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Review Article

The cutting-edge training modalities and educational platforms for accredited surgical training: A systematic review

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Background: Historically, operating room (OR) has always been considered as a stand-alone trusted platform for surgical education and training.However, concerns about financial constraints, quality control, and patient safety have urged the surgical educators to develop more cost-effective, surgical educational platforms that can be employed outside the OR. Furthermore, trained surgeons need to regularly update their surgical skills to keep abreast with the emerging surgical technologies. This research aimed to explore the value of currently available modern surgical tools that can be used outside the OR and also elaborates the existing laparoscopic surgical training programs in world-class centers across the globe with a view to formulate a blended and unified structured surgical training program. **Materials and Methods:** Several data sources were searched using MeSH terms "Laparoscopic surgery" and "Surgical training" and "Surgical curriculum" and "fundamentals of endoscopic surgery" and "fundamentals of laparoscopic surgery" and "Telementoring" and "Box trainer." The eligibility criteria used in data extraction searched for original and review articles and by excluding the editorial articles, short communications, conference proceedings, personal view, and commentaries. Data synthesis and data analysis were done by reviewing the initially retrieved 211 articles. Irrelevant and duplicate and redundant articles were excluded from the study. **Results:** Finally, 12 articles were selected for this systematic review. Data results showed that a myriad of cutting-edge technical innovations have provided modern surgical training tools such as the simulation-based mechanical and virtual reality simulators, animal and cadaveric labs, telementoring, telerobotic-assisted surgery, and video games. Surgical simulators allow the trainees to acquire surgical skills in a tension-free environment without supervision or time constraints. **Conclusion:** The existing world-renowned surgical training centers employ various clusters of training tools that essentially endeavor to embed the acquisition of knowledge and technical skills. However, a unified training curriculum that may be accepted worldwide is currently not available.

Key words: Laparoscopic surgery, surgical training, telementoring, telerobotic assistance, virtual reality simulator

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INTRODUCTION

Although surgical techniques have significantly evolved in the last 20 years, most of the practicing surgeons have learned emerging surgical technologies on patients without going through any formal training. The current hierarchy of surgical training and education, worldwide, is primarily based on the Halsted model with very little regional modifications.[1] Furthermore, a great majority of the surgical residents even in the USA and UK do not feel comfortable in performing even a highly standardized and moderately simple procedure such as colectomy and the level of difficulty escalates for procedures done by minimally invasive approaches.[2] This paradigm leads to inequalities in the delivery of a standard modern surgical care, significant complications, and poses financial burden to the communities.

The existing laparoscopic surgical training and assessment modalities include, but not limited to, laparoscopic surgery courses, surgical fellowships,

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on-site mentoring programs, and accredited surgical residency programs conducted at the designated training institutions.[3] A modest exposure to the OR setup with state-of-the-art equipment and the acquisition of laparoscopic surgical skills provide a step forward for the surgical trainees wishing to master laparoscopic surgery.[4] In addition, current surgical trainees routinely attain sufficient experience of basic laparoscopic procedures such as laparoscopic cholecystectomy and appendectomy. In the wake of the described advantages, surgical trainees are perceived to be sufficiently trained in their pertinent subspecialties of laparoscopic surgery. "Unfortunately, a recent Dukes' Club survey of colorectal trainees has stated that 85% felt that they would not be adequately trained or confident to independently perform a laparoscopic colorectal resection by the end of their higher surgical training."[5] These disappointing figures urge the surgical educators and trainees to explore gaps in laparoscopic surgery training and to recommend a unified training strategy that can produce safe and competent laparoscopic surgeons.[6]

A range of innovative surgical training tools are commercially available that can facilitate learners in acquiring their desired surgical armamentarium. Throughout the training period, there is a pressing need to ensure active participation of learners such as by placing information in a clinically meaningful context or by creating situations that facilitate deliberate practice.[7] The overarching goal is to make learning an active process rather than a passive engagement by learners. There is paucity of knowledge about the emerging and innovative tools for surgical training and education. At the same time, very few of the world-renowned laparoscopic surgery training and education centers apply a standardized surgical training curriculum for accreditation and validation of training programs. Every center has its own training agenda and protocol that is primarily driven by the available resources, surgical training tools, and expertise and legislative guidelines. This systematic review provides a deep insight into the merits and demerits of some modern surgical training tools and elaborates some of the existing laparoscopic surgery training programs worldwide.

