Virtual reality training in laparoscopic colorectal surgery

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Due to the critical balance between patient safety and long learning curves for new surgical techniques, there has been rising interest in *ex vivo* surgical training models using simulators. Currently used training methods that thought to be beneficial in improving laparoscopic skills are lately questioned due to their limitations. The most realistic option, live animal training models, is expensive and has limited access for many practitioners. As opposed to other simulators, cadaveric platforms provide excellent tissue felling; however, it is not commonly easy to get to and requires supervision by experienced teachers (1).

On the other hand, virtual reality (VR) simulators are considered as being safe, effective and may be an available tool and can overcome problems regarding legal issues and time-consuming features of conventional apprenticeship. This system has been probably best described by Riva as a communication interface through interactive three-dimensional visualization which enables users to interface, interact with, and integrate different types of sensory inputs stimulating real-world practice (2). With this toll, monitoring learning process by autonomic and instantaneous measures seems to be ergonomic for the aim of acquisition of basic skills in laparoscopic surgery (3). However, despite its early introduction to surgery in 1990s (4), adoption of VR training appears to be slower paced, particularly due to the lack of well-designed clinical trials. Earliest comparison of standard surgical residency and VR was drawn in prospective, randomized double-blinded fashion for part of a laparoscopic cholecystectomy.

The earliest comparison of standard surgical residency and VR was drawn in prospective, randomized double-blinded fashion for part of a laparoscopic cholecystectomy and showed improved intraoperative performance with VR (5). More research is pending to delineate outcomes for the application of VR systems for more complex minimally invasive procedures.

Laparoscopic approach for colorectal surgery is considered as representative of complex procedures with its technology-dependent features (6,7). Although colorectal surgery showed a significant modernization in regards to operative approach in favor of the minimal invasive techniques, it still constitutes more technically challenging areas of laparoscopic surgery. The advantages—reduced morbidity, hospital length of stay, and institutional cost, and equivalent oncological outcomes—of laparoscopic approach however, are mitigated by its time-consuming technical complexity that imposes a long learning curve (8-10). A survey of program directors revealed that general surgery residents are inadequately prepared with respect to technical and non-technical skills during their minimally invasive and colorectal practices (11). Moreover, surgical residents face the need to learn relatively complex laparoscopic surgical skills within a limited time frame and in an environment where health system payers pay attention to competence, quality, and particularly cost-effectiveness (12). Considering required high number of cases (at least 30) for the learning curve of laparoscopic colorectal surgery (LCS) as the primary surgeon and that this expertise is not expected to be reached at the end of residency, simulation-based training of these technical skills has gained paramount importance.

Although a significant amount of work has been performed to validate simulators as viable systems for teaching technical skills outside the operating room, it is necessary to integrate simulation training into comprehensive curricula. The

Table 1 Studies addressing virtual reality simulators in colorectal surgery

Author	Year	Method	Participants, numbers	VR simulator	Procedure (assessment method)	Outcome assessment
Beyer-Berjot L	2016	Randomised, multicenter	Novice (n=20) *vs.* intermediate (n=7) *vs.* experienced (n=6)	LAP Mentor*	Sigmoid colectomy	Time, path length, number of movements,
Araujo SE	2014	Nonrandomised	Novice (n=14)	LAP Mentor	sigmoid colectomy	Global rating scale
Araujo SE	2014	Randomised	Novice (n=7) *vs.* control (n=7)	LAP Mentor	Sigmoid colectomy	Generic technical skills Likert ratings
Neary PC	2008	Randomised	Novice (n=11) *vs.* experienced (n=3)	ProMIS VR&	Left-sided colectomy	Time, instrument path length, and the smoothness of the trajectory of the instruments

*, LAP Mentor (Simbionix, Cleveland, OH, USA); &, ProMIS augmented-reality simulator (Haptica, Dublin, Ireland). VR, virtual reality.

optimal introduction of a VR simulator into an evidence-based, effective, and ergonomic surgical skills curriculum is a core and contentious issue. Before its utilization as training and assessment tool, the validity of simulation, as a first step, should be demonstrated based on performance metrics. One of the most important types of validation is demonstration of construct validity, which is best characterized as the ability to distinguish between surgeons with different levels of experience or skills. Demonstration of validity enables to further establish a technical skill proficiency level. The establishment of a level of proficiency allows determining an objective benchmark for trainees to reach before they can operate on a patient. In todays' surgical era, set up of structured curricula for laparoscopic colorectal procedures is crucial as there are few reports on dedicated programs for advanced techniques (13,14). As a further step, all metrics showing validity evidence can be ultimately incorporated in the training curriculum.

