Simulation in Medical Education: A Review

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Simulation in medical education: A review

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Simulation is used widely in medical education. The simulation methodologies used at the present time range from low technology to high technology. This article describes how role play, standardized patients, computer, videotape, and mannequin simulations are integrated into the educational curricula for medical students and physicians. Advantages and disadvantages of simulation and barriers to the use of simulation are discussed.

KEYWORDS: *assessment; clinical skills; computer instruction; medical education; OSCE; role play; simulation; standardized patients; videotaping.*

Simulation is an integral part of today's undergraduate, postgraduate, and continuing medical education curricula. It has been recognized for some time that simulation is a valuable and necessary adjunct to the educational experience because opportunities to learn essential clinical skills in the real clinical setting may be inadequate. To be competent, a medical student must master a basic skill set by the time of graduation, continue to master new skills during further training, and pursue lifelong learning skills once formal training is completed.

Skills needed by physicians may be divided into three distinct areas: (a) patient-centered skills, (b) process-centered skills, and (c) environment-centered skills. Patient-centered skills are those related to the direct care of an individual patient and include data-gathering skills (history taking and physical examination), communication skills, interpersonal skills, and technical skills. Implementation of these skills combined with a sound knowledge base and clinical reasoning ability generally results in successful diagnosis and management of a patient. Process-centered skills are those that allow physicians to practice successfully in their local environment and include information management skills, teamwork skills, patient advocacy skills, and self-directed learning skills. Environment-centered skills are those that enable the physician to be successful in the culture of medicine and the wider medical practice

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environment and include business skills, administration skills, and leadership skills. Undergraduate medical education, in general, focuses more on the patient and process skills and less on the environment-centered skills. The need to focus more on the environment-centered skills increases as physicians differentiate and expand their role in the wider medical community.

In the clinical setting, there is no guarantee that every trainee will have a uniform clinical experience, see a representative patient mix, and learn all the necessary skills (Friedman, C., & Purcell, E.; Swanson et al., 1992). Moreover, practicing clinicians who have trainees working with them may not be familiar with the learning goals and objectives nor have the knowledge, attitudes, or skills to teach successfully. They may also have little or no time to teach trainees because of pressure to see patients. In addition, patient considerations such as safety, quality of care, inconvenience, and discomfort as well as medico-legal issues may make it impossible for a novice to practice and acquire skills even when a suitable patient is encountered during the clinical experience. Simulation offers an alternative to learning with real patients and allows a wide range of skills to be practiced and mastered. Specific learning goals and objectives can be defined, and all learners can successfully fulfill the goals and objectives, because learning takes place using trained instructors in dedicated teaching time rather than patient care time. Simulation techniques vary from simple to complex and may be divided into those that use real people—that is, the simulated patient encounters; those that use computers and/or video; the screen-based simulations; and the complex, interactive, high-technology simulators that create a variably complex environment.

In this article, we describe how these three simulation techniques are used in the medical education continuum and describe some of their specific applications related to the skills that physicians need to acquire to practice medicine and take care of patients successfully.

Simulated patient encounters

Role play

Role play is a technique that allows the exploration and discussion of patient-, process-, and environment-centered skills. This is a small-group exercise where, after reading brief descriptions of the part they are to play, two or three learners simulate a situation before a group of observers. Although the learners are assigned scenarios, much of what they bring to the role play reflects their own response and bias. Role play, therefore, can be a powerful way of self-discovery and self-understanding not only for the simulators but also for the observers who respond to what they see simulated. The facilitator or teacher needs to be highly skilled and perceptive for the role play experience to be a positive one for all participants. To succeed, a group dynamic that allows for suspension of disbelief within a safe environment is required. Role play may be ineffective as a learning tool when participants are reluctant to commit to the exercise because of self-consciousness. However, it can be a valuable technique for exploring patient-related and non-patient-related issues in the medical environment, such as the meaning of illness, cultural context, teamwork, management, and negotiation (Simpson, 1985). It can also be used to develop the skills needed to deal with emotionally charged situations such as distressed or angry patients, families, coworkers, and administrators (Cushing & Jones, 1995). In its simplest form, role play can be used to teach and practice the basic communication skills that are needed for effective history taking and information giving and can significantly improve performance (Mansfield, 1991). There are no data currently available to indicate how many medical schools incorporate role play into their clinical skills courses.

