Editor
David Chen

Senior Editor
Justin Smith

Proofreader
Alistair Lau

Senior Proofreader
Emily Feng-Gu

Date of submission: 25 March 2020

Date of acceptance: 5 September 2020

Date of online publication: 10 September 2020

Review Article

Simulation training in laparoscopic surgery

Daisy Lu
BMedSc (Hons) BMedSc/MD
Five-year degree, currently in fifth year.
Monash University
Student

A/Prof. Alex Ades
MBBS MD PhD FRANZCOG
Consultant Minimally Invasive Gynaecological Surgeon
Epworth Hospital and Royal Women's Hospital
Associate Clinical Professor, University of Melbourne

Dr. Pavitra Nanayakkara
MBBS/BMedSc (Hons) MRANZCOG MRMed (Hons)
Fellow in Minimally Invasive Gynaecological Surgery
Epworth Hospital

Corresponding Author
Daisy Lu
Monash University
Email address: daisylu878@gmail.com

Source of submission
Prepared specifically for AMSJ.

Summary
This article summarises the role of simulation-based training in laparoscopic surgery, exploring elements for curriculum development, implementation, and current practice.

Keywords
simulation, laparoscopy, education

Number of tables: 1
Number of figures: 1
Word count: 2857

Abstract

Introduction

This article summarises the evidence surrounding the development of simulation-based training curriculums in laparoscopic surgery.

Summary

Laparoscopic or "keyhole" surgery involves the use of small incisions and delicate instruments to perform abdominal surgery. This minimally invasive procedure has significant benefits in patient outcomes over open surgery. However, the learning curve for acquiring skills in laparoscopy differs from open surgery, primarily due to the greater requirements for manual dexterity and coordination. Additionally, the transference of skills from open to laparoscopic surgery is minimal, indicating the need for new methods of training. There has been a growing body of research to suggest that simulation-based training can supplement the early portion of the learning curve for acquiring laparoscopic skills and is most effective if delivered in a structured course. Yet, there is still no standardised laparoscopic simulation course in Australia nor a framework for curriculum development. This review explores current evidence surrounding the development and implementation of simulation-based education curriculums in laparoscopic surgery.

Learning points

- Simulation is a tool that can supplement the early portion of the learning curve in laparoscopic surgical training.
- The development of a laparoscopic simulation curriculum should involve the consideration of simulation modality, cost, transfer of skills into the operating theatre, and long-term retention.
- Further high-powered, long-term trials are needed to characterise how to optimise these elements in a training curriculum.

Introduction

Simulation is a technique used to "replace or amplify real experience with guided experiences, often immersive in nature, that evoke or replicate substantial aspects of the real world in a fully interactive fashion" [1]. Advancements in medical technology and restrictive work hours, have seen a shift in Halsted's traditional "see one, do one, teach one" training paradigm and simulation training is becoming widely adopted within the medical field [2].

Simulation has long been a core component of training in other high-risk professions, including training of pilots and military personnel. In healthcare education, simulation is used to recreate the clinical and intraoperative experience. Due to an increasing number of medical graduates and pressure for reduced work hours, trainees have less exposure to patients than previous generations [3]. Didactic lectures, case-based learning, and direct supervision are insufficient replacements for clinical experience, particularly in surgical specialties [3]. Although trainees' quality of life has improved, opportunities to develop proficiency in skills has become limited, and there is an increasing need to train outside of direct clinical exposure [3]. Simulation training allows for deliberate practice and immediate feedback, facilitating skill acquisition in a safe environment before moving into the operative field; this is particularly true in procedures that require advanced technical skills such as laparoscopic surgery [4].

Laparoscopic surgery has brought benefits to both the patient and surgeon including shorter operation time and improved patient outcomes such as quicker recovery, smaller wounds, reduced rates of infection, and less pain [5]. The learning curve of laparoscopic surgery differs from open surgery, due to the higher requirement for manual dexterity, hand-eye coordination, and adaption to the fulcrum effect [6]. Consequently, the technical skills acquired from open surgical experience has limited transference to minimally invasive techniques [6].

