# THE APPLICATION OF VIRTUAL REALITY SIMULATORS IN LAPAROSCOPIC SURGERY TRAINING (A REVIEW)

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## ABSTRACT

**INTRODUCTION: The last decade saw a significant introduction of minimally invasive surgery into medical practice. Laparoscopy has even become the gold standard for some interventions. This has led to an increased demand for qualified specialists. The acquisition of laparoscopic surgery skills entrains a time investment both on part of the trainee and the instructor. The need for an accelerated development of specific psycho-motor perceptions which are a requirement for the execution of laparoscopic procedures, led to the establishment of virtual reality simulator training. For the first time in Bulgaria, in 2016, the Medical University of Varna introduced formal education via the way of virtual reality laparoscopic simulators. They permit the development of laparoscopic skills even at the level of a medical student.**

**AIM: The aim of the article is to analyze the efficiency of existing virtual reality simulators and their application in laparoscopic surgery training.**

**MATERIALS AND METHODS: A systematic literature analysis was performed via the databases PubMed, Web of Science, Scopus and Google Scholar using various combinations of the following keywords: "simulation", "virtual*", "VR", "laparoscopic*", "surgery", "education", "LapMentor", "LapSim", for articles published in the past 10 years. The keywords were in combination with Boolean operators "and", "or". After a thorough review of all pertinent articles the most relevant publications were selected.**

**CONCLUSION: Advancements in the field of surgery follow closely the introduction of new technologies. This leads to the need for a change of traditional surgery training practices. The need of laparoscopic surgery specialists becomes greater with every passing year. The new generation of virtual reality simulators provides a complete set of basic skill procedures and complete operative procedures. Due to their limitless repeatability, an expert level of proficiency is able to be reached in a relatively short period of time. The surgical community must take note of the practices that have already been adopted by aviation training and introduce mandatory laparoscopic surgery training programs, which all specialists must undergo before undertaking procedures in the operating theater.**

**Keywords:** *virtual reality, surgery simulation, simulation training, laparoscopic virtual reality*

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## INTRODUCTION

The last decade saw a significant introduction of minimally invasive surgery into medical practice. Laparoscopy has even become the gold standard for some interventions. This has led to an increased demand for qualified specialists. The acquisition of laparoscopic surgery skills entrains a time investment both on part of the trainee and the instructor, often at odds with societal demand and the scarcity of laparoscopic specialists globally. William Halstead's surgical mantra „see one, do one, teach one" seems to be out of date (1). This philosophy of education is rapidly losing its significance in the face of novel simulation methods of education, which are rapidly gaining traction around the world and which pose no risks for patients. While in conventional surgery a surgeon can enjoy the maximal mobility and dexterity of his arms and fingers, in minimally invasive laparoscopic interventions these capabilities are significantly reduced. The visual perception of the operative field and the reach of the laparoscopic tools are also restricted. Initial laparoscopic training revolves around the acquisition of specific levels of competence and psychomotor perception of the depth of the operative field and hand-eye coordination. Novice trainees need to get accustomed to the lack of direct visual control and the necessity of monitoring the field via a screen. Another highly specific distinction, which needs to be accounted for, is the effect of the abdominal wall as a point of leverage, which causes the movement of laparoscopic tools in the abdominal cavity to be opposite of the hand movement outside of it. For example, a rightward movement of the hand with a tool would move the tool in the operative field leftward. Economic factors also influence the process. The ever-increasing waiting list and the reduction of available time for manipulations in the operative theater also have an impact on trainee surgeons. Supervisors are also limited by the constantly increasing cost of equipment and the ongoing economic recession. All the aforementioned factors contribute to the need for optimization of the educational process with the goal of providing the trainee with the specific laparoscopic skills needed for a short duration of time and no risk for the patients. The solution to these problems can be found easily in the development and implementation of innovative education programs for virtual environment laparoscopic surgery simulators. Asides from box trainers and video trainers, virtual reality (VR) simulators contribute to an increasingly bigger part of the education of medical students and residents in the early stages of laparoscopic surgery training. These methods are safe and completely ethical in regard to patients, their training regimens can be repeated, and there is available software for scoring the practice procedure and providing real-time feedback (1,2). An additional benefit is the lack of necessity of a supervisor's presence at all times (3). For the first time in Bulgaria, in 2016, the Medical University of Varna introduced VR laparoscopic surgery simulators to their curriculum. Using them, the acquisition of laparoscopic skills can commence even before the graduation of medical students..

