Surgical Education Assessment of simulators for training and selection of trainees

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Surgical Education

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Assessment of simulators for training and selection of trainees

Kristine Hagelsteen

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Title and subtitle

Surgical Education. Assessment of simulators for training and selection of trainees

Background

Approximately 15 % of surgical patients in hospital are affected of an adverse event, which is a medical error caused by the health care system. Laparoscopy is the preferred surgical technique in common procedures. Societal changes with shorter working hours, patient safety and ethics demand optimisation of resources to achieve the goal of educating competent surgeons within a reasonable time frame. Errors related to procedures is more often due to communicational skills and lack of situational awareness than pure technical skills. Laparoscopic simulation creates a safe training environment to spare patients being operated on by surgeons at the steepest part of their learning curve. Selection of surgical trainees by testing different areas of technical and non-technical competence and personality traits is uncommon in the surgical community.

Aim.

The aim of the research project is to investigate laparoscopic simulators used for training and potential unsuitable behaviour of surgical trainees as defined for the selection process.

Methods

Three studies were conducted with surgical novices, trainees and experienced surgeons by using laparoscopic simulators. Trainee and expert performance were investigated for simulator feasibility, effect of training of novices with sense of touch (haptics) and 3D vision, and opinion of experienced surgeons in using a virtual reality (VR) simulator.

A mixed methods design with questionnaires and interviews with experienced surgeons was used to identify unsuitable behaviour and traits in trainees.

Results

The Simball® Box is a new type of laparoscopic simulator which showed good feasibility and has the potential to mirror the technical progression with metrics. LapSim® Haptic Virtual Reality simulator with 3D and haptics shortens the acquisition of basic skills in novices with 32 %. Experienced surgeons considered that haptics in LapSim® had limited fidelity, but in spite of this, produced less stretch damage to the simulated tissue with haptics enabled.

Experienced surgeons have quite consistent views on what makes a person unsuitable as a surgeon. This knowledge have been systematized in 11 problem domains and a list of early "warning signs" in addition to a structured interview guide.

Significance

The findings from the studies concerning laparoscopic simulators have increased the knowledge of their usefulness and effectiveness and could assist in the construction of training curricula.

The findings from the study on unsuitable behaviour could increase awareness and suggest the possibility to identify these signs early during training and initiate actions to remediate. The interview guide could contribute to increased quality and transparancy amongst candidates applying for a trainee position.

Key words; Surgery. Laparoscopy. Simulation. 3D. Haptic feedback. Personnel selection. Surgical training. Human factors. Residency. Interview. Professionalism. Professional competence. Remediation

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LUND UNIVERSITY

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To Magnus,
- new adventures ahead

To Luna & Morris
-stay curious

"If you think education is expensive, - try ignorance"

Eppie Lederer, Washington Post on October 6, 1975

Table of Contents

List of publications

I. **Hagelsteen, K**., Sevonius, D., Bergenfelz, A., & Ekelund, M. (2016). Simball Box for Laparoscopic Training With Advanced 4D Motion Analysis of Skills. *Surg Innov*, 23(3), 309-316. doi:10.1177 /1553350616628678

II. **Hagelsteen, K**., Langegard, A., Lantz, A., Ekelund, M., Anderberg, M., & Bergenfelz, A. (2017). Faster acquisition of laparoscopic skills in virtual reality with haptic feedback and 3D vision. *Minim Invasive Ther Allied Technol*, 26(5), 269-277. doi:10.1080/13645706.2017.1305970

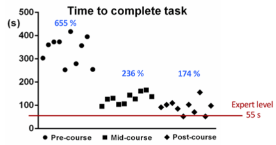
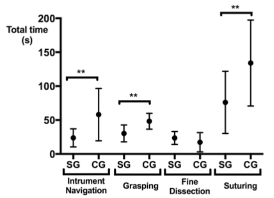
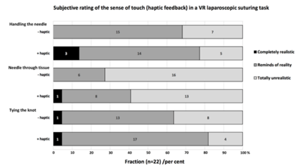
III. **Hagelsteen, K**., Ekelund, M., Bergenfelz, A., & Anderberg, M. (2018). Performance and perception of haptic feedback in a laparoscopic 3D virtual reality simulator. *Minim Invasive Ther Allied Technol*, Accepted. DOI: 10.1080/13645706.2018.1539012

IV. **Hagelsteen K**, Johansson B-M, Bergenfelz A, Mathieu C. Identification of warning signs during selection of surgical trainees. Manuscript accepted and will be published in: Journal of Surgical Education in the May/June 2019 issue, volume 76(3).

Declaration of interests

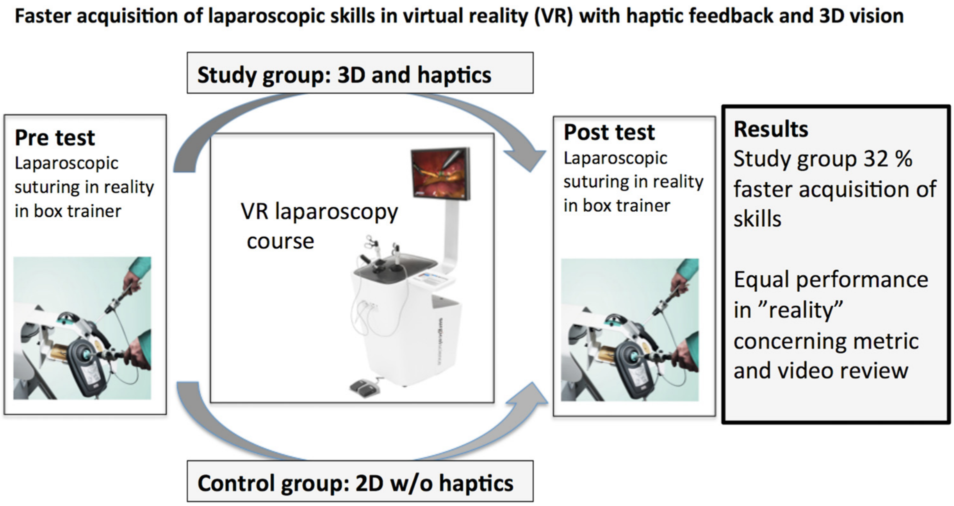
The author has no conflicts of interest and no financial ties to disclose in any form, related to the manufacturers of the simulators that were studied in the current thesis. The work was financed by Practicum Clinical Skills Centre and by research grants from Skåne County Council

Thesis at a glance

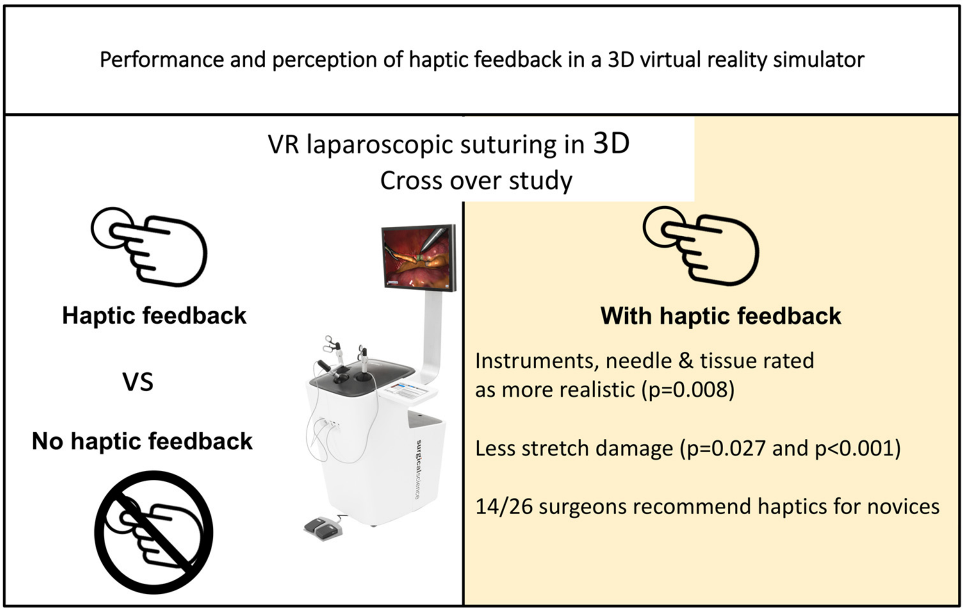
	Question	Method	Results		Main conclusion
I	How does the Simball® Box laparoscopic simulator reflect the progression of skills for surgical trainees when learning laparoscopic suturing.	Feasibility study. Novices (n=10) compared to expert performance. Multiple comparisons.	Improvement was seen in all measured variables when comparing values before vs mid course ($p < .05$) and before and after ($p < .001$) the course		The metrics mirrored the progression of laparoscopic suturing skill.
II	How does the addition of 3D-vision and haptic feedback in a laparoscopic simulator affect the learning curve for novices.	Prospective stratified trial. Novices (n=20) trained to proficiency. Two different settings in a VR simulator. Study group: 3D + haptics Control group: 2D no haptics Non-parametric test	The study group (n=10) completed the training course in 146 (range 100 – 291) minutes, compared to 215 (175 – 489) minutes in the control group, and were significantly faster in three out of four tasks studied; instrument navigation, grasping, and suturing		Training in the LapSim® Haptic VR simulator with features of 3D vision and haptic feedback, reduced training time to acquire basic laparoscopic skills by one third.
III	How is the haptic feedback in a 3D VR laparoscopic simulator perceived by surgeons, and does it affect performance in the simulator.	Face validity of a virtual reality simulator with surgeons (n=26) performing laparoscopic suturing. Questionnaire data. Perfomance metrics. Descriptive statistics Linear mixed model	A sum score of the rating of haptics showed a significant higher total score in the haptic setting, p=0.008. The “maximum stretch damage” parameter decreased significantly when haptic feedback was enabled.		Suturing in a VR with 3D and haptic feedback caused less stretch damage to the simulated tissue, even though the sense of touch was rated as limited
IV	How are unsuitable behavior and traits, as viewed by experienced surgeons, reflected in the current Swedish selection process for surgical residency.	Mixed methods design. Questionnaire quried experienced surgeons (n=83) and head of departments (n=7). Interviews (n=13) with experienced surgeons. Quantitative and qualitative analysis. Grounded theory approach.	Questionnaire response rate 65 % (54/83) surgeons, 4/7 heads of departments. 46/54 and 4/4 had experience with trainees that were deemed to be unsuitable to work as surgeons.	• Identification of 11 problem domains. • Associated list of warning signs. • Construction of trainee interview guide.	Increased knowledge of the current selection process in Sweden. The list of warning signs and the comprehensive interview guide may facilitate to discover warning signs early during training.

Visual abstracts paper II – IV

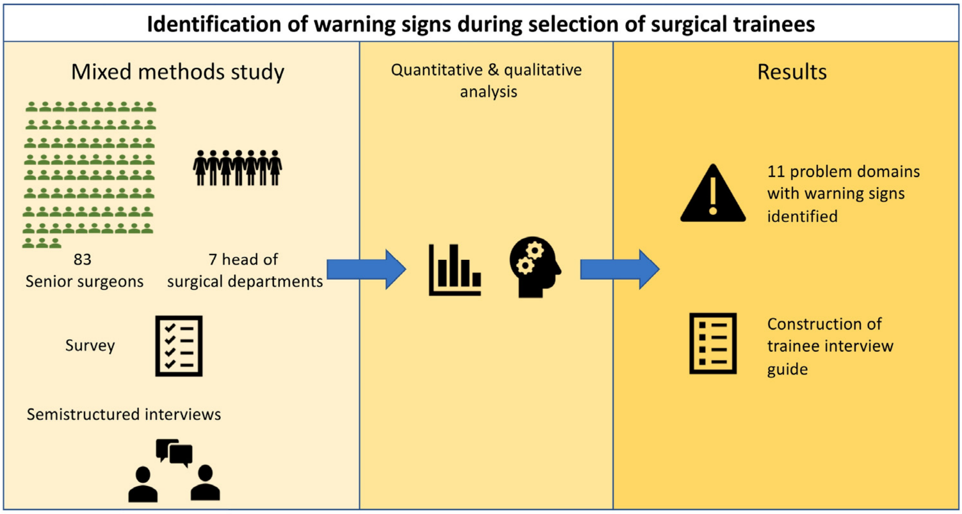
Paper II



Paper III



Paper IV



Identification of warning signs during selection of surgical trainees
Mixed methods study
83
Senior surgeons
7 head of
surgical departments
Survey
Semistructured interviews
Quantitative & qualitative
analysis
Results
11 problem domains
with warning signs
identified
Construction of
trainee interview
guide

Abbreviations & Word definitions

2D	Two dimensional
3D	Three dimensional
Adverse event	An unintended injury or complication resulting in prolonged length of hospital stay, disability at the time of discharge or death caused by healthcare management and not by the patients' underlying disease [1]. Sweden: Vårdskada. Norway: Pasientskade
ANOVA	Analysis of variance
CanMeds	A framework for improving patient care by enhancing physician training. Developed by the Royal College of Physcians and Surgeons of Canada in the 1990s
Degree	A unit of measurement of angles, the angle subtended by one three-hundred-and-sixtieth of the circumference of a circle (1/360)
Fidelity	The degree of exactness with which something is copied or reproduced
Haptic or force feedback	The sense of touch that is made by a machine when manipulating virtual objects to create the illusion of substance and force within the virtual world
HRO	High Reliability Organisation. An organization that has succeeded in avoiding catastrophes in an environment where normal accidents can be expected due to risk factors and complexity.
LapSim® Haptic	Virtual Reality laparoscopic simulator. Joystick instruments
Metrics	Quantitative measurements in order to track performance.
MIS	Minimal invasive surgery. Surgical techniques that limit the size of incisions, for example laparoscopy
MMI	Multiple Mini Interviews
NOTSS	Non-Technical Skills for Surgeons
OR	Operating room
Parameter	A numerical or other measurable factor.
RACS	Royal Australasian College of Surgeons
Radian	SI-unit for angles. 360 degrees correspond to $2\pi r$
RCSI	Royal College of Surgeons Ireland
TER	Transfer effectiveness rate. The difference in the number of trials or time taken to achieve performance criterion (in the air) between untrained and simulator trained pilots divided by total training time received by the simulator-trained group [2]
Trocar	A surgical instrument formed as a tube through the abdominal wall in laparoscopy. Used for inserting and removing instruments during the procedure
Simball® Box	Hybrid laparoscopic simulator. Authentic instruments are used
Surgical trainee	Physician in training to become a specialist in surgeon Sweden: ST-läkare Norway: LIS-lege.
Laparoscopy	A surgical procedure in which a fibre-optic instrument is inserted through the abdominal wall to view the organs in the abdomen. Sweden: Titthålskirurg. Norway: Kikkhullskirurgi.
Sorting hat	Enchanted hat in Harry Potter that decides very subjectively into which Hogwarts house (Gryffindor, Hufflepuff, Ravenclaw, Slytherin) the new students belong.
Södra Sjukvårdsregionen	Sweden's southern healthcare region: Region Skåne, Region Halland (southern part), Region Kronoberg, and Blekinge County Council. Total 1.85 mill inhabitants.
VR	Virtual Reality

Introduction

Surgical education is by tradition done according the apprenticeship model and by learning the craft on patients under supervision. The norm is that it should take a minimum of five years to become a specialist surgeon and training may be extended until the candidate has reached the predefined competence level.

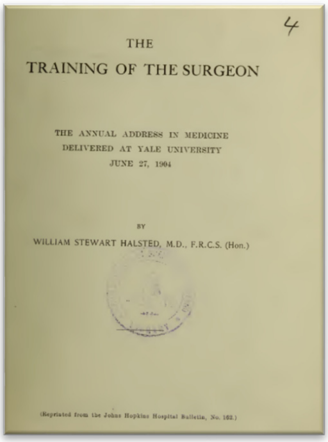
Approximately 15 % of all surgical patients in hospitals are affected of an adverse event, i.e. a medical error caused by the health care system[3]. These errors are to a large extent caused by deficiencies in non-technical skills, for instance a lack of communication. The number of affected patients and the cost is unacceptable. This thesis is aimed at two different aspects of surgical education in order to contribute to the important mission towards "zero" patient adverse events.

- To gain a better understanding of simulators used for learning minimal invasive surgery and their role in surgical training.
- To increase the knowledge of the unsuitable behaviour and traits for a surgeon and the current selection process to surgical training in Sweden.

Surgical training

The Legacy of Halsted

Since the beginning of the 19th century, the legacy of William Halsted "see one, do one, teach one" was considered the rule of surgical training. Halsted coined these famous words as chief surgeon of Johns Hopkins Hospital at Yale University in 1904. Halsted implemented important basic principles that influenced surgical training for years to come, as a pioneer surgical "program director" [4].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THE

TRAINING OF THE SURGEON

THE ANNUAL ADDRESS IN MEDICINE
DELIVERED AT YALE UNIVERSITY
JUNE 27, 1904

BY

WILLIAM STEWART HALSTED, M.D., F.R.C.S. (Hon.)

(Reprinted from the Johns Hopkins Hospital Bulletin, No. 162.)

Halsted's model consisted of recurrent surgical training opportunities, caring for patients under skilled supervision, and an understanding of the scientific basis of the surgical disease. The trainees were assigned increasing case complexity and consecutively more responsibility, and reached professional independence after serving as house officer for 2 years [4]. Interestingly, the term “resident” is derived from Halsted´s training program since the surgeons in training actually lived in the hospitals during the trainee years [5].

Until the mid-1960’s there was no formalized surgical education in Sweden Formalized surgical training was introduced in 1969 with implementation of Fortsatt Vidareutbildning (FV) [6]. The Swedish Surgical Society worked actively with educational and organizational structures during the following twenty years, and in 1992 a goal-oriented and competency-based five-year educational programme was implemented [6]. The Surgical Society released the first Swedish guidelines and regulations to support the surgical trainee, and site visits to oversee the local programmes were performed by Specialistutbildningsrådet (SPUR) to ensure the the quality of education at the Surgical Departments [6].

Paradigm shift in surgical training

Even though improvements in training were made, the paradigm shift from the Halstedian model towards a modern surgical training curriculum took place at the end of the 20th century due to several contributing factors [5, 7]:

- Knowledge of sleep deprivation and its effects on human performance led to regulations in maximum weekly working hours in the United states (80 hours) and Europe (48 hours) [8]
- Knowledge of adult learning and how professionals in other high-performance and high-reliability organizations work and train [5, 9]
- The introduction of minimal invasive surgery (MIS) resulted in new challenges towards procedural and patient-related complications with implications for training [7, 10]
- Public awareness of medical scandals being reported world-wide, i.e. The Bristol Case[1] [5, 11].
- The Institute of Medicine Report (IOM) in 1999, “ To Err is Human; Building a Safer Health system”, which claimed that between 44 000 – 98 000 peopled died in American hospitals each year due to medical errors [12].
- Increased understanding of the impact of non-technical skills on surgical outcome [13]

[1] A cardiothoracic surgeon with an unacceptable high mortality rate compared to other hospitals.

Training is patient safety

The list above is not exhaustive but covers some important factors to understand where surgical training and patient safety come together. The adaptation to restricted working hours initiated a need to restructure the way residents were taught and trained [7, 14-16]. Trainees' competency had been assessed based on the numbers of procedures or completing a predetermined number of years, and not on competence or passing a formal exit exam. The assumption that extensive surgical exposure would by default result in an expert level of competence, however, lacked evidence as showed by the learning psychologist K.A. Ericsson. Ericsson introduced the concept of deliberate practice after having studied the behaviour of professional athletes and musicians [9]. He emphasized the importance of focused attention and continued deliberate practice in order to maintain expert performance [9]. Deliberate practice needs less hours and thus creates more effective training [9].

Minimal Invasive Surgery and learning curve

At the end of the last century, Minimal Invasive Surgery (MIS) started to gain popularity and is now considered as the technical standard for many common procedures such as appendectomy, cholecystectomy and bariatric surgery. Minimal Invasive Surgery has shown to decrease surgical trauma, lead to faster recovery, shorten hospital stay and to give better cosmetic results. The change from open technique to MIS resulted in experienced surgeons turning into novices during the initial learning phase with an increase in complications and procedural time [17, 18]. The time for the teaching doctrine of Halsted ("see one, do one, teach one") had passed. It was no longer accepted by patients, health care providers and by new demands and advances in education and technology [7].

There is evidence for the use of simulation-based training for laparoscopic skills acquisition in several systematic reviews, reviews, meta-analyses and randomized controlled trials, and results confirm improved performance in the operating room [19-26]. Surgical skills laboratories have been implemented worldwide (for instance Practicum Clinical Skills Centre, Lund, Sweden[2]), to provide surgeons with facilities to develop necessary skills in a safe training environment before operating on patients [27].

The learning curve may be graphically presented to show the acquisition of skills until an accepted plateau is reached [28]. The learning curve in laparoscopic surgery can be presented as procedural time, blood loss, complication rate and recurrence of cancer and is dependent on the procedures complexity [18]. Studies have shown that factors like the surgeon's previous experiences, e.g., of videogaming or assisting in laparoscopy and visuospatial aptitude have a positive effect on the learning curve

[2] Practicum Clinical Skills Centre, Skåne University Hospital, p. 29

[29-32]. These investigations have also identified slow learners and those who almost never reach a pre-defined proficiency level [32, 33].

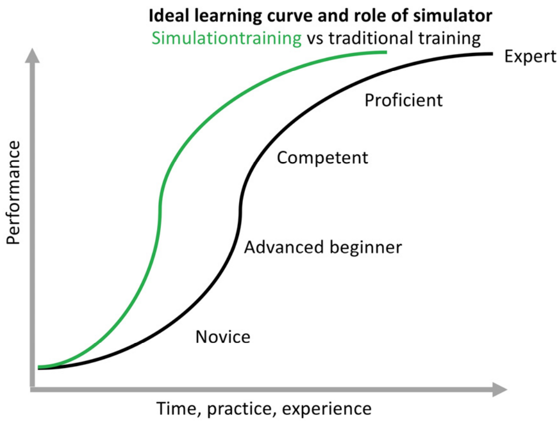


Figure 1. The ideal learning curve and role of simulator training. Illustration by KH 2018.

Curricula for training

Extensive research has been performed to understand the different aspects on training complex procedural and perceptual motor skills for laparoscopic surgery and much of this research share similarities with other demanding complex task in sports and aviation [5, 34]. To achieve proficiency, automatization and retention of a procedural skill, training should be mandatory, spaced, structured, deliberate and with benchmarking towards an expert [34, 35]. Further, there should be access to an instructor, to meet individual needs and with a clear relation to the real task [34, 35]. The curriculum depends on the training objective and what types of simulators are available, since several proposed and validated templates for curricula are available [35-39].

Non-technical skills for surgeons

Although technical skills are important, research has shown that errors associated with surgery are often a combination of several system factors occurring during different phases of care [40, 41]. Communication breakdowns contribute substantially to errors (Table 1) [40-42]. High level of technical performance is therefore not sufficient to ensure patient safety in the operating room [13]. Understanding how decisions are made intraoperatively and assessing behaviour in a structured way has been proven valuable using for instance the non-technical skills for surgeons (NOTSS) framework [13, 42]. NOTSS include situational awareness, decision making, communication, teamwork and leadership [13]. Failure to identify abnormal situations (situational awareness) was found to contribute to the majority of the 252 bile duct injuries in a large retrospective study [10]. Training in situational awareness have shown to reduce surgical errors in the operating room [43]

Table 1.
Factors that have been linked to poor surgical outcomes [40]

Factors assoiated with errors in surgery
Surgeon inexperience
Low hospital volume for some operations
Excessive workload
Fatigue
Lack of optimal technology
Poor supervision of trainees
Inadequate hospital systems (ergonomy, infrastructure, administration)
Poor staffing
Communication
Emergency surgery
Time of day

Simulators for laparoscopic training

Kurt Semm, a German gynaecologist and laparoscopic pioneer performed the first laparoscopic appendectomy in 1982. His commitment to minimal invasive surgery and teaching lead to the invention of the first box trainer the Pelvitrainer (Figure 2, left) in 1985. This basic construction with a box connected to a video camera is still commonly used to acquire skills in laparoscopy (Figure 2, right). Multiple descriptions of how to build your own laparoscopic simulator at a low cost is easily found on the internet. For these simulators an ordinary box could be used together a tablet, a mobile phone or a webcam [44]. Although simple in construction, box trainers resemble real-life surgery since authentic laparoscopic trocars, instruments, camera and video monitor, are used to mimic the clinical situation. Box trainers provide the surgeon with opportunities to acquire basic surgical skills, shorten the learning curve, and learn to master the fulcrum effect[3]. It has also been shown that acquired skills are transferred to the operating room [19, 26, 45]. Box trainers use consumable material and the trainee is dependent on a faculty member for

[3] Fulcrum effect. The inverse movement of the instruments intraabdominally contra hand movements that occur in laparoscopy e.g. when the hand goes right, the instrument tip goes left.

assessment and feedback which adds to cost. Further there is also an intra- and inter-observer variation for rating.

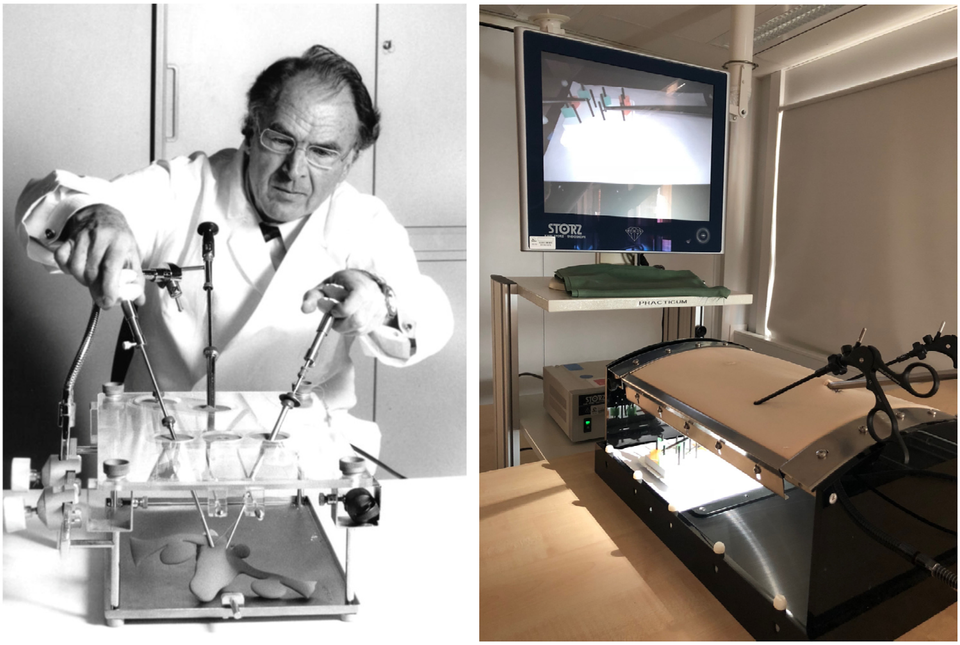


Figure 2 Left. Dr Semm in 1985 demonstrating the Pelvitrainer, reprint with permission from Archiv der Klinik für Gynäkologie und Geburtshilfe der Christian-Albrechts-Universität zu Kiel Right. Commonly used video box trainer. Photo by KH 2018

Virtual reality

Virtual Reality (VR) simulators were developed during the 1990's with the aim to overcome the negative aspects of box trainers. VR simulators offer an objective motion analysis with tracking of the instruments spatial movements (metrics) and full procedures for infinite repetition. In 2002, the first study was published that showed that surgeons that trained to proficiency on the MIST VR (Minimally Invasive Surgical and Trainer Virtual Reality, Mentice, Göteborg, Sweden), outperformed a case-matched group of surgical trainees with traditional training without simulation for laparoscopic cholecystectomy. [19]. In the Seymour et al study, the standard trained trainees made six times as many errors during the operation and takeover by the attending surgeon only occurred in this group of trainees. Since then, similar studies have confirmed these results, and a recent investigation showed that simulation-trained junior trainees perform better than general surgeons even on advanced laparoscopic tasks, like a stapled jejuno-jejunostomy [46].

Laparoscopic skills training may be performed by using a variety of different trainers, for example box trainers, hybrid box trainers, live or cadaveric animal tissues, cadaveric human tissues, Nintendo Wii U, immersive VR (Figure 3) or augmented reality (AR) simulators [47-49]. A perfect simulator should preferably come with a reasonable price, with authentic tissue and texture, and offer full procedures and valid measurements of instrument movements on performance.

Figure 3. Left. Immersive Virtual Reality trainer construction where no monitor is needed (LapSim® Simulator and Simball® joysticks). Right. Operating room as viewed by the surgeon in the simulator with the monitor in the virtual OR displaying the same task as in Figure 5 upper right corner. Full procedures can be trained in this environment [47]. Reprint with permission from Springer Nature

Haptic feedback in VR

To mimic the sense of touch (force feedback or haptic feedback), different simulators use different types of actuation e.g., shape memory metals, magnetic, piezoelectric materials, electrorheological fluids, direct current (DC) electric motors, pneumatic, as well as hydraulic actuation and vibrations [50]. Computer programming can also be used to achieve resistance in the trocars[4] to mimic" real life" resistance when inserting instruments [51]. The visual system is not as fast as haptic perception. This can therefore be used to achieve a sense of touch by increasing the speed of interlacing images from 25 – 30 per second to up to 1000 Hz, depending on the stiffness to be simulated (higher rate for stiff objects) [50]. Several studies in different simulators using different haptic interfaces show ambiguous results, but with most of effects seen in novice training [52.].

Validation

Before a simulator can be used or implemented in a surgical skills curriculum, it needs to be tested for feasibility and thoroughly validated. Validation is a process

[4] Trocar; hollow tube placed through the abdomen in laparoscopic surgery that function as a portal for other instruments used during the procedure.

where the simulator is examined in several ways to assure that it measures what is intended to be measured and teach what it is supposed to teach (Table 2).

Table2.
Qualities in assessment tools. Explanation of the terms and definitions of feasibility and validity in this thesis. Adapted from [53]

Term	Definition
Feasibility	Measure of whether something is capable of being done or carried out
Validity	
Face	is the extent to which the examination resembles real life situations
Content	is the extent to which the domain that is being measured is measured by the assessment tool — for example, while trying to assess technical skills we may actually be testing knowledge
Construct	is the extent to which a test measures the trait that it purports to measure. One inference of construct validity is the extent to which a test discriminates between various levels of expertise
Concurrent	is the extent to which the results of the assessment tool correlate with the gold standard for that domain
Predictive	is the ability of the examination to predict future performance
Reliability is a measure of a test to generate similar results when applied at two different points	
Test-retest	Measure of a test to generate similar results when applied at two different points
Inter-rater	Measure of the extent of agreement between two or more observers when rating the performance of an individual

Simulators studied in this thesis

Simball® Box

Simball® Box (former G-coder Systems, now Surgical Science, Gothenburg, Sweden) is a hybrid video box trainer that offers performance feedback using authentic laparoscopic instruments (Figure 4). LED lights are situated around the camera to mimic the light from a laparoscope.

The position and motion parameters of the instruments are recorded continuously (i.e., one hundred times per second) through the laser-marked pattern on the ball joint trocar using patented machine vision technology (Figure 4). Feedback after each attempt is given in per cent of the tutorial video performance of each parameter.

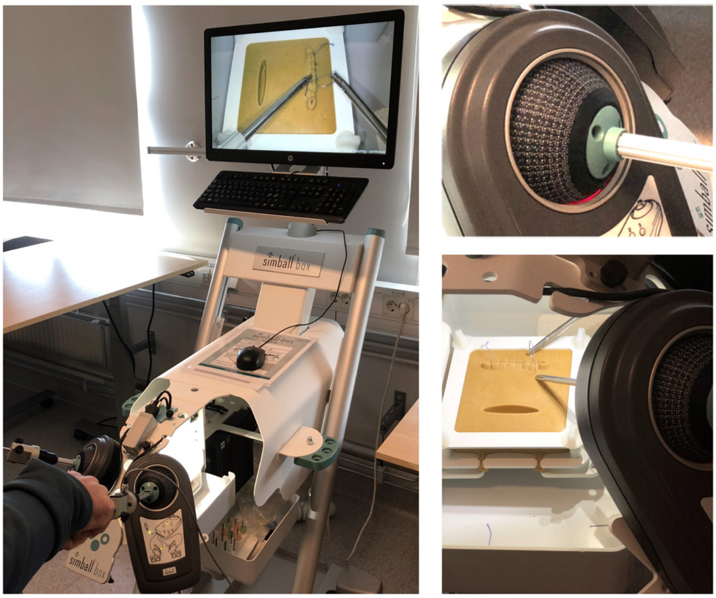


Figure 4. Simball® Box simulator. Upper right, laser-marked pattern which allow instrument tracking. Lower right, suture pad exercise. Photo by KH 2018

LapSim® Haptic System

Lapsim® Haptic System is a virtual reality (VR) simulator with advanced force feedback technology and 3D imaging (Figure 5). Previous versions of LapSim® had 2D screens and did not provide force feedback. The setup used in the present studies are those of the LapSim® Haptic released in 2013. The instrument joysticks are constructed to mimic authentic laparoscopic instruments. Haptics (i.e., force feedback) is provided to the joysticks by electrical motors, connected through an application programming interface to the software. When the user is touching objects in the virtual operating space the software delivers haptic feedback experienced as tactile sensations.

Within the LapSim® software, a set of parameters quantify the performance of each attempt for a specific training scenario. The parameters measure either metric units or the number of events (for instance for tissue damage).

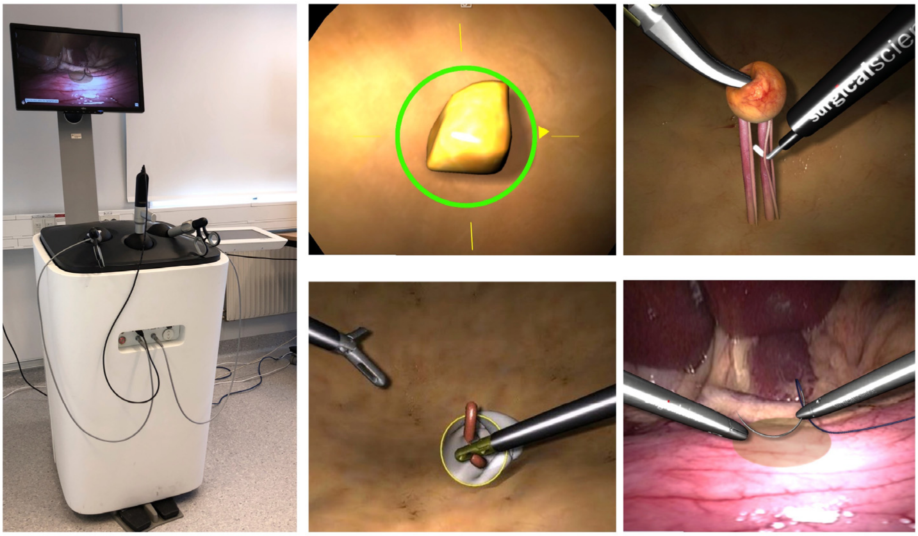
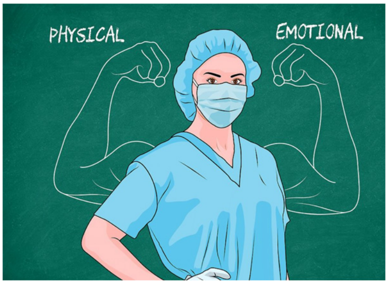


Figure 5. Lapsim® Haptic System. Screenshots from the Basic Skills training program; upper middle – camera navigation, upper right – fine dissection, lower middle – grasping, lower right – suturing. Photo by KH 2018

Selection of trainees, - a missing link in patient safety?

The current Swedish selection process



The Swedish recruitment process to surgical trainee positions is decentralized to the local level of each hospital. The medical school and internship period do not generate grades as for a pass-fail system. The traditional way to receive a trainee position is by six to twelve months employment as a locum, and if clinical performance is deemed favourable, a position as surgical trainee will follow. Some hospitals advertise all trainee positions externally, conduct interviews and have a more structured concept, but at present there is no consensus in Sweden regarding the selection process.

One of the driving forces to modernize surgical education has been increased focus on patient safety [5]. Unexpected medical problems or errors that happen during treatment are called adverse events [1]. Adverse events are not due to the underlying disease of the patient but caused by health care providers. In Sweden, 15 % of surgical patients admitted in hospital are affected by an adverse event and a majority of these events are estimated to be avoidable [1, 3]. Some 3,6 - 4,7 % adverse events will lead to permanent harm or death [1, 3]. Adverse events are costly and a tragedy for the affected patient and involved personnel [54].

Compared to other high-risk fields, healthcare has not achieved the same dramatic improvement in safety as for instance the airline industry [55, 56]. Thus, other high-risk organisations have developed into High-Reliability Organisations (HROs) through systematic safety work, including powerful systems for selection of staff and training [55-57]. It is known that an adverse event to a great extent is due to communication errors, lack of situational awareness and other non-technical skills. Selection of surgical trainees has therefore been proposed as a ”missing link” within the concept to develop healthcare into a HRO [56].

In general, selection processes often use strategies to find the best candidate based on certain criteria. However, the notion that these criteria prevents employment of those who are unsuitable for the surgical profession is not necessarily true, since some positive and negative criteria are context dependent. When selection to a training position is based on few candidates, it is more important to identify unsuitability for training to mitigate a detrimental employment.

What are we looking for?

Lists of desirable qualities for basic surgical trainees exists, and Ireland has been in the frontline of implementing a comprehensive two-step selection process for higher surgical training [58-62]. However, there is no global consensus concerning what, when and how to assess applicants [58, 60, 63-76].

Selection based on medical school grades or exam, CV, reference-taking and non-structured interviews are commonly used. Studies investigating other possible assessment instruments have suggested aptitude testing, structured interviews, personality- and situational judgment tests [29, 63, 64, 67, 69, 77-79]. A recent review found that no single test or combination of tests has been identified that with high validity and reliability can predict technical aptitude [80]. This is of importance since studies have showed that between 8 – 30 % of trainees struggle to learn laparoscopy to a proficient level within reasonable time frame [32, 33, 81].

Studies on problem trainees and remediation practices have revealed that the predominant issues for struggling trainees are non-technical competencies, such as knowledge, interpersonal skills, and professionalism [82-86]. Bergen et al found that over a ten year period, 21 % of residents in surgery at a single institution were high-risk or problem residents [87]. These residents exhibited deficiencies in interpersonal behaviour, including professional behaviour, ethics, cognitive skills , clinical judgment and decision-making, family or health areas but *per se* had no technical difficulties [87].

