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Training Tools and Methods for Laparoscopic Surgery

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Abstract

Background: Laparoscopic surgery has been rapidly advancing and is being disseminated worldwide. Therefore, laparoscopic surgeons have to further their efforts to acquire basic and advanced technical skills in laparoscopic surgery through training. Presently, numerous training tools and methods of training in laparoscopic surgery, such as box trainers, virtual reality simulators, animal models and human cadavers, have been developed.

Methods: We reviewed the reports published in the English-language literature to evaluate the training tools and training methods available for laparoscopic surgery.

Results: Numerous studies have evaluated each of the various training tools and methods and have reported their positive impact on the teaching of laparoscopic technical skills. Among them, the most popular studies compared the educational effectiveness of training using the box trainer versus the VR simulator for laparoscopic surgical trainees. However, it might be difficult to determine which of these two training tools is superior for trainees. Recently, the usefulness of educational programs that combine various training methods to acquire basic laparoscopic surgical skills has been reported, and these combination methods may become a new trend.

Conclusion: In the future, the impacts of multimodal educational programs or those combining training methods should be evaluated by assessing patient outcomes after laparoscopic surgery performed by the laparoscopic surgical trainees.

Keywords: Laparoscopic surgery; Training tools; Training methods

Introduction

Since the late 1990s, minimally invasive laparoscopic surgery has become the standard treatment for not only benign but also for malignant disease because of the quicker postoperative recovery compared with that of conventional open surgery. However, laparoscopic procedures sometimes require more advanced surgical techniques than do open abdominal procedures. As well, much time and work must be invested to acquire laparoscopic surgical skills that have a prolonged learning curve in the clinical setting. Furthermore, patient safety concerns have made it more difficult for trainees to learn laparoscopic technical skills on real patients. The 100-year-old Halstedian surgical mantra of "see one, do one, teach one" [1] is now unacceptable for the practice of laparoscopic skills by trainees in the operating room because it exposes patients to potential risks. Additionally, previous studies reported that many surgeons with little or no advanced laparoscopic skills might have higher rates of postoperative complications and procedure failure [2-4]. Therefore, an appropriate and safe training method is essential for trainees to learn basic to advanced laparoscopic procedures with shortened learning curves and to reduce postoperative complications. Therefore, the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) has recommended incorporating educational programs for laparoscopic surgery into the training of general surgical residents [5].

In this article, we review the reports published in the English-language literature that have evaluated individual training tools and educational programs for the acquisition of laparoscopic surgical skills.

Development of training tools for laparoscopic surgery

In the past, various training tools for laparoscopic surgery were developed outside of the operating room [6]. Simulator training using classical box trainers was first proven to be a useful teaching method in the field of anesthesiology [7,8]. These trainers are being used to acquire basic surgical skills in laparoscopic surgery because of their low cost, portability, and time efficiency. They provide tactile feedback and practice through repetition for multiple trainees [9]. However, trainees require more realistic simulations to learn complex skills as they progress to advanced laparoscopic procedures. Therefore, other training tools, such as virtual reality (VR) simulators, animal and human cadavers, and live animal models, have been used to improve the trainees' skills. Recently, a number of studies have shown that well-designed training methods for trainees have a significant impact on the clinical setting in laparoscopic surgery [10].

Evaluation of individual training tools for laparoscopic surgery

Box Trainer: The box trainer has been used to learn basic laparoscopic skills for trainees around the world for well over a decade, and this training method has been applied in many first-year surgical residency programs. The generically manufactured box trainer contains an opaque box that approximates the size of the

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Table 1: application of training methods to educational programs: box trainer and/or virtual reality simulator.