On a larger scale, role play is used to train multidisciplinary medical teams to respond to a cardiopulmonary arrest, the so-called mock code. Similarly, hospital- and community-wide medical personnel practice responding to regional disasters by participating in emergency drills during which multiple role-playing patients arrive at the medical facility as part of a simulated disaster.

Role play has also been used in faculty development to improve the teaching skills of medical school faculty and has been shown to improve the teaching effectiveness of basic science and clinical teachers (Quirk, DeWitt, Lasser, Huppert, & Hunniwell, 1998; Skeff, Stratos, Bergen, & Regula, 1998). For medical administrators, the "in-basket simulation" is useful for teaching and assessing a defined set of environment- and process-centered skills because it places the individual in a realistic situation and requires him or her to manage the contents of an in-basket appropriately and effectively (Andes, 1997; M. Friedman, 1992).

Simulated or standardized patients

Simulated or standardized patients (SPs) are individuals who are selected and trained to portray a patient accurately and consistently. One of the earliest reports of the use of SPs was in 1975 by Harden, Stevenson, Wilson-Downie, and Wilson (1975), who described the Objective Structured Examination. Now many medical schools around the world use SPs in their curricula. SP cases are developed by experts specifically to teach or assess defined skills. Trainee performance on a case is usually rated using objective checklist items for history and physical examination and behaviorally anchored rating scales for communication, interpersonal, and patient satisfaction skills. Real patients who have fixed physical findings can be used, or individuals can be trained to simulate physical findings (Barrows, 1993). In the United States in 1998, 50.4% of the 125 medical schools used SPs in one or more of the clerkships compared to 34.1% in 1993 (Kassebaum & Eaglen, 1999). SP programs require personnel who can recruit and train the SPs and coordinate the sessions. Depending on the scope of the educational goals and objectives and the number of trainees, SP programs may have specially equipped facilities separate from the clinical care facilities. Some U.S. medical schools belong to consortia around the country and share resources and facilities (Morrison & Barrows, 1994); other schools run SP programs of varying size and capability within their own medical school. An overview of the use of SPs in the teaching and evaluation of clinical skills was given in a 1993 Association of American

Medical Colleges consensus conference (Anderson & Kassenbaum, 1993). The scope of the use of SPs is continually expanding, and they are now used for teaching and assessment of patient-centered skills for curriculum assessment and for quality management of process- and environment-centered skills.

Clinical teaching using SPs. The basic patient-centered skills of history-taking skills, interpersonal skills, communication skills, and physical examination skills lend themselves to teaching using SPs (Boulet et al. 1998; Hodges, Turnbull, Cohen, Bienenstock, & Norman, 1996; Kleinman, Hage, Hoole, & Kolowitz, 1996). Ideally, all these skills should be taught in the real clinical environment using direct observation (Lane & Gottlieb, 2000). However, because direct observation is time consuming, it rarely takes place at the present time. Simulation provides an alternative training modality by which trainees can learn to take a history, perform a physical examination, or give information. A trainee can do this one on one with the SP, or a trainee can work with an SP in front of a group of his or her peers. Feedback on performance is an essential component of the learning experience and can be given verbally or in writing by a faculty observer, the peer group, or the SP (J. Martin, Reznick, Rothman, Tamblyn, & Regehr, 1996; Singleton, Smith, Harris, Ross-Harper, & Hilton, 1999). SP feedback may be valuable to trainees because the communication skills emphasized by academic teachers may not reflect the skills considered to be important by the SPs (Cooper & Mira, 1998). SP encounters can also be videotaped, which allows the trainees to assess themselves (Kaiser & Bauer, 1995). Some institutions use senior trainees to act as simulators for their more junior peers, which may have the added advantage of improving the skills of the teachers as well as the learners (Sasson, Blatt, Kallenberg, Delaney, & White, 1999).