STUDY DESIGN AND METHODOLOGY

Data sources

During November 2015, the databases of Educational Resources Information Center, the Web of Science, EBSCO and MEDLINE, and the Cochrane Library were searched using MeSH terms "Laparoscopic surgery" and "Surgical training" and "Surgical curriculum" and "fundamentals of endoscopic surgery (FES)" and "fundamentals of laparoscopic surgery (FLS)" and "Telementoring" and "Box trainer" for the full-text English language review and original articles published during 1995–2015. The preferred reporting items for systematic reviews and meta-analyses (PRISMA) was used for this research.[8,9] Data extraction was done using the eligibility criteria of selecting the original and review articles and by excluding the editorial articles, short communications, conference proceedings, personal view, and commentaries. The initial search yielded 211 results. Data synthesis and data analysis were undertaken by scrutinizing the initially retrieved articles. In cases of duplicate studies, only the latest article was included. Irrelevant articles and abstracts were excluded from this search. Differences between data results were resolved by discussions between two independent researchers and by reaching general consensus. Finally, 12 articles were selected for this systematic review. A schematic step-wise algorithm of short listing the final list of 12 articles is shown in Figure 1. The key characteristics of each article are shown in Table 1.

This systematic review lays down a blend of surgical educational tools in the first part and later, elaborates the effectiveness of accredited centers that can be used to measure surgical competence. In addition, several accredited surgical training and educational venues, available worldwide, are briefly described.

MODALITIES FOR SURGICAL EDUCATION

Numerous models for surgical education are available that can complement the accredited surgical residency programs worldwide. Some models for surgical education using modern cutting-edge technologies are elaborated hereunder.

Simulation-based surgical education

Several studies have reported that approximately 10% of the admitted patients develop some kind of unwanted surgical complications due to human error.[21-23] Traditionally, surgical education has been based on the popular "see one, do one,

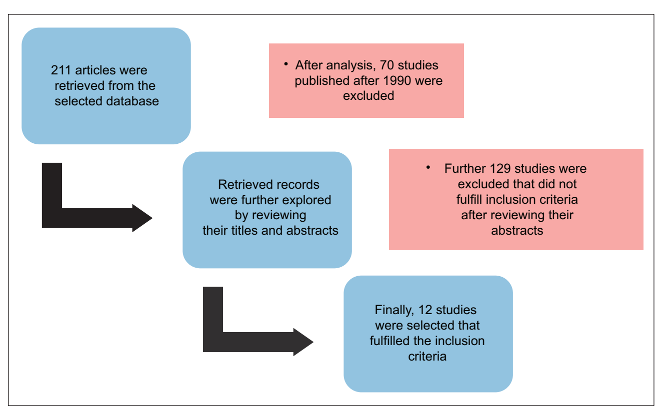

Figure 1: Schematic presentation of selection of studies about laparoscopic surgery training and education

Table 1: The key findings of the selected studies in this systematic review (*n*=12)

