Simulation and Its Role in Training

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Abstract

Despite its short history, surgical simulation has been successfully introduced into surgical residency programs in an effort to augment training. A wide range of simulator types and levels of complexity have proven an effective teaching method for surgical trainees. They have been used for training in areas such as general surgery, urology, gynecology, and ophthalmology among others. Coincident with the introduction of simulators is the need for objective evaluation of skills learned on them, which has led to the development and validation of multiple evaluation tools. This article evaluates the drivers for simulation, types of simulators, training, and evaluation of them especially as it pertains to laparoscopic colorectal surgery.

Keywords

- simulator
- education
- laparoscopic colorectal surgery

Objectives: On completion of this article, the reader should be able to summarize the drivers for simulation, simulator types, and training, as well as evaluation, especially as it pertains to colorectal surgery.

Surgical simulation currently plays an ever-increasing role in the training of multiple specialties including colorectal surgery. Subsequently, the need for objective evaluation of skills learned on them has led to the development and validation of multiple evaluation tools. Here we review the drivers for simulation, types of simulators, training, and provide evaluations.

Drivers for the Use of Simulation in Medical Education

The driving force behind the use of simulation in medical education is multifactorial. Of prime importance are issues related to patient safety, as well as ACGME requirements, and increasing complexity of procedures, especially in minimally invasive surgery.

Patient Safety

Patient safety has always been at the heart of surgical education. Concern that resident participation in the operating room may lead to worse patient outcomes has prompted much research in this area. Veterans Affairs hospitals, unlike any other teaching hospital, have been tracking the level of

operating room supervision within the NSQIP database since its inception in 1994.¹ Using this database, Itani et al showed that resident level of supervision did not affect clinical outcomes for patients, even when attending surgeons were not present in the operating room, but were available if needed.¹ Despite these positive findings, they also noted that the level of supervision in the operating room has been steadily increasing over the years because of a general concern for patient safety by attendings.¹ In a prospective randomized trial by Mahmoud et al, it was shown that there was no significant difference in duration of surgery, hospital stay, or postoperative complications between senior residents who are acting as teaching assistants to junior residents and attending faculty in the operating room.² In laparoscopic colorectal surgery, Maeda et al found that trainee surgeons do not cause more conversions when they are minimally supervised by an attending.³

Despite these findings supporting the confidence in residents, a national survey of 125 surgical residency programs addressed resident satisfaction with teaching and showed that 40% of residents sometimes felt “oversupervised” in the operating room, contributing to decreased satisfaction.⁴ Bell et al found that of 121 procedures residency program directors felt were essential, residents only reported 20 or more repetitions in nine of them.⁵ The American Board of Surgery has expressed concern about residents’ readiness to enter practice after training^{6,7} as residents consistently state feeling unprepared, resulting in four out of five extending their

training beyond 5 years to gain more experience.⁵ In laparoscopic colorectal surgery, research has shown a lack of successful completion of enough essential surgery cases by trainees⁵⁻⁸ and that the protracted learning curve extends beyond fellowship training.⁸ It has been shown that junior surgeons have a higher conversion rate to open⁹ as well as higher intraoperative, and postoperative complication rates than senior surgeons.¹⁰

The New ACGME

Recent changes to ACGME work hours require surgical residents to acquire basic and advanced surgical skills in less time than their predecessors.⁸⁻¹⁰ In resident surveys, residents felt these changes caused their surgical experience to be negatively impacted.^{11,12} Sixty percent reported doing fewer procedures, 50% felt they missed out on important operative learning opportunities, and 40% felt an overall worsened quality of training.¹ With residents reporting spending less time in the operating room, they will need to spend more time practicing at other sites—such as simulation laboratories—to attain equivalent experience.

