TRAINING EQUIPMENT USABILITY AND EFFICACY | LEARNERS TIME RESOURCES AND MOTIVATION |
|---|---|---|---|---|
| Perceptual & motor demands | Prior learning experiences | Structure of training | Realism of training environment | Time to participate |
| Individual abilities | Different learning styles | Instructions, support & feedback | Interactivity and learner control | Motivation to deliberate and repeated practicing |
| | Learning speeds | Setting the learning objectives | Potentials to enhance skills learning and transfer | Capability to maintain training intensity |

Medical educators today are seeking to develop physicians who are competent in self-assessment and self-monitoring, as well as orientated to lifelong learning and skills development throughout their practice lifetime (Mann, 2011). Mann defines these meta-skills as knowledge on “how to learn” and “what to learn”. Porte et al., 2007, suggest in their study that the availability of expert demonstrations, together with motion feedback, and along with appropriate instruction in self-evaluation, might prove to be an effective educational method for surgical skills learning with simulators. In the studies investigating surgical residents’ self-assessments, it has been noticed that residents’ self-assessments and expert independent assessments might correlate poorly, and therefore regular technical feedback during training is essential (Pandey et al., 2008). These poor correlations, however, might relate to the lack of surgical trainees’ self-assessment skills. Self-assessment is rarely utilized in surgical training even though residents could play an active role in identifying their training needs through self-assessment of their procedural skills (Suwanabol et al., 2009). Suwanabol et al. also argues that residents’ experiences can be used as a means for self-directed learning.

## Research Design and Study

Surgical residents’ laparoscopic skills training were organized and studied in the Central Hospital of Central Finland, which caters for a population of almost 280 000. The training program for surgical residents was constructed within a multidisciplinary project, bringing together knowledge gained from education, cognitive science, and surgery. Participation in training was voluntary. A quantitative study on residents' experiences and their perceptions on training was conducted during the training program.

## *Laparoscopic Skills Curriculum*

The training program for surgical residents was launched in March 2008. Objectives for the simulator training were to be effective and motivating, and to offer adequate challenges to maintain the learners' interests towards their training. Both specialists and resident surgeons were offered additional user support during training that was provided by a facilitator. Working independently or in pairs, the residents were instructed and supervised by a specialist surgeon in using the simulator and in practicing exercises. Figure 1 presents the structure of the training curriculum, including three short, approximately one hour sessions with a specialist instructor, and two longer independent self-training periods.

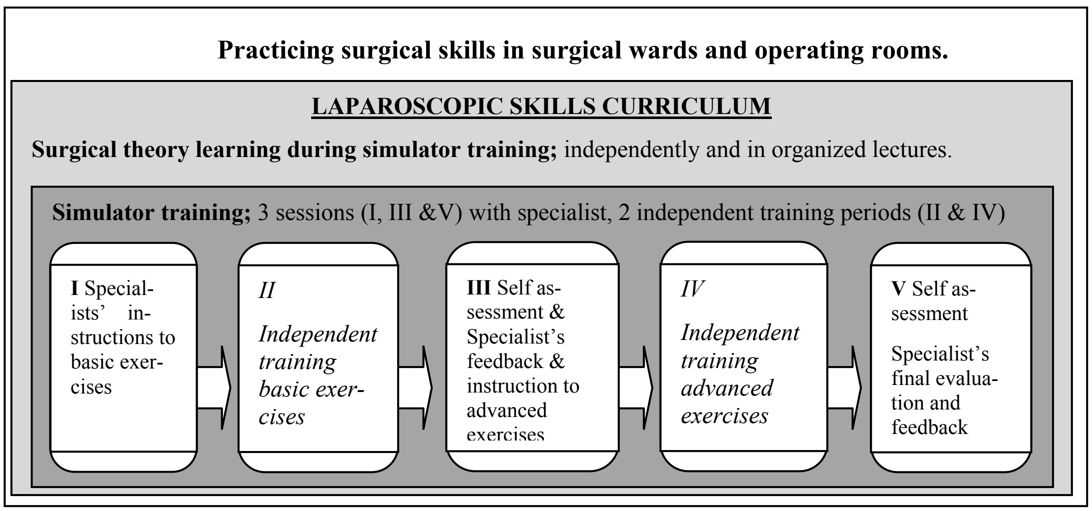


**Figure 1: Surgical residents' laparoscopic skills training curriculum**

The three instructive sessions with both the specialist and the resident surgeon are sessions I, III and V. The independent training phases are II and IV. All residents practiced the same selected exercises at an individual pace. Simulator training is seen as a complementary element in surgical resident training, where the overall aim is to integrate the residents' surgical theory learning and instructed training within both authentic and simulated environments. Simulator training objectives were to learn laparoscopic basic skills, such as instrument manipulation in three-dimensional spaces, and to further proceed towards a more efficient acquisition of laparoscopic operating skills by training whole surgical operations in the phase IV. During the training period, specialist surgeons organized lectures on laparoscopy, during which, for example, video material from real operations was presented to trainees.

