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A Multicenter Prospective Cohort Study on Camera Navigation Training for Key User Groups in Minimally Invasive Surgery

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Abstract

Background. Untrained laparoscopic camera assistants in minimally invasive surgery (MIS) may cause suboptimal view of the operating field, thereby increasing risk for errors. Camera navigation is often performed by the least experienced member of the operating team, such as inexperienced surgical residents, operating room nurses, and medical students. The operating room nurses and medical students are currently not included as key user groups in structured laparoscopic training programs. A new virtual reality laparoscopic camera navigation (LCN) module was specifically developed for these key user groups. *Methods*. This multicenter prospective cohort study assesses face validity and construct validity of the LCN module on the Simendo virtual reality simulator. Face validity was assessed through a questionnaire on resemblance to reality and perceived usability of the instrument among experts and trainees. Construct validity was assessed by comparing scores of groups with different levels of experience on outcome parameters of speed and movement proficiency. *Results*. The results obtained show uniform and positive evaluation of the LCN module among expert users and trainees, signifying face validity. Experts and intermediate experience groups performed significantly better in task time and camera stability during three repetitions, compared to the less experienced user groups ($P < .007$). Comparison of learning curves showed significant improvement of proficiency in time and camera stability for all groups during three repetitions ($P < .007$). *Conclusion*. The results of this study show face validity and construct validity of the LCN module. The module is suitable for use in training curricula for operating room nurses and novice surgical trainees, aimed at improving team performance in minimally invasive surgery.

Keywords

simulation, surgical education, ergonomics, human factors study, evidence-based medicine/surgery

Introduction

Lack of experience is a major cause of errors and surgical complications.[1] Surgical residency training programs increasingly recommend trainees to complete a virtual reality (VR) simulation training before they participate in minimally invasive surgery (MIS) procedures.[2] Camera handling in MIS can wrongly be perceived as an easy skill and is frequently entrusted to the least experienced member of the operating team, including operating room (OR) nurses and medical students.[3,4] These groups do not currently receive any training on handling MIS instruments. Rotation of the field of view due to suboptimal camera handling negatively influences operative speed and enhances the number of errors.[5,6] Following the commitment to reduce preventable errors in surgery, training all members of the surgical team is viewed as logical step by legislators.[7]

Laparoscopic camera navigation (LCN) requires specific psychomotor abilities, including centering the operative range of vision, maintaining a correct horizontal axis, and tracking moving instruments while simultaneously stabilizing the scope. Furthermore, angled scopes are used in advanced procedures, requiring specific orientation skills. Currently, no established or accepted LCN curricula for this purpose are in use. Laparoscopic training courses for OR nurses, such as the European Institute for TeleSurgery course, primarily teach relevant knowledge

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on laparoscopic surgery and equipment combined with only a brief introduction to handling on a box trainer.[8]

VR simulators are effective in off-site training of basic laparoscopic psychomotor skills.[9-12] Although basic skills curricula frequently include simple camera navigation exercises, these skills curricula do not focus on camera navigation alone.[13] Few data on VR LCN training are currently available in comparison to data on VR instrumental tissue manipulation.[4] A randomized study by Andreatta et al[12] showed that VR LCN training led to significant better operative results in interns. Comparable results could be reproduced in medical students as well.[14,15] Only one study on the validity of tailored LCN modules is known to authors.[16]

A specified LCN module for novice laparoscopists on the Simendo VR simulator (Simendo BV, Rotterdam, The Netherlands) was therefore developed.[17,18] This module can be applied in structured training programs for all members of the MIS operating team, including surgical residents, OR nurses, and medical students.[19] Prior to implementation of any teaching instrument, validation is mandatory.[20,21] Face validity and construct validity are important testing stages. This study aims to evaluate the LCN module according to the following hypotheses: (*a*) groups of laparoscopic trainees and laparoscopic experts give a uniform and positive evaluation of its resemblance to reality and usability (face validity) and (*b*) the instrument can measure inherent difference in performance of groups with different experience in MIS (construct validity).