Shortening the Learning Curve

Laparoscopic surgery, in general, is more difficult to learn and master than open surgery, leading to a longer learning curve.¹³⁻¹⁵ This is especially true of laparoscopic colorectal surgery. The American Board of Colon and Rectal Surgery has introduced a minimum requirement of 50 laparoscopic colorectal resections for completion of training. Research has shown that this is a reasonable number to reach a level of comfort with the procedure⁸; however, general surgeons are the group that perform most of these procedures in practice (nationwide) and ~70% of general surgery residents report having completed less than 10 laparoscopic colectomies as the primary surgeon.⁸ It is unlikely that the volume of laparoscopic colon resections performed by general surgery residents will dramatically increase. Therefore, the learning curve must be shortened by learning outside of the operating room. Dedicated practice on simulators has correlated with improved operative times, and efficiency of movement for clinical laparoscopic cholecystectomy. This finding suggests that the learning curve for laparoscopic colorectal surgery may be shortened with this approach.¹⁶

The Operating Room Is Suboptimal

It has been shown that the operating room can be a suboptimal place for novice learning as high stress leads to deleterious effects on performance.¹⁷ This is especially true in laparoscopic colorectal surgery because of the high complexity and variability of cases. During these cases, trainers often assist in intraoperative decision making, comprehension of anatomy, and subconsciously guide the trainee in an attempt to reduce errors or conversion. This assistance is perceived by the attending as keeping control of the case, and perceived by the resident as a false sense of control and mastery.¹⁸ Furthermore, surgeons will often “slow down” during an anticipated or crucial part of the procedure, or when they encounter an unexpected situation or complication.¹⁹ This

slowing down is a transition from routine to effortful functioning. At this time, they are more likely to take control away from the resident, and less likely to teach, or explain to a trainee the series of events that are occurring.²⁰ This is deleterious to resident learning because these are the times in the procedure the resident needs the most guidance. Simulation allows residents to encounter these crucial moments and complications in a controlled setting.

Types of Simulators

Simulators are often described as low-tech versus high-tech. Low-tech simulators range from plastic models of organ systems to basic plastic manikins and skills trainers. Human cadavers and harvested animal tissue is also included in this group. These simulators are not computer-driven, are usually low cost, and low maintenance. High-tech simulators are typically computer-based, utilizing increasingly advanced hardware and software in the quest for complex, realistic, and adaptive simulation. Another way to classify simulators is by the degree of fidelity based on characteristics like tactile feedback, visual clues, and interaction with the trainee. ▶ **Table 1** outlines the different types of simulators, their uses, and limitations.

Low-Fidelity Trainers

Low-fidelity trainers include simple static devices like knot-tying boards, tissue models to practice dissection and suturing, and box-trainers. Box-trainers are used to teach basic laparoscopic skills. They use surgical instruments and some form of camera/video equipment. The tasks are designed to develop hand-eye coordination, cutting, suturing, and bimanual dexterity. Box-trainers provide sensory feedback that allows the learners to familiarize themselves with instrument, needle, and tissue handling. These simulators are typically portable, low maintenance, of relatively lower cost, and can be used repeatedly by multiple users. A shortcoming of low-fidelity trainers is that information about trainee progress and skills acquisition can only be acquired by direct observation.

High-Fidelity Trainers

High-fidelity trainers include virtual reality endoscopic and laparoscopic simulators, and live animal models. Virtual reality (VR) trainers allow the learner to interact with a computer-generated environment that recreates individual skills or entire procedures along with possible complications that may occur during the procedure. Haptic systems are an advancement that provides tactile feedback to the user. However, despite a significant difference in cost, haptic systems have not been shown to improve efficiency or effectiveness of laparoscopic surgery simulation.²¹ A significant advantage of VR systems is their ability to measure detailed objective data on a vast array of parameters for every encounter with the simulator. This allows for monitoring trainee progress and in some cases, preparedness to progress to actual procedures such as colonoscopy. One of the first commercially available laparoscopic trainers was the Minimal