Working with SPs allows the trainee to learn the basics of effective communication. Trainees can learn the skills needed to establish the rapport that is essential for patient satisfaction, adherence, and positive clinical outcomes (Colliver, Swartz, Robbs, & Cohen, 1999; Novack, 1987). Creating challenging cases such as dealing with angry or depressed patients, giving bad news, counseling about medical decision making, or communicating about risk enables trainees to acquire higher level skills (Edwards, Elwyn, & Gwyn, 1999; Greenberg, Ochsenschlager, et al., 1999; Greenberg, Pedreira, Getsson, & Brosseum, 1999; Sutton, 1998; Vaidya, Greenberg, Patel, Strauss, & Pollack, 1999).

Using SPs to teach physical examination allows students to demonstrate that they have mastered the performance of the examination technique before they examine real patients. Any part of the physical examination can be taught using SPs. For example, many schools recruit and train SPs to teach the female and male genital examinations (Neiman, Kelliher, Sachdeva, & Cohen, 1994). The advantage of using SPs is that patients are available at a time that is convenient for students, and SPs are ready and willing to be examined. The disadvantage is that unless it is possible to recruit SPs with stable physical findings, students will not have the challenge of identifying abnormal physical findings.

Performance assessment using SPs. SP simulators are widely used for assessment of performance. Skills assessments are often classified as objective structured clinical examinations (OSCE) or as clinical skills assessments (CSA) (Harden & Gleeson, 1979; Lane, Ziv, & Boulet, 1999). An OSCE has multiple short stations that ask trainees to perform a specific task. A CSA uses 10 or 12 complete patient cases that require students to integrate history taking, physical examination, and information giving and perhaps write a patient note or answer questions.

On an international level, the Educational Commission for Foreign Medical Graduates has developed and, in 1998, implemented a CSA that has 10 complete SP encounters. On a national level in the United States, the National Board of Medical Examiners is in the process of developing a CSA as a licensing requirement for medical school graduates. The Medical Council of Canada has used an SP-based skills assessment as part of its licensing procedure since 1993. At the regional level, half (48%) of medical schools in the United States require their students to pass a skills assessment to be promoted to the next year or as a requirement for graduation (Association of American Medical Colleges and the American Medical Association, 1991).

Use of clinical skills assessments in graduate medical education currently appears to be more prevalent in Great Britain than in the United States. Tools such as the Leicester assessment package, which includes simulated surgeries (consultations) for assessment of general practitioners, are able to distinguish competent from incompetent physicians with satisfactory reliability (Allen & Rashid, 1998; Fraser, Mckinley, & Mulholland, 1994). It is likely that this type of assessment will increasingly be adopted for postgraduate education in the United States, because several studies indicate that physicians in the United States have deficient skills when compared to expectations (Chalabian, Formenti, Russell, Pearce, & Dunnington, 1998; Joorabchi & Devries, 1996; Lane et al., 1999; Ramsey, Curtis, Paauw, Carline, & Wenrich, 1998). Apparent performance deficiencies, however, must be considered in the light of data that suggest that there is considerable disagreement among experts who develop checklists as to what the expected performance level of trainees is (Malloy, Perkowski, Callaway, & Speer, 1998). There is also concern that checklists may not be a valid way to assess the skills of experienced physicians because their clinical reasoning method is one of pattern recognition with a few critical questions asked compared to the comprehensive questioning used by novices. There have been studies looking at the possibility of using holistic ratings of performance because this method may yield more accurate assessments (Regehr, Freeman, Robb, Missiha, & Heisey, 1999).

