**Name of journal:** World Journal of Gastrointestinal Surgery

**ESPS Manuscript NO: 19466**

**Manuscript Type: MINIREVIEWS**

**Need for simulation in laparoscopic colorectal surgery training**

Celentano V. Simulation in colorectal surgery

Valerio Celentano

**Valerio Celentano,** Colorectal Unit, Federico II University, 80131 Naples, Italy

**Author contributions:** Celentano V solely contributed to this manuscript.

**Conflict-of-interest:** As a corresponding author I declare that there is no conflict of interest.

**Open-Access:** This article is an open-access article which was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

**Correspondence to:** **Dr. Valerio Celentano,** Colorectal Unit, Federico II University, Via Pansini, 5, 80131 Naples, Italy. valeriocelentano@yahoo.it

**Telephone:** +39-33-95023785

**Received:** May 9, 2015

**Peer-review started:** May 11, 2015

**First decision:** June 2, 2015

**Revised:** June 30, 2015

**Accepted:** July 8, 2015

**Article in press:**

**Published online:**

**Abstract**

The dissemination of laparoscopic colorectal surgery 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 laparoscopic colorectal surgery 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 laparoscopic colorectal surgery could be reduced through practice and skills development in a risk-free setting.

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

**© The Author(s) 2015.** Published by Baishideng Publishing Group Inc. All rights reserved.

**Core tip:** Performing advanced laparoscopic procedures requires dedicated surgical skills and new simulation methods tailored precisely for laparoscopic colorectal surgery 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 laparoscopic colorectal surgery training.

Celentano V. Need for simulation in laparoscopic colorectal surgery training. *World J Gastrointest Surg* 2015; In press

**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.

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 US$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 LAPAROSCOPIC COLORECTAL SURGERY**

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 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 tfor 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 pretraining 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.

**REFERENCES**

1 **Guillou PJ**, Quirke P, Thorpe H, Walker J, Jayne DG, Smith AM, Heath RM, Brown JM. Short-term endpoints of conventional versus laparoscopic-assisted surgery in patients with colorectal cancer (MRC CLASICC trial): multicentre, randomised controlled trial. *Lancet* 2005; **365**: 1718-1726 [PMID: 15894098 DOI: 10.1016/s0140-6736(05)66545-2]

2 **Faiz O**, Warusavitarne J, Bottle A, Tekkis PP, Darzi AW, Kennedy RH. Laparoscopically assisted vs. open elective colonic and rectal resection: a comparison of outcomes in English National Health Service Trusts between 1996 and 2006. *Dis Colon Rectum* 2009; **52**: 1695-1704 [PMID: 19966600 DOI: 10.1007/dcr.0b013e3181b55254]

3 **Hewett PJ**, Allardyce RA, Bagshaw PF, Frampton CM, Frizelle FA, Rieger NA, Smith JS, Solomon MJ, Stephens JH, Stevenson AR. Short-term outcomes of the Australasian randomized clinical study comparing laparoscopic and conventional open surgical treatments for colon cancer: the ALCCaS trial. *Ann Surg* 2008; **248**: 728-738 [PMID: 18948799 DOI: 10.1097/sla.0b013e31818b7595]

4 **Miskovic D**, Ni M, Wyles SM, Tekkis P, Hanna GB. Learning curve and case selection in laparoscopic colorectal surgery: systematic review and international multicenter analysis of 4852 cases. *Dis Colon Rectum* 2012; **55**: 1300-1310 [PMID: 23135590 DOI: 10.1097/dcr.0b013e31826ab4dd]

5 **Bardakcioglu O**, Khan A, Aldridge C, Chen J. Growth of laparoscopic colectomy in the United States: analysis of regional and socioeconomic factors over time. *Ann Surg* 2013; **258**: 270-274 [PMID: 23598378 DOI: 10.1097/sla.0b013e31828faa66]

6 **Kemp JA**, Finlayson SR. Nationwide trends in laparoscopic colectomy from 2000 to 2004. *Surg Endosc* 2008; **22**: 1181-1187 [PMID: 18246394 DOI: 10.1007/s00464-007-9732-8]

7 **Tekkis PP**, Senagore AJ, Delaney CP, Fazio VW. Evaluation of the learning curve in laparoscopic colorectal surgery: comparison of right-sided and left-sided resections. *Ann Surg* 2005; **242**: 83-91 [PMID: 15973105 DOI: 10.1097/01.sla.0000167857.14690.68]

8 **Choi DH**, Jeong WK, Lim SW, Chung TS, Park JI, Lim SB, Choi HS, Nam BH, Chang HJ, Jeong SY. Learning curves for laparoscopic sigmoidectomy used to manage curable sigmoid colon cancer: single-institute, three-surgeon experience. *Surg Endosc* 2009; **23**: 622-628 [PMID: 18270771 DOI: 10.1007/s00464-008-9753-y]

9 **Kim J**, Edwards E, Bowne W, Castro A, Moon V, Gadangi P, Ferzli G. Medial-to-lateral laparoscopic colon resection: a view beyond the learning curve. *Surg Endosc* 2007; **21**: 1503-1507 [PMID: 17641928 DOI: 10.1007/s00464-006-9085-8]