Simulation training can supplement the early portion of the learning curve and a structured curriculum can further shorten the learning curve inside the operating room [4, 7]. Randomised control trials show that residents who received a simulation-based laparoscopy curriculum before entering the operating theatre had fewer errors and improved performance when compared to those who received conventional training [4]. A 2013 systematic review showed that simulation training for laparoscopic skills was significantly more effective than standard training, regardless of study design, previous experience of participants, outcomes tested, or specific skills measured [8].

Laparoscopy is preferred over open surgery when possible, but with the difficult learning curve, it is both unsafe and time-consuming to begin by practicing on real patients. Simulation training is an advantageous method for training in laparoscopy, with a strong body of supporting evidence. Despite this, there is no standardised laparoscopic simulation curriculum in Australia, likely a result of multiple factors including costs, lack of infrastructure, and limited understanding of how best to integrate the technology into practice. The development of such a curriculum should be evidence-based, to optimise the different components of training and maximise its benefits. This review explores current evidence surrounding the development and implementation of simulation-based education curriculums in laparoscopic surgery. The authors hope that by raising awareness of the benefits of such a curriculum, training centres may be encouraged to implement such programs, and trainees may be more inclined to pursue these.

Simulation modalities

Multiple modalities exist for simulated training. Traditionally, animal models and human cadavers were used to simulate disease and practice laparoscopic techniques [9]. However, animal models differ from human anatomy, and whilst cadaveric models are the closest replication of reality, they are both costly and are limited in availability. Box trainers and virtual reality simulators present a new method of training technique [10, 11].

Box trainers

Box trainers present a simple, low-cost method for training basic laparoscopic skills, including suturing and knot tying [10]. Synthetic materials or animal tissues are placed inside the box; performance is captured by a laparoscope and viewed in real-time on an external monitor (Figure 1A). In a Cochrane systematic review of surgical trainees with no prior laparoscopic experience, box trainers improved time to task completion and reduced errors when compared to no training [10]. However, the majority of studies on the efficacy of this modality are limited to small, short-term, single-centre trials that are prone to bias, and many of which are difficult to compare in method and outcomes measured [10].

Virtual reality

Virtual reality (VR) training uses computer-generated simulations and specially designed laparoscopic arms to simulate laparoscopic surgery (Figure 1B). There are multiple systems available to facilitate the training of basic skills to entire operations [11]. VR training has been validated by the landmark randomised controlled trial by Seymour *et al.*, which demonstrated that VR simulation improved operating room performance in laparoscopic cholecystectomies [12]. Since then, there has been a growing body of research exploring the integration of VR training into the surgical curriculum.

Comparing box trainer and VR training

There is no consensus on the best simulation training in laparoscopic surgery; both box and VR simulators have their advantages (Table 1). Some evidence favours box trainers as an equally if not more effective and more feasible training option than VR training [8]. A recent meta-analysis of 14 randomised controlled trials showed that VR was significantly more efficient than box trainers in improving the time to complete the peg transfer task [13]. In all other areas, including performance scores for basic skills and advanced tasks, box trainers and VR were equivalent [13]. This marginal improvement questions whether the cost of VR is justified by its additional benefit. Again, there is a significant gap in the evidence exploring the impact on clinical outcomes between these two modalities.

Interestingly, some studies show that skills learned on box trainers are transferrable to VR simulators, but not all skills learned on VR training can be transferred to box trainers [14]. This suggests that VR allows for the acquisition of skills that cannot be learned on the bench-top models alone. However, this also represents a concept that can be transferred to multimodal models for training; which trainees can begin with box trainers and transition to VR simulators with more complex tasks. Unfortunately, one of the biggest gaps in the literature is the cost-effectiveness and long-term clinical benefit of both interventions. Additionally, the majority of trials investigating the efficacy of simulation training in laparoscopy are single centre studies involving small sample sizes, and often use different methodologies and outcome measures [10, 13, 15]. There remains a need for larger, multi-centre trials, and consistent standardised methodology to allow for better comparison. Importantly, there seems to be one consensus in the literature and that is either modality is better than no simulation training at all [8, 10, 15].