Table 1 Types of simulators

	Types	Uses, advantages	Limitations	Trainee population	Cost
Low fidelity					
Physical simulator	Box trainers	Task-training Develop hand–eye coordination	Limited Realism/ haptics No inherent metrics (requires observers for assessment)	Beginner	Set-up: Low Ongoing: Low
Cadaver	Human	Task-training (laparoscopy, endoscopy) Procedure training (vascular) Detailed/accurate anatomy	Loss of tissue fidelity compared with live model Single use Not portable Ethical and disease transmission concerns	Beginner to advanced	Set-up: High Ongoing: Very high
Animal model	Porcine Canine Bovine Baboon Avian	Task, procedure, and team training Open and laparoscopic skills training Realistic haptic feedback	Requires large facility, and veterinarian staff Single use Ethical concerns	Beginner to advanced	Set-up: High Ongoing: Moderate
Harvested tissue model	Animal tissue attached to synthetic frames	Training for skills that require repetition May provide haptic feedback	Limited procedures Requires special facilities for storage	Beginner to intermediate	Set-up: Low Ongoing: Very low
High fidelity					
Computer simulation	Virtual reality	Task and procedure training Provides detailed metrics May be portable	May have limited haptics (depending on type)	Beginner to advanced	Set-up: High Ongoing: Moderate
Hybrid	Combined virtual reality and physical simulator	Simulates entire operative experience Procedure and Team training	Requires facility, time and effort in preparation and maintenance Not portable	Intermediate to advanced	Set-up: High Ongoing: High

Table 2 Types of validity

Type	Definition	In simulation
Face	The overall property of a test intended to measure something	Does the simulator “look like” it is going to simulate what we want it to simulate?
Content	The systematic examination of the test to determine if it covers all facets of what is to be measured	Is the simulator an appropriate training tool? Does it cover all the critical steps in what we want to simulate?
Construct	The extent to which a test actually measures what it is supposed to measure	Is there a statistical difference in performance measured between different groups based on level of expertise?
Concurrent	The degree to which the test correlates with other measures of the same type of test at the same time	Is there a correlation between measured performance on the simulator and another already validated simulator of the same type?
Predictive	The degree of which the test can correlate with other measures of a same type test at some time in the future	Can the measured performance on the simulator predict the future performance in the operating room?

Invasive Surgery Trainer-Virtual Reality (MIST-VR). This device had simple imagery with tasks related to placement and transfer of virtual objects. The LapSim system is a commonly used VR simulator and has a more advanced graphic interface that has multiple modules ranging from camera handling to procedures like laparoscopic cholecystectomy, colectomy, hernia repair, and bariatric procedures. Hybrid virtual reality or augmented reality systems such as HapticaProMis combine anatomically correct models placed within a simulated torso with laparoscopic monitors. Live mammalian animal models are also considered high fidelity and have been used for decades to teach, develop, and test surgical innovations for both laparoscopic and open surgery. This mode of simulation is an excellent model to teach dissection, tissue handling, and complex surgical procedures. However, there are significant challenges related to cost, availability of appropriate logistical support, and ethical concerns. Despite these concerns, the porcine model has been used widely for simulation of both open and laparoscopic procedures. Bidarkar et al recently published their 3-year experience in developing a successful porcine model for pediatric minimally invasive surgery.²²

Simulators for Training

Simulators, both high-fidelity and low-fidelity, have become the cornerstone for laparoscopic training for both basic and advanced laparoscopic skills. Of particular importance is the Fundamentals of Laparoscopic Surgery (FLS) program that was developed by the Society of American Gastrointestinal Endoscopic Surgeons (SAGES), with the goal of creating uniformity in laparoscopic training. This educationally validated program is a combination of a web-based educational module and a box training device referred to as the McGill Inanimate System for Evaluation and Training of Laparoscopic Skills (MISTELS). Currently, FLS certification is a prerequisite for certification by the American Board of Surgery and the American Board of Colon and Rectal Surgery. The MISTELS system has been shown to be a valid and reliable tool to teach basic laparoscopic skills.²³