By comparison, using an aviation personality inventory, hazardous attitudes amongst orthopaedic surgeons were studied. The results showed that 38 % had at least one score that would have been considered dangerously high in pilots [88]. Further, 28 % exhibited dangerous levels of macho behaviour and 11 % dangerous levels of self-confidence [88]. The association of hazardous attitudes and adverse events in surgery is not fully understood or investigated, but macho attitude was found to explain 19 % of the variance in a 2-year study on reoperation and readmission rates amongst 41 orthopaedic surgeons [89].

Aims

The aim of this thesis is to contribute to patient safety in surgery by focusing on different aspects of surgical training; technical skills acquisition and evaluation in minimal invasive surgery using laparoscopic simulators and the selection process of surgical trainees.

The specific aims of the respective papers were:

Study I

To investigate if the Simball® Box laparoscopic simulator reflect the progression of skills for surgical trainees when learning laparoscopic suturing.

Study II

To investigate if the addition of 3D-vision and haptic feedback in a laparoscopic simulator affect the learning curve for novices.

Study III

To investigate how the haptic feedback in a 3D virtual reality laparoscopic simulator is perceived by laparoscopically trained surgeons and if it influences performance in the simulator.

Study IV

To investigate how unsuitable behaviour and traits, as viewed by experienced surgeons, are reflected in the current Swedish selection process for surgical specialist training.

If it is possible to incorporate identified predictors of unsuitable behaviour and traits in assessment instruments to be used in a selection process of surgical trainees.

Timeline

Methods & materials

Practicum Clinical Skills Centre

All studies were performed at Practicum Clinical Skills Centre[5], Skåne University Hospital, a centre accredited by the Network of Clinical Skills Centres (NASCE), UEMS (Union of European Medical Specialists), and the American College of Surgeons. The centre provides training by means of a wide variety of surgical and non-surgical simulators.

Research methods and collaborations

In this thesis both quantitative and qualitative methods have been used. The first three studies use a quantitative approach and the fourth study is a mixed methods study combining quantitative and qualitative methodology. The fourth study was done in collaboration with sociological researchers at the Faculty of Social Sciences at Lund University.

Evaluation of surgical simulators

The first three papers (I-III) investigated different aspects of laparoscopic simulators.

Study I was a feasibility study of the simulator Simball® Box, which uses a novel technology for motion tracking of ordinary laparoscopic instruments.

Study II compared two different settings in a well-known virtual reality simulator, LapSim®, which has been upgraded to offer features of 3D imaging and haptic feedback; LapSim® Haptic. The previous version of this simulator has been proven to transfer obtained skills to the operating room.

[5] Practicum Clinical Skills Centre, Skåne University Hospital, Lund, photo by KH 2018

Study III was a face validity study collecting opinion of experts on the use of 3D imaging and haptic feedback, and concomitantly evaluate expert's performance on the upgraded LapSim® Haptic simulator.

Participants and study design

Paper I

Surgical trainees participating in a three-day national course in laparoscopic surgery, and with the minimal requirement of having completed a first-year course in basic surgical skills, were included in the study. The participants were tested for the skill of laparoscopic suturing in Simball® Box at three times during the course; before the course, in the middle of the course and at the end of the course. During the course, the participants were trained in various laparoscopic simulated environments to achieve proficiency in laparoscopic suturing. The metrics of the participants were compared to the tutorial performance made by an expert laparoscopist, with experience of more than 1000 gastric bypass procedures. The simulator used in paper I and II, Simball® Box, is equipped with a 2D camera and the performance is shown on a 2D screen. A suture pad with a simulated incision, a 3-0 braided suture on an SH needle and two 5 mm authentic needle holders were used for training

Simball® Box Metrics

Measurements provided by the simulator were time (s), linear (m) and angular distance (radians), average acceleration (mm/s2), average speed (cm/s) and motion smoothness ($\mu m/s^3$) for left and right hand separately (detailed description in Appendix A). The smoothness parameter was removed by the manufacturer before study II had commenced.

Paper II

Medical students without previous experience in laparoscopy or laparoscopic simulation were included in the investigation. Not being able to perceive cinema 3D, as rated by self-assessment, was an exclusion criterion. The 3D technology is based on the Film Patterned Retarder (FPR) technology were the monitor displays separate images to the left and right eye in different circular polarized patterns. Using 3D glasses that are left-and-right-polarized, the images are perceived by the viewer as 3D, also known as cinema 3D. The participants were stratified according to sex, video game habits, self-assessed motor coordination skills and handedness into two groups. Self-perceived motor coordination skills were graded on a scale 1 to 5, where 1 equalled not very skilled, 3 ordinary skills and 5 highly skilled. The students were introduced to Simball® Box and LapSim® and received instructions on laparoscopic knot tying by using the Simball® Box. The participants completed a validated basic skills training course in the LapSim® to a predetermined level of proficiency. The course consisted of 'instrument navigation', grasping', fine dissection' and 'suturing' exercises. The study group performed the LapSim® course with haptic feedback and 3D vision, and the control group without. Testing was done in the Simball® Box. A qualitative review of all recorded video performances in the Simball® Box was done to ensure that the knot was tied correctly. Performance levels were compared before and after the course.

LapSim® Metrics

Different measured parameters are related to the specific task that are performed. Common to all tasks are measurements of number of attempts (#), time (s), instrument path length (m) and instrument angular path (degrees). Depending on the task, measurements are done for tissue damage as number of events (#) and deviation from pre-set perfect instrument position (mm), instrument misses (%), time (s) and frequency (#) of instruments outside view. Furthermore, ripping, energy damage or burning of vessels (%) and target error (%) are also analysed. The proficiency settings in study II and III were the same as in previous published validation studies [21].

Paper III

Surgeons with a minimum experience of 100 laparoscopic procedures were included in the study. The surgeons started with two warm-up exercises in the LapSim® Haptic simulator with haptics and 3D enabled. The surgeons then performed five suturing attempts with haptics enabled at start (referred to as 'haptic-first' group) or disabled at start (referred to as 'haptic-last' group), followed by five new suturing attempts in the opposite haptic setting (Figure 6). Perception of three haptic aspects; needle, tissue and thread, on a 3-point Likert scale, and five graphical aspects; visceral anatomy, instruments, needle, thread and complete task, on a 5-point Likert scale, was recorded after each set of five attempts. The graphics were identical throughout the study, and thus, only the haptic setting was changed between the two set of five attempts. Maximum time for each suturing attempt was pre-set to maximum 180 seconds.

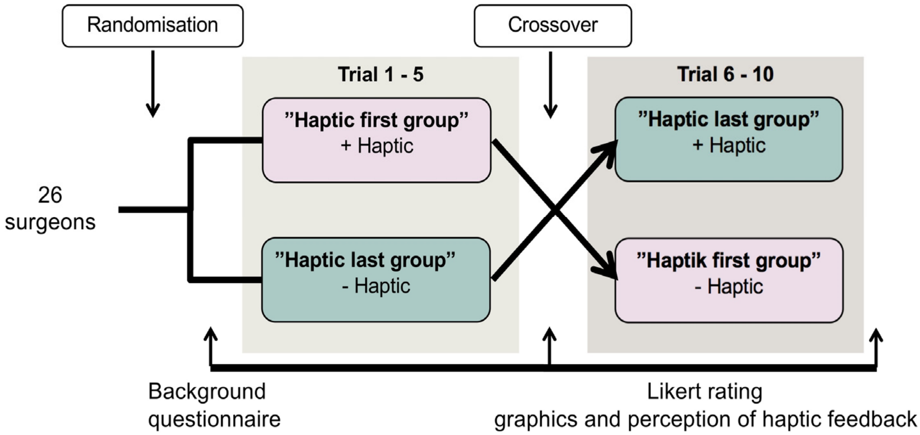


Figure 6 The cross over studydesign in Paper III

Paper IV

All general surgeons over 50 years of age (n=87), and heads of surgical departments (n=7), in the South Swedish Health Care Region, (Södra Sjukvårdsregionen) in December 2013 were included in the study. Experienced surgeons were operationalized as general surgeons over 50 years of age.

Mixed method design

A mixed method with qualitative and quantitative data acquired from multiple sources was applied. A questionnaire consisting of open and closed format questions was distributed. A key-informant interview guide was created based on the results from the questionnaire including open questions regarding traits and behaviours for suitability and unsuitability as a surgeon (Appendix B). Semi-structured interviews were conducted after purposeful selection of candidates to ensure representation from all hospital categories (university, regional and local), age and gender.

Survey

A questionnaire consisting of open and closed format questions was distributed to experienced surgeons and head of departments. The questions concerned organisational contexts and current assessment processes for surgical trainees and experience with individuals with unsuitable behaviour. One question involved rating of important competencies, personal attributes and behaviour on a 5-point Likert scale. The surveys were anonymized and coded, distributed by mail, with a maximum of three reminders, and the coded list was kept by an independent administrator who sent out reminders.

Qualitative semi-structured interviews

The interview guide based on the survey results was used for the qualitative semi-structured interviews (Appendix B). All interviews were performed by at least one experienced sociologist and with the informed consent of the interviewed person. Twelve interviews were done on site, one over telephone. One participant did not agree to be recorded during the interview and therefore notes were taken. The interviews were designed to probe for unsuitable behaviour and situations where this would be revealed, together with descriptions and characterisation of the opposite; the 'ideal' surgeon. Saturation was obtained after 11 interviews, i.e., sufficient data had been acquired to enable a comprehensive understanding of the studied phenomena and new information did not provide further insight.

Statistical and qualitative methods

All study variables were presented with descriptive statistics. In paper I – III, p-values of < 0.05 were considered statistically significant. Ordinal variables and non-normally distributed data were reported with medians and interquartile or complete range.

Study I

The trainee's individual performance parameters were compared for the three different time points and compared as percent of expert performance. The variable 'time' had a Gaussian distribution and was therefore analysed by one-way ANOVA. Friedman´s test for multiple comparisons was used to analyse individual learning curves.

Study II

Results between groups generated in LapSim® and Simball® Box, were tested for statistical significance using Mann-Whitney U-Test. Differences in Simball® Box-performance of the two groups were calculated using a Fishers' exact test.

Study III

A sum score of variables concerning perception of haptic feedback and graphics was constructed and compared using Wilcoxon signed rank test. Results obtained for the three variables that were deemed to be influenced by haptic (maximum stretch damage [%], maximum damage [mm] and number of events with tissue damage) were analysed using a linear mixed model, allowing for repeated measurements.

Study IV

Data acquired in the questionnaire and key-informant interviews were synthesized and analysed using a constructivist grounded theory approach [90]. 'Open coding' of the transcribed interview material was performed separately by two researchers - a specialist surgeon and a sociologist. The lists of codes were compared, and 58 codes was agreed upon after discussion, and formed the horizontal analysis of the interview data.

The transcripts were read more than once to obtain deeper understanding of thoughts and argumentation of each informant. The audio files were revisited in some cases. The results were then sorted into categories (questionnaire data) and domains (complete material), shared within the research group. These results formed the vertical analysis of the material.

The coded material was analysed in terms of the following five primary dimensions:

1. Basic problems that lead to unsuitability ("problem domains")
2. Basic root causes of these problems (for instance personality, lack of physical or cognitive ability, lack of motivation)
3. Defining behavioural indicators of these problems ("warning signs", with a focus on possible early detection)
4. Understanding if certain behaviours are more resistant to change or innate (flexibility)
5. Identifying when, how, and where these indicators may be detected

Statistical software

All data was saved and stored in Microsoft Excel© 2010. For statistical analyses in paper I and II, data were analysed by using GraphPad Prism© version 6.0f for Mac (GraphPad Software, Inc., La Jolla, CA 92037 USA). Statistical analysis in paper III was done in the software R (ver 3.4.2.). Descriptive statistical calculations in paper IV were done in Microsoft Excel©, and NVivo© (Alfasoft AB, Sweden) was used for qualitative analysis.

Ethical considerations

Informed consent was retrieved from all participants in the conducted studies before inclusion. It was made clear that participants in the studies could end the partaking at any moment without giving reason and with no consequence. No individual sensitive information was queried, and all data were collected anonymized and presented at group level. For the qualitative interviews, no ethical approval was sought since the interviewees were asked for opinions in their professional role and no sensitive data were collected. The interviewees were advised not to use names in specific cases and elaborate on the situational descriptions to avoid individual identification. However, having only a few hospitals and employers, and a limited number of surgeons, both the subject of the interview and the trainee mentioned had a risk of becoming identified on situational basis. To decrease the risk of identification and to maintain confidentiality, the information gathered was de-identified during transcription. The material was not presented in full version and only relevant quotes were selected. The raw material was only available to the research group.

Results

Paper I. Simball® Box metrics mirror progression of skills

Ten surgical trainees without previous experience of laparoscopic knot tying and suturing were trained to proficiency during a three-day course. Data was recorded at three assessment points; before-, at the middle and at the end of the course. Results showed that there was significant improvement for the parameters of time, total instrument movement in linear distance (both left and right hand) as well as angular distance (Figure 7).

The computer program automatically presented the performance parameters in per cent of the tutorial performance. The results showed a decrease in total instrument motion (cm) from the pre-course to the midcourse test with a median of 1208 (range, 845-1751) cm to 522 (range 411-810) cm; ($p = .042$), to a post-course median of 405 (range, 246-864) cm giving a ($p < .0001$). Significant improvement was also seen for the time parameter (s) when comparing pre- and mid-course time to complete task ($p < 0.0001$), pre- and post-course ($p < 0.0001$) and mid- and post-course ($p = 0.0050$) (Figure 7). Total angular distance (range) combines yaw, pitch and roll for both instruments and was median 150 (range 87-251), median 65 (range 42-116), and median 50 (range 33-136) radians, with significant improvement pre- versus midcourse ($p = .022$) and pre- versus post course ($p = .0002$). For details of separate linear and angular measures, see Figure A.

The average speed (cm/s) showed that it was only the right hand that improved significantly. The average acceleration (mm/s^2) parameter did not reflect the improvement and showed no significant change between the three different timepoints, and this was also true for the constructed parameter "average motion smoothness".

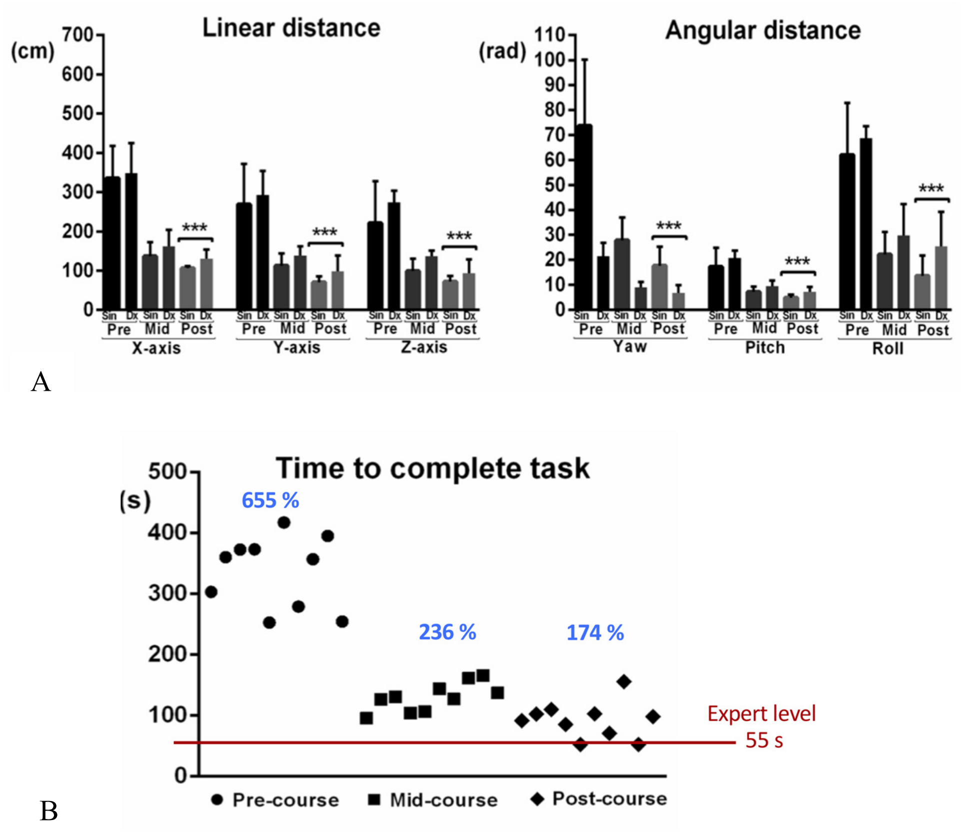


Figure 7. A. Improvement was shown in all measured variables when comparing both pre- and mid-course ($p < .05$) and pre- and post-course (***$p < .001$). Linear instrument distance in cm to the left and angular distance in radians to the right, with bars representing interquartile range. B. Individual plot of participants time (s) to complete task.

Paper II. Haptic feedback and 3D vision in virtual reality

Twenty novices in laparoscopy were included and stratified into two groups. The study group that performed the LapSim® basic skills course with haptic feedback and 3D vision completed the training course in median 146 (range 100 – 291) minutes, compared to median 215 (range175 – 489) minutes in the control group which was trained in 2D and without haptic feedback (Table 4). Compared to the control group, the study group was significantly faster and needed less attempts to succeed in three out of four tasks; instrument navigation, grasping, and suturing (Figure 8, Table 4). The results from the 'fine dissection task' did not differ between the two groups.

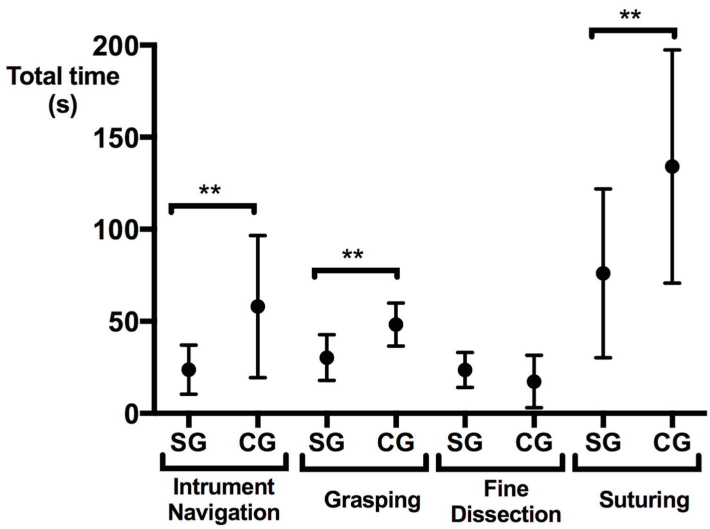


Figure 8. Time needed to complete the different tasks in the basic skills course. SG: Study Group, CG: Control Group.

Video analysis of the knot tying test in Simball® box before- and after the LapSim® course showed no differences in performance as estimated by provided metrics and video review ratings (Table 3). One video in the control group was corrupted and could not be analysed.

Table 3
Video review of performance in Simball® Box. Comparison of performance before and after Lapsim® Haptic VR training with or without 3D and haptic settings. Correct choreography = correctly surgeon's knot. Sufficient knot= knot keeps wound edges together.

Parameter	Study group N=10 improved/not improved	Control group N=9†† improved/not improved	p-value[1]
Instrument outside of view	9/1	9/0	1.000
Instrument outside of zone	10/0	7/2	.476
Needle outside of zone	9/1	9/0	1.000
Correct knot choreography (yes/no)	10/0	7/2	.211
Sufficient knot (yes/no)	10/0	8/1	.474

[1] Fisher's exact test, †† One video could not be analysed due to corrupt video file

Table 4.
Task parameters of the LapSim® training course.

Course task	Study group Median (range)	Control group Median (range)	p-value [1]
Instrument navigation			
Total Attempts (#)	27 (13 – 79)	65 (29 – 196)	0.005**
Total Time (min)	19 (9 – 52)	46 (20 – 149)	0.003**
Total Instrument Path Length (m)	41 (17 – 136)	94 (43 – 331)	0.007**
Total Instrument Angular Path (degrees)	7606 (3529 – 27301)	17490 (8133 – 60693)	0.007**
Total Tissue Damage (#)	138 (42 – 739)	347 (95 – 1550)	0.015*
Total Maximum Damage (mm)	109 (60 – 1048)	422 (92 – 1834)	0.003**
Total Instrument Misses (%)	2,2 (0 – 8)	1,5 (0 – 3)	0.288
Grasping			
Total Attempts (#)	19 (10 – 34)	29 (19 – 36)	0.017*
Total Time (min)	29 (16 – 55)	49 (30 – 65)	0.007**
Total Instrument Path Length (m)	83 (30 – 226)	104 (55 – 152)	0.306
Total Instrument Angular Path (degrees)	15660 (5932 – 44600)	19648 (10471 – 29054)	0.347
Total Tissue Damage (#)	155 (40 – 396)	254 (103 – 537)	0.188
Total Maximum Damage (mm)	178 (45 – 380)	390 (107 – 847)	0.019*
Total Instrument Misses (%)	22 (18 – 27)	14 (16 – 31)	0.183
Fine Dissection			
Total Attempts (#)	7 (5 – 22)	8 (3 – 21)	0.236
Total Time (min)	22 (13 – 40)	13 (5 – 55)	0.060
Total Instrument Path Length (m)	12 (7 – 38)	8 (2 – 29)	0.071
Total Instrument Angular Path (degrees)	2858 (1778 – 10210)	1882 (441 – 6992)	0.089
Total Instruments Outside View (#)	3 (0 – 16)	4 (0 – 12)	0.864
Total Instruments Outside View (s)	4 (0 – 49)	7 (0 – 37)	0.927
Total Ripped or Burned Blood Vessels (%)	7 (0 – 25)	16 (0 – 43)	0.088
Total Energy Damage on Blood Vessels (%)	7 (1 – 26)	5 (0 – 25)	0.469
Total Ripped Small Vessels (%)	5 (0 – 14)	12 (0 – 26)	0.127
Total Burned Small Vessels (%)	94 (83 – 97)	88 (73 – 100)	0.287
Total Burned Small Vessels without Stretch (%)	0 (0 - 15)	0 (0 - 3)	0.249
Suturing			
Total Attempts (#)	24 (15 – 73)	41 (30 – 93)	0.011*
Total Time (min)	62 (40 – 194)	115 (67 – 265)	0.007**
Total Instrument Path Length (m)	99 (50 – 500)	169 (86 – 516)	0.030*
Total Instrument Angular Path (degrees)	20191 (10375 – 100768)	36027 (17387 – 92798)	0.052
Total Target Error (mm)	55 (15 – 90)	41 (1 – 195)	0.645
Total Knot Error (%)	42 (27 – 59)	41 (34 – 52)	0.725
Total training course parameters			
Total Training Course Time (min)	146 (100 – 291)	215 (175 – 489)	0.002**
Total Training Course Instrument Path Length (m)	237 (134 – 683)	356 (216 – 976)	0.063
Total Training Course Instrument Angular Path (degrees)	47511 (27891 – 137858)	70566 (42982 – 177728)	0.063

[1] Mann-Whitney U test, * Statistical significance < 0.05, ** Statistical significance < 0.01, # = numbers

Paper III. Effect of haptic feedback in a 3D VR simulator

Twenty-six surgeons were enrolled and completed the study. Four surgeons lacked experience in laparoscopic suturing and were excluded from rating of haptic feedback.

Ratings of the perceived sense of touch for the task "handling of the needle", showed that 3 of 22 participants found it to be completely realistic in the haptic setting and no one found it realistic without haptic feed-back. The aspect of the task "needle through tissue" was considered the most unrealistic for the three different aspects that were investigated, with 13 of 22 participants rating it as totally unrealistic in the haptic setting and 16 of 22 participants in the non-haptic setting. The ratings for "tying the knot" were considered moderately realistic by 17 of 22 participants in the haptic setting and 13 of 22 participants in the non-haptic setting (Figure 9).

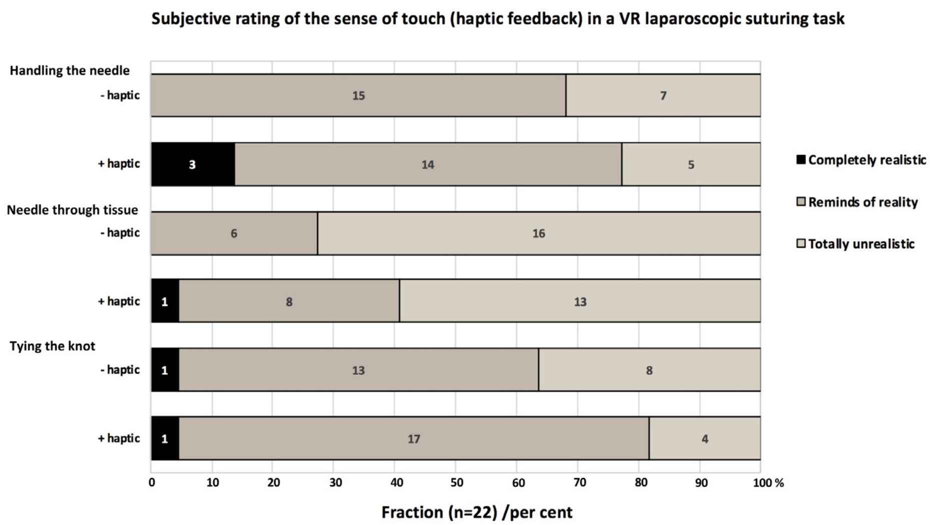


Figure 9.
Ratings on a 3-point Likert scale of the sense of touch (haptic feedback) for the laparoscopic VR suturing task. User experience ratings of 'handling the needle', 'needle through tissue' and 'tying the knot' with or without haptic feedback enabled in the LapSim® Haptic simulator. Scoring was done by 22 of the 26 surgeons (four had never performed laparoscopic suturing and were excluded). Values shown in per cent. A sum score of the rating showed a significant higher total score in the haptic setting, p=0.008.

Some 14 of 26 surgeons recommended the haptic setting and 8 of 26 found them to be equally good when performing laparoscopic suturing. A difference in rating between the two groups were seen: 9 of 13 participants in the "haptic last" group preferred the haptic setting and 7 of 13 participants in the "haptic first" group found them equally good (p=0.029).

The surgeons' performance metrics were recorded and showed that the parameter "maximum stretch damage" decreased significantly when haptic feedback was enabled. This parameter reflects the tearing when placing the stitch and both groups outperformed the other group and achieved better scoring when haptic was enabled (Table 5). The crossover showed that the "haptic first" group kept the level of skills that were acquired after switching to the non-haptic setting, and the "haptic last"-group improved in skills when haptics was added (Table 5).

Four individuals managed to pass in the first five attempts and eight in the following five.

Table 5.
Maximum Stretch Damage. Comparison of performance metrics for 'Maximum stretch damage' parameter between and within study groups with and without haptic feedback. Means and SD are presented for sum scores, analysed using a linear mixed model, allowing for repeated measures. P- value < 0.05 was considered significant.

Between group comparison	**Mean (SD)**	**Mean (SD)**	**P-value**
'Haptic first'-group (+ haptic) vs 'Haptic last'-group (- haptic)	60 (27)	77 (20)	0.027*
'Haptic first'-group (- haptic) vs 'Haptic last'-group (+ haptic)	77 (18)	49 (34)	<0.001***
'Haptic first'-group (+ haptic) vs 'Haptic last'-group (+ haptic)	60 (27)	49 (34)	0.693
'Haptic last'-group (- haptic) vs 'Haptic first'-group (- haptic)	77 (20)	77 (18)	0.999
Within group comparison	**Mean (SD)**	**Mean (SD)**	**P-value**
'Haptic first'-group (+ haptic) vs (- haptic)	60 (27)	77 (18)	0.308
'Haptic last'-group (- haptic) vs (+ haptic)	77 (20)	49 (34)	0.048*

P < 0.05*, P < 0.001***

Paper IV. Early warning signs in surgical trainees

Survey

The questionnaire with closed and open-ended questions that were distributed to experienced surgeons had a response rate of 65 per cent (54 of 83 surgeons), and for heads of departments the response rate was 4 out of 7. Results showed that 46 of 54 of surgeons and all heads of departments had experience with trainees that they considered to be unsuitable to work as surgeons. The reasons for their opinions were gathered in free text and later organised into six categories; technical ability; judgment; communication and interpersonal factors; personality, personal resources and skills; cognitive and miscellaneous (Table 6).

Some 14 of 54 surgeons and one of four heads of department were of the opinion that it should be possible to detect an unsuitable trainee in conjunction with the employment process, and 31 of 54 surgeons and three of four heads of department were of the opinion that it should be possible to detect unsuitable trainees during the early training years. Based on the results from the survey, an interview guide with questions concerning inappropriate and desired behaviours was constructed (Appendix B).

Table 6.
Survey results with stated reasons for being unsuitable as a surgeon by 54 consultants and 4 head of departments. The 107 statements are sorted into six categories.

Categories	Free text answer (numbers)
Technical skills	Lack of psychomotor skills (9), lack of savoir-faire (8), lack of visuo-spatial skills (2), clumsiness; lack of progress; technically ungifted; uncareful tissue handling
Judgment	Bad judgment (8), lack of judgment (4), injudicious (2), overconfident (too decisive)
Communication and interpersonal skills	Lack of, or difficulties with, communicational skills (7), inappropriate patient communication (7), lack of ability to co-operate (5), lack of leadership (2), inappropriate towards other personnel
Personality, personal resources and skills	Lack of empathy (5), inability of self-evaluation of own abilities (3), lack of self-knowledge or self-awareness (3), personality (2), overinflated ego; narcissism or megalomania; seeing the patient as an object; too prestigious / not receptive for feedback; lack of structure
Cognitive skills	Lack of in-depth knowledge (7), stress intolerant (5), disability to make decisions and prioritize (4), lack of clinical decision-making
Miscellaneous	Lack of passion/ motivation/interest (4), gut feeling; employed to fill a gap at emergency department; with good supervision most residents can be trained to become a surgeon; lack of insight of job demands outside normal working hours; does not understand that it is not sufficient to only handle the surgical craft; focuses more on him/herself than the patient; inappropriate priorities concerning own comfort and economy; love to surgery is not mutual

Interviews

A total of 13 in depth interviews with experienced surgeons were conducted. In the survey and interviews, the importance of organisational context and culture was emphasised for the progression of the trainee. The contextual aspects were not pursued in further analysis, since the focus of the study was on ”early warning signs” or descriptions of inappropriate behaviour. Twelve of the interviewees confirmed that they had come across unsuitable trainees and that these individuals had a negative influence on patient care and working environment. It was felt that the trainee needs to possess realistic judgment of their knowledge and skills. The importance of asking for help or make a change of surgical tactics when necessary were stated explicitly by seven of the interviewees. To do this was considered as good judgment. Lack of judgement was considered an important reason for being unsuitable as a surgeon. The most feared behaviours were hubris, macho attitudes and putting one's own career aspirations before the well-being of the patient.

Contrasting unwanted behaviour by describing the desired behaviour was common. Honesty and transparency when communicating with patients, relatives, personnel and colleagues were mentioned as major issues, together with the necessity to be mentally fit to deal with complications. Several interviewees gave descriptions of the surgical "role model" and the unspoken "code of conduct". Two basic abilities that are context dependent were found important; clear and unequivocal leadership on one hand, and to be a team player on the other hand.

The interviewees were aware of that skills and behaviour develop over time, and adaptability and interest to receive feedback were considered crucial. Trainees that did not take instructions or feedback, or showed a lack of empathy by viewing the patient as a "training object", and had difficulties with working in a team, were considered "problematic".

> *" The patient is no training object, but an individual that should receive good and safe treatment. Just because you are a surgical trainee you have no right to try your surgical skills on everyone" (IP6)*

Doubts were expressed about the possibility to change certain personality traits like conscientiousness, honesty, hubris, empathy, self-knowledge, decision-making, stress tolerance, egoism, feedback receptibility, prioritizing and inner motivation or drive for surgical craft. An important issue that was brought up by eight of the interviewed surgeons was the need to be a problem-solver with the ability to change strategy if needed.

> *"We have this group that perhaps can perform technically but does not think right. They who believe that surgery is only technique but lack the other dimension" (IP8)*

Insight in how professional life affects social life, and the necessity to meet the work demands with physical and mental fitness, were stressed by several surgeons.

Deficiencies in technical ability and progression were not seen as problems of same dignity as mental and behavioural issues. Most interviewees expressed that "almost everyone" can be trained to become a fairly good surgeon technically by compensating lack of technical abilities with strong non-technical skills. Despite this opinion, several mentioned problems with technically struggling trainees;

> *"…with unanswered love to surgery" (IP3)*

These trainees have an irregular or slow learning curve. Technical skills were considered easier to recognize and assess objectively and to talk about, compared to personal and social behavioural dimensions.

In the interviews, five surgeons explicitly mentioned the lack of control systems within the hospital and the Swedish health care system in order to identify unsuitable behaviour of trainees and with a possibility to terminate the employment as surgical trainee if necessary. A barrier to identify a "problem-trainee" was the fragmented supervision which lead to that these problems often surface after 2 -3 years of surgical training. Faculty meetings existed at some hospitals, but the question of suitability for the surgical profession was a sensible issue to discuss.

> *"No one wanted to be the one with the axe" (IP12)*

Lack of adequate taking of references were described as reasons for accepting unsuitable candidates. Furthermore, an unclear non-transparent assessment of applicants or locum employees were also considered. Description of "turfing[6]" of trainees were described as an acceptable action that directed them to a different department or team or to less dangerous sub-speciality [91].

> *"...to direct or encourage an individual towards education, research or a part of surgery less dangerous" (IP9)*

No one of the interviewed surgeons expressed negative opinions towards the common practice of six months of probation before getting a trainee position as part of the selection process. However, no one could describe in detail on what grounds selection of trainees were made or the prerequisites for "passing" the probation period other than "if it worked out well".

> *"it's no disaster to realise after six months that one is not suited (for surgery), and then giving (the trainee) a chance for a happier life by changing specialization and neither acquired knowledge nor time is lost" (IP3).*

Consolidation: Eleven problem domains and an interview guide

Categories known from the core competencies frameworks of Non-Technical Skills for Surgeons (NOTSS), Royal Australasians College of Surgeons (RACS) or Royal College of Physicians and Surgeons of Canada (CanMeds) were investigated and did not fully describe the aspects of unsuitability emerging from the survey and interviews [13, 59, 92].

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[6] Turfing: To find any excuse to refer a patient, i.e. in this context the trainee, to a different department or team. Expression borrowed from The House of God, Samuel Shem, 1985

Further reviewing and revision of codes and categories resulted in identification of 11 problem domains that could describe or explain different aspects of unsuitable behaviour; indecisiveness, timidity, lack of self-awareness and overconfidence, inability to receive criticism and take instructions, lack of appropriate communication, lack of empathy and instrumentalization of the patient, inability to meet the demands of the job, inability to gain sufficient level of craft proficiency, insufficient cognitive abilities (problem solving, identification, finding), dishonesty, and inappropriate priorities (Table 7). Additional content analysis led to identification of behavioural warning signs within each domain that would act as indicators (Table 7, for collection of example quotes, see Appendix C).

Using the findings above, an assessment instrument was constructed in the form of an interview guide to be applied during the selection process. To avoid a negative phrasing of the questions in the interview guide, traditional areas of competence were used in a purposeful and holistic manner to cover the warning signs or problematic behaviour with several questions, i.e. 'timidity' vs 'self-assurance', 'lack of empathy or instrumentalization of patient' vs 'understanding others, empathy', 'inappropriate priorities' vs 'dedication and motivation' (Table 8).

Table 7
List of problem domains and warning signs. Warning signs are indicators for unsuitability with the future professional role as a surgeon if not detected and acted upon early.

Problem domain	Warning signs Indicators or observed behavior
1. Indecisiveness	Long procedural time (even simple tasks) Slow procedural progression Inability to work unsupervised Nervousness about tasks Poses questions for reassurance rather than information
2. Timidity	Reluctance to operate Small numbers of total and independently performed procedures compared to peers Inability to give criticism
3. Lack of self-awareness and overconfidence	Making decisions or performing procedures beyond competence Expressed desire to undertake procedures beyond achieved competence. Underestimation of complexity of given procedures (situation awareness or hubris). Avoid seeking advice or ask for help
4. Inability to receive criticism and take instructions	Inappropriate response to feedback Anti-authority attitude Repeating actions that instructions or feedback has sought to correct
5. Lack of appropriate communication	Disliked by nurses or other categories of personnel Addresses different personnel categories differently in an unjustified manner Deficient documentation in medical journal Patient complaints about insufficient information or inappropriate tone.
6. Lack of empathy, instrumentalization of the patient	Disliked by or conflicts with nurses Inappropriate communication with patients, leading to patient complaints Expressed desire to try new procedures on patients to gain experience Advocates surgical procedures without making a holistic judgement about what is best for patient.
7. Inability to meet the demands of the job	Not completing assignments Lack of physical and mental well-being Sloppy, unstructured and unengaged work Colleagues or nurses having to “mop up” after the individual
8. Inability to gain sufficient level of craft proficiency	Slow or deficient technical progression Reluctance amongst consultants to let the trainee operate independently Careless tissue handling
9. Insufficient cognitive abilities (problem solving, identification, finding)	Difficulties sorting and prioritizing independently (stress management) Difficulties with identifying differential diagnosis Incomplete patient history or medical records (cognitive or negligence) Not understanding or being able to discuss the wider picture of a clinical problem
10. Dishonesty	Not sharing or denying experiences of complications Not taking responsibility for errors Claiming complications are patient related Nurse complaints
11. Inappropriate priorities	Lack of insight into work demands Exhibits more concern with social status of the professional role than the content of the role

Table 8
Interview guide. Letters in heading and brackets explaining within which theme the questions are probing. Note that a positive phasing contrasting the negatively loaded description of problem domains is used to be in line with traditional known areas of competence. Motivation (M), Empathy (E), Communication (Cm), Self-assurance and flexibility (SF), Attention (A), Leadership (L), Lifelong learning (LL), Cooperation and teamwork (Co) and Problem solving (PS).