Effective and motivating training, however, necessitates intense commitment from all the participants, including surgical trainees and their supervisors. To support residents' learning, and to maintain their motivation and active participation, residents were offered support for equipment usage during training, and freedom to decide when they were skilled enough to move on to the next level. No upper or minimum limit to training times was assigned. Residents were also given support for evaluating their own skills, since they had simulator parameter information available to help them fill self-assessments after their independent training periods. A safe and supportive training environment was created, allowing time for the repetitive practices (see Kolb & Kolb, 2009, & Ericsson, 2006).

Simulator training took place in a medical skills learning center inside the hospital, where residents could practice their skills at an individual pace when actual patient care allowed. The support during training was offered through a specialist demonstrating the tasks and procedures at the beginning of each session. After self-training periods and resident self-assessments, the supervisors offered individual feedback for each resident. Supervision was seen as an important element during the whole training program. Specialist instructors were encouraged to give feedback to residents verbally, and also to fill in an evaluation form when observing residents performing the exercises. Supervisors were also instructed to discuss skills learning and performance development with learners after each evaluation. The simulator automatically measured the learning results as performance parameters during training. Both objective and subjective evaluation information were therefore present for both learners and their instructors during training. The training was organized at hospital within real patient treatments. This was considered to be an additional connective link from the simulator to real workplace learning.

## Training Equipment and Participants

Training was conducted in medical skills learning centers using the interactive LAP Mentor™ surgery simulator, which is a computer specifically designed for laparoscopic training. It has real surgical instrument handles and pedals for conducting procedures in three-dimensional virtual interfaces.

**Picture 1 LAP Mentor™ surgery simulator**

Surgical instruments are inserted through specific instrument ports, creating a haptic sensation, a realistic sense of "touch" on contact with tissues and organs. Instrument tips and movements are visualized artificially and presented on a computer screen. The simulator allows for a variety of practice opportunities, beginning from a total of nine basic game tasks intended to familiarize one with the instruments and laparoscopic movement patterns, right up to suturation training, several advanced tasks on various partial procedures, and full procedures with anatomical variations and anomalies. Each of the basic game exercises takes only a few minutes to perform. The whole operation lasts naturally longer, even half an hour. The precise time to conduct one exercise is dependent on the nature of the exercise as well as the performer's skill and style. Some of the exercises also include video images of real operations. Immediately after each exercise in the performance, the training results are presented to the learner (the simulator automatically logs a set of primary performance parameters for each task).

We studied 14 surgical residents who completed the first part of training sessions I & II (Figure 1). Participants included 7 men and 7 women with an average age of 31 years. All residents worked in a hospital while participating in the training programme.

## Research Questions

In the hospital environment it was expected to come across various challenges concerning time usage and adaptation to new workplace learning methods. In this study, the main interests were learners' perceptions as well as their experiences with simulator training and exercises.

The goal of this study was to answer four main questions:

(1) What were the surgical residents' learning expectations and perceptions pertaining to laparoscopic simulator training?

(2) How did the surgical residents self-assess their progress during training?

(3) How were the simulator training and exercises experienced?

(4) What were the residents' self-assessed advantages on simulator training?

## Research Data and Analysis

In the study, we administered questionnaires both before and after training. Data was collected from the first and third sessions of the training program, both before and after the participants trained in the basic skills exercises. The research data contained participants' background information as well as information concerning training experience and exercises. This information was collected via questionnaires (see Figure 2) before training (I), and also after the basic skills training period (III). This first simulator training period lasted approximately 1 to 4 months and contained five basic skills exercises. The five exercises included: 1) camera manipulation; 2) clip applying; 3) picking up objects; 4) cutting with electricity; and 5) translocation of objects.