Another possible shortcoming of SP assessments of experienced physicians is discussed in a study from the Netherlands. In this study, the performance of general practitioners was assessed using a series of SP cases and a series of real consultations. It was found that performance was better with SPs than with real patients (Pieters, Touw-Otten, De Melker, 1994). This finding highlights the difference between competence as assessed in a testing situation and true performance in real clinical settings. Another study from the Netherlands recently demonstrated that valid and reliable assessments of general practitioners are possible using a carefully chosen series of real patients seen by the physician in his or her office (Ram, van der Vleuten, Rethans, Grol, & Aretz, 1999). Whether this methodology will supplant the use of SPs for post-graduate assessment remains to be seen.

Curriculum assessment using SPs. SP simulation is also used to evaluate the success of a curriculum even when the curriculum has been taught by other means than SP methodology (Ali, Cohen, Gana, & Al-Bedah, 1998; Campbell, Weeks, Walsh, & Sanson-Fisher, 1996; Constanza, Greene, McManus, Hoople, & Barth, 1995; Haponik et al., 1996). It is a valid and reliable way to compare the performance of individuals and groups. Preintervention and postintervention SP cases can be administered to look for improvement in performance. Trainees may act as their own controls, or an OSCE or CSA with multiple stations can be administered to intervention and control groups to assess overall level of performance and to look for statistically significant differences.

Quality management using SPs. Improving the quality, consistency, and cost-effectiveness of care delivered by practicing physicians is one of the major foci of today's medical environment (Chalabian & Dunnington, 1997). SPs have been introduced into physicians' offices to look at such diverse issues as the ability to diagnose a specific condition (Carney, Dietruch, Freeman, & Mott, 1995), manage a specific condition (Franco et al., 1997; Saebu & Rethans, 1997), assess resource utilization (McLeod et al., 1997), assess billing practices (Woodward, Hutchison, Norman, Brown, & Abelson, 1998), provide referral for unwarranted services (H. Gallagher, Lo, Chesney, & Christensen, 1997), and provide health promotion practices (Hutchison, Woodward, Norman, Abelson, & Brown, 1998; Wong, Nordin, & Suleiman, 1995). Data gathered from these real life situations allow the educational needs of practicing physicians to be assessed and allow for the logical planning of continuing medical education. The data may also provide some insight into deficiencies in the curricular content of medical school and residency training and identify what changes might be expected to improve the competence of graduates.

On a wider scale, fake patients or undercover care seekers are being used to evaluate the quality of care delivered in hospitals or clinics and to examine larger scale resource utilization (Madden, Quick, Ross-Degnan, & Kafle, 1997; Saidel et al., 1998; Van der Geest & Sarkodie, 1998).

Screen-based simulations

Computer-based clinical simulations

In recent years, screen-based simulations, particularly computer-based simulations, have been introduced and are now widely used in medical education. Computer-based clinical case simulations were first developed in the 1960s, but not until the advent of the personal computer in the 1980s did this approach to clinical education really begin to proliferate. Although the use of computer-based case simulations is increasing, it is certainly not yet ubiquitous. In the 1997-1998 academic year, 33.6% of medical schools reported using software for clinical (case) problem solving and diagnostic or therapeutic decision-making exercises in basic science courses, whereas 28% used this teaching method in a core clerkship (Moberg & Whitcomb, 1999). In this section, we will discuss the use of screen-based simulations in preclinical and clinical teaching, clinical reasoning, and problem-solving and performance assessment.

Preclinical and clinical teaching. Computer simulations are being used more and more extensively in many basic science courses to supplement or replace other teaching methods. Curricular material can be presented with interactive features; one example is the second-year pathology course at Robert Wood Johnson Medical School where lectures have been completely eliminated and replaced by readings, small-group discussions, and computer-assisted learning (Raskova & Trelstad, 1996). Students rate the course very positively and perform well on national certification examinations.

