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Surgical Education in the 21st Century

Anthony P. Allsbrook and Roderick M. Quiros

Abstract

Surgical education has evolved drastically since the 19th century. Previously education of surgical residents was limited to on job clinical training following the “see one, do one, teach one” model with knowledge gleaned from textbooks and journals. Presently a growing emphasis has been placed on both patient safety and resident well-being leading to a development of novel training paradigms. The textbook, while remaining a core source of knowledge, is now only one of many resources available to residents. Many residencies have their libraries online, making learning possible almost anywhere, even without physical books in hand. Most programs now incorporate education days where a structured curriculum allows for standardized education; this makes it less likely that residents miss out on mandatory concepts. The 2020 Covid-19 pandemic has led to further evolution of this model, making the classroom virtual yet interactive. Technology has allowed for residents to train on surgical simulators, so that laparoscopic and robotic skills may be practiced before application on a live patient. Altogether residents are afforded multiple ways to learn due to greater availability of time, structured educational modules, and technology.

Keywords: Surgical education, residency, training, curriculum, simulation

1. Introduction

Surgical education has evolved drastically over the centuries. Before the 19th century, the main model of surgical training and education was centered around apprenticeship, when instruction was garnered through direct observation from a mentor. There were no formalized standards on age or length of training; however, typical training would begin at the age of 12–13 and would last 5–7 years [1–3]. It was not until the end of the 19th century that Dr. William Halstead made the shift to a standardized training model.

In the late 1800s, Dr. Halstead pioneered a new era for surgical education in the United States. Using principles from the German philosophy of surgical education, he set forth to create a formalized, structured surgical curriculum. Incorporating Sir William Osler’s bedside teaching and integration of basic science into surgical education, he developed a training model [1, 4]. Halstead’s concept of surgical training was based on the following: First, the trainee must have repetitive opportunities to take care of surgical patients under the supervision of an experienced surgical teacher. Second, the trainee must understand the scientific basis of surgical disease. Lastly, the trainee obtains graded enhanced responsibility in patient care until independence [1]. The maxim, “see one, do one, teach one” was developed,

allowing surgeons to pass down operative techniques from one generation to the next. Using this principle, one was able to accept increasing responsibility in the operating room and eventually progress to surgical independence [1, 3].

Surgical training in the 21st century has been affected by challenges not identified in previous eras. In 1999, a paper published by the Institute of Medicine reported that preventable medical errors kill between 44,000–98,000 patients per year [3]. In 2003, the Accreditation Council for Graduate Medical Education (ACGME) instituted an 80-hour work week to prevent unfavorable outcomes secondary to resident fatigue. This focus on restricting the amount of work hours has been seen not only in the United States, but throughout the world. For example, the new European working time directive restricted work hours to 48 hours per week [5]. Globally, this has caused surgical residency programs to reform past curriculums to fulfill this new training requirement [3]. Programs began incorporating part of their training outside of the operating room to accommodate these new restrictions. Curricula were now refocused to prioritize quality over quantity of education. There has now been a spotlight on the well-being of trainees as a crucial element to the benefit of their own health as well as that to their patients [6].

Simulation-based training in surgical education has rapidly developed during the 21st century. While some aspects of training occur outside of the operating room and trainees are working less clinical hours, surgical residents are still expected to reach the same technical proficiency as their predecessors [1, 3]. With patient safety in mind, the development of simulation has become a cornerstone of today's surgical training. Simulation training provides an opportunity to develop both open and minimally invasive surgical techniques on artificial platforms before utilizing them on a live patient [3].

Lastly the 2020 COVID-19 pandemic has not only impacted millions of lives on a personal level but has also significantly affected medical education. Surgical training has been uniquely impacted both operatively and nonoperatively. Residents had to quickly adapt to a 'new normal' as many elective surgeries were canceled, resident lectures and conferences were moved to online platforms, and rotations were canceled or shortened to redistribute the workforce [7, 8]. This pandemic has demonstrated that surgical education needs to adapt to train tomorrow's surgeons.