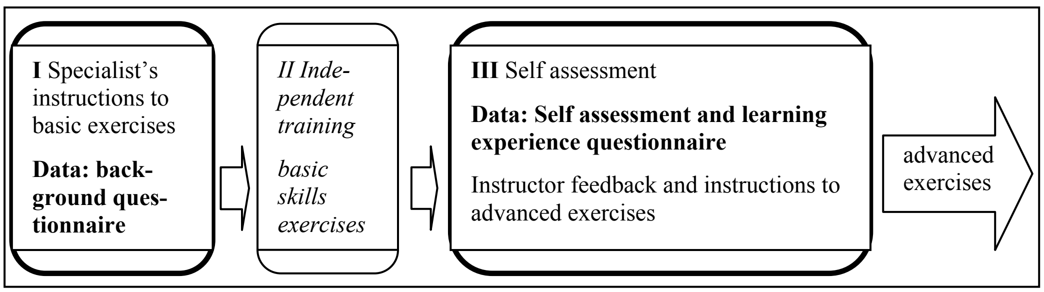


**Figure 2: Questionnaire data gathering during surgical skills training.**

Residents were instructed in the simulator and laparoscopic skills learning, and thereafter they individually defined the learning and training objectives and expectations in the background questionnaire. They were told to practice each exercise several times until they felt confident and skillful in it. After each training period, the residents filled in self-assessment forms designed to help them to reflect on their performances and learning. Residents were also asked questions concerning their training experiences and exercises. The transfer of skills from a simulated to an authentic environment was not measured. However, in the self assessment questionnaire there were questions related to self experienced skills transfer.

Analysis of all results were conducted *(n = 14)*, and divided into two groups. The distribution of prior experience was: *Group 1 (n = 6), no laparoscopic operating experience*, although some had performed preparative actions and wound closures in the operating theatre, and had acted as assistants under senior supervision; and *Group 2 (n=8), laparoscopic operating experience*, which meant that these residents had performed at least part of a laparoscopic operation under senior supervision. The most experienced residents in Group 2 had performed a few laparoscopic operations independently and without supervision. We compared the effect of laparoscopic operating experience on participants' questionnaire results.

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 results (after the course). In addition, questions included assessing exercises and a nonparametric Wilcoxon signed-rank test was used to determine improvement or change within groups, with a Mann-Whitney *U* test used to evaluate differences between the two groups.

# Results

Surgical residents' learning 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.

## *Training and Learning Expectations and Perceptions*

We were interested in the learning objectives of the residents, and whether there were any inconsistencies concerning learning expectations and curriculum objectives—such as unrealistically high expectations towards simulator training—that could affect training motivation.

The results of the learning expectations (n=14) regarding the simulator training indicated that the residents without operating experience (Group 1) mostly expected to become better acquainted with laparoscopic techniques and instrument handling, and to adapt to the new surgical technique. They also expected to be able to comprehend a two-dimensional video picture while they were operating. The experienced trainees (Group 2) mostly expected to achieve better dexterity and more efficient hand-eye coordination. They further expected to develop a routine in the procedure, and to learn new procedures. The results were consistent with the curriculum objectives, which were first to teach the basic skills— such as instrument manipulation and adaptation to three dimensional spaces—and then, at a more advanced level, to teach complete surgical operations and suturations.

The residents' perceptions on simulator training were defined through argumentative questions. To clarify whether these perceptions had changed during training, the same questions were asked before and after the training period. The expectation concerning perceptions was that through experience, training time within normal working hours might be found inadequate, and that difficulties finding training time might emerge. Also, to accumulate adequate training time, motivated residents were expected to be more willing to practice skills outside their working hours. Results showed significant changes in residents' perceptions during training, see Table 2.

**Table 2: Residents' perceptions on simulator training and changes during training period.**

| Arguments | Total group (n=14) | | | Group 1 (n=6) | | | Group 2 (n=8) | | |
|---|---|---|---|---|---|---|---|---|---|
| (1=totally agree - 5= totally disagree) | Mean before | Mean after | Wilcoxon test (p) | Mean before | Mean after | Wilcoxon test (p) | Mean before | Mean after | Wilcoxon test (p) |
| I will experience difficulties to find time for training | 2.93 | 2.14 | **.008** | 3.33 | 2.67 | p=.125 | 2.63 | 1.75 | .063 |
| I am also willing to exercise outside working hours | 1.64 | 2.43 | **.020** | 1.67 | 2.17 | p=.188 | 1.63 | 2.63 | .063 |
| I am motivated for training | 1.54 | 1.86 | .125 | 1.17 | 1.50 | p=.250 | 1.86 | 2.13 | .500 |
| The simulator training is necessary for me | 1.38 | 1.50 | .234 | 1.17 | 1.50 | p=.250 | 1.57 | 1.50 | .500 |

(p <.05 significant)

Increased training time difficulties was seen with half (7 out of 14 residents), with the other half expressing no change in their perceptions. Opposite to our expectations, a significant change was seen in the willingness to exercise outside working hours. Only one resident was willing to practice skills outside working hours more than at the beginning of training. Seven residents' perceptions concerning training outside normal working hours changed negatively, and they were not as enthusiastic to this training option after the first training period. Six residents expressed no change. The change in the more experienced residents' group was almost significant.