Number	References (publication year)	Location of study	Year of study	Key features of the study
1	Pugliese *et al*. (2015)[10]	Italy	2010-2013	Surgical training courses enhance the trainees' anatomical knowledge and manual dexterity Surgical trainees like hands-on training in operating room and tutoring by skilled colleagues for enhancing their surgical skills Modern surgical technologies have major role in skills acquisition
2	Forgione *et al*. (2015)[11]	Italy	2011	Well-structured clinical mini-fellowship programs can potentially foster the acquisition of surgical skills in novice surgeons This study endorsed the feasibility and effectiveness of a comprehensive theoretical and hands-on long-distance telementoring training program The mini-fellowship training programs including initial telementoring assistance can help trainees to start to perform advanced laparoscopic procedures in remote areas
3	Pena *et al*. (2015)[12]	Australia	2013-2014	A person's judgment to perform a specific task is driven by his self-efficacy Newly qualified surgeons and surgical trainees possess poor nontechnical skills Specific workshops dedicated to enhancing the surgeons' non-technical skills are highly recommended
4	Siddiqui *et al*. (2014)[13]	USA	2012	This study assessed the robotic surgical skill through five inanimate exercises as scored by three blinded judges The assessment sheet for evaluation of robotic surgical skill used in this study showed construct validity, inter- and intra-rater reliability Such evaluation instruments can reliably distinguish various levels of surgical competence
5	Crossley *et al*. (2011)[14]	UK	2008-2010	The NTSS specifically assess the desired nonsurgical skills of surgeons The trainees nontechnical skills are procedure dependent and can vary from one to other procedure There is an element of discrimination and bias inherent in NTSS
6	Hull *et al*. (2011)[15]	UK	2009-2010	Nonadherence to nontechnical and teamwork skills invariably lead to adverse events The OTAS tool is used to evaluate teamwork of the entire surgical team in the operating room This study proposed that OTAS is a psychometrically robust tool for evaluating the teamwork in operating room
7	Wyles *et al*. (2011)[16]	UK	2010	This study compared the perceptions of surgical trainees and trainers about the difficulties encountered during a simulation-based training event The trainees greatly underrated the peers and were able to recognize the procedure difficulties Cadaveric models were shown to carry higher fidelity and educational edge
8	Choy and Okrainec (2010)[17]	Canada	2010	With the advent of emerging surgical technologies, the surgical trainees need to acquire greater more skills in less time Minimally invasive and endoluminal surgical modalities demand the trainees to develop special set of psychomotor skills Simulation-driven laparoscopic surgery training programs are valuable training tools in improving trainees' psychomotor skills
9	Cottam *et al*. (2007)[18]	USA	2006	This study evaluated the effectiveness of a 6-week customized hands-on surgical training course The authors deduced that the training course markedly improved the surgical skills of the trainees in laparoscopic bariatric surgery skills
10	Rosser *et al*. (2007)[19]	USA	2002	Anecdotal remarks by trainee surgeons argue that video game play significantly improves laparoscopic surgery skills Surgical education programs should include video games that can thin the technical interface between surgeons and screen-mediated applications such as laparoscopic surgery Video games can be recognized as a valuable training tool for surgical residents

Contd...

Table 1: Contd...

Number	References (publication year)	Location of study	Year of study	Key features of the study
11	Munz *et al*. (2004)[20]	UK	2004	This study compared the virtual reality simulator with the classical box trainer on novice trainers In this cross-sectional study, the box trainer group performed substantially better than the LapSim group LapSim is effective in training for surgical skills with comparable results with real laparoscope
12	Scott *et al*. (2000)[2]	USA	1998-1999	Basic surgical skills' acquisition in operating rooms is inefficient and expensive Rigorous surgical training promotes video-eye-hand skills and results in better operative performance of trainee surgeons Surgical training program and curricula should embed laparoscopic surgical training

NTSS = Nontechnical skills for surgeons; OTAS = Observational teamwork assessment for surgery

teach one" approach.[24] This approach inadvertently exposes patients to inexperienced trainees that endangers their health and safety. Climbing the steep learning curve by surgical trainees can no longer be accomplished by trial and error, necessitating the need to explore, define, and implement surgical educational models that do not jeopardize patient safety.[25] One such model implies simulation that refers to "a technique to replace or amplify real-patient experiences with guided experiences, artificially contrived, that evokes or replicates substantial aspects of real world in a fully interactive manner."[26] Simulation has the potential to enhance experiential learning and patient safety, recreate scenarios that are rarely encountered,[17] and can assess the trainees' skills and competence in diverse situations.[27]

Two popular simulation-based models for surgical training are described.