10 **Miskovic D**, Wyles SM, Ni M, Darzi AW, Hanna GB. Systematic review on mentoring and simulation in laparoscopic colorectal surgery. *Ann Surg* 2010; **252**: 943-951 [PMID: 21107103 DOI: 10.1097/sla.0b013e3181f662e5]

11 **The Southern Surgeons Club**. A prospective analysis of 1518 laparoscopic cholecystectomies. The Southern Surgeons Club. *N Engl J Med* 1991; **324**: 1073-1078 [PMID: 1826143 DOI: 10.1056/nejm199104183241601]

12 **Stein S**, Stulberg J, Champagne B. Learning laparoscopic colectomy during colorectal residency: what does it take and how are we doing? *Surg Endosc* 2012; **26**: 488-492 [PMID: 21938581 DOI: 10.1007/s00464-011-1906-8]

13 **Bass BL**. Matching training to practice: the next step. *Ann Surg* 2006; **243**: 436-438 [PMID: 16552192 DOI: 10.1097/01.sla.0000205222.95167.a4]

14 **Pugh CM**, Darosa DA, Bell RH. Residents' self-reported learning needs for intraoperative knowledge: are we missing the bar? *Am J Surg* 2010; **199**: 562-565 [PMID: 20359575 DOI: 10.1016/j.amjsurg.2009.11.003]

15 **Blencowe NS**, Parsons BA, Hollowood AD. Effects of changing work patterns on general surgical training over the last decade. *Postgrad Med J* 2011; **87**: 795-799 [PMID: 21984742 DOI: 10.1136/postgradmedj-2011-130297]

16 **Varley I**, Keir J, Fagg P. Changes in caseload and the potential impact on surgical training: a retrospective review of one hospital's experience. *BMC Med Educ* 2006; **6**: 6 [PMID: 16420692 DOI: 10.1186/1472-6920-6-6]

17 **Taylor IA**, Alexander F. Preface to the ISCP report. ISCP Evaluation Task Group, 2006. Available from: URL: http: //www.mee.nhs.uk/pdf/FinalReportISCP - MichaelEraut.pdf

18 **Bell RH**, Biester TW, Tabuenca A, Rhodes RS, Cofer JB, Britt LD, Lewis FR. Operative experience of residents in US general surgery programs: a gap between expectation and experience. *Ann Surg* 2009; **249**: 719-724 [PMID: 19387334 DOI: 10.1097/sla.0b013e3181a38e59]

19 **Kerr B**, O'Leary JP. The training of the surgeon: Dr. Halsted's greatest legacy. *Am Surg* 1999; **65**: 1101-1102 [PMID: 10551765]

20 **Heemskerk J**, Zandbergen R, Maessen JG, Greve JW, Bouvy ND. Advantages of advanced laparoscopic systems. *Surg Endosc* 2006; **20**: 730-733 [PMID: 16528462 DOI: 10.1007/s00464-005-0456-3]

21 **Scott DJ**, Young WN, Tesfay ST, Frawley WH, Rege RV, Jones DB. Laparoscopic skills training. *Am J Surg* 2001; **182**: 137-142 [PMID: 11574084 DOI: 10.1016/s0002-9610(01)00669-9]

22 **Smith CD**, Farrell TM, McNatt SS, Metreveli RE. Assessing laparoscopic manipulative skills. *Am J Surg* 2001; **181**: 547-550 [PMID: 11513783]

23 **Dutta S**, Gaba D, Krummel TM. To simulate or not to simulate: what is the question? *Ann Surg* 2006; **243**: 301-303 [PMID: 16495691 DOI: 10.1097/01.sla.0000200853.69108.6d]

24 **Celentano V**, Finch D, Forster L, Robinson JM, Griffith JP. Safety of supervised trainee-performed laparoscopic surgery for inflammatory bowel disease. *Int J Colorectal Dis* 2015; **30**: 639-644 [PMID: 25669758 DOI: 10.1007/s00384-015-2147-4]

25 **Park J**, MacRae H, Musselman LJ, Rossos P, Hamstra SJ, Wolman S, Reznick RK. Randomized controlled trial of virtual reality simulator training: transfer to live patients. *Am J Surg* 2007; **194**: 205-211 [PMID: 17618805 DOI: 10.1016/j.amjsurg.2006.11.032]

26 **Bridges M**, Diamond DL. The financial impact of teaching surgical residents in the operating room. *Am J Surg* 1999; **177**: 28-32 [PMID: 10037304 DOI: 10.1016/s0002-9610(98)00289-x]

27 **Gurusamy KS**, Aggarwal R, Palanivelu L, Davidson BR. Virtual reality training for surgical trainees in laparoscopic surgery. *Cochrane Database Syst Rev* 2009; **21**: CD006575 [PMID: 19160288 DOI: 10.1002/14651858.cd006575]

