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MINIREVIEWS

Need for simulation in laparoscopic colorectal surgery training

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Abstract

The dissemination of laparoscopic colorectal surgery (LCS) has been slow despite increasing evidence for the clinical benefits, with a prolonged learning curve being one of the main restrictions for a prompt uptake. Performing advanced laparoscopic procedures requires dedicated surgical skills and new simulation methods designed precisely for LCS have been established: These include virtual reality simulators, box trainers, animal and human tissue and synthetic materials. Studies have even demonstrated an improvement in trainees' laparoscopic skills in the actual operating room and a staged approach to surgical simulation with a combination of various training methods should be mandatory in every colorectal training program. The learning curve for LCS could be reduced through practice and skills development in a riskfree setting.

Key words: Surgical simulation; Laparoscopic surgery; Surgical training; Colorectal surgery

Core tip: Performing advanced laparoscopic procedures requires dedicated surgical skills and new simulation methods tailored precisely for laparoscopic colorectal surgery (LCS) have been established. This review focuses on a very actual topic in gastrointestinal surgery: The learning curve in minimally invasive surgery and the need for mechanisms to shorten the time needed for a trainee surgeon to safely move towards independent practice. This review article critically analyses the current role of simulation for LCS training.

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INTRODUCTION

Laparoscopic colorectal surgery (LCS) has been increasingly applied because of its many advantages over conventional surgery, including reduced postoperative pain, earlier recovery of bowel function and shorter hospital stay[1].

Despite the evidence for the clinical benefits of LCS and its oncologic safety[2,3], the dissemination of this technique has been hesitant, one of the main constraints for a swift uptake being an extended learning curve[4].

The high level of technical complexity associated with laparoscopic colectomies was held partially responsible for its relatively low adoption rate when compared with other laparoscopic operations[5,6] and learning curves have been estimated as being between 30 and 60 cases[7,8] with the need to acquire specific skills dissimilar to those used during conventional surgery[9].

LCS is a technically challenging procedure, frequently being self-taught by senior surgeons[10], despite there is available evidence that the absence of appropriate training may lead to patient safety compromise[11].

Nowadays, trainee surgeons are required to gather more technical skills in less time[12]: Research has demonstrated a deficiency of successful performance of enough critical laparoscopic colorectal cases by trainees[13,14].

The proportion of operations undertaken by surgical trainees has reduced in the past decade[15] as they spend less time in theatre and more time covering nights and acute admissions[16,17].

This gap between expected level and actual practice[18] has promoted the use of advanced training in laparoscopic colorectal surgery, with the evident need to improve the training opportunities available to trainees out-of-hours. Aim of this review is to summarize the different simulation strategies currently available for LCS training and the evidence demonstrating their advantages for colorectal trainees.

NEW CHALLENGE FOR SURGICAL TRAINING

Surgical training has traditionally been one of apprenticeship, based on a Halsted's "see one, do one, teach one" classic scheme[19] where the surgical trainee learns to perform surgery under the supervision of an experienced surgeon.

Performing laparoscopic procedures requires special surgical skills to overcome the technical difficulties that it presents (Table 1), which include two-dimensional vision with loss of depth perception, less range of motion of the instruments when compared with open surgery, impaired tactile sensation, and the disparity between visual and proprioceptive feedback known as the fulcrum effect[21,22]. Laparoscopic surgery is difficult to learn by observation and practice alone[23] and competency requires dedicated training and mentoring[24].

Moreover, augmented rates of adverse clinical outcomes at the beginning of the learning curve introduce ethical questions and emphasize the demand for mechanisms to decrease complications and unnecessary conversions to open surgery during the early stage of independent practice. As it is no longer accepted that surgeons acquire experience at the expense of patient safety, patients should not be exposed to the opportunity of harm when other training approaches are available for skill acquisition.

Table 1 Distinctive features and challenges of laparoscopic surgery[20]

Features	Challenges
Two dimensional vision	Reduced perception of depth
A disturbed eye-hand-target axis	Decreases ergonomy and dexterity
Long and inflexible instruments	Natural hand tremor magnified
Rigid instruments with five degrees of freedom	Decreased dexterity and range of motion
Fixed abdominal entry points	Limited freedom of motion and movement of the instrument: The fulcrum effect
Camera instability	Increased fatigue
Limited tactile feedback	Decreases dexterity

It has also been demonstrated that the surgical theatre can be a suboptimal place for beginner learning as high stress leads to deleterious effects on performance[25] and surgical training in the operating room implicates additional cost, estimated in approximately United States $47979 per year per trainee[26].

Concerns regarding cost, time, schedule restriction and safety have arisen and this forced surgeons to innovate and develop new methods of surgical training[27,28] and it became obvious that the learning curve must be abbreviated by learning outside of the surgical theatre[29].