## AIM

The aim of this review is to analyze the efficiency of existing VR simulators and their application in laparoscopic surgery training.

## MATERIALS AND METHODS

A systematic review of available research was conducted via the databases PubMed, Web of Science, Scopus, and Google Scholar, using different combinations of the following keywords in the title/abstract: "simulation", "virtual*", "VR", "laparoscopic*", "surgery", "education", "LapMentor", "LapSim", "box trainer", spanning the last 10 years. The keywords were used in various combinations and with the conjugations "and" and "or". After a selection of the most appropriate titles and abstracts was made, the full text of the publications was used for the review. The study included all articles regarding authorized VR laparoscopic surgery simulators, separating them from all other non-VR simulators. Only VR laparoscopic simulators for abdominal and pelvic surgery were considered. Studies pertaining to other endoscopic manipulations (e.g. bronchoscopy, thoracoscopy, endoscopy) were excluded, as these procedures require a different basic skillset (1,4)..

## RESULTS

The electronic searches generated 106 studies in total. After the application of the inclusion and exclusion criteria, 8 randomized controlled trials were included in this study, and 98 were excluded. The inclusion criteria consisted of well-systematized randomized prospective studies regarding VR simulators in laparoscopic surgery.

### *Included Trials*

Eight randomized controlled studies were used, including one regarding systemic laparoscopic surgery training for students, surgeons and specialists. A total of 942 participants were included in the review, of which 44 (43 senior residents and 1 surgeon) had laparoscopic surgery experience. The number of novices was 898 (46 junior residents and 852 students). As of this point there are no studies comparing the different forms of VR training. Participant age varied between 20 and 34 years and gender ratios were 59.79% women and 40.21% men. Detail about the included research are systemized in Table 1.

### *Types of the Included Simulators*

Over the last few years, laparoscopic surgery training simulators have seen rapid improvement. The leading cause is their proven efficiency in laparoscopic surgery training. Leading laparoscopic surgery training centers in the USA, England, Germany, and other countries have created their own laboratories and workshops for simulation training where students can practice their skills in a myriad of different procedures. The simulators used therein are presented in Table 2.

### *Results of Included Studies*

### *Camera Navigation*

Beginner laparoscopic surgery training is associated with the development of fundamental psy-

*Table 1. Characteristics of the included studies.*

| | ID Author | Year | Citation | Participants(n) | Participants number | VR Simulator | Assessment method | Outcome assessment |
|---|---|---|---|---|---|---|---|---|
| 1 | K. F. Kowalewski1 | 2017 | Surgical Endoscopy https://doi.org/10.1007/s00464-018-6110-7 | 33 novice 31 experts | 64 | LapMentor II with combination of box trainer and POP trainer | Post-test performing LC on VR trainer and LC using POP trainer | Time, efficiency of cautery, safe cautery, path length, global assessment of technical skills |
| 2 | Markus Paschold | 2012 | Surg Endosc (2013) 27:2169–2177 DOI 10.1007/s00464-012-2735-0 | Novice | 488 | LapSim | Camera navigation | Maintaining the horizontal view Questionnaire |
| 3 | T. Huber | 2015 | Journal of Surgical Simulation (2015) 2, 35–39 DOI: 10.1102/2051-7726.2015.0008 | Novice | 148 | LapSim | Camera navigation | Z-score, Questionnaire |
| 4 | Jeanett Strandbygaard | 2013 | Ann Surg 2013;257: 839–844 | Novice | 91 | LapSim | Operation task | Time, blood loss, economy of motion, safe cutting |
| 5 | Radu Moldovanu, | 2011 | JSLS. 2011 Oct-Dec; 15(4): 533–538. doi: 10.4293 / 108680811X 13176785204409 | 1 expert 1 cameraman | 2 | LapMentor | Preoperative warm up with VR | Global Rating Score: respect for the "tissue"; time and motion; instrument handling; depth perception; bimanual dexterity; overall impression |
| 6 | Cui Yang | 2018 | Surgical Endoscopy https://doi.org/10.1007/s00464-018-6156-6 | Novice | 44 | LapMentor II | Laparoscopic appendectomy Laparoscopic cholecystectomy | Safe cautery, economy of motion, complications |
| 7 | Joalee Paquette | 2017 | JSLS. 2017 Jul-Sep; 21(3): e2017.00048. doi: 10.4293/JSLS.2017.00048 | 13 Junior resident 11 Senior resident | 24 | LapMentor II | Basic skill tasks | Total time, accuracy, economy of motion, safe retraction |
| 8 | Felix Nickel | 2015 | Md-journal, ISSN: 0025-7974 DOI: 10.1097/MD.00000000 00000764 | Novice | 84 | LapMentor II POP trainer Box trainer | Basic skill tasks, laparoscopic cholecystectomy | OSATS score, MC test |

chomotor perceptions. Upon entering an operating theater, novice specialists must become acquainted with the specifics of work in surgical rooms and their equipment as well as the specifics of laparoscopic camera and instrument manipulation. This is often associated with significant stress and requires time for adaptation.