Considerations for practice

Certain elements need to be considered when developing a curriculum. This article explores the transfer of skill into the operating theatre, cost, and factors that influence long-term retention.

Transfer of skill

In laparoscopic surgery, the transfer of skills from simulation to the intraoperative environment is incomplete. Residents trained to the same level of proficiency as experienced surgeons in the simulation laboratory, do not translate to equal proficiency in the operating room [16]. Addressing this performance gap is important when considering the transition between the simulator and operative environment, thus identification of factors contributing to these factors and developing an intermediary platform is warranted. The gradual incrementation of real-life intraoperative tasks alongside simulation training, beginning with basic skills and progression to complete procedures, may aid this transition.

A major barrier for transfer is that intraoperative performance is not determined by technical proficiency alone, but is also combined with surgical judgment, quick decision-making skills, aptitude, temperament, and background of experience gained so far by the trainee. The global operative assessment of laparoscopic skill (GOALS) was developed and the objective structured assessment of technical skill (OSATS) scoring systems was adapted for objective assessment in laparoscopic surgery [17, 18]. However, these systems purely test technical skills, and do not assess non-technical skills such as surgical judgment. In real operations, anatomical variations and unplanned complications require quick decision-making skills from the attending surgeon [19]. This ability to adapt and use intuitive judgment is underdeveloped in novice surgeons [19]. In laparoscopic simulation training, we still lack an objective method of teaching and assessing intraoperative judgment.

Another reason for incomplete transfer of skills pertains to differences in the training environment and the distracting conditions of realistic clinical practice. Studies that incorporate the addition of realistic distractions, such as noise, into the design model showed improved surgical proficiency in the operating room [20]. Another hypothesis is that increased stress impacts laparoscopic skills transfer. Arora *et al.* established the empirical link between stress and psychomotor performance on a VR simulator. They found that higher levels of stress, measured by heart rate, salivary cortisol, and an anxiety inventory, correlated with the number of errors [21]. The transition from the laboratory to the real intraoperative environment is difficult, stressful, and leads to an incomplete transfer of skill [21]. Indeed, it seems simulation alone is not sufficient to adequately train laparoscopic surgeons to expert proficiency.

Cost

Cost is a barrier in the uptake of simulation training in laparoscopic surgical programs and laparoscopic surgery, particularly in less developed nations. This is largely due to the lack of a long-term funding structure to support the maintenance of laparoscopic facilities and equipment, trained supervisors and staff, and costs of resource utilisation [22]. The development of low-cost programs is therefore an incredibly important aspect to improve access to sustainable minimally invasive surgery.

A step-wise approach is the most time and cost-efficient way of training laparoscopic surgeons [7]. Learning basic laparoscopic skills shortens the learning curve for more complex tasks with subsequent cost savings on materials and supervising personnel salary [7]. Additionally, learning tasks through a series of step-wise advances reduces the amount of time needed to learn the full task [23]. This suggests that a training curriculum involving a multistage progressive approach is substantially more time-efficient and likely more cost-effective.

Some evidence supports the effectiveness of video tutorials in teaching laparoscopic techniques and optimising learning on simulator trainers [24]. Video tutorials minimise the need for supervision and thus reduce the costs associated with supervision salary [24]. However, video learning alone is not as effective as simulators in skill acquisition processes [8]. Combining video tutorials and simulator training may optimise cost reduction without sacrificing the quality of skill development.

Long-term retention

The decay of acquired surgical skills and subsequent need for retraining represents a significant but potentially avoidable cost burden. Whilst short-term training can be effective in acquiring proficiency in basic laparoscopic skills, these skills are likely to decay over time [25, 26].