There were no significant differences in perceptions between the two groups (Mann-Whitney *U* test: [p>.05]). There was also a slight, although non-significant, decrease in motivation in both groups, which might relate to the significant decrease in willingness to exercise outside working hours. Despite this, all residents felt that simulator training was necessary for them both before and after the training period. It was also interesting to note that residents' perceptions on simulator training necessity became congruent while training proceeded (Group 1: before 1.17=> after 1.5; and Group 2: before 1.7 => after 1.5). The less experienced residents felt the training to be slightly less necessary for them after than before training, contrary to the experienced residents, who felt training to be slightly more necessary for them after than before training.

## *Learning Confidence – Self-Assessed Progress*

There was a prior expectation that during the training period the laparoscopic skills of all residents would increase. It was anticipated that especially the less experienced residents would express more significant improvements on their skills assessments. The residents were asked to score their current laparoscopic skills on a scale 0 – 10 both before and after the training period. Results showed that self-assessed skills were significantly improved in the total group compared to the state before training, see Table 3). Improvement was expressed by 12 residents out of a total of 14.  The self-assessed development of skills changed significantly, and the change was equal in both groups separately. All residents in Group 1 valued positive skills development after the training period. Only two residents in the more experienced Group 2 reported no change in their laparoscopic skills. The assessed level of skills before and also after training was assumable higher in Group 2.

**Table 3: Self-assessed laparoscopic skills scores before and after the training period and significance of the changes.**

| **Laparoscopic skills (n=14)**<br>(0 = no skills) – (10 = excellent skills) | Mean | Stdev. | Wilcoxon test (p) |
|---|---|---|---|
| Skills before | 1.29 | 1.326 | |
| Skills after | 3.86 | 1.791 | .000 |
| Skills before (Group1) | 0.17 | 0.408 | |
| Skills after (Group1) | 3.17 | 1.722 | .016 |
| Skills before (Group2) | 2.13 | 1.126 | |
| Skills after (Group2) | 4.38 | 1.768 | .016 |

(p <.05 significant)

The significant change in laparoscopic skills within both groups is naturally affected by both simulator training and also operating room experience. However, the skills where improvement was also assessed related to simulator training only, which also provided positive results (see Table 4). After the training period, residents were requested to assess their skill development from 1 to 5 during simulator training in twelve specific laparoscopic skills.

**Table 4: Self assessed improvement in laparoscopic skills during simulator training.**

| **Laparoscopic skills (n=14)**<br>(1 = weak skill development) – (5 = remarkable skill development) | Mean | Stdev. |
|---|---|---|
| All 12 skills | 3.41 | 0.92 |
| Camera optics (smallest) | 2.93 | .997 |
| Moving objects (greatest) | 3.71 | .825 |

Self-assessed skills improvement during simulator training in all twelve skills combined varied from 1 to 5 (Stdev. = 0.92). The skill improvement in camera optics was assessed smallest. The skill improvement in moving objects was assessed greatest. It was anticipated that less experienced participants would express notable skills development. However, there were no significant differences in assessments (Mann-Whitney *U* test: [p>.05]) between the mean values of groups 1 and 2. Consistent to prior expectations, the self-assessed skill improvement during simulator training was fairly high in all skills combined. Several participants also reported considerable improvements in various skills. On the other hand, some residents reported minor skills development.

It was assumed that skills would be assessed high after training, although the participants were instructed to practice until they felt that the task proceeded fluently when they would need no further exercises on current tasks. The residents were requested to assess their skill development in the five simulator exercises that they practiced, on a scale 1 – 5, after the training period. The results showed self-assessed improvements in all five exercises, see Table 5.

**Table 5: Self assessed improvement in the simulator exercises.**

| **Simulator exercises (Total n=14)**<br>(1=weak skill development) – (5= remarkable skill development) | **n** | **Mean** | **Stdev** | **Min** | **Max** |
|---|---|---|---|---|---|
| Camera | 13 | 2.92 | .494 | 2 | 4 |
| Clipping | 12 | 3.58 | .515 | 3 | 4 |
| Picking up | 13 | 3.85 | .376 | 3 | 4 |
| Electricity | 13 | 3.46 | .660 | 2 | 4 |
| Translocation | 13 | 3.08 | .862 | 1 | 4 |
| Total | | 3.38 | .673 | 1 | 4 |