Mechanical simulators

The mechanical simulators are boxes where objects or organs are placed and accessed using surgical instruments.[28] The trainers incorporate the conventional laparoscopic instruments and are primarily used by novice surgeons who start to learn laparoscopic skills. Synthetic materials as well as animal organs or tissues are used in this simulation model.[29] The quality of the tactile feedback is perceived to be the same as in the operating room (OR), and the surgical performance can be monitored by trained surgeons.

A study by Bonrath *et al*. compared the baseline laparoscopic skills of 24 novices by randomizing them in three groups: LapSim virtual reality simulator (VRS), mechanical box trainer, and no training (control).[20] After 3 weeks of training, all trainees were assessed for motion analysis and error scores. Both trained groups showed significantly improved scores in all domains under consideration.

Virtual reality simulators

The VRS recreates the OR environment without supervision or time constraints, allowing surgeons to acquire required skills with confidence at their own learning pace.[30] Modern VRSs such as the well-recognized MIST-VR and the newer LapSim (Surgical Science, Gothenburg Sweden) are equipped with abstract graphics and can create a high-fidelity simulation that can be used for both training and assessment.[20] These gadgets can recreate simple scenarios and clinical cases both for the instructors and trainees. Users can navigate through and interact with the environment using their natural senses and skills.[31] Currently available laparoscopic VRS software replicate tasks, such as cutting, grasping, and suturing, that help them acquire psychomotor skills essential to perform real-time procedures.[32,33]

Unfortunately, to date, the conclusive value of VRS in terms of its cost-effectiveness has not been determined.

Video games

Over the past two decades, the cultural and social significance of video games have been widely acknowledged.[34] Apart from numerous negative impacts of excessive game playing,[35,36] several studies have argued that video-gaming promotes spatial attention and hand-to-eye coordination.[19] Trainees experience technical challenges during laparoscopic surgery such as limited motion range of instruments, loss of depth perception, haptic feedback, and fulcrum effect.[37] Video games are cost-effective and can help the trainers develop cognitive skills.[38] Schlickum *et al*. probed the impact of prior gaming experience on the acquisition of laparoscopic surgical skills.[39] The study showed that systematic video game training significantly enhanced surgical competence in advanced virtual reality endoscopic simulators. Another study has reported that "medical students and experienced laparoscopic surgeons with continuing video game experience showed better laparoscopic skills for simulated tasks in terms of time to completion, improved efficiency, and fewer errors when compared to nongaming counterparts."[40]

Animal labs simulation

Animal models play significant role in surgical training, education, and research and facilitate the initial applications of innovative technique.[41] Live animal surgery remains the best training models, offering a high level of fidelity unmatched by other kinds of simulation models. Globally, the use of animal labs is accepted if there is no reliable substitute for training and education, however, stringent implementation of legislative protocol of Rs. 3: "Refine the procedure to limit suffering, Reduce the number of animals to a minimum, Replace the use of animals with nonanimal alternatives when appropriate" should be observed.[42] Simulations in animal labs are the only portals in surgical training that allow training on live tissues and learners can work in real OR-simulated situations.