One of the proposed methods for improving long-term retention is spaced training sessions, deemed the “spacing effect” [25]. A recent systematic review showed that the spacing effect in surgical skills programs improved long-term retention when compared to mass learning [25]. However optimal duration and frequency of practice between each training session are unclear, and there is minimal evidence on the impact of spaced training on current programs and the cost-effectiveness of spaced programs.

Simulation modality and skill type may also affect retention. Box trainers have been shown to lead to more consistent retention of basic laparoscopic skills six months post-training when compared to VR simulators [27]. Additionally, different skills seem to deteriorate quicker than others and may require more frequent sessions [26]. This suggests curriculum adaptions need to be made between different skills, as well as different modalities of training, to maximise long-term retention.

Ongoing training is also shown to aid the maintenance of skill proficiency. Adding maintenance training sessions has been shown to not only reduce skill loss but also improve performance [28]. Although there is no consensus yet on how best to structure these post-training intervals in the literature; there is support for monthly [28], three-monthly [29], and biannual [30] training sessions. A higher number of repeat practices have also been shown to improve the speed of task completion, without sacrifice in precision, accuracy, and performance [14]. If improvement in task time translates to clinical practice, this could potentially reduce operative time, shorten hospital stay, and further reduce the risk of infection from prolonged exposure. Others argue it is not the number of practices but rather "deliberate practice" which leads to the most improvement. Deliberate practice is a theoretical framework proposed by Ericsson and colleagues describing the actions for optimal learning to reach expert performance, including motivated learners, focused tasks, feedback, and area for repetition to refine performance [31]. A combination of simulation-based training and deliberate practice is suggested to be most beneficial, particularly in virtual reality-based curriculums [32].

The difficulty in studying long-term retention of skills is in part due to the high number of non-completers, withdrawals, and loss to follow up. This combined with the niche study population and small sample sizes make it difficult to establish high-powered results. There is a need for high-powered, long-term trials to truly characterise effective methods of improving long-term retention in laparoscopic surgical trainees.

Timing of training delivery

Multiple factors influence the suggested timing of laparoscopic simulation in the surgical curriculum. This includes, but is not limited, many of the components previously mentioned in this article; including trainee experience levels, the availability and flexibility of facilities, the availability of training staff, and the opportunity to practice in the intraoperative environment. In trials assessing simulation training for basic laparoscopic skills, the target population has predominantly consisted of surgical trainees in their early postgraduate years, with some studies investigating medical students [13]. Studies involving more difficult and specialised techniques, including multistep procedures, have targeted advanced trainees [13]. Simulation training can, therefore, support the acquisition of skill at all training levels. However, it is not sufficient alone; laparoscopic simulation training should be strategically implemented alongside real-life intraoperative experience to utilise the technology to its fullest potential.

Current curriculums

In Australia, there is no standardised national curriculum for training basic laparoscopic skills. Instead, laparoscopic surgery forms a component of the specialty-specific logbooks as part of the competency-based assessment [33]. Whilst there are some specialty accredited short courses and workshops that utilise simulation training to teach basic laparoscopic techniques, the evidence for these courses are often limited to small, single-centre studies [34]. Consequently, a simulation-based curriculum for laparoscopic surgery, with a strong evidence base and robust evaluation, is lacking in Australia and needs development.

Currently, the only standardised laparoscopic training curriculum is the Fundamentals in Laparoscopic Surgery (FLS) certification in the United States, developed by the