There was one participant's answer missing from these questions, and one participant's answer also missing from the question on the clipping task. The amount of improvement in translocation varied most, from 1 – 4 (Stdev. = 0.862). The skill in camera task was least improved. The skill in picking up objects was most improved. There was no significant difference between groups 1 and 2 (Mann-Whitney *U* test [p>.05]). Surprisingly, there was not a single value of 5 in the participants' answers. In fact there were values of 1 and 2 in three exercises, which meant that the residents' self-assessed improvements were weak (or somewhat weak), and they still wanted to continue to the next, more advanced level of training. This indicated that residents were either in a hurry or wanted more challenges. The participants also reported that they found it somewhat difficult to self-value their skills (n=14). Difficulties on evaluating skills might be a reflection of uncertainty of individual skill level, or a lack of experience on self-assessment.

## *User Experience*

The user experience was first studied by defining if the difficulty level of the selected exercises was appropriate for the residents: on one hand, not too easy to maintain their interest and motivation; and on the other hand, not too demanding to hinder their learning progress. The expectation was that there would be differences in the assessments between more experienced and less experienced residents. The residents' experiences on the difficulty level of the exercises were quite easy, see Table 6.

**Table 6: Experienced difficulty level of the exercises**

| **Simulator exercises (Total n=14)**<br>(1 = easy ) – (5 = extremely difficult) | **n** | **Mean** | **Stdev** |
|---|---|---|---|
| Camera | 13 | 2.77 | .303 |
| Clipping | 12 | 1.67 | .188 |
| Picking up | 13 | 2.31 | .308 |
| Electricity | 13 | 2.62 | .290 |
| Translocation | 13 | 3.38 | .290 |
| Total | | 2.56 | 1.125 |

There was again one participant's answer missing from these questions, and one participant's answer also missing from the question on the clipping task. According to the participants' experiences, the clipping task was clearly valued easiest, and the translocation of objects was experienced as the most difficult exercise. However, the deviation within answers was notable both within and between exercises (Stdev. = 1.125). Surprisingly, the results of the Mann-Whitney *U* test showed significant difference ($p<.05$) between the mean values of Groups 1 and 2 only in one exercise: camera ($p=.025$). All residents in Group 2, as well as five out of a total of six residents in Group 1 (who had already worked as assistants in the operating room), had camera usage experience from the operating room. The assistant's main task is to hold and use the laparoscopic camera. On the other hand, it was surprising that even though the residents in Group 2, contrary to those in Group 1, had experience from operating and using other laparoscopic instruments as well, they still expressed a difficulty level similar to that of the less experienced residents in all other four exercises.

Secondly, the simulator functionality (as an important feature affecting user experience), was studied. We anticipated that if the residents were facing technical problems, it might have a negative effect on further training activity and motivation. The participants were asked to score whether they had experienced any functionality problems in the simulator exercises while training on a scale 1 – 5. They were also told to elaborate on an open question, if they had experienced problems. All the exercises were scored as having a rather similar amount of problems, see Table 7.

**Table 7: Level of functionality problems experienced in each of five simulator exercises and amount of residents expressing problems in these exercises.**

| **Simulator exercises (n=12 /14)** (1= plenty of problems) – (5 = no problems) | **Mean** | **Amount of residents expressing problems / no problems during training** | |
|---|---|---|---|
| | | *Plenty/quite plenty of problems (values 1&2) n* | *No problems (value 5) n* |
| Camera | 3.17 | 3 | 2 |
| Clipping | 3.17 | 3 | 1 |
| Picking up | 3.08 | 3 | 1 |
| Electricity | 3.33 | 3 | 2 |
| Translocation | 3.17 | 4 | 2 |

There was two participant's answer missing from these questions. The results also showed that at least three out of twelve respondents in each exercise reported having plenty or quite plenty (values 1/2) functionality problems with the simulator. Only one respondent reported no problems in the exercises. In the translocation exercise, 1/3 of the participants had experienced simulator functionality problems. Translocation was also previously scored as the most difficult exercise, which might also result from functionality problems rather than a lack of skills.

More complete information on simulator user experience, satisfaction, and additional learning information was collected from four argumentative questions, see Table 8.

