Evolving Educational Techniques in Surgical Training

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KEYWORDS
- Surgical education • Training • Innovations • Educational techniques
- Medical student • Resident • Surgeon

KEY POINTS
- Surgical education has undergone a tremendous transformation since its advent in the early twentieth century, transitioning from an “apprenticeship” and “journeymanship” toward a training model based on knowledge of basic sciences, research, and graduated patient responsibility for the resident.
- Training competent and professional surgeons efficiently and effectively requires innovation and modernization of educational methods, with recognition that surgical classroom is under constant transformation, and an understanding of today’s learner and learning styles.
- E-learning and the use of online curricula allows educators to overcome obstacles related to surgical education with increased accessibility of learning material, ease in updating and editing content, personalized instruction, simplicity of distribution, standardization of content, and learner accountability.
- Today’s medical learner is using multiple platforms to gain information, including online surgical resources, videos, social media, and podcasts, providing surgical educators with numerous innovative avenues to promote learning.
- With the growth of technology, and the restriction of work hours in surgical education, there has been an increase in use of simulation, including virtual reality, robotics, telemedicine, and gaming. The use of simulation has shifted the learning of basic surgical skills to the laboratory, reserving limited time in the operating room for the acquisition of complex surgical skills.

INTRODUCTION
Surgical education has undergone a tremendous transformation since its advent under William S. Halsted, MD, in the early 20th century, transitioning from an “apprenticeship” and “journeymanship” toward a training model based on knowledge of
basic sciences, research, and graduated patient responsibility for the resident. Training competent and professional surgeons efficiently and effectively requires innovation and modernization of educational methods, recognition that surgical classroom is under constant transformation, and an understanding of today’s learner and learning styles. To understand today’s educational climate, one must first examine the history of surgical education.

HISTORY

*Study the past if you would define the future.*

—Confucius

In the early twentieth century, William Welch, the founding dean at Johns Hopkins; William Osler, Hopkins’ first chief of medicine; Frederick Gates, a Baptist minister and trusted adviser to John D. Rockefeller; and Abraham Flexner, a former high school teacher, gathered as the “Hopkins Circle” and forever altered the course of medical education in the United States by advancing the science-based foundation of medical training. Flexner was invited to survey the quality of medical schools throughout America and Canada and provide suggestions for their improvement. Specifically, his assignment was to “sweep clean the medical system of substandard medical schools that were flooding the nation with poorly trained physicians.” Flexner’s 1910 report on the state of medical education was historic, not only for its comprehensive review of all 155 medical and osteopathic institutions in the United States and Canada but because of its impact on the manner in which medicine was taught. Flexner’s report is often credited with having laid the groundwork for modern medical education. Huge financial bequeaths were made by the Rockefeller and Carnegie Foundations, which in turn affected the fashion in which medical faculty would live their lives in academic medicine. Medical professors were to be freed from patient care responsibilities so as to dedicate their lives to teaching and research. At the time, most hospitals reluctantly tolerated medical student teaching. Students could receive good training in physical diagnosis and the use of certain medical instruments, but they were rarely permitted to have responsible contact with patients. Acting on his firm belief in the value of learning from patients, Sir William Osler, MD, in 1893, introduced the concept of clinical clerkships, and incorporated bedside rounds into student classes at Johns Hopkins University and, thus, the first true teaching hospital.

Paralleling medical education, surgical education has also undergone significant changes since its origin. Up until the nineteenth century, surgeons learned their craft through “apprenticeship,” similar to the modern day surgical residency, followed by a “journeysmanship,” similar to the modern day surgical fellowship. The typical surgical apprenticeship in the mid-sixteenth century started at approximately age 12 and lasted 5 to 7 years. The young surgeon-to-be learned the craft through direct observation, then imitating the actions of a skilled mentor, both in the operating room and at bedside, providing history to the popular saying: “See One, Do One, Teach One.” The masters taught with the same principle as the popular saying, they taught what they themselves had “seen” and “done.” Without structure for what should be taught, guiding principles for training, or investigative inquiry for new methods or practices, medical education reached an unfortunate standstill by the late nineteenth century. The beginning of the twentieth century marked the first major shift from “apprenticeship” training to surgery residency as we know it today. The surgical training model used to train residents in the United States for the past century is, in part, due to the principles laid forth by William S. Halsted, MD, FACS. The Halstedian training model was
built on the triad of surgical education: knowledge of basic sciences, research, and graduated patient responsibility for the resident.

