The Revolution in Medical Education—The Role of Simulation

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Abstract

The last major change in medical education was the Flexner Report, over a century ago. Since that time, iterative improvements have occurred to the question-and-answer and "see one, do one, teach one" educational environment. However, multiple external forces—from the 80-hour work week to the emphasis on patient safety to competing demands on student and faculty time—have raised calls for a fundamental revamping of the entire medical educational process. Fortunately, new methods, curricula, and processes, such as Accreditation Council for Graduate Medical Education competencies or Objective Structured Assessment of Technical Skills, as well as innovative technologies such as web-based learning and simulation, have provided opportunities to support the revolution in medical education that will be responsive to national priorities, the public concern, and, most of all, to patient safety.

Introduction

For the first time in over 100 years, since the Flexner Report[1] in 1910, the structure in medical education is undergoing a complete revolution. This is a revolution that is touching every facet of medical education, and one that involves a transition to the Information Age that is driven by new methodologies, innovative technologies, as well as academic, social, and political factors. This change involves all of the components of education, the changing learning environment, respect for the personal and social welfare of the students/residents, and a pragmatic redesign of education in facing the external pressures of reimbursement, transparency, and public awareness. Nothing short of a complete redesign of our educational process will satisfy these competing interests; incremental changes to traditional methods of question-and-answer teaching, mentoring on rounds, and "see one, do one, teach one" will not be sufficient. We must preserve the very best of the validated (evidence-based medicine) methods, while introducing the remarkable advantages of the new innovations.

The most striking change has been introduced by the Accreditation Council for Graduate Medical Education in redefining the focus of education from a time-based system, in which the student/resident would spend a given number of years in training, to a competency-based system, in which progress was determined by reaching specific benchmarks of proficiency as opposed to time in service. But even more far reaching is the reorganizing of the components of competency into 6 basic areas (BOX 1): knowledge, patient care, professionalism, communication and interpersonal skills, practice-based learning and improvement, and systems-based practice. The first 2 components, knowledge and patient care, have been part of our traditional process, but the remaining 4 have not been addressed in the didactic and pedagogic fashion, leaving the individual faculty member (mentor) to informally include the topics during rounds, at the end of lectures, during a procedure, and so forth. The result has been a scrambling to establish and validate outcomes measures and curricula that can be used to adequately train and assess these competencies. Most noteworthy, there is no singling out of technical skills, which is incorporated as part of patient care, although at the writing of this article, there is serious consideration to adding technical skills as a seventh competency. Organizations have addressed the curricular aspects of technical skills, such as the American College of Surgeons' core competencies in basic skills[2] (BOX 2), full procedures, and team training. Given these new requirements, it has become necessary to reach outside the traditional educational tools.

Although all other industries (eg, aviation, mining, architecture, military, textile, etc) have been using simulation for virtual design, virtual prototyping, virtual testing and evaluation, training, and assessment, simulation has entered the health care industry for medical education only in the past decade. However, the impact of simulation has been, and will continue to be, profound. It will encompass all aspects of education, from initial screening of applicants, to laboratory-based training, to "in situ" training in the hospital, to clinical preoperative planning and surgical rehearsal, and preoperative warm-up before a procedure. The merit of simulation has been proven for over

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BOX 1 The 6 Competencies[a]

- Knowledge
- Patient care
- Interpersonal and communication skills
- Professionalism
- Practice-based learning and improvement
- Systems-based practice

[a]By the 2001 consensus by the Accreditation Council for Graduate Medical Education and the American Board of Medical Specialties.

50 years in all other industries and professions, and there is absolutely no reason why health care should not select those areas of education where simulation can support the training goals that have been established.

It is crucial to understand that simulation is a tool, not an end in itself. It is all about the curriculum, and the curriculum begins by setting the goals for the teaching/training of specific tasks to be accomplished. Once the objective measures have been established for the curriculum, development occurs, being certain to include the teaching of errors as part of the curriculum. Too often the curriculum focuses only on the correct action to take, without explaining the possible errors; as a result, students will continue to make the same mistakes repeatedly until they either figure it out themselves by trial and error (poor teaching method) or the errors are clearly and unambiguously explained to them. Then and only then will the students be able to avoid making errors, or if an error is committed, to identify the error and immediately remediate. The power of simulation is that it gives "permission to fail" in a safe environment (the laboratory setting), so students learn from their mistakes. Until now, whenever an error was committed, the patient suffered.