Computers and CD-ROMS may be used to teach the basics of history taking and physical examination to prepare students for their first encounters with real patients. They may also be used as part of multimedia curricular development in various fields and disciplines. In the field of cardiology, medical students need to develop skills in auscultation of the heart, but it is unlikely that any individual student will be able to encounter all the various murmurs and other heart sounds during their clinical training. Some medical schools recruit patients with abnormal cardiac exams for physical examination teaching sessions, but these sessions are difficult to organize, and a student has only one opportunity to examine a particular patient. Computer simulations in cardiology offer students the chance to listen to a patient repeatedly and immediately correlate clinical findings with laboratory and/or radiographic studies. Petrusa et al. (1999) described the development of a 4-year multimedia computer curriculum in cardiology that has been implemented at six medical schools. The curriculum is composed of 10 case-based modules that address core topics in cardiology and include digitized audio, full-motion video, electrocardiograms, radiographs, angiograms, and doppler studies. The modules can be learned independently or in groups with an instructor. Students report that the curriculum has high educational value, enhances their bedside skills, and is superior to other teaching materials and methods.

In the pulmonary examination, like the cardiac exam, medical students need to acquire sophisticated auscultation skills. Again, the limitations of clinical experience described above serve as barriers to the mastering of this clinical skill. Kompis and Russi (1997) have developed a computer-based lung sound simulation in which lung sounds can be added or removed and the attributes of the individual sound components such as loudness, frequency, duration, or number of occurrences within one breathing cycle can be controlled by the user.

To date, computer-based simulations have been developed for other clinical areas including neurology, nephrology, rheumatology/immunology, and anesthesiology (Berger & Boxwala, 1995; Elliott & Gordon, 1998; Fulkerson, Miller, & Lizer, 1999;

Howard, Gaba, & Fish, 1992). New software for teaching in other clinical disciplines is continuously being developed and marketed.

Clinical reasoning and problem solving. Many medical schools have adopted Problem Based Learning (PBL) in which students acquire basic science and clinical knowledge and learn the bio-psycho-social model while solving a clinical problem. Computer cases and simulations are complimentary to this curriculum. In Philadelphia, computer-based cases dealing with asthma and tuberculosis for the second year of a PBL track have been developed by Bresnitz (1996). Each case is encountered over 3 to 4 days and is fully integrated into small-group PBL sessions. A course in the second year at the University of Pittsburgh, designed to bridge the gap between the basic science years and clinical experience, has successfully used computer-based cases (Schor et al., 1995). The course uses 13 cases in a small-group, PBL format with a faculty facilitator. Responses from students and faculty have been very favorable. At the University of California, Los Angeles (UCLA), Stevens, Lopo, and Wang (1996) have developed computer-based cases in immunology. A striking feature of this program is that student problem-solving strategies can be recorded and analyzed. The authors compared students' strategies to those of experts in immunology and found very different patterns of problem solving for the majority of students. Computer programs of this type may offer an opportunity better to understand the dynamics of learning and clinical problem solving at the individual and population level.

Performance assessment. Computer-based cases are also used to assess individual student learning. On a national level in the United States, the National Board of Medical examiners has developed computer-based clinical cases to supplement the traditional multiple-choice examination. In the PBL track at the Ohio University College of Osteopathic Medicine, students are evaluated using computer-based case simulations (Costello, Mann, & Dane, 1997). The evaluation assesses diagnostic reasoning and ability to retrieve case-relevant information.

Video-Based Simulations

Significantly less work is being done with video simulations than with computer-based simulations, and few reports of video simulations have appeared in the literature in the past several years as more medical schools have embraced computerized technology. From these few reports in the literature and from informal conversations with colleagues at other medical schools, a slightly murky picture of the state of the use of video simulations in medical education can be described.

The focus of video simulations appears to be somewhat different than computer-based simulations. The four areas in which videos seem to be most widely used are: demonstration of physical exam techniques; demonstration of dynamic processes; teaching communication skills, professionalism, and ethics; and the doctor-patient relationship.

Physical examination and dynamic processes. A number of videotape series demonstrating physical examination techniques have been commercially produced, but it is not clear how widely and, in what manner, they are currently being used. Videotapes demonstrating dynamic processes such as aspects of child development (i.e., language, gross and fine motor development in different aged children) offer clear advantages when compared with recruiting a number of children of different ages for a live demonstration. Again, the prevalence of use of this teaching modality is not clear.