The American College of Surgeons (ACS) was formed in 1913, and has remained a strong advocate and leader in surgical education since its inception. In 1939, the ACS published the Fundamental Requirements for Graduate Training in Surgery, the first to offer criteria for hospitals that trained surgical residents, along with guidelines for achieving training criteria.7 From 1920 to 1940, numerous medical specialty boards followed suit, and in 1928, the American Medical Association published the “Essentials of Approved Residencies and Fellowships.”8 When Medicare was approved in 1965, the medical education community realized that multiple Resident Review Committees, each with its own practices, policies, and standards, was not a coordinated standard and required focused oversight. In 1981, the Accreditation Council for Graduate Medical Education (ACGME) was born. In the years since its inception, the ACGME has strived to ensure baseline qualities in medical education through implementation of several initiatives, including the Outcomes Project in 1999, Duty-Hour Restrictions in 2003, the Next Accreditation System in 2013, and the current Milestones Project,9 which have dramatically changed the landscape of surgical education. As governing bodies and individual training programs attempt to adapt to today’s environment, we have seen an emergence of evolving educational techniques in surgical education. Just as Flexner and Halsted asked, we continue to question: How can we improve surgical education? How do we train competent and professional surgeons more efficiently and effectively? How can we reorganize surgical education to train physicians able to achieve better surgical outcomes?

CATALYST FOR CHANGE

If you aren’t in over your head, how do you know how tall you are?10

—T.S. Eliot

Several factors served as the catalyst for change in the structure of medical and surgical education. To answer the question of how we can improve surgical education, one must first examine the shifting medical environment in which we practice today, and how the medical learner has changed from Generation X to Generation Y.

Shifting Medical Environment

In 1980, the average length of stay at teaching hospital was 7.3 days, compared with 4.5 days in 2012.11 This change reflects technologic advances in medical care, such as improved therapeutic agents, growing use of the electronic medical record (EMR), minimally invasive surgery (MIS), and efforts by the health care system to reduce hospital costs. Shorter hospital stays have changed medical education by forcing medical schools to educate in an atmosphere in which time is of the essence. As a result, students have gone from being active learners to passive observers. Furthermore, in today’s clinical environment, patients are admitted with the diagnoses known and treatment plans already determined. A student on the surgery clerkship can certainly learn the technical aspects of an operation, but recognizing the symptoms of a disease process, appropriate diagnostic tests, and interpretation of those tests remains crucial to students’ acquisition of clinical decision-making. Patients are frequently discharged before the effects of therapy can be observed, thus circumventing students’ opportunity to follow the course of a disease and its treatment. Last, faculty are under intense pressure to be clinically productive. This pressure has resulted in many faculty having little time to teach, advise, conduct research, or serve as mentors.12
A Different Medical Learner

Today’s medical students and surgical residents were born into the Millennial generation. The Millennial generation, or Generation Y, includes individuals born from 1982 to 2004, although precise dates vary between demographers. Although one cannot stereotype an entire generation, the Millennials are perhaps the most studied, such that their differing traits and characteristics from Generation X become quite apparent (Table 1). The Millennial generation not only differs from Generation X in characteristics, but also in learning style (Table 2). Engels and de Gara found that this generation of medical students learns by assimilation, compared with the converging style of general surgery residents and faculty. To train these learners effectively and efficiently, one must consider not only what is being taught, but how it is taught.

Millennials are “digital natives,” a term coined by author Marc Prensky in 2001 to describe today’s students who are all “native speakers” of the digital language of the Internet, computers, and video games. Prensky states that “the arrival and rapid dissemination of digital technology in the last decade of the 20th century” has changed the way “digital natives” think and process new information, making it difficult for them to excel in classrooms using outdated teaching methods commonly used in medical education today. How does this effect surgical education? Of US general surgeons currently in practice, 78% are older than 40. Most surgical educators are “digital immigrants,” or individuals born before the widespread adoption of digital technology, and therefore are forced to adopt the technology to survive in today’s environment. According to Prensky, as “digital immigrants” learn to adapt in the new digital technology, they always retain certain old habits, such as reading the manual instead of assuming the program will teach us to use it or printing out e-mails to read them. Essentially, “digital immigrants” are learning a new language every day. A language learned later in life uses a different part of the brain than one learned as a primary language. Literally, “digital natives” think differently from “digital immigrants.”