Methods

Participants

Sixty subjects from various user groups were asked to participate in a multicentre prospective cohort study. Participants included licensed surgical specialists, surgical residents, OR nurses with experience in MIS, and medical students. Participants were grouped according to experience with MIS according to the criteria described in the following sections and were recruited through the departments of general surgery and gynecology in two university hospitals. None of the subjects had previous experience with the module. The number of participants was powered on an estimated effect size of 0.33, requiring a minimum of 12 participants per group.

Materials and Techniques

The Simendo LCN module consists of one hardware instrument, a simplified version of a standard laparoscopic camera, and a software interface that can be installed on a regular PC or laptop (Figure 1).[22] The camera handle is retractable and able to rotate. Rotating the handle controls the 30° angled view whereas the light cable remains its point of orientation. The module consists of six exercises, described in Table 1. Examples of the exercises are shown in Supplementary Videos 1 to 6 (available online at http://SRI.sagepub.com/supplemental). The first exercise is an introductory exercise in which the camera instrument is used as grasper (Touch). The second exercise uses a 0° camera (Aim); the third, fourth, and fifth exercises use a 30° camera (4 Boxes, 6 Boxes, Trace); and the last exercise of the curriculum (Choice) uses a 0° or 30° camera randomly.

Face Validity

Opinions on the instruments resemblance to reality were assessed and compared between experts (the educators) and trainees (all other lesser experienced users) in MIS. Trainees were defined as having performed ≤100 procedures as primary surgeon in MIS, having participated as camera navigator only, or having no experience in MIS at all. Experts were defined as having performed >100 procedures in MIS as primary surgeon.[23]

All participants in the study filled out a questionnaire after completing the LCN curriculum. The questionnaire contained 111 short items, including an inventory on basic characteristics, experience in MIS, experience in MIS training outside the OR, and experience with videogames, as this may influence performance on VR simulators.[24] Per exercise, questions on realism of graphics, camera movement and camera range, ability to aiming, zooming and stabilizing the scope, level of difficulty, and usefulness were presented on a 10 cm visual analogue scale, ranging from "fully disagree" at 0 cm to fully agree" at 10 cm. Marks at 6.0 cm or beyond were considered as positive judgment toward the questionnaire statement. Furthermore, the questionnaire contained items on usability of the module as a whole and its place in current teaching curriculum, as well as an open inventory for additional comments.

Construct Validity

The participants were divided into groups with different levels of experience in order to measure the instruments' discriminatory ability: *novices*, no experience with MIS; *Camera Navigation only*, experience with camera handling in MIS; *Intermediate*, primary surgeon in MIS (<100 procedures); and *Experts*, primary surgeon in MIS (>100 procedures).

After a standardized instruction, all participants performed three consecutive repetitions of the six exercises in the LCN curriculum. One repetition consisted of the complete execution of exercises 1 to 6 (Table 1). The software interface measured four parameters. Task time was