Metrics and Validity

Multiple metrics and parameters can be measured on surgical simulators to monitor learning. However, simulators are also becoming tools for assessment of competence. Used for this purpose, the metrics used must be both valid and reliable. There are five types of validities that are applicable to simulators: face, content, construct, concurrent, and predictive validity. Face and content validity relate to the qualities of the simulator itself, whereas the last three relate to the metrics that are measured by the simulator. ▶ **Table 2** describes types of validity and how they are applied to surgical simulation.

Transfer of Skills, Retention, and Proficiency

Expert performance has been described as the ability to maintain a complex balance of planning, executing, monitoring, and assessing a skill. Thus, the acquisition of skills can be approached in a stepwise manner, comprised initially of individual components of a procedural skill and progressing to complex variations of the entire procedure.^{24–26} Deliberate, directed, repetitive practice allows identification of specific areas of weakness and correction of these deficits in a low-stakes environment with no risk of patient injury, which is ultimately the goal of surgical education. Directed practice has demonstrated superior transfer from simulator to real tissues.²⁷ Transfer of skills from a simulator to the patient has been shown by multiple authors. Seymour et al were the first to report a prospective, randomized, blinded study that validated the transfer of virtual reality skills to the operating room.²⁸ Park et al evaluated the impact of training on a computer-based colonoscopy simulator on conduct of the procedure on actual patients as assessed by expert evaluators. They found that there was a significant improvement of performance for trainees that had practiced on the simulator when compared with those who had no practice.¹⁷ Similarly, Stroka et al demonstrated that proficiency training with the Fundamentals of Laparoscopic Surgery simulator was reflected in an improvement of performance of laparoscopic cholecystectomy.²⁹

Traditionally, certification bodies have used case numbers as a surrogate for proficiency. However, the shortfall of that system is obvious. The number of cases required to master a particular procedure is difficult to determine, and dependent on many factors other than volume. This is further complicated by variables related to the learner, the trainer, and the environment. Proficiency-based training aims to achieve defined performance targets.³⁰

Acquiring a measureable level of competency based on validated measures of a skill has been shown to be superior to case numbers as a measure of proficiency.³¹ Targets are achieved by deliberate directed practice and can be used for the entire spectrum of learners, with each trainee acquiring proficiency at their own pace depending on natural ability, level of training and motivation. This mode of training also shows excellent skills retention.^{32–34}

Simulators as Part of a Surgical Curriculum

To develop a comprehensive surgical curriculum, it is essential that cognitive knowledge and skills acquisition are recognized, taught, and assessed as discrete elements. With the transition from novice to expert, these components merge into the ability of surgical decision making and execution, the ultimate goal of surgical education. A simulator-based curriculum should have some form of pretraining education to ensure that the trainee has an understanding of the skill, its components, the correct and incorrect methods of performance, and both inconsequential and significant errors. This can be achieved through reading, videos, or live interactions. The next step is for the learner to begin acquiring skills that progress from simple to complex in an organized manner. Generally, novice learners do well with low-tech trainers that allow attainment of proficiency in the building block skills, e. g., knot tying, peg transfer, intracorporeal cutting, and suturing. For VR simulators, it is reasonable to begin with simple depth-perception and hand-eye coordination exercises before progressing to complete procedures. Each learner must be able to acquire proficiency without constraints of time and with the option of receiving expert feedback and/or assistance if required. Proximate feedback is provided by most VR simulators and aids learning.^{35,36}

Practice regimen has been extensively studied since the 1940s. It is generally agreed that distributed interval training is superior to massed training. This principle should be utilized while creating a simulation curriculum. Multiple groups have described simulation-based curricula for basic laparoscopic skills and simple procedures like cholecystectomy. Typically, these are proficiency based and are developed using indigenous experts.^{37,38} Palter et al designed a VR laparoscopic colorectal surgery curriculum using the Delphi method to determine expert consensus. They achieved consensus for seven basic tasks, and one advanced suturing task.³⁹