**Table 8: Satisfaction towards the exercises and the simulator**

| Arguments (**Total n=14**) (1=totally agree) – (5= totally disagree) | n | Mean | Stdev. |
|---|---|---|---|
| The amount of exercises was inadequate | 13 | 4.15 | 1.068 |
| The variability of the exercises was adequate | 12 | 1.75 | .622 |
| The exercises offered challenges for me | 13 | 2.23 | .927 |
| Learning to use the simulator was difficult. | 12 | 4.42 | .515 |

There was one participant's answer missing from two of these questions, and two participants' answer also missing from another two questions. The residents in both groups were overall rather satisfied with the amount and variability of the exercises. They also felt that the exercises were somewhat challenging, and that they somewhat disagreed that learning to use the simulator was difficult. Based on prior results received from skills improvements which indicated that the residents might had wanted more challenges concerning the exercises is contrary to these results. Residents felt the exercises somewhat challenging, so this refutes the earlier speculation. There were no significant differences between the two experience groups (Mann-Whitney *U* test [$p>.05$])

## Advantages Gained from Training

After training, the residents were asked in an open question whether they had already worked in an OR, and if so, what skills learned during simulator training had they been able to use in the OR. Seven residents out of fourteen answered that they had been able to use their learned simulator skills in OR. These skills pertained mostly to the manipulation and identification of instruments. Residents felt that the simulator training was particularly useful in familiarizing oneself with the laparoscopic view of an abdominal cavity, as well as instrument manipulation in three-dimensional spaces. Five residents also felt that either assisting with the camera, or with instrument usage, had become easier for them in operations.

They were asked what benefits from the training related to instrument handling and their confidence to operate on real patients. We expected that, along with the simulator training, both instrument manipulation and experienced readiness to operate would have become easier, especially in the less experienced Group 1. The results showed significant differences between experience groups (Mann-Whitney *U* test [p>.05]), see Table 9.

**Table 9: Surgical resident's experiences on simulator training advantages**

| Arguments (1 = totally agree) – (5 = totally disagree) | Total n=14 | | Laparoscopic operating experience | | | | Mann-Whitney test |
|---|---|---|---|---|---|---|---|
| | | | Group 1 n=6 | | Group 2 n=8 | | |
| | Mean | Stdev. | Mean | Stdev. | Mean | Stdev. | |
| The confidence in instrument manipulation increased along with simulator training. | 1.93 | .829 | 1.33 | .516 | 2.38 | .744 | .013 |
| Readiness to operate patients increased along with simulator training. | 2.29 | 1.204 | 1.33 | .516 | 3.0 | 1.069 | .004 |

(p <.05 significant)

Residents somewhat agreed that their confidence in instrument manipulation had increased along with simulator training and actually none disagreed with this argument. Similarly, the residents somewhat agreed that their readiness to operate patients had increased along with simulator training. Two residents from Group 2 disagreed with this argument, which can be explained from their higher level of experience. They probably felt that they had already gained an adequate amount of confidence to operate during their work in OR.

The results of showed that there was significant difference between the mean values of Groups 1 and 2. The residents without operating experience felt significantly more that their readiness to operate had increased along with simulator training, and their confidence in instrument manipulation had increased along with simulator training significantly more compared to residents with operating experience. These results indicated that the less experienced learners felt the simulator training to be more beneficial based on these training advantages. However, the results also indicated that residents with operating experience also found the simulator training beneficial, especially concerning instrument manipulation confidence. There was also greater individual variation within Group 2 (Stdev. = 1.069), which revealed that some of the participants agreed that readiness to operate had also increased along with simulator training.

# Discussion

Today, surgical laparoscopic operating skills in Finland can be practiced both traditionally, by gaining experience in the operating room, and also, increasingly, with simulators. As also discussed in earlier studies (e.g., Aggarwal et al., 2006; Cosman et al, 2002; Schjiven et al., 2005), simulator training should be introduced to surgical resident education. These techniques should preferably be practiced repeatedly, within longer periods, and with pedagogically designed and systematically implemented training programs. This paper demonstrates that there are various factors influencing surgical skills learning with simulators. These begin from the learning objectives and skills in question, to learners' individual characteristics and resources as well as training environmental factors. These factors should be taken into account when implementing and designing surgical training programs utilizing simulators.

This paper also highlights that the implementation of training programs should be based on the theoretical guidelines of skills learning. During surgical residency, learners should be offered increasingly more opportunities to learn laparoscopy through experiential learning. The curricula should be an optimal combination of: theory learning; instructed simulator exercises aiming at further skills and practicing in an authentic environment under a senior surgeon's supervision. This study presents one suggestion on how to improve and intensify laparoscopic skills learning. It highlights that self-assessment of skills is an important way to become aware of one's weaknesses and strengths— an imperative meta-skill for learning. Therefore self-assessment opportunities should be supported in skills curricula. In this study, the learning was supported by an interval form of simulator training, where there were alternating instruction and assessment sessions with specialist surgeons together with individual training periods. Self-assessment could also be used as one tool in defining the success of training programs. This study argues that it is important for educational implementation that the learner's experience is considered.