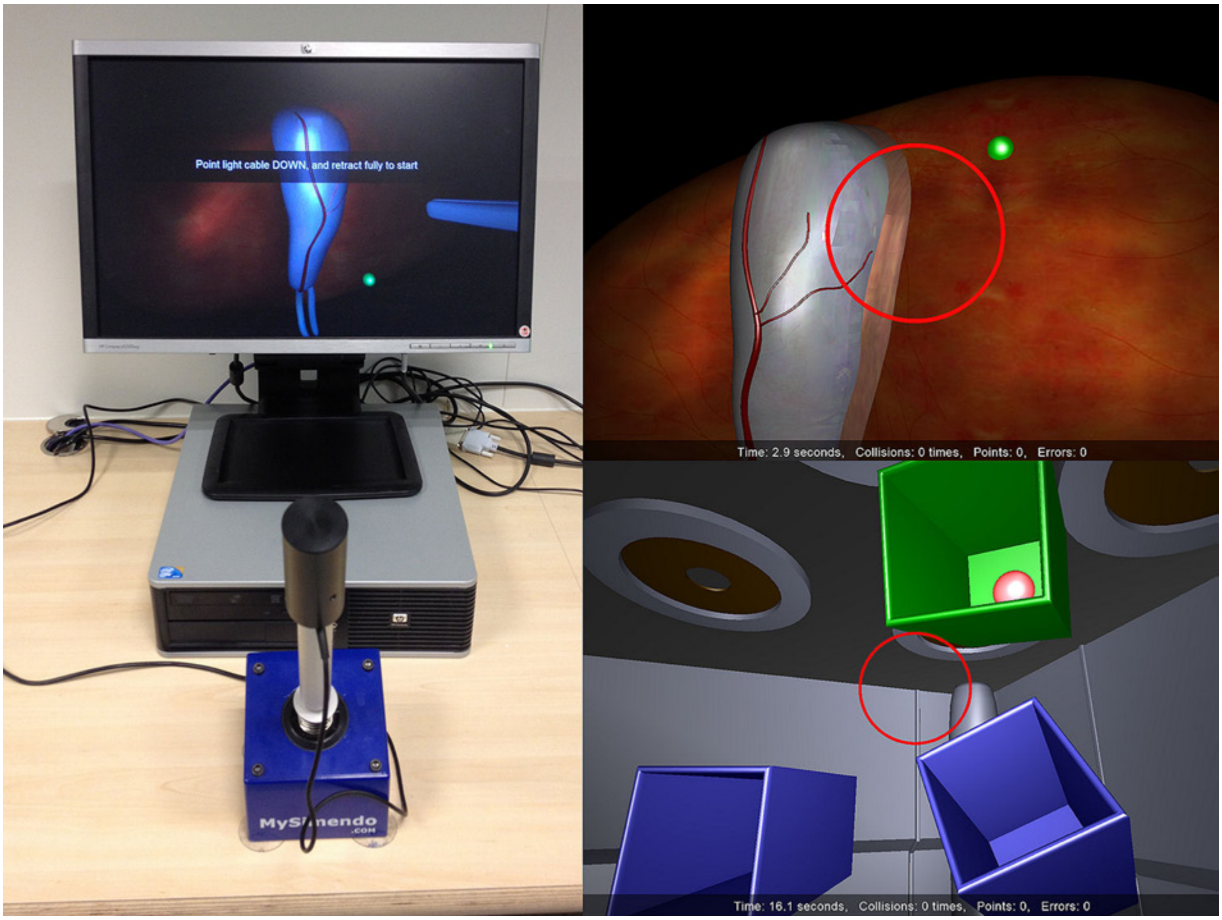

Figure 1. Screenshots of the LCN module.
The left image shows the VR simulator set up, depicting a camera controller handle plugged into a standard PC desktop. The right upper image shows a screenshot of Exercises 2 (Aim) and the lower right image a screenshot of Exercise 4 (6 Boxes).

Table 1. Description of Exercises in the Simendo LCN Module.

Exercise Name	Exercise Description	Exercise Goal
1. Touch	Touch 12 targets appearing randomly in the upper abdomen with a grasper	Basic coordination
2. Aim	Aim a 0° endoscope at 12 targets appearing randomly in the upper abdomen	Basic coordination, handling a 0° endoscope
3. Four boxes	Aim a 30° endoscope at targets in 4 different boxes placed in different angles	Basic handling of a 30° endoscope
4. Six boxes	Aim a 30° endoscope at targets in 6 different boxes randomly placed in different angles	Basic handling of a 30° endoscope
5. Trace	Trace a target around the gall bladder with a 30° endoscope	Basic handling of a 30° endoscope
6. Choice	Aim a 0° or 30° endoscope at 4 targets and decide which scope is provided (answer question)	Basic handling of a 0° and 30° endoscope

Abbreviation: LCN, laparoscopic camera navigation.

defined as the time span necessary to complete the exercise (in seconds). Number of collisions was defined as impact in a structure other than the target (in numbers). Path length was defined as path length of instruments other than laparoscopic camera (in arbitrary units). This parameter is used in exercise 1 only (Table 1). Camera stability referred to the reversals made by the camera (in numbers). A small number of camera reversals indicated a stable field of vision. Learning curves were calculated to assess progress of the trainees during three repetitions.

Statistical Analysis

Measurements were recorded and analyzed with Statistical Package of Social Software (SPSS version 16.0.2 SPSS Inc, Chicago, IL).

Table 2. Demographic Characteristics[a].