Communication, professionalism, ethics, and the doctor-patient relationship. Several reports about the use of videotapes to demonstrate communication skills, professionalism, ethics, and the doctor-patient relationship have appeared in recent years. Videotapes have also been used extensively in the doctoring course at the UCLA School of Medicine (Wilkes, Slavin, & Usatine, 1994; Wilkes, Usatine, Slavin, & Hoffman, 1998). This is a longitudinal, multidisciplinary course spanning the first 3 years of medical school. The curriculum focuses on issues of professionalism, communication, ethics, and the doctor-patient relationship. The course is largely case-based, and SPs are usually used to present a case to a small group of students. Videotapes are used in various ways in the course: to present material in the sequential evolution of a case and to teach about the culture of medicine. Video offers compelling advantages over a written case because of the reality and immediacy of the emotions of the actors on the tape, which enables students to assess and discuss how the physician handled the situation and how they might have handled it differently.

Handmaker, Hester, and Delaney (1999) described the use of a 20-minute docudrama to teach obstetric care providers about motivational interviewing skills relating to problem drinking. A pretest/posttest study using role play demonstrated significant improvement in motivational interviewing skills by the intervention group compared to the control group.

Videotapes have also been used in faculty-development to teach faculty how to promote professional behavior in students. “Teaching Caring Attitudes” is a 1-day faculty development program at the Indiana University School of Medicine (Cottingham, Marriott, & Litzelman, 1998). It uses video trigger tapes in a small-group setting to equip faculty to introduce the issue of attitudes in clinical teaching as well as to identify a range of difficult student attitudes and to develop intervention techniques to deal with them.

In the Family Medicine residency program at the University of Toronto, videotapes are used to help residents improve their self-assessment skills (D. Martin, Regehr, Hodges, & McNaughton, 1998). Residents perform an initial 10-minute interview of a standardized patient that involves a difficult communication problem. After assessing their own performance, they view videotapes of four interviews (ranging in quality from *poor* to *good*) of the same scenario by different practitioners. The residents then evaluate the communication skills displayed in each performance and reevaluate their own performance. An increased correlation between experts’ evaluations and residents’ self-evaluations was found after the intervention.

At the University of New Mexico, a performance-based, sequential approach to assessing medical students' competence with respect to professional attitudes, values, and ethics has been used for a number of years (Roberts & the Subcommittee, 1997). The program employs a number of different approaches to assessment, including a station in which students perform a written analysis of the clinical and ethical issues observed in a videotaped interaction between a doctor and a patient that involves decision making.

A final application of videotaped simulations that is particularly innovative is to study how nonmedical factors influence physician decision making. Two studies have examined the influence of patient characteristics (e.g., age, race, socioeconomic status, gender, and presentational style) on physicians' decision making in the evaluation and treatment of patients with chest pain and dyspnea and patients with breast cancer (Feldman et al., 1997; Irish, Kasten, & Moskowitz, 1997). The studies demonstrated that videotaped clinical simulations are an effective tool.

Realistic interactive simulators

The SP, computer, and video simulations described earlier in this article generally lack the capability to teach and evaluate technical skills. Because medicine is becoming more challenging, emphasizing high-tech procedural skills while demanding higher standards of patient safety and clinician accountability, the need for safe and effective training solutions has acted as a catalyst for the development of medical simulators (Committee on Quality in America, 1999). Simulators may be relatively simple or extremely complex and capable of teaching and evaluating either a specific task or a linked series of tasks. That the simulator environment can be modified to incorporate teaching and evaluation of the other skills (such as professional, teamwork, communication, interpersonal, and clinical reasoning) required for optimal task performance is critical to appreciating the versatility of this type of simulation.

