The virtual surgeon:

Using medical simulation to train the modern surgical resident

by **David T. Cooke, MD; Ramin Jamshidi, MD; Julian Guitron, MD;** *and* **John Karamichalis, MD**

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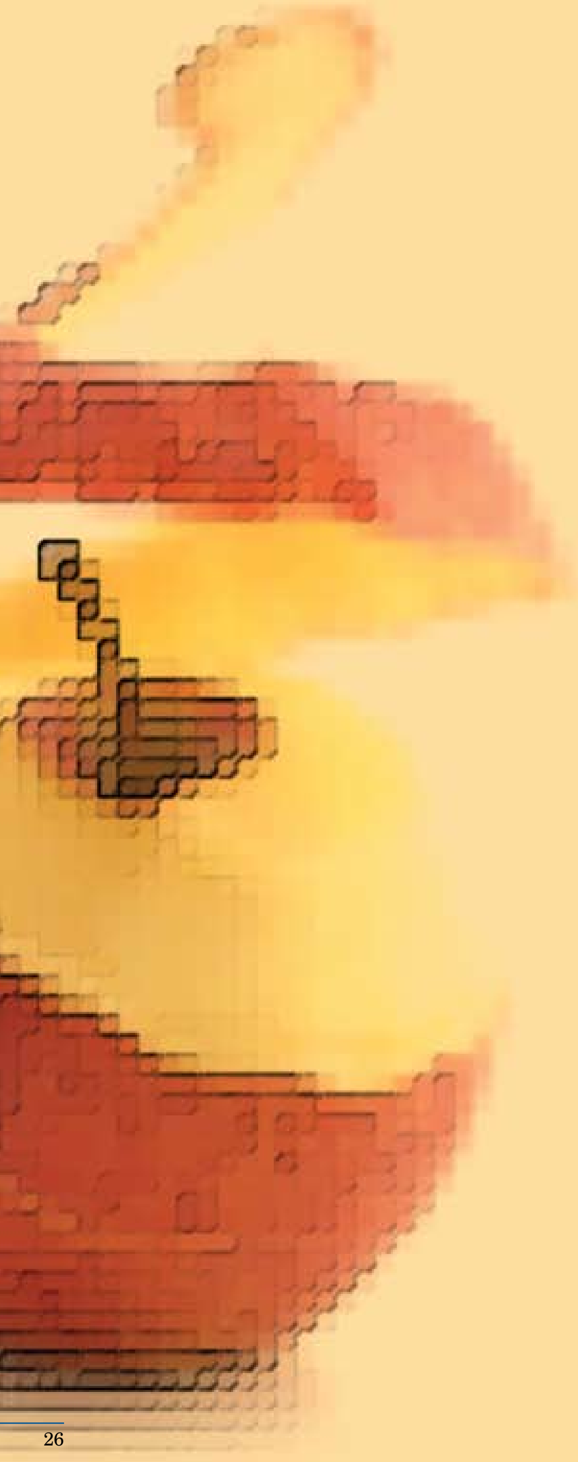
edited by **Dr. Cooke**



Surgical training has reached a point where the old adage, "See one, do one, teach one," has become antiquated. The surgical resident of today faces a field with numerous complex technologies that reset the bar for core competencies. There is a challenge to meet those core competencies in the 80-hour work-week era, especially as work hours may become even more restricted in the future. Most importantly, patient safety and the quality of medical care provided must be protected as we develop strategies to better educate our residents.