Metrics and Measuring Progress

The use of metrics to provide proximate feedback and enhance the learning experience would be ideal. However, the metrics available on VR simulators at this time require

continued development. For example, although the time taken to tie an intracorporeal knot is easily available, crucial information regarding security of the knot is absent. Fortunately, the FLS simulator is able to provide both pieces of information. Work has been done that indicates changes in instrument path trajectory and efficiency of nondominant hand movement with expertise.⁴⁰ Similarly, error metrics if available can be of great benefit to the learner.⁴¹

Teaching New Technology

With the continued progress in minimally invasive surgery, the need for training the “experts” has come to the forefront. In addition, technologic innovations ranging from robotic systems to novel stapling devices require appropriate user orientation and training. VR simulators, in conjunction with other modalities, have been shown to be effective in skills acquisition.⁴²

Simulators for Assessment of Surgical Skills

Surgical skills have long been established as a component of training best acquired while “on the job.” It is only in recent years that it has become clear that junior surgeons will exit training under-skilled. However, the learning curve for surgical techniques and procedures could be reduced if there was an opportunity to practice and develop those skills in a risk-free setting.²⁸ Many virtual reality laparoscopic simulators have been shown to be valid tools for teaching, providing exposure to a variety of simulated situations. Laparoscopic simulators such as Minimally Invasive Surgery Trainer (MIST), SimbionixLAPMentor™, and CAE ProMIST™, as well as endoscopic simulators such as the Simbionix GI Mentor II™ provide a realistic environment for inexperienced trainees to experience these techniques and for advanced practitioners to hone technically challenging components of procedures in a controlled, safe environment. Breaud and colleagues recently published its details of the first surgical resident program of its kind in Nice, France.⁴³ Adopting a simulator-based assessment system incorporating mannequin models for simulation of clinical scenarios as well as simulators for training in technical gestures for open and laparoscopic surgery, this curriculum has been approved by the American College of Surgeons and is part of the curriculum for all surgical residents in post at the Medical School of Nice Sophia-Antipolis. The Mayo Clinic, Rochester, have also developed a knowledge and skills based curriculum for laparoscopic totally extraperitoneal (TEP) inguinal hernia repair, and trainees were quickly able to master the technique to standards set by experts.⁴⁴

Before any simulator-based model can be reliably used as a training and assessment tool, rigorous construct and criterion validity determinations must be made. A prospective study from Canada in 2012⁴⁵ evaluated performances of novice versus experienced robotic surgeons on the da Vinci Trainer™ robotic surgical simulator, and endpoints were able to differentiate between experienced and novice surgeons and hence prove its validity. Whether this infers predictive validity would require more evaluation in a higher-powered study,

but this suggests simulators can be used as assessment tools. However, similar endoscopic evaluations with the GI Mentor II expert benchmark revealed results that varied widely between groups of individuals, even among a group of experienced endoscopists.⁴⁶ This suggests more stringent expert evaluation is necessary before it can be used to validate competence.

Basic surgical skills and manipulative techniques performed on a simulator have been validated, but there is a paucity of data for advanced laparoscopic surgery. The ProMIS laparoscopic simulator has construct validity^{6,7} but further work is needed to establish this trainer as predictively valid. The laparoscopic approach, particularly in colonic surgery, is widely accepted as safe and effective, yet still fewer than 10% of colectomies in the United States are being performed laparoscopically. A recent study showed that surgeons attending laparoscopic colectomy courses have a lack of access to a senior mentor following course completion, which may be limiting the uptake of the technique in smaller institutes, and a proposed method to continue skills training and encourage development is simulator training.⁴⁷ A group in Toronto, Canada who are developing a proficiency-based, content-validated virtual reality curriculum for laparoscopic colorectal surgery is addressing the need for training and assessment in advanced laparoscopic skills.³⁹ Leblanc and colleagues^{42,48} have compared augmented reality simulators to human cadaver models for laparoscopic colectomy, and though skills scores demonstrated a role for the virtual reality simulator, inefficiencies were demonstrated in the anatomic replication for this modality. This training model may be better suited for more junior trainees and those early in the learning curve.