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Comparison of traits and characteristics of Generation X and Generation Y</th>
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<tbody>
<tr>
<td><strong>Generation X</strong></td>
<td><strong>Generation Y</strong></td>
</tr>
<tr>
<td>Age in 2015: 36–50</td>
<td>Age in 2015: 11–33</td>
</tr>
<tr>
<td>Accept diversity</td>
<td>Celebrate diversity</td>
</tr>
<tr>
<td>Pragmatic/practical</td>
<td>Optimistic/realistic</td>
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<tr>
<td>Self-reliant</td>
<td>Self-inventive</td>
</tr>
<tr>
<td>Rejects rules</td>
<td>Rewrites rules</td>
</tr>
<tr>
<td>Mistrusts institutions</td>
<td>Irrelevance of institutions</td>
</tr>
<tr>
<td>Personal computer</td>
<td>Smart phones and Internet</td>
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<tr>
<td>Digital immigrant</td>
<td>Digital native</td>
</tr>
<tr>
<td>Uses technology</td>
<td>Assumes technology</td>
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<tr>
<td>Convergent learner</td>
<td>Assimilative learner</td>
</tr>
<tr>
<td>Multitasks</td>
<td>Multitasks fast</td>
</tr>
<tr>
<td>Latch-key kids</td>
<td>Helicopter parents</td>
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Evolving Techniques in Surgical Education

We need to prepare students for their futures, not our past.18
—Ian Jukes

The role of the teacher in surgical education is quickly changing. As new technologies are developed, such as online learning portals, social media outlets, and virtual reality, the surgical educator is challenged to adapt educational techniques to meet the needs of the twenty-first century medical learner.

Defining E-learning

Traditional teacher-centered didactic teaching is yielding way to a learner-centered approach in online Web-based arena. The term “e-learning” refers to the delivery of learning, training, or education programs by electronic means. E-learning overcomes several educational obstacles and, therefore, is gaining popularity in surgical education. Delivery is the most commonly cited advantage of E-learning, as online curricula facilitates increased accessibility of learning material, ease in updating and editing content, personalized instruction, simplicity of distribution, standardization of content, and learner accountability. E-learning also can potentially improve the efficiency and effectiveness of surgical education. The software used to create e-learning modules, such as Articulate, Camtasia, and Elucidat, allow educators to create a learning platform based on adult learning theory; that is, encourage the learner to relate new learning to past experiences by linking learning to specific needs, then create practical application. Engaging the learner in the online environment and promoting interactivity with the material stimulates efficiency, motivation to learn, and cognitive effectiveness. Evidence suggests that e-learning is a more

<table>
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<th>Table 2 Comparison of traditional and evolving educational techniques</th>
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<tr>
<td><strong>Traditional Educational Techniques</strong></td>
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<tr>
<td>Teacher-led, memory-focused</td>
</tr>
<tr>
<td>Knowledge bestowed from authoritative source</td>
</tr>
<tr>
<td>Isolated work on prepared exercises</td>
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<tr>
<td>Predetermined progression</td>
</tr>
<tr>
<td>One path</td>
</tr>
<tr>
<td>Single-sense stimulation, limited media</td>
</tr>
<tr>
<td>Taught to one learning style</td>
</tr>
<tr>
<td>Mastery of fixed content and specified processes</td>
</tr>
<tr>
<td>Competence defined by facts and literal thinking</td>
</tr>
<tr>
<td>In class expertise, content, and activities</td>
</tr>
<tr>
<td>Written communication and information</td>
</tr>
<tr>
<td>Primary focus on school and local community</td>
</tr>
<tr>
<td>Outcome-based assessment</td>
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</tbody>
</table>

Data from Nicholas A. Preferred learning methods of the Millenial Generation. Faculty and Staff – Articles & Papers. 2008; Paper 18.
effective method of teaching because learners gain knowledge and skills faster than through traditional teacher-focused methods, leading to improved motivation and performance. However, for e-learning to be successful, several elements must exist: content management, course design, learning objectives and measurable outcomes, and communication (Table 3).

Web-based tools offer several advantages over in-person/printed educational tools: few physical or time-based barriers, searchable content, and interactivity. Furthermore, students can view the material at their own pace, and review material as needed, which is not possible in a live lecture. In the current training climate, in which surgeons are expected to reach proficiency despite a decrease in work hours, e-learning can make educational time more efficient. For example, Gonzalez and colleagues23 restructured the neurosurgical teaching program at their institution by providing trainees with tablet devices as an educational resource. The investigators report a subsequent significant improvement in examination scores: 92% of trainees attributed increased time spent studying outside of hospital to the provision of tablets, and 67% used these devices as the primary means of accessing educational resources.