	Question
	Introduction
1.	Why do you want to become a surgeon? Goal? (M)
2.	What makes you feel good at work? (SF)
3.	What makes you feel bad at work? (SF)
4.	What are you good at? What are your weaknesses? (SF)
5.	What is your biggest failure that occurred in your job? (SF)
	Understanding others (E)
6.	Can you describe how you act when you first meet a patient? What is the most important thing about that situation? (E)
7.	What are the 3 most important sources you base your decision on when diagnosing? (PS)
8.	How do you act when you feel you do not know how to proceed and treat a patient? (E)
9.	If you have to communicate a negative message to a patient, how do you handle it? (Cm)
10.	If your patient questions your assessment, how do you handle it? (SF)
	Communication skills (Cm)
11.	How do you ensure that important information you have about a patient reaches the right people?
12.	Supervising others. How do you feel? How do you give criticism? Give example(C)
13.	If you get criticism from a colleague, how do you handle it? (SF)
	Self-awareness/assurance? (SF)
14.	Can you give an example of a situation where you quickly had to make a decisive decision in your job? How did you proceed? (SF)
15.	Have you been involved in an adverse event? Describe. What happened? How did you handle it? What did you learn from it? (SF)
16.	Can you give an example of a situation where you changed a planned action because of advice or recommendation from someone else? What happened and what was the consequence? [When do you get help from others?] (SF)
	Attention (A)
17.	How do you handle a situation when you have many tasks to perform at once, for example in an emergency situation where you are forced to leave the emergency room for a few hours to operate? (A) What do you do when you come back? (A)
	Leadership (L)
18.	Can you give examples of when and how you tried to exert influence over a situation? (L)
19.	Have you had a formal or informal leadership role during your professional life or as a student? How did you get these roles? How do you function as a leader? How is it expressed? (L)
	Lifelong Learning (LL)
20.	What do you think is the most important thing for maintaining skills in the role of surgeon? (LL)
	Cooperation and teamwork (Co)
21.	How would you like to describe the different teams that a surgeon is part of, and the roles and responsibilities of these team members? Provide examples of teams in the ward, outpatient clinic, emergency department or in the operating room
22.	Have you experienced conflicts in your workplace? Can you give examples? How did you act then? (Co)
23.	What is collegiality for you? (Co)
24.	If you witness that any of your colleagues act in a detrimental way, what will you do? For example, if you assist during surgery and notice something that you consider erronous?(Co)
	Motivation (M)
25.	How important is work in your life? (M) How do you cope with working nightshifts?
26.	What do you think you will do in 10 years? (M)

Discussion

Simulators for surgical training

Three studies on laparoscopic simulators were conducted to investigate properties and effects on laparoscopic training; one study on Simball® Box and two studies on LapSim® Haptic. Surgical trainees have previously found that practicing laparoscopic skills in virtual reality is less useful compared to box trainers [93]. This has been proposed to be due to limited haptic feedback and sense of reality although acquired and transfer skills to the operating room seem to be approximately equal [93-95].

However, the studies on the impact of 3D and haptics on training showed that the virtual reality LapSim® Haptic with 3D reduced the time for novices to learn basic laparoscopic skills. The haptic feature was rated to have limited fidelity by surgeons, which is in line with previous results on other haptic VR devices [96]. However, the haptics had a positive impact on metrics when suturing in virtual reality (VR). Only a third of the surgeons managed the suturing task in VR and a slight majority of surgeons recommended the haptic feature to novices.

The new hybrid simulator Simball® Box was feasible to use for training, with metrics that mirrored progression of skills. Training in ordinary video box trainers gives the trainee limited feedback on hand movements and correctness of the performance if not supervised by an instructor. The Simball® Box bridges this gap by tracking of authentic laparoscopic instruments in a haptic environment. The results showed that the non-complex metrics provided by Simball® Box are relevant, and mirror individual progression and were consistent with similar types of simulators [97, 98]. Complex metrics, like motion smoothness[7], did not correlate to performance, and have shown inconsistent results in other hybrid box trainers as well [99-102]. Feedback to the manufacturer (G-coder, now Surgical Science) on this aspect led to that motion smoothness was removed from the metrics presented to the trainee after task completion.

[7] Smoothness: The third derivate of instrument position with respect to time which is a measure of the variation of the acceleration

Laparoscopic suturing training in Simball® Box attained a functional correspondence between simulation and the task in “real life”. Thus, the functional properties of the entire simulation context will align with the learning objectives as described and recommended by Hamstra et al [103].

A previous investigation in which the study groups practiced with individual self-training showed that the VR trained group performed better than the group trained in a video box trainer. This difference was suggested to depend on metrics feedback for the trainee [95].

Simball® Box offers appealing properties with the combination of “natural environment” and metrics, thereby reducing faculty supervision during training. The hybrid simulator cost less than LapSim® but has currently not been assessed for construct and validated to show that it can discriminate between different levels of skills l, i.e., novices, senior trainees and experts. Furthermore, there is a need for an instructor supervising the trainee or alternatively a video recording to confirm that the level of proficiency has been reached. To date, a validation study based on metrics obtained by Simball® Box to discriminate novices from intermediate learners and experts, has not been performed.

The release of LapSim® Haptic was expected to ameliorate the lack of fidelity previously shown for VR laparoscopic training. Two studies investigated the use of this new simulator. The first study in novices showed that the upgraded version with 3D and haptic feedback resulted in a steeper learning curve with 32 per cent faster course accomplishment. However, based on the study design it was not possible to conclude which of the new features that were the most contributing to this outcome; the use of 3D or haptics. In a systematic review of training effect in simulators with 3D vision consisting of 28 randomised controlled trials, 71 % reported reduced training time to reach the pre-defined competence level and 63 % a lower rate of errors and more accurate performance with 3D vision [20].

However, outcomes of the use of haptic feedback are inconsistent, with some studies showing beneficial transfer effect to the operating room, and some showing a negative effect of training with haptic feedback [104-107]. The investigation of the haptic feature of LapSim® Haptic was performed with laparoscopically trained surgeons. Although VR simulators are aimed at novices, laparoscopic suturing is a complex task typically executed by established surgeons and not novices. Thus, established surgeons were considered a reliable study population to investigate the impact on perception and performance with and without haptics.

The results showed that the surgeons performed significantly better with the haptic feedback feature. Haptic feed-back, according to obtained metrics, enabled surgeons to cause less “*stretch damage*” to the simulated tissue when the stitching was carried out. The surgeons also rated the sense of touch significantly higher compared with training without the haptic feature. Albeit these findings, only a handful of surgeons considered the aspects of the simulated environment to be completely realistic; a majority rated the task "*needle through tissue*" as completely unrealistic. However, although the sense of touch was rated as limited, a slight majority of surgeons recommended the haptic setting for novices. An interesting aspect of this finding was that the group that improved in performance after addition of haptics in their last five trials displayed a more positive attitude to the haptic setting with 9 of 13 recommending it. The group that performed with haptics in their first five trials retained performance in the non-haptic environment and 7 of 13 found the settings equally good.

Tissue texture and other haptic aspects as the surgeon perceive them in "real life laparoscopy" are difficult to mimic and evaluate and it is a fine line between too little and too much haptic feedback [108]. Compared to the study by Våpenstad et al on a haptic devise from Xitact® connected to LapSim®, where the majority of study subjects had a negative impression of the haptic feature, the haptic feature in LapSim® Haptic might be a step closer towards realism in training. Furthermore, in the study by Våpenstad et al, the haptic feature of this VR simulator additionally showed negative transfer effect of skills to the operating room [96, 106]. Thus, the technical aspects of the haptic feature are obviously of importance.

Undoubtedly there is room for improvement to increase haptic fidelity. With the limited perceived haptics in the current LapSim® Haptic VR trainer, one may question if the addition of haptics is worth the investment. A recent review on haptic (i.e. force feedback) in VR trainers confirms the contradicting results in this field of research and conclude that the extra added value for training with haptic feedback is unclear [52]. The study on haptics in the LapSim® Haptic trainer additionally revealed that even though 22 of 26 surgeons had performed intracorporal suturing before the study, only 8 surgeons managed to pass the suturing task within the time limits set by the study. This outcome reflects that laparoscopic suturing skill should be considered as an advanced and complex task in the simulated environment.

Less than half of the participating surgeons had previous experience of simulator training, which seems to be representative for specialist surgeons in Sweden. As seen in the third study, a majority of the surgeons struggled with the suturing task in the VR simulator and could probably improve with training. The obtained results could be related to unfamiliarity of VR training and that the computer program only approves the choreography and time limits set in the task program of the simulator. One the other hand, laparoscopic suturing is today a pre-requisite for emergency surgery, and the results may point to a need for surgeons to practice laparoscopy in a simulated environment prior to operating on "real patients" [7].

Advanced or simple simulators

One of the most important aspect of laparoscopic simulated training is to reach a predefined level of proficiency to lower the risk of adverse events in "real life", i.e., in the operating room. The inherent hypothesis is that advanced simulators, like VR simulators, can replace instructors, and enable the surgical trainee to practice in a risk-free environment, and as a positive side-effect, also save money compared with traditional training. Clearly, there is a trade-off between fidelity and cost, and extreme-high fidelity might not always be necessary to gain relevant training benefits [108, 109]. Considering the high cost of advanced simulators, it is important to evaluate advantages and disadvantages of added features for fidelity.

Although 3D and haptic feedback significantly was shown to have a positive effect on performance and to save time during training, the true value of simulation-based training should be shown with transfer of obtained skills to the operating room [110]. This has been shown for previous 2D non-haptic models VR simulators [111].

While the 3D feature is accepted to increase performance in the OR, the VR haptic feedback feature is still debated and there is no consensus on the hardware setup [50, 52, 112, 113]. It is difficult to compare results between different haptic VR simulators. Further, the haptic software set-up within the same VR simulator may vary [96, 106, 114]. Contributing to the confusion, the presently available simulators are not comparable to those used in scientific studies just a few years ago due to technological development and market competition between manufacturers [115-117].

Considering the cost of the haptic VR simulator and the reduced measured stretch damage found in one of the present studies, it remains to be seen if surgeons trained in VR simulators with haptic feature are less likely to cause tissue damage during stitching in real life. The answer to this question is beyond the scope of this thesis but will of course depend on cost benefit of the VR simulator regarding training, and the willingness to finance these technologically advanced simulators by the relevant party (i.e., the one who pays for the surgeon being away from production to practice in the skills lab).

Transfer effectiveness of simulation and cost issues

Studies of laparoscopic simulation trainings transfer effectiveness rate[8] (TER) have shown that every minute spent in simulator reduces time to proficiency, verified in cholecystectomy and Nissen´s fundoplication, for VR and video box trainers [2]. Laparoscopic simulation training has even been suggested to be more effective than the accepted TER for airline simulation.

In spite of this, simulation-based training has been difficult to introduce as mandatory in the surgical curriculum in Sweden. Two recent surveys across surgical specialties reveal a strong opinion amongst surgeons for the need to implement mandatory simulation training as a component of surgical training [118, 119]. Globally there is a lack of access to simulators, which is not the case in Scandinavia, but the pattern is the same worldwide that surgical trainees mainly still develop their skills practicing on patients during supervised procedures [118, 119].

To get value for training and return of investments of equipment and skills laboratories, the simulators need to be used frequently and be imbedded in a structured program with specifically trained staff and faculty to run courses and deliver individual coaching [27].

Education and simulation training demands resources and has an investments horizon beyond that of the local surgical department and hospital. Educational activities interfere with surgical production and are therefore often not of high priority in a busy schedule. The decentralized Swedish healthcare is therefore, unfortunately, a barrier to these investments. Financing surgical education, in order to prevent surgical adverse events, needs to be a high-level decision, possibly even on a national level. In the Prato Statement of cost and value in professional and interprofessional education, there is a call for economic analyses in professional and interprofessional education to create an evidence based delivery of maximum value for a given spend on education [120]. Cost and outcomes are important aspects of education in simulated environments, and the perceived value will influence decision makers willingness to make changes [121].When presenting scientific knowledge of training effectiveness to decision makers, potential patient safety gains and cost analysis allow for informed decisions to implement mandatory simulation-based training based on cost estimates.

[8] TER: the difference in the number of trials or time taken to achieve performance criterion between untrained and simulator trained group divided by total training time received by the simulator-trained group. [2]

Selection of surgical trainees: A competent surgeon needs more than technical skills

The fourth study in the present thesis investigated possible unsuitable behaviour amongst surgical trainees from a point of view of experienced surgeons. A majority of the surgeons had experience of surgical trainees whom they had found unsuited for the surgical profession.

The qualitative analysis identified 11 problem domains, with warning signs extracted from the empirical material, that were considered potential threats to patient safety and work environment. A majority of the surgeons believed that warning signs of unsuitable behaviour could be detected early in the surgical career. Differences in opinion were found regarding whether the different warning signs were resistant to change or not. The study also revealed several barriers to detect warning signs in the current trainee system, with potentially unsuitable candidates for surgical training slipping through the system.

Warning signs that were closely linked to personality traits were thought to be highly important but also the most difficult to change. These signs reflected behavioural patterns and traits of: indecisiveness, lack of self-awareness and overconfidence, anti-authority attitude with inability to take instructions, cognitive aspects like problem-solving capacity, dishonesty and not taking responsibility for errors. Efforts have been made to identify if a "surgical personality" associated with the so-called Big Five personality traits (openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism), used in psychology, with no clear answer [122-125]. A discourse to whether personality is innate or if it may develop during life is part of this ongoing debate [126, 127]. However, the identified warning signs related to personality play a crucial role in remedial activities or dismissal [83-85, 87]. Personality has influence on behaviour, but cannot be accepted as an excuse for maintaining unsafe behaviour, and personality will make it more or less easy to meet the expected standard of behaviour [128].

Overconfidence, macho and anti-authority attitudes, inability to receive criticism and to take instructions and lack of self-knowledge, are considered hazardous traits that can be subjected to testing, for example to prevent aviation accidents or incidents within the airline industry. Studies performed on orthopaedic surgeons found that 38 per cent displayed hazardous traits, above a specified level considered dangerous for pilots, like machismo, self-confidence, impulsivity and anti-authority [88]. Macho attitudes were also found to be associated with a higher number of readmissions and reoperations [89], and positively associated with a tendency to choose operative treatment over other treatment modalities [129]. Poor behaviour was thought by the interviewees in the present study to negatively affect both patients and the work environment.

The problem domains resemble the well-known ‘dirty dozen’ in the airline industry [130]. The “dirty dozen” reflect common human errors that can act as precursors to negatively impact flight or patient safety and working climate. The results therefore support the notion that the problem domains and warning signs can be used early on to identify undesirable behaviour. Thus, the tutor will be able to clarify which types of behaviour that are unacceptable, in line with other types of competence guides [59, 131].

Surgery is teamwork, and communication skills were emphasized as extremely important and consistent with other studies on desired non-technical skills for surgeons [131]. Communicational skills are reflected in several areas, like empathetic ability, situational awareness, judgment and problem-solving capabilities. Most interviewed surgeons described that they evaluated the potential and empathy of a trainee on their choice of treatment, and how this was communicated to the patient (and thereby the patient´s expectations). Furthermore, how the trainee talked about their patients and how they handled complications were considered important. It was considered as a severe problem if the trainee referred to patients as “training objects”, i.e. *cases*.

Empathy issues were thought to be resolvable through feed-back to a higher extent than problem-solving capacity. Remedial activity to problem-solving issues [132] could for example be to use situational judgment discussions customized to the local context. Trainees exhibiting problem-solving difficulties could benefit from normative training with scenarios targeted for situational judgment discussions customized to fit the local context of the department. Situational judgment scenarios are presented as realistic hypothetical situations that the trainees are likely to encounter and the task is to determine the appropriate action from a list of potential options [133]. Situational judgment tests have high reliability in assessing candidates for desirable non-academic personal qualities. If these tests are used during the early part of employment for a trainee, they could possibly detect warning signs [79, 133]. Questions that probe for situational judgment are included in the constructed interview guide and will therefore allow the candidate to describe their experiences and patterns of behaviour (Table 8, p.48). A study where behavioural questions in the admission interviews was included to identify predictors of success found that it also identified risk factors for failure during residency [134].

Through structured interviews it is possible to display behaviour patterns and personality traits and assess interpersonal communication skills, maturity, interest in the field, dependability and honesty [72, 135]. These interviews are therefore more efficient than *ad hoc* interviews [69, 72, 136]. **M**ultiple **M**ini **I**nterviews (MMI) consists of multiple standardized structured interviews and have been implemented in some countries to ensure a reliable and unbiased process for central selection of trainees [137, 138]. However, MMIs are resource demanding and do not fit a decentralized selection process as it currently the case in Sweden, with moreover, only a handful of applicants to each position. The constructed interview guide (Table 8, p.48) would therefore contribute to fairness amongst candidates in the Swedish context by asking the same questions to all applicants.

References from previous workplaces is a valuable source of information according to the interviewed surgeons. Studies on reference-taking confirm that any tendency of negative remarks are associated with higher degree of attrition and problematic behaviour [75].

Even though non-technical skills were dominant in the problem domains and warning signs, the participants stressed the need of having adequate visuospatial skills and a technical ability. Visuospatial perception is tested during pilot selection in aviation, although studies have shown conflicting results regarding correlation to the laparoscopic learning curve [29, 68, 78, 139]. Studies on laparoscopic learning curves have shown that between 8 to 30 % of trainees never achieve proficiency for advanced surgical laparoscopic skills like suturing [32, 33, 81]. One might speculate, that visuospatial perception difficulties may be exhibited as a reluctance to operate or a divergent learning curve compared to peers. Even though the interviewees confirmed to have experience with trainees with technical struggles, they seldom found this being a reason for unsuitability for the surgical profession.

Some of the inappropriate behaviour described by the interviewed surgeons and questionnaire respondents may represent extremes, but it is obvious that "outliers" within the surgical profession exist. The findings from the present study complement, and are consistent with previous literature in the field of professional competency, exemplified by the Royal Australasian College of Surgeons' (RACS) '*Guide of Surgical competence and performance'* [59]. According to Dent et al., is a surgical training program no better than the worst to graduate, and program directors and employers need to be "gatekeepers" in order to reduce variability and ensure quality amongst graduates [140]. All interviewed surgeons agreed that dealing with trainees that seem unfit for the profession is difficult and describe a cultural "unwillingness" to act within the organisation. They also mention information sharing between hospitals as part of the problem.

Studies that have investigated if trainees are prone to have higher rates of adverse events, show longer operating time for a specific procedure, which in itself is a risk factor for complications [141, 142]. In a report from the UK it was noted as a risk factor for adverse events, that trainees did not ask for help in due time. This finding is consistent with the result from present study [143]. The cost of failing to identify "a problem trainee" in time could be considered a poor return of investment since remediation activities are resource demanding, costly, and not always successful [79, 82, 84].

Trainee selection in a decentralized system

The participants in the present study were satisfied with the routine of 6-months' probation period since this gives them the opportunity to evaluate the trainees' talents and work ability. Some complained that it was hard to evaluate surgical competency since trainees initially predominantly work in the emergency department and with acute surgical care. Assessment was considered easier in the surgical wards and in the operating room. At the same time, several barriers to detect and act on warning signs in due time were identified due to lack of a structured assessment, fragmented trainee rotations, insufficient reference-taking and transparency on what is expected and assessed on part of the trainee.

Probing for warning signs may be performed simultaneously as looking for the top achievers. As warning signs are made explicit (Table 7, p.47), and characteristics and identification of the signs are known, detection and reporting are facilitated and the legitimacy of taking action is solidified.

A rigorous and resource demanding selection process, as conducted by the Royal College of Surgeons Ireland (RCSI), is unfortunately not applicable to surgical departments with a strictly local employment processes, as is the case in Sweden.

In a decentralized system, selection is rarely based on a large number of candidates, which is why it is all the more important to objectively test for unsuitability to mitigate a detrimental employment of a surgical trainee.

Strengths & limitations

Simulators for surgical training

The greatest strength of the conducted simulator studies is that they were conducted from a teaching surgeon's point of view. As new simulators and new updates are released by the manufacturers it is important to test these for feasibility and how they are perceived by the end users (study I and III) even though the level of scientific value may be somewhat limited [144]. The scientific value of comparing expert and novice performance (study I) may be questioned but is still an important first step in the evaluation of training devices [144]. Further, novices have little experience of "real life" and asking laparoscopically trained surgeons for their opinion is valuable from a teaching and supervising perspective. In paper III the surgeons were able to evaluate the simulators to the predefined proficiency level that trainees need to fulfil. Insight on the part of the individual surgeon in the study in the need for own simulation-based training might have been a positive side effect.

Investigating the synergistic effect of the two new features in study II, 3D vision and haptic feedback together, was purposeful from an educational point of view, since the studied feature combination is a new standard for training. Although scientifically four groups would have been better to discriminate all possible setting (2D no haptic, 2D + haptic, 3D no haptic and 3D+haptic), this would have demanded a much larger study cohort resulting in multiple comparisons, more participants and resources. To reduce the number of confounders due to the small study cohort in the second study with novices training in the LapSim® Haptic, the participants were demographically stratified. Efforts were also made to ensure a similar baseline level by pre-training participants to a proficient level in the Simball® Box before the VR course. In the third study, a crossover study design was chosen to provide unbiased estimates regarding the difference between the two groups: each surgeon served as their own control.

One of the common limitations to all three studies were the limited number of participants. No power calculation was performed since we did not know what differences to expect. Further, for the first study, comparison towards one tutorial expert performance in Simball® Box makes it a natural next step to collect data of performance of several experts and thereby creating a robust reference interval.

In the second and third study, the participants were not specifically tested for their 3D perception abilities and this ability was self-reported. Senior medical students, and not laparoscopic experts, coached their peers in the second study as this has previously been deemed appropriate [145].

Comparison towards other VR simulators using a different hardware setup to provide haptic feedback may result in that the outcomes of study II might not be comparable to similar studies.

In the third study the participants were randomized, with no statistical differences between the groups, but five of the six surgeons who had performed over 1000 laparoscopic procedures were randomized to the 'haptic first'-group. A sub-analysis of these surgeons' performances was done and no statistical difference on the evaluated parameters was found. Although a lack of evidence for a difference is not an evidence that differences might not exist if the numbers had been larger. Furthermore, the group with experience of between 100 – 1000 procedures may be heterogenous, with some having done 101 and others 999 laparoscopic operations.

Open-ended questions revealing descriptions on what aspects the surgeons found realistic or unrealistic would have given more in-depth information concerning their opinions and evaluation of the LapSim® Haptic simulator. The three minutes per trial time cap and limiting the number to five trials per setup prohibit us to know the true time needed to complete and pass the suturing task. If failure in passing the task influenced the opinion of the surgeon of the simulator is unclear, but no significant difference was found in ratings based on this assumption.

Selection of surgical trainees

One of the strengths of the conducted study is the mixed methods design that allowed for data and method triangulation by using multiple data sources (questionnaire and interviews). [90]. Further, the research group consisted of different professionals as social scientists and surgeons, allowing researcher triangulation and contributing to make the findings trustworthy and believable to others. Open and explorative type of questions made it possible to follow up on the answer of the informant and to probe for additional information or to confirm information [146]. Extensive descriptions of the findings and context was performed and the results showed, in line with previous research, for example the RACS framework [59].

Data was collected over an extended period of time, which gave the opportunity for iterative data collection and analysis until saturation criteria for the content of the interviews were fulfilled. No published literature was found that disconfirmed the findings of the study.

The limitations of the study are that no questions were asked in the survey about how many and during what time the surgeons had experienced trainees unsuited for the surgical profession. A Delphi approach[9] would have allowed for consensus between participants on what traits and behaviours being the most or least important. Moreover, the survey had limited space for comments and only one participant chose to enclose a letter with deeper explanations. To the best of the authors' knowledge, the system for recruiting and 6 months' probation is the same throughout Sweden. All participants were from the same health care region in Sweden and even if they had different backgrounds and work experiences, this could affect the generalization of the findings.

[9] Delphi method: a structured communication method with a panel of experts who answer questionnaires in two or more rounds. After each round, a facilitator provides an anonymized summary from the previous round. The experts are encouraged to revise their earlier answers in the light of the replies provided by other members. It is believed that this process will converge towards the "correct" answer (Wikipedia).

Conclusion and implications

Simulator studies

- Simball® Box, the hybrid laparoscopic simulator using new technology for obtaining metrics on performance using authentic instruments, was found feasible for training and to mirror the progression of skills through the obtained metrics.

  Implication. If further developed, construct validated and with proven transfer of skills to the OR, the Simball® Box simulator has the potential to become a consummate simulator. Validation is suggested before inclusion in a curriculum.

- Training in the LapSim® Haptic VR simulator with features of 3D vision and haptic feedback reduced time by one third for novices acquiring basic laparoscopic skills.

  Implication. Training novices in the newest LapSim® Haptic is more time efficient compared with 2D VR simulators.

- Training to proficiency in a virtual reality 3D and haptic environment did not negatively affect the later performance in a 2D environment.

  Implication. Training with 3D and haptics in the VR simulator is safe even if 2D laparoscopy is still widely used in the OR.

- Surgeons performing laparoscopic suturing in a virtual reality 3D environment and with haptic feedback caused less stretch damage in the simulated tissue, even though they rated the sense of touch to have limited fidelity.

  Implication. Even if the perceived sense of touch is limited, it might contribute to teach even skilled surgeons a correct suturing technique. Transfer to the OR needs to be proven.

Wider implications. A high level of laparoscopic technical skills is important to deliver safe surgery. Laparoscopic simulator training is feasible and possible to achieve in a time efficient manner for novices and experienced surgeons using modern simulator equipment. All surgeons that use laparoscopy should be able to demonstrate proficiency in laparoscopic suturing in the event of unexpected perioperative complications that may arise. Simulation training to proficiency is the safest way. Which simulator to use is of less importance if it is validated, and the as long as the curriculum has shown transfer to the operating setting. Importantly, no trainee should be allowed to operate on patients until a predefined proficient level is achieved in a simulated environment. This calls for a cultural change within the surgical community and also investments in surgical education by health care decision makers. The local context and a cost-benefit analysis need to be taken in consideration when deciding which simulator and curriculum to choose.

Selection of surgical trainees

- The study has provided knowledge of the current selection process in a decentralized health care organization.
- A great majority of the participating surgeons had experience of trainees not suited for the surgical profession.
- Identification of characteristics of unsuitable behaviours in surgical trainees contribute to new knowledge to be considered during the recruitment process
- Surgeons believe that traits and practices of unsuitable behaviours can be detected early.
- The results has been systematized to construct a set of 11 problem domains; indecisiveness, timidity, lack of self-awareness and overconfidence, inability to receive criticism and take instructions, lack of appropriate communication, lack of empathy and instrumentalization of the patient, inability to meet the demands of the job, inability to gain sufficient level of craft proficiency, insufficient cognitive abilities (problem solving, identification, finding), dishonesty, and inappropriate priorities.
- In addition to the problem domains, a list of 'warning signs', have been produced that reflect the content of the problem domains and a comprehensive interview guide has been constructed to facilitate to discover these warning signs.

Implications. The findings can contribute to a state of "collective mindfulness" so that when the warning signs become obvious and known, they can be acted upon. The list of warning signs and the comprehensive interview guide may facilitate to discover warning signs early in the selection process or during training, which is important for patient safety. The interview guide aims to promote and be part of a transparent and unbiased selection process applicable in a decentralized health care organisation.

Future perspective

New tools for the "surgical sorting hat"

> *The enchanted sorting hat in Harry Potter decides very subjectively into which Hogwarts house the new students belong. It can also provide help to students in need.*

Surgical trainees in Sweden are part of a health care system delivering high quality healthcare, but all aspects of their surgical education are not of high quality. Almost twenty years have passed since the first studies revealed a positive transfer of skills, from training minimal invasive surgical skills in a simulated environment, to the operating room [19]. The international surgical community has embraced simulation training in laparoscopy and countries from Denmark to the USA have made it mandatory to pass certain levels of skills before the trainee is allowed to perform surgery on patients or to advance to the next level of training [36, 147, 148]. Finding a program fit for the Swedish context is an important step in the near future.

Further research is required to see if simulators have predictive potential for the individual surgical career and if they can be used in selection processes and to minimal invasive surgery (MIS) fellowships or positions.

There is huge opportunity in Sweden to use the established 6 months' probation period for structured and transparent assessment. With little effort and low expenses, the quality of the recruited trainees can be secured, thus minimizing the risk of employing unsuitable candidates with a potential risk to become a dysfunctional specialist. A suggested framework is presented in table 9 and consist of external notification of all vacancies, structured reference-taking, personality profiling, a structured interview preferably using the constructed interview guide (Table 8, p.48), together with surgical assessment of all candidates during the 6 months period. This process should be scientifically grounded and with a holistic approach. The framework would also aim to secure fairness and transparency for employers, colleagues and potential surgical trainees, giving the opportunity to probe for excellence as well as warning signs without heavy costs.

The framework is currently being tested in an explorative study approved by the ethical committee (CEPN 2016-1050) on all applicants to surgical trainee positions and locums in the Southern Health Care Region in Sweden. Hopefully, the results will benefit future trainees, employers, colleagues and patients by transforming the magical sorting hat to a scientifically based surgical sorting hat.

Table 9
Suggested framework

Tool	Reason
External announcement with description of selection process	Transparency
Structured reference taking, minimum 2 (preferably oral)	Holism Former behavior predicts future behaviour.
Personality assessment (computer based)	Holism Fit in the group of other employees, diversity, strengths and weaknesses, hazardous traits.
Visuospatial test (computer based)	Aptitude Could predict future laparoscopic ability
Semi-structured job interview using an **interview guide**, see tabl 8 p.48 Lead by employer, program director or experienced colleague. Preferably two from faculty participating. Separate documentation on each interview for later comparison and dialogue	Fairness Get to know the person's communication skills, reasoning and insight of the craft of surgery, grit, behaviours and attitudes. Situational judgment aspects incorporated.
Multi source feedback	Holism Reliable source from other health care personnel
Dexterity test	Aptitude Possible correlation of skills for open surgery
Laparoscopy test Meaningful only if structured curriculum for simulator training exists	Aptitude Baseline for learning curve at time for employment. Individual learning curve visualise need for tailored training.
Situational Judgement Testing (computer based) Contextual dependent	Holism High reliability in assessing problem solving

Thoughts for the future

Considering the technical advances in surgery the last 30 years, the next 30 years will be even more exciting. Building resilience for trainees is important since the technical aspects of the surgical craft will change, and non-technical skills behaviour may be more important as a dominating factor for success. It has been said that surgery is 25 % dexterity and 75 % decision-making [149]. Simulation will expand with the use of artificial intelligence (AI) and serious gamification. Already, full immersive VR [47] and augmented reality (AR) [150] are in use for a "real" experience and surgical simulators will probably become an integrated part of our work. Learning successively on increased levels of difficulties will allow surgeons to train and plan full procedures on simulators as a "warm-up" before operation

Making use of all data that is generated in the operating room to foresee and prevent adverse events and near-accidents has already been initiated through the OR

BlackBox initiative [151-153]. Patients will probably in the future request that surgeons use advanced technologies in order to have the best results.

Artificial Intelligence may in the long perspective replace surgeons in some of the tasks, and definitely assist us in for instance decision-making, in the operating room. Mini-robots will with high precision and no tremor cut and suture delicate tissue and use preoperative imaging for precise localization to minimise unnecessary tissue damage.

Computers do not have emotions and empathy, they do not see the frailty of the patient, mood or read between the lines. The Hippocrates oath will still be utterly important to guide us in ethical and moral dilemmas.

Populärvetenskaplig sammanfattning

Denna avhandling handlar om blivande kirurger och deras utbildning som sker samtidigt som klinisk tjänstgöring. De tre första studierna handlar om teknikinlärning och den fjärde om beteenden och bedömning av lämplighet för yrket.

Trots att Sveriges sjukvård håller hög kvalitet drabbas 15 % av alla kirurgiska patienter av medicinska misstag eller oförutsedda händelser som inte beror på patientens underliggande sjukdom – så kallad vårdskada. Sjukvården, och kirurgi i synnerhet, är en högriskbransch. Misstag kan vara mer eller mindre allvarliga och mer än 2/3 anses vara undvikbara. Mellan 3,6 – 4,7 % av misstag leder till permanent skada eller död. För kirurger är det oftast inte tekniska brister som leder till vårdskador utan snarare bristande kommunikation, överblick över situationen och samarbete. Patientsäkerhet är ett prioriterat område inom sjukvården. Som exempel ses EUs direktiv om arbetstidsförkortning till max 48 timmars arbetsvecka, och begränsningar i jourpassens längd, som hänger ihop med insikt om att sömnbrist och trötthet leder till misstag.

Arbetstidsförändringar skedde några år efter millennieskiftet. Samtidigt hade en teknisk omvälvning påbörjats: från att tidigare ha opererat öppet med stora snitt över buken började man nu använda titthålskirurgi (laparoskopi). Tekniken innebär att kirurgen opererar genom små hål (3-12 mm) i bukväggen och ser operationsområdet på en TV-skärm. En av skillnaderna jämfört med öppen kirurgi är att man vid titthålskirurgi inte får samma känsla för vävnadernas struktur och konsistens. Vid titthålskirurgi ges samma uppfattning av det tredimensionella utrymmet som upplevs i dataspel. Förmågan till tredimensionellt tänkande är viktig, då skärmen vanligen visar en tvådimensionell bild. Instrumenten är långa, vassa och potentiellt livsfarliga om man inte uppfattar hur djupt in instrumenten är. Det kan gå så illa att organ eller kärl skadas och buken behöver öppnas. Behovet att ändra från titthål till öppen kirurgi kan uppstå akut då skadan kan vara potentiellt livshotande. De stora vinsterna med titthålstekniken är kortare sjukhusvistelse, snabbare återhämtning och därmed kortare tids sjukskrivning, mindre blodförlust, färre sårinfektioner, minskad risk för ärrbråck och mindre smärta efter operationen.

De två stora förändringarna, arbetstidsförkortning och titthålskirurgisk teknik, har påverkat den kirurgiska utbildningen. Eftersom utbildningen sker samtidigt som att man fyller en viktig plats i sjukvårdens produktionskedja har kirurgisk utbildning traditionellt skett enligt den så kallade lärlingsmodellen. I USA kallas de blivande kirurgerna för ”residents”, som betyder bosatt, då de i början på 1900-talet faktiskt bodde på sjukhuset för att alltid vara tillgängliga. Att lära sig laparoskopi enligt den traditionella lärlingsmodellen är svårare jämfört med öppen kirurgi. Simulatorträning har visat sig ge förbättrade tekniska färdigheter som kan överföras till operationssalen och bespara patienterna den brantaste delen av kirurgens inlärningskurva (d.v.s., bättre resultat med större erfarenhet och antal operationer). Blivande kirurger har tidigare varit negativa till virtual reality (VR) simulatorer då de inte uppfattats verklighetstrogna. Strukturerade obligatoriska program för inlärning av titthålskirurgisk färdighet i simulerad miljö finns internationellt men inte ännu i Sverige. Moderna riktlinjer anger att utbildningen till kirurg bör ta minst 5 år på heltid och är kompetensstyrd. Hur den blivande kirurgspecialisten spenderar sin tid under dessa år har därför avgörande betydelse.

De förste tre studierna i avhandlingen handlar om hur blivande kirurger kan träna upp titthålskirurgiska färdigheter med hjälp av avancerade simulatorer, designade att likna en titthålskirurgisk utrustning (Figur 10). Återkoppling med mätvärden som ges av simulatorn under träning är i teorin tänkta att kunna ersätta handledarnärvaro. När nya simulatorer släpps på marknaden är det därför viktigt att undersöka deras användbarhet och utbildningsvärde.

Figur 10. Tre vanliga simulatorer. Vä, vanlig video boxtränare där inga mätvärden erhålles. Mitten, Simball® Box, där vanliga instrument används och man får mätvärden. Hö: Virtual Reality simulator, LapSim® Haptic, där instrumenten är joysticks och man får mätvärden. I VR kan man träna hela procedurer. Photo by KH 2018

I vår första studie undersöktes hybridsimulatorn Simball® Box under en titthålskirurgisk kurs med 10 deltagare. Simulatorns mätvärden återspeglade kirurgens förbättring under träning. Deltagarna bedömdes samtidigt av en erfaren kirurg. Detta var första gången denna typ av simulator utvärderades vetenskapligt. Om ytterligare undersökningar och kvalitetsförbättringar görs har den potential att kunna inkluderas i ett strukturerat träningsprogram.

I den andra studien lät vi 20 studenter gå en kurs i den nya LapSim® Haptic simulatorn, en VR simulator, som erbjuder såväl 3D bild som haptik (=”känsla” av beröring) inbyggd i joysticken. Denna version av simulatorn jämfördes med standard LapSim® med enbart 2D bild utan vävnadskänsla. Det tog i medel 2,5 timmar för den snabbaste gruppen och drygt 3,5 timmar för kontrollgruppen att genomföra kursen med olika träningsmoment. Vi fann att de som använt den uppgraderade LapSim® uppnådde grundläggande titthålskirurgiska färdigheter drygt 30 procent snabbare än de som använt den äldre versionen. Om det berodde på 3D bilden eller ”vävnadskänslan” var i detta läge oklart.

Vi fortsatte därför med en tredje studie där vi lät specialister i kirurgi sy laparoskopiskt med 3D bild och antingen funktionen ”vävnadskänsla” på- eller avslagen i LapSim® Haptic. De fick bedöma känslan av ”beröring” i LapSim® Haptic. Samtidigt mättes deltagarnas prestation när de sydde med och utan funktionen med vävnadskänsla inkopplad.

Kirurgerna ansåg inte att beröringskänslan var speciellt verklighetstrogen, men när deltagarna sydde i den simulerade vävnaden gjorde de klart bättre ifrån sig med vävnadskänslan påkopplad. Av de 26 kirurgerna som testades, var det bara 8 som klarade syövningen efter 10 försök. Om det berodde på simulatorn eller kirurgerna går inte uttala sig om. Att sy titthålskirurgiskt är svårt samtidigt som det är en viktig färdighet att behärska t ex i akuta situationer. Slutsatsen blev att även om den simulerade vävnadskänslan inte var så tydlig för deltagarna så presterade kirurgerna lite bättre med vävnadskänslan i simulatorn påkopplad jämfört med funktionen avslagen.

Baserad på våra studier anser vi att träning i den nyaste LapSim® simulatorn går lite snabbare, och att Simball® Box har potential för titthålsträning, men båda behöver ingå i ett strukturerat curriculum för att ge maximal inlärningseffekt. Ett naturligt nästa steg vore att införa ett program där obligatorisk simulatorträning ingår för att dra nytta av den kunskap som finns inom området.

Det sista arbetet, studie IV, skiljer sig från de tre första då det handlar om hur man anställs och bedöms vara lämplig för det kirurgiska yrket. Kirurgen är alltid huvudansvariga för ett genomfört ingrepp. God kompetens inom tekniska och icke-tekniska färdigheter är en förutsättning för att leverera patientsäker vård. Selektion av rätt person i samband med anställning som ST-läkare, d.v.s., läkare som genomgår kirurgisk specialistutbildning, har föreslagits vara en ”missing link” i sjukvårdens patientsäkerhetsarbete jämfört med andra högriskbranscher. Detta har vi undersökt närmare.