Palter and colleagues conducted the first randomized controlled trial developing and validating a comprehensive technical skills curriculum for LCS (15). During the study design, a total of eight tasks were ideally identified based on a 'consensus' of a large international team, rather than personal choice of tutors (16). They assessed the 'real' surgical performance in operating room and demonstrated higher performance in curricular-trained residents compared to controls, who followed only classical apprenticeship.

Table 1 summarizes the main studies regarding VR simulation for colorectal surgery (17-20). Beyer-Berjot and colleagues firstly implemented a competency-based VR curriculum in advanced training in laparoscopic abdominal surgery (17). The concept of this study is crucial when considering only few structured guidelines exist in the training of this field. In a sigmoid colectomy simulation, tasks comprising medial dissection, lateral dissection, anastomosis and full laparoscopic sigmoid colectomy have been measured with respect to time taken to complete each task, the total number of movements, and the total path length. Authors stated that these metrics—which showed validity evidence based on relations to experience during laparoscopic sigmoid colectomy simulation—had already been validated for specific tasks laparoscopic cholecystectomy as a basic laparoscopic procedure. These findings were confirmed by another work by Shanmugan and colleagues who questioned the optimal metrics for laparoscopic sigmoid colectomy demonstrating validity evidence (21). In their report, unexperienced general *vs.* experienced laparoscopic colorectal surgeons were participated in a prospectively designed study, in which only procedural metrics including reduced instrument path length, accuracy of the peritoneal/medial mobilization, and dissection and division of the inferior mesenteric artery showed evidence of construct validity. Contrary to these findings, intraoperative errors, e.g., grasping tumor, major vessel injury, minor bleeding episodes and injury of vital structures did not differentiate between surgeons varying degrees of expertise for laparoscopic sigmoid procedure. However, at this point, we are a bit skeptical to VR simulator in terms of their capability to determine intraoperative errors—which can be directly associated with morbidity and perhaps mortality in a real operating theater—when considering these errors can be lessened with increasing laparoscopic experience for colectomy (18). Moreover, suturing is not considered a task for sigmoid colectomy simulation in Beyer-Berjot and colleagues' work (17). Although this task can be considered more demanding, novices should be familiar with suturing before experiencing real atmosphere of the operating room, to be able to manage complications including iatrogenic bowel injury and perhaps anastomotic separation.

What constitutes an acceptable outcome measure as a proxy for clinical effectiveness in LCS is a contentious issue. Dedicated performance metrics for an advanced and more complex procedure, laparoscopic sigmoid colectomy, could be used for a more realistic measurement. To our knowledge, operating time does not perfectly reflect learning curve characteristics in LCS due to its complex nature. Time taken has been broadly criticized as a weak proxy for learning curve evaluation and does not relate to proficiency (1,22). From this perspective, in addition to time-related and instrument handling-related parameters used, assessment of error-related parameters including tissue damage, instrument misses, badly placed and/or dropped clips, burn damage and blood loss, would be more convenient. As there is always a risk of facing with these unpleasant complications, even for experienced surgeons, during LCS.

We believe that VR simulators designed to assess relevant performance metrics are selected optimally based on outcome measures, with patient specific data would be more reliable and show better validity evidence. Since colonic VR simulations designed based on individual patient's imaging data may improve training by a stepwise increase in task difficulty similar to the real practice. Novel high-quality educational tools such as specially embalmed human anatomical specimen can offer unexperienced surgeons more accurate interpretation of tissues before operating room (23).

Methodologically, learning curves and quality of surgery should be measured and controlled through risk adjusted cumulative sum (CUSUM) analysis, which is an extension of the original CUSUM method, plotting the difference between the cumulative expected failures and the failures that actually occurred (8,24,25). With respect to the fidelity, effect on clinical training, trainee satisfaction; released reports questioning the utilization of VR tools demonstrated obvious contribution to learning process for LCS (15,26). However, determining how many cases are required to achieve learning curve is critical in order to give reliable data to colorectal surgeons. For this aim, specific and optimal outcome measures should be assessed in a statistically sound fashion. Beyer-Berjot and colleagues noted that there were no significant differences between novice surgeons' 10th attempt and experienced surgeons' performance based on VR training assessment (17). On the other hand, other works characterizing the learning curve for LCS indicated that at least 30 cases were necessary to demonstrate a significant improvement in outcomes (8,27,28). They justified this finding based on different characteristics between simulation, which has a fixed nature, and additional challenges encountered during real procedure (necessity of splenic flexure mobilization and small bowel to recline). Additionally, it would be addressed that end points of conversion, harvested lymph nodes, perioperative complications, morbidity, and mortality were used for learning curve evaluation, in addition to the end point of operating time, which can probably better reflect surgical complexity for LCS.

In summary, current standard of residency training in LCS would be better qualified by a curriculum including competency-based VR training. Further research is required to characterize more dedicated VR simulators and which metrics in VR training should be assessed to improve its educational value.

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Footnote

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