In the initial stages of training, while participating in laparoscopic surgery as a first assistant, surgeons would be relegated to the functions of a cameraman. The movements of the assistant during interventions must be moderate, precise and safe, even more so during laparoscopic surgery. A cameraman must provide adequate and stable visualization of the operative field, while maintaining movement in a horizontal plane. The object of interest for the surgeon must always be centered on the screen. These are complex skills, which require developed fine motor skills by the first assistant. Adequate cameramen work contributes to the normal course of the intervention, which has a direct correlation to the time requirements for its completion.

A major prospective study published by Paschold et al. in 2013 (10), which included 488 students, evaluated personal characteristics and abilities which have an impact on camera manipulation skill acquisition with 0o and 30o optics. The study proves that students are capable of acquiring significant skills and knowledge in a short time span, as long as their laparoscopic surgery training correlates to their specific needs. Another significant study by Huber et al. (11) with the participation of 145 students confirms these results. The subjects were divided into two groups: a camera-training group (CTG) and a non-training group (NTG). CTG underwent simulator training via the LapSim system, after which their skills were evaluated by surgeons. Specialist satisfaction by the work of the subjects was 49% for CTG and 41% for NTG.

### *Operation Time*

The shorter an intervention is, the better it is for the patient. However, speed must not come at the expense of quality. This does not differ greatly in laparoscopic interventions, even with their lowered patient traumatism. The quality and speed of a laparoscopic intervention depends above all on the experience of the operative team. Following previous statements, adequate camera visualization allows for an uncomplicated surgery course and precision laparoscopic instrument work. A 2017 study by Kowalewski et al. (12) analyzes junior and senior residents, by randomizing them in two groups: Training group (TG) and Control group (with no training). The experimental group of 33 participants underwent multi-modal training via box trainer, VR training and 3D VR training. The Global Operative Assessment of Laparoscopic Skills (GOALS), which was developed as an adequate laparoscopic surgery

*Table 2. Types of the simulators included in the studies.*

| Simulator Name | Description |
|---|---|
| **LapSim (Surgical Science, Sweden)** | This is one of the first simulators to have ever been officially introduced to formal laparoscopic surgery training. As a product it has undergone numerous improvements over the course of its existence and newer models have tactile feedback, precise scoring software and anastomosis suturing and laparoscopic gynecologic surgery options. The simulator can measure time, instrument distance travel and specific errors during procedures. LapSim has proven to be effective in different publications (5–7). |
| **LapMentor (Simbionix, USA)** | A simulator with virtual reality and tactile feedback. It has a complete procedure set, divided into 4 fields: basic skills modules, advanced skills modules, guided operations, complete operative procedures. Every procedure is measured with specific parameters, which include: time, safety, economy of motion, complications and errors of procedures. It also provides result improvement advice. Its efficiency is proven by research (5,8,9). |
| **P.O.P trainer** | Pulsating Organ Perfusion (P.O.P.) is a mechanical laparoscopic system for realistic recreation of laparoscopic interventions. It makes use of animal cadaver organs or organ systems. P.O.P. simulators can be used for abdominal, thoracic, urological vascular and gynecological surgery training. |
| **Box trainer (Karl Storz GmbH,Tuttlingen, Germany)** | A conventional basic laparoscopy skill training system. It consists of a plastic polymer box with a built-in camera, and incision sites for trocar placement and laparoscopic surgery instrument positioning. |

skill assessment tool and has since become standard, was used for capability scoring. Both groups underwent a post-test on the P.O.P. trainer and also laparoscopic cholecystectomy (LC) on VR. The Training group demonstrated significantly higher GOALS scores in comparison to the Control group (16.7 ± 4.1 vs. 15.0 ± 2.9). The Training group operative time was also markedly smaller (40.0 ± 17.0 min vs. 55.0 ± 22.2 min). During LC on VR, according to simulator parameters TR demonstrated significantly better results on economy of motion and instrument speed of movement scoring.