	Group			
	Trainee			
Characteristics	Novice	Cam nav only	Intermediate	Expert
Group size	19	16	9	16
Function				
Medical student	15	0	0	0
OR nurse	3	12	0	0
Resident	1	4	8	2
Specialist	0	0	1	14
Specialty (residents/specialists only)				
Surgery	0	0	2	10
Gynaecology	1	4	7	6
Age (mean, years)	25	34	31	42
Gender (% male)	32%	6%	33%	80%
Hand dominance				
Left (%)	11%	13%	11%	0
Ambidextrous (%)	5%	0	0	6%
Laparoscopic training experience				
Box trainer (%)	5%	56%	89%	81%
VR simulator (%)	16%	50%	78%	75%
Animal model (%)	0	6%	11%	94%

Abbreviations: Cam nav, camera navigation; OR, operating room; VR, virtual reality.
[a]Measurements in numbers, unless stated otherwise.

Face Validity. Results were compared between trainee and expert groups with a nonparametric test (Mann–Whitney U test) when relevant. Statistical significance was considered at $P < .05$. Observer reliability was calculated for the items on resemblance to reality of graphics, camera movements, and camera range that were repeated per exercise, using Cronbach's α.

Construct Validity and Learning Curves. Measured parameters for four groups with varying level of experience were summarized per repetition and compared using nonparametric tests (Kruskal–Wallis test with post hoc Mann–Whitney U test and Bonferoni correction for multiple testing). Measured parameters were analyzed for intragroup comparison per repetition to assess the learning curve, using nonparametric tests (Friedman test with post hoc Wilcoxon signed rank test and Bonferoni correction for multiple testing). Statistical significance was considered at $P \leq .007$.

Results

Face Validity

Table 2 depicts demographic characteristics and prior experience per study group. None of the participants were excluded from analysis. Supplementary Table 3 (available online at http://SRI.sagepub.com/supplemental) represents opinions toward the instruments' resemblance to reality. The internal consistency of the questions repeated per exercise was good to excellent (Cronbach's α >.8 and >.9, respectively). The overall judgments on realism of graphics, camera movements, and camera range were positive (median >6.0). No significant differences between experts and trainees were measured.

Supplementary Table 4 (available online at http://SRI.sagepub.com/supplemental) gives an overview of the statements per exercise. Both expert and trainee groups thought the exercises to be able to teach camera handling, aiming, zooming, and stabilizing. The overall level of difficulty was deemed adequate, with the exception of Exercise 6 (too easy).

Supplementary Table 5 (available online at http://SRI.sagepub.com/supplemental) gives an overview of the judgments on the usability of the LCN module as a whole. Experts and trainees considered the module to be useful to adopt in OR nurse training curricula, curricula for medical students in their surgical clerkships, and surgical residency curricula. The participants considered the LCN module a useful addition to basic skills curricula on VR simulators.

In the open inventory, seven participants stated lack of realism in graphics and anatomy. Also, seven participants