More recently, advanced laparoscopic surgical skills were assessed in a laparoscopic colectomy training program assessing time taken to perform sigmoid colectomy, motion analysis, psychomotor and visual-spatial aptitude, and tray errors.⁴⁹ The study concluded that there was a correlation between a candidates' aptitude based on the warm-up session and ultimate performance of the laparoscopic colectomy, and that advanced laparoscopic surgical teaching curricula should take into account any assessment of baseline aptitude.

The previously mentioned Fundamentals of Laparoscopic Surgery (FLS) was developed for surgical trainees at varying levels of experience, with endorsement by the American College of Surgeons (ACS) and the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES). The premise of providing an inanimate model on which surgical trainees can develop basic laparoscopic skills can accelerate maturation of laparoscopic surgical technique leading to a safer surgical skill-set for surgical trainees. A randomized controlled trial in 2010 clearly demonstrated the educational value of FLS in a surgical training program.²⁹ A FLS course was successfully implemented this year in a National Surgical Skills Curriculum with 60 surgical residents assigned to the Penn Surgical Skills & Simulation Rotation in Philadelphia. Based upon Objective Structured Assessment of Technical Skills score (OSATS) and FLS, significant overall performance

was shown and retention of skill was demonstrated up to 1 year later.⁵⁰ Although the FLS box-trainer is accepted as the gold standard for developing laparoscopic skills, virtual reality simulators too have shown evidence of concurrent and construct validity.⁵¹

Role of Simulation in Team Training

A novel technique known as distributed simulation (DS) was explored and evaluated at a center in London, United Kingdom (UK).⁵² The concept was aimed at immersive simulation, with a "key components" attempt at recreating an authentic operating room simulation. Although this model enlisted the use of pull-up photographic representations of the anesthetic machine and surgical trolley, and recorded noises, which emulate a real operating theater experience with a surgical assistant and a scrub-nurse, the only person training is the surgical candidate. This concept was found to have strong face and content validity, though some of the novice scores might have been affected by the added complexity of the simulated environment. This adoption of a full-experience simulation could potentially be used to evaluate trainees from multiple disciplines in one scenario, with each trainee in his/her own right being required to interact with a trainee from another specialty. The role of team-based simulation has been assessed in specialties such as pediatrics, trauma but only a few aspects of surgical training.^{53–55} The surgical "dance," as such, involves a myriad of participants including anesthetists, surgeons, nurses, and assistants, referred to by one review as *choreography*.⁵⁶ Teamwork has been assessed for several years now in generic training courses such as Advanced Trauma and Life Support (ATLS), but it has been proposed that actors can be used to portray members of an operating room team to simulate a full surgical environment and in a small study, actors were used to emulate operating room staff. Participants perceived the actors as realistic and data from 12 surgeons enrolled indicated the model was a success.⁵⁷

Another approach to assessing team skills, especially in surgery, is the evaluation of performance in a high-stress situation such as that in an operating room emergency. A study from Boston, Massachusetts simulated a bleeding scenario in a laparoscopic setting and measured time to diagnose bleeding, time to inform team to convert, and time to perform conversion.⁵⁸ Between five experts and five non-FLS certified novices, there was a significant difference in surgical technical skills, identifying and controlling bleeding and team skills; however, it was noted that experts persisted for a longer time laparoscopically than novices.