2. Surgical requirements and education during the 21st century

Prior models of surgical education emphasized an acquisition of technical and practical knowledge as paramount, even at potential personal cost to the trainee. Surgical education has taken on a more holistic approach with a focus on developing a well-rounded physician both inside and outside the operating room. The American Board of Surgery (ABS) reports that the purpose of graduate surgical education is, "to acquire a broad understanding of human biology as it relates to surgical disorders, and the technical knowledge and skills appropriate to be applied by a surgical specialist" [9]. In some regards surgical education is still influenced by the previous Halsteadian model in which the resident gradually assumes increased levels of responsibility until the final stage of training when he or she handles complete patient management [3]. However, education today is equally focused on resident well-being and education. In the United States, now work a maximum of 80 hours per week, with allotted time set aside for protected, uninterrupted education time. Didactics, journal clubs, and weekly conferences are also incorporated into current residency training programs.

Previous eras were not guided by standards in terms of length of training or what information/skills needed to be taught [1]. The ABS has since developed a set

of standards and minimum requirements for individual trainees and their residency programs. As of 2021, in the United States, training requirements include:

1. A minimum of 60 months in a progressive residency program with at least 48 weeks of full-time clinical activity each year. At least 54 of these months must be dedicated to clinical surgical experience.
2. No more than 6 months of nonclinical or nonsurgical disciplines during years 1–3
3. Completion of Fundamentals of Laparoscopic Surgery (FLS)
4. Completion of the ABS Endoscopy Curriculum and the Fundamentals of Endoscopic Surgery (FES)-residents are required to perform 50 colonoscopies and 35 upper endoscopies.
5. The entire chief resident experience is in content areas of general surgery [9].

In addition to training, minimum requirements for the operative experience have been set forth by the ABS. This includes a minimum of 850 operative procedures over 5 years with at least 200 occurring during the chief resident year. Residents are also required to perform 25 teaching assistant cases in which a senior resident guide another through an operative procedure. Lastly, 40 surgical critical care cases are required prior to graduation [9].

Didactics and lectures make up an important component of surgical training. In the early 2000's there was push among resident education leaders to develop a standardized national curriculum. In response the Surgical Counsel on Resident Education (SCORE) was developed in 2004 with the mission to improve resident education in general surgery. SCORE developed a curriculum which lists the topics that should be covered in a five-year general surgery residency training program. The curriculum was developed in agreement with the six core competencies defined by the ACGME. The competencies expected from a graduating resident include: patient care, medical knowledge, professionalism, interpersonal and communication skills, practice-based learning, and systems-based practice [10, 11].

In addition to the curriculum, SCORE developed an online "Portal" to provide residents and residency training programs with educational materials and a structured learning schedule. Today, most surgical programs in the United States utilize this resource for resident education. The Portal provides over 800 topics, a topic of the week program, over 13 surgical textbooks, 2,000+ multiple choice questions, and 200+ narrated operative videos. The portal provides a weekly structured program which repeats over two-year cycle. This program specifically dives into the SCORE curriculum, providing a methodical way for residents and programs to learn material expected of a practicing general surgeon [11].

3. Simulation-based training

Simulation training has quickly become a standard among surgical residents in the 21st century. The first roots of simulation training were set by the aviation industry in the early 1900s. With many accidents attributed to novice aviators and a high demand for pilots secondary to World War I, there was a push to develop better, cheaper, and safer approaches to training. The first widely used flight simulator was created by Edwin Link in 1928 [12]. The medical community was slower

to utilize simulation and the first examples were not seen until the late 1950s where the Laerdal Company developed Resusi-Anne. This was a full-sized mannequin helped trainees practice a variety of clinical scenarios including management of obstructed airways and administration of chest compressions [12]. The field of anesthesia was one of the earliest adopters of simulation in the medical community; in the 1960s anesthesiologists utilized simulators that were able to replicate some basic human physiology and respond to medications [12]. From the basic models to teach CPR to sophisticated virtual reality simulators that can replicate the most complex human physiology, simulation training is now at the forefront of medical education.

Surgical training today has moved away from the traditional apprenticeship model where skills are developed solely in the operating room. In an era where minimizing healthcare expenditure is at the forefront; operating room time is too valuable for the development of basic surgical skills [13]. In a 2018 article published in JAMA, every minute in the operating room costs between \$36 to \$37 dollars [14]. Bridges et al. found that increased operative times related to resident training cost approximately \$53 million dollars per year [15]. Surgical simulation has provided opportunities for residents to develop competence with surgical skills, increase dexterity, and become more comfortable using a variety of instruments [1]. Montbrun et al. argues the ethical basis for incorporating stimulation into surgical education. He states that it ensures that at least some practice has taken place prior to operating on a patient [13]. Lastly, simulators help combat the work hour restriction as simulators are always available to be used during a resident's free time. There are a variety of different simulators that residents use today.