There are 2 major components of simulation: the training tools and the assessment tools. The first development of training tools was using a "patient" manikin that provided real-time physiologic feedback. Gaba and DeAnda[3] demonstrated its effectiveness in teaching basic anesthesia skills, airway management, and team training. Shortly thereafter Satava[4] created the first virtual reality surgical simulator, bringing the opportunity for interactive, computer-based training and assessment of technical surgical skills. At the same time, Reznick et al[5] were developing critical, objective assessment tools, the Objective Structured Assessment of Technical Skills, or OSATS. Applying these assessment principles, Derossis et al[6] developed and then validated a simple but powerful curriculum using inexpensive models for training and assessing laparoscopic skills, which evolved into the fundamentals of laparoscopic surgery.[7] Finally in 2002, Seymour et al[8] demonstrated the validity of virtual reality simulation in what has become known as the "VR to OR" validation. More recently, Kahol et al[9] published a study that has proven the effectiveness of virtual reality simulation in preoperative warm-up. In all these pioneering efforts, the measure for success has not only been decreasing time while increasing precision in performance of the competencies, but also in reducing errors while conducting a procedure or process, thereby improving patient safety.

BOX 2 20 Basic Skills

Asepsis and instrument identification
Suturing
Advanced tissue handling
  Flaps
  Skin grafts
Airway management
Central line insertion
  Arterial lines
Vascular anastomosis
Principles of bone fixation and casting
Upper endoscopy
Basic laparascopy skills
Hand-sewn GI anastomosis
Knot tying
Tissue handling
  Dissection
  Wound Closure
  Wound management
Catheterization
  Urethral and suprapubic
Chest tube/thoracentesis
Surgical biopsy
Laparotomy opening/closure
Introduction: inguinal anatomy
Colonoscopy
Advanced laparoscopy skills
Stapled GI anastomosis

Abbreviation: GI, gastrointestinal.

Today there are numerous methods and curricula for training and assessment of literally every aspect of medicine. The simple task trainers and virtual reality simulators of basic skills are not only used to train incoming residents in technical skills, but they are also "moving down" the curriculum into the medical schools, with simulations such as starting intravenous access, airway management/intubation, and simple suturing and wound closure. Consideration has been voiced to using these same simulations in the initial assessment of the technical skills when medical students are applying to residency programs, whether it is family medicine, internal medicine, anesthesiology, or a surgical specialty. Not only are technical skills addressed, but patient actors with the objective structured clinical examination, or OSCE (now a mandate for all medical students), are being used for physical examination, communication, and professionalism. Future directions include supplementing patient actors with "virtual patients" on the Internet or Second Life virtual worlds, as well as "virtual cadavers" for dissection for medical students. However, the workhorse has become the patient manikins, which serve a dual role. One role is to teach fundamental skills for the operating room (OR), intensive care unit (ICU), emergency department, clinic, and so forth, such as airway management, wound management, and recognition and treatment of critical events like arrhythmias. The other use for manikins is for team training, which today has matured to interprofessional team training, with each different professional (eg, nurse, anesthetist, technician, nurse anesthetist, surgeon, resident) training together as a team. Although this training usually has been performed safely in the laboratory (or simulation center) setting, team training is moving out into the hospital environment (in situ training) of the ICU, emergency department, obstetrics suite, and other areas. What has been discovered is that when training is performed in situ, systems-based errors are discovered in the actual environment that do not show up in the laboratory, errors such as incorrect labeling of medications, supplies or equipment not being in their proper place or absent, and improper notification procedures. This adds a whole new dimension of systems integration and realism beyond what can be accomplished in the simulation center.