Society of American Gastrointestinal and Endoscopic Surgeons (SAGES). Introduced over a decade ago, FLS is a board certification and pre-requisite for general surgery residency training in the United States [35]. FLS comprises online education modules, hands-on box model training, and examination testing both cognitive and motor skills. Despite the widespread acceptance of the FLS certification in the United States, the program still has its limitations. First, there is little evidence on the impact on patient outcomes, likely because FLS was only adopted recently as the gold standard for general residency board certification [36]. Secondly, the significant costs associated with implementing the program may not be feasible in low-income countries. Solutions presented for this issue are to cut costs by replacing dedicated human and material resources in specific tasks and using lower-cost equipment [37]. However, the lower cost adapted simulators are not as validated in the literature as the commercially available simulators. This highlights how simulation in laparoscopic surgery is also driven by industry; the widespread dissemination and testing of simulation technology, such as the FLS, is central to its implementation into the surgical training curriculum. Thirdly, there is currently no recommended time for residents to undertake the examination for the FLS certification. Although increased success rates for successful certification are associated with a more senior level of training, there is no current recommended time for application [36]. Lastly, although the FLS program was initially intended to apply to multiple surgical specialties, the literature suggests the FLS is not universally applicable. For example, in gynaecology, FLS falls short in the cognitive skills and testing [38]. Researchers have begun to develop a tailored curriculum for this specialty [39]. However, FLS is the only program to date to be extensively investigated in the literature. Consequently, FLS has the highest validity compared with other programs, which are by contrast still in their infancy.

Conclusion

Simulation is recognised as an important component of surgical training in the current landscape. This is particularly relevant in the acquisition of the necessary psychomotor skills in minimally invasive surgery. Within the last two decades, there has been an overwhelming amount of research supporting the efficacy of simulation in laparoscopic training. We are now transitioning from the phase of ‘if we should’ to ‘how we should’ integrate this into practice. This paper has discussed several factors that should be considered during the development of a training curriculum, including method of simulation, transfer to the operating theatre, cost implications, and improving long term retention. There is a need for further analysis into cost-effectiveness, long-term and larger trials, and a more rigorous standardised method for trials to be adequately compared. Regardless, it is clear that the era of “see one, do one, teach one” is over; now is the time for “see some, simulate some, do some, teach some”.

Acknowledgements
The author would like to acknowledge Dr. Pavitra Nanayakkara and A/Prof. Alex Ades for their guidance and support with this paper.

Conflicts of interest
None declared.

Funding
None declared.

Authors Contribution
P.N. and A.A. devised the original concept, provided critical revisions, and supervised this project. D.L. wrote and revised the manuscript.

References

[1] Gaba DM. The future vision of simulation in health care. *BMJ Qual Saf.* 2004;13:i2-i10.

[2] Scott DJ, Dunnington GL. The new ACS/APDS skills curriculum: moving the learning curve out of the operating room. *J Gastrointest Surg*. 2008;12(2):213-21.

[3] Lindeman BM, Sacks BC, Hirose K, Lipsett P. Duty hours and perceived competence in surgery: are interns ready? *J Surg Res*. 2014;190:16-21.

[4] Palter VN, Orzech N, Reznick RK, Grantcharov TO. Validation of a structured training and assessment curriculum for technical skill acquisition in minimally invasive surgery: a randomized controlled trial. *Ann Surg*. 2013;257(2):224-30.

[5] Zullo F, Falbo A, Palomba S. Safety of laparoscopy vs laparotomy in the surgical staging of endometrial cancer: a systematic review and metaanalysis of randomized controlled trials. *Am J Obstet Gynecol*. 2012;207(2):94-100.

[6] Figert PL, Park AE, Witzke DB, Schwartz RW. Transfer of training in acquiring laparoscopic skills. *J Am Coll Surg*. 2001;193(5):533-7.

[7] Stefanidis D, Hope WW, Korndorffer JR, Markley S, Scott DJ. Initial laparoscopic basic skills training shortens the learning curve of laparoscopic suturing and is cost-effective. *J Am Coll Surg*. 2010;210(4):436-40.

[8] Zendejas B, Brydges R, Hamstra SJ, Cook DA. State of the evidence on simulation-based training for laparoscopic surgery. *Ann Surg*. 2013;257(4):586-93.