This study defined the surgical resident's expectations, perceptions, and experiences pertaining to laparoscopic simulator training, as well as their self-valued progress and the advantages gained from the training period. An overview of these results is presented in Table 10.

These results show that even though the expectations towards simulator training were realistic, and congruent with training objectives, the surgical residents' perceptions on performing simulator training changed during their studied training period. Results indicated that the expectations towards one's own opportunities to practice with a simulator were somewhat overestimated, and that residents felt significantly less enthusiastic to train outside normal working hours after the first period. Their motivation also slightly decreased during the first part of the training. Also the residents self-valued skill levels might still be rather weak when they wanted to move on to the next level of training. Could these results indicate that the residents were not motivated to undergo further practice in basic level tasks? On the other hand the results could indicate time allocation problems, where residents did not have sufficient time to practice as much as they would have needed to reach the preferred skill levels. Participants did express considerable skills development; although self-valued performance improvements in specific simulator training tasks remained rather low. The fact that laparoscopic skills are complex and need plenty of time to learn could explain this incongruence. In the study of van Dongen et al., 2011, all subjects completed 15 repetitions of basic skills tasks which still proved to be insufficient for novices to be able to reach expert scores. In our study, the average amount of resident performance was around 10 repetitions or less depending on the task. Obviously, optimal skill development would have needed more repetition and training and exercises were to some extent done in a hurry. In that light these results indicate that the training time within normal working hours was found inadequate, and difficulties finding time for training emerged.

The problems with the training schedule support the results from our prior study, where during the training emerged as time allocation difficulties, as well as a lack of commitment of some residents and supervisors (Silvennoinen, Antikainen, & Mecklin, 2009). This is supported, also, in the earlier study results of van Dongen et al., 2008, which address that residents do not use personal free time for simulator training to improve their skills. Therefore, the problematic aspect is not so much the residents' lack of interest towards simulator training, or that they do not see the training as necessary. Instead, we should consider this result as a residents' training resource problem. Surgical skills learning at hospitals should be supported at the organizational level and working time should be allocated to enable more flexible training schedules. It is in the hands of superiors to concentrate more on issues how to improve and intensify commitment and the orderliness of surgical skills learning at hospitals.

**Table 10: Summary of the main results on surgical residents' experiences**

| THEMES | SURGICAL RESIDENTS LEARNING EXPERIENCES | MAIN CONCLUSIONS |
|---|---|---|
| ***Training and learning expectations and perceptions*** | Learning expectations congruent with curriculum objectives, realistic expectations concerning the type of practiced skills.Group 1: techniques, instrument handling, dimensional adaptation. Group 2: dexterity, efficiency, routines, and new procedures.<br>Along with training: 1. Decreased willingness to exercise outside working hours; 2. Perceived difficulties of finding time for training; 3. Slightly decreased motivation.<br>Simulator training was felt necessary both before and after the first training period. Group 1 felt the training slightly less necessary for them after training than before, contrary to operation-experienced residents, who felt training slightly more necessary for them after training than before. | **Expectations towards individual opportunities to practice with simulator were overestimated—problems with the training schedule.**<br>**Simulator training was experienced necessary and therefore should be offered for all surgical residents. Allocating training and working schedules must be managed more systematically in the future.** |
| ***Learning confidence – self-assessed progress*** | Significant positive skills development in laparoscopic skills during simulator training. All residents without operating experience expressed skills development.<br>Excellent skills levels on exercises were not reached when participants already wanted to continue to the next, more advanced, level of training. This indicates that the residents were in a hurry when practicing simulator exercises.<br>Instrument handling, for example laparoscopic camera skill, needs further training. Self-assessment of skills experienced as somewhat difficult. Lack of significant differences between the two experience groups. | **Residents were confident on their skills development during training— important for maintenance of training motivation.**<br>**Probably not enough time for training to reach a preferred skill level.**<br>**Skills development during simulator training experienced similar, irrespective of residents' prior operating experiences.** |
| ***User experience*** | The amount, variability, difficulty, and level of challenge that the exercises gave was rather satisfying.<br>Lack of significant differences between the two experience groups, except on camera exercise, which was considered more difficult by residents without laparoscopic operating experience than those with operating experience.<br>Simulator was considered relatively easy to use, despite that 1/3 reported plenty / quite plenty functionality problems in each task. Only one participant reported no problems. | **Functionality problems should be diminished, even though the learners were rather satisfied with the simulator and the exercises.**<br>**Equipment functionality might distort skills and difficulty level assessments.** |
| ***Advantages gained from training*** | Skills learned and transferred in OR; instrument manipulation; instrument identification; adjusting to laparoscopic view. Simulator training had positive effects on skills in OR. Both assisting and operating became easier.<br>Residents without laparoscopic operating experience considered simulator training to be more beneficial compared to residents with laparoscopic operating experience. However, the more experienced residents also found simulator training beneficial, especially concerning confidence gained in instrument manipulation. | **Residents acquired confidence, and their readiness to operate increased; training made assisting and operating in OR easier.**<br>**Simulator training was considered a beneficial experience, especially by residents without laparoscopic operating experience, but also by more experienced residents.** |