**Flipped Versus Blended Classroom Versus Massive Open Online Courses**

If a child can’t learn the way we teach, maybe we should teach the way they learn.24

—Ignacio Estrada

The advent of e-learning has introduced several new terms used to describe the use of online curricula in the classroom, including the “flipped classroom,” “blended classroom,” and the Massive Open Online Course. The “flipped classroom” is a concept first presented by J. Wesley Baker25 in 2000 in “The “Classroom Flip: Using Web

<table>
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<tr>
<th>Necessary Elements in E-Learning</th>
<th>Description</th>
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<tr>
<td>Content management</td>
<td>Storing, indexing, and cataloging of learning materials necessary to make content available to learners</td>
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</table>
| Course design                   | Synchronous: real-time, instructor-led e-learning, where all learners receive information simultaneously and communicate directly with one another  
Asynchronous: transmission and receipt of information do not occur simultaneously, learners are responsible for pacing their own self-instruction and learning |
| Learning objectives and measurable outcomes | Description of what the learner should know or be able to do at the end of course, serves as basis for the larger educational materials |
| Teacher/student communication   | Face-to-face ± online social media |
| Multimedia                      | Animations, videos, audio, print |
| Engagements                     | Opportunities for the learner to interact with the material |
| Assessment                      | Formative vs summative |
Course Management Tools to Become the Guide by the Side,” and by Lage and colleagues26 in their article “Inverting the Classroom: A Gateway to Creating an Inclusive Learning Environment.” In this model, what is traditionally done in class (teacher-led lecture with students listening and taking notes) is done before class, and what was traditionally homework (problems solved using information from lecture) is done in the scheduled class.27 This model flips the traditional roles of the teacher and student, leading to the ability to cover more material, accommodation of students with different learning styles, better engagement of students with collaborative exercises, and improved assessment of understanding.

The “blended classroom” first appeared in a press release in 1999 by the Interactive Learning Centers.28 The blended learning model allows the student to learn, at least in part, through delivery of content and instruction online, such that the student has control over time, place, path, or pace.29 Advocates of blended learning state that incorporating the “asynchronous Internet communication technology” into higher education serves to “facilitate a simultaneous independent and collaborative learning experience”30 and this mix of independence and collaboration leads to student satisfaction and learning success.

A Massive Open Online Course, or MOOC, is an online course aimed at unlimited participation and open access via the Internet. The MOOC was first introduced in 2008, and by 2012, emerged as a popular mode of learning.31,32 The MOOC is a type of distance learning that incorporates traditional course materials, such as readings, problem sets, and videos with an interactive user format to support interface between learners and teachers. According to the New York Times, 2012 became the “year of the MOOC,” as several online providers, associated with top academic universities, emerged.31,33 MOOCs carry great potential in surgical education, as the learning material can reach learners regardless of time or distance, and can be used for new material, certification, or maintenance of certification. In a 2014 review, the investigators identified 98 free health and medicine-related MOOCs, of which 90 were offered by major universities. The duration of MOOCs varied from 3 to 20 weeks, with an average of 6.7 weeks. The MOOCs required an average of 4.2 hours per week of participant work, and verified certificates were offered by 14, with another 3 offering professional recognition.34

It is important to note that these types of online curricula are not simply the opportunity to access online lectures. The Millennial learner prefers teamwork and interactive learning by engaging with the materials, faculty, and colleagues.35 Furthermore, online learning material works best when it addresses lower-order cognitive skills, including knowledge and comprehension. Higher-order skills, such as application and analysis, are best taught face-to-face, with faculty supervision and input.36 Millennial learners want to have a close relationship with authority figures, similar to the relationship they grew accustomed to with their “helicopter” parents.37 The term “helicopter” parents first appeared as a metaphor in 1969, and refers to the parent who pays extremely close attention to a child’s experiences and problems, particularly in education.38 Millennial learners also want to feel that their supervisors care about them personally, and prefer to work with superiors who are approachable, supportive, good communicators, and good motivators. This brings new function to the role of teacher. In the Halstedian era, learners were taught to think critically through “pimping,” where the medical trainee was asked a series of questions designed to test the boundaries of known knowledge. However, in the current environment, there is concern about both the term “pimping” and its purpose. Kost and Chen have suggested that educators focus on questioning that “is more learner centered; aids in the acquisition of knowledge and skills; performs helpful formative and summative assessments of the
leaner; and improves community in the clinical learning environment.\textsuperscript{38} This shift from “pimping” to learner-centered dialogue can be challenging for surgical educators; however, it better meets the educational needs of today’s learner.