Simulators range from low-tech, simple plastic models of infants, children, or adults to realistic, high-tech simulators. They can be integrated into the medical curriculum to teach and evaluate three levels of skills that range from basic, unidimensional, individual skills through higher level, multidimensional, individual skills to very complex, multidimensional, teamwork skills. An example of the first skill level would be how to correctly place a stethoscope for cardiac examination. An example of the second skill level would be how to perform a full cardiac examination, interpret the findings, and prescribe medication. An example of the third skill level would be how to work in a team to manage a patient in cardiac arrest and then give bad news to the family.

An inherent feature of most advanced medical simulators is the ability to provide immediate feedback about clinical decisions and quality of actions. However, despite the continued development and marketing of new simulators, medical education still lags behind the aviation industry and the armed forces in its use of sophisticated simulation and focused debriefing.

Early simulators

One of the earliest simulators, a mannequin named Rescusi Anne, was developed by Laerdal Corporation 35 years ago when modern mouth-to-mouth resuscitation protocols were introduced (American Heart Association, 1997, pp. 4-19). The prototype focused on airway management and basic life support techniques, and it paved the way for the new generation of high-tech simulators. The latest Rescusi Anne model is computer driven, has a cardiac rhythm generator, and is used worldwide as the standard simulator for teaching and evaluating life support skills.

About the same time as Rescusi Anne was developed, Sim 1, a fairly sophisticated simulator for training anesthesiologists, was developed at the University of Southern California (Denson & Abrahamson, 1969), and Harvey, a simulator to teach cardiac examination skills, was developed by a team of educators at the University of Miami (Gordon et al., 1981). Whereas Sim 1 was only used for a very short period of time, Harvey is still used worldwide in medical schools and hospitals.

Task-specific simulators

The increasing complexity of some clinical tasks has led to the development of task-specific computer-driven simulators for training. Two good examples of task-specific simulators are CathSim and Ultrasim. Cathsim is used for phlebotomy and IV insertion training (www.ht.com). UltraSim, an ultrasound simulator developed by MedSim in 1996, operates like an actual ultrasound system and has a fully functional control panel (Nisenbaum et al., 2000). It includes various ultrasound "transducers" and a realistic patient mannequin. The UltraSim allows users to move the transducer over the mannequin in any direction or at any angle and to view actual ultrasound images changing in real time on the system's monitor. The system also includes performance assessment features, a built-in "instructor," and an extensive library of clinical cases (Meller, 1997). The clinical cases are based on real-patient 3-D ultrasound images, covering a wide range of organ systems and pathologies, such as abdominal, obstetrics/gynecology, breast, and vascular. Many systems have been installed worldwide in ultrasound technician schools, radiology, and obstetrics/gynecology training programs. In addition, the simulator is increasingly used for training surgeons and emergency room physicians in the acute care setting.

Other new, minimally invasive procedures that are increasingly used and that present a challenge in terms of ensuring safe training and proper acquisition of technical skills are well represented by the latest available simulators. MIST VR (A. Gallagher, McClure, McGuigan, Crothers, & Browning, 1999; Taffinder et al., 1998) and Cinemed (www.cine-med.com) are used for laparoscopic surgery training. Simulator platforms have also been developed that are used for endoscopic sinus surgery, endoscopic GI procedures, bronchoscopy, arthroscopy, cardiac catheterization, and opthalmological surgery (Bro-Nielsen, Tasto, Cunningham, & Merril, 1999; Cotin, Dawson, Meglan, Shaffer, & Ferrell, 2000; Logan et al., 1996; Mabrey et al., 2000; Rudman et al., 1998).

Complex interactive simulators

Advances in computer technology, bioengineering, and learning and behavioral sciences have led to the development of realistic patient simulators. High-tech simulators are sophisticated, computer-driven platforms that model human anatomy and physiology and allow trainees to manage complex clinical situations in a realistic setting. This new generation of simulators was developed initially in the field of anesthesia and, in that respect, is a late follower of Sim 1. However, unlike Sim 1, the new simulators have gained greater acceptance and are used more widely. This generation includes sophisticated mannequin platforms with humanlike tactile and visual appearance, and virtual reality devices and simulators that replicate a virtual or simulated clinical setting. These simulators are unique in their ability to train medical professionals in the hands-on aspects of their craft.