The next generation after team training is ''continuity of care'' training, the objective of which is to safely transfer a patient from one team to the next (emergency department to OR, OR to postoperative holding, postoperative holding to ICU, and so forth). The critical issues are errors in handoff, including equipment (Does the endotracheal tube used in the emergency department fit the ventilator in the OR?) as well as communication skills (Do the vital signs and laboratory studies accompany the patient? Have critical events been communicated from one nurse to the next?)

Finally, simulation is extending into clinical practice in the form of preoperative planning/surgical rehearsal (to expose the surgeon to the 3-dimensional computed tomography scan images of the exact patient anatomy for practice before operating on the patient, making the errors on the computer simulation and not on the patient) in addition to preoperative warm-up immediately before a procedure (to improve the performance of a surgeon during an operative procedure). All other professionals (eg, basketball, soccer, symphony, dance) warm up before performing their skill, and recent data[8] confirm the benefit of this process to surgeons.

The power of simulation has not gone unnoticed. Although there have been a few required training courses using simulation in the past, such as Advanced Trauma and Life Support and Focused Assessment with Sonography in Trauma, there are new mandates that will provide further stimulus to accepting simulation. The Residency Review Committee for Surgery of the Accreditation Council for Graduate Medical Education has required that all surgical residency programs must have access to a simulation facility,[10(p10)] and the American Board of Surgery now requires that all surgical residents must have completed the fundamentals of laparoscopic surgery simulation course[11(p14)] or their application will be returned and the surgical resident will not be eligible to sit for the certifying board examination.

Simulation is and will be pervasive, and the impact will be on all aspects of the learning environment. Some of our most challenging problems will benefit from the implementation of simulation. The 80-hour work week requirement stressed students to a point where there are not enough hours within the day for education; however, with many of the simulations being web-based, students will be free to ''read'' the didactic portions of simulation from home, or even practice technical skills at a time and place of their convenience outside the limitations of work. This type of learning is analogous to students spending their free time in the library to increase their knowledge and competency. Even when there is adequate time for training the student, there is a shortage of faculty time; with simulation, much of the mentored practice can be performed with self-directed, computer-based skills training (which contains both formative and summative evaluation and feedback) or with the supervision of ''technician coaches'' to predetermined proficiency benchmarks, which is primarily valid for basic skills. Also, the issue of not enough exposure to a wide variety of operative and procedural cases can be supplemented by simulated procedures on many different cases (derived from a patient-specific library of common diseases and variations), which in turn will permit development of a ''standard curriculum'' of every important procedure that the resident must learn and practice—some virtual and some real—rather than the resident experience being hostage to whatever type of case that happens to come through the door. Likewise, the major cost burden and time involved with the patient actors of the mandated OSCE examination will soon be supplemented by virtual patients in web-based training of individual institution websites or even in the virtual world of Second Life on the Internet.

But the most important impact is the dramatic improvement in patient safety, on many levels. First, medical ''practice'' will no longer mean practicing on the patient; rather, the student/resident will be able to practice in the simulation laboratory and make mistakes on the images or models, not the patient. This practice will also be to proficiency, implying that the resident does not operate on a patient until he or she has performed to the benchmarks set by experienced surgeons; then and only then will the resident operate on patients. The ''learning curve'' of making mistakes takes place in the laboratory, not on the patient. Second, by using the patient-specific image of the patient, the surgeon repeatedly performs the procedure (surgical rehearsal) on the patient's image, until performing the procedure without error. This will result in decreased operating time, less blood loss during surgery (J. Marescaux, written communication, May 2008), and fewer errors. Third, immediately preceding the operation, the surgeon will perform preoperative warm-up simulation, further decreasing the operating time and errors. Finally, there is the issue of reimbursement/liability. With simulation of the procedure, operating time decreases, efficiency increases, and errors decrease, the latter of which should be able to decrease liability. One of the contentious aspects of this scenario is that there is no reimbursement for the additional time needed to perform the rehearsal.

The application of simulation in health care is in its infancy. By leveraging over half a century of simulation in other industries, as well as investing in research for new, innovative approaches to education, training, and assessment, it will be possible to establish an infrastructure to revolutionize medical education that will persist for the next century.

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