Author	Country	Year	Citation	Study design	Training		Participants (n)	Assessment		Results
					Training method	Training period		Method	Outcome assessment	
Minz Y [8]	UK	2004	Surg Endosc 18, 485-494	RCT	VRS vs BT	3 week lasting 30 min	MS (24)	Laproscopic task	Motion analysis and error score	No difference
Debes AJ [29]	Norway	2010	Am J Surg 199, 840-845	RCT	VRS vs BT		MS (46)	Crossover assessment of the other method	Time, movements, path length, and total score	VRS
Mchammadi Y [35]	USA	2010	JSLS 14, 205-212	Prospective observational study	BT+ VRS vs BT a lone		MS (43)	5 standard exercises	Time, accuracy, and surveys	BT + VRS
Youngbbod PL [30]	USA	2005	J Am Coll Surg 200, 546-551	RCT	VRS vs BT	12 dys	MS (46)	3 laproscopic tasks on live anesthetized pigs	Time and accuracy scores	VRS
Madan AK [34]	USA	2007	Surg Endosc 21, 209-213	RCT	VRS vs BT vs combination of both	200 min	MS (65)	4 laproscopic tasks in a porcine laboratory	Time and error scores	Combination of both
Diesen DL [33]	USA	2011	J surg Educ 68,289-299	RCT	VRS vs BT	6 months	MS (12) and surgical (11)	5 laproscopic exercises in a live porcine model	Scoring system	No difference
Mulk M [31]	UK	2012	J surg Educ 69, 190-195	RCT	BT vs BT + additional practice vs VRS vs mental training	1 week	MS (41)	Task on the VRS and on a BT	Time, precision, accuracy, and performance	VRS
Orzech N [32]	Canada	2012	Am J Surg 255, 833-839	RCT	VRS vs BT		Surgical residents (24)	Laproscopic stiches during operation on a patient	Time, global rating score, checklist score, and cost	VRS (more efficient) BT (cost-effective)

RCT: Randomized Controlled Trails; VRS: Virtual Reality Simulator; BT: Box Trainer; MS: Medical Students

human abdominal cavity, video monitor, camera, and laparoscope. Various targets are manipulated inside the box based on visual information. One of the important attributes of the box trainer is the sensory feedback, also called haptics, that it provides [9]. Haptics is physical sensory feedback conferred via the box trainer that is on par with that of real laparoscopic operations. An additional attribute of this trainer is its lower acquisition cost. These reasons make the box trainer the most widely expanding training method in the world. A recent systematic literature review on box trainers showed evidence that surgical training using a box trainer appears to improve the basic laparoscopic skills of trainees without previous laparoscopic experience compared with limited prior laparoscopic experience [11]. Therefore, training box of the fundamentals of laparoscopic surgery (FLS) that was developed by the SAGES is already accessible to surgical trainees to hone their laparoscopic skills [12]. However, the problems about FLS skills test are still remain. One of the problems is high cost [13]. And the other is the most appropriate time when do they should perform for trainees [14].

VR simulators: Training using VR simulators is currently the most evolutionally advanced simulation training method in the area of laparoscopic surgery. VR simulators can assess various laparoscopic skills, such as camera navigation, object manipulation, insular dissection, and extracorporeal suturing [15]. VR simulators make many kinds of surgical training more believable for trainees than those using traditional box trainers do because the situation is made to be as real as possible [16]. Using the latest computer software, these training systems can be set up to record and save data for teaching the advanced skills required for laparoscopic surgery. These data make it possible for the educators to evaluate the trainees' performance of various laparoscopic tasks, to track the progress of individual trainees, and to compare the trainees' results [17,18]. In addition, several VR simulators, such as hybrid simulators, can provide the tactile feedback that is lacking in most simulators. VR training with haptic feedback is at least as effective as box trainers are and resulted in shorter operating times, less distance travelled, and fewer unnecessary movements when compared to VR training without haptic feedback [19]. Although these VR simulators are largely used for learning and practicing skills, they are rarely used as an assessment tool [20]. These training systems are relatively more expensive than box trainers, but their incorporation into laparoscopic surgical training programs may be increasingly encouraged if the price of these systems can be lowered. In recent years, low-cost laparoscopic simulators is regarded as being the most equitable solution to allow basic skills practice for junior surgical trainees [21].