Cadaveric labs simulation

Training of surgical skills on a cadaver offers the greatest anatomy realism for a surgical trainee before embarking on living human beings.[43] A study compared the human cadaver model with an augmented reality simulator for laparoscopic colorectal skills acquisition and argued that, although difficult, the human cadaver model was better appreciated than simulators for laparoscopic sigmoid colectomy.[44] The investigators proposed that simulator-based training followed by cadaver training can be conveniently integrated into surgical learning curve. Further technological refinements have introduced new cadavers with embalmed features and beating cadavers that can provide fundamental substrate for surgical education.[45]

Mini-fellowship surgical training programs

Studies have shown that focused mini-fellowship with hands-on operative and clinical sessions enables practicing surgeons to acquire the desired surgical competence that can allow to successfully implement a laparoscopic surgical practice.[18,46] Similarly, a mini-fellowship surgical training program was successfully employed at the Advanced International Mini-invasive Surgery (AIMS) Academy that included telementoring sessions in the remote area of Russia.[11] The overarching lesson from this program signifies that, for being a competent surgeon, the acquisition of technical skills is as important as the attainment of clinical knowledge. It is noteworthy that similar protocol can be employed for training the personnel from other surgical disciplines as well. Jenkins *et al*. studied a proficiency-based structured task-specific training program for the laparoscopic colorectal surgery.[47] The study applied training in a sequential manner by fragmenting complex laparoscopic colorectal procedures for each trainee and concluded that multi-modality training with modular operative strategy shortened the time to proficiency gain with low morbidity and an error rate of 25%.

Preceptoring and proctoring

Preceptoring is practiced when an experienced surgeon scrubs with the learner to guide the surgical procedure or is ready to intervene. On the other hand, a proctor is a supervisor who monitors surgery, gives advice, and intervenes when necessary. Preceptoring is often required before the trainee has acquired the desired surgical skills for a given procedure. Because of the escalating ethical and medicolegal issues, preceptoring allows training on patients while maintaining the standards set for patients safety.[48] Nevertheless, there is a need to implement guidelines and proctoring recommendations that can protect surgeons, proctors, institutions, and above all, the patients.[49] Medicolegal risks and patient safety should be considered while practicing such educational strategies.[50]

Telementoring

Telementoring entails "the process of remote guidance and technical assistance to surgical procedures, utilizing telecommunication techniques."[51] Telemedicine sweeps away distance barriers and can provide sufficient expertise to novices in remote rural areas. This innovative technology provides a high-definition profile of operative field, allows verbal communication between the mentor and mentee, and allows the trainer to point on the screen for further operative steps.[52] Since the mentoring process is not restricted by distance, the costs of formal mentoring programs may be reduced and remote assistance can be incorporated into formal training schedule.[53]

Forgione *et al*. developed a comprehensive theoretical and practical mini-fellowship program that incorporated telementoring mode of training at the AIMS Academy at Milan, Italy.[11] AIMS Academy is equipped with the state-of-the-art videoconference tools and high-definition projectors that can conveniently connect this center with rest of the world. A Russian surgeon, after successfully passing the required theoretical and skills landmarks at AIMS, was telementored from Milan, Italy, to Northern Medical Clinical Centre Arkhangelsk Russia, 2868 km from Milan. Several other successful telementoring training events have been reported from across the world.[54-56]

Telerobotic manipulation and assistance

Using Zeus TS microjoint system (Computer Motion Inc., Santa Barbara, CA, USA), an expert robotic surgeon can provide telepresence for trainee surgeons in rural and remote areas across the world. The telerobotic expert can guide intraoperatively at a remote site, looking at the same images as the primary surgeons, as both are located outside the surgical field.[57] The primary goal of this modern strategy for surgical training is to enable local surgeons to perform a range of robotic surgical cases to gain sufficient expertise with the assistance of an expert surgeon. However, as a prerequisite, the trainee surgeon should be first trained in basic and advanced laparoscopic procedures by short courses and training for mentoring and telementoring applications. Anvari *et al*. established the world first remote telerobotic surgical service by providing advanced laparoscopic surgical services in rural community.[57] As many as 21 telerobotic laparoscopic operations were performed without any intraoperative complication. The investigators have argued that refinements in the robotic and telecommunication technology would provide a platform for routine use of the state-of-the-art laparoscopic surgical services in rural communities.

The salient features of all the aforementioned surgical educational modalities along with their merits and demerits are outlined in Table 2.