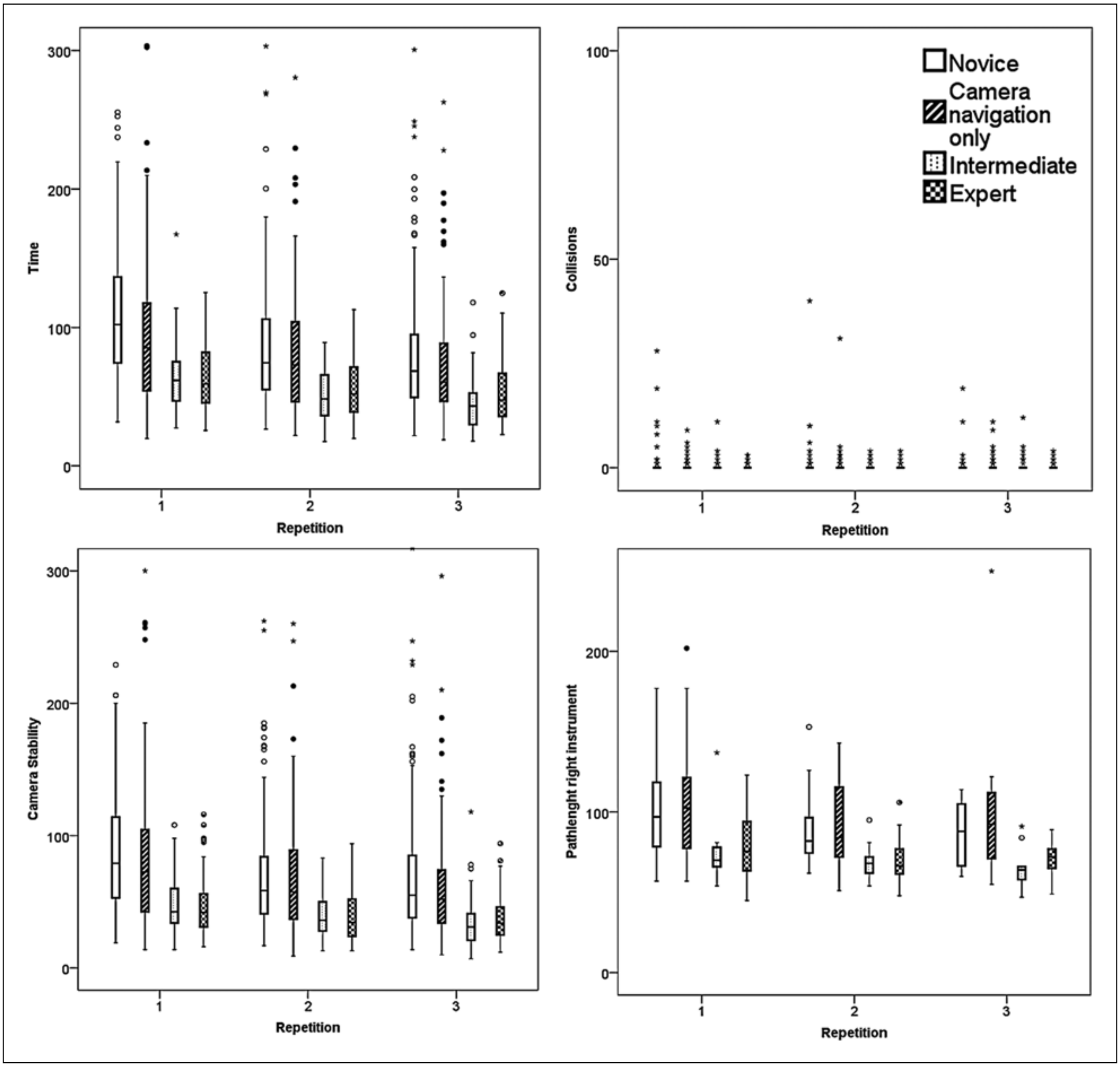

Figure 2. Scores of the Novice, Camera Navigation only, Intermediate and Expert groups during 3 repetitions.
Boxes represent median and interquartile range.

stated a difficulty in moving the instrument through the neutral position.

Construct Validity

Figure 2 shows the performance of the four groups per outcome parameter (time, stability, collisions, and path length) during three consecutive repetitions of the LCN curriculum. Total task time varied significantly between the groups for all three repetitions independently (Kruskal–Wallis, $P = .00$, $P = .00$, $P = .00$, respectively). The novice and camera navigation only groups executed the tasks significantly slower than intermediate and expert groups during all three repetitions independently ($P < .002$). The difference in task time between the novice and camera navigation only groups was statistically significant in the first repetition ($P = .007$) but not in the second and third repetitions. Differences in task time between intermediate and expert groups were not statistically significant.

The camera stability measurements also showed statistically significant differences between less experienced groups and more experienced groups for all three repetitions independently. Novice and camera navigation only groups showed significantly less camera stability than intermediate and expert groups during each of the three repetitions independently (Mann–Whitney *U*, *P* = .00). Camera stability did not differ significantly between novice and camera navigation only groups, neither between intermediate and expert groups. The majority of the participants did not make collisions with the camera during any of the three repetitions. The path length covered by the grasper in exercise 1 did not show statistically significant differences between the groups.

