Developments in the use of simulators and multimedia computer systems in medical education

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SUMMARY *Medical practice changes that limit teacher time and patient availability and advances in technology are stimulating the greater use of simulators and multimedia computers in medical education. Such systems address the problem of a decline in bedside skills training and proficiency. For over 30 years, The University of Miami Center for Research in Medical Education, in collaboration with 12 other university medical schools, has developed simulation teaching and assessment systems for multiprofessional training. 'Harvey', the Cardiology Patient Simulator, teaches bedside skills that are transferrable to live patients. The UMedic Multimedia Computer cardiology curriculum has been fully integrated into all years of medical school and postgraduate training and also assesses bedside skills. Programs are being developed in oncology, neurology and emergency medicine. Our Emergency Medical Skills programs utilize simulation technology and standardized patients to train multiprofessional populations, including paramedics/firefighters. The expanded use of simulation for training and certification is inevitable.*

Advanced simulation technology and multimedia computers will provide a significant component of medical education and skills assessment in the 21st century. The major driving forces are : (1) changes in medical practice that reduce clinician teacher's time and patient availability; and (2) advances in technology that make it possible for simulators and multimedia computers to represent complex bedside findings and concepts.

The use of simulation and computers for medical education is well established in certain disciplines. Proven simulation devices are used in teaching and testing basic knowledge and skills in areas such as cardiac life support, anesthesiology, surgery and the bedside physical examination (Emergency Cardiac Care Committees and Subcommittees, 1992; Schwid & O'Donnell, 1992; Satava & Jones, 1996; St Clair *et al.*, 1992; Woolliscroft *et al.*, 1987). The use of standardized patients is widely utilized and accepted for learning and assessing history taking and other bedside skills. Multimedia computers are now being used to teach material that was previously possible only through live lectures and demonstration. In addition, national certifying organizations such as the National Board of Medical Examiners and the American Board of Internal Medicine are using or planning to use multimedia computers in their medical licensing examinations.

For over 30 years, the University of Miami Center for Research in Medical Education (CRME) has developed and used teaching and assessment systems that wed simulation and technology to medical education. The Center houses full facilities for simulation and computer design engineering, production and manufacturing, a high technology auditorium, a self-learning laboratory and skills training areas. These projects have been carried out by a national consortium of internists, educators and specialists in cardiology, oncology, neurology and emergency medicine from 12 medical centers including Allegheny, Arizona, Duke, Emory, Florida, Illinois, Iowa, Miami, Mayo, Northwestern, Pennsylvania and Rush. Current major projects involved in multiprofessional training and skills assessment include 'Harvey', the Cardiology Patient Simulator (CPS) and the UMedic Multimedia Computer System (MCS). These systems are currently used at over 75 medical centers worldwide and train many thousands of learners annually. The Center also houses an Emergency Medical Skills Training (EMST) Laboratory that trains over 4000 course registrants annually, including 3000 paramedic firefighters.

'Harvey', the cardiology patient simulator

'Harvey' is a proven teaching device that provides a comprehensive cardiology curriculum by realistically simulating 27 common and rare cardiac conditions (Figure 1). The physical findings programmed in 'Harvey' for each disease include blood pressure, bilateral jugular venous pulses, bilateral carotid and peripheral arterial pulses, precordial impulses in six different areas and auscultatory events. The latter are heard in the four classic auscultatory areas, are synchronized with the pulses and vary with respiration when appropriate. More than one example of a particular disease state may be represented, simulating the marked difference in the clinical presentation of a particular disease that depends upon its chronicity and severity.

The consortium developed the curriculum of diseases with learning goals, a teaching manual, test instruments and self-assessment slide programs for each condition. The slide programs include all the elements that should be available with a live patient, including the history, blood chemistries, electrocardiograms (ECGs), X-rays and noninvasive and invasive laboratory data. Finally, appropriate medical and surgical therapy is presented, along with a summary of the pathology and epidemiology of each disease.

UMedic, Multimedia Computer System

The UMedic MCS has been developed over the last 14 years with multimedia features that include computer and video graphics and real-time digitized video and audio

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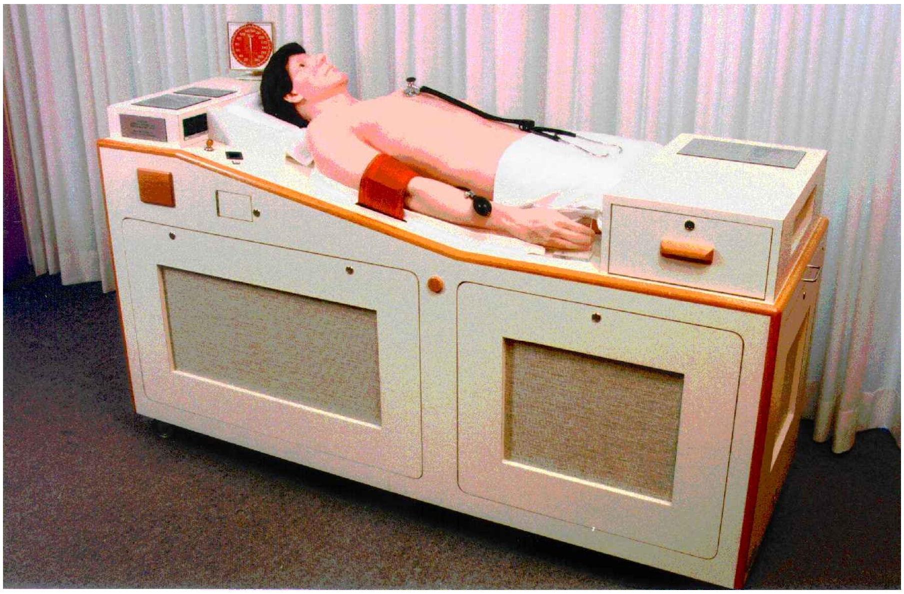

Figure 1. 'Harvey', the Cardiology Patient Simulator.