Animal model training: Animal models, such as the anesthetized porcine model, are used to learn surgical skills for laparoscopic surgery because they have been shown to be a substitute for human tissues. Especially, the abdomen of the porcine model is sufficiently similar to the adult human in size and in intraabdominal anatomy [22]. Animal models are the only models in a non-patient environment for laparoscopic training that can simulate intraoperative bleeding and complications that can occur in a live patient. Therefore, animal models are frequently used for training together as a team before an operation [23]. It was recently reported that porcine-based training is useful in pediatric minimally invasive surgery [24], and a new animal model of calculous cholecystitis was created [25]. However, these training methods are prohibitive because of the substantial costs involved in providing appropriate staff and facilities. In addition, there are still some problems related to moral, ethical, and infection concerns with this particular training method [26].

Cadaver training: Cadaver training models that include animal and human cadavers have been useful in learning surgical anatomy and in performing tissue dissection, surgical handling, and complex laparoscopic procedures. Many reports have stressed the importance of cadaver training in the acquisition of laparoscopic skills. Fresh frozen cadavers have been recommended for wider use in a realistic laparoscopic operative training experience because of the perfect anatomy, normal colors, and consistency of the tissues [27,28]. Some authors have also recommended a training method using human cadavers embalmed by the Thiel method because this method provides

Table 2: Effective management of training methods for educational programs.

Author	Country	Year	Citation	Study design	Training			Assessment		
					Training method	Training period	Participants (μ)	Method	Outcome assessment	Results
Nickel F [40]	Denmark	2015	Medicine S4, e764	RCI	VRS *vs* Low cost blusted learing (BL) (BI + E learning)	12 hrs	MS (84)	Operative performance on cadaveric porcine laproscopic	OSAIS score, operation time, rate of operations completed and knowledge test	VRS
Bridusu VM [41]	The Netherlands	2012	Surg Endosc 26, 21, 72-78	Comparative study	Single Modality (VRS abuse) *vs* Multimodality (VRS + BI)	45 minutes × 6	MS (36)	Pre and post tests and VRS	Five different basic skills and	No difference
Sra [37]	Japan	2013	22, 150-156	RCI	BI- VRS group (BI followed by VRS) *vs* VRS-BI group(VRS followed by VRS)	60 minutes for each	Surg without prior laproscopic experience (20)	Motion analysis system	Laproscopic skills	VRS-BI
Botlen SM [39]	The Netherlands	2008	Surg Endosc 22, 1214-1222	Compartive study	BI-VRS group (BI followed by VRS) *vs* VRS-BI (VRS followed by VRS) & BI ab	One 30 minutes session	surgical gynecology (45)	Sub	structural	No difference
Bri WM [38]	The Netherlands	2013	Surg Endosc 27, 3581-3590	Compartive study	BI-VRS group (BI followed by VRS) *vs* VRS-BI (VRS followed by BI)	-	Eperienced laproscopic and medical interns (28)	Eight repetitions of the transfer fish and questionarie	Completion time and error	BI- VRS
Khan MW [33]	Austrlia	2014	J surg Educ 71, 79-84	RCI	BI *vs* VRS	6 months	MS interns,	2 practices on both simulators	Score	BI IS
Van Bro S [43]	Belgium	2013	J surg Educ 27, 3823-9	RCI	maintanance programe after training No training *vs* unused training *vs* BI (*vs* VRS (	missed training-150 min after 2.5 months distrbuted training -5 monthly 30-mintues training sessions	MS (39)	Model	On performance (time and	BI

RCT: Randomized Controlled Trials; VRS: Virtual Reality Simulator; BT: Box Trainer; MS: Medical Students; OSATS: Objective Structured Assessment of Technical Skills

better tissue flexibility and colors [29,30]. However, this embalming process is very complex and expensive, and it results in shorter conservation times [31]. The disadvantages of these cadaver-training methods are the limited availability of specialized environments and the high cost of their maintenance [32]. The limited supply of cadavers also constricts the wide use of cadaver training methods around the world.