Bench top models are an example of one of the oldest and most effective tools in surgical simulation. These models use synthetic or animal tissue to replicate a variety of surgical procedures. Different specialties have developed unique bench top models to replicate real life procedures. Montbrun et al. describe benchtop models in surgical education as inexpensive, allowing familiarity to equipment along with unlimited practice opportunities, which translates well to operative skills on live patients [13].

Skill acquisition is the goal of bench top models and has been supported by a variety of studies. Lauscher et al. performed a randomized control trial comparing the Berlin Operation Trainer (BOPT), a benchtop model, to conventional training methods. Results demonstrated significant improvements in speed and performance score among the BOPT group [16]. Anastakis et al. demonstrated improved performance among surgical interns in multiple open surgical procedures like fascial closure and bowel anastomosis [17]. Multiple studies have also demonstrated that the skills obtained from bench top models can be translated to improved performance on a live patient [13]. For example, Palter et al. demonstrated that learning abdominal fascial closure on a benchtop model correlated to improved operating room performance among surgical novices [18]. Furthermore, Datta et al. demonstrated that assessment of skills on a benchtop model correlates well to performance on a live patient. The authors argue that use of benchtop work can also be used in the assessment of surgical skills [19].

Laparoscopic surgery advanced quickly in all surgical specialties since the first laparoscopic cholecystectomy was performed in 1988 by J. Barry McKernan and William Sayer [20]. Because of the early learning curve, there was a push to introduce simulation into laparoscopic surgery [10]. Compared to open surgery, laparoscopy forced the surgeon to work in a two-dimensional space with minimal tactile feedback. The ABS noticed the effectiveness of simulation in assessing laparoscopic skills and developed the Fundamentals of Laparoscopic Surgery (FLS) and introduced it into their graduation curriculum in 2008 [9, 13].

There are a variety of laparoscopic trainers used today by surgical residents, but the most well-known is the McGill Inanimate System for Training and Evaluation of Laparoscopic Skills (MISTELS) [13]. The MISTELS trainer is used to evaluate precision and speed during FLS. This low fidelity system is a simple box trainer that uses a variety of laparoscopic instruments and a laparoscope [13]. This system evaluates basic laparoscopic skills including peg transfer, intra- and extracorporeal knot tying, pattern cutting, and ligating loop placement [13, 21]. The benefit of the MISTELS system has been demonstrated in multiple studies. McCluney et al. performed a prospective study which demonstrated that FLS simulator scores independently predicted intraoperative laparoscopic performance [22]. Sroka et al. established in a randomized control trial, residents who underwent FLS training with MISTELS had significant improvement in elective laparoscopic cholecystectomies [23]. In addition to the low fidelity trainers such as MISTELS, some surgical programs incorporate virtual reality laparoscopic trainers into surgical education. These virtual reality simulators include full procedure models in which a variety of different surgical procedures can be performed [13].

Robotic surgery has quickly developed a niche among the surgical community. Sheetz et al. demonstrated that robotic surgery accounted for 15.1% of all surgeries in 2018, up from 1.8% in 2012 [24]. The rapid implementation of robotic surgery has led to specific robotic curriculums among training programs. Just as with laparoscopic surgery, robotics offers the opportunity for the trainee to become proficient prior to use in the operating room. Current robotic curriculums follow a stepwise progression for trainees, starting with observation, then providing bedside assistance, then performing with supervision, and lastly practicing independently [24].

Robotic surgical curriculums first start with patient side training. During this phase, the trainee is not personally at the console performing the operation but aiding the surgeon at bedside. Besides the obvious benefit of observing and learning the steps to the operative procedure, the trainee also develops a variety of necessary skills, including patient positioning, robot docking, and port placement. While assisting at bedside the resident learns how to help the procedure run more efficiently [25].

The second phase of the robotic curriculum includes console training. The console is a distinct area where the surgeon gets a 3D image of the patient's anatomy and where the surgeon performs the operation. The robot converts the operator's hand and finger motion into simultaneous movement of the surgical instruments [26]. Console training begins with online computer modules which include basic information on the robot, the parts of the system, and trouble shooting. After obtaining this certification, training begins on the console [25]. Similar to laparoscopic training, there are variety of different tools with which the resident can become proficient prior to operating on patients. Current techniques used for console competency include virtual reality simulators along with dry and wet lab training [25].