[9] Sutherland LM, Middleton PF, Anthony A, Hamdorf J, Cregan P, Scott D, et al. Surgical simulation: a systematic review. *Ann Surg*. 2006;243(3):291.

[10] Nagendran M, Toon CD, Davidson BR, Gurusamy KS. Laparoscopic surgical box model training for surgical trainees with no prior laparoscopic experience. *Cochrane Database Syst Rev*. 2014(1).

[11] Alaker M, Wynn GR, Arulampalam T. Virtual reality training in laparoscopic surgery: a systematic review & meta-analysis. *Int J Surg*. 2016;29:85-94.

[12] Seymour NE, Gallagher AG, Roman SA, O'brien MK, Bansal VK, Andersen DK, et al. Virtual reality training improves operating room performance: results of a randomized, double-blinded study. *Ann Surg*. 2002;236(4):458.

[13] Guedes HG, Ferreira ZMCC, de Sousa Leao LR, Montero EFS, Otoch JP, de Almeida Artifon EL. Virtual reality simulator versus box-trainer to teach minimally invasive procedures: a meta-analysis. *Int J Surg*. 2019.

[14] Mulla M, Sharma D, Moghul M, Kailani O, Dockery J, Ayis S, et al. Learning basic laparoscopic skills: a randomized controlled study comparing box trainer, virtual reality simulator, and mental training. *J Surg Educ*. 2012;69(2):190-5.

[15] Nagendran M, Gurusamy KS, Aggarwal R, Loizidou M, Davidson BR. Virtual reality training for surgical trainees in laparoscopic surgery. *Cochrane Database Syst Rev*. 2013(8).

[16] Crochet P, Agostini A, Knight S, Resseguier N, Berdah S, Aggarwal R. The performance gap for residents in transfer of intracorporeal suturing skills from box trainer to operating room. *J Surg Educ*. 2017;74(6):1019-27.

[17] Vassiliou MC, Feldman LS, Andrew CG, Bergman S, Leffondré K, Stanbridge D, et al. A global assessment tool for evaluation of intraoperative laparoscopic skills. *Am J Surg*. 2005;190(1):107-13.

[18] Martin J, Regehr G, Reznick R, Macrae H, Murnaghan J, Hutchison C, et al. Objective structured assessment of technical skill (OSATS) for surgical residents. *Br J Surg*. 1997;84(2):273-8.