Evaluations to establish well-designed educational programs for laparoscopic surgery

Application of training methods to educational programs: Box trainer and/or VR simulator (**Table 1**): Many studies have compared the effectiveness of training methods for laparoscopic surgery using the box trainer and the VR simulator. Most of these studies were performed as prospective randomized controlled trials, and the participants in most were novices, such as medical students and surgical interns. The assessments of each training method were based on the performance of several laparoscopic tasks or exercises on the box trainer, VR simulator, or in animal models. These tasks or exercises were scored for several parameters, such as time, movements, accuracy, and others. In these studies, the trained groups performed significantly better on most of the parameters than the control (no training) groups in learning laparoscopic skills. Most of these previous studies reported that VR simulator training was a more efficient method for trainees than the box trainer [33-36]. Youngblood et al. [34] reported that the mean Global ratings scores (1-5) of the VR training group was significantly better than both Box training and no training group (3.31 vs. 2.27 and 2.31, p=0.005). However, some studies reported that both the box trainers and VR simulators were equally effective means of teaching laparoscopic skills [8,37]. Reported that VR training was the more efficient training modality, whereas box training was the more cost-effective option [36]. Thus, from these randomized controlled trials, it remains controversial whether VR training or box training is more useful for laparoscopic surgical training.

Some reports stressed that the combination of box trainer and VR simulator training methods was more useful to acquire laparoscopic surgical skills. Both Madan et al. [38] and Mohammadi et al. [39] found that the combination of both training methods led to better laparoscopic skill acquisition than the use of either training method alone. Palter et al. also reported that residents with structured training methods consisting of a box trainer, VR simulator training, and several training sessions outperformed residents with conventional training in technical performance during the first to fourth sequential laparoscopic cholecystectomies ($p<0.05$) [40]. The combination of both methods of training may become an important part of the early stages of laparoscopic skills acquisition for trainees.

Effective Management of Training Methods for Educational Programs (**Table 2**): A number of studies also addressed the effective management of laparoscopic surgical training methods, such as the order of training, multimodality training, and the maintenance of training. The participants of most of these studies were also medical students and surgical interns. The assessments of each study were based on laparoscopic performance or technical skills demonstrated on either a simulator or a porcine cadaver.

Some research investigated the optimal order of these training methods. Sumitani et al. [41] determined that VR training followed by box training effectively improved the dexterity of surgeons [41], but Brinkman et al. implied that assessment on the VR simulator after pretraining on the box trainer was acceptable [42]. Botden et al. [43] reported that the total score of the group who started training on the box trainer and subsequently moved to the VR simulator was

Table 3: Application of cadaver training to educational programs.

Author	Country	Year	Citiation	Study design	Training method	Assessment Participants (μ)	Assessment Method	Outcome assessment	Results
Le Blanc F [46]	USA	2010	J am coll surg 211, 290.5	Comparative study	Laproscopic signoid colectonies during human cadaver training (n=7) vs augmente drealty simulator (n=28)	Trainers and trainees (35)	OSATS forms	Technical skills,event scores, and satisfaction with training model	Simulator training (global satisfaction was better for the cadaver traning)
Le Blanc F [47]	USA	2010	J Surg educ 67,2004	Observational prospective comparative study	Hand assisted colectomies during human cadaver training (n=7) vs augmented realty simulator (n=27)	Practicing surgeons (34)	OSATS forms	Technical skills,event scores, and satisfaction with training model	Simulator training
Wyles SM [48]	UK	2011	Srg endosc 25, 1559-1566	A standardized anaymous questionarie survey	Fresh frozen cadavers vs Anesth	Trainers and trainees (103)	standardized anaymous questionarie and global assessment score	Questionarie and performance	Fresh frozen cadaver
Sharma M [44]	UK	2012	World J Surg 36, 1732.1	A prospective comparative face validity study	Fresh froozen cadavers vs high fidelty VRS	Surgeons (45)	Questionaire	Grade and level of training score, and open ended questionarie	Fresh frozen cadaver
Van Bruwaene S [45]	Belgium	2015	J Surg Educ 72, 483.90	RCT	No training vs pacine cadaver vs VRS	MS (30)	Laproscopic cholecystectamy on a live anesthetized pig	Time and quality	Cadaver training

RCT: Randomized Controlled Trials; VRS: Virtual Reality Simulator; MS: Medical Students; OSATS: Objective Structural Assessment of Technical Skills

higher than group who began on the VR simulator followed by the box trainer, but not significantly so. Although the combination of VR training and box training is a better method for trainees than either training method alone, the optimal order of these training methods continues to be unclear.