There is no doubt that to perform safely and effectively in the operating room, one needs repeated practice. Furthermore, in the current surgical training climate of reduced training time, this repeated practice will need to be supplemented by efforts outside the operating room. Indeed, in the UK, simulated laparoscopic skills are a component of general surgical registrar interview processes as a discriminant, and as such, are to be an inherent part of surgical training to come.

Though the learning curve for advanced laparoscopic skills has been demonstrated to be steep, it could be assumed that in an age where the next generation of trainees is exposed to such technology at a much earlier stage in their career, that learning curve shall change shape accordingly. Nevertheless, no simulated environment can substitute the innate pressures of working in a team in a true surgical case and all efforts must be made to monitor progress beyond the simulated-suite and ensure technical ability is paralleled with clinical acumen, and decision making and team-working skills.

Measuring Skills Transfer from Simulators to the Operating Room

Several skills assessment tools are available for objectively assessing skills acquisition and transfer from simulator to operating room. Objective skills assessment has been well studied in the literature with various global and task-specific assessment tools having been created and validated.

The Global Assessment of Laparoscopic Skills (GOALS) tool was developed by Vassiliou et al in 2005 to assess laparoscopy.⁵⁹ It assessed depth perception, bimanual dexterity, efficiency, tissue handling, and autonomy as well as the critical steps for different laparoscopic procedures. It has been validated for the assessment of basic laparoscopic skills,⁵⁹ laparoscopic cholecystectomy,⁵⁹ appendectomy,⁶⁰ and inguinal hernia repair.⁶¹

Another assessment model known as the Objective Structured Assessment of Technical Skills (OSATS) assesses global tasks such as respect for tissues, time and motion, instrument handling, operative flow and planning, and procedure knowledge.⁶² It has been validated for objective evaluation of basic laparoscopic skills,⁶³ laryngoscopy, and bronchoscopy,⁶⁴ and obstetrics and gynecology skills.⁶⁵

The Competency Assessment Tool (CT) is a summative assessment method encompassing basic and procedure specific skills and has been validated in assessing laparoscopic colorectal resection.⁶⁶ It was originally developed for the specialist surgeon, but it evaluates both the process of performance (instrument use, tissue handling, and committed errors) and the quality of the end product of component tasks for laparoscopic colorectal resection making it ideal for evaluating performance of trainees.

The Observational Clinical Human Reliability Analysis (OCHRA) tool is an analysis method that is specialized in counting errors and near misses. It has been validated in assessment of laparoscopic colorectal skills⁶⁶ and is especially useful when analyzing operative videos.

Using these, and other nonvalidated assessment tools, several prospective trials have shown transfer of skills from simulator to the operating room in general surgery procedures.^{67–70}

Recently, The National Training Program for laparoscopic colorectal surgery in England has developed, validated, and implemented a monitoring tool for skill training. It consists of a generic scale for different tasks in laparoscopic colorectal surgery and provides individualized proficiency gain curves for trainees in level of support required and the competency

level achieved.⁷¹ With the growing need for a structured skills assessment curriculum for laparoscopic colorectal surgery, several more evaluation tools are in early stages of development and validation.^{39,72,73} However, despite the many validated tools available, it is important to note that only 18% of U. S. surgical programs have a formal basic surgical skills evaluation with or without an objective method of assessment.⁷⁴

Future Directions

The future of simulation in laparoscopic colorectal surgery is affected by industry-driven technological advances and a growing consensus by regulation bodies for the need to bridge the gap in laparoscopic colorectal skills learning curves. Of the five recognized validities, content, face, and more recently construct validity have been evaluated with simulators, whereas predictive and concurrent validity have not. If predictive validity for simulators is demonstrated for clinical cases, the potential implications for training would be substantial. An elaborate curriculum involving the mastery of proficiency with simulator models prior to the OR could be established. This model could then also be used to objectively evaluate graduating residents for both board exams and to help determine if further training is required prior to performing these cases independently.

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