OBJECTIVE MEASUREMENT OF TECHNICAL AND NONTECHNICAL SURGICAL SKILLS: A FUNDAMENTAL ELEMENT OF MODERN SURGICAL TRAINING PROGRAMS

Objective structured assessment of technical skill

There has always been low validity and reliability by subjective assessment of any skill and competence. This is mainly attributed by variations in understanding, expectations, and differing parameters applied by various assessors. On the contrary, objective assessment carries a stringent pathway with no room for personal judgment by the assessors. Objective structured assessment of technical skill (OSATS) is a valuable objective assessment tool that can provide both an overall and in-detail evaluation of open surgical skills.[58] This process contains standard assessment forms with predefined criteria indicating how to score performance on a technical skill. "Compared to traditional surgical evaluations, OSATSs allow for less biased assessments of technical performance and have demonstrated validity and reliability."[13]

Fundamentals of laparoscopic surgery

FLS, a joint venture by Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) and the American College of Surgeons, has been developed to teach and assess the knowledge, judgment, and skills inherently required for laparoscopic surgery.[59] The program of FLS meets the required standards of inter-rater and test–retest reliability as well as internal consistency that are fundamental to a valid assessment strategy. A physical endotrainer box simulator is used for assessment.[60] During assessment, each designated action is ranked using measures of efficiency (time) and precision, with negative marking for errors. A trained proctor supervises this process and awards marks to each task. FLS offers a cheap as well as complete learning protocol for teaching laparoscopic surgery with an added advantage of a validated assessment strategy.[61]

Fundamentals of endoscopic surgery

Flexible endoscopy is a key domain of surgical services. Surgeons perform upper and lower gastrointestinal endoscopy as part of preoperative work-up, for intraoperative evaluation and postoperatively to identify the anatomic changes induced by surgical intervention.[62] FES is a comprehensive educational tool that includes (a) web-based didactic component of flexible endoscopy, (b) written multiple choice exam (cognitive component), and (c) a 5-module virtual reality skills examination (hands-on component).

Fundamental skills for robotic surgery

Fundamental skills for robotic surgery has been validated as an effective, feasible, and structured curriculum that demonstrates its effectiveness by significant improvements in basic robotic surgery skills.[63] This incorporates a simulation-based robotic curriculum that can be

Table 2: Advantages and disadvantages of the commercially available surgical training models

Surgical training model	Advantages	Disadvantages
Mechanical simulator	Reproducible Standardized Training of isolated skills Cheap	No high fidelity No tissue rendering
Virtual reality simulator	Performance of real operations Evaluation of isolated skills Instant objective feedback	Expensive Questionable software and interface reliability
Animal lab	Easy availability Good tissue handling	Ethical issues Expensive
Cadaver lab	High fidelity Same anatomy (included individual variation) No time pressure	Ethical issues Limited availability Noncompliant bloodless tissues
Telementoring	Exact anatomy Realistic bleeding Real or setting Independence of first operator	Requires another surgeon throughout surgery Expert surgeon cannot operate directly
Telerobotic assistance	Exact anatomy Realistic bleeding Real or setting	Expensive Requires another surgeon throughout surgery Pressure of training

conveniently embedded in surgical training and educational programs.

Measuring nonsurgical skills: The nontechnical skills for surgeons

A growing body of literature has shown that surgeons' intraoperative nontechnical skills are strongly correlated with surgical outcomes.[14,15,64] Breakdowns in surgeon's behavior in the OR negatively affect nontechnical characteristics such as teamwork, leadership, communication, confidence, and decision-making.[65] Lack of such cognitive and interpersonal skills inadvertently leads to surgical errors and high compensation payouts.[66,67] Education and assessment of nontechnical skills in surgery leads to enhanced surgeons' performance in the OR that will improve quality as well as patient safety.[12,68] Surgical educators are gradually involving virtual and E-learning tools in surgical training and the distance learning arm of these modalities makes E-learning more attractive and feasible.