Simulation-based education is the use of technology—such as computer programs with three-dimensional reconstruction of surgical anatomy, high-fidelity tissue-based surgical models, and endovascular and laparoscopic simulation systems—to train the surgeon in a classroom environment. Other professions have used simulation-based education for decades. Many of us learned to drive in high school using video simulation. The aerospace industry has had long success with flight simulation. Surgery, it seems, is ideally suited for the simulation-based education medium. Numerous publications have shown benefits of surgical simulation, including training surgical residents in flexible bronchoscopy and catheter-based vascular surgery.[1-2]

The growing literature supporting medical simulation led the American Council for Graduate Medical Education to comment on the need for residency programs to include simulation and skills laboratories in their curriculum in its most recent Program Requirements for Residency Education in Surgery.[3] Anticipating this need, the American College of Surgeons Division of Education developed the ACS Program for the Accreditation of Education Institutes.[4] This body determines two levels of accreditation for medical education institutes with simulation centers. Level I-accredited centers, the highest level of accreditation, must provide simulation-based education programs to surgeons as well as at least three other specialty groups and adhere to facility design requirements. Currently there are 18 level I-accredited centers. One level I-accredited center, the University of Michigan, provides 24-hour access to its simulation facilities for surgical residents. In addition, interns in general surgery, plastic surgery, and urology must complete a laparoscopic simulation skills program and reach performance targets using box trainers (developed at the University of Texas, Southwestern) and virtual reality trainers before being allowed to scrub for a laparoscopic case (Pamela B. Andreatta, EdD, MFA, director, University of Michigan Clinical Simulation Center, personal communication, April 28, 2008).

An advantage of the ACS Program for the Accreditation of Education Institutes is the ability to advocate standards and implementation guidelines for the simulation technology available. Medical simulation technology should provide the appropriate biofeedback and subject responsiveness, which would allow the resident to work and learn with some independence. However, there should be an appropriate level of attending instruction within the simulation curriculum, as many surgical nuances and, more importantly, surgical judgment might not be found in a computer model.

The American College of Surgeons has also collaborated with the Eastern Virginia Medical School to establish the Medical Modeling and Simulation Database (*www.medicalmodsim.com*). This Web portal is dedicated to medical simulation and modeling and provides information on related products, companies, and relevant publications.

In the following articles, the authors discuss the role of surgical simulation in the training of two fields of surgery that may most benefit from the technology. Dr. Jamshidi reviews the role of medical simulation in training surgical residents in laparoscopic surgery, and Drs. Guitron, Karamichalis, and Cooke describe how cardiothoracic surgical training is using simulation-based education, including a novel high-fidelity tissue-based cardiac surgical simulator.[5]

Simulation in laparoscopic training

by Ramin Jamshidi, MD

Simulation provides a means of developing technical competency without experimenting on patients. Furthermore, simulation facilitates training without the use of inhospital hours, which are an increasingly valuable commodity since implementation of duty-hour restrictions. Myriad options exist for both the manner of implementation and the actual equipment to be used, but a few central principles will be discussed here.[6-7]

Simulator technology

The unique components of laparoscopy that differentiate it from open surgery are lack of depth perception (a consequence of monocular vision); inability to look directly at work being performed; decreased degrees of freedom in motion (resulting from use of narrow-shaft instruments with fixed ports); and loss of tactile feedback. All the complexities of laparoscopic operations derive from these fundamental limitations combined with differences in exposure. Conveniently, simulation of these characteristics for initial practice and skill development does not require human or even live animal subjects.

In order to mimic these characteristics, training equipment has been developed across a wide spectrum from plastic boxes to extremely costly, computer-powered, force-feedback systems. Some educators advocate for higher complexity and more lifelike simulation, arguing that this will translate best from simulator to patient. Others contend that as long as the underlying dexterity and practice is developed, skills will translate to the patient-care environment without need for "hi-fi" simulation.[8] In fact, some investigators have demonstrated that not only do low-complexity simulators develop skills that translate to patient care, but even video games not intended to simulate operative skills actually develop abilities that are applicable to patient care.[9] The approach at the University of California–San Francisco (UCSF) incorporates both aspects. On one end of the spectrum, one of the authors (RJ) has developed a videoscopic practice system powered by a personal computer, which any resident can build for home use with less than $100. On the other end, we also use complex LAP Mentor™

units (Simbionix, Cleveland, OH), particularly for mock performance of bariatric and anti-reflux operations. Though these machines are extremely costly, they appear to attract residents by virtue of their novelty.