Inom flyget har man arbetat mycket med urvalstester för att hitta rätt kandidater till pilotutbildningen och bland annat testar man visuospatial förmåga samt risktagande beteenden. Inom kirurgin används urvalstester och urvalsintervjuer endast på några få ställen i världen. Listor på önskade kvaliteter finns men motsatsen, d.v.s. oönskade beteende och egenskaper är sämre beskrivet. Det finns ingen konsensus inom den kirurgiska professionen hur urvalet till ST-tjänster skall ske. Vanligt är att man skickar in CV, examensbevis och referenser och genomgår en intervju. Det finns de som förespråkar andra bedömningsinstrument som tester som visuospatial[10] förmåga, fingerfärdighet, personlighetstest, strukturerade intervjuer och patientfall baserade scenarion. Teknisk begåvning kan ha betydelse då studier har visat att mellan 8 – 30 % av kirurger har problem med att lära sig den titthålskirurgiska tekniken. Om någon inte slutför en påbörjad utbildning är det en förlorad investering för båda individ och arbetsgivare.

Det är ofullständigt klarlagt hur rekryteringen till kirurgutbildningen sker i Sverige. Det traditionella är att man anställs som vikarie och sedan får förlängt om ”allting fungerar bra”. I studien undersöktes vilka egenskaper och beteenden som erfarna kirurger över 50 år ansåg gjorde någon olämplig för yrket samt hur de såg på den nuvarande urvals-och anställningsprocessen. En enkät skickades först ut till alla 83 kirurger över 50 år i Södra Sjukvårdsregionen och 65 % svarade, och då framkom att hela 85 % av kirurgerna under sin karriär hade stött på individer de fann olämpliga. En majoritet ansåg det vara möjligt att upptäcka detta tidigt under kirurgutbildningen. Vi gick vidare med att djupintervjua 13 kirurger för att få bättre beskrivningar av icke önskvärda beteenden. I intervjuerna framkom även en olust att ta tag i ”problemindivider” och att ”ingen” ville vara den som ”höll i yxan” och berätta för någon att man valt fel yrkesbana. Det framkom att den tekniska färdigheten inte var viktigast utan snarare ansågs samarbets- och problemlösningsförmågan viktigare. Vissa personlighetsdrag som machobeteende ansåg intervjupersonerna det svårt att ändra på.

Baserad på enkätsvaren och intervjumaterialet har vi tagit fram en lista över 11 problemområden samt något vi kallar ”varningstecken” (tabell7, s47). Problemområdena är 1) obeslutsamhet 2) skygghet, undvikande beteenden 3) brist på självmedvetenhet och övertro på egen förmåga 4) oförmåga att ta emot kritik och ta instruktioner 5) brist på lämplig kommunikation 6) bristande empati/ objektifiering av patienten 7) oförmåga att uppfylla kraven i jobbet 8) oförmåga att få tillräcklig nivå av yrkeskunnande 9)otillräckliga kognitiva förmågor

[10] Förmåga som gör att vi kan urskilja former och konturer, avstånd, rörelse och föremålens förhållande till varandra

(problemlösning, identifiering, upptäckande) 10) oärlighet 11) olämpliga prioriteringar

Dessa varningstecken innebär inte nödvändigtvis att man inte kan bli kirurg, men däremot att kollegor och handledare tidigt bör bli varse om att det kan bli problem framöver om inte personen ändrar sitt beteende. Vidare blev en intervjuguide framtagen som kan användas vid anställningsintervju för att ge arbetsgivaren en bättre helhetsbild av den sökande (tabell 8, s48).

Med liten ansträngning och låga kostnader kan anställningsprocessen professionaliseras, göras transparent och kvaliteten på de rekryterade läkarna säkras. Detta i sin tur minimerar risken att låta olämpliga kandidater fortsätta hela vägen genom specialistutbildningen med risk att bli dåligt fungerande inom yrket.

Provanställnings-perioden på 6 månader är ett etablerat koncept som kan utnyttjas bättre med en mer innehållsrik verktygslåda. Idag går blivande kirurger ibland på långa vikariat, men bättre vore att utannonsera Specialistutbildningstjänst direkt så att man får flera sökanden till varje position. Strukturerad referenstagning, personlighetstest och strukturerade anställningsintervjuer gör att arbetsgivaren kan få en bättre uppfattning om den sökandes personliga kvaliteter och dennes möjlighet att passa in i den kirurgiska yrkesrollen. Att testa visuospatial förmåga samt tidig utvärdering och uppföljning av inlärningskurvan för simulerade ingrepp under första halvåret kan vara av värde. Emellertid är det främst icke-tekniska egenskaper som har betydelse för att bli en patientsäker kirurg. Nära förestående strukturförändringar av den kirurgiska specialistutbildningen, där flera specialiteter ska göra ett gemensamt basår innan de går vidare till sin respektive moderklinik, innebär utmaningar för selektion och träning, men öppnar samtidigt upp nya möjligheter för en strukturerad selektion och simuleringsbaserad utbildning.

Populærvitenskapelig sammendrag

Denne avhandlingen handler om fremtidige kirurger og deres utdanning som foregår samtidig som høykvalitativ helseproduksjon skal opprettholdes. De tre første studiene handler om innlæring av kikkhullkirurgisk teknikk, og den fjerde om atferd og vurdering av egnethet for yrket.

Til tross for den høye kvaliteten i Sveriges moderne helsevesen, rammes 15% av alle kirurgiske pasienter av medisinsk feilbehandling eller uforutsette hendelser som ikke er avhengige av pasientens underliggende sykdom – såkalte pasientskader. Helsevesenet, og i særdeleshet kirurgi er høyrisiko. Pasientskadene kan være mer eller mindre alvorlige og mer enn 2/3 anses å kunne forebygges. Mellom 3,6 - 4,7% fører imidlertid til permanent skade eller død. For kirurger har det vist seg at det vanligvis ikke er sviktende tekniske evner som fører til skader, men derimot brist på kommunikasjon, oversikt over situasjonen og samarbeid. Pasientsikkerhet er prioritert i helsevesenet. EUs krav om redusert arbeidstid (maks 48 timers uke) skjedde rundt tusenårsskiftet.

Samtidig begynte en teknisk omstilling i operasjonsteknikk, fra tidligere å operere åpent med store snitt på magen til kikkhullsoperasjon (laparoskopi). Med denne teknikken opererer kirurgen gjennom små hull (3-12 mm) på magen og ser allting på en TV-skjerm. En av forskjellene i forhold til åpen kirurgi vs. en laparoskopisk operasjon er at kirurgen ikke får samme følelse for struktur og tekstur av vevet. Ved laparoskopi er oppfatningen av det tredimensjonale rommet samme som i dataspill. Evnen til tredimensjonal tenkning er viktig siden skjermen vanligvis viser et todimensjonalt bilde. Instrumentene er lange, skarpe og potensielt farlige hvis du ikke oppfatter hvor dypt inne de er. Det kan gå så galt at organer eller blodkar skades og magen må åpnes. De store gevinstene med kikkhullsteknikk er kortere rekonvalesenstid og dermed færre dager på sykehus og redusert sykefravær, mindre blodtap, færre sårinfeksjoner, redusert risiko for arr og mindre smerte etter operasjon.

De to store endringene med arbeidstidsforkortelse og kikkhullkirurgisk teknikk har påvirket den kirurgiske utdannelsen. Siden utdannelsen foregår samtidig som man skal fylle en viktig rolle i helseproduksjonskjeden, har kirurgisk opplæring tradisjonelt sett fulgt lærlingeprinsippet. Å lære seg kikkhullskirurgi etter den tradisjonelle mester-svennmetoden er vanskeligere enn å lære åpen kirurgi. Ved kikkhullskirurgi kan simulatortrening være effektivt. Det er bevist at trening i slike simulatorer gir økte tekniske ferdigheter i operasjonsstuen og besparer pasientene den bratteste delen av kirurgens læringskurve. Kirurger under utdannelse har tidligere vært negative til den virtuelle virkeligheten i simulatorer da de ikke oppfattes å stemme med virkeligheten. Internasjonalt har mange land innført krav om å gjennomgå simulatortrening, men ikke i Sverige.

Når nye simulatorer slippes ut på markedet, er det viktig å undersøke deres anvendbarhet og utdanningsverdi, slik studie I, II og III viser. Det finnes ulike typer simulatorer som gir tilbakemeldinger og måleverdier på kirurgens bevegelsesmønster som antas å kunne erstatte veilederens tilstedeværelse.

Figur 11. Tre vanliga simulatorer. V; vanlig video boxtrenar der man ikke får ut måleverdier på bevegelsemønsteret. Midten, Simball Box, der vanliga instrument brukes og man får ut måleverdier. H; Virtual Reality simulator, LapSim Haptic, der instrumenten er joysticks og man får ut måleverdier. I VR kan man trene hele prosedyrer. Photo by KH 2018

I studie I ble hybrid simulator Simball® Box undersøkt på et kikkhullkirurgisk kurs med 10 deltakere. Simulatorens målinger viste seg å gjenspeile kirurgens forbedring. Deltakerne ble samtidig vurdert av en erfaren kirurg. Dette var første gang denne simulatoren ble evaluert vitenskapelig. Hvis det gjøres ytterligere undersøkelser og kvalitetsforbedringer, har den potensiale til å kunne brukes i et strukturert opplæringsprogram.

I studie II lot vi 20 studenter ta et kurs i den oppgraderte virtual reality (VR) LapSim® Haptic med 3D og "følelse av berøring". Denne oppgraderte simulatoren ble sammenlignet med den gamle som hadde 2D uten berøringsfølelse. Det tok gjennomsnittlig 2,5 timer for den raskeste gruppen, og mer enn 3,5 timer for kontrollgruppen å gjennomføre kurset. Vi fant at de som brukte den oppgraderte LapSim® nådde ferdighetskravet i grunnleggende laparoskopiske ferdigheter på 30 prosent kortere tid. Om forbedringen skyldtes 3D eller berøringsfølelse gikk ikke å avgjøre fra studien.

Vi fortsatte derfor med en tredje studie der vi spurte gastrokirurger å vurdere hvordan de opplevde følelsen av "berøring" i den oppgradert LapSim® Haptic. Samtidig ble bevegelsene deres målt med og uten berøringsfunksjonen aktivert når de sydde. Det viste seg at kirurgene ikke syntes berøringsfølelsen var særlig realistisk, men når vi så på hvordan de flyttet instrumentene sine mens de sydde i det simulerte vevet, gjorde de det klart bedre når de hadde vevsfølelse på. Av de 26 kirurgene som ble testet var det bare 8 som klarte øvelsen etter 10 forsøk. Om det er avhengig av simulatoren eller kirurgene kan vi ikke si. Å sy når man gjør kikkhullskirurgi er vanskelig, men det er en viktig ferdighet å beherske f eks ved akutte situasjoner. Konklusjonen var at selv om vevsfølelsen ikke var så realistisk så presterte de faktisk litt bedre med enn uten.

Basert på våre gjennomførte studier på simulatorene ser vi att opplæring i den nyeste LapSim® Haptic simulatoren går litt raskere sammenlignet med den tidligere versjonen, og at Simball® Box har potensiale, men begge må forankres i et strukturert pensum for å gi maksimal læring for å være verdt investeringen. Et naturlig neste steg vil være å innføre et program med obligatorisk simulatortrening får å dra nytte av den kunnskap som finns på området i dag.

Den siste studien, studie IV, er forskjellig fra de tre første ettersom den handler om hvordan en blir ansatt og anses å være skikket for yrket som kirurg. Kirurger er alltid hovedansvarlige for en gjennomført prosedyre. Gode ferdigheter, både tekniske og ikke-tekniske, er en forutsetning for å levere trygg og sikker pasientbehandling. Derfor må valg av riktig person i en ansettelsesprosess baseres på flere ulike kvaliteter slik det f.eks. gjøres i andre høyrisikoyrker. Dette har vi undersøkt nærmere i denne siste studien.

I luftfartsindustrien har de jobbet mye med utvalgstester for å finne de rette kandidatene for pilottrening. Blant annet tester de visuospatial[11] evne, risikovurdering og atferd. I kirurgi blir utvalgstester, strukturerte intervjuer og systematisk referanseinnhenting kun brukt på noen få steder i verden. Lister over ønskede kvaliteter er tilgjengelige, men det motsatte, eller uønskete, er mindre beskrevet. Det er ingen konsensus innen kirurgi på hvilke kriterier som skal legges til grund for hvem man skal velge. Vanligvis brukes CV'er, diplomer og referanser, og at søkeren gjennomgår et intervju. Det finnes talspersoner som hevder at andre vurderingsverktøy som tester visuospatial evne, fingerferdighet, personlighetstester, strukturerte intervjuer og case-baserte tester må tas i bruk. Teknisk talent er også viktig siden studier har vist at mellom 8 og 30% har problemer med å lære

[11] Evne som gjør at vi kan skille former og konturer, avstand, bevegelse og avstand mellom gjenstander

kikkhullkirurgisk teknikk. Slutter man mitt i utdannelsen er det en mislykket investering for både kirurgen og arbeidsgiveren.

Det er ikke kartlagt hvordan rekruttering til kirurgisk utdanning foregår i Sverige. Det tradisjonelle er at du blir ansatt som vikar og deretter får fornyet vikariatet eller går over i fast ansettelse om "alt fungerer bra".

Studie IV undersøkte egenskaper og atferd hos blivende kirurger slik de opplevdes av erfarne kirurger over 50 år, og fokus var på yrket, upassende atferd og hvordan de så på dagens utvalgs- og ansettelsesprosess. En undersøkelse ble først sendt til alle 83 kirurger over 50 år i Södra sjukvårdsregionen med en svarfrekvens på 65%, og 85% hadde møtt personer som de fant upassende for yrket i løpet av karrieren. Et flertall anså det mulig å oppdage dette tidlig under kirurgisk trening. Vi fortsatte med dybdeintervjuer med 13 kirurger for å få en bedre beskrivelse av uprofesjonell og uakseptabel oppførsel. Det fremkom i intervjuene en vegring for å ta tak i problemindivider, og ingen vil være den som tar ansvar for å fortelle noen at de har valgt feil karriere. Basert på spørreskjemaet og intervjumaterialet har vi utviklet en liste over 11 problemområder og noe vi kalte signaler (tabell 7, s47). Problemområdene er 1) ubesluttsomhet 2) blyghet, unnvikende atferd 3) manglende bevissthet om egne begrensinger og overmot 4) manglende evne til å motta kritikk og ta instruksjoner 5) dårlig kommunikasjon 6) manglende empati og objektivering av pasienten 7) manglende evne til å oppfylle krav i jobben 8) manglende evne til å oppnå tilstrekkelig faglig kompetanse f ex teknisk ferdighet 9) utilstrekkelige kognitive evner (problemløsning, -identifikasjon, -oppdagelse) 10) uærlighet 11) upassende prioriteringer. Disse signalene betyr ikke nødvendigvis at du ikke kan bli kirurg, men kolleger og veiledere kan tidlig bli oppmerksomme på at det kan oppstå problemer i fremtiden om ikke personen endrer atferd. Videre ble en intervjuguide konstruert som kan brukes i ansettelsesintervjuer som bl. a undersøker atferd (tabell 8, s48). Den kan gi arbeidsgiver et bedre helhetsbilde av søkeren.

Med litt innsats og lave ekstra kostnader kan kvaliteten på de blivende kirurgene sikres, samtidig som risikoen for å la mindre egnede kandidater gå hele veien gjennom systemet og bli dysfunksjonelle spesialistleger. En ansettelse med 6 måneders prøvetid er et etablert konsept som gjennom en mer innholdsrik verktøykasse for arbeidsgiver kan gi økt kvalitetssikring i ansettelsesprosessen.

Det beste ville være å annonsere alle utdannelsestillinger i kirurgi i stedet for at det som i dag er mange fremtidige kirurger som går på lange vikariat. I tillegg til mange andre fordeler vil dette bety flere søkere for hver stilling. Strukturert referansetagning, personlighetstesting og strukturerte jobbintervjuer vil gjøre det mulig for arbeidsgiver å få bedre forståelse for søkerens personlige kvaliteter og evne til å passe inn i den profesjonelle rollen. Å teste visuospatial evne og implementere tidlig kirurgisk vurdering og oppfølging av læringskurven kan være av verdi - selv om det er stort sett ikke-tekniske egenskaper som er viktigst for å bli en kompetent kirurg. De forestående strukturelle endringer i den kirurgiske spesialistlegeutdannelsen, der flere spesialiteter kommer til å få et felles basisår før de går til sine respektive klinikker, er en utfordring, men samtidig en mulighet til å innføre en strukturert og transparent ansettelsesprosess av potensielle kirurger

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Illustrations

p.15 Screenshot of Halsted speech held in 1904, found in *The Internet Archive*, (501(c)(3) non-profit) is building a digital library of Internet sites and other cultural artifacts in digital form https://archive.org/details/b2246413x

p.25 by Wikivisual /CC BY. http://creativecommons.org/licenses/by/4.0/ for CC BY.

p.63 “The surgical sorting hat” by Luna Hagelsteen

Appendices

Appendix A. Simball® Box parameter description

Average speed (cm/s) is the average speed with which the instruments are moved.

Angular distance (radians) is the sum of angular movements at every sampling instant (i.e. every 0.01s). At every sampling instant the difference in orientation from the previous instant is computed in the form of an axis-angle rotation. The sum of the absolute values of these angles during all the task time provides the angular distance.

Average acceleration (mm/s^2) is defined as the sum of the accelerations impressed to the tool at every sampling instant. At every sampling instant the difference in position from the previous instant is computed as a vector. The magnitude of the vector divided by the sampling time provides the sampled velocity, the variation of the velocity along two subsequent sampling instants (i.e. the final velocity minus the initial velocity) divided by the sampling time provides the sampled acceleration. The sum of the absolute values of the sampled acceleration during all the task time, divided by the task time, provides the average acceleration.

Smoothness (µm/s^3) is defined as the third derivate of instrument position with respect to time, which is a measure of the variation of the acceleration. The variation of the sampled acceleration (as defined in the "average acceleration" definition) between subsequent sampling instants, divided by the sampling time, provides the so-called jerk (derivative of the acceleration or third derivative of the position). The sum of the absolute value of the sampled jerk provides the average jerk, which is motion smoothness. Motion smoothness was calculated for both right and left instruments, as done by others [101, 102]

4D motion. The metrics obtained from measured movement in X, Y, Z dimensions and instrument roll was initially called 4D motion by the manufacturer. Normally, 4D is considered a function of movement in space over time, and the 4D phrase is no longer used in the describing material from the manufacturer.

Appendix B. Interview guide for surgeons (English)

Part 1. Tell me a little bit about yourself

- Education, when and where (Internship, trainee)
- How long have you been a specialist in surgery?
- Workplaces
- How do you hire surgeons at your workplace? Selection? (known persons, temporary staff, etc.)
- What characterizes a good surgeon according to you?
- Is there an established approach to what a good surgeon is?

Part 2. Inappropriate surgeon

Have you in your role as a supervisor or surgeon, encountered staff who you did not consider to be suitable as a surgeon? Can you describe?

- Inappropriate - in what way?
- When does inappropriateness appear? Visible and invisible and to whom?
- Individual-related? The importance of education. Clinical (working environment) importance.
- Change over time? Alternative forms of care, heterogenic educational background

What do you do if you consider someone inappropriate?

To distinguish – how and when do you think it would be possible? Internship years? At what stage? During trainee years? At what stage? Practical activity?

Good surgeon

What is a good surgeon? Can you describe quite concrete?

How do you become a good surgeon?

- Try to investigate this in terms of knowledge, skills and skills
- Temporal and learning environment dimensions - career stages, good environments to evolve in, developing in different ways in different environments.
- Feedback - About Who?

Part 3. Formal educational role

- What can not be learned (screening question)
- Are there any skills and / or competencies that you have to bring from the start? How can you test for these?
- Are there skills, competences, settings, attitudes like in a formal education situation:

o Promote development
o inhibits development

Finally, there are things we have not talked about that should be taken into account when recruiting the surgeon education? And of all the things we have discussed today, what do you think is most important to consider in recruiting - a top five list?

Intervjuguide för kirurger (svenska)

Del 1. Berätta lite om dig själv

- Utbildning, när, var (AT, ST)
- Hur länge har du varit specialist?
- Arbetsplatser
- Hur anställer ni kirurger på din arbetsplats? Urval? (kända personer, vikarier, etc)
- Vad kännetecknar en bra kirurg enligt dig?
- Finns det ett etablerat synsätt på vad som är en bra kirurg?

Del 2. Olämplig kirurg

I din roll som handledare/kirurg stött på medarbetare som du inte ansett varit lämplig som kirurg? Kan du beskriva?

- Olämplig – på vilket/vilka sätt?
- När blir olämpligheten synlig? Synlig och osynlig och för vem?
- Individrelaterat? Utbildningens betydelse. Klinikens (arbetsklimat)betydelse.
- Förändring över tid? Alternativa vårdformer, heterogen utbildningsbakgrund

Hur gör ni om ni anser någon som olämplig?
Om urskilja – hur tycker du det skulle gå till? AT utbildning? I vilket skede? ST utbildning? I vilket skede? Praktisk verksamhet?

Bra kirurg

Vad är en bra kirurg? Kan du beskriva ganska konkret?
Hur blir man en bra kirurg?

- Försök utröna detta i termer av kunskap, färdigheter och kompetens
- Temporala och inlärningsmiljö-dimensioner – karriärstadier, bra miljöer att utvecklas i, att utvecklas på olika sätt i olika miljöer.
- Feedback – om vad av vem?

Del 3. Formell utbildningsroll

- Vad kan man inte lära sig (screeningfrågan)
- Finns det färdigheter eller kompetenser som man måste ha med sig från början? Hur kan man testa för dessa?
- Finns det färdigheter, kompetenser, inställningar, attityder som i en formell utbildningssituation:
    - Främjar utveckling
    - Hämmar utveckling

Avslutningsvis finns det saker som vi inte har pratat om som man borde ta hänsyn till vid rekrytering till kirurgutbildningen? Och av alla de saker som vi har diskuterat idag, vad anser du är viktigaste att ta hänsyn till i rekryteringen – en fem-i-topp lista.

Appendix C. Table of problem domains, warnings signs and quotes

Problem domain	Examples of inappropriate behavior observed Quotes (interviewee) [survey respondent]	Warning signs Indicators of behaviour
1. Indecisiveness	"When I assisted him, he performed very well and we were very content, but when he was left alone in the OR, things stood still " (IP3) "Those who continuously ask lots of questions and who end up not daring to make decisions, they do not manage to become doctors at the independent level " (IP7) "Neurotic and worried all the time ... you cannot let this worry for the patient impact how you act in the OR, it's something you have to be able to deal with " (IP08)	• Long procedural time (even simple tasks) • Slow procedural progression • Inability to work unsupervised • Nervousness about tasks • Poses questions for reassurance rather than information
2. Timidity	"He couldn't really cope. He fled from the role when he was going to operate, did not show up and had different excuses " (IP1) "Be able to communicate mistakes (especially one's own) with patients and relatives and colleagues "[s84] "He was not, well, motivated enough, or he was too shy or did not believe himself " (IP8) "Some have the perception that asking question is a sign of weakness, and in some way the wrong question does reveal ignorance, but if it's the right question, it is justified and should be asked more often" (IP11).	• Reluctance to operate • Small numbers of total and independent performed procedures compared to peers • Inability to give criticism
3. Lack of self-awareness and overconfidence	"Really high self-confidence, and when you have been back-up for the person on-call you suspect that there might be a problem, and you say to the individual that "you have to call me if you make certain decisions", and so on, and then there is no call for backup and a decision is made. Then,let's say after two to three days, we have to rescue the situation and re-operate" (IP7) "Not knowing one's limitations and harming a person because you undertake surgery that you are not ready [capable] to carry out " (IP9) " That you do not have respect for how difficult the task can be. Taking on things that you are not capable of, and not understanding what consequences it may have later on for the patient " (IP13)	• Making decisions or performing procedures beyond competence • Expressed desire to undertake procedures beyond achieved competence. • Underestimation of complexity of given procedures (situation awareness or hubris). • Avoid seeking advice or ask for help
4. Inability to receive criticism and take instructions	"Even though they have been corrected many times, the same problem and the same mistakes happen time after time so to speak. So the problem lies within the individual, as the shortcomings cannot be compensated for by education or corrective reprimands" (IP6)	• Inappropriate response to feedback • Anti-authority attitude

	”You should know when to ask for help and you should know when to change tactics, if I've done something and it has not worked, it's pretty stupid to do the same again, because it will not work this time either” (IP12) ”Appraise suitability; is this a person ... who seems to be able to correct a behavior that is not perfect or is it a stubborn person who will be difficult to control ” (IP8)	• Repeating actions that instruction or feedback has sought to correct
5. Lack of appropriate communication	” People who are correct in interacting with colleagues, but their shortcomings become more visible in interaction with other staff ” (IP6) ”It sometimes also appears in some cases in entries of the medical case notes, they are incomplete, a little sloppy. I cannot say they are wrong, but incomplete, the most important things are not there and things are missing and it causes problems for the next party that must search out and complete it and it takes time and effort to make it work” (IP11) ”It’s almost a personality trait, not paying attention to the feelings of others, don’t understand the vibe, you go through a room and make everyone crazy without understanding that you have trampled on a number of people’s feet, people who were there to help them” (IP11)	• Disliked by nurses or other categories of personnel • Addresses different personnel categories in unjustified manner • Deficient documentation in medical journal • Patient complaints about insufficient information or inappropriate tone.
6. Lack of empathy, instrumentalization of the patient	“Is a skilled person but is completely lacking empathy ” (IP4) ”To be able to realize the limitations and risks of surgery for a patient and in combination with the patient consider benefits and disadvantages of a surgical procedure ... if one does not care about this matter, it is a sign of lack of commitment and there is a risk of becoming a dangerous surgeon” (IP6) ” You should not do things just because it's possible, many do not take time to understand the patient's situation and what's right for the patient ” (IP10)	• Disliked by or conflicts with nurses • Inappropriate communication with patients, leading to patient complaints • Expressed desire to try new procedures on patients to gain experience • Advocates surgical procedures without making a holistic judgement about what is best for patient.
7. Inability to meet the demands of the job	”Could not cope physically and mentally. You have to be strong mentally to work as a surgeon ” (IP2) ”You have to have a different pace and you have to have a different attitude. “Ahh, I probably cannot do this. It is not possible.” For example, if you find it too tough here. Then I think it will be dangerous if you have such a personality at this workplace, because it almost always leads to conflicts” (IP4) ”Good and bad actions show up in the wards, - the wards are tough. [Though] Nurses try to cover for doctors’ incompetence ” (IP10)	• Not completing assignments • Lack of physical and mental well-being • Sloppy, unstructured and unengaged work • Colleagues or nurses having to “mop up” after the individual

8. Inability to gain sufficient level of craft proficiency	”Unrequited love, or unanswered love for surgery ... often someone who feels a social pressure that now I have to become a doctor and I'll be one and so I have to become a surgeon ” (IP3) ”Some are very impractical and not really dexterous ... you can still look in hindsight through the years, and see how well you succeed in handicrafts ” (IP5) ”There are those who say that you can teach a monkey to operate, that you can teach anyone ... I think there is a group that is not appropriate for it and most of them do not want to be surgeons either, so they are not a problem. The problem group is those who want to but don't recognize their technical shortcomings” (IP8) ”There is no point in being fast if you are not careful ” (IP6)	• Slow or deficient technical progression • Reluctance amongst consultants to let the trainee operate independently • Careless tissue handling
9. Insufficient cognitive abilities (problem solving, identification, finding)	“We have the group that maybe manage operate, but does not really think the right way, those who think surgery is just a technical matter and who lack the other dimension ” (IP8) ”Those who see a single solution that they consider great, until you point out that they will need to have a broader perspective in this situation. They are almost the most dangerous, because they make a decision without asking anyone else, and they make their own decision premised on the idea that asking others is a weakness”(IP11) ”A conscientiousness mind and orderliness, that you complete what you have begun, and conscientiously complete your journal entries ” (IP6)	• Difficulties sorting and prioritizing independently (stress management) • Difficulties to identify differential diagnosis • Incomplete patient history or medical records (cognitive or negligence) • Not understanding or being able to discuss the wider picture of a clinical problem
10. Dishonesty	”Macho culture. They say things to the patient even if they are not sure, - they do not want to appear unknowledgeable and judged as ignorant by others ” (IP10) ”He left all the time, he tried to leave as soon as he had the opportunity. If you lie, and if you let your peers do your work for you, if you cheat, if you prioritize other things ” (IP7) ”Unable to communicate mistakes (especially one's own) with patients and relatives and colleagues ”(s84)	• Not sharing or even denying experiences of complications • Not taking responsibility for errors • Claiming complications are patient related • Nurse complaints
11. Inappropriate priorities	”Not focused on the patient, but rather on their own development, financial situation and comfort. Surgery is not a 8-16 job ”[s85] ”Macho personalities are drawn to surgery due to prestige, because it is tough ” (IP10) ”Insufficient insight into the need for work outside working hours (for example: literature studies, preparing presentations) [s65]	• Lack of insight into work demands • Exhibits more concern with social status of the professional role than the content of the role

References

1. Anderson, O., et al., *Surgical adverse events: a systematic review.* Am J Surg, 2013. **206**(2): p. 253-62.
2. Orzech, N., et al., *A comparison of 2 ex vivo training curricula for advanced laparoscopic skills: a randomized controlled trial.* Ann Surg, 2012. **255**(5): p. 833-9.
3. Nilsson, L., et al., *Preventable Adverse Events in Surgical Care in Sweden: A Nationwide Review of Patient Notes.* Medicine (Baltimore), 2016. **95**(11): p. e3047.
4. Halsted, W.S., *The Training of the surgeon.* the Johns Hopkins Hospital Bulletin,, 1904(No. 162.): p. 267-275.
5. Gallagher, A.G. and G.C. O'Sullivan, *Fundamentals of Surgical Simulation*, in *Principles and Practices*, P. Apell, Editor. 2012, Springer.
6. Förening, S.K., *Svensk kirurgisk förening 100 år. 1905 - 2005*. 2005. 360.
7. Rodriguez-Paz, J.M., et al., *Beyond "see one, do one, teach one": toward a different training paradigm.* Postgrad Med J, 2009. **85**(1003): p. 244-9.
8. Pickersgill, T., *The European working time directive for doctors in training.* BMJ, 2001. **323**(7324): p. 1266.
9. Ericsson, K.A., *Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains.* Acad Med, 2004. **79**(10 Suppl): p. S70-81.
10. Way, L.W., et al., *Causes and prevention of laparoscopic bile duct injuries: analysis of 252 cases from a human factors and cognitive psychology perspective.* Ann Surg, 2003. **237**(4): p. 460-9.
11. Treasure, T., *Lessons from the Bristol case. More openness--on risks and on individual surgeons' performance.* BMJ, 1998. **316**(7146): p. 1685-6.
12. Kohn, L.T., J.M. Corrigan, and M.S. Donaldson, *To Err is Human: Building a Safer Health System*. To Err is Human: Building a Safer Health System. 2000, Washington (DC).
13. Flin, R., et al., *Non-Technical Skills for Surgeons (NOTSS)*. 2012.
14. Temple, J., *TempleTime for training: a review of the EWTD on the quality of training*. 2010: Department of Health, London.
15. Aggarwal, R., T.P. Grantcharov, and A. Darzi, *Framework for systematic training and assessment of technical skills.* J Am Coll Surg, 2007. **204**(4): p. 697-705.
16. Nguyen, L., et al., *Education of the modern surgical resident: novel approaches to learning in the era of the 80-hour workweek.* World J Surg, 2006. **30**(6): p. 1120-7.

17. Avital, S., et al., *Learning curve in laparoscopic colorectal surgery: our first 100 patients.* Isr Med Assoc J, 2006. **8**(10): p. 683-6.
18. Lin, Y.Y., A. Shabbir, and J.B. So, *Laparoscopic appendectomy by residents: evaluating outcomes and learning curve.* Surg Endosc, 2010. **24**(1): p. 125-30.
19. Seymour, N.E., et al., *Virtual reality training improves operating room performance: results of a randomized, double-blinded study.* Ann Surg, 2002. **236**(4): p. 458-63; discussion 463-4.
20. Sorensen, S.M., et al., *Three-dimensional versus two-dimensional vision in laparoscopy: a systematic review.* Surg Endosc, 2016. **30**(1): p. 11-23.
21. Ahlberg, G., et al., *Proficiency-based virtual reality training significantly reduces the error rate for residents during their first 10 laparoscopic cholecystectomies.* Am J Surg, 2007. **193**(6): p. 797-804.
22. Wohaibi, E.M., et al., *Surgical resident performance on a virtual reality simulator correlates with operating room performance.* J Surg Res, 2010. **160**(1): p. 67-72.
23. Palter, V.N. and T.P. Grantcharov, *Individualized deliberate practice on a virtual reality simulator improves technical performance of surgical novices in the operating room: a randomized controlled trial.* Ann Surg, 2014. **259**(3): p. 443-8.
24. Alaker, M., G.R. Wynn, and T. Arulampalam, *Virtual reality training in laparoscopic surgery: A systematic review & meta-analysis.* Int J Surg, 2016. **29**: p. 85-94.
25. Nagendran, M., et al., *Virtual reality training for surgical trainees in laparoscopic surgery.* Cochrane Database Syst Rev, 2013. **8**: p. CD006575.
26. Zevin, B., R. Aggarwal, and T.P. Grantcharov, *Surgical simulation in 2013: why is it still not the standard in surgical training?* J Am Coll Surg, 2014. **218**(2): p. 294-301.
27. MacRae, H.M., L. Satterthwaite, and R.K. Reznick, *Setting up a surgical skills center.* World J Surg, 2008. **32**(2): p. 189-95.
28. Cook, J.A., C.R. Ramsay, and P. Fayers, *Using the literature to quantify the learning curve: a case study.* Int J Technol Assess Health Care, 2007. **23**(2): p. 255-60.
29. Harrington, C.M., et al., *Visuospatial abilities and fine motor experiences influence acquisition and maintenance of fundamentals of laparoscopic surgery (FLS) task performance.* Surg Endosc, 2018.
30. Jalink, M.B., et al., *The effects of video games on laparoscopic simulator skills.* Am J Surg, 2014. **208**(1): p. 151-6.
31. Buckley, C.E., et al., *Does aptitude influence the rate at which proficiency is achieved for laparoscopic appendectomy?* J Am Coll Surg, 2013. **217**(6): p. 1020-7.
32. Buckley, C.E., et al., *The impact of aptitude on the learning curve for laparoscopic suturing.* Am J Surg, 2014. **207**(2): p. 263-70.
33. Grantcharov, T.P. and P. Funch-Jensen, *Can everyone achieve proficiency with the laparoscopic technique? Learning curve patterns in technical skills acquisition.* The American Journal of Surgery, 2009. **197**(4): p. 447-449.
34. Spruit, E.N., et al., *Optimal training design for procedural motor skills: a review and application to laparoscopic surgery.* Psychol Res, 2014. **78**(6): p. 878-91.

35. Kolozsvari, N.O., et al., *Sim one, do one, teach one: considerations in designing training curricula for surgical simulation.* J Surg Educ, 2011. **68**(5): p. 421-7.
36. Strandbygaard, J., et al., *A structured four-step curriculum in basic laparoscopy: development and validation.* Acta Obstet Gynecol Scand, 2014. **93**(4): p. 359-66.
37. Zendejas, B., et al., *Mastery learning simulation-based curriculum for laparoscopic TEP inguinal hernia repair.* J Surg Educ, 2012. **69**(2): p. 208-14.
38. Palter, V.N., et al., *Validation of a structured training and assessment curriculum for technical skill acquisition in minimally invasive surgery: a randomized controlled trial.* Ann Surg, 2013. **257**(2): p. 224-30.
39. van Dongen, K.W., et al., *European consensus on a competency-based virtual reality training program for basic endoscopic surgical psychomotor skills.* Surg Endosc, 2011. **25**(1): p. 166-71.
40. Rogers, S.O., Jr., et al., *Analysis of surgical errors in closed malpractice claims at 4 liability insurers.* Surgery, 2006. **140**(1): p. 25-33.
41. Agha, R.A., A.J. Fowler, and N. Sevdalis, *The role of non-technical skills in surgery.* Ann Med Surg (Lond), 2015. **4**(4): p. 422-7.
42. Madani, A., et al., *What Are the Principles That Guide Behaviors in the Operating Room?* Annals of Surgery, 2017. **265**(2): p. 255-267.
43. Graafland, M., et al., *Training situational awareness to reduce surgical errors in the operating room.* Br J Surg, 2015. **102**(1): p. 16-23.
44. Li, M.M. and J. George, *A systematic review of low-cost laparoscopic simulators.* Surg Endosc, 2017. **31**(1): p. 38-48.
45. Kundhal, P.S. and T.P. Grantcharov, *Psychomotor performance measured in a virtual environment correlates with technical skills in the operating room.* Surg Endosc, 2009. **23**(3): p. 645-9.
46. Boza, C., et al., *Simulation-trained junior residents perform better than general surgeons on advanced laparoscopic cases.* Surg Endosc, 2017. **31**(1): p. 135-141.
47. Huber, T., et al., *Highly immersive virtual reality laparoscopy simulation: development and future aspects.* Int J Comput Assist Radiol Surg, 2018. **13**(2): p. 281-290.
48. Mason, J.D., et al., *Is motion analysis a valid tool for assessing laparoscopic skill?* Surg Endosc, 2013. **27**(5): p. 1468-77.
49. Sutherland, L.M., et al., *Surgical simulation: a systematic review.* Ann Surg, 2006. **243**(3): p. 291-300.
50. Coles, T.R., D. Meglan, and N.W. John, *The Role of Haptics in Medical Training Simulators: A Survey of the State of the Art.* IEEE Trans Haptics, 2011. **4**(1): p. 51-66.
51. Buzink, S.N., et al., *Training of basic laparoscopy skills on SimSurgery SEP.* Minim Invasive Ther Allied Technol, 2010. **19**(1): p. 35-41.
52. Overtoom, E.M., et al., *Haptic Feedback, Force Feedback, and Force-Sensing in Simulation Training for Laparoscopy: A Systematic Overview.* J Surg Educ, 2018.

53. Aggarwal, R., et al., *An evaluation of the feasibility, validity, and reliability of laparoscopic skills assessment in the operating room.* Ann Surg, 2007. **245**(6): p. 992-9.