**Online Surgical Resources**

*Online learning is not the next big thing, it is the now big thing.*\textsuperscript{39}  
—Donna J. Abernathy

The growth in online surgical resources speaks to the popularity of e-learning in surgical education. The Surgical Council on Resident Education (SCORE) initiative was created in 2004 to “provide residents with high-quality educational materials and a structured program for self-learning in all areas of general surgery.”\textsuperscript{40} By 2014, approximately 200 programs subscribed to the SCORE Web portal. Early data suggest that SCORE improves the education of surgical residents. Klingensmith and colleagues\textsuperscript{41} found considerable improvement in mean qualifying exam scaled scores for residents in programs that subscribed to the Web portal.

The Web Initiative for Surgical Education of Medical Doctors (WISE-MD) is a series of Web-based modules built on the theoretic framework laid out by Dr Richard E. Mayer, who proposed that improved learning occurs when animation and narration occur simultaneously, especially if this process activates prior knowledge.\textsuperscript{42,43} WISE-MD started in 2003 with the Computer-assisted Learning in Pediatrics Program (CLIPP) cases based on the national pediatric medical student curriculum. In 2006, the nonprofit MedU was founded to sustain CLIPP. In 2009, the WISE-MD modules for surgical education, developed by the Department of Surgery and the Division of Educational Informatics at NYU in collaboration with the Association for Surgical Education, was integrated into MedU.\textsuperscript{44} In 2013, 99 medical schools in the United States subscribed to WISE-MD, paralleling the popularity of online surgical resources even in graduate medical education.\textsuperscript{45}

Dr Mayer’s research prompted educators to create learning environments such as WISE-MD, and may also explain the surge of surgical videos used by learners to augment their operative experience. WebSurg, the e-Surgical reference, is a “virtual surgical university, accessible from anywhere in the world through the Internet.” WebSurg is available in 6 languages, and has approximately 323,000 registered users.\textsuperscript{46} YouTube is a video-sharing Web site founded in 2005. The site allows users to upload non–peer-reviewed videos that can be viewed anywhere in the world. It is the third most popular Web site in the world, accounting for 60% of all videos watched online. Glass and colleagues\textsuperscript{47} surveyed members of the Resident and Associate Society of the ACS concerning educational resources used, and found that 30.8% of all respondents used online videos and lectures to prepare for examinations, 34.4% for building fund of knowledge, and 22.6% for information regarding patient care. Use of online videos and lectures was higher in senior residents compared with junior residents. This percentage is even higher in medical students. In a study by Barry and colleagues,\textsuperscript{48} 78% of second-year undergraduate medical and radiation therapy students surveyed reported using YouTube as their primary source of anatomy-related video clips.

A Podcast is a series of audio files downloaded through Web syndication or streamed online to a computer or mobile device, whereas a Vodcast is a video podcast.\textsuperscript{49} In a study of 112 medical students, 68% reported listening to at least one podcast (average of 6) during their general surgery clerkship. When surveyed about efficacy, 84% agreed the podcasts helped them learn core topics, and more than 80% found the recordings interesting and engaging.\textsuperscript{50} Medical students report using podcasts and vodcasts regularly to supplement their learning in novel ways, even
while driving to clinic or exercising, providing educators with yet another avenue to reach learners.51

Social Media

With the boom of social media in the early 2000s, educators have used this technology to promote learning. Social media is defined as “a group of Internet-based applications that build on the ideological and technological foundations of Web 2.0, and allow the creation and exchange of user-generated content.”52 The most popular forms of social media used by medical students and residents include blogs, wikis, Twitter, and Facebook (Table 4). Cheston and colleagues52 reported that blogs were the most commonly used social media tool (71%) by medical students, followed by wikis (21%), Twitter (14%), and Facebook (14%). When students were asked to write essays, they generally favored blogging for the purpose of reflection, but favored in-person problem-based learning over virtual collaborative learning for improvement of clinical reasoning skills. Students who actively participated in blog-based discussion forums had higher grades than those who posted less often. Social media tools also provided opportunities for more feedback on their performance.53 Twitter has been suggested as a medium to involve students by creating a dialogue on the subject matter through retweeting key points and messages from lecture material. Twitter enables students to continue a discussion about a lecture and tie information to current events by using hashtags.51 Social media platforms such as Facebook also provide a powerful way to integrate medical education globally. In an New England Journal of Medicine Facebook group, a new “image challenge” is posted each week, and Facebook users can comment and give their diagnosis.51