A notable study by Nickel et al. (13) with the participation of 84 students demonstrates similar results. The subjects were divided into a Blended learning group (BL) and a Virtual reality group (VR). The BL group underwent electronic LC training and practiced basic skills via a box trainer. The VR group underwent LapMentor II simulator basic skill training and LC training. After the completion of the training both groups were to perform LC on a porcine liver with a preserved gallbladder. Objective Structured Assessment of Technical Skills (OSATS), another validated surgical skills assessment tool, was used. Average operation time for the VR group was markedly shorter in comparison to the BL group (75.8 min vs 77.6 min). In a timeframe of 80 min the BL group managed to complete 9 operative interventions while the VR group completed 19. However, the BL group presented better theoretical knowledge in regard to LC execution.

### *Economy of Motion (Path Length of the Instruments)*

Economy and precision of motion contribute to the speed of operative interventions and to lesser amounts of fatigue for the operative team, which is another significant factor. In the period between September 2016 and July 2017, Yang et al. (14) analyzed 44 medical students in a prospective randomized study of transferability of laparoscopic skills between two laparoscopic interventions on the VR simulator LapMentor II. Group I was to perform laparoscopic appendectomies until reaching proficiency and then perform LC. Group 2 performed LC directly. Results showed that Group I needed significantly less movements and an overall shorter path length of instruments to complete the procedure. This supports the claim that skills obtained during one laparoscopic intervention can be transferred to another. However, some results, such as time and safety, remain the same overall.

Moldovanu et al. (15) used a VR simulator in a novel way to demonstrate its efficiency in every aspect of laparoscopic surgery. An experienced surgical team performed LC on two patient groups: group A had the operation performed on them without preoperative preparation by the team, while group B had it performed on them with a brief preparation by the team beforehand. The preoperative preparation consisted of a 20-minute training course on the LapMentor simulator on basic manipulations such as instrument coordination, clipping, grasping, electrocauterization, camera navigation, and cutting. The Global Rating Score (GRS) was used to evaluate the procedure. Results showed that group B had a higher GRS score in time, movement, instrument control, safety, operative field depth, ambidextrous orientation, and overall performance. This suggests that short preoperative training with VR simulators could improve the intraoperative results of the surgical team.

### *Instructor Feedback vs. No Instructor Feedback*

One of the main advantages of VR simulators is the lack of requirement for constant supervisor presence during training. Scoring on different aspects of a completed procedure can be performed by software. Strandbygaard et al. (16) analyzed the need of specific feedback during training. A total of 91 medical students took part in the study. They were divided into an Intervention group, where participants received direct feedback with advice on procedure execution (laparoscopic salpingectomy), and a Control group, which received no such instructions. Results showcased that both groups reached predefined proficiency level, but the Intervention group did so in less time and with fewer repetitions, yielding mostly uniform results in contrast to the Control group. Two main conclusion could be drawn from the results—that the simulators can be used on their own, without any human feedback, but the presence of an instructor and his advice would increase the precision of procedure execution and greatly speed up skill acquisition.

## CONCLUSION

The introduction of new technology allowed for significant advancements in the field of surgery. This has led to the need to change traditional training methods. The limited available time in a surgical setting and the need for patient safety increase the need for the unique opportunities, presented by simulation technology in a safe environment. Multiple publications showcase the efficiency of VR simulator training. The new generation of VR training simulators provide a complete set of basic skill procedures and complete operative procedures. Their use is effectively unlimited, which allows reaching an expert level of proficiency in a short period. According to Boehler et al. (17) it is possible for novices to acquire basic laparoscopic skills for a few days, which would take a resident one month to acquire with conventional training in comparison. Virtual reality simulator use does have some limitations. First, VR simulators come at a high monetary cost. Second, while it is not strictly mandatory for all trainees to be guided in their actions, it is highly recommended to have a supervisor monitor their work to avoid the development of wrong habits, which might prove dangerous in real-life situations. Third, instrument orientation in some of the simulators is perfectly aligned in the operative field, which does not correspond to reality. The first steps of an operative intervention, like equipment positioning, instrument layout, and pneumoperitoneum creation, which is paramount for the execution of any procedure, cannot be correctly replicated by any simulator. As of today, it is a skill which can only be acquired in a surgical theater. Despite this, VR simulators might serve to create a stable basis on which a resident can acquire additional skills upon entering the surgical room.

The surgical community must follow the example of aviation training, in order to create mandatory laparoscopic surgery training programs for residents to undertake before entering operative theaters.

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