(Figure 2). Ten patient-centered case-based programs comprise a comprehensive generalist curriculum in cardiology. Their structure includes:

- **The history**
- **Bedside findings**—including appearance, blood pressure, arterial and venous pulses, precordial movements and auscultation, presented by an instructor on videos of 'Harvey', the CPS
- **Diagnosis**
- **Laboratory data**—including blood chemistries, ECGs, X-rays, scintigraphy and real-time echo-Dopplers and angiograms
- **Treatment**—including videos of interventional therapy/surgery
- **Pathology**
- **Discussions**—including case reviews by authoritative cardiologists.

Learners can choose to study an entire program that includes all of the above sections or choose to study only the bedside evaluation (e.g. a first or second year medical student) in which the Laboratory Data and Treatment sections are omitted. The programs operate in two modes: a self-learning mode for between one and five learners and an instructor mode for teaching large numbers in a classroom or auditorium with a video projector or multiple monitors. The latter was created to reduce the time and effort instructors invest preparing their presentations by providing all of the data necessary to teach. It is flexible, providing a menu of over 20 choices from the patient evaluation, and the narrative voiceovers are inactivated to allow instructors to make their own teaching points. Each mode may be used as a 'stand alone' training program or be linked to 'Harvey'.

Throughout each patient-centered, self-learning program, a physician instructor, who provides demonstrations of

Figure 2. The UMedic Multimedia Computer System.

bedside findings, narrative explanations and feedback on important points, guides the learners in video segments. Multiple choice questions are presented during the program to focus on key teaching points, to encourage problem solving and to enhance interactive learning. The learner can pause or review any of the previously presented material as often as desired before answering a question. When correct, an optional 'further discussion' of the correct answer may be chosen. When incorrect, a brief review of the incorrect answer and 'further discussion' are mandatory. The discussion that follows auscultation also provides a step by step 'dissection' of heart sounds and murmurs in order to simplify complex auscultatory findings.

A randomized pre- and post-testing system has been developed to assess basic bedside skills and measure outcomes of learner performance. An administrative program tracks learners by name and social security number and records their performance and time spent completing the tests. Twenty-seven categories of learners can be tracked. These include medical students, nurses, house officers, fellows, generalists and cardiologists. Based on the success of these programs, similar modules in oncology have already been developed and more are planned for neurology.

Emergency Medical Skills Training

At the requests of the University of Miami School of Medicine Curriculum Committee and the City of Miami Fire Rescue, the CRME began to train medical students and paramedics in Advanced Cardiac Life Support (ACLS) over 15 years ago. Contributors to the programs represent a spectrum of medical personnel that serve to enhance the validity of the teaching programs and include: rescue chiefs, paramedic trainers, medical directors, emergency physicians, trauma surgeons, anesthesiologists, pediatricians, cardiologists, neurologists and emergency nurses. All courses are designed to be population specific, while ensuring strict adherence to national guidelines. Multiprofessional programs are structured to address the trainee's particular needs and role in the delivery of patient care from the paramedic to the nurse, medical student, emergency physician, pediatrician, cardiologist and trauma surgeon. Since 1982, over 40,000 course registrants have been trained at the CRME. The EMST programs have grown from ACLS to include Trauma, Pediatrics, Advanced Airway and Hazardous Materials Management, Acute Myocardial Infarction (AMI) and, most recently, Acute Stroke.

The Center's facilities include a simulated full-size equipped rescue vehicle and an automobile for extricating 'accident' victims. There is also a large hazardous materials decontamination shower and a mock-up emergency room that includes an ECG receiving base station. Patient simulations are used on a daily basis in all of the emergency skills training programs. The trauma courses include basic prehospital training and Advanced Trauma Life Support provider courses carried out under the auspices of the American College of Surgeons. Live patients are routinely moulaged to represent bleeding and injuries and are included in an annual competition among Emergency Medical Services that involves multiple emergency situations.

We are now collaborating with the Florida Chapter of the American College of Cardiology to make "Florida the safest state in America to have an Acute Myocardial Infarction" and have recently added acute stroke to our mission. As in all of the skills training courses, real-life field simulations are carried out. Actors and our own paramedic training officers have been taught to be victims of AMI and stroke. Course trainees are dispatched in teams to the 'scene' (home, office, car). They 'care' for the patient on a rigid time line from the scene to the fire rescue unit to the emergency Department, all housed at the CRME (Figure 3).

An advanced AMI course has recently been developed that places more emphasis on the recognition of the high risk patient. It includes bedside skills training using 'Harvey', a breath sound simulator, multimedia computer programs