Simulation

We are what we repeatedly do. Excellence, then, is not an act but a habit.54

—Aristotle

Table 4 Forms of social media

<table>
<thead>
<tr>
<th>Platform</th>
<th>Origin</th>
<th>Usage as of 2014</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Blog</td>
<td>1994</td>
<td>207.3 million bloggers</td>
<td>Short for “Web log,” is an online discussion or informational site published on the Web and consists of discrete entries or “posts” typically displayed in reverse chronologic order</td>
</tr>
<tr>
<td>Wiki</td>
<td>1994</td>
<td>4.9 million wiki pages</td>
<td>A Web site that allows collaborative editing of its content and structure of a Web site by its users. The best known example of a wiki Web site is Wikipedia (<a href="http://www.wikipedia.com">www.wikipedia.com</a>)</td>
</tr>
<tr>
<td>Twitter</td>
<td>2006</td>
<td>236 million users</td>
<td>Online social networking service that enables users to send and read short 140-character messages called “tweets” (<a href="http://www.twitter.com">www.twitter.com</a>)</td>
</tr>
<tr>
<td>Facebook</td>
<td>2004</td>
<td>1.23 billion users</td>
<td>Online social networking service that connects people with friends and others who work, study, live, and engage around them. People use Facebook to keep up with friends, to share links, to share photos and videos of themselves and their friends, and to learn more about people and organizations (<a href="http://www.facebook.com">www.facebook.com</a>)</td>
</tr>
</tbody>
</table>
With the growth of technology, and the restriction of work hours in surgical education, we have seen an increase in use of simulation. This is likely related to how surgical residents learn the technical aspects of surgery. Surgical residents advance through the 4 stages of learning as they progress through residency: the novice, the apprentice, the journeyman, and finally, the master. Knowledge and skills are developed with repetition in a number of venues: on the wards, in the classroom, and in the operating room. Time in the operating room is limited by service duties and work hours, and, therefore, is too valuable to be used for the acquisition of basic technical skills such as knot tying and suturing. In the novice and apprentice stages of learning, complex operative tasks are deconstructed into component skills, then taught individually until mastered. Virtual reality, including mechanical simulators, robotics and telesurgery, and animate models provide learners with the opportunity to acquire familiarity with instruments, improve dexterity, and gain knowledge about management, techniques, and potential complications of treating surgical conditions.

Virtual reality (VR) is an artificial environment that is created with software and presented such that the user suspends belief and accepts it as a real environment. There are two important components of VR in surgical education: realism and fidelity. If the environment appears realistic, the trainee’s emotional and physiologic response to the simulation will have a more accurate translation into the operating room. Fidelity refers to the degree with which the artificial environment looks, feels, and acts like a human patient. Mechanical simulators, or boxes in which objects or organs are placed and manipulated using surgical instruments, are the most primitive and the least expensive form of VR. They can define grades of difficulty and are capable of immediate performance feedback, making mechanical simulators ideal for initial acquisition of basic skills, familiarization with instruments, and basic techniques. Computer-based simulators provide an environment to apply basic skills to more complex operations. The degree of difficulty can be altered, along with modifications of the normal anatomy, forcing the learner to make intraprocedural decisions. Dutta and colleagues suggested that the unmet needs in our current training environments could be addressed by VR, to include exposure to rarely encountered conditions; focus on the learning needs of trainees in a cost-effective manner outside the OR; and performance assessment that includes decision-making, leadership, communication and judgment, all of which are difficult to assess in actual patient care. For VR to fill the gaps in surgical education, simulators must be realistic and, according to surgical innovators, “accurately teach the ergonomics, dexterity, steps of procedures and the more intangible visualization all at once, without risk to the patient….The ultimate goal is to have an adaptive and intelligent training and assessment system. It should not only be level-appropriate but also have the capability to change based on recognition of the user’s performance and deficiencies to this point, as well as how quickly the learner has improved in the past.”