Learning Curves

Figure 3 shows the mean scores of the four groups during three repetitions per outcome parameter (time, stability, collisions, and path length grasper). A clear improvement is seen in median task time and camera stability for every group. The improvement in task time for novice group is statistically significant (*P* = .00), as for camera navigation only (*P* = .00), intermediate (*P* = .00), and expert groups (*P* = .00). The improvement in camera stability is also statistically significant for all groups (*P* = .00). Differences in the parameters' path length covered by the grasper (exercise 1 only) and collisions were not statistically significant between the repetitions.

Discussion

The first goal of this study was to establish the LCN modules' face validity, defined as uniform and positive evaluation of the instrument as a valuable learning environment among trainees and experts.[21] The graphics, camera range, and movements resembled reality adequately and the exercises were seen as useful to train handling, aiming, zooming, and stabilizing the laparoscopic camera. Although seven participants experienced the bump when the handle moved through neutral position as problematic, the majority of the participants did consider the camera handling similar to reality. Furthermore, key user groups displayed a positive attitude toward application of the module in their own training curricula. This ensures a solid base for clinical implementation among both trainees and presumed facilitators of the system (ie, expert laparoscopists concerned with improving their team performance).

The second goal of this study was to establish construct validity, defined as the degree to which the instrument can discriminate between different levels of experience in the skills it intends to measure. The instrument proved to be able to discriminate between levels of proficiency in speed and camera stability between novice and expert laparoscopists. The learning curves of the groups show an approaching trend toward each other, leading to the presumption that novice laparoscopists may reach the level of expert proficiency after a certain amount of repetitions of the LCN module. Collisions and path length (exercise 1 only) do not show a significant relation with level of expertise.

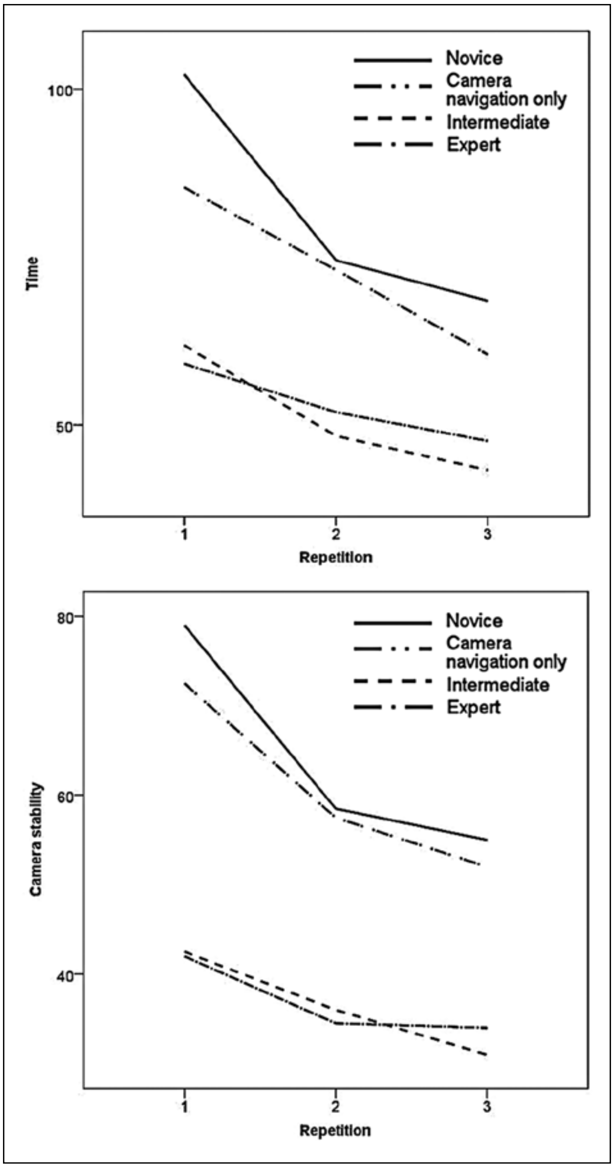

Figure 3. Learning curves of Novice, Camera Navigation only, Intermediate and Expert groups during three repetitions. Values represent means.