54. Andersson, R., et al., *Iatrogenic bile duct injury--a cost analysis.* HPB (Oxford), 2008. **10**(6): p. 416-9.

55. Chassin, M.R. and J.M. Loeb, *High-reliability health care: getting there from here.* Milbank Q, 2013. **91**(3): p. 459-90.

56. Paice, A.G., R. Aggarwal, and A. Darzi, *Safety in surgery: is selection the missing link?* World J Surg, 2010. **34**(9): p. 1993-2000.

57. Weick, K. and K. Sutcliffe, *Managing the unexpected: resilient performance in an age of uncertainty, second edition*. 2007: John Wiley \& Sons, Inc. 208.

58. Gallagher, A.G., et al., *An objective evaluation of a multi-component, competitive, selection process for admitting surgeons into higher surgical training in a national setting.* World J Surg, 2014. **38**(2): p. 296-304.

59. RACS, *Royal Australasian College of Surgeons. Surgical Competence and Performance. A guide to aid the assessment and development of surgeons.* . 2011: www.surgeons.org. p. 39.

60. Cuschieri, A., et al., *What do master surgeons think of surgical competence and revalidation?* Am J Surg, 2001. **182**(2): p. 110-6.

61. Baldwin, P.J., A.M. Paisley, and S.P. Brown, *Consultant surgeons' opinion of the skills required of basic surgical trainees.* Br J Surg, 1999. **86**(8): p. 1078-82.

62. Arora, S., et al., *What makes a competent surgeon?: Experts' and trainees' perceptions of the roles of a surgeon.* The American Journal of Surgery, 2009. **198**(5): p. 726-732.

63. Bogdanyova, S., et al., *Becoming a resident in Germany: an experience-based practical guideline.* Arch Gynecol Obstet, 2015. **291**(2): p. 457-60.

64. Gardner, A.K. and B.J. Dunkin, *Evaluation of Validity Evidence for Personality, Emotional Intelligence, and Situational Judgment Tests to Identify Successful Residents.* JAMA Surg, 2018. **153**(5): p. 409-416.

65. RCSI, *Selection Process for Core Surgical Training, Guide to the Marking System.* 2013. **July 2014 intake**.

66. Bann, S. and A. Darzi, *Selection of individuals for training in surgery.* Am J Surg, 2005. **190**(1): p. 98-102.

67. Louridas, M., et al., *Optimizing the Selection of General Surgery Residents: A National Consensus.* J Surg Educ, 2017. **74**(1): p. 100-107.

68. Maan, Z.N., et al., *Systematic review of predictors of surgical performance.* Br J Surg, 2012. **99**(12): p. 1610-21.

69. Schaverien, M.V., *Selection for Surgical Training: An Evidence-Based Review.* J Surg Educ, 2016. **73**(4): p. 721-9.

70. Kelz, R.R., et al., *Prevention of surgical resident attrition by a novel selection strategy.* Ann Surg, 2010. **252**(3): p. 537-1; discussion 541-3.

71. Bell, R.M., et al., *Determining personal talents and behavioral styles of applicants to surgical training: a new look at an old problem, part II.* J Surg Educ, 2012. **69**(1): p. 23-9.
72. Stephenson-Famy, A., et al., *Use of the Interview in Resident Candidate Selection: A Review of the Literature.* J Grad Med Educ, 2015. **7**(4): p. 539-48.
73. Gallagher, A.G., G. Leonard, and O.J. Traynor, *Role and feasibility of psychomotor and dexterity testing in selection for surgical training.* ANZ J Surg, 2009. **79**(3): p. 108-13.
74. Bell, R.M., et al., *Determining personal talents and behavioral styles of applicants to surgical training: a new look at an old problem, part I.* J Surg Educ, 2011. **68**(6): p. 534-41.
75. Brenner, A.M., et al., *Can we predict "problem residents"?* Acad Med, 2010. **85**(7): p. 1147-51.
76. Hennessey, I.A.M. and P. Hewett, *Virtual Reality Versus Box Laparoscopic Simulators in Trainee Selection and Aptitude Testing.* Surgical Laparoscopy Endoscopy & Percutaneous Techniques, 2014. **24**(4): p. 318-321.
77. Phillips, D., et al., *Personality Factors Associated With Resident Performance: Results From 12 Accreditation Council for Graduate Medical Education Accredited Orthopaedic Surgery Programs.* J Surg Educ, 2018. **75**(1): p. 122-131.
78. Henn, P., et al., *Visual spatial ability for surgical trainees: implications for learning endoscopic, laparoscopic surgery and other image-guided procedures.* Surg Endosc, 2018. **32**(8): p. 3634-3639.
79. Gardner, A.K., T. Grantcharov, and B.J. Dunkin, *The Science of Selection: Using Best Practices From Industry to Improve Success in Surgery Training.* Journal of Surgical Education, 2018. **75**(2): p. 278-285.
80. Louridas, M., et al., *Can We Predict Technical Aptitude?: A Systematic Review.* Ann Surg, 2016. **263**(4): p. 673-91.
81. Schijven, M.P. and J. Jakimowicz, *The learning curve on the Xitact LS 500 laparoscopy simulator: profiles of performance.* Surg Endosc, 2004. **18**(1): p. 121-7.
82. Roberts, N.K. and R.G. Williams, *The hidden costs of failing to fail residents.* J Grad Med Educ, 2011. **3**(2): p. 127-9.
83. Resnick, A.S., et al., *Patterns and predictions of resident misbehavior--a 10-year retrospective look.* Curr Surg, 2006. **63**(6): p. 418-25.
84. Williams, R.G., et al., *The nature of general surgery resident performance problems.* Surgery, 2009. **145**(6): p. 651-8.
85. Yaghoubian, A., et al., *General surgery resident remediation and attrition: a multi-institutional study.* Arch Surg, 2012. **147**(9): p. 829-33.
86. Sanfey, H., R. Williams, and G. Dunnington, *Recognizing residents with a deficiency in operative performance as a step closer to effective remediation.* J Am Coll Surg, 2013. **216**(1): p. 114-22.
87. Bergen, P.C., et al., *Identification of high-risk residents.* J Surg Res, 2000. **92**(2): p. 239-44.

88. Bruinsma, W.E., et al., *How Prevalent Are Hazardous Attitudes Among Orthopaedic Surgeons?* Clinical Orthopaedics and Related Research®, 2014. **473**(5): p. 1582-1589.
89. Kadzielski, J., et al., *Surgeons' attitudes are associated with reoperation and readmission rates.* Clin Orthop Relat Res, 2015. **473**(5): p. 1544-51.
90. Creswell, J.W., *Qualitative Inquiry & Research Design : Choosing among five approaches*. 3rd ed. 2013: SAGE.
91. Shem, S., *The House of God*. 1985: Black Swan.
92. CanMeds, *CanMEDS 2015 Physician Competency Framework*. 2015.
93. Palter, V.N., et al., *Resident perceptions of advanced laparoscopic skills training.* Surg Endosc, 2010. **24**(11): p. 2830-4.
94. Kanumuri, P., et al., *Virtual reality and computer-enhanced training devices equally improve laparoscopic surgical skill in novices.* JSLS, 2008. **12**(3): p. 219-26.
95. Hamilton, E.C., et al., *Comparison of video trainer and virtual reality training systems on acquisition of laparoscopic skills.* Surg Endosc, 2002. **16**(3): p. 406-11.
96. Vapenstad, C., et al., *Perceiving haptic feedback in virtual reality simulators.* Surg Endosc, 2013. **27**(7): p. 2391-7.
97. van Empel, P.J., et al., *Learning curve on the TrEndo laparoscopic simulator compared to an expert level.* Surg Endosc, 2013. **27**(8): p. 2934-9.
98. Aggarwal, R., et al., *Training junior operative residents in laparoscopic suturing skills is feasible and efficacious.* Surgery, 2006. **139**(6): p. 729-34.
99. Oostema, J.A., M.P. Abdel, and J.C. Gould, *Time-efficient laparoscopic skills assessment using an augmented-reality simulator.* Surg Endosc, 2008. **22**(12): p. 2621-4.
100. Van Sickle, K.R., et al., *Construct validation of the ProMIS simulator using a novel laparoscopic suturing task.* Surg Endosc, 2005. **19**(9): p. 1227-31.
101. Hiemstra, E., et al., *Intracorporeal suturing: economy of instrument movements using a box trainer model.* J Minim Invasive Gynecol, 2011. **18**(4): p. 494-9.
102. Chmarra, M.K., et al., *The influence of experience and camera holding on laparoscopic instrument movements measured with the TrEndo tracking system.* Surg Endosc, 2007. **21**(11): p. 2069-75.
103. Hamstra, S.J., et al., *Reconsidering fidelity in simulation-based training.* Acad Med, 2014. **89**(3): p. 387-92.
104. Salkini, M.W., et al., *The role of haptic feedback in laparoscopic training using the LapMentor II.* J Endourol, 2010. **24**(1): p. 99-102.
105. Thompson, J.R., et al., *Limited value of haptics in virtual reality laparoscopic cholecystectomy training.* Surg Endosc, 2011. **25**(4): p. 1107-14.
106. Vapenstad, C., et al., *Lack of transfer of skills after virtual reality simulator training with haptic feedback.* Minimally Invasive Therapy & Allied Technologies, 2017. **26**(6): p. 346-354.

107. Strom, P., et al., *Early exposure to haptic feedback enhances performance in surgical simulator training: a prospective randomized crossover study in surgical residents.* Surg Endosc, 2006. **20**(9): p. 1383-8.
108. Lamata, P., et al., *Tissue consistency perception in laparoscopy to define the level of fidelity in virtual reality simulation.* Surg Endosc, 2006. **20**(9): p. 1368-75.
109. Andreatta, P., et al., *Low-hanging fruit: a clementine as a simulation model for advanced laparoscopy.* Simul Healthc, 2014. **9**(4): p. 234-40.
110. Stefanidis, D., et al., *Simulation in Surgery: What's Needed Next?* Ann Surg, 2014.
111. Zendejas, B., et al., *Simulation-based mastery learning improves patient outcomes in laparoscopic inguinal hernia repair: a randomized controlled trial.* Ann Surg, 2011. **254**(3): p. 502-9; discussion 509-11.
112. Zhang, L., et al., *The added value of virtual reality technology and force feedback for surgical training simulators.* Work, 2012. **41 Suppl 1**: p. 2288-92.
113. Botden, S.M., et al., *The importance of haptic feedback in laparoscopic suturing training and the additive value of virtual reality simulation.* Surg Endosc, 2008. **22**(5): p. 1214-22.
114. Hagelsteen, K., et al., *Faster acquisition of laparoscopic skills in virtual reality with haptic feedback and 3D vision.* Minim Invasive Ther Allied Technol, 2017. **26**(5): p. 269-277.
115. Schijven, M. and J. Jakimowicz, *Virtual reality surgical laparoscopic simulators.* Surg Endosc, 2003. **17**(12): p. 1943-50.
116. Pinzon, D., S. Byrns, and B. Zheng, *Prevailing Trends in Haptic Feedback Simulation for Minimally Invasive Surgery.* Surg Innov, 2016. **23**(4): p. 415-21.
117. Vapenstad, C., et al., *Limitations of haptic feedback devices on construct validity of the LapSim(R) virtual reality simulator.* Surg Endosc, 2013. **27**(4): p. 1386-96.
118. Partridge, R.W., et al., *There is a worldwide shortfall of simulation platforms for minimally invasive surgery.* JOurnal of Surgical Simulation, 2015. **2**: p. 12-17.
119. Fjortoft, K., et al., *The Implementation Gap in Laparoscopic Simulation Training.* Scand J Surg, 2018: p. 1457496918798201.
120. Maloney, S., et al., *The Prato Statement on cost and value in professional and interprofessional education.* J Interprof Care, 2017. **31**(1): p. 1-4.
121. Tolsgaard, M.G. and D.A. Cook, *New roles for cost as an outcome: opportunities and challenges.* Med Educ, 2017. **51**(7): p. 680-682.
122. Grossman, R., *The surgical personality: does it matter?* The Bulletin of the Royal College of Surgeons of England, 2018. **100**(3): p. 130-132.
123. Swanson, J.A., et al., *Personality profiling of the modern surgical trainee: insights into generation X.* J Surg Educ, 2010. **67**(6): p. 417-20.
124. Hoffman, B.M., M.J. Coons, and P.C. Kuo, *Personality differences between surgery residents, nonsurgery residents, and medical students.* Surgery, 2010. **148**(2): p. 187-193.
125. Whitaker, M., *The surgical personality: does it exist?* Ann R Coll Surg Engl, 2018. **100**(1): p. 72-77.

126. Allemand, M., V. Gomez, and J.J. Jackson, *Personality trait development in midlife: exploring the impact of psychological turning points.* European Journal of Ageing, 2010. **7**(3): p. 147-155.

127. Roberts, B.W., K.E. Walton, and W. Viechtbauer, *Patterns of mean-level change in personality traits across the life course: a meta-analysis of longitudinal studies.* Psychol Bull, 2006. **132**(1): p. 1-25.

128. Flin, R., P. O'Connor, and M. Chrichton, *Safety at the Sharp End : a guide to non-technical skills*. 2008: Ashgate.

129. Meunier, A., et al., *Risk preferences and attitudes to surgery in decision making.* Acta Orthop, 2017. **88**(5): p. 466-471.

130. Canada, T., *Human Performance Factors for Elementary Work and Servicing TP14175E*. 2003, Transport Canada.

131. Yule, S. and S. Paterson-Brown, *Surgeons' Non-technical Skills.* Surgical Clinics of North America, 2012. **92**(1): p. 37-+.

132. Naylor, R.A., J.S. Reisch, and R.J. Valentine, *Factors related to attrition in surgery residency based on application data.* Archives of Surgery, 2008. **143**(7): p. 647-651.

133. Patterson, F., L. Zibarras, and V. Ashworth, *Situational judgement tests in medical education and training: Research, theory and practice: AMEE Guide No. 100.* Med Teach, 2016. **38**(1): p. 3-17.

134. Strand, E.A., E. Moore, and D.W. Laube, *Can a structured, behavior-based interview predict future resident success?* Am J Obstet Gynecol, 2011. **204**(5): p. 446 e1-446 e13.

135. Schmidt F, H.J., *The validity and utility of selection methods in personnel psychology: Practical and theoretical implications of 85 years of research findings.* Psychological Bulletin, 1988. **Vol 124(2)**: p. pp. 262-274.

136. Hern, H.G., Jr., et al., *How prevalent are potentially illegal questions during residency interviews?* Acad Med, 2013. **88**(8): p. 1116-21.

137. Dore, K.L., et al., *The reliability and acceptability of the Multiple Mini-Interview as a selection instrument for postgraduate admissions.* Acad Med, 2010. **85**(10 Suppl): p. S60-3.

138. Eva, K.W., et al., *An admissions OSCE: the multiple mini-interview.* Med Educ, 2004. **38**(3): p. 314-26.

139. Louridas, M., L.E. Quinn, and T.P. Grantcharov, *Predictive value of background experiences and visual spatial ability testing on laparoscopic baseline performance among residents entering postgraduate surgical training.* Surg Endosc, 2016. **30**(3): p. 1126-33.

140. Dent, D.L., M. Al Fayyadh, and R.E. Willis, *We are the Gatekeepers Or "Your Residency is Only as Good as Your Worst Graduate".* J Surg Educ, 2018.

141. Papandria, D., et al., *Assessing trainee impact on operative time for common general surgical procedures in ACS-NSQIP.* J Surg Educ, 2012. **69**(2): p. 149-55.

142. Allen, R.W., M. Pruitt, and K.M. Taaffe, *Effect of Resident Involvement on Operative Time and Operating Room Staffing Costs.* J Surg Educ, 2016. **73**(6): p. 979-985.

143. K Wilkinson, I.C.M., M J Gough, J A D Stewart, S B Lucas, H Freeth, B Bull and M Mason, *An Age Old Problem. A review of the care received by elderly patients undergoing surgery*. 2010: http://www.ncepod.org.uk/.
144. Korndorffer, J.R., Jr., S.J. Kasten, and S.M. Downing, *A call for the utilization of consensus standards in the surgical education literature.* Am J Surg, 2010. **199**(1): p. 99-104.
145. Vedel, C., et al., *Medical students as facilitators for laparoscopic simulator training.* J Surg Educ, 2015. **72**(3): p. 446-51.
146. Brinkman, S. and S. Kvale, *InterVIews*. Third Edition ed. 2015: SAGE Publications.
147. Ritter, E.M. and D.J. Scott, *Design of a proficiency-based skills training curriculum for the fundamentals of laparoscopic surgery.* Surg Innov, 2007. **14**(2): p. 107-12.
148. Cullinan, D.R., et al., *Fundamentals of Laparoscopic Surgery: Not Only for Senior Residents.* J Surg Educ, 2017. **74**(6): p. e51-e54.
149. Pugh, C.M., et al., *Intra-operative decision making: more than meets the eye.* J Biomed Inform, 2011. **44**(3): p. 486-96.
150. Vavra, P., et al., *Recent Development of Augmented Reality in Surgery: A Review.* J Healthc Eng, 2017. **2017**: p. 4574172.
151. SurgicalSafetyTechnologies. *Operating Room Black Box®*. 2018 [cited 2018 2018-10-23]; Available from: http://www.surgicalsafety.com/index.html.
152. Fecso, A.B., et al., *Relationship between intraoperative non-technical performance and technical events in bariatric surgery.* Br J Surg, 2018. **105**(8): p. 1044-1050.
153. Jung, J.J., et al., *First-year Analysis of the Operating Room Black Box Study.* Ann Surg, 2018.

Paper I

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Simball Box for Laparoscopic Training With Advanced 4D Motion Analysis of Skills

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Abstract

Background. Laparoscopic skills training and evaluation outside the operating room is important for all surgeons learning new skills. To study feasibility, a video box trainer tracking 4-dimensional (4D) metrics was evaluated as a laparoscopic training tool. *Method*. Simball Box is a video box trainer with authentic surgical instruments and camera with video recording, equipped with 4D motion analysis registered through trocars using machine vision technology. Residents attending a 3-day laparoscopy course were evaluated performing a laparoscopic surgical knot at start, middle, and end. Metrics were obtained. Feedback data were presented in reference to expert/tutorial performance. *Results*. Ten right-handed residents were included. Median time (range) to finish the task was 359 (253-418), 129 (95-166), and 95 (52-156) seconds; 655%, 236%, and 174% of tutorial performance, with significance pre-/midcourse ($P < .0001$), pre-/postcourse ($P < .0001$), and mid-/postcourse ($P = .0050$). Combined median total instrument motion decreased pre-/midcourse from 1208 (845-1751) to 522 cm (411-810 cm); $P = .042$ to 405 cm (246-864 cm) postcourse; pre-/postcourse $P < .0001$; 673%, 291%, 225% of tutorial performance. Total angular distance in radians (range) was 150 (87-251), 65 (42-116), and 50 (33-136) with significance pre-/midcourse ($P = .022$) and pre-/postcourse ($P = .0002$). Right-handed average speed (cm/s) increased: 1.94 (1.11-2.27) pre-, 2.39 (1.56-2.83) mid-, 2.60 (1.67-3.19) postcourse with significance pre-/midcourse ($P = .022$) and pre-/postcourse ($P = .002$). Average acceleration (mm/s^2) and motion smoothness (μm/s^3) failed to show any difference. *Conclusion*. For laparoscopic training and as a promising evaluation device, Simball Box obtained metrics mirroring progression well.

Keywords

assessment, box trainer, evaluation, laparoscopy, medical education, motion tracking, simulation, skills, surgical education

Introduction

Minimally invasive surgery (MIS) has, by the use of minimal incisions and videoscopic technology, revolutionized the field of general surgery. MIS decreases the surgical trauma leading to reduced postoperative pain, making patients more mobile and thus reduce time in hospital. MIS is routine for a vast number of surgical disorders in general surgery exemplified by laparoscopic appendectomy, laparoscopic cholecystectomy and the expanding field of bariatric surgery and associated surgical interventions due to complications. A prerequisite for all emergency surgeons is to master internal herniation and intracorporeal suturing of the mesenteric gaps after gastric bypass surgery. The time has passed for single surgeon experimentation for this and many other routine MIS procedures.[1]

Because of restrictive working-hour limitations both in Northern America and the European Union, the need to practice more effectively and shortening learning curve is obvious. Patient safety issues has also played a role in the paradigm shift of surgical training as the Halstedian principle of "see one, do one, teach one" has been abandoned for a competence-based one.[1]

Training ex vivo on simulators increases MIS skills in clinical practice.[2-4] MIS skills can be trained using live or

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Figure 1. The Simball box. A laser marked pattern on the ball joint's surface forms a dot pattern code with a configuration being unique depending on its position on the ball surface (A). The instrument holder is inserted in the ball joint (A + B) and equipped with a linear potentiometer measuring linear motion of the instrument holder. During box training authentic surgical instruments are inserted and fixed in the instrument holder (B).

cadaveric animal tissues, cadaveric human tissues, video box trainers, virtual reality (VR) or augmented reality (AR) simulators.[5,6] Using animal or human tissue is associated with intricate acquisition and concerns regarding ethics as well as those of transmission of contagious diseases. VR simulators are high-priced and with the drawbacks of semiauthentic animations, shady haptic feedback, and computer program bugs. On the positive side is the possibility of infinite repetition, automatic registration of performance metrics, and feedback. Only a few VR simulators offer haptic feedback but the surgical community has not acknowledged the feedback authenticity compared with using real laparoscopic instruments and frequently residents prefer box trainers to VR trainers.[7-10] Since the area of more advanced laparoscopic procedures is progressing, there is a need to find simulators that allow for complex skills training, but still give an objective feedback of spatial instrument movements.

Traditional box trainers reflect real-life surgery using authentic laparoscopic trocars, instruments, camera, and video monitor to mimic the clinical situation. A weakness is that scoring and feedback traditionally is dependent on a faculty member adding cost and in addition the possibility for intra- and interobserver variation. AR allows blending of VR elements and real objects within a real-world scene. Different aspects of performance may be registered. Although many advantages, VR simulators are often criticized for poor representation of organs, tasks, and haptic sense.[10-13] VR-based training necessitates a heavy financial investment. As the trainee advances, many find the VR trainers less useful because of the lack of visual and haptic reality and avoid using them after having acquired the most basic skills.[8,9]

Simball Box is a newly developed advanced box trainer with automatic recording of metrics for motion in 4 dimensions using ordinary 5-mm laparoscopic tools. Video demos of tasks, possibility of video recording, automatic time measurement for task completion, and registration of instrument speed, acceleration, angular distance and smoothness is displayed. The user automatically gets a comparison of performance based on expert performance of the task set to a 100% level. Different modules for training of basic and advanced skills can be used in the box. The tracking system of instruments is technically different from previously described systems in literature, not relying on video or optical tracking of the instruments, sensors fixed to the surgeons hand or sensor-magnetic field.[5]

In this study, Simball Box was tested as a training tool for laparoscopic knot tying and concomitantly analyzing if obtained metrics mirrored the development of laparoscopic suturing skills. All available dimensions were recorded and analysed.

Methods

Simball Box

Simball Box (Simball, G-coder Systems, Västra Frölunda, Sweden) is a video box trainer giving performance feedback using authentic standard surgical instrument. The position and motion parameters of the surgical instruments are detected by the Simball 4D input devices integrated in Simball Box (Figure 1). Simball 4D is based around a ball joint with 3 degrees of freedom. Using patented machine vision technology, the 3D angular position of the ball joint is detected. A laser marked pattern on the ball joint's surface forms a dot pattern code with a configuration being unique depending on its position on the ball surface (Figure 1A). The image of the dot pattern is updated 100 times per second and every image is analyzed giving the exact 3D angular position of the ball joint.[14]

Through the ball joint, a so-called instrument holder is inserted. The holder is equipped with a linear potentiometer exactly measuring linear motion of the instrument holder (ie, "in-and-out motion"). During box training authentic surgical instruments are inserted and fixed in the instrument holder (Figure 1B). A variety of trays with different tasks may be placed in the box. In the present study a suture pad with a simulated incision was used. Authentic laparoscopic 5 mm, 45 cm, needle drivers (Pajunk, Geisingen, Germany) were used.

Communication was enabled via USB protocol with a standard computer; in this case a PC laptop (Windows 8.1, 2 GB RAM, 500 GB HDD, AMD Radeon HD 8400 graphics card, 2 USB2 and 1 USB3). In the present study, video recording and image capture was done using a See3CAM 80, a high-performance 8MP auto focus UVC USB camera module based on OV8825 CMOS image sensor (OmniVision Inc, Santa Clara, CA, USA). LED lights were positioned around the camera to mimic the light from a laparoscope.

Computer analysis gives the measured parameters to quantify performance of each attempt, including instrument distance, speed, acceleration, angular distance, smoothness, and time to finish task. Instrument holders are equipped with buttons for computer program maneuvering and video recording. Statistics and graphs are routinely saved and shown in Microsoft Excel 2010.

Simball Box Metrics

With the measured 3D angular position of the ball joint and the linear position of the instrument holder (and thereby surgical instrument) the exact position and motion of the tip of the instrument is continuously detected. The instrument movement for both hands in all dimensions (X, Y, Z and instrument rotation) gives the value of total motional instrument distance, so called 4D motion. Feedback after each attempt is given in per cent of the tutorial video performance of this parameter. Average speed (cm/s) is the average speed with which the instruments are moved. Angular distance (radians) is the sum of angular movements at every sampling instant (ie, every 0.01 seconds). At every sampling instant the difference in orientation from the previous instant is computed in the form of an axis-angle rotation. The sum of the absolute values of these angles during all the task time provides the angular distance.

Average acceleration (mm/s^2) is defined as the sum of the accelerations impressed to the tool at every sampling instant. At every sampling instant the difference in position from the previous instant is computed as a vector. The magnitude of the vector divided by the sampling time provides the sampled velocity, the variation of the velocity along two subsequent sampling instants (ie, the final velocity minus the initial velocity) divided by the sampling time provides the sampled acceleration. The sum of the absolute values of the sampled acceleration during all the task time, divided by the task time, provides the average acceleration. Smoothness ($\mu m/s^3$) is defined as the third derivate of instrument position with respect to time, which is a measure of the variation of the acceleration. The variation of the sampled acceleration (as defined in the "average acceleration" definition) between subsequent sampling instants, divided by the sampling time, provides the so-called jerk (derivative of the acceleration or third derivative of the position). The sum of the absolute value of the sampled jerk provides the average jerk, which is motion smoothness. Motion smoothness was calculated for both right and left instruments, as done by others.[15,16]

Study Subjects and Setup

Residents in surgery with the minimal requirement of having completed a first-year mandatory course in basic surgical skills[17] were offered a 3-day national course in laparoscopic surgery. Applicants were from different sized hospitals in Sweden with a wide geographical spread and various laparoscopic experiences.

Lectures and practical laparoscopic training was alternated during the course. During the first half of the course, practical training was conducted interchanging between Simball (G-coder, Västra Frölunda, Sweden), LapSim (Surgical Sciences, Göteborg, Sweden), and ordinary laparoscopic video training boxes, the latter with instruments, optics, light sources, camera units, and monitors from Storz (Karl Storz, Tuttlingen, Germany). All participants rotated between the different setups and simulators in a structured manner for equal amount of practice. Total time for deliberate practice of laparoscopic suturing skill was 12 hours. The first day focused on technical laparoscopic skills and instrument handling. On the following two days practical training was predominantly with focus on more advanced box training on porcine small intestine including intestinal handling, closure of mesenteric gaps and performing anastomoses. Instructions and feedback from laparoscopic experts were given to all participants continuously throughout the course. Regarding the laparoscopic knot task that was studied, the participants were allowed to watch the video instruction as many times desired both before and after performing the pre-, mid-, or posttest. At all times, an instructor was available for supervision and feedback.

At the start (precourse) of the 3-day course, the residents were given a presentation of the Simball equipment, the computer program and instructions for instrument

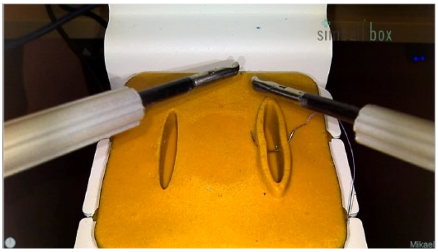

Figure 2. Surgical pad with prepositioned needle at start of the task.

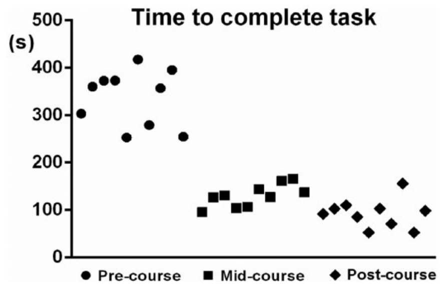

Figure 3. Time to complete task (seconds) significantly improved comparing pre- and midcourse (P < .0001), pre- and postcourse (P < .0001), and mid- and postcourse (P = .0050).

handling. A tutorial video of the laparoscopic knot-tying task was shown before each student performed the task. Performance was automatically recorded when the resident pressed a "start task" button and stopped by the resident pressing the "end task" button. All training and all testing were supervised by an instructor.

The needle (3-0 Vicryl, Ethicon, Somerville, NJ, USA) was pre-positioned on the pad (Figure 2) and a 3-throw surgical knot was tied in a standardized manner.

Data were simultaneously recorded and a video was saved with a possibility for later feedback by faculty. The procedure was repeated at the end of day 2 (midcourse) and at the end of the course at day 3 (postcourse). Distance of movements of the instruments was recorded in all dimensions (X, Y, Z, and instrument rotation) together with average instrument speed, smoothness and time to complete the task. Data were also compared to reference values from the tutorial performance made by a laparoscopist having performed more than 1000 gastric bypass procedures. Student data were expressed in percent hereof.

Statistics

Data were saved and stored in Microsoft Excel 2010. For statistical analyses, data were transferred and analyzed using GraphPad Prism 6 for Windows, version 6.03. Data were tested for Gaussian distribution using D'Agostino-Pearson omnibus K2 normality test. With normally distributed data; 1-way analysis of variance with Greenhouse-Geisser correction was used. For multiple comparisons Holm-Sidak's test was used with individual variances computed for each comparison. For nonparametric data; Friedman test was used with Dunn's posttest for multiple comparisons. $^*P \leq .05$, $^{**}P \leq .01$, $^{***}P \leq .001$, $^{****}P \leq .0001$.

Results

Ten course participants, 4 females and 6 males, all right-handed, were recruited for the study. Median age was 32 years (range 29-48 years) and median time as resident was 14 months (range 6-52 months). None of the participants had previously performed laparoscopic knot tying or suturing. At completion of the course, all participants had been proctored by laparoscopic experts to proficiency in laparoscopic knot tying.

Median time (range) to finish the suturing task at the 3 assessment points were 359 (253-418), 129 (95-166), and 95 seconds (52-156 seconds), corresponding to 655%, 236%, and 174% of tutorial performance, respectively. There was a significant improvement when comparing pre- and midcourse time to complete task (P < .0001), pre- and postcourse (P < .0001), and mid- and postcourse (P = .0050). Data are presented in Figure 3.

Total instrument motion in cm (range) changed for left instrument from 555 (369-1044), 234 (162-418) to 181 (132-444) cm with significance when comparing pre- and midcourse (P = .022) and pre- and postcourse (P = .0002) and for right instrument from 617 (384-869), 290 (185-392) to 220 (115-420) cm with significance when comparing pre- and midcourse (P = .042) and pre- and postcourse (P < .0001). For both instruments, total instrument motion (cm) decreased from the precourse to the midcourse test from a median of 1208 (range, 845-1751) cm to 522 (range 411-810) cm; P = .042 to a postcourse median of 405 (range, 246-864) cm giving a P < .0001 when comparing pre- and postcourse performance. This corresponded to 673%, 291%, and 225% of tutorial performance, respectively.

In addition to linear distance, angular distance was measured and expressed in radians. When combining yaw, pitch and roll for both instruments, total angular distance (range) was 150 (87-251), 65 (42-116), and 50 (33-136) radians with significant improvement pre- versus midcourse (P = .022) and pre- versus postcourse (P = .0002).

For a detailed graph of linear and angular distance, see Figure 4.

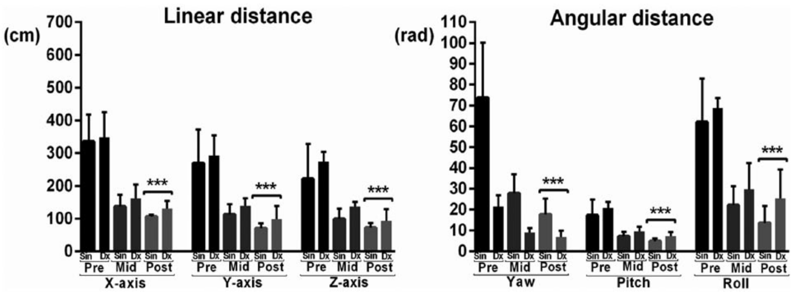

Figure 4. Linear instrument distance (cm) is shown to the left and angular motion distance to the right. In all measured variables, improvement was shown when comparing both pre- and midcourse ($P < .05$) and pre- and postcourse (***$P < .001$).

For average speed (cm/s) no difference was noted for left hand performance with a median (range) of 1.80 (1.19-2.80), 2.12 (1.28-2.58) and 2.04 (1.63-2.85). For right hand performance however, an increase in speed was noted 1.94 (1.11-2.27) pre-, 2.39 (1.56-2.83) mid-, 2.60 (1.67-3.19) cm/s postcourse, reaching significance comparing pre- and midcourse ($P = .022$) and pre- and postcourse ($P = .0024$).

Average acceleration (mm/s^2) did not differ with a median (range) for left instrument of 0.39 (0.28-0.85) pre-, 0.43 (0.27-0.55) mid-, 0.45 (0.30-0.65) mm/s^2 postcourse, and for right instrument 0.42 (0.26-0.58) pre-, 0.45 (0.34-0.57) mid-, and 0.52 (0.37-0.63) mm/s^2 postcourse.

Also the constructed estimation of average motion smoothness (μm/s^3) failed to show any difference with median (range) for left instrument of 25.0 (16.5-73.0) pre-, 27.8 (18.9-36.2) mid-, 28.7 (20.9-38.6) μm/s^3 postcourse, and for right instrument 29.2 (15.3-53.8) pre-, 29.8 (20.3-38.4) mid-, and 34.2 (21.7-42.9) μm/s^3 postcourse.

Discussion

The results in the present study suggest that the metrics provided by Simball Box, with authentic instruments and 4D total motional instrument distance tracking when performing a laparoscopic surgical knot, can be used to monitor individual progression of skills. All residents showed improvement in time, total motional distance parameters, linear and angular distance. This was expected and in consistence with previous literature on similar types of simulators and VR simulators.[18-20] All course participants were right-handed, and it was only the right-handed speed that significantly increased. The participants' laparoscopic experience varied, but none had previously performed laparoscopic knot tying or suturing and the range of precourse test performance was significantly wider than after completing the course, mirroring participants having reached proficiency accordingly.

Total time with deliberate practice of technical laparoscopic skills was 12 hours during the 3-day course. To put this in perspective, most of the effect of training is implied to be seen after 2 to 3 hours of training[21] to 5 to 7 hours.[22] When interpreting data comparing pre-, mid-, and postcourse, it should be noted that midcourse testing was on average after 7 hours of training, thereby having reached a significant level of proficiency and every improvement hereafter is in all probability in smaller steps.

No significant improvement of motion smoothness was detected during the course. Hiemstra et al[16] found that improvement of smoothness in the TrEndo system was shown only for novices, but no difference was noted comparing residents and experts. In another study using the TrEndo box trainer system measuring smoothness during a positioning task, no significant difference between experts and residents was detected.[15] In studies of the ProMIS laparoscopic hybrid box trainer with augmented reality, smoothness has shown to differ up to 4 times between experts and novices in a suturing task.[23] Oostema et al[24] found that smoothness and time correlated more strongly with experience than did path length using the ProMIS. The term *smoothness* might seem attractive, but the parameter may be questioned if giving added value for residents in training past the most basic level. It seems that studies have shown inconsistency in usefulness of recording smoothness and, if presented, this metric should be used and interpreted with caution.

At the end of the course, all participants had reached proficiency in laparoscopic closure of mesenteric gaps. Training to proficiency in laparoscopic suturing is of importance to deal with intraoperative complications, and is difficult to learn and practice in the operating room.[8] Suturing in Simball gives a functional correspondence between simulation and the task in reality, so that the functional properties of the entire simulation context will align with the learning objectives, for example, suturing, as recommended by Hamstra et al.[25] Residents in surgery prefer training suturing in box trainers to VR simulators even though the result of acquired skill may be the same.[8,26,27]

Training to proficiency in Simball Box by deliberate practice and comparison of metrics to expert performance may be an ideal model of training, which could be transferable to operative performance in a real live setting. In a study comparing a regular video box trainer and VR training, the VR trained group performed better. Both groups had trained in a self-directive manner, which is often the case, since faculty is expensive and residents often practice by them self whenever they find time. In that study, the video box trainer group received no other metrics than time to completion. The better result by the VR trained group was probably due to the metrics feedback.[26] On the other hand, Kanumuri et al[27] demonstrated that training on either a VR simulator or a box trainer may be equivalent for learning laparoscopic suturing.

The present study has some potential weaknesses. The comparison of performance to a single expert/tutorial execution may be questioned. None of the participants reached the tutorial level regarding basic metrics. However, this was never the goal, and should be with difficulty to reach with the tutor having performed more than 1000 laparoscopic gastric bypass procedures. As a tutorial instrument with automatic metrics and the possibility to review the tutorial and also own performance, the matching is of self-instructive importance. An integrated score with individually obtained motion analysis parameters compared with an expert performance, gives an easy-to-read and intuitive indication of progression of laparoscopic skills,[20] which is in concordance with the information given by the Simball Box.

A natural next step of improvement would be including several expert performances and thereby creating an expert reference interval. As stated by Korndorffer et al,[28] the scientific value of comparing expert and novice performance may be questioned. On the other hand, it is difficult to compare simulator performance and operative performance, which would be ideal. Even though the scientific value of measurements and comparisons may be low, a first step in the evaluation of training devices may still be, as performed, to compare novice and expert performance.[28]

Simball is a combination of what surgeons in training prefer regarding authenticity as in "old style" video box trainers combined with the automatic metrics registration as offered by VR trainers. The trainee may use the automatic video recording to get expert opinion and feedback at a suitable time with a possibility for tutors/proctors to follow the trainee's training and development without being present at all times. Video recording of performance opens the possibility to better feedback, and also training of critical procedural steps, for example, by using synthetic or real intestines mimicking suturing of gastric bypass mesenteric defects or cholecystectomy with porcine liver placed in the box.

