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Review

Virtual reality training in laparoscopic surgery: A systematic review & meta-analysis☆

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HIGHLIGHTS

- Virtual reality simulation in laparoscopic surgery is a mainstay in surgical training.
- Virtual reality simulation improves operative performance and times.
- Proficiency-based training on increasing levels of difficulty enhances outcomes.

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ABSTRACT

Introduction: Laparoscopic surgery requires a different and sometimes more complex skill set than does open surgery. Shortened working hours, less training times, and patient safety issues necessitates that these skills need to be acquired outside the operating room. Virtual reality simulation in laparoscopic surgery is a growing field, and many studies have been published to determine its effectiveness.
Aims: This systematic review and meta-analysis aims to evaluate virtual reality simulation in laparoscopic abdominal surgery in comparison to other simulation models and to no training.
Methods: A systematic literature search was carried out until January 2014 in full adherence to PRISMA guidelines. All randomised controlled studies comparing virtual reality training to other models of training or to no training were included. Only studies utilizing objective and validated assessment tools were included.
Results: Thirty one randomised controlled trials that compare virtual reality training to other models of training or to no training were included. The results of the meta-analysis showed that virtual reality simulation is significantly more effective than video trainers, and at least as good as box trainers.
Conclusion: The use of Proficiency-based VR training, under supervision with prompt instructions and feedback, and the use of haptic feedback, has proven to be the most effective way of delivering the virtual reality training. The incorporation of virtual reality training into surgical training curricula is now necessary. A unified platform of training needs to be established. Further studies to assess the impact on patient outcomes and on hospital costs are necessary. (PROSPERO Registration number: CRD42014010030).

1. Introduction

Minimally invasive techniques have become the standard for patients needing surgical intervention for elective abdominal surgery. The introduction of laparoscopic surgery has modernised surgical care [1]. Laparoscopic surgery can be challenging, as acquiring the skills needed to become competent, such as depth perception and video-hand-eye coordination is associated with a long learning curve and requires extensive training in order to be able to move instruments within the operative field safely and effectively. Furthermore, the fulcrum effect of the abdominal wall on instruments is a major obstacle for junior laparoscopic trainees [2]. Learning these skills in the operating room can be inefficient, time consuming, and may pose safety concerns for patients [3].

Surgical training has been described as going through a paradigm shift [4]. It is now unacceptable for surgical trainees to practice basic surgical and laparoscopic skills in the operating

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room, exposing patients to potential risk. The 100-year old Halstedian surgical mantra “see one, do one, teach one” has become obsolete. The apprentice-tutor model of surgical training has lost favour to a variety of simulation methods that, whilst improving the skills of the trainee, offer zero risk to patients [5]. Indeed, learning technical and non-technical skills outside of the operating room has now become an essential part of surgical training [6,7]. In addition to physical box trainers and video trainers, virtual reality (VR) simulation has become an increasingly important part of the early stages of technical skills acquisition in laparoscopic surgery; as it is safe, ethical, and repeatable alternative; it produces objective measures of performance; and allows real-time feedback to trainees [6]. It also does not necessarily require regular supervision in a safe environment by the trainer [8]. Table 1 summarises the available models of simulation.

1.1. Aims and objectives

The aims of this systematic review are:

1. To evaluate the published studies assessing VR as a training tool in laparoscopic surgery;
2. To compare virtual reality simulation to no training, box trainers, and to video trainers.

2. Methods

A systematic review was carried out until January 2015. Databases searched were Pubmed, Ovid Medline, Cochrane library's Central, Clinicaltrials.gov, and Controlled-trials.com. Terms used for the search were: virtual reality, Lapmentor, MIST-VR, Lapsim, Simendo, Laparosc*, surg*, colo*, colorect*, key hole, Minimally Invasive train*, simulat*. These were combined with Boolean characters “AND” and “OR”. Wildcards, such as “*” and “?” were also used to broaden the search terms.

PRISMA guidelines were adhered to in reporting the results of this study [9]. The study has been registered in PROSPERO, the international prospective register of systematic reviews, where the protocol can be accessed (Registration number: CRD42014010030).

2.1. Study eligibility

2.1.1. Study designs

All randomised controlled studies and cross over design studies comparing virtual reality training to other models of training or to no training were included. Single group studies with pre and post intervention assessments were excluded.

2.1.2. Participants

Participants in included studies are categorised into three levels of experience:

1. No experience: medicine students or lay people with no previous laparoscopic experience.
2. Novice laparoscopic surgeons: surgery residents and registrars with some experience in laparoscopic surgery, but haven't reached the plateau phase on the learning curve.
3. Expert laparoscopic surgeons: Surgeons who have reached a plateau in their learning curve, where no further incremental improvements can be seen on task repetition [10].

The incremental benefit of these three different levels of expertise were compared in order to assess which expertise group benefit the most from VR training.

2.1.3. Intervention

Studies that include any of the validated VR simulators as an intervention are included in this review [40]. Studies that include the VR simulator as a sole intervention were included, while studies that included a full learning curriculum which includes a VR model have been excluded, as this fails to isolate the effect of the VR model. VR models that offer simulation training to cavities other than the abdomen and pelvis, e.g. bronchoscopy or endoscopy, were excluded; as they require different sets of fundamental skills, and utilises different instruments [40].

Characteristics of the training sessions were recorded, including the training module, whether they were proficiency-based or time based, the training session's lengths, number of repetitions, and whether it was supervised with instructions and feedbacks.

2.1.4. Outcomes

Only studies that involve an objective assessment of outcome or an equivalent appropriate scoring system were included. Non validated assessment tools were excluded. Subjective assessments such as questionnaires and Likert scales were excluded.

The primary outcome measures calculated and used in the meta-analysis were:

1. Change in time taken to complete a task: this can be calculated by the VR simulator, by a tracking device, or by the observer. Change in time has been standardised among studies by measuring the absolute percentage change from pre-intervention to post-intervention; the higher the number, the more the change from baseline.
2. Objective scoring tools, such as Objective Structured Assessment of Technical Skills (OSATS), Global Operative Assessment of Laparoscopic Skills (GOALS), and the Global Rating Scale (GRS).

Other outcome measures and metrics used in the studies include [1]: Integrated simulator metrics: these are measured metrics such as: total path length, error counts, and differential number of movements of each hand; and [2] Error scores. The method of assessment and the outcome performance measures were extracted from each study.

Table 1
Description of simulation models.

Tool	Description
Bench-top simulators	Models or Mannequins used to practice simple physical manoeuvres or procedures. (e.g. artificial skin pad for suturing practice)
Box trainers	A Simple box, utilizing a camera, screen, light source and instruments used for laparoscopic training.
Video trainers	Box trainers with embedded motion sensors and recorders that measure distance and direction moved in order to calculate economy of movement.
Virtual reality (VR) simulators	Screen-based computer software and hardware similar to that used in laparo-endoscopic surgery.
Low-fidelity	Computer training programmes that provide an abstract environment to teach basic laparo-endoscopic skills (see text).
High-Fidelity	Computer training programmes that utilise motorised instruments to provide haptic feedback (see text).
Complex task trainers	Hybrid models that provide visual, audio and touch cues, and uses integrated hardware to replicate a clinical setting.