Context-specific training

As with all knowledge, retention is greatest when lessons are learned in a contextually relevant situation and applied soon thereafter. Nationwide, focus on skills training for general surgery house staff has concentrated on interns since they presumably require the greatest amount of training. As skills-training programs have matured, the intern-level curricula have come to include complex anastomotic techniques or laparoscopic skills. Interns generally enjoy these activities, but they do not have the subsequent opportunities to apply these skills in the operating room and hence the lessons are not reinforced. Thus, advanced laparoscopic techniques such as suturing are more useful when reserved for mid-level residents. An attending surgeon can guide an intern through a complex pancreatic resection or vascular reconstruction, but the novice's skills, comprehension, and experience are likely insufficient priming for them to derive lasting benefit from the experience. Just as in patient care, training by simulation should be level appropriate.

Program integration

Finding time to incorporate skills training in a busy surgical residency can be a tremendous challenge. It may require reorganization of service staffing or operating room block time, but most importantly it requires a shift in philosophy about surgical education. Residents require independent access to the program's training laboratory in order to allow practice during the late hours when they are free of patient care duties. However, purely voluntary participation is inadequate; ideally, residency programs will incorporate formal curricula. At UCSF, we have a set protected time for skills laboratory participation—a weekly session—which follows grand rounds and a basic science lecture. A culture shift was required within the program to allow interns to be absent from clinical duty for the first several hours of the day, but this arrangement has gradually gained acceptance.

Another challenge in incorporating a thorough skills program is that of involving higher-level residents. Senior and chief residents reach a level of skill in which simulation becomes inadequate. However, junior and mid-level residents can benefit from more advanced inanimate practice such as laparoscopic suturing or use of a complex simulator to perform anti-reflux or bariatric operations. Such activities also hold potential benefit for residents returning from research fellowships, in order to refresh their technical skills. Although house staff have adapted to the absence of their teams' front-line soldiers (interns), protected training sessions for junior and mid-level residents will create deeper personnel shortages on clinical teams, and this will require further adjustments in the scheduling of operations and coverage of patient care.

Conclusion

The modern era of graduate medical education has evolved from traditional approaches to an emphasis on patient safety and supervision of trainees. Training of technical operative skills before teaching patient care is a major tenet of modern training paradigms, but accommodation of such educational programs requires surmounting logistical and philosophical obstacles. The most educationally valuable, cost-effective, and time-efficient implementation of inanimate skills practice will consider relevant technology, context-specific implementation, and the involvement of trainees beyond the most junior level.

Simulation in cardiothoracic training

by Julian Guitron, MD; David T. Cooke, MD; and John Karamichalis, MD

As patient safety, changes in resident training, and introduction of techniques requiring new skill sets become increasingly more important, the notion that "the operating room is not the place to learn new techniques" is now more valid than ever. Simulation training in cardiothoracic surgery as a technology is gaining ground and offers invaluable assistance in training. It can also offer operative teaching assessment predicting future performance, training of stepwise operative sequences, and identification of appropriate