Just as with laparoscopic surgery, virtual reality simulators are essential for robotic procedures. This often serves as the first step in developing basic to advanced robotic skills. There are variety of robotic simulators in use today which have been shown to be effective in the development of robotic skills. These simulators all enhance the trainee's skill set through task which incorporate needle control, suturing, clutching, energy use, and dissection. Dry skills lab is another area utilized in robotic surgical training. This is a cost-effective method in which the surgical trainee sits at the actual daVinci robot. Here utilizing the console, the trainee will use the actual robotic instruments on material mimicking human tissue. This allows development of advanced robotic skills in real time with no patient risk. The last form of console training is wet skills lab training. This method allows one to perform full surgical procedures utilizing the robot on both live animal as well as human cadaveric models [25].

4. Resident education during COVID

The 2020 COVID-19 pandemic has had an impact on all aspects of general surgery training. Residency conferences and didactics moved to online platforms, rotations were canceled to reduce viral exposure, and non-urgent elective cases were delayed or rescheduled [7, 8, 27]. A concern for skills decay with the decrease in opportunities for procedural training emerged as a result.

There has been a significant reduction in surgical case volumes among all surgical specialties throughout the COVID 19 pandemic. For example, Aziz et al. found a significant reduction in operative case volume among 1,102 general surgery trainees in the United States [8]. Reduction in case volume has caused concern among both residents and directors as minimum case requirements are increasingly difficult to obtain. Rosen et al. demonstrated these results among the urological community as 60% of urology program directors were concerned that residents would not reach required operative volumes secondary to the COVID pandemic [28]. Similarly, there has been a shift to nonoperative management among previously emergent presentations like appendicitis [27]. The pandemic has shed light on an evident shift in surgical management that has been occurring over the past 50 years. Even before the emergence of COVID-19, the introduction of new data and technologies for certain disease processes, that were managed with complex surgical procedures in the past, has led to treatment with less invasive methods. For example, in surgical oncology the advent of the sentinel lymph node biopsy has drastically decreased the amount of completion lymph node dissections for melanoma and breast cancer [29, 30]. The advent of endovascular surgical techniques in vascular and cardiothoracic surgery has decreased trainee's exposure to a variety of open surgical cases. Smith et al. demonstrated a significant decrease in the amount of open abdominal aortic aneurysm repairs. Over a five-year study period from 2010 to 2014 trainees demonstrated a 38% decrease in open repairs, with one half of trainees in 2014 having exposure to less than five open repairs [31].

The obvious concern among surgical residents is inadequate operative skills secondary to decreased case volumes. Simulation training is now as important as ever to develop surgical skills among trainees. Doulias et al. argues that to prevent deterioration of operative skills, programs need to expand simulation training [32]. To improve surgical skills, online video conferencing platforms are now used to provide real time feedback from experts to surgical trainees undergoing laparoscopic and robotic training.

Despite many negative impacts from COVID on training Hope et al. argues for some positive implications. The authors argue that the adaptation of online learning has allowed greater access to educational material. Electronic-learning has now become a staple within surgical education [27]. Focus has shifted from in person lectures to a variety on online tools like podcasts, social media, YouTube videos, virtual peer reviewed libraries, and video conferencing platforms. Video conference platforms like Microsoft Teams and Zoom have provided an outlet for remote didactics, conferences, and virtual rounding [32]. Future studies will investigate the effectiveness of these new learning modalities on surgical education, but they will likely continue to have an impact in the post COVID era.

5. Conclusion

Surgical education over the last 50 years has proven to be a constantly evolving process. No longer is the Hasteadian "see one, do one, teach one" the sole maxim in training. With a growing emphasis on both patient safety and resident well-being,

there has been a development of novel training paradigms. Greater emphasis has been placed on surgical simulation as a means for increasing operative skills. Training today also places an emphasis on didactics, conferences, and research as protected time is set aside for during the 80-hour work week for residents to develop their skills outside of the operating room. The lasting effects of the COVID-19 pandemic on surgical education are unknown, but the use of simulation and online training will likely continue to increase throughout the remainder of the 21st century to ensure stable and consistent training.

Author details


Anthony P. Allsbrook^{1,2} and Roderick M. Quiros^{1,2*}

1 Department of Surgery, St. Luke's University Health Network,
Bethlehem, Pennsylvania, USA

2 Department of Research and Innovation, St. Luke's University Health Network,
Bethlehem, Pennsylvania, USA

*Address all correspondence to: roderick.quiros@sluhn.org

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