Committed practice on simulators corresponds with improved operative times and efficiency of movement for minimally invasive cholecystectomy. These results indicate that the learning curve for LCS may be reduced with this approach[30]. However, colonic and rectal resections performed laparoscopically are retained to be more difficult than a cholecystectomy as they involve added challenges like the need to operate within multiple quadrants in the abdominal cavity, the dissection of inflamed or obliterated tissue planes, and the safe mobilization of the bowel from confined spaces. LCS training is obviously less adapt to simple box trainers because of the necessity to work in multiple quadrants, transect and extract often large bulky specimens, and perform bowel anastomosis: Advanced surgery needs advanced simulation training.

Laparoscopic training not only has changed the traditional perspective challenging the Haldsted's one century old apprenticeship model[31], but has also induced a prompt development of simulation techniques given the versatility of the video environment and the capability to monitor the motions of the trainees. Adequate training clearly is the desirable way to prevent and diminish potential laparoscopic surgical errors[32].

SIMULATION PRACTICE IN LCS

New simulation methods designed peculiarly for LCS have been established (Table 2). These embrace a combination of virtual reality simulators and box trainers, animal and human tissue, and synthetic materials[33-36].

Traditionally, animal and human cadaver training models have been utilized to improve spatial perception

Table 2 Characteristics of the different types of simulators

Type of simulator	Main features
Box trainers	Low-cost, portable, can be used repeatedly by multiple users. Used to teach basic laparoscopic skills: hand-eye coordination, cutting, suturing, bimanual dexterity. Provide sensory feedback Requires direct observation and supervision by a trainer
Virtual reality simulators	Record several procedure metrics providing feedback to trainees. Recording of training performance for objective evidence of skill performance. Minor degree of sensory feedback and higher initial are the main disadvantages
Hybrid models	Reduced costs compared to cadaveric models. Questionable value of a training model with an alternative structure
Animal and human cadaveric models	Best anatomic and clinical-like model. Avaibility is limited and their use is expensive. Require operative facilities and a funeral service

of surgical anatomy[37,38]: This method of simulation is outstanding to demonstrate dissection, tissue handling and complex surgical techniques, but unfortunately, both these models require very specialized training environments, are very expensive with limited availability, and each trainee probably only gets to perform part of the procedure once.

Box-simulators use laparoscopic instruments set within a physical box. They provide tactile feedback and are relatively inexpensive, however require ongoing maintenance and materials, and require feedback from an observing trainer for maximum efficacy. Lack of availability of trainers and dedicated time for feedback may therefore limit this system.

Virtual reality simulators enable trainees to interface with a computer-generated environment that reproduces individual skills or entire procedures. Modern virtual reality simulators utilize increasingly advanced hardware and software for complex and realistic simulation: They have an higher initial cost but are valuable not only as a training device but also as a tool to assess surgical skills. In fact they provide pre-task tutorials and feedbacks at the completion of the procedure on a range of outputs such as time taken, efficiency of motion and knot integrity. Virtual reality simulator systems are convenient for the trainer as performance of the trainee can be monitored easily and remotely, meaning this system can be well utilized out-of-hours.

FUTURE PERSPECTIVES

Several studies have demonstrated that training in laparoscopic techniques in a simulated setting, including on virtual-reality simulators, has enhanced the capabilities of the surgical trainees during and beyond the course of their training[39,40]. Some studies have even shown an amelioration in trainees' laparoscopic skills in the actual surgical theatre[41,42] and it is now largely accepted that laparoscopic simulation training should be mandatory[43] to facilitate trainees acquire basic laparoscopic skills, and a growing consensus by regulation training bodies is desirable.

Proficiency-based simulator curricula have proven effective in improving the performance of trainees. An assessment of baseline skills level on laparoscopic colectomy for trainee surgeons may be used to fashion a tailored program dedicated to improve specific competences and to meet the needs of novice surgeons according to their specific pre-training skills.

Skills of different complexity can be achieved using a phased approach and a mixture of distinct simulation training techniques. Basic surgical competences such instrument handling and suturing should be developed in box trainers and virtual reality simulators, while advanced key steps in complex procedure mastered using torso-shapped mannequin with synthetic materials. Finally, as LCS requires cooperation among the surgeon, the assistants and the operating team personnel, advanced laparoscopy team training should be done in animal/cadaver/hybrid labs with a minimal number of required animals or cadavers.

CONCLUSION

Training in LCS requires specific psychomotor skills that trainee surgeons are required to gather in less time. Simulation may offer a safe, reproducible environment for development of technical skills and procedural knowledge. The learning curve for LCS could be reduced through practice and skills development in a risk-free setting and a staged approach to simulation training should be mandatory in every colorectal training program.

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