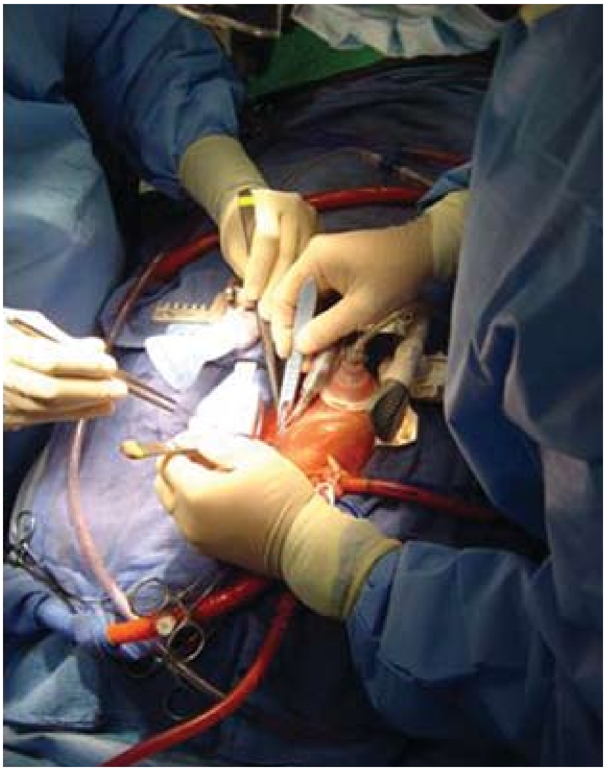


Figure 1. Close-up of the operative field, where an off-pump coronary bypass is being simulated at the Cardiothoracic Technology Symposium 2008. The coronaries bleed as the surgeon opens them, later controlled with an intracoronary shunt. (Photo courtesy of Walter Merrill, MD, FACS.)

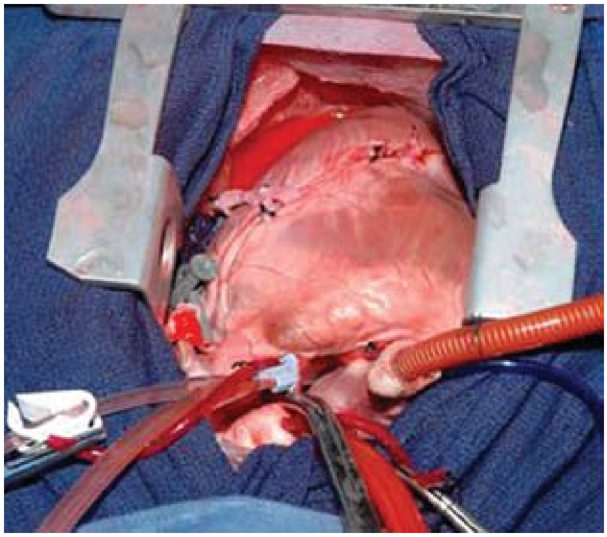


Figure 2. Coronary grafts placed during an on-pump procedure at the Cardiothoracic Technology Symposium 2008. (Photo courtesy of Walter Merrill, MD, FACS.)

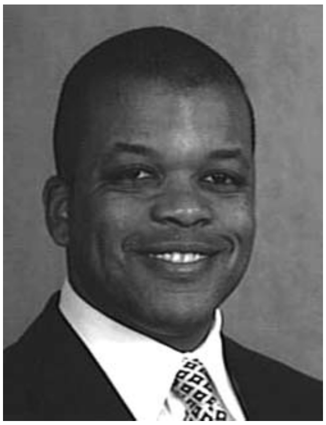
tools and instruments in a low-stress environment. Some of the simulation tasks that can be accomplished include, but are not limited to, sternotomy and redo-sternotomy, internal mammary artery takedown, aortic and venous cannulation, coronary anastomosis, valve replacements and complex repairs, and video-assisted thoracic surgery (VATS) lobectomy and other complex VATS procedures.

Currently there are several companies developing a wide range of models specific for cardiothoracic surgery, such as Immersion Medical (Gaithersburg, MD), which produces multiple simulators, including CathLabVR™, which develops vascular access skills—including percutaneous coronary and carotid interventions and percutaneous pulmonary and aortic valve surgery (thoracic and abdominal aortic interventions are in development)—and the Endoscopy AccuTouch® System, which provides virtual bronchoscopy and esophagoscopy. These devices use a tactile feedback technology that combines realistic visual and audio responses to mimic an actual procedure.

At this point in the surgical simulation evolution, the mere fact that simulator devices are available is no longer sufficient; there need to be carefully considered programs or curricula that bring out the most of every model. To that end, there are symposia that advocate the use of surgical simulators in cardiothoracic surgery and centers dedicated to simulated training. The Visioning Simulation Conference, for example, is considered a landmark event in the cardiothoracic surgery arena.[10] This meeting was held April 19–20, 2007, in Cambridge, MA, and addressed essential aspects of the specialty in relation to simulation such as resident and staff education; skill acquisition for new technology; and certification and recertification, which in the foreseeable future will likely incorporate simulator skill-set testing.