**Robotics**

Perhaps the single greatest surgical innovation of the past 3 decades is the advent of MIS. Education and proficiency in MIS requires intensive and ongoing training, as it is technically difficult given the unnatural visual and haptic perceptions. The 2-dimensional monitor alters in-depth perception and hand-eye coordination, while the laparoscopic equipment changes force feedback while manipulating tissue. Computer-integrated surgery using robotics augment the surgeon’s skill by providing additional information that is less available to surgeons through human senses, specifically, with endo-wrist technology, ×10 magnification and 3-dimensional vision, when compared to laparoscopic surgery. With the introduction of robotic surgery,
surgical educators are now challenged with how to teach, train, and credential surgeons to use this technology. Robotic simulators were created to replicate the surgery, develop the skills necessary to perform robotic procedures, and help the surgeon learn to negotiate the “human-machine” interface. Robotic surgery allows the learner to practice within countless patient scenarios created by the computer, in addition to video and calculation of hand motion data. Mistakes made in simulation do not have human consequence, and actually have a positive impact on learning under proper supervision and feedback. The clearest role for robotic simulation is in practicing before performing a surgery. A presurgical warm-up gives the surgeon an opportunity to prepare for the case, with the ability to use the patient’s own imaging as a 3-dimensional virtual anatomic model via the simulator software. The major barrier to robotic simulation is cost and access, with a single robot costing approximately $800,000, with a $100,000 per year running cost.

Telesurgery

The robotic surgery system allows a surgeon to perform a surgical procedure at a remote site, known as telesurgery. Telesurgery is defined as “a procedure performed on an inanimate trainer, animate model, or patient in which the surgeon is not at the immediate site of the model or patient being operated on.” Robotic platforms were originally developed by the military to address the need to deploy robotic surgical capabilities in forward conflict arenas. The first long-distance telesurgery procedure was successfully completed in 2002. In the clinical realm, telesurgery is limited by legal barriers, as physicians cannot practice medicine across state lines without having a medical license in each state. The benefit of telesurgery in education is in mentoring. Telementoring, or real-time interactive teaching of techniques by an expert surgeon to a student not at the same site, was first reported in 1965 by Dr Michael DeBakey, who transmitted guidance on an open heart surgery from the United States over broadband satellite to surgeons in Europe. Since then, a number of laparoscopic procedures have been performed by less experienced surgeons under the guidance of more experienced surgeons. Teleproctoring, or the monitoring and evaluation of surgical trainees from a distance, is used for credentialing purposes and to set a standard of care and assessment for skills across hospitals. Teleconferencing and teleconsulting involve more demonstration and discussion than just interaction and intervention, where live surgeries can be transmitted for guidance and review.

Animate Models

In addition to computer-created simulation, the use of cadavers allows for the realism of real tissue, without the risks associated with learning on human subjects. Kaplan and colleagues developed an emergency surgical skills laboratory (ESSL) using a non-preserved cadaver during the third-year surgery clerkship. Students in this study were able to obtain suturing proficiency as well as important technical skills in the ESSL that were previously taught in the operating room, emergency department, or wards.

Gaming

The traditional medical model of “see one, do one, teach one” is no longer adequate to train physicians, because many skills cannot be developed by merely watching an expert. Minimally invasive operations provide an additional set of challenges that are not inherent in open operations, such as decreased tactile feedback, the fulcrum effect and working in 3 dimensions while focusing on 2. Video games offer visually realistic simulations that demand the same visual-motor dexterity sought in a surgical resident. Rosser demonstrated that past video game play in excess of
3 hours per week has been correlated with 37% fewer errors and 27% faster completion. In his study, current video gamers made 32% fewer errors, performed 24% faster, and scored 26% better overall than their nonplaying colleagues. He concluded that “training curricula that include video games may help thin the technical interface between surgeons and screen-mediated applications, such as laparoscopic surgery. Video games may be a practical teaching tool to help train surgeons.” Similar results were found in a study of veterinary medical students, where a significant positive association was detected between summary scores for video game performance and laparoscopic skills, but not between video game performance and traditional skills scores. In a study comparing video games and laparoscopy simulators in the development of laparoscopic skills in surgical residents, residents were randomly assigned to 1 of 3 interventions: a traditional laparoscopic box trainer, an Xbox gaming console, or a Nintendo DS handheld gaming system. Residents assigned to the Xbox 360 spent more time each week playing their game, and had the greatest improvement of the tested peg transfer time. Residents who reported a history of playing video games (at least 5 hours per week) performed better on the initial peg transfer than residents who reported having never played video games.

Surgical Improvement of Clinical Knowledge Ops (SICKO) is an educational tool that applies gamification techniques and teaches the workup and operative management of classic surgical diseases. SICKO uses an immersive, interactive, and media-rich user interface along with a point system to reward or penalize right or wrong actions, offering instant feedback. All actions, answers, and consequences, are compiled into a final end-of-game report for the learner to review. Researchers noted expert players outperformed less experienced players, suggesting that educational games may be a valid assessment of medical decision-making.