Simball Box tracking system consists of a patented machine vision technology, with 3D angular position of the ball joint, which has not been described earlier. Similar box trainers using an optical tracking system have been described for TrEndo[15] and with electromagnetic sensors for D-box.[7] A box trainer with tracking sensors also located in the trocars has newly been described as having construct validity in showing capacity to differentiate between novices, intermediates, and experts by tracking acceleration and extreme velocity in 4 dimensions, giving the same parameters as the Simball Box.[29] The metrics converted by the Simball Box to percentage of actual expert/tutorial performance, are in line with those having been shown to be valid in previous studies in laparoscopic simulators. The presently studied simulator converts motion data metrics into a competence-based score as requested by Mason et al.[5]

In its current state, Simball Box is used for instructional purposes and formative assessment (feedback), and not summative assessment (pass/fail). We have demonstrated initial utility and made a description of the simulator metrics that mirror participants' progress toward proficiency in laparoscopic suturing well. The participants reported handling very intuitive and the setup was reliable without many disturbing bugs. As Ghaderi et al[30] emphasize, feasibility is a crucial aspect before considering a simulator as an assessment tool. If further evaluated and validated, the Simball Box has the potential to become a simulator providing competence based assessment for specific procedures. Further evaluation regarding transferability (from box to OR performance) comprising investigations of how the metrics obtained in Simball Box correlate to performance in the real-life surgical setting is needed.

In short, the advantages of this new training device are several. The Simball Box allows the possibility of using ordinary 5-mm laparoscopic instruments in the trocars without the need of calibration maneuvers and the possibility to obtain advanced metrics. It allows full flexibility regarding tasks ranging from original basic training pads to organ models and even surgical tasks on explanted organs. It is possible to practice in both 2D and 3D. The system is very intuitive and as easy to handle as an ordinary video box trainer, even for nontechnical individuals. The cost is significantly lower compared to an ordinary

VR trainer and the small size of Simball Box makes it easily transportable. Having the trainer near at hands may make simulation training happen, as the best training is the training done and not only planned.

Conclusion

The Simball Box trainer provides objective metrics on performance with the use of ordinary instruments and a 4D total motional tracking system. The improvement in 4D motion and metrics, when performing a laparoscopic surgical knot, was well mirrored. When transferability is validated and if combined with further development of synthetic tissues and organ models, the Simball Box will provide surgeons in training with a consummate laparoscopic simulator.

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Author Contributions

Study concept and design: Kristine Hagelsteen, Mikael Ekelund
Acquisition of data: Kristine Hagelsteen, Mikael Ekelund, Dan Sevonius
Analysis and interpretation: Kristine Hagelsteen, Dan Sevonius, Anders Bergenfelz, Mikael Ekelund
Study supervision: Mikael Ekelund, Anders Bergenfelz

Declaration of Conflicting Interests

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References

1. Rodriguez-Paz JM, Kennedy M, Salas E, et al. Beyond "see one, do one, teach one": toward a different training paradigm. *Postgrad Med J*. 2009;85:244-249.
2. Kundhal PS, Grantcharov TP. Psychomotor performance measured in a virtual environment correlates with technical skills in the operating room. *Surg Endosc*. 2009;23:645-649.
3. Seymour NE, Gallagher AG, Roman SA, et al. Virtual reality training improves operating room performance: results of a randomized, double-blinded study. *Ann Surg*. 2002;236:458-463.
4. Zevin B, Aggarwal R, Grantcharov TP. Surgical simulation in 2013: why is it still not the standard in surgical training? *J Am Coll Surg*. 2014;218:294-301.
5. Mason JD, Ansell J, Warren N, Torkington J. Is motion analysis a valid tool for assessing laparoscopic skill? *Surg Endosc*. 2013;27:1468-1477.
6. Sutherland LM, Middleton PF, Anthony A, et al. Surgical simulation: a systematic review. *Ann Surg*. 2006;243: 291-300.
7. Debes AJ, Aggarwal R, Balasundaram I, Jacobsen MB. A tale of two trainers: virtual reality versus a video trainer for acquisition of basic laparoscopic skills. *Am J Surg*. 2010;199:840-845.
8. Palter VN, Orzech N, Aggarwal R, Okrainec A, Grantcharov TP. Resident perceptions of advanced laparoscopic skills training. *Surg Endosc*. 2010;24:2830-2834.
9. Shetty S, Zevin B, Grantcharov TP, Roberts KE, Duffy AJ. Perceptions, training experiences, and preferences of surgical residents toward laparoscopic simulation training: a resident survey. *J Surg Educ*. 2014;71: 727-733.
10. Vapenstad C, Hofstad EF, Langø T, Mårvik R, Chmarra MK. Perceiving haptic feedback in virtual reality simulators. *Surg Endosc*. 2013;27:2391-2397.
11. Botden SM, Buzink SN, Schijven MP, Jakimowicz JJ. Augmented versus virtual reality laparoscopic simulation: what is the difference? A comparison of the ProMIS augmented reality laparoscopic simulator versus LapSim virtual reality laparoscopic simulator. *World J Surg*. 2007;31:764-772.
12. Botden SM, Torab F, Buzink SN, Jakimowicz JJ. The importance of haptic feedback in laparoscopic suturing training and the additive value of virtual reality simulation. *Surg Endosc*. 2008;22:1214-1222.
13. van der Meijden OA, Schijven MP. The value of haptic feedback in conventional and robot-assisted minimal invasive surgery and virtual reality training: a current review. *Surg Endosc*. 2009;23:1180-1190.
14. G-coder. *G-coder sensor technology*. http://g-coder.com/technology. Accessed February 4, 2015.
15. Chmarra MK, Kolkman W, Jansen FW, Grimbergen CA, Dankelman J. The influence of experience and camera holding on laparoscopic instrument movements measured with the TrEndo tracking system. *Surg Endosc*. 2007;21: 2069-2075.
16. Hiemstra E, Chmarra MK, Dankelman J, Jansen FW. Intracorporeal suturing: economy of instrument movements using a box trainer model. *J Minim Invasive Gynecol*. 2011;18:494-499.
17. BKT. *Basal Kirurgisk Teknik*. http://www.demo.svenskkirurgi.se/index.php?option=com_content&view=article&id=216&Itemid=313. Accessed January 8, 2016.
18. Aggarwal R, Hance J, Undre S, et al. Training junior operative residents in laparoscopic suturing skills is feasible and efficacious. *Surgery*. 2006;139:729-734.
19. Cook JA, Ramsay CR, Fayers P. Using the literature to quantify the learning curve: a case study. *Int J Technol Assess Health Care*. 2007;23:255-260.
20. van Empel PJ, Commandeur JP, van Rijssen LB, et al. Learning curve on the TrEndo laparoscopic simulator

compared to an expert level. *Surg Endosc*. 2013;27: 2934-2939.
21. Vossen C, Van Ballaer P, Shaw RW, Koninckx PR. Effect of training on endoscopic intracorporeal knot tying. *Hum Reprod*. 1997;12:2658-2663.
22. Zhang L, Sankaranarayanan G, Arikatla VS, et al. Characterizing the learning curve of the VBLaST-PT© (Virtual Basic Laparoscopic Skill Trainer). *Surg Endosc*. 2013;27:3603-3615.
23. Van Sickle KR, McClusky DA 3rd, Gallagher AG, Smith CD. Construct validation of the ProMIS simulator using a novel laparoscopic suturing task. *Surg Endosc*. 2005;19:1227-1231.
24. Oostema JA, Abdel MP, Gould JC. Time-efficient laparoscopic skills assessment using an augmented-reality simulator. *Surg Endosc*. 2008;22:2621-2624.
25. Hamstra SJ, Brydges R, Hatala R, Zendejas B, Cook DA. Reconsidering fidelity in simulation-based training. *Acad Med*. 2014;89:387-392.
26. Hamilton EC, Scott DJ, Fleming, et al. Comparison of video trainer and virtual reality training systems on acquisition of laparoscopic skills. *Surg Endosc*. 2002;16: 406-411.
27. Kanumuri P, Ganai S, Wohaibi EM, Bush RW, Grow DR, Seymour NE. Virtual reality and computer-enhanced training devices equally improve laparoscopic surgical skill in novices. *JSLS*. 2008;12:219-226.
28. Korndorffer JR Jr, Kasten SJ, Downing SM. A call for the utilization of consensus standards in the surgical education literature. *Am J Surg*. 2010;199:99-104.
29. Trudeau MO, Nasr A, Carrillo B, Gerstle JT, Azzie G. Construct validity and educational role for motion analysis in a laparoscopic trainer. *Surg Endosc*. 2014;29: 2491-2495.
30. Ghaderi I, Manji F, Park YS, et al. Technical skills assessment toolbox: a review using the unitary framework of validity. *Ann Surg*. 2015;261:251-262.

Paper II

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ORIGINAL ARTICLE

Faster acquisition of laparoscopic skills in virtual reality with haptic feedback and 3D vision

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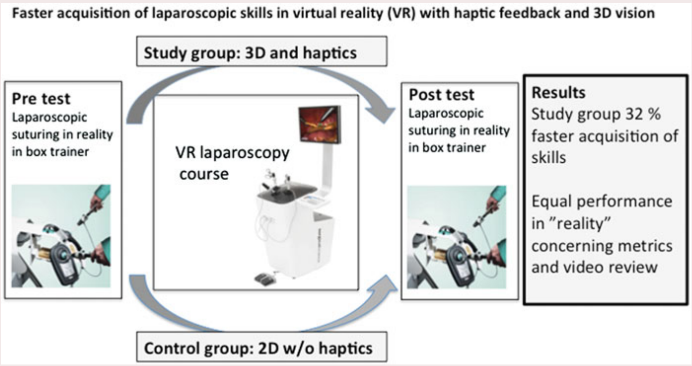
ABSTRACT

Background: The study investigated whether 3D vision and haptic feedback in combination in a virtual reality environment leads to more efficient learning of laparoscopic skills in novices.

Material and methods: Twenty novices were allocated to two groups. All completed a training course in the LapSim® virtual reality trainer consisting of four tasks: 'instrument navigation', 'grasping', 'fine dissection' and 'suturing'. The study group performed with haptic feedback and 3D vision and the control group without. Before and after the LapSim® course, the participants' metrics were recorded when tying a laparoscopic knot in the 2D video box trainer Simball® Box.

Results: The study group completed the training course in 146 (100–291) minutes compared to 215 (175–489) minutes in the control group ($p = .002$). The number of attempts to reach proficiency was significantly lower. The study group had significantly faster learning of skills in three out of four individual tasks; instrument navigation, grasping and suturing. Using the Simball® Box, no difference in laparoscopic knot tying after the LapSim® course was noted when comparing the groups.

Conclusions: Laparoscopic training in virtual reality with 3D vision and haptic feedback made training more time efficient and did not negatively affect later video box-performance in 2D.



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Haptic feedback; laparoscopy; surgical education; virtual reality; 3D vision

Introduction

The LapSim® Virtual Reality simulator (LapSim® VR; Surgical Science, Göteborg, Sweden) is designed to teach basic skills as well as some procedures in laparoscopic surgery. The simulator has been validated in several studies and has been shown to distinguish experts from novices and to predict operative skills following curriculum training. In addition, transferability of VR surgical skills to the operating theatre has been shown (1–4).

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Recently, an updated version was released with features of 3D vision and haptic feedback. Since advanced laparoscopic procedures that require complex skills are frequently performed, there is a need for laparoscopic training with objective feedback of instrument movements. Previous studies have evaluated earlier versions of LapSim® (5), but none have reported on the hardware set-up with haptic feedback and 3D vision used in this study. One pilot study performed on LapSim with an earlier software version (2011) and a different 3D monitor than the current set-up, did not show improved novice performance with 3D (6). Another study using LapSim with haptic feedback handles from Xitact IHP (Xitact, Lausanne, Switzerland) was unable to establish construct validity, and the results were partly explained by the participants experiencing unrealistic trocar friction (7).

VR simulators have been criticized for poor illustration of organs, tasks and lack of haptics (8–14). Previous VR models developed to provide haptic feedback have not been shown to do so convincingly and have therefore not added clinical value to VR training (7,15–18). A challenge in simulating laparoscopic surgery is the difficulty of providing authentic haptic feedback. Providing too little or too much feedback will probably lead to negative effects of training (19). A recent study on a laparoscopic grasper tip force model showed promising results but has not yet been tested in a VR environment (20). Studies have shown that tasks that rely on force application, such as stretching and grasping, are better performed when true haptic feedback is provided in a video box trainer (21,22). In addition, residents seem to prefer box trainers to VR trainers (13,14).

An environment with 3D vision offers a higher degree of realism with depth perception and conceivably reduced visual misperceptions. In a recent review of randomized control trials, laparoscopic simulators with 2D or 3D vision were compared. In this review, 28 of 31 studies were conducted in a simulated environment and a majority included novices (23). Of the 19 trials published from 2004 to 2014, ten studies showed a reduced performance time, 12 of 19 trials reported a lower rate of errors and two trials reported more accurate performance in favour of 3D vision (23). A diversity of 3D vision systems were used and the results were not consistent, though some studies showed a benefit of 3D for accuracy, reduction in errors and time (23). Four studies found no additional benefit of 3D (6,24–26). Another recent review investigating 3D and 2D laparoscopy concluded that conflicting evidence for the benefit of 3D visualisation greatly depends on stereovisual ability and viewing conditions in the test set-up (27).

Considering the high cost of VR simulators with 3D vision and haptic feedback, it is important to evaluate the possible advantages of these added features for laparoscopic training. There is a trade-off between fidelity and cost, and ultra-high fidelity might not always be necessary to gain relevant training benefits (19). There are no current published studies investigating the combination of 3D and haptic feedback in simulated environments.

The study aimed to investigate whether 3D vision and haptic feedback in combination lead to more efficient learning in novices. A secondary aim was to investigate whether there is a difference between novices trained with and without 3D and haptic feedback when tested in a 2D environment.

Material and methods

Participants

A single-blinded controlled trial was carried out, with equal numbers of participants in each group, stratified according to sex, video game habits, self-perceived motor coordination skills and handedness. Self-perceived motor coordination skills were graded on a scale 1–5, where 1 equals not very skilled, 3 ordinary skills and 5 highly skilled.

The participants were not allowed to have practised laparoscopic surgical knot tying or suturing, nor witnessed live laparoscopic surgery and had to be able to perceive picture depth in 3D cinema movies. All participants gave informed consent and were informed that they could leave the study at any time.

Simulators

LapSim® on SimFrame (LapSim®, Surgical Science Sweden AB, Göteborg, Sweden) is a virtual reality simulator designed to teach basic skills and some laparoscopic procedures (Figure 1(a)). The version used in the present study was launched in 2013 and uses a haptic hardware platform together with 3D vision. The FUJITSU 3D Display (P23T-6 FPR) attached to the SimFrame uses the Film Patterned Retarder (FPR) 3D technology, developed by LG Corporation (Fujitsu Sweden AB, Kista, Sweden). The monitor displays separate images to the left and right eye through the FPR in different circularly polarized patterns. These images are perceived by the viewer as 3D when seen through left-and-right-polarized glasses, commonly known as cinema 3D (28).

Figure 1. (a) LapSim® on SimFrame virtual reality simulator with haptic feedback and 3D vision. (b) Simball® Box video trainer delivering objective metrics on performance using ordinary laparoscopic instruments. (c) Close-up on the Simball® Box laser-marked pattern in the trocar responsible for recording metrics.

Simball® Box (Simball®, G-coder Systems, Västra Frölunda, Sweden) is a video box trainer with 2D vision (3D vision possible but not used in this setup) that provides metrics on performance using standard laparoscopic surgical instruments through a potentiometer and with a patented laser-marked pattern in the trocars (Figure 1(b,c)) (29).

The Simball® Box is under validation. The first results show that Simball® Box metrics (time, linear and angular distance, average acceleration and average speed) mirror progression when performing laparoscopic suturing (30).

Study design

Each participant was introduced to LapSim® on SimFrame (Figure 1(a)) and Simball® Box (Figure 1(b,c)). The participants received introduction to laparoscopic knot tying and were allowed three attempts to practice a surgeon's knot in the Simball® Box. During these attempts, they were coached to tie a knot with only verbal instructions. Subsequently, the participants were granted one attempt to tie the knot with video and metrics recording in the Simball® Box.

The novices fulfilled a training course in LapSim® consisting of four tasks from the basic skills program to a predetermined proficiency level: 'instrument navigation', 'grasping', 'fine dissection' and 'suturing' (Configuration and proficiency settings, Appendices A and B). The study group performed the LapSim® course with haptic feedback and 3D vision and without the control group. After completing the LapSim® course, the participants were allowed to practice three knots in the Simball® Box before a second video and metrics recording of the knot tying was carried out.

Two 5th-year medical students educated in laparoscopic suturing, LapSim® on SimFrame and Simball® Box coached all study participants individually. The training sessions were limited to six hours with regular breaks, and a maximum of seven days were allowed to pass between each training session.

A laparoscopic surgeon, who had performed more than 200 laparoscopic procedures, complemented the automatically recorded metrics in the Simball® Box with a qualitative review of all recorded video performances to ensure correctness of the knot together with performance levels comparing the first and second attempt. The videos were reviewed with regard to the number of times the instruments were out of view or outside the suture pad zone, whether the needle was outside suture pad zone, the correctness of knot choreography and whether the knot was sufficient. This reviewer was blinded to the allocated groups.

Statistics

The parameters registered in the LapSim® and Simball® Box were calculated for each participant. Data were saved and stored in Microsoft Excel© 2010. For statistical analyses, data were transferred and analysed by using GraphPad Prism© version 6.0f for Mac (GraphPad Software, Inc., La Jolla, CA). All data are expressed as median and range. Data were considered nonparametric and a Mann–Whitney *U*-test was performed to compare the two groups.

Change in Simball® Box-performance was calculated by comparing the performance parameters before and after the LapSim® course. A Fishers' exact test was performed to compare the two. A *p* value of <.05 was considered significant.

Results

Forty-seven novices attending the first, second or third year of medical school expressed interest in participating in the study and answered the questionnaires used for recruitment. Twenty-one novices were excluded due to previous practice in either open or laparoscopic knot tying or suturing. Four novices could not participate due to scheduling reasons. Two novices declined participation. Twenty novices, mean age 21 (19–28) years, were finally included in the study and divided into two equal groups ($n = 10$) (Table 1). All participants stated that they were able to perceive cinema 3D vision.

The study group performed the LapSim® course with haptic feedback and 3D vision and completed

Table 1. Demography of study participants.

Variables	Study group	Control group	*p* value[a]
Total subjects	10	10	–
Sex			
Female	5	5	–
Male	5	5	–
Age (year)	21 (19–28)	21 (19–27)	.606
Dominant hand (#)			
Right	9	9	–
Left	1	1	–
Video games (hours/week)	4,5 (0–14)	1 (0–11)	.559
Stated psychomotor skills by participants (scale 1–5)	3 (2–5)	3 (2–5)	.720

[a]Mann–Whitney *U*-test.

the training course in 146 (100–291) minutes compared to 215 (175–489) minutes in the control group ($p = .002$), which was 69 minutes (32%) faster than the control group (Figure 1).

The study group was significantly faster in three out of four tasks; instrument navigation, grasping and suturing (Table 2). In the 'instrument navigation' task, all parameters except 'total instrument misses' showed a superior performance by the study group compared to the control group (Table 2). In the study group, the number of attempts to reach proficiency was significantly lower for instrument navigation with a median of 27 (13–79) attempts compared to 65 (29–196) attempts in the control group ($p = .005$) (Table 2). The number of attempts in the grasping task was fewer for the study group with 19 (10–34) attempts compared with 29 (19–36) attempts in the control group ($p = .017$) (Table 2). For the 'suturing task', the corresponding figures were 24 (15–73) attempts and 41 (30–93) attempts, for the study group and control group, respectively ($p = .011$) (Table 2). However, total training course instrument path length and total training course instrument angular path parameters for the study group were similar to those of the control group (Table 2).

Subanalysis

Total path length was lower in the study group in the 'instrument navigation' ($p = .003$) and 'suturing task' ($p = .030$) (Table 2). Angular path length was found to be significantly shorter in the study group in 'instrument navigation' ($p = .007$) (Table 2).

Total tissue damage parameter was similar in both groups, although the novices in the study group performed superiorly regarding total maximum damage in 'instrument navigation' and 'grasping task' ($p = .003$ and $p = .019$, respectively). The results from the 'fine dissection task' did not differ between the two groups. A better performance was observed in the

Table 2. Task parameters of the LapSim® training course.

Course task	Study group Median (range)	Control group Median (range)	*p* value[a]
Instrument navigation			
Total attempts (#)	27 (13–79)	65 (29–196)	.005[c]
Total time (min)	19 (9–52)	46 (20–149)	.003[c]
Total instrument path length (m)	41 (17–136)	94 (43–331)	.007[c]
Total instrument angular path (degrees)	7606 (3529–27301)	17,490 (8133–60,693)	.007[c]
Total tissue damage (#)	138 (42–739)	347 (95–1550)	.015[a]
Total maximum damage (mm)	109 (60–1048)	422 (92–1834)	.003[c]
Total instrument misses (%)	2,2 (0–8)	1,5 (0–3)	.288
Grasping			
Total attempts (#)	19 (10–34)	29 (19–36)	.017[b]
Total time (min)	29 (16–55)	49 (30–65)	.007[c]
Total instrument path length (m)	83 (30–226)	104 (55–152)	.306
Total instrument angular path (degrees)	15,660 (5932–44,600)	19,648 (10,471–29,054)	.347
Total tissue damage (#)	155 (40–396)	254 (103–537)	.188
Total maximum damage (mm)	178 (45–380)	390 (107–847)	.019[b]
Total instrument misses (%)	22 (18–27)	14 (16–31)	.183
Fine dissection			
Total attempts (#)	7 (5–22)	8 (3–21)	.236
Total time (min)	22 (13–40)	13 (5–55)	.060
Total instrument path length (m)	12 (7–38)	8 (2–29)	.071
Total instrument angular path (degrees)	2858 (1778–10,210)	1882 (441–6992)	.089
Total instruments outside view (#)	3 (0–16)	4 (0–12)	.864
Total instruments outside view (s)	4 (0–49)	7 (0–37)	.927
Total ripped or burned blood vessels (%)	7 (0–25)	16 (0–43)	.088
Total energy damage on blood vessels (%)	7 (1–26)	5 (0–25)	.469
Total ripped small vessels (%)	5 (0–14)	12 (0–26)	.127
Total burned small vessels (%)	94 (83–97)	88 (73–100)	.287
Total burned small vessels without stretch (%)	0 (0–15)	0 (0–3)	.249
Suturing			
Total attempts (#)	24 (15–73)	41 (30–93)	.011[b]
Total time (min)	62 (40–194)	115 (67–265)	.007[c]
Total instrument path length (m)	99 (50–500)	169 (86–516)	.030[b]
Total instrument angular path (degrees)	20,191 (10,375–100,768)	36,027 (17,387–92,798)	.052
Total target error (mm)	55 (15–90)	41 (1–195)	.645
Total knot error (%)	42 (27–59)	41 (34–52)	.725
Total training course parameters			
Total training course time (min)	146 (100–291)	215 (175–489)	.002[c]
Total training course instrument path length (m)	237 (134–683)	356 (216–976)	.063
Total training course instrument angular path (degrees)	47,511 (27,891–137,858)	70,566 (42,982–177,728)	.063

[a]Mann–Whitney *U*-test,
[b]Statistical significance =0.050,
[c]Statistical significance =0.010

Table 3 Simball box® metrics. Change (in per cent) $\Delta = \frac{(\text{pre course value} - \text{post course value})}{\text{pre course value}} \times 100$ of obtained metrics in Simball Box® pre and post LapSim® training course (median and range).

Parameters	Study group	Control group	*p* value[a]
Δ Total time (%)	26.9 (2.4–61.2)	19.7 (−2.5–51.5)	.326
Δ Linear distance (%)	14.2 (−5.3–56.9)	6.7 (−34.8–54.6)	.151
Δ Angular distance (%)	13.7 (−22.6–66.5)	8.0 (−76.2–55.1)	.364
Δ Average acceleration (%)[b]	−12.3 (−55.8–32.5)	−22.6 (−54.0–30.1)	.545
Δ Average speed (%)	9.7 (−40.4–51.2)	1.1 (−34.4–82.8)	1.000
Δ Motion smoothness (%)	5.9 (−55.5–46.6)	2.1 (−27.5–50.0)	.940

[a]Mann–Whitney *U*-test.
[b]A negative value implies that the acceleration is increased in the post-course performance.

study group concerning time, attempts and path length parameters in the 'suturing task' (Table 2).

After completing the virtual reality course in LapSim®, analysis of the knot tying test in Simball® box did not show any difference in performance pre- and post the LapSim® course in the provided metrics or as rated by the video reviewer (Tables 3 and 4). One video in the control group was corrupted and could not be analysed.

Discussion

The main aim of this study was to investigate whether virtual reality with 3D vision and haptic feedback leads to faster acquisition of laparoscopic skills in novices. The current study showed that the study group's performance was superior to the control group in total time spent in the simulator to reach the set proficiency level. The novices training with 3D vision and haptic feedback reached the proficiency

Table 4. Video review of performance in Simball Box®.

Parameters	Study group $N = 10$ improved/no improvement	Control group $N = 9$[b] improved/no improvement	p value[a]
Instrument outside of view	9/1	9/0	1.000
Instrument outside of zone	10/0	7/2	.476
Needle outside of zone	9/1	9/0	1.000
Correct knot choreography (yes/no)	10/0	7/2	.211
Sufficient knot (yes/no)	10/0	8/1	.474

Comparison of performance before and after Lapsim® VR training with or without 3D and haptic settings.
[a]Fisher's exact test.
[b]One video could not be analysed due to corrupt video file.

level 32% faster than the control group. Hence, novices in laparoscopy may shorten the learning curve when 3D vision and haptic feedback are added to the VR simulator.

For the 'instrument navigation' task about half as much time was needed to reach proficiency in the study group compared to the control group. For this task, haptic feedback is of little relevance and consequently the better results are in all probability due to 3D vision.

In the 'grasping task', the study group used less total time and number of attempts. In addition, the study group novices had less maximum tissue damage. This may be interpreted as the study group benefited from the haptic feedback or had a better perception of picture depth.

Early exposure to haptic feedback during surgical simulator training has been suggested to improve basic skill acquisition and performance for novices (17,22). These findings provide support for the integration of haptic feedback in VR simulators.

Possibly due to low complexity of the task, the results from the 'fine dissection task' did not differ between the study and control group. Previous studies on laparoscopic performance in a VR simulator have suggested that a certain complexity of the task is required to affect outcome, a so-called ceiling effect (16,22). If the 'fine dissection task' was too easy, it is reasonable to assume that the 3D vision and haptic feedback would have no effect on performance.

In the 'suturing task', the study group performed better than the control group concerning time, attempts and path length. Suturing was the most complex task in the LapSim® course and requires depth perception and advanced instrument coordination. An interpretation could be that the more complex the task, the larger the benefit of 3D vision and haptic feedback.

Some previous investigations have suggested that practicing with 3D vision gives superior performance compared to standard 2D vision (31–33). Another study has shown a reduced rate of task errors for inexperienced individuals when practicing in 3D and a positive transfer of motor skills when switching to 2D vision (34). In the present investigation, the post-course test in the 2D environment did not detect differences in performance between the study and the control group. Hence, it may be hypothesized that training with 3D vision does not affect performance, neither to the better nor to the worse, when later performing 2D laparoscopy.

As the trainees advance, many find the VR trainers less useful because of the lack of visual and haptic reality and therefore avoid using them after having acquired the most basic skills (13,14). A study of training perseverance, using VR simulators and comparing standard to those with these added features, would therefore be of interest.

There are some limitations of the present study that should be acknowledged. The study cohort is relatively small. No correction for confounders could be made with the current number of participants, and consequently, excluding potential outliers was not possible. To compensate for lack of Gaussian distribution, the groups were demographically stratified. Excluding participants with experience of surgical knot tying or laparoscopic procedures reduced the number of confounders. All participants reached the same level of proficiency in performing a laparoscopic surgical knot before commencing the VR simulator training course. Hence, the baseline of this skill was fairly equal. There were no exclusion criteria to sort out participants with physical impairments or illnesses. The participants were not specifically tested for their 3D perception abilities and the ability was self-reported. The study did not compensate for height and hand size of the participants. Although the instructors were not laparoscopic experts, using senior medical students to coach their peers has previously been deemed eligible (35).

Other VR simulators use different hardware to provide haptic feedback and the results of the present study may not be comparable to other studies using other simulators. Studies using other simulators have failed to support positive skill acquisition effects of haptic feedback (18,19). The fidelity of previous models of haptic feedback in VR simulators has been questioned (7,19). Hence, a general conclusion of the usefulness of haptic feedback in VR simulators cannot be drawn.

It might be hypothesized that the superior performance of the study group may be accredited to the 3D vision due to the lack of evidence supporting an added value of haptic feedback. No effort was made to discriminate between the contributing roles of 3D and haptic feedback in the current study since these features in combination are standard in the newest version of LapSim®. The synergistic effect of 3D vision and haptic feedback seen in the current study is relevant from a practical point of view when constructing training of novices. Future studies are needed to reveal whether the same effect is noticed in surgical trainees with previous experience in laparoscopy.

Within the context of these limitations, the current study suggests that training in virtual reality with 3D vision in combination with haptic feedback provides a time-efficient acquisition of laparoscopic proficiency compared with 2D without haptic feedback. In addition, the present study shows that training with 3D vision is not a disadvantage when later performing an authentic laparoscopic task in 2D.

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Declaration of interest

Drs. Anderberg, Bergenfelz, Ekelund, Hagelsteen, Langegård and Lantz have no conflicts of interest or financial ties to disclose. This statement covers all parts of the study and includes no attachment, in any aspect, to the manufacturers of LapSim® or Simball®.

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References

1. Palter VN, Grantcharov TP. Individualized deliberate practice on a virtual reality simulator improves technical performance of surgical novices in the operating room: a randomized controlled trial. Ann Surg 2014;259:443–8.
2. van Dongen KW, Tournoij E, van der Zee DC, Schijven MP, Broeders IA. Construct validity of the LapSim: can the LapSim virtual reality simulator distinguish between novices and experts? Surg Endosc 2007;21:1413–17.
3. Ahlberg G, Enochsson L, Gallagher AG, Hedman L, Hogman C, McClusky DA, III, et al. Proficiency-based virtual reality training significantly reduces the error rate for residents during their first 10 laparoscopic cholecystectomies. Am J Surg 2007;193:797–804.
4. Palter VN, Grantcharov TP. Development and validation of a comprehensive curriculum to teach an advanced minimally invasive procedure: a randomized controlled trial. Ann Surg 2012;256:25–32.
5. Fairhurst K, Strickland A, Maddern G. The LapSim virtual reality simulator: promising but not yet proven. Surg Endosc 2011;25:343–55.
6. Kneist W, Huber T, Paschold M, Lang H. [3D virtual reality laparoscopic simulation in surgical education – results of a pilot study]. Zentralbl Chir 2016;141:297–301.
7. Vapenstad C, Hofstad EF, Bo LE, Chmarra MK, Kuhry E, Johnsen G, et al. Limitations of haptic feedback devices on construct validity of the LapSim® virtual reality simulator. Surg Endosc 2013;27:1386–96.
8. van der Meijden OA, Schijven MP. The value of haptic feedback in conventional and robot-assisted minimal invasive surgery and virtual reality training: a current review. Surg Endosc 2009;23:1180–90.
9. Botden SM, Buzink SN, Schijven MP, Jakimowicz JJ. Augmented versus virtual reality laparoscopic simulation: what is the difference? A comparison of the ProMIS augmented reality laparoscopic simulator versus LapSim virtual reality laparoscopic simulator. World J Surg 2007;31:764–72.
10. Botden SM, Torab F, Buzink SN, Jakimowicz JJ. The importance of haptic feedback in laparoscopic suturing training and the additive value of virtual reality simulation. Surg Endosc 2008;22:1214–22.
11. Vapenstad C, Hofstad EF, Lango T, Marvik R, Chmarra MK. Perceiving haptic feedback in virtual reality simulators. Surg Endosc 2013;27:2391–7.
12. Debes AJ, Aggarwal R, Balasundaram I, Jacobsen MB. A tale of two trainers: virtual reality versus a video

trainer for acquisition of basic laparoscopic skills. Am J Surg 2010;199:840–5.
13. Palter VN, Orzech N, Aggarwal R, Okrainec A, Grantcharov TP. Resident perceptions of advanced laparoscopic skills training. Surg Endosc 2010;24: 2830–4.
14. Shetty S, Zevin B, Grantcharov TP, Roberts KE, Duffy AJ. Perceptions, training experiences, and preferences of surgical residents toward laparoscopic simulation training: a resident survey. J Surg Educ 2014;71:727–33.
15. Zendejas B, Brydges R, Hamstra SJ, Cook DA. State of the evidence on simulation-based training for laparoscopic surgery: a systematic review. Ann Surg 2013;257:586–93.
16. Zhang L, Grosdemouge C, Arikatla VS, Ahn W, Sankaranarayanan G, De S, et al. The added value of virtual reality technology and force feedback for surgical training simulators. Work 2012;41 Suppl 1:2288–92.
17. Strom P, Hedman L, Sarna L, Kjellin A, Wredmark T, Fellander-Tsai L. Early exposure to haptic feedback enhances performance in surgical simulator training: a prospective randomized crossover study in surgical residents. Surg Endosc 2006;20:1383–8.
18. Salkini MW, Doarn CR, Kiehl N, Broderick TJ, Donovan JF, Gaitonde K. The role of haptic feedback in laparoscopic training using the LapMentor II. J Endourol 2010;24:99–102.
19. Coles TR, Meglan D, John NW. The role of haptics in medical training simulators: a survey of the state of the art. IEEE Trans Haptics 2011;4:51–66.
20. Susmitha WK, Devasahayam SR, Manivannan M, Mathew G. Force model for laparoscopic graspers: implications for virtual simulator design. Minim Invasive Ther Allied Technol 2016. DOI: 10.1080/13645706.2016.1252779
21. Chmarra MK, Dankelman J, van den Dobbelsteen JJ, Jansen FW. Force feedback and basic laparoscopic skills. Surg Endosc 2008;22:2140–8.
22. Panait L, Akkary E, Bell RL, Roberts KE, Dudrick SJ, Duffy AJ. The role of haptic feedback in laparoscopic simulation training. J Surg Res 2009;156:312–16.
23. Sorensen SM, Savran MM, Konge L, Bjerrum F. Three-dimensional versus two-dimensional vision in laparoscopy: a systematic review. Surg Endosc 2016;30:11–23.
24. Bittner JG, Hathaway CA, Brown JA. [Not Available]. J Minim Access Surg 2008;4:31–8.
25. LaGrange CA, Clark CJ, Gerber EW, Strup SE. Evaluation of three laparoscopic modalities: robotics versus three-dimensional vision laparoscopy versus standard laparoscopy. J Endourol 2008;22: 511–16.
26. Mistry M, Roach VA, Wilson TD. Application of stereoscopic visualization on surgical skill acquisition in novices. J Surg Educ 2013;70:563–70.
27. Sakata S, Watson MO, Grove PM, Stevenson AR. The conflicting evidence of three-dimensional displays in laparoscopy: a review of systems old and new. Ann Surg 2016;263:234–9.
28. LG. 3D FPR Technology Never Loses Its Value. 2014. Available at: http://www.lgnewsroom.com/2011/01/lg-electronics-cinema-3d-technology-creates-movie-theater-experience-at-home/2014. Available at: http://lgdnewsroom.com/products-solutions/tv/4251.
29. G-coder. G-coder sensor technology. 2015. Available at: http://g-coder.com/technology. [Accessed February 04, 2015].
30. Hagelsteen K, Sevonius D, Bergenfelz A, Ekelund M. Simball box for laparoscopic training with advanced 4D motion analysis of skills. Surg Innov 2016;23:309–16.
31. Schoenthaler M, Schnell D, Wilhelm K, Schlager D, Adams F, Hein S, et al. Stereoscopic (3D) versus monoscopic (2D) laparoscopy: comparative study of performance using advanced HD optical systems in a surgical simulator model. World J Urol 2016;34:471–7.
32. Ashraf A, Collins D, Whelan M, O'Sullivan R, Balfe P. Three-dimensional (3D) simulation versus two-dimensional (2D) enhances surgical skills acquisition in standardised laparoscopic tasks: a before and after study. Int J Surg 2015;14:12–16.
33. Alaraimi B, El Bakbak W, Sarker S, Makkiyah S, Al-Marzouq A, Goriparthi R, et al. A randomized prospective study comparing acquisition of laparoscopic skills in three-dimensional (3D) vs. two-dimensional (2D) laparoscopy. World J Surg 2014;38:2746–52.
34. Votanopoulos K, Brunicardi FC, Thornby J, Bellows CF. Impact of three-dimensional vision in laparoscopic training. World J Surg 2008;32:110–18.
35. Vedel C, Bjerrum F, Mahmood B, Sorensen JL, Strandbygaard J. Medical students as facilitators for laparoscopic simulator training. J Surg Educ 2015;72:446–51.

Appendix A. LapSim® task configurations settings.

Parameter description	Instrument navigation	Grasping	Fine dissection	Suturing[a]
Randomize				
Random sequence (#)	45638954	685798	1234	–
Spread wide	Yes	Yes	–	–
Camera options				
Rotate degree	0	0	0	0
Use moving camera	Y	No	No	No
Object options				
Left objects (#)	6	7	–	–
Right objects (#)	6	7	–	–
Object size (mm)	6	8	–	–
Timing				
Use object timeout	Yes	Yes	No	Yes
Timeout after (S)	10	15	1000	180
Target options				
Target size (mm)	–	15	–	–
Vessel options				
Number of blood vessels	–	–	2	–
Number of small vessels	–	–	3	–
Stretch sensitivity (easy–hard)	–	–	2	–
Instrument options				
Cutter instrument	–	–	Thermo hook	–
Easy grip and knot	–	–	–	No
Needle size (mm)	–	–	–	15
Suture length (mm)	–	–	–	150
Environment options				
Environment	–	–	–	Realistic
Stitching options				
Target area diameter (mm)	–	–	–	10
Maximum stretch sensitivity (mm)	–	–	–	20
Knot detection (easy–hard)	–	–	–	Easy

[a]Configuration settings according to Ahlberg et al (3).