Several reports assessed the effectiveness of multimodality training. Nickel et al. [44] compared VR training with low-cost blended training, which combined e-learning with box training, and they concluded that both methods could be applied for training on the basics of laparoscopic cholecystectomy [44]. Brinkman et al. [45] reported that performance outcomes of training basic skills did not differ between VR simulator training alone and multimodality training practiced on a VR simulator, box trainer, and an augmented reality simulator [45]. These studies suggest that the combination of several training methods may become a new trend. However, the most suitable combination of training methods remains controversial.

Two reports investigated the maintenance of training. Khan et al. [45] studied laparoscopic skills maintenance by assessments made at 1, 3, and 6 months after box trainer and VR simulator training [46]. They concluded that basic laparoscopic maintenance was more consistently achieved after initial training using a box trainer than a VR simulator, although over the long term, the skill levels were similar. Van Bruwaene et al. [47] also showed that a maintenance-training interval of 1 month with training on box trainers seemed ideal, and VR simulator training did not show any benefit after the completion of laparoscopic suturing training [47]. Box training may be more suitable for the maintenance of training, especially suturing training, for laparoscopic surgery.

Application of Cadaver Training to Educational Programs (**Table 3**): Among the studies of cadaver training for laparoscopic surgery, the participants were surgeons and medical students taking a training course. Four studies were performed that compared cadaver and simulator training methods. The assessments of each training method were based on the technical skills demonstrated during cadaver training and operation on a live anesthetized pig, and on a questionnaire. Two of these studies reported that the cadaver training method was more useful than the VR simulator method [48,49]. Sharma et al. [50] demonstrated that median scores for basic laparoscopic tasks in senior surgeons were significantly higher in cadaver training group compared to VR simulator training group ($p < 0.01$) [48]. However, the other two studies reported that the VR simulator training method was adequate for laparoscopic surgery training [50,51]. And, these studies also stressed that overall satisfaction grade was significantly better for the cadaver training method than for the simulator methods ($p=0.009$). Wyles et al. performed a detailed opinion analysis of two training course models, fresh-frozen cadavers and anaesthetized pigs, for laparoscopic colorectal surgery, and they reported that the cadaveric model was perceived to be superior as a training model (Global assessment score 4.53 vs. 3.61, $p=0.001$) [52]. Even though the cadaver training method requires not only financial and time resources but also carries some ethical concerns, it provides realistic and satisfying training for the trainees.

Development of new training methods for educational programs

Recently, there has been a rapid growth in studies suggesting that training methods using video games have positive effects on the acquisition of basic laparoscopic skills. Several experiments showed that video games could help to improve basic laparoscopic skills [53-56]. Jalink et al. [57] suggested that video games can be used as a temporary warm-up before laparoscopic surgery [57], and they confirmed the face validity of video games in the training of basic laparoscopic skills [58]. Overtoom et al. [59] also reported that the game was considered most suitable for residents in the first part of their postgraduate training with a mean score of 3.73 (standard deviation 0.97) [59]. However, there is no standard method to assess the effects of video games on laparoscopic skills. Thus, further evidence of the role of video games on the standard laparoscopic training methods is needed.

Conclusion

The validity of any kind of training method over no training at all for laparoscopic trainees is no longer in doubt. However, the best training method for laparoscopic surgeons is still being debated. The most interesting problem is whether the laparoscopic skills acquired from these laparoscopic training methods are transferrable to real operations. In the future, multimodality or combined training programs for laparoscopic trainees according to their skill levels will be developed and standardized, and then these training programs should be evaluated by assessment of their impact on patient outcomes after laparoscopic surgery performed by the laparoscopic surgical trainees.

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