TRAINEES' PERCEPTIONS OF SURGICAL EDUCATION TOOLS AND STRATEGIES

It is imperative to deeply understand the preferred resources of surgical education as desired by the surgical trainees.[69] Guraya *et al*. explored the preferred learning resources of the participants attending surgical courses at the AIMS Academy during 2010–2013 and found that a great majority of respondents (467/636; 73%) preferred "direct experience in the OR" as their favorite educational resource, followed by "tutoring by skilled trainer" by 426/636 respondents.[10] The study had concluded that surgical trainees preferred hands-on training and mini-fellowship courses for enhancement of their surgical skills.

In view of these findings, surgical educators can utilize a myriad of training tools for the purpose of imparting knowledge and skills to surgical trainees. Depending on the available resources and expertise, varying combinations and extent of the described surgical tools can be embedded into the training programs of a given surgical specialty. In the later section of this article, some popular models for surgical training are described.

STATE-OF-THE-ART SURGICAL TRAINING AND EDUCATION CENTERS

Numerous centers dedicated to surgical education and training are available worldwide. The most popular training centers across the world are outlined in Table 3. The l'Institut de Recherche contre les Cancers de l'Appareil Digestif (IRCAD) offers the opportunity to train with animals, while the UK centers use cadavers, as animal surgical training is forbidden. The AIMS Academy is a state-of-the-art training venue for hands-on surgical training along with the opportunity for in-campus and telementoring laparoscopic surgery courses and fellowship programs.

Table 3: World's most popular surgical training and education centers

Training centre	Country
IRCAD	Strasbourg, France Taichung, Taiwan Barretos, Brasil
AIMS	Milan, Italy
MATTU Centre	Guilford, UK
Cushieri's Skills Centre	Dundee, UK
MITIE	Houston, USA
Centre for the Future of Surgery	San Diego, USA
European Surgical Institute	Norderstedt, Germany

IRCAD = l'Institut de Recherche contre les Cancers de l' Appareil Digestif; AIMS = Academy for Int'l Minimally Invasive Surgery; MATTU = Minimal Access Therapy Training Unit; MITIE = Methodist Institute for Technology, Innovation and Education

The major online resources for surgical education and training are provided by WebSurg, SAGES Online, European Association for Endoscopic Surgeons, and American Society for Gastrointestinal Endoscopy. WebSurg is an international E-learning website offering first-rate educational content in all fields of minimally invasive surgery provided by world-renowned experts. This E-learning platform hosts a repository of virtual library containing high-quality videos from expert laparoscopic surgeons across the world. Using a blend of educational tools, structured training programs can provide accredited surgical training to residents.

CONCLUSION

In view of the escalating concerns about patient safety and quality control in surgery, there is an ever-increasing need for modifications and interventions in surgical training. These objectives can be successfully achieved by complementing traditional training with teaching, training, and assessment of laparoscopic skills outside the OR. The surgical residents would get their validated and accredited training for certifications while established surgeons will be able to update and refresh their surgical knowledge and skills. A myriad of surgical training tools can help complement the surgical training and education. Owing to ethical and medicolegal issues, the usage of both animal and cadaver models can be gradually replaced by virtual simulators. Virtual surgical simulators represent the futuristic educational bridge between *ex vivo* and *in vivo* surgical training. Several state-of-the-art surgical institutions such as IRCAD, AIMS Academy, and Minimal Access Therapy Training Unit offer promising resources for surgical training and accrediting the trainees' performance. However, these centers are employing different tools and modalities each with some advantages and some disadvantages. Hence, at the moment, we cannot recommend a single superior model for surgical training and assessment.

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Conflicts of interest

There are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

AF contributed in the conception of the work, conducting the study, revising the draft, approval of the final version of the manuscript. SYG contributed in the conception of the work, performed literature review and data synthesis using PRISMA guidelines, drafting and revising the draft, approval of the final version of the manuscript. Both authors approved all aspects of this research.

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