Residents were confident with their skills development during training, which can be seen as an important feature for maintaining training motivation. It is important for residents to feel that their training needs are being met (Suwanabol et al., 2009). In this study, skills development during simulator training was similar, irrespective of residents' prior operating experiences. Even though residents' training motivation was probably not decreased by the lack of confidence in the benefits of simulator training, they were facing not only time allocation problems but also simulator functionality problems. The result that plenty of functionality problems occurred within training is quite concerning, and leads to questioning of how these technical problems could be eliminated, and what designers could do to develop the simulator to be more user friendly.

Also, the self-assessment of skills was considered somewhat difficult, which might have reflected on the results. Therefore, more practice on both exercises, as well as on self-assessment skills, is justifiable—although the difficulties in self-assessment could have partially been interfered with, or complicated by, equipment functionality problems during training. The ability to assess one's own performance—critical in surgery—is important throughout one’s working career, and should be highlighted by educators (Pandey et al., 2008).

The differences between residents with and without laparoscopic operating experience were generally not as significant as expected before the study, even though a few differences were found. Simulator training was considered beneficial, especially by residents without laparoscopic operating experience. Similar arguments have also been presented by Huang et al., 2005 and Sturm et al., 2008, that simulator learning experience creates a feeling of confidence—especially on novice trainees. In this study, also, more experienced residents gained confidence from simulator training. This study’s results indicating that practicing laparoscopic skills with a simulator made assisting and operating in the OR easier are supported by earlier studies arguing that skill transfer from simulator training to authentic operating occurs (Seymour et al., 2002, Sturm et al.,2008). However, we have to be aware of the fact that self-assessed progress in skill development is not a valid measure for skills learning, even though learner experiences and learner perceptions towards training are important factors in explaining motivation and training activity. This study demonstrated that the skills were learned (according to the trainees); although there is no proof that skill development really occurred. Simulators, as well, have limitations for assessment purposes (Silvennoinen et al., 2011).

Limitations of the study are that the results were obtained from a relatively small sampling and not drawn until the end of the entire training program; however, there were only a few residents who completed the whole training program within this particular period of the study, and therefore the sampling would have been even smaller. The surgical residents also received instructor assessments on their performances. These assessments were also excluded from this study, because there was no homogenous form or line between instructors. Assessments conducted with several different specialists were mainly designed for learner support, and as a basis for learner-instructor discussions, not for comparative evaluations. Within this perspective, it would be interesting to further investigate whether these skills (and in what quantities), actually transfer in the OR (for example), according to the instructor specialists. Further research is obviously still needed to investigate the efficacy of surgical curricula using simulator training.

The implications of this research for the design and implementation of effective curricula for surgical residents are that the teaching and learning of surgical skills in a hospital environment with simulator training needs careful planning. Recent review by McGaghie et al., 2011 also highlights that simulation-based medical education needs to be planned and practiced with attention to organizational contexts. This study showed that several aspects would be beneficial to recognize in future curriculum implementation, especially allocating and coordinating residents’ time more effectively for the obligatory participation and goal oriented practice. Similar arguments are presented by van Dongen et al., 2011, in his thesis, that proficiency-based training programs should include reference points based on expert scores on standardized expert evaluations, instead of training curricula based on a fixed number of repetitions.

# Conclusion

Simulator training is seen as a beneficial way to enhance complex video-assisted surgical skills during residency. We should continue to create new skills, learning/teaching methods, and pedagogical cultures, as well as a safety-oriented operating culture for hospitals educating medical specialists. In this study, simulator training had a supplementary role within the residents' traditional work-place learning. The fact that while participating in the training programs both residents and supervisors are working at the hospital creates challenges for simulator curriculum realization. In the future, we should aim to solve these resource problems so that learning and teaching at hospitals using surgical simulators will become more systematic and efficient. Innovations in training methods and the implementation of curriculas into practice are still needed.

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# Biography

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