Appendix B. Proficiency-level settings in LapSim®

Parameters	Instrument navigation	Grasping	Fine dissection	Suturing[a]
Total instrument time (s)[b]	34.0	110	160	120
Right	17.0	55	–	–
Left	17.0	55	–	–
Total instrument path length (m)[b]	2.0	4.4	–	3.0
Right	1.0	2.2	–	1.5
Left	1.0	2.2	–	1.5
Total instrument angular path (degrees)[b]	280	740	–	800
Right	140	370	–	400
Left	140	370	–	400
Tissue damage (#)	1.0	3.0	–	–
Maximum damage (mm)	2.0	5.0	–	–
Average instrument misses (%)	0.0	6.0	–	–
Right	0.0	3.0	–	–
Left	0.0	3.0	–	–
Total instruments outside view (#)[b]	–	–	1.0	–
Right	–	–	1.0	–
Left	–	–	0.0	–
Total instruments outside view (s)[b]	–	–	5.0	–
Right	–	–	5.0	–
Left	–	–	0.0	–
Vessel options				
Ripped or burned blood vessels (%)	–	–	0.0	–
Energy damage on blood vessels (%)	–	–	20.0	–
Ripped small vessels (%)	–	–	0.0	–
Burned small vessels (%)	–	–	100.0	–
Burned small vessels w/o stretch (%)	–	–	25.0	–
Cutter angular path (degrees)	–	–	200	–
Cutter outside view (#)	–	–	1	–
Cutter outside view (s)	–	–	5	–
Cutter path length (m)	–	–	0.9	–
Grasper options				
Grasper angular path (degrees)	–	–	60	–
Grasper outside view (#)	–	–	0	–
Grasper outside view (s)	–	–	0	–
Grasper path length (m)	–	–	0.3	–
Maximum target error (mm)	–	–	–	0.0
Knot error (%)	–	–	–	0.0

[a]Right and left instrument parameters are measured separately in the LapSim® software.
[b]According to Ahlberg et al. (3).
Total parameters are the sum of right and left instrument parameters.
Total parameter values were used for statistical analysis.

Paper III

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RESEARCH-ARTICLE

Performance and perception of haptic feedback in a laparoscopic 3D virtual reality simulator

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ABSTRACT

Background: The benefit of haptic feedback in laparoscopic virtual reality simulators (VRS) is ambiguous. A previous study found 32% faster acquisition of skills with the combination of 3 D and haptic feedback compared to 2 D only. This study aimed to validate perception and effect on performance of haptic feedback by experienced surgeons in the previously tested VRS.
Material and methods: A randomized single blinded cross-over study with laparoscopists (>100 laparoscopic procedures) was conducted in a VRS with 3 D imaging. One group started with haptic feedback, and the other group without. After performing the suturing task with haptics either enabled or disabled, the groups crossed over to the opposite setting. Face validity was assessed through questionnaires. Metrics were obtained from the VRS.
Results: The haptics for 'handling the needle', 'needle through tissue' and 'tying the knot' was scored as completely realistic by 3/22, 1/22 and 2/22 respectively. Comparing the metrics for maximum stretch damage between the groups revealed a significantly lower score when a group performed with haptics enabled $p = .027$ (haptic first group) and $p < .001$(haptic last group).
Conclusion: Haptic feedback in VRS has limited fidelity according to the tested laparoscopic surgeons. In spite of this, significantly less stretch damage was caused with haptics enabled.

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Haptic feedback; laparoscopy; simulator; surgical education; virtual reality; 3D vision

Introduction

High fidelity virtual reality simulators (VRS) have shown to be as effective as box trainers in teaching laparoscopic suturing [1–4]. Constructors of VRS have tried to mimic the authentic sense of touch in laparoscopic surgery for years [5,6]. Haptic feedback is not a generic property and different simulators use different types of actuation with different qualities to mimic touch, i.e. shape memory metals, magnetic, piezoelectric materials, electrorheological fluids, DC electric motors (the most common), pneumatic, as well as hydraulic actuation [6]. To compensate for lack of haptic feedback in the simulator, researchers have also tried to mimic this through programming increased resistance in the trocars to mimic the resistance when inserting instruments through the trocars [7].

There is a lack of validation studies on VRS offering this sense of touch, called haptics or force feedback. The few studies performed on VRS with haptics have shown conflicting results concerning usefulness and transferability to the operating room [8–11].

LapSim® (surgicalscience, Gothenburg, Sweden) is a worldwide well-known VRS validated in several studies [12–15]. A previous study found that the time to reach a set proficiency level in a VRS basic skills course, using the LapSim® Haptic System (surgicalscience) with 3 D vision and haptic feedback, was significantly faster than not having 3 D or haptic feedback [16]. Another study using the same LapSim® simulator without haptic feedback, but with 3 D vision, found that skills acquisition was enhanced by the 3 D feature [17]. No validation on the latest LapSim® Haptic System considering haptic feedback has previously been reported.

The primary aim of this study was to establish face validity regarding user experience and perception of haptic feedback in the LapSim® Haptic System by experienced laparoscopic surgeons. The secondary aim was to assess if haptic feedback affected the performance in the VRS for experienced surgeons.

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Table 1. Demography and experience of participating surgeons.

Variable	Group	
	Haptic first ($n = 13$)	Haptic last ($n = 13$)
Men/Women	10/3	8/5
Age in years: median (range)	50 (36–66)	44 (34–70)
Laparoscopic procedures as primary surgeon (#)		
100–1000	8	12
>1000	5	1
Laparoscopic suturing observed (# Yes)	13/13	13/13
Laparoscopic suturing performed		
0	1	3
1–10	5	6
>10	7	4
Previously trained in virtual reality simulator (# Yes)	6/13	6/13
Play video games >1 h/week (# Yes)	1/13	3/13
Dominant hand (Right / left)	13 / 0	13 / 0

Material and methods

Participants

Surgeons with a minimum experience of 100 laparoscopic procedures were included in this study. All surgeons employed at the Department of Surgery or Paediatric Surgery, Skåne University Hospital, Sweden, were invited to participate and the first 26 responders were included. Background information was obtained (Table 1). Self-perception of not being able to perceive 3 D was an exclusion criterion. Microsoft® Excel 2013 was used for randomization into two groups.

Study design and setup

A randomized single blinded cross over study was conducted in a VRS with 3 D imaging (LapSim® VR Haptic System, Surgical Science Sweden AB, Gothenburg, Sweden). The instrument joysticks delivered haptic feedback to the user, which was interpreted as tactile sensations, or force feedback, when touching objects in the virtual operating space. The haptic feedback was provided to the joysticks by electrical motors, connected through an interface to the software.

The experiment started with standardized oral instructions and warm-up consisting of a basic "grasping and holding" task with haptics enabled followed by a suturing instruction video on the VRS. The surgeons then performed five suturing attempts with haptics either enabled at start (referred to as 'haptic-first' group) or disabled at start (referred to as 'haptic-last' group), followed by five new suturing attempts in the opposite haptic setting. The participants rated their perception of three haptic aspects; the needle, tissue and thread, on a 3-point Likert scale, and five graphical aspects; the visceral anatomy, instruments, needle, thread and complete task, on a 5-point Likert scale after each set of five attempts (Appendix A). Graphics were identical throughout the study. The setup and difficulty level for the suturing task were the same as in previous studies examining novices' learning curves with 3 D and haptics [16]. The participants were informed that the maximum time for each suturing attempt was set at 180 s.

Ethical approval was considered unnecessary since all data were non-sensitive and collected anonymously. Consent for participation was retrieved from each participant before entering the study and it was made clear that participation could be cancelled by the participant without questions and at any moment.

Data analysis and statistical methods

Data from the questionnaire regarding the experts' opinions were presented with descriptive statistics. A sum score of variables concerning perception of haptic feedback and graphics was constructed and compared using Wilcoxon signed rank test.

Metrics was extracted from the LapSim® software for the parameters *time* (s), *maximum target error* (mm), *knot error* (%), *instrument path length* (m), *instrument angular path length* (degrees), *instrument outside view* (# and s), *tissue damage* (#) and *maximum stretch damage* (mm and %) for each attempt in both settings. The three variables that could potentially be influenced by haptics; *maximum stretch damage* (%), *maximum damage* (mm) and number of *damages to the tissue* were analyzed using a linear mixed model, allowing for repeated measures. A p values of $<.05$ was considered significant. All statistical computations were performed by a statistician using the computer program R (version 3.4.2) [18].

Results

All 26 surgeons enrolled completed the study. Four participants, one in the 'haptic first'- group and three in the 'haptic last'-group, had no experience in laparoscopic suturing and were excluded from rating the haptic feedback.

Face validity haptic feedback

The sense of '*handling the needle'* was scored as completely realistic by 3/22 and moderately realistic by 14/22 in the haptic setting. No surgeon rated

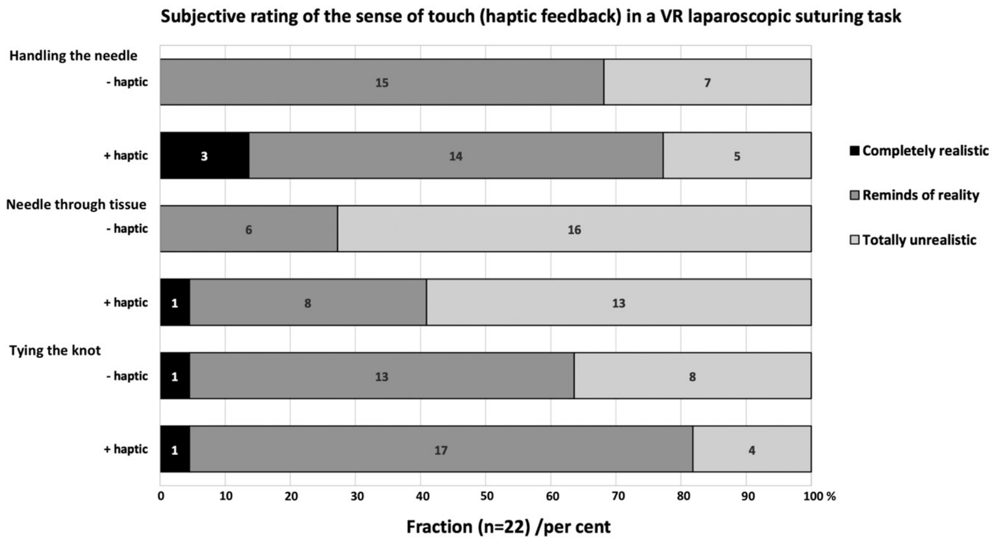

Figure 1. Subjective rating of the sense of touch (haptic feedback) in a VR laparoscopic suturing task. Results from questionnaire rating user experience of 'handling the needle', 'needle through tissue' and 'tying the knot' with or without haptic feedback enabled in the VR simulator on a 3-point Likert scale. Haptic feedback was scored by 22 of 26 surgeons; the four who had never performed laparoscopic suturing were excluded. Values are shown in percent. A sum of the rating showed a significantly higher total score in the haptic setting, $p = .0008$.

"handling of the needle" as completely realistic without haptic feedback. One participant found the '*needle through tissue*' completely realistic in the haptic setting, but a majority considered this aspect totally unrealistic both with (13/22) and without (16/22) haptic feedback (Figure 1). For 'tying the knot' 17/22 and 13/22 considered it moderately realistic with and without haptic, respectively (Figure 1). One person (the same) considered 'tying the knot' completely realistic in both settings. A sum score of the rating of the haptic feedback (the needle, tissue and thread), showed a significant difference and a higher total score from both groups in the haptic setting ($p = .008$) and no difference in rating between the two groups ($p = .10$).

Face validity graphics

The graphics was identical when haptics was enabled or disabled, and was rated twice by the 26 participants. No significant difference in scores between the two settings or groups ($p > .3$ and $p = .07$ respectively) was seen. The graphics for 'instruments' and 'needle' received the highest score as it was considered completely realistic by 12/52 and 13/52, respectively. The graphics of the 'visceral anatomy' and the 'thread' received the lowest scores for 'completely realistic', with 2/52 and 6/52, respectively (Figure 2). One participant considered the overall graphics for the 'suturing task' completely realistic in the haptic setting. All graphical aspects received most ratings as 'moderately realistic', ranging from 40 to 65% (Figure 2).

Educational value

A majority of the surgeons (14/26) considered the haptic setting best for education of novices for laparoscopic suturing. One third found the two settings equally good for education (Figure 3). There was a significant difference in the answers between the two groups; 9/13 participants in the 'haptic last' group preferred the haptic setting, and 7/13 in the 'haptic first' group considered the two tested settings to have equal educational value ($p = .029$).

Performance

Four of 26 surgeons reached the required passing level during the first five attempts, and 8/26 in the following five. The passing participants were equally distributed between the groups and settings. *Maximum stretch damage* changed significantly when haptic feedback was enabled. With this feature both

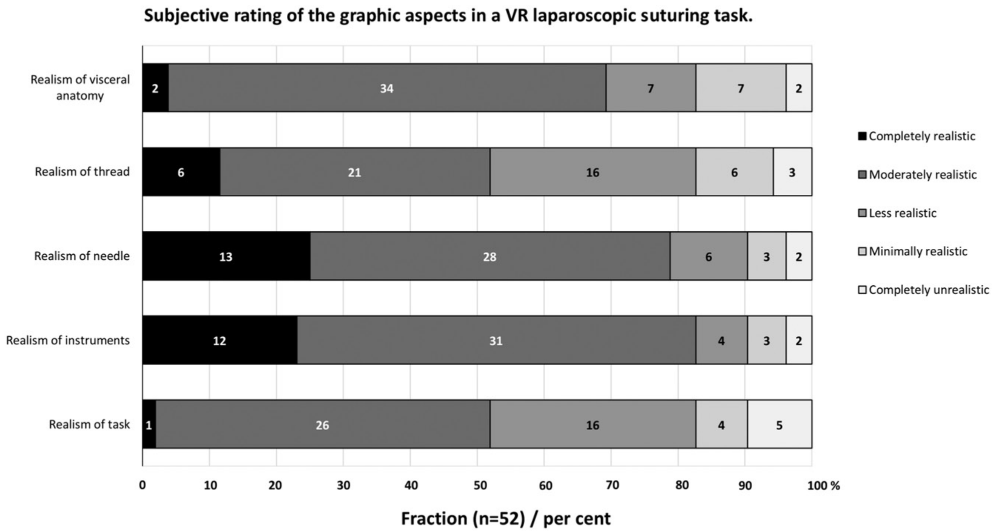

Figure 2. Subjective rating of the graphic aspects in a VR laparoscopic suturing task. Results from questionnaire rating the graphical interface on a 5-point Likert scale with and without haptic feedback. The needle and instruments were considered the most realistic. A majority found all aspects moderately realistic for all aspects queried. Values are shown in percent. There was no difference in the scores depending on whether haptics was enabled or not.

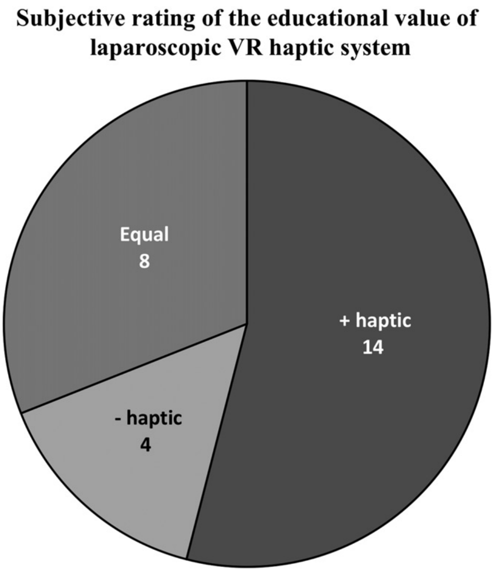

Figure 3. Subjective rating of the educational value of the laparoscopic VR haptic system. Fourteen of 26 surgeons recommended the haptic setting for novices for laparoscopic suturing.

groups outperformed the other group (Table 2). The 'haptic first'-group had a significantly lower score compared to 'haptic last'-group in the first five attempts, $p = .027$. The 'haptic last'-group performed better in the last five attempts (haptic setting) compared to the 'haptic first'-group without, $p < .001$.

Within-group comparisons after cross-over showed that the 'haptic first'-group had the same level of skills in the non-haptic setting, $p = .308$, while the 'haptic last'-group improved when they had haptic feedback, $p = .048$ (Table 2). The other two performance parameters that possibly could be influenced by haptic feedback; *maximum damage* (mm) and number of *tissue damages* (#), did not show any significant difference within or between the groups. No sex difference was noted.

Discussion

The aim of this study was to investigate how laparoscopists perceived the new haptic interface of a common laparoscopic VRS and how it affected their performance in the simulator. The results showed that the surgeons exhibited less *stretch damage* to the simulated tissue when haptics was enabled. However, their rating of the experienced haptic sense showed limitations in perception of fidelity.

The surgeons rated the VRS sense of touch significantly more realistic with haptic feedback enabled than without. However, only a handful considered any of the haptic feedback aspects to be completely realistic. A majority found 'tying the knot' and 'handling the needle' to 'resemble reality' and rated it 2 on a 3-point Likert scale. A majority thought the 'needle through tissue' was completely unrealistic (Figure 2). These results indicate that true sense of touch is yet to be achieved.

The surgeons rated 'needle through tissue' to be the most unrealistic part of the task concerning sense of haptic feedback; thus a discrepancy towards the graphical rating of the tissue which scored well with a total of 36/52 considering the visceral anatomy 'moderately' or 'completely' realistic. In what way the participants felt the 'needle through tissue' to be unrealistic is not known since no in-depth questions were asked. The well-known 'representation' of tissue texture for surgeons with years of experience may be hard to evaluate [19].

Even if the experience of haptic feedback was considered not completely realistic, a majority preferred the haptic setting and would recommend it to novices for training. The 'haptic last'-group who improved their performance with the addition of haptics displayed a more positive attitude towards haptic feedback than the 'haptic first'-group, with nine of 13 recommending the haptic setting for novices. It is likely that this shows performance influence since a small majority in the 'haptic first'-group found the settings equally good, in agreement with that their performance did not improve during the last five attempts. This is in contrast to Våpenstad et al. who found that the surgeons preferred the non-haptic system [20]. However, in the Våpenstad study, other instrument handles and older software for the haptic feedback with LapSim® VRS were used, indicating that the quality of the haptic feedback in the latest LapSim® Haptic System is now enhanced compared to previous systems.

In spite of the perceived limited sense of touch, a significantly better performance score for the parameter most sensitive to force, *maximum stretch damage* was seen with haptic feedback enabled, for both groups (Table 2). This is of importance since this parameter describes, on a linear scale, how much the surgeon tears the tissue when performing the stitching. Thus, 100% represent >21 mm deviation from the optimal stitch position and possible tearing of tissue, 50% represent >15 mm deviation and 0% represent <10 mm stretch by the stitch. With haptic feedback enabled, better scores were seen. The 'haptic last'-group improved their individual scores when haptic feedback was enabled, while the 'haptic first'-group maintained theirs. There was no difference in performance level between the two groups when performing with haptic feedback. This could indicate that haptics 'guide' the surgeon to more precise needle movements and thereby reduce the tearing of tissue and have a positive effect on performance right from the start.

Table 2. Maximum stretch damage.

Between group comparison	Mean (SD)	Mean (SD)	*P*-value
'Haptic first'-group (+ haptic) vs 'Haptic last'-group (– haptic)	60 (27)	77 (20)	.027*
'Haptic first'-group (– haptic) vs 'Haptic last'-group (+ haptic)	77 (18)	49 (34)	<.001***
'Haptic first'-group (+ haptic) vs 'Haptic last'-group (+ haptic)	60 (27)	49 (34)	.693
'Haptic last'-group (– haptic) vs 'Haptic first'-group (– haptic)	77 (20)	77 (18)	.999
Within group comparison	**Mean (SD)**	**Mean (SD)**	***P*-value**
'Haptic first'-group (+ haptic) vs (– haptic)	60 (27)	77 (18)	.308
'Haptic last'-group (– haptic) vs (+ haptic)	77 (20)	49 (34)	.048*

Comparison of performance metrics for 'Maximum stretch damage' parameter between and within study groups with and without haptic feedback. Means and SD are presented for sum scores, analyzed using a linear mixed model, allowing for repeated measures. p values <.05 is considered significant. $P < .001$***; $p < .05$*.

Moreover, only four out of 26 surgeons 'passed' the suturing task in the first five attempts and another four managed the task in their last five attempts regardless of whether haptics were added or not. If this finding was due to the unfamiliar simulator environment or a lack of intracorporeal suturing skills is unknown. Even for experienced surgeons, as in the present investigation in which 22 of 26 previously had performed laparoscopic suturing, suturing may not be part of the participants' daily surgical routine. Studies investigating the surgeons' sense of touch during laparoscopy have revealed that this is quite subtle, but it could still help the surgeon to apply the appropriate tension [19,21,22]. Too much haptic feedback could on the other hand lead to a negative training effect [6,10,23].

In a previous study, novices acquired a predetermined proficiency level of skills 32% faster with 3 D vision and haptic feedback enabled than without neither 3 D nor haptic feedback [15]. The results from the present study suggest that haptic feedback in itself plays a role to aid surgeons to apply proper force to the tissue when practicing intracorporeal suturing. Salkini et al. and Thompson et al. on the other hand found no beneficial effect at all of haptic feedback, while Ström et al. found that haptic feedback in VRS had a transfer effect [11,24,25]. However, there were important differences between these studies. In the study by Ström et al. all participants were novices and they benefitted from haptic feedback in the early learning phase while, in contrast, experts in the current study already should have passed the initial learning phase. The studies of Salkini et al. and Thompson et al. were conducted on a different VRS with a different haptic technology, LapMentor II (3 D Systems, Littleton, CO, USA), whereas Ström et al. also had a different haptic setup compared to the current study [11,24,25]. A recent study by Våpenstad et al found a negative training effect for transfer to the operating theatre when combining LapSim with Xitact haptic handles (Mentice, Gothenburg, Sweden) [10]. Comparisons between different simulator setups are difficult to make, since there is an on-going development in the field. The commercially available simulators are at present not comparable to those used in studies performed just a few years ago [8,26,27]. Further, one LapSim® study is not easily comparable to another since haptic setups may differ [10,16,20].

In other studies, investigating user experience of VRS, surgical residents preferred porcine models or high fidelity synthetic models to VRS [28–31]. However, these studies used VRS without haptic feedback. Expert opinion is important when new VRS are released since novices are unfamiliar with the true sense of touch and texture doing laparoscopic surgery.

Strengths and limitations

The suturing task is an advanced laparoscopic task that offers a good opportunity to study the haptic feedback settings in the VRS. The suturing task and particular level of difficulty has been used in previous studies showing transfer to the operating room, though without haptic feedback [12]. The crossover study design provided unbiased estimates for the difference between the two groups. A limitation of this study was the relatively small group of participants, with only 13 in each group and four were excluded from rating the experienced sense of touch from haptic feedback due to lack of suturing experience, leaving only 22 participants left for this part. There were no statistical differences between the groups, but five of the six surgeons who had performed over 1000 laparoscopic procedures were randomized in the 'haptic first'-group. A sub analysis of the surgeons with more than 1000 procedures was performed and no statistical difference on the evaluated parameters was found. However, lack of evidence for a difference is not evidence that differences might have been found if the numbers had been larger. Potential confounding factors are that only six individuals had this large experience. Furthermore, the group with experience of between 100 – 1000 procedures might be heterogenous, with some having done 101 and others 999 laparoscopic operations. A 3-point Likert scale was chosen to 'force' the surgeons to clearly state if they perceived the haptic feedback to be completely realistic or not. More important, open-ended questions revealing descriptions on what aspects they found realistic or unrealistic would have given more in-depth information concerning their opinions.

The use of a time cap of three minutes per trial and a number of five trails per setup inherently prohibit us to know the true time needed to complete and pass the suturing task. To what extent this failure for many of the participants affected their opinion on the simulator is unclear, but no significant difference was found in ratings between the haptic and non-haptic setting based on passing the task or not.

This study evaluated expert opinion of the latest LapSim® Haptic System, with 3 D vision and haptic feedback. Future studies are suggested to compare this version of VRS to other VRS with haptic feedback (i.e LapMentor), video box trainers, augmented VRS (i.e ProMIS) or hybrid systems (i.e Simball Box, TrEndo, VBLaST) to further investigate the added value of haptic feedback [25,32–35]. Research should also aim to evaluate the transfer effect from acquired skills in haptic simulators to the operating room to ensure that no negative effects of haptic feedback occur.

Conclusion

The surgeons performed significantly better causing less *stretch damage* with haptic feedback enabled. However, the haptic feedback feature in this 3 D VR simulator has limited fidelity according to the tested surgeons' opinion. Despite the limited perception of haptic feedback, and when blinded, a small majority preferred the setting with haptic feedback for educational purposes in novices. This implies that not only novices could benefit from haptic feedback and that it gives no disadvantage in the VR simulator investigated.

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Declaration of interest

Drs. Anderberg, Bergenfelz, Ekelund, Hagelsteen and Johansson have no conflicts of interest or financial ties to disclose. This statement covers all parts of the study and includes no attachment, in any aspect, to the manufacturers of LapSim®. Surgical Science Sweden AB provided technical support for the VRS, but had no influence on financing, design, data analysis and interpretation of the results and
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References

[1] Dehabadi M, Fernando B, Berlingieri P. The use of simulation in the acquisition of laparoscopic suturing skills. Int J Surg. 2014;12:258–268.
[2] Orzech N, Palter VN, Reznick RK, et al. A comparison of 2 ex vivo training curricula for advanced laparoscopic skills: a randomized controlled trial. Ann Surg. 2012;255:833–839.
[3] Zhou M, Tse S, Derevianko A, et al. Effect of haptic feedback in laparoscopic surgery skill acquisition. Surg Endosc. 2012;26:1128–1134.
[4] McDougall EM, Kolla SB, Santos RT, et al. Preliminary study of virtual reality and model simulation for learning laparoscopic suturing skills. J Urol. 2009;182:1018–1025.
[5] Westebring-van der Putten EP, Goossens RH, Jakimowicz JJ, et al. Haptics in minimally invasive surgery-a review. Minim Invasive Ther Allied Technol. 2008;17:3–16.
[6] Coles TR, Meglan D, John NW. The role of haptics in medical training simulators: a survey of the state of the art. IEEE Trans Haptics. 2011;4:51–66.
[7] Buzink SN, Goossens RH, De Ridder H, et al. Training of basic laparoscopy skills on SimSurgery SEP. Minim Invasive Ther Allied Technol. 2010;19: 35–41.
[8] Vapenstad C, Hofstad EF, Bo LE, et al. Limitations of haptic feedback devices on construct validity of the LapSim® virtual reality simulator. Surg Endosc. 2013;27:1386–1396.
[9] Chmarra MK, Dankelman J, van den Dobbelsteen JJ, et al. Force feedback and basic laparoscopic skills. Surg Endosc. 2008;22:2140–2148.
[10] Vapenstad C, Hofstad EF, Bo LE, et al. Lack of transfer of skills after virtual reality simulator training with haptic feedback. Minim Invasive Ther Allied Technol. 2017;26:346–354.
[11] Strom P, Hedman L, Sarna L, et al. Early exposure to haptic feedback enhances performance in surgical simulator training: a prospective randomized crossover study in surgical residents. Surg Endosc. 2006; 20:1383–1388.
[12] Ahlberg G, Enochsson L, Gallagher AG, et al. Proficiency-based virtual reality training significantly reduces the error rate for residents during their first 10 laparoscopic cholecystectomies. Am J Surg. 2007; 193:797–804.
[13] Duffy AJ, Hogle NJ, McCarthy H, et al. Construct validity for the LAPSIM laparoscopic surgical simulator. Surg Endosc. 2005;19:401–405.
[14] van Dongen KW, Tournoij E, van der Zee DC, et al. Construct validity of the LapSim: can the LapSim virtual reality simulator distinguish between novices and experts?. Surg Endosc. 2007;21:1413–1417.
[15] Fairhurst K, Strickland A, Maddern G. The LapSim virtual reality simulator: promising but not yet proven. Surg Endosc. 2011;25:343–355.
[16] Hagelsteen K, Langegard A, Lantz A, et al. Faster acquisition of laparoscopic skills in virtual reality

with haptic feedback and 3D vision. Minim Invasive Ther Allied Technol. 2017;26:269–277.
[17] Sorensen SMD, Konge L, Bjerrum F. 3D vision accelerates laparoscopic proficiency and skills are transferable to 2D conditions: a randomized trial. Am J Surg. 2017;214:63–68.
[18] R Core Team. (2017). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2017.
[19] Lamata P, Gomez EJ, Sanchez-Margallo FM, et al. Tissue consistency perception in laparoscopy to define the level of fidelity in virtual reality simulation. Surg Endosc. 2006;20:1368–1375.
[20] Vapenstad C, Hofstad EF, Lango T, et al. Perceiving haptic feedback in virtual reality simulators. Surg Endosc. 2013;27:2391–2397.
[21] Bholat OS, Haluck RS, Murray WB, et al. Tactile feedback is present during minimally invasive surgery. J Am Coll Surg. 1999;189:349–355.
[22] Picod G, Jambon AC, Vinatier D, et al. What can the operator actually feel when performing a laparoscopy? Surg Endosc. 2005;19:95–100.
[23] van der Meijden OA, Schijven MP. The value of haptic feedback in conventional and robot-assisted minimal invasive surgery and virtual reality training: a current review. Surg Endosc. 2009;23:1180–1190.
[24] Thompson JR, Leonard AC, Doarn CR, et al. Limited value of haptics in virtual reality laparoscopic cholecystectomy training. Surg Endosc. 2011;25:1107–1114.
[25] Salkini MW, Doarn CR, Kiehl N, et al. The role of haptic feedback in laparoscopic training using the LapMentor II. J Endourol. 2010;24:99–102.
[26] Pinzon D, Byrns S, Zheng B. Prevailing trends in haptic feedback simulation for minimally invasive surgery. Surg Innov. 2016;23:415–421.
[27] Schijven M, Jakimowicz J. Virtual reality surgical laparoscopic simulators. Surg Endosc. 2003;17:1943–1950.
[28] Shetty S, Zevin B, Grantcharov TP, et al. Perceptions, training experiences, and preferences of surgical residents toward laparoscopic simulation training: a resident survey. J Surg Educ. 2014;71:727–733.
[29] Botden SM, Buzink SN, Schijven MP, et al. Augmented versus virtual reality laparoscopic simulation: what is the difference? A comparison of the ProMIS augmented reality laparoscopic simulator versus LapSim virtual reality laparoscopic simulator. World J Surg. 2007;31:764–772.
[30] Madan AK, Frantzides CT, Tebbit C, et al. Participants' opinions of laparoscopic training devices after a basic laparoscopic training course. Am J Surg. 2005;189:758–761.
[31] Palter VN, Orzech N, Aggarwal R, et al. Resident perceptions of advanced laparoscopic skills training. Surg Endosc. 2010;24:2830–2834.
[32] Zhang L, Grosdemouge C, Arikatla VS, et al. The added value of virtual reality technology and force feedback for surgical training simulators. Work. 2012;41: 2288–2292.
[33] Hagelsteen K, Sevonius D, Bergenfelz A, et al. Simball box for laparoscopic training with advanced 4D motion analysis of skills. Surg Innov. 2016;23:309–316.
[34] Botden SM, Buzink SN, Schijven MP, et al. ProMIS augmented reality training of laparoscopic procedures face validity. Simul Healthc. 2008;3:97–102.
[35] Chmarra MK, Grimbergen CA, Dankelman J. Systems for tracking minimally invasive surgical instruments. Minim Invasive Ther Allied Technol. 2007;16:328–340.

Paper IV

Identification of warning signs during selection of surgical trainees

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Abstract

Objective:

The aim was to document empirical observations about antecedents to and practices of unsuitable behaviours amongst surgical trainees and develop an interview guide that could be part of a selection process.

Design:

A mixed methods design was adopted combining a survey distributed to senior surgeons and heads of departments followed by semi-structured interviews.

Setting:

All surgical departments and hospitals in The South Swedish Health Care Region, Sweden.

Participants:

The survey was completed by 54 of 83 eligible surgeons above 50 years of age, and four of seven heads of surgical departments. Semi-structured interviews with 13 surgeons representing local, regional and university hospitals from the same cohort.

Results:

Forty-six (85%) surgeons and four of seven heads of departments responded that they had come across surgical trainees deemed unsuitable to train and work as surgeon. All head of departments and 31 of 54 of the surgeons believed tendencies of unsuitability are evident early. From the survey, 107 statements described reasons for finding a trainee unsuitable. Qualitative analysis of the interviews and survey's free text answers led to identification of 11 problem domains with associated 'warning signs'. An interview guide to help detect unsuitability tendencies in candidates during selection procedures was constructed.

Conclusions:

Experienced surgeons have quite consistent views on what makes someone an unsuitable surgeon. This knowledge has been systematized into 11 problem domains and a set of 'warning signs'. They act as human error conditions or precursors to negative effects if allowed to go on unnoticed, and early detection is important for the individual, the work environment and patient safety. A recommendation for a minimum framework for selection including the constructed interview guide is presented.

Introduction

Adverse events in surgery are common, affecting 5-15% of all hospital admissions and a majority (62,5%) are estimated to be avoidable, with 3,6 - 4,7 % leading to permanent harm or death [1, 2]. Compared to other high-risk fields, healthcare has not achieved the same dramatic improvement in safety as e.g. the airline industry [3, 4]. Systematic safety work has resulted in other high-risk organisations to develop into High-Reliability Organisations (HROs) [3, 5]. In HROs, powerful systems for personnel selection and training exist and selection of surgical trainees has been proposed to be a ”missing link” within the concept of reducing adverse events in surgery [4]. The recruitment system varies from country to country, with some recruiting trainees directly from medical school and others after an internship period of 1 -1,5 years, some have a national selection process while others have local ones [6-15].

In general, selection processes tend to follow the strategy of trying to find the best candidate based on a set of criteria. While one might believe that this process, selecting the best, mitigates taking those who are unsuitable, this is not necessarily the case, as some positive and negative criteria lie very close to each other or may even be the same disposition, but come to expression in the wrong context. Thus, in contexts oriented towards selecting “the best” one should also actively test for unsuitability, as one and the same candidate can be both. In contexts where selection is rarely based on selection from a number of candidates, it is more important to objectively test for unsuitability to mitigate a detrimental hiring into a training position.

Studies investigating the desirable qualities in basic surgical trainees have resulted in lists of favourable traits [16-19]. Ireland has been in the frontline of the selection process for higher surgical training and implemented a transparent and rigorous model [15]. By design, the Irish selection process is holistic with the aim to also identify candidates ‘*who are likely to be unsuccessful in training or problematic as future surgeons’* [7]. However, there is no consensus in the global surgical community concerning what to assess, when and how to do it [6, 7, 10, 12, 15, 17, 20-29]. Most commonly, selection is currently based on a combination of medical school grades or exams, CVs, reference taking and non-structured interviews, but recent studies advocate to even include and investigate further the value of aptitude tests, structured interviews, personality inventories and situational judgment tests [6, 10, 12, 20, 30-33]. No single test or combination of tests have been identified which with high validity and reliability can predict technical aptitude [34]. Studies on surgical trainee’s technical performance development have shown that between 8 – 20 %, will struggle with learning arthroscopy[35] or laparoscopy [36-38] to a proficient level within reasonable time.

Studies on the opposite side of the scale, of problem trainees and remediation practices reveal that the predominant issues exhibited by struggling trainees involve nontechnical competencies, such as knowledge, interpersonal skills, and professionalism [39-43]. Bergen et al found in 2000 that 21 % of residents in surgery at a single institution were high-risk or problem resident over a 10 year period [44]. These residents exhibited deficiencies in interpersonal behaviour (including professional behaviour and ethics), cognitive, synthetic, technical, family or health areas and showed no technical difficulties [44].

In Sweden, the recruitment process is decentralized and performed at the local level of each hospital. After medical school, an internship period of 1,5 years is undertaken. The traditional way to become accepted for a trainee position is by six to twelve months employment as a locum, and if performance is deemed favourable, a trainee position will follow.

This article reports on a multidimensional study aimed at documenting experienced surgeons' empirical observations about antecedents to and practices of unsuitable behaviours in the surgical environment, and the development of an interview guide central to a recruitment process to detect this. We have strategically chosen to call the consolidated and refined results "warning signs".

Research design and Methods

A mixed method with qualitative and quantitative data acquired from multiple sources was applied (Figure 1). First, a broad-based questionnaire was distributed to senior surgeons in the South Swedish Health Care Region (SSHCR) and heads of surgical departments. Based on the results of the questionnaire, a key-informant interview guide was created, including open questions about suitability and unsuitability as a surgeon and then administered to 13 experienced surgeons. Data acquired in the questionnaire and key-informant interviews was synthesized and analysed using a constructivist grounded theory approach [45]. Statistical calculations were done in Microsoft Excel, and NVivo was used for qualitative analysis.

Data collection: quantitative survey

A questionnaire with open and closed format questions was sent to a total population (n= 87) of experienced surgeons and their department heads (n=7) in the SSHCR (Appendix A). "Experienced surgeon" was operationalized as general surgeons over 50 years of age and employed in December 2013 in the SSHCR, in hospitals ranging from university to local hospitals. Seven heads of surgical departments received a similar survey with questions also concerning the recruitment process (Appendix

B). The questions concerned organisational contexts and current assessment processes for surgical trainees, encounters with individuals with unsuitable behaviour, and rating of competencies and personal attributes and behaviour on a 5-point Likert scale. The survey was mailed, with a maximum of three reminders. Surveys were coded, and the list of persons contacted was kept separate from the responses, so that the researchers were blinded to the name of the respondent. Only an administrator had access to both lists to be able to send out reminders. The administrator was not part of the later research process.

Data collection: qualitative semi-structured interviews

The survey results were analysed and used to construct the interview guide for the qualitative semi-structured interviews (Appendix C). A purposeful selection of interview candidates was performed to ensure representation from each hospital category (university, regional and local), and distribution by age and sex. All interviews were performed by at least one experienced sociologist. Twelve interviews were performed on site and one by phone. The semi-structured interviews probed for descriptions of unsuitable behaviour and situations where this would be revealed, together with descriptions and characterisation of the opposite, the 'ideal' surgeon. Saturation was obtained. All interviews were carried out with the informed consent of the interview person. All except one were recorded and later transcribed. One interviewee did not agree to recording, and notes were taken during the interview.