The Human Patient Simulator manufactured by METI and the PatientSim, a product of MedSim, represent the most advanced and comprehensive platforms for training a wide range of health professionals in acute care clinical skills (Good & Gravenstein, 1989; Schwid & O'Donnell, 1990). The patient simulators are versatile and sophisticated and incorporate responsive eyes, anatomic airways, patient voices, arm movements, and heart and breath sounds. They feature physiologic modeling of ventilation and gas exchanges, cardiopulmonary functions, and the pharmacological actions of more than 80 agents, including anesthesia gases. The mannequin's internal components can interface with various types of patient monitors and medical devices, including anesthesia machines, ventilators, and defibrillators. The mannequin may be used to teach basic sciences such as pharmacology and physiology as well as to teach complex medical management of a patient case, including drug administration, cardiopulmonary resuscitation, endotracheal intubation, tracheostomy, and insertion of chest tubes. These patient simulators are often used as the core platforms of simulation centers. Simulation centers attempt to replicate fully functioning operating rooms, intensive care units, emergency departments, or patient rooms. Space is available in the simulation center for debriefing of trainees. Debriefing might include review of video footage of the case, self-assessment, and faculty and/or peer feedback. A well-structured case in the simulation center can teach and assess many, if not all, of the patient and process- centered skills.

Discussion

Several reports published in the 1980s (M. Friedman, 1992; Josiah H. Macy, Jr. Foundation, 1988; Muller, 1984) called for educational reform within U.S. medical schools in part because physicians were graduating from educational programs without adequate skills. In the United States, the governing bodies that oversee undergraduate and postgraduate medical education have provided critical stimuli for reform and innovation in medical education. These bodies are now mandating competency-based teaching and assessment in defined skill areas. So as not only to meet the moral imperative of training competent physicians but also to comply with licensing guidelines, many medical schools have completed or are in the process of completing curricular reform. New teaching and evaluation methodologies, many of which incorporate simulation, have been introduced to increase the overall competence of medical school and residency graduates.

We have described a wide variety of simulation methodologies that are currently being used in medical student and physician education. Where and how these simulations are used depends on the curriculum and culture of the individual medical schools and training programs. However, economic considerations still continue to dictate what medical schools can do in terms of teaching and evaluating skills using low-tech and high-tech simulation. Initial capital expenditure and cost of ongoing maintenance is high; personnel costs to maintain a cadre of properly trained faculty and support staff are also high. Therefore, even the most motivated medical schools, where the educational mission is a high priority, may be limited in what they can implement by financial considerations. However, because simulation-based medical training has the potential to reduce medical errors, the high training costs might be translated into an overall reduction in national costs in the long term.

Training competent physicians is difficult to achieve when institutions are accountable but are not given or do not have adequate resources. Clearly, a paradigm shift has to occur at all levels, from the regulating bodies down to the individual physician educators, if we are going to succeed in incorporating the necessary simulation modalities into a comprehensive educational experience. This will require a reassessment of how medical education is funded at a government level and a reemphasizing and redefining of the primacy of the educational mission by medical schools and postgraduate training programs. Last, a comprehensive educational experience will require the implementation of mission-based budgeting and support for and recognition of the individuals involved in the day-to-day teaching and evaluation of trainees.

There is always a danger that educators might be seduced into using simulation to achieve educational goals that are easily and effectively met using nonsimulation modalities. It is essential, therefore, to evaluate critically whether educational goals can be better met in traditional clinical settings using innovative teaching techniques rather than simulation techniques. The use of rigorous qualitative and quantitative measures of educational outcomes to demonstrate the value added by simulation techniques and programs is also essential. Finally, it must be remembered that simulation is not real life, that simulated performance does not completely correlate with performance with real patients, and that even in the age of advanced simulation, the value of instruction and learning at the bedside is still critically important.

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