Surgery is teamwork. Surgical residents should not be allowed to operate on patients unsupervised unless they are proven to be competent through successful completion of technical surgical skills examinations.[19] In contrast, MIS teams frequently rely on OR nurses and medical students in their surgical clerkship to operate the camera. It is not illegal for nonregistered medical practitioners to participate in medical procedures. However, the responsible surgeon must ascertain that the person to whom the task is delegated is indeed competent enough.[25]

OR nurses may participate in laparoscopy courses aimed at knowledge and technical espects,[8] but structured training of camera handling skills is currently lacking. Without formal structured training and assessment in laparoscopic psychomotor skills and camera navigation, no objective statement on competency can be made. Poor camera handling by novice assistants will result in unnecessary delay and frustration for all members of the surgical team. Moreover, it may very well hinder the establishment of a critical view of safety in laparoscopic procedures.

The exact percentage of OR nurses participating in LCN is not well documented, and the demand for VR simulator training in the nursing community is largely unknown. Twelve of the 15 OR nurses participating in this study indicated to have camera navigation experience in MIS without following any structured training outside the OR. Furthermore, all of the OR nurses participating in the study considered simulator-based LCN training in OR nurse teaching programs desirable, which corresponds with the positive attitude reported in a recent study that conducted simulator-based laparoscopy training to OR nurses in Finland.[26]

VR simulators have proven to be effective tools for basic eye–hand coordination skills training in MIS.[9,13] When performing simple laparoscopic tasks, task time, instrument path length, and depth perception are valid parameters for predicting laparoscopic training outcome.[27] For camera navigation specifically, other skills are of importance, such as camera stability. Path length of the camera is less important, as this depends on the movements of the primary surgeon.

This study has limitations. First, the study design introduced the possibility of systematic error. Measuring face validity through a questionnaire relies on opinions of trainees and experts. Although care was taken to optimize the study design and observer reliability could be measured for certain items, systematic error could not be completely ruled out. Construct validity measurements may include systematic error as the groups vary significantly in baseline characteristics (age, gender, and experience with VR simulators).

Second, skills improvement by the expert group during the three repetitions may be seen as a shortcoming of the instrument, as one may expect a more consistent performance by expert laparoscopic surgeons on a surgical simulator. However, this finding is similar to other studies investigating VR simulators' construct validity[18] and signifies a necessary period of acquaintance to the instrument.

Furthermore, the instrument did not measure a significant difference between intermediate and expert groups. The Intermediate group did not reach the previously calculated group size, limiting the statistical power. However, the discriminatory ability of the instrument could be determined because of the statistically significant differences between the other groups. Exploration of expert proficiency levels and learning curves could clarify the discriminatory ability between Intermediate and Expert groups.

Finally, the fact that this instrument has proven to be valid in terms of face validity and construct validity should not be mistaken with proof of its capability to improve camera navigation skills in reality. The latter is known as predictive validity and is viewed as the final step in a validity process.[20,21]

Franzeck et al[14] recently showed that camera navigational skills acquired through structured simulator-based LCN training could be transferred to the operating room. They used LCN exercises in LapMentor and ProMIS basic skills curricula and showed improved handling of the 30° angled camera.[14] Disadvantages of these simulators are that they do not offer specific LCN curricula and require a large hardware component, reducing accessibility in the workspace.

A VR simulator camera navigation module on Endotower was validated previously and showed transferability of skills to a live animal model.[15,28] However, this VR simulator is no longer in production. In addition, several box trainer set ups for LCN have been developed and validated.[29,30] Although easy to build and relatively cheap, these models require human observation to score trainees, which compromises their objectiveness. Plug-and-play VR simulators, such as the simulator used in this study, are relatively affordable and easy to use, compared to earlier generations of VR simulators.[31]

The outcome of this study suggests that simulator-based LCN curriculum is both realistic and usable for LCN training and is capable of discriminating different levels of skill. As with any type of simulation trainer (box or VR), repeated training can be expected to lead to a better LCN performance, and for this simulator, recommendation for use in training programs can now be reliably stated. Future research should investigate transference of skills learnt on the simulator to the operating room.

Declaration of Conflicting Interests

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