At the University of Cincinnati, the Center for Surgical Innovation (CSI) was established to develop, assess, and disseminate new technologies in biomedical and surgical care, bridging the expertise of the University of Cincinnati Colleges of Medicine and Engineering and several industrial partners, focusing on advancing robotic, simulation, and modeling capabilities, among other features.

The Cardiothoracic Technology Symposium for residents has been held at the CSI for the past three years and organized by the Thoracic Surgery Residents Association, with the support and collaboration of the Thoracic Surgery Directors Association and *CTSnet.org*. On April 18–20, Richard Feins, MD, FACS, and other collaborators from the University of North Carolina presented their cardiac surgery simulator. It was originally reported by Paul Ramphal, DM, and colleagues and has been developed further at the University of North Carolina through sponsorship by the American Board of Thoracic Surgery.[5] It is centered on a specially prepared pig heart, which is placed in a modeled mediastinum. It is then draped in the same fashion used for cardiac surgery patients. On the other side of the "curtain" stands the "anesthesiologist" who controls the computer that coordinates vital signs monitors (just as they are displayed in the operating room) as well as a modified cardiopulmonary bypass machine, which makes the heart actually beat. The trainee then cannulates for bypass or positions the heart for an off-pump procedure (see Figures 1 and 2 on page 29). All hemodynamics are traced and modified according to the clinical scenario desired, creating an endless array of circumstances such as ventricular fibrillation, hypotension, and so forth, which the trainee has to recognize and solve.



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The realism achieved with this simulator has surpassed even the most optimistic expectations (coronaries that bleed, irregular heart beats, hemodynamic instability, and so on) and has resulted in suspension of disbelief as described by Dr. Feins, where the simulator users actually get fully involved and react in a similar fashion as they would in the operating room. The skills that can be acquired with this model include cardiac cannulation, on-pump and off-pump coronary bypass, aortic valve replacement, and mitral valve repair/replacement. The cost, while still undetermined, will most likely be affordable to most residency programs. Setting up the simulator to be ready for use takes approximately one hour.

When asked how the residents perceived this simulator, Dr. Feins stated, "The feedback was universally very positive. On average, the residents thought that about 25 percent of their training should be simulator based. We were very pleased with the way the simulator performed and we are convinced that a heavily simulator-based education in cardiothoracic surgery will be a more enjoyable and more beneficial way to go" (personal communication, April 20, 2008). One of the attendees of the symposium, Daniel Tang, MD, a cardiothoracic resident at the University of Michigan, confirmed that sentiment, stating, "The resident symposium was excellent. In particular, the cardiac surgery simulator, the live animal, cadaver, and pig heart wet labs provided the opportunity to try a wide variety of techniques that I otherwise would not have had much exposure to. The enthusiasm and involvement of the faculty and the generous support of industry contributed greatly to its success" (personal communication, April 27, 2008).

James I. Fann, MD, FACS, is doing related work at Stanford University using a similar heart model. In particular, he is attempting to quantify how effective simulators are in educating cardiothoracic residents at that institution. He is using synthetic models produced by The Chamberlain Group (Great Barrington, MA).[11]

Conclusion

In summary, simulators and animal laboratories in conjunction with expert guidance now make for a robust training curriculum. It is clear that simulation training should become a mandatory part of cardiothoracic surgery curriculum, with regular sessions required for practice, verification of proficiency, and accreditation of skills. This new approach will mean the development of dedicated simulation centers and mandatory attendance, while the costs involved are being worked out as part of this new training path. Surgical simulation has the potential to effectively allow cardiothoracic residents to develop their basic skills so that the real-life operating room experience becomes all about perfecting them. Ω

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