28 **Scott DJ**, Bergen PC, Rege RV, Laycock R, Tesfay ST, Valentine RJ, Euhus DM, Jeyarajah DR, Thompson WM, Jones DB. Laparoscopic training on bench models: better and more cost effective than operating room experience? *J Am Coll Surg* 2000; **191**: 272-283 [PMID: 10989902 DOI: 10.1016/s1072-7515(00)00339-2]

29 **Samia H**, Khan S, Lawrence J, Delaney CP. Simulation and its role in training. *Clin Colon Rectal Surg* 2013; **26**: 47-55 [PMID: 24436648 DOI: 10.1055/s-0033-1333661]

30 **Aggarwal R**, Ward J, Balasundaram I, Sains P, Athanasiou T, Darzi A. Proving the effectiveness of virtual reality simulation for training in laparoscopic surgery. *Ann Surg* 2007; **246**: 771-779 [PMID: 17968168 DOI: 10.1097/sla.0b013e3180f61b09]

31 **Halsted WS**. The training of the surgeon. *Bull Johns Hopkins Hosp* 1904; **15**: 267-276

32 **Moore MJ**, Bennett CL. The learning curve for laparoscopic cholecystectomy. The Southern Surgeons Club. *Am J Surg* 1995; **170**: 55-59 [PMID: 7793496 DOI: 10.1016/s0002-9610(99)80252-9]

33 **Bashankaev B**, Baido S, Wexner SD. Review of available methods of simulation training to facilitate surgical education. *Surg Endosc* 2011; **25**: 28-35 [PMID: 20552373 DOI: 10.1007/s00464-010-1123-x]

34 **Roberts KE**, Bell RL, Duffy AJ. Evolution of surgical skills training. *World J Gastroenterol* 2006; **12**: 3219-3224 [PMID: 16718842]

35 **Waseda M**, Inaki N, Mailaender L, Buess GF. An innovative trainer for surgical procedures using animal organs. *Minim Invasive Ther Allied Technol* 2005; **14**: 262-266 [PMID: 16754173 DOI: 10.1080/13645700500273841]

36 **Ramshaw BJ**, Young D, Garcha I, Shuler F, Wilson R, White JG, Duncan T, Mason E. The role of multimedia interactive programs in training for laparoscopic procedures. *Surg Endosc* 2001; **15**: 21-27 [PMID: 11178755 DOI: 10.1007/s004640000319]

37 **Ross HM**, Simmang CL, Fleshman JW, Marcello PW. Adoption of laparoscopic colectomy: results and implications of ASCRS hands-on course participation. *Surg Innov* 2008; **15**: 179-183 [PMID: 18757376 DOI: 10.1177/1553350608322100]

38 **Katz R**, Hoznek A, Antiphon P, Van Velthoven R, Delmas V, Abbou CC. Cadaveric versus porcine models in urological laparoscopic training. *Urol Int* 2003; **71**: 310-315 [PMID: 14512654 DOI: 10.1159/000072684]

39 **Grantcharov TP**, Kristiansen VB, Bendix J, Bardram L, Rosenberg J, Funch-Jensen P. Randomized clinical trial of virtual reality simulation for laparoscopic skills training. *Br J Surg* 2004; **91**: 146-150 [PMID: 14760660 DOI: 10.1002/bjs.4407]

40 **Gallagher AG**, Ritter EM, Champion H, Higgins G, Fried MP, Moses G, Smith CD, Satava RM. Virtual reality simulation for the operating room: proficiency-based training as a paradigm shift in surgical skills training. *Ann Surg* 2005; **241**: 364-372 [PMID: 15650649 DOI: 10.1097/01.sla.0000151982.85062.80]

41 **Hyltander A**, Liljegren E, Rhodin PH, Lönroth H. The transfer of basic skills learned in a laparoscopic simulator to the operating room. *Surg Endosc* 2002; **16**: 1324-1328 [PMID: 11988802]

42 **Seymour NE**, Gallagher AG, Roman SA, O'Brien MK, Bansal VK, Andersen DK, Satava RM. Virtual reality training improves operating room performance: results of a randomized, double-blinded study. *Ann Surg* 2002; **236**: 458-63; discussion 463-4 [PMID: 12368674]

43 **Zimmerman H**, Latifi R, Dehdashti B, Ong E, Jie T, Galvani C, Waer A, Wynne J, Biffar D, Gruessner R. Intensive laparoscopic training course for surgical residents: program description, initial results, and requirements. *Surg Endosc* 2011; **25**: 3636-3641 [PMID: 21643881 DOI: 10.1007/s00464-011-1770-6]

**P-Reviewer:** Fukunaga Y, Lakatos PL **S-Editor:** Ji FF **L-Editor: E-Editor:**

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

|  |  |
| --- | --- |
| **Features** | **Challanges** |
| 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 |

**Table 2 Characteristics of the different types of simulators**

|  |  |
| --- | --- |
| **Type of simulator** | **Main features** |
| Box trainers | Low-cost, portable, can be used repatedly by multple users. Used to teach basic laparoscopic skills: hand-eye coordination, cutting, suturing, bimanual dexterity. Provide sensory feedbackRequires 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 |