[19] Pugh C, Plachta S, Auyang E, Pryor A, Hungness E. Outcome measures for surgical simulators: is the focus on technical skills the best approach? *Surg*. 2010;147(5):646-54.
[20] Szafranski C, Kahol K, Ghaemmaghami V, Smith M, Ferrara JJ. Distractions and surgical proficiency: an educational perspective. *Am J Surg*. 2009;198(6):804-10.
[21] Arora S, Sevdalis N, Aggarwal R, Sirimanna P, Darzi A, Kneebone R. Stress impairs psychomotor performance in novice laparoscopic surgeons. *Surg Endosc*. 2010;24(10):2588-93.
[22] Choy I, Kitto S, Adu-Aryee N, Okrainec A. Barriers to the uptake of laparoscopic surgery in a lower-middle-income country. *Surg Endosc*. 2013;27(11):4009-15.
[23] Dubrowski A, Park J, Moulton C-a, Larmer J, MacRae H. A comparison of single-and multiple-stage approaches to teaching laparoscopic suturing. *Am J Surg*. 2007;193(2):269-73.
[24] Stefanidis D, Korndorffer JR, Heniford BT, Scott DJ. Limited feedback and video tutorials optimize learning and resource utilization during laparoscopic simulator training. *Surg*. 2007;142:202-6.
[25] Cecilio-Fernandes D, Cnossen F, Jaarsma DADC, Tio RA. voiding surgical skill decay: a systematic review on the spacing of training sessions. *J Surg Educ*. 2018;75(2):471-80.
[26] Sinha P, Hogle NJ, Fowler DL. Do the laparoscopic skills of trainees deteriorate over time? *Surg Endosc*. 2008;22(9):2018-25.
[27] Khan MW, Lin D, Marlow N, Altree M, Babidge W, Field J, et al. Laparoscopic Skills Maintenance: A Randomized Trial of Virtual Reality and Box Trainer Simulators. *J Surg Educ*. 2014;71(1):79-84.
[28] Stefanidis D, Korndorffer Jr JR, Markley S, Sierra R, Scott DJ. Proficiency maintenance: impact of ongoing simulator training on laparoscopic skill retention. *J Am Coll Surg*. 2006;202(4):599-603.
[29] Van Bruwaene S, Schijven MP, Miserez M. Maintenance training for laparoscopic suturing: the quest for the perfect timing and training model: a randomized trial. *Surg Endosc*. 2013;27(10):3823-9.
[30] Wenger L, Richardson C, Tsuda S. Retention of fundamentals of laparoscopic surgery (FLS) proficiency with a biannual mandatory training session. *Surg Endosc*. 2015;29(4):810-4.
[31] Ericsson KA. Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. *Acad Med*. 2004;79(10):S70-S81.
[32] Palter VN, Grantcharov TP. Individualized deliberate practice on a virtual reality simulator improves technical performance of surgical novices in the operating room: a randomized controlled trial. *Ann Surg*. 2014;259(3):443-8.
[33] RANZCOG. Guidelines for performing gynaecological endoscopic procedures C-Trg 2. Accessed from: https://ranzcog.edu.au/statements-guidelines: *The Royal Australian and New Zealand College of Obstetricians and Gynaecologists*; 2019 [cited 2020 31 March].
[34] Janssens S, Beckmann M, Bonney D. Introducing a laparoscopic simulation training and credentialing program in gynaecology: an observational study. *Aust N Z J Obstet Gynaecol.* 2015;55(4):374-8.
[35] Peters JH, Fried GM, Swanstrom LL, Soper NJ, Sillin LF, Schirmer B, et al. Development and validation of a comprehensive program of education and assessment of the basic fundamentals of laparoscopic surgery. *Surg*. 2004;135(1):21-7.

[36] Okrainec A, Soper NJ, Swanstrom LL, Fried GM. Trends and results of the first 5 years of fundamentals of laparoscopic surgery (FLS) certification testing. *Surg Endosc*. 2011;25:1192-8.

[37] Franklin BR, Placek SB, Wagner MD, Haviland SM, O'Donnell MT, Ritter EM. Cost comparison of fundamentals of laparoscopic surgery training completed with standard fundamentals of laparoscopic surgery equipment versus low-cost equipment. *J Surg Educ*. 2017;74(3):459-65.

[38] Zheng B, Hur H-C, Johnson S, Swanström LL. Validity of using Fundamentals of Laparoscopic Surgery (FLS) program to assess laparoscopic competence for gynecologists. *Surg Endosc*. 2010;24(1):152.

[39] Shore EM, Grantcharov TP, Husslein H, Shirreff L, Dedy NJ, McDermott CD, et al. Validating a standardized laparoscopy curriculum for gynecology residents: a randomized controlled trial. *Am J Obstet Gynecol*. 2016;215(2):204. e1-. e11.

[40] Shetty S, Zevin B, Grantcharov TP, Roberts KE, Duffy AJ. Perceptions, training experiences, and preferences of surgical residents toward laparoscopic simulation training: a resident survey. *J Surg Educ*. 2014;71(5):727-33.

[41] Yiasemidou M, de Siqueira J, Tomlinson J, Glassman D, Stock S. "Take-home" box trainers are an effective alternative to virtual reality simulators. *J Surg Res*. 2017;213:69-74.

[42] Steigerwald SN, Park J, Hardy KM, Gillman LM, Vergis AS. Does laparoscopic simulation predict intraoperative performance? a comparison between the fundamentals of laparoscopic surgery and lapvr evaluation metrics. *The Am J Surg*. 2015;209:34-9.