Coding was performed separately by two researchers – a specialist surgeon and a sociologist. Both generated a list of codes separately and applied these to the interview transcripts. A set of 58 codes was agreed upon after discussion. The coding process led to the analysis of a standardized set of factors or variables across the total interview material; in effect a horizontal analysis across the interview data. To obtain understanding of the thought and argumentation structure of each informant, each interview transcript was read more than once by two researchers, and in some cases the audio files were revisited. This resulted in vertical analyses of each specific interview, which were written and shared in the research group. The coded material was analysed in terms of the following five primary dimensions: 1) what are the basic problems that lead to unsuitability ("problem domains"); 2) what are the basic causes of these problems (personality, lack of physical or cognitive ability, lack of motivation, etc); 3) what are the (especially early) behavioural indicators of these problems ("warning signs"); 4) are some behaviours more resistant to change or innate (flexibility); and 5) when, how, and where may those indicators can be detected?

Results

Survey

Of 87 surveys distributed to surgeons, 54 responses were retrieved. Four were excluded: one respondent worked at two hospitals, two did not fulfil the age criteria, and one person had retired. The response rate was 54 of 83 (65 %), with a median experience as specialist surgeon of 23 years. Four of seven heads of surgical departments responded, with a median experience as a specialist surgeon of 17 years and management experience ranging from one to four years (Table 1).

Forty-six (85%) surgeons responded that they had come across surgical trainees they deemed unsuitable to train and work as surgeon. A total of 107 statements described what the respondents perceived as reasons for being unsuitable for the surgical profession in free text answers. The answers were categorized into six domains: technical ability; judgment; communication and interpersonal factors; personality, personal resources and skills; cognitive and miscellaneous (table 2). Statements concerning technical ability was most frequent, in total 23, followed by 22 on communication and interpersonal skills, 18 for personality, personal resources and skills, 17 concerned cognitive ability, 15 for judgment, and 12 in the miscellaneous category.

The heads of departments stated ‘lack of judgement’ (4/4), ‘not able to work in teams’ (2/4), ‘lack of engagement’ (1/4), ‘overestimating own ability’ (1/4), and ‘lack of competence’ (1/4) as reasons for unsuitability for the surgical profession. Whether it was possible to detect signs of being unsuited for surgical training in conjunction with hiring, one of four heads of department and 14 of 54 of the surgeons thought this was possible. When asked the same question but evaluating the possibility of doing so early in the trainee process, three of four heads of department and 31 of 54 (57%) surgeons believed this was likely. In summary, a clear majority believed that tendencies towards unsuitability are evident early. Three of four heads of departments stated that the selection of trainees was done amongst those individuals that had worked or worked in the clinic as locum, and one stated that scientific achievements were the main selection criteria. Based on the results from the survey, an interview guide with questions concerning inappropriate and desired behaviours was constructed (Appendix C).

Table 1
Demography of study participants. All numbers in median (range). M; male, F;female, NN; not stated

Survey		Consultants	Head of department
Responders / Denominator		54/83	4/7
Age		58 (50 – 70)	57 (41 – 59)
Sex	M	41	3
	F	8	1
	NN	5	
Work experience as Specialist (Year)		23 (8 - 45)	17 (5 – 28)
Hospital type	Local	13	1
	Regional	19	2
	University	22	1
Experience as Head of department (year)			1 - 4
Estimated attrition rate (%)			7,5 (0 – 20)
Current selection process for surgical training			6 - 12 months locum (n=3) Scientific merits (n=1)
Satisfaction with current selection process? 1=not at all satisfied 5= very satisfied			4 (2 – 5)
Encountered unsuitable trainee's? (# yes)		46	4
"Do you believe it is possible to detect signs of unsuitability for surgical training (# yes)	During selection	14	1
	Early during surgical training	31	3
Interviews with senior consultants >50 years of age (n=13)			
Sex	M	9	
	F	4	
Hospital type	Local	3	
	Regional	5	
	University	5	

Interviews

Twelve of the thirteen interviewees confirmed that they had come across unsuitable colleagues. Furthermore, they held the view that these individuals had negatively affected patients as well as the work environment of teams and colleagues. Responses in the survey and interviews stressed the importance of the organisational context and educational culture for trainees to adopt the unwritten surgical ‘code of conduct’ and professional behaviour – i.e. to produce suitable conduct.

The contextual aspects were kept separate from the behavioural and considered a separate domain that was not pursued. With focus on inappropriate behaviour, categories known from the core competencies of Accreditation Council for Graduate Medical Education (ACGME), Non-Technical Skills for Surgeons (NOTSS), Royal Australasians College of Surgeons (RACS) or Royal College of Physicians and Surgeons of Canada (CanMeds) framework did not fit all aspects [16, 46-48]. Reviewing and revision of codes identified 11 problem domains that were likely to result in unsuitability: indecisiveness, timidity, lack of self-awareness and overconfidence, inability to receive criticism and take instructions, lack of appropriate communication, lack of empathy and instrumentalization of the patient, inability to meet the demands of the job, inability to gain sufficient level of craft proficiency, insufficient cognitive abilities (problem solving, identification, finding), dishonesty, and inappropriate priorities (Table 3). Through further content analysis, behavioural warning signs emerged within each domain that could act as indicators for detecting tendencies towards unsuitability and incompatible with the future professional role as a surgeon (Table 3). There were differences of opinion among the interviewed persons concerning how resistant to change and correction the behaviour displayed within a problem domain were, and some of the signs were considered more resistant to change than others.

An aspect emphasized explicitly by seven interviewed persons is the need for a trainee to possess realistic assessments of their own knowledge and skills and ask for help or change of tactics when necessary. This was considered having good judgement and was the most frequently used description of being suitable as a surgeon. The senior surgeons assessed and judged the trainee’s suitability in their clinical reasoning based on handling of individual patients, which surgical procedure that was suggested with actual technical performance during operation and progression in the surgical setting.

A variety of different content descriptions and nuances were contained in the expression ‘judgment’. Contrasting unsuitability by describing the opposite was common. Lack of judgment among trainees was attributed to hubris, macho attitudes, putting one’s own career aspirations before the patient, and this was considered most dangerous to surgical care. These attitudes become apparent to senior surgeons particularly in the trainee’s choice of treatment and how they handled patients with complications. A majority of those interviewed mentioned the need to be transparent, honest and communicate correctly with patients, relatives and colleagues, as well as being mentally fit to handle a situation with a complication. Trainees seen as challenging and problematic were the ones who did not take instructions and feedback or expressing a view on the patient as a '*training object',* and thereby showing lack of empathy.

The interviews were rich in description of desired traits and competencies, describing the surgical 'role model' or 'code of conduct'. The desired behaviours and personality traits were summarized by one interviewee (IP13); *'someone who is both a team player and an individualist, ready to take responsibility and make decisions, and at the same time humble, with transparency if complications arise'*. Far from being a paradox, this quote puts its finger on two basic abilities (lead unequivocally and be a team player) that are necessary in different contexts, with "judgment" being the capacity to see when the one or the other is appropriate.

Emerging from the interviewees were doubts about the possibility to change certain personality traits like conscientiousness, honesty, hubris, empathy, self-knowledge, decision-making, stress tolerance, egoism, feedback receptibility, prioritizing and inner motivation or drive for surgical craft: *'Is it possible to learn to have judgment? I'm not sure. If you don't know your own limitations, I'm not sure about that either. But, to learn to handle a scalpel, about medications and medical knowledge, and gain clinical experience, that is possible. But if you lack judgement, then it's difficult'* (IP13). An awareness that behaviours and skills develop with time and considered as part of a learning process was phrased by one interviewee as *'you cannot ask a first-year student to play Beethoven'* (IP11).

Insight that physical fitness, mental strength, and stress resistance are prerequisites for the surgical profession was considered a postulate to manage the long shifts, surgical procedures, night-shifts, and complications. A few of the interviewed surgeons mentioned that some trainees seemed to have an unrealistic view on how professional life effects social life, with on-calls and procedures beyond ordinary working hours. Being realistic about the ability to meet the demands of the surgical profession was considered important and perceived as not always clear to trainees struggling with aspects of prioritizing and stress. The joy and curiosity of the craft were expressed important to last a whole career.

An issue considered important and brought up by a majority (8 of 13) of the interviewed surgeons was the need to be a problem-solver and based on knowledge and science be able to change strategy if needed, also under pressure. Parallels to civil life and childhood were brought up to identify those who enjoyed 'fixing things' or 'technical problems'. Some expressed that this was an inherent trait and were sceptical to if everyone could learn how to master this.

Lack of technical ability was not seen as a problem of same dignity as mental and behavioural issues. A majority expressed that most individuals can be trained to become fairly good surgeons, compensate with stronger non-technical skills or eventually realize themselves that surgery is not for them. The respondents were divided on the significance of lack of technical proficiency as a warning sign and several mentioned the struggling resident who has an '*unanswered love to surgery'* (IP3) with an irregular or slow learning curve. It was also clear that this area was considered more objective, recognizable and easier to talk about than personal and social dimensions.

All surgeons interviewed mentioned the ability to work in teams as a prerequisite for surgical work. This entails communication skills and individuals lacking these skills were problematic, and that personnel categories other than physicians were generally considered good sources for information to assess if communication skills and tone were acceptable. On the other hand, several made ambiguous comments that modern surgical education now consisted more of communication training than 'surgical' training.

Five interviewees pointed to the lack of control systems within hospitals and the Swedish health care system to identify unsuitable behaviour in trainees with the possibility to terminate the surgical education if necessary. This was aggravated by the perceived fragmented supervision, leading to that issues often emerged or were identified first after 2-3 years of surgical training. One informant had experienced in a faculty meeting that aspects of social character were considered more important than professional development when having raised the question of suitability of a trainee due to slow progression. The interviewed surgeons also mentioned a cultural context where '*no one wanted to be the one with the axe*' (IP12) and that this lack of "courage" led to unsuitable individuals being allowed to proceed. One interviewee referred to one person not considered suitable that '*it was not communicated to the individual in a clear manner, and the person has now become a specialist surgeon, but wandered between five clinics, and no one sat down and told X that this might not be the right thing for you*' (IP8). A primary reason for accepting unsuitable candidates into the specialist training system was, as commented on by several interviewed surgeons, the lack of adequate reference taking. A common practice also described was '*turfing*' (to find any excuse to refer a patient (here trainee) to a different department or team)[49] individuals to what is considered less dangerous professional areas; *'to direct or encourage an individual towards education, research or a part of surgery less dangerous'* (IP9).

No respondent in the survey or interviews expressed themselves negative towards the common practice of six months of locum. This was considered a good way to get to know the potential surgical trainee in a working situation; '*it's no disaster to realise after six months that one is not suited for [surgery], and then you have the chance for a happier life by changing specializations and neither knowledge nor time is lost'* (IP3). However, none of the interviewed surgeons could describe on what specific grounds selection was done.

Table 2. List of problem domains and observed behavior likely to result in unsuitability. Indicators for detecting unsuitability thought by the study participants to be incompatible with the future professional role as a surgeon if not detected and acted upon early.

Problem domain	Warning signs Indicators or observed behavior
Indecisiveness	Long procedural time (even simple tasks) Slow procedural progression Inability to work unsupervised Nervousness about tasks Poses questions for reassurance rather than information
Timidity	Reluctance to operate Small numbers of total and independent performed procedures compared to peers Inability to give criticism
Lack of self-awareness and overconfidence	Making decisions or performing procedures beyond competence Expressed desire to undertake procedures beyond achieved competence. Underestimation of complexity of given procedures (situation awareness or hubris). Avoid seeking advice or ask for help
Inability to receive criticism and take instructions	Inappropriate response to feedback Anti-authority attitude Repeating actions that instruction or feedback has sought to correct
Lack of appropriate communication	Disliked by nurses or other categories of personnel Addresses different personnel categories in unjustified manner Deficient documentation in medical journal Patient complaints about insufficient information or inappropriate tone.
Lack of empathy, instrumentalization of the patient	Disliked by or conflicts with nurses Inappropriate communication with patients, leading to patient complaints Expressed desire to try new procedures on patients to gain experience Advocates surgical procedures without making a holistic judgement about what is best for patient.
Inability to meet the demands of the job	Not completing assignments Lack of physical and mental well-being Sloppy, unstructured and unengaged work Colleagues or nurses having to “mop up” after the individual
Inability to gain sufficient level of craft proficiency	Slow/deficient technical progression Reluctance amongst consultants to let the trainee operate independently Careless tissue handling
Insufficient cognitive abilities (problem solving, identification, finding)	Difficulties sorting and prioritizing independently (stress management) Difficulties identifying differential diagnosis Incomplete patient history or medical records (cognitive or negligence) Not understanding or being able to discuss the wider picture of a clinical problem
Dishonesty	Not sharing or denying experiences of complications Not taking responsibility for errors Claiming complications are patient related Nurse complaints
Inappropriate priorities	Lack of insight into work demands Exhibits more concern with social status of the professional role than the content of the role

Synthesis, construction of a trainee interview guide

The findings from the survey and key informant interviews resulted in the identification of 11 problem domains with associated warning signs (table 3). The problem domains and warning signs formed the basis for the development of an assessment instrument in the form of an interview guide applicable to candidates during selection (table 4). The interview guide's questions are organized using positive phrasing and contrasting the negatively loaded descriptions of the problem domains and are instead organized using traditional areas of competence i.e. 'timidity' vs 'self-assurance', 'lack of empathy, instrumentalization of patient' vs 'understanding others, empathy', 'inappropriate priorities' vs 'dedication/motivation'. Organizing the interview questions in this purposeful and holistic manner was done for maximal coverage of warning signs, with several questions covering behaviour within the same problem domain.

Table 3
Interview guide. Letters in heading and brackets explaining within which theme the questions are probing. Note that a positive phasing that is contrasting the negatively loaded description of problem domains is used to be in line with traditional known areas of competence. Motivation (M), Empathy (E), Communication (Cm), Self-assurance and flexibility (SF), Attention (A), Leadership (L), Lifelong learning (LL), Cooperation and teamwork (Co) and Problem solving (PS).

Question
Introduction
Why do you want to become a surgeon? Goal? (M)
What makes you feel good at work? (SF)
What makes you feel bad at work? (SF)
What are you good at? What are your weaknesses? (SF)
What is your biggest failure that occurred in your job? (SF)
Understanding others (E)
Can you describe how you act when you first meet a patient? What is the most important thing about that situation? (E)
What are the 3 most important sources you base your decision on when diagnosing? (PS)
How do you act when you feel you do not know how to proceed and treat a patient? (E)
If you have to leave a negative message to a patient, how do you handle it? (Cm)
If your patient questions your assessment, how do you handle it? (SF)
Communication skills (Cm)
How do you ensure that important information you have about a patient reaches the right people?
Supervising others. How do you feel? How do you give criticism? Give example(C)
If you get criticism from a colleague, how do you handle it? (SF)
Self-awareness/assurance? (SF)
Can you give an example of a situation where you quickly had to make a decisive decision in your job? How did you proceed? (SF)
Have you been involved in an adverse event? Describe. What happened? How did you handle it? What did you learn from it? (SF)
Can you give an example of a situation where you changed a planned action because of advice or recommendation from someone else? What happened / what was the consequence? [When do you get help from others?] (SF)
Attention (A)
How do you handle when you get very many tasks at once, for example in an emergency situation where you are forced to leave the emergency room and the department for a few hours to go to surgery? (A) What do you do when you come back? (A)
Leadership (L)
Can you give examples of when and how you tried to exert influence over a situation? (L)
Have you had a formal or informal leadership role during your professional or student time? How did you get these roles? How are you as a leader? How is it expressed? (L)
Lifelong Learning (LL)
What do you think is the most important thing for maintaining skills in the role of surgeon? (LL)
Cooperation and teamwork (Co)
How would you like to describe the team that a surgeon is part of, the roles and responsibilities of these persons? (other specialists, nurses, patients) provide examples of reception, emergency or surgery (may not be possible through all 3?) (Co) Focus on 2 different roles to compare, for example, surgery and treatment teams before and after.
Have you experienced conflicts in your workplace? Can you give examples? How did you act then? (Co)
What is collegiality for you? (Co)
If you witness that any of your colleagues act in a wrong way, what will you do? For example, if you assist during surgery (Co)
Motivation (M)
How important is work in your life? (M) How do you cope with working nightshifts?
What do you think you will do in 10 years? (M)

Discussion

A majority of the experienced surgeons participating in the study had come across surgical trainees who they found unsuited for the surgical profession. A majority believed that signs of unsuitability are possible to detect in connection with recruitment or early in surgical training. Qualitative analysis identified 11 problem domains directly linked to unsuitability as they cause harm directly to patients or to the wider work environment. Associated with each domain, a set of warning signs were extracted from the empirical material. Warning signs can either be direct manifestations of unsuitable actions, or indicators that unsuitable actions can be expected. These warning signs are considered potential threats to patient safety if not corrected. Some of the signs were thought to be inherent in personality traits and more resistant to change, whilst some were seen as correctable, but necessitating early detection – hence the emphasis on warning signs. The identification of warning signs can be seen as part of a process of "collective mindfulness" operating at several inter-related levels [5]. As warning signs are made explicit, their characteristics and how they could be identified are known, which facilitates detection and reporting. Once classified as warning signs, the legitimacy of taking seriously detection and reporting is solidified.

The warning signs considered most difficult but important to change are related to indecisiveness, lack of self-awareness and overconfidence, anti-authority attitude with inability to take instructions, cognitive aspects like problem-solving capacity, dishonesty and not taking responsibility for errors. The above-mentioned signs are closely linked to personality. Personality traits and characteristics influence behavior patterns and will make it more or less easy to adopt to the demanded standards of expected behavior [50]. If the 'surgical personality' or personality traits associated with the 'Big Five' (openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism) is something innate or can be developed through training, self-perceived psychological turning points, and environment is an on-going debate with no clear answer [51-56]. Either way, warning signs play a crucial role in remedial activities (for those who believe they are changeable), or dismissal (for those who believe they are uncorrectable). Personality and especially high levels of contentiousness has implications on job performance [33, 57]. Personality profiling would allow the employer to judge if a person has potential to fit into the trainee position, future professional role, group of colleagues, aiming for diversity, and potentially avoid those with high scores on hazardous traits, using it similar to the industry and high reliability organizations (HROs) [30, 33, 58].

Concerning the described warning signs of indecisiveness, inability to meet job demands, inappropriate priorities and timidity, this could also be a feature of insecurity related to lack of knowledge of the work itself, supervision and mentoring, and could potentially profit from a formative training process with coaching [43]. Contrasting these are warning signs pointing to overconfidence, macho and anti-authority attitudes, inability to receive criticism, take instructions and, lack of self-knowledge. These are considered hazardous traits within the airline industry and considered useful to test for in preventing aviation accidents or incidents. A survey of orthopedic surgeons found that hazardous traits like machismo, self-confidence, impulsivity and anti-authority above a specified level considered dangerous for pilots existed in 38 % of their material [59]. Further, Kadzielski et al (2015) found that macho attitudes were associated with the readmission and reoperations rate for the individual surgeon and *'although widely accepted for the last 20 years in aviation, the idea that a hazardous attitude may contribute to an undesirable outcome is still largely foreign to the surgical world* '[58]. A study on Swedish orthopedists found that choosing non-operative treatment was associated with long experience, while macho-attitude positively associated with a tendency to operate [60]. The described problem domains and behaviors resemble the hazardous traits and the interviewed surgeons acknowledge the fact that poor behavior affects the work environment as well as the patient. A person exhibiting behavior with a tendency to produce negative outcomes for patients, colleagues for any or a combination of reasons needs to be identified. Drawing a parallel to aviation, the warning signs are similar to the well-known 'dirty dozen' in the airline industries [61]. 'The dirty dozen' reflect common human error conditions that act as precursors to negative effects on flight safety and the working environment if allowed to go on unnoticed. With this in mind, the results from the present and previous studies on performance problems support action being taken early towards a trainee to clarify that this type of behavior is unacceptable and if continued, it may prohibit them from pursuing a career in surgery [41].

Both survey respondents and interviewed surgeons mentioned the need for a surgeon to have adequate visuospatial skills. It has been shown in some studies that high-level visuospatial perception correlates with the learning curve in laparoscopic technique and a recent study found that two percent were statistically worse than their peers, but the results are inconsistent, and no reliable test exists to predict future performance [22, 32, 62, 63]. Possibly, difficulties with technical aspects or visuospatial skills can show up as a reluctance to operate or a divergent learning curve compared to peers making documentation of a trainee's progression over time crucial [15, 43]. Studies have shown that between 8–30% never achieve proficiency for advanced skills like laparoscopic suturing [37, 38, 64, 65]. For the trainee to overcome insufficient technical skills, mentoring and formative assessment is needed, with a possibility of self-understanding, i.e., to choose a different career path.

A relatively new marker associated with completion of surgical programs is "grit", defined as passion and perseverance for the achievement of long-term goals, and is present to a higher degree in consultants than trainees [66]. Further, grit is intimately related to character traits of conscientiousness, which in turn encompass dependability, punctuality and thoroughness [66]. Most interviewed surgeons mention the need for the trainees to possess a strong inner motivation to be able to succeed. Thus, “grit” could potentially help trainees to overcome some warning signs that were believed to be correctable in the domains of technical craft proficiency, timidity, meeting the demands of the job, priorities and communication.

Communication is closely related to how empathetic the doctor is perceived, and non-technical skills training was something most interviewees appreciated. Deficient communication was emphasized as one of the most important warning signs. The judgment of the trainee’s skill in this area was reflected in the communicated choice of treatment for the patient and thereby patient´s expectations. Considering the patient as a ‘training object’ was considered very severe but thought to be correctable through formative assessment and thereby adjusting the trainee to the surgical professional expectations. Judgment is closely related to the cognitive warning sign pointing to problem-solving abilities, and the respondents were divided in their views concerning potential development in this area. Trainees exhibiting problem-solving difficulties could possibly benefit from normative training through i.e cases with situational judgment discussions customized to fit the local context, and situational judgment tests have high reliability in assessing candidates for desirable qualities [33, 67]. Since these tests measure a wide array of professional attributes, it is reasonable to believe that they would identify warning signs if conducted already during the first period of employment. The interview guide (table 4) probes for situational judgement through the candidates own experiences and behaviors, with the advantage is that it’s not context dependent like a summative test.

The problem domains complement and are consistent with previous literature in the field, with a best fit to the Royal Australasians College of Surgeons (RACS) acknowledgement of poor behaviour in ‘Guide of Surgical competence and performance’ [16]. The inappropriate behaviour described by the participants represents extremes, but it is obvious that ‘outliers’ in surgical professional performance currently exists at both ends. All interviewees agreed that dealing with trainees that seem unfit for the job is difficult and describe a cultural ‘unwillingness’ to take action.

A useful predictor of future behavior is relevant previous behavior, and references from other categories of personnel are valuable according to study participants. Studies on references have shown that any tendency of negative remarks were associated with higher degree of attrition and problematic behavior [28, 68]. Behavior patterns and personality traits can also become evident during a structured interview [57]. Research has shown that a personal interview in a structured manner is more efficient and gives more valuable information than an unstructured interview and avoids asking illegal questions [10, 25, 33, 69]. The interview allows the candidate to elaborate on certain aspects of previous performance and behavior, ideas and insight of the surgical training and career pathway, and simultaneously be assessed on interpersonal and communication skills, maturity, interest in the field, dependability and honesty [25, 44]. Brothers et al found that personal characteristics assessed during the faculty interviews and reference letters were more important predictors of success than academic achievements and USMLE in their material [70].

The participants were satisfied with the 6-month routine of locum employment, but at the same time several barriers to detect and act on warning signs in due time were identified i.e. lack of structured assessment. Considering the results and current practice in selection, probing for warning signs may be performed simultaneously as looking for the top achievers, although the risk that someone with warning signs is not identified cannot be excluded. Though, the cost of failing to identify a problem trainee will be a bad return of investment since remediation activities are costly, resource demanding and not always successful [33, 39, 41]. A rigorous selection process like the Royal College of Surgeons Ireland (RCSI) conduct is not applicable to most surgical clinics with local employment processes (as in Sweden), due to heavy cost and need for resources. With a local selection system, there is a need for an evidence-based solution with a less costly framework.

In the local context in Sweden, the custom of 6 months' locum is established, and this period can be used for assessment. Additionally, we suggest a transparent process consisting of a minimum framework with external announcement of all positions, structured reference-taking, personality profiling, a structured interview preferably using the constructed interview guide (table 4), together with laparoscopic assessment of all candidates. This would secure fairness and transparency for employers, colleagues and potential surgical trainees, be scientifically grounded and with a holistic approach by design. Using this framework would also give the opportunity to probe for excellence as well as warning signs without heavy costs.

Strengths and limitations

One limitation of this study is that no questions were asked in the survey about how many and during what time the consultants had come across trainees they found unsuited for the surgical profession. Further, there was no Delphi approach, and thus the participants were only rated on traits and attitudes once. The survey had limited space for comments, and only one participant enclosed an extra letter to explain more in-depth opinions. Another limitation is that all participants where from the same region in Sweden (though several have educational and work experience from other countries) which could affect generalization of the findings, but to the best of the authors' knowledge, the selection system for surgical training works in the same manner throughout Sweden.

Conclusion

A majority of surgeons with several years of experience have met trainees they found unsuited for the surgical profession and have quite consistent views on what makes someone unsuitable. This knowledge has been systematized to construct a set of problem domains with ‘warning signs’, reflecting human error conditions or precursors to expected negative effects, and a comprehensive interview guide to facilitate discovering them. Detecting these signs early is important for the individual, the work environment and patient safety. A recommendation for a minimum framework for selection is presented that could make the process transparent, scientifically grounded and bring surgical trainee selection one step closer to working like an HRO.

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References

1. Nilsson L, Risberg MB, Montgomery A, Sjodahl R, Schildmeijer K, Rutberg H. Preventable Adverse Events in Surgical Care in Sweden: A Nationwide Review of Patient Notes. *Medicine (Baltimore).* 2016;95:e3047.

2. Anderson O, Davis R, Hanna GB, Vincent CA. Surgical adverse events: a systematic review. *American journal of surgery.* 2013;206:253-262.

3. Chassin MR, Loeb JM. High-reliability health care: getting there from here. *Milbank Q.* 2013;91:459-490.

4. Paice AG, Aggarwal R, Darzi A. Safety in surgery: is selection the missing link? *World journal of surgery.* 2010;34:1993-2000.

5. Weick K, Sutcliffe K. *Managing the unexpected: resilient performance in an age of uncertainty, second edition*: John Wiley \& Sons, Inc.; 2007.

6. Bogdanyova S, Lermann J, de Sousa Mendes M, Schott S. Becoming a resident in Germany: an experience-based practical guideline. *Arch Gynecol Obstet.* 2015;291:457-460.

7. RCSI. Selection Process for Core Surgical Training, Guide to the Marking System. 2013;July 2014 intake.

8. National Health Services (NHS) HEE. Applicant Guide, 2018 Core Surgical Training CT1/ST1.

9. Veldkamp J. *The Royal College of Surgeons of England Bulletin.* 2007;89:92-93.

10. Schaverien MV. Selection for Surgical Training: An Evidence-Based Review. *Journal of surgical education.* 2016;73:721-729.

11. (CaRMS) TCRMS. 2018.

12. Louridas M, Szasz P, Montbrun S, Harris KA, Grantcharov TP. Optimizing the Selection of General Surgery Residents: A National Consensus. *Journal of surgical education.* 2017;74:100-107.

13. Australia TASoSGStaGS. 2018 SELECTION FOR 2019 INTAKE GUIDELINES. 2018.

14. Specialistutbildningsfrågor SSAfP-o. Läkares vidareutbildning i de nordiska länderna2010.

15. Gallagher AG, O'Sullivan GC, Neary PC, et al. An objective evaluation of a multi-component, competitive, selection process for admitting surgeons into higher surgical training in a national setting. *World journal of surgery.* 2014;38:296-304.

16. RACS. Royal Australasian College of Surgeons. Surgical Competence and Performance. A guide to aid the assessment and development of surgeons. . www.surgeons.org2011:39.

17. Cuschieri A, Francis N, Crosby J, Hanna GB. What do master surgeons think of surgical competence and revalidation? *American journal of surgery.* 2001;182:110-116.

18. Baldwin PJ, Paisley AM, Brown SP. Consultant surgeons' opinion of the skills required of basic surgical trainees. *The British journal of surgery.* 1999;86:1078-1082.

19. Arora S, Sevdalis N, Suliman I, Athanasiou T, Kneebone R, Darzi A. What makes a competent surgeon?: Experts' and trainees' perceptions of the roles of a surgeon. *The American Journal of Surgery.* 2009;198:726-732.

20. Gardner AK, Dunkin BJ. Evaluation of Validity Evidence for Personality, Emotional Intelligence, and Situational Judgment Tests to Identify Successful Residents. *JAMA Surg.* 2018;153:409-416.

21. Bann S, Darzi A. Selection of individuals for training in surgery. *American journal of surgery.* 2005;190:98-102.

22. Maan ZN, Maan IN, Darzi AW, Aggarwal R. Systematic review of predictors of surgical performance. *The British journal of surgery.* 2012;99:1610-1621.

23. Kelz RR, Mullen JL, Kaiser LR, et al. Prevention of surgical resident attrition by a novel selection strategy. *Annals of surgery.* 2010;252:537-531; discussion 541-533.

24. Bell RM, Fann SA, Morrison JE, Lisk JR. Determining personal talents and behavioral styles of applicants to surgical training: a new look at an old problem, part II. *Journal of surgical education.* 2012;69:23-29.

25. Stephenson-Famy A, Houmard BS, Oberoi S, Manyak A, Chiang S, Kim S. Use of the Interview in Resident Candidate Selection: A Review of the Literature. *J Grad Med Educ.* 2015;7:539-548.

26. Gallagher AG, Leonard G, Traynor OJ. Role and feasibility of psychomotor and dexterity testing in selection for surgical training. *ANZ journal of surgery.* 2009;79:108-113.

27. Bell RM, Fann SA, Morrison JE, Lisk JR. Determining personal talents and behavioral styles of applicants to surgical training: a new look at an old problem, part I. *Journal of surgical education.* 2011;68:534-541.

28. Brenner AM, Mathai S, Jain S, Mohl PC. Can we predict "problem residents"? *Academic medicine : journal of the Association of American Medical Colleges.* 2010;85:1147-1151.

29. Hennessey IAM, Hewett P. Virtual Reality Versus Box Laparoscopic Simulators in Trainee Selection and Aptitude Testing. *Surgical Laparoscopy Endoscopy & Percutaneous Techniques.* 2014;24:318-321.

30. Phillips D, Egol KA, Maculatis MC, et al. Personality Factors Associated With Resident Performance: Results From 12 Accreditation Council for Graduate Medical Education Accredited Orthopaedic Surgery Programs. *Journal of surgical education.* 2018;75:122-131.

31. Harrington CM, Dicker P, Traynor O, Kavanagh DO. Visuospatial abilities and fine motor experiences influence acquisition and maintenance of fundamentals of laparoscopic surgery (FLS) task performance. *Surgical endoscopy.* 2018.

32. Henn P, Gallagher AG, Nugent E, et al. Visual spatial ability for surgical trainees: implications for learning endoscopic, laparoscopic surgery and other image-guided procedures. *Surgical endoscopy.* 2018;32:3634-3639.

33. Gardner AK, Grantcharov T, Dunkin BJ. The Science of Selection: Using Best Practices From Industry to Improve Success in Surgery Training. *Journal of surgical education.* 2018;75:278-285.

34. Louridas M, Szasz P, de Montbrun S, Harris KA, Grantcharov TP. Can We Predict Technical Aptitude?: A Systematic Review. *Annals of surgery.* 2016;263:673-691.

35. Alvand A, Auplish S, Khan T, Gill HS, Rees JL. Identifying orthopaedic surgeons of the future THE INABILITY OF SOME MEDICAL STUDENTS TO ACHIEVE COMPETENCE IN BASIC ARTHROSCOPIC TASKS DESPITE TRAINING: A RANDOMISED STUDY. *Journal of Bone and Joint Surgery-British Volume.* 2011;93b:1586-1591.

36. Schijven MP, Jakimowicz J. The learning curve on the Xitact LS 500 laparoscopy simulator: profiles of performance. *Surgical endoscopy.* 2004;18:121-127.

37. Grantcharov TP, Funch-Jensen P. Can everyone achieve proficiency with the laparoscopic technique? Learning curve patterns in technical skills acquisition. *The American Journal of Surgery.* 2009;197:447-449.

38. Buckley CE, Kavanagh DO, Nugent E, Ryan D, Traynor OJ, Neary PC. The impact of aptitude on the learning curve for laparoscopic suturing. *American journal of surgery.* 2014;207:263-270.

39. Roberts NK, Williams RG. The hidden costs of failing to fail residents. *J Grad Med Educ.* 2011;3:127-129.

40. Resnick AS, Mullen JL, Kaiser LR, Morris JB. Patterns and predictions of resident misbehavior--a 10-year retrospective look. *Curr Surg.* 2006;63:418-425.

41. Williams RG, Roberts NK, Schwind CJ, Dunnington GL. The nature of general surgery resident performance problems. *Surgery.* 2009;145:651-658.

42. Yaghoubian A, Galante J, Kaji A, et al. General surgery resident remediation and attrition: a multi-institutional study. *Archives of surgery.* 2012;147:829-833.

43. Sanfey H, Williams R, Dunnington G. Recognizing residents with a deficiency in operative performance as a step closer to effective remediation. *Journal of the American College of Surgeons.* 2013;216:114-122.

44. Bergen PC, Littlefield JH, O'Keefe GE, et al. Identification of high-risk residents. *The Journal of surgical research.* 2000;92:239-244.

45. Creswell JW. *Qualitative Inquiry & Research Design : Choosing among five approaches.* 3rd ed: SAGE; 2013.

46. Flin R, Youngson G, Yule S, Maran N. Non-Technical Skills for Surgeons (NOTSS). System Handbook v1.2 ed2012.

47. CanMeds. CanMEDS 2015 Physician Competency Framework2015.

48. Homlboe ES, Egdar L, Hamstra S. The Milestones Guidebook: ACGME; 2016.

49. Shem S. *The House of God*: Black Swan; 1985.

50. Flin R, O'Connor P, Chrichton M. *Safety at the Sharp End : a guide to non-technical skills*: Ashgate; 2008.

51. Roberts BW, Walton KE, Viechtbauer W. Patterns of mean-level change in personality traits across the life course: a meta-analysis of longitudinal studies. *Psychol Bull.* 2006;132:1-25.

52. Allemand M, Gomez V, Jackson JJ. Personality trait development in midlife: exploring the impact of psychological turning points. *European Journal of Ageing.* 2010;7:147-155.

53. Whitaker M. The surgical personality: does it exist? *Ann R Coll Surg Engl.* 2018;100:72-77.

54. Hoffman BM, Coons MJ, Kuo PC. Personality differences between surgery residents, nonsurgery residents, and medical students. *Surgery.* 2010;148:187-193.

55. Swanson JA, Antonoff MB, D'Cunha J, Maddaus MA. Personality profiling of the modern surgical trainee: insights into generation X. *Journal of surgical education.* 2010;67:417-420.

56. Grossman R. The surgical personality: does it matter? *The Bulletin of the Royal College of Surgeons of England.* 2018;100:130-132.

57. Schmidt F HJ. The validity and utility of selection methods in personnel psychology: Practical and theoretical implications of 85 years of research findings. *Psychological Bulletin.* 1988;Vol 124(2):pp. 262-274.

58. Kadzielski J, McCormick F, Herndon JH, Rubash H, Ring D. Surgeons' attitudes are associated with reoperation and readmission rates. *Clin Orthop Relat Res.* 2015;473:1544-1551.

59. Bruinsma WE, Becker SJE, Guitton TG, Kadzielski J, Ring D. How Prevalent Are Hazardous Attitudes Among Orthopaedic Surgeons? *Clinical Orthopaedics and Related Research®.* 2014;473:1582-1589.

60. Meunier A, Posadzy K, Tinghog G, Aspenberg P. Risk preferences and attitudes to surgery in decision making. *Acta Orthop.* 2017;88:466-471.

61. Canada T. Human Performance Factors for Elementary Work and Servicing TP14175E. Vol 2018. 10/2003 ed: Transport Canada; 2003.

62. Louridas M, Quinn LE, Grantcharov TP. Predictive value of background experiences and visual spatial ability testing on laparoscopic baseline performance among residents entering postgraduate surgical training. *Surgical endoscopy.* 2016;30:1126-1133.

63. Way LW, Stewart L, Gantert W, et al. Causes and prevention of laparoscopic bile duct injuries: analysis of 252 cases from a human factors and cognitive psychology perspective. *Annals of surgery.* 2003;237:460-469.

64. Crochet P, Aggarwal R, Dubb SS, et al. Deliberate practice on a virtual reality laparoscopic simulator enhances the quality of surgical technical skills. *Annals of surgery.* 2011;253:1216-1222.

65. Palter VN, Grantcharov TP. Individualized deliberate practice on a virtual reality simulator improves technical performance of surgical novices in the operating room: a randomized controlled trial. *Annals of surgery.* 2014;259:443-448.

66. Walker A, Hines J, Brecknell J. Survival of the Grittiest? Consultant Surgeons Are Significantly Grittier Than Their Junior Trainees. *Journal of surgical education.* 2016;73:730-734.

67. Patterson F, Zibarras L, Ashworth V. Situational judgement tests in medical education and training: Research, theory and practice: AMEE Guide No. 100. *Med Teach.* 2016;38:3-17.

68. Naylor RA, Reisch JS, Valentine RJ. Factors related to attrition in surgery residency based on application data. *Archives of surgery.* 2008;143:647-651.

69. Hern HG, Jr., Alter HJ, Wills CP, Snoey ER, Simon BC. How prevalent are potentially illegal questions during residency interviews? *Academic medicine : journal of the Association of American Medical Colleges.* 2013;88:1116-1121.

70. Brothers TE, Wetherholt S. Importance of the faculty interview during the resident application process. *Journal of surgical education.* 2007;64:378-385.

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Surgical Education

The enchanted sorting hat in Harry Potter decides very subjectively into which Hogwarts house the new students belong.

Kristine Hagelsteen is a Paediatric Surgeon and head of the Paediatric Surgery training program at the Department of Paediatric Surgery, Skåne University Hospital, Sweden. Her interest is to improve surgical education and her research interests cover both technical and non-technical aspects on surgical skills. This thesis focus on aspects on selection and training of future surgeons. Hopefully, this thesis will provide guidance for future trainees, employers and colleagues by transforming the magical sorting hat into a scientifically based surgical sorting hat.

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