CHALLENGES OF INNOVATION IN SURGICAL EDUCATION

The mother of excess is not joy but joylessness.
—Friedrich Nietzsche

Technological innovations may enhance surgical education; however, they also bring new challenges. Electronic devices used to deliver e-learning also tempt the learner to multitask, such as reading several articles at once, or checking e-mail or reviewing patient’s charts while studying. Millennials are reported to be superb multi-taskers. However, the science tells a different story. A study examining whether texting or posting to a social network site has negative impacts on students’ learning found that students who were not using their mobile phone wrote down 62% more information in their notes, took more detailed notes, were able to recall more detailed information from the lectures, and scored a full letter grade and a half higher on a multiple choice test than those students who were actively using their mobile phones. Others have investigated the relationship between classroom laptop usage and course achievement. Kraushaar and Novak developed a rubric to classify programs as productive or distractive toward the student (productive programs were course-related; distractive programs included Web surfing, e-mail, or instant messaging). They found that 62% of the programs that students had open on their laptops were considered distracting. They additionally found that instant messaging was negatively correlated with quiz averages, project grades, and final examination grades.

Studies on multitasking have shown greater vulnerability to interference, leading to worse performance. But, is the Millennial generation really multitasking? Newer
research suggests that Millennials can switch tasks so quickly that it appears they are doing the tasks simultaneously without truly multitasking. The Millennial generation appears to be rewiring the brain with fast simultaneous tasking, such as playing on the computer while watching TV and reading a book. This retraining allows the brain to reduce performance deterioration of multitasking by increasing the speed of information processing by the brain, thereby allowing multiple tasks to be processed in more rapid succession.

Fast simultaneous tasking appears to be the new norm, as new technologies, such as smart phones and tablet devices, continue to grow in number and popularity. In a survey of medical students, residents, and faculty members at 4 Canadian medical schools, mobile devices were commonly used to find drug information (73.5%), perform clinical calculations (57.9%), take notes (51.6%), search for journal articles (46.5%), and read journal articles (50.2%). Medical students and residents additionally used their mobile devices to find clinical practice guidelines, read point-of-care information, do clinical calculations for performing differential diagnoses, and access medical resources. In a review of smart phone uses in medicine, research has demonstrated that the smartphone is improving communication on internal medicine wards, suggesting that there may be a role for better communication between doctors and nurses. A systematic review of the literature by Mobasheri and colleagues demonstrated the widespread potential of smartphone and tablet platforms within surgery. Preoperatively, these technologies have been used to aid surgical diagnosis, assist in operative planning, educate patients regarding scheduled operations, and decrease anxiety in pediatric surgical patients. Intraoperatively, such technology has been used for telementoring. Postoperatively, these platforms have been used to monitor and review patients remotely. In terms of operative training, tablet devices have been used as simulators and as a means of improving accessibility to educational content both at the user’s convenience and at the point-of-care delivery. In contrast to previous smart phone study results, access to EMRs was one of the most frequently reported uses of the tablet computer. The investigators speculate that tablet computers are preferred over smart phones for EMR access primarily as a result of the large displays and a greater number of integrated EMR platforms.

The effect of increased use of smart phones and texting in medicine has changed the way medical professionals communicate. In a study of text messaging among residents and faculty in a university general surgery residency program, most surgery residents (88%) and attendings (71%) texted residents. Fewer residents (59%) and attendings (65%) texted other faculty. Most resident-to-resident texting occurred 3 to 5 times per day (43%), whereas most attending-to-resident texts occurred 1 to 2 times per day (33%). Among those who texted, the most frequently reported purpose was patient-related care among all groups. A drawback to this technology was weakened interprofessional relationships.

SUMMARY

The “Hopkins Circle” gathered in the early twentieth century, likely unaware of the tremendous impact their shared thoughts and innovation would have on medical education in the United States. Flexner’s report spurred changes in the medical education, while the leadership of Osler and Halsted formed surgical residency as we know it today. A common thread throughout surgical history is the desire to improve surgical education such that graduates are competent, professional, compassionate, and safe. As technology has advanced, so has the educational armamentarium
available to surgical educators. Embracing both the learning styles of this generation and the evolving technological advances, such as the “flipped” and “blended” classroom, MOOCs, videos, social media, and podcasts, is not only inevitable but necessary to engage today’s medical learner. Simulation, VR, robotics, telemedicine, and gaming are no longer the future of surgical education, but represent the standard by which competence will be developed and measured. If Halsted were alive today, he may not recognize the technology and methods, but he would embrace the current academic model that fosters scientific knowledge, research, and learner and patient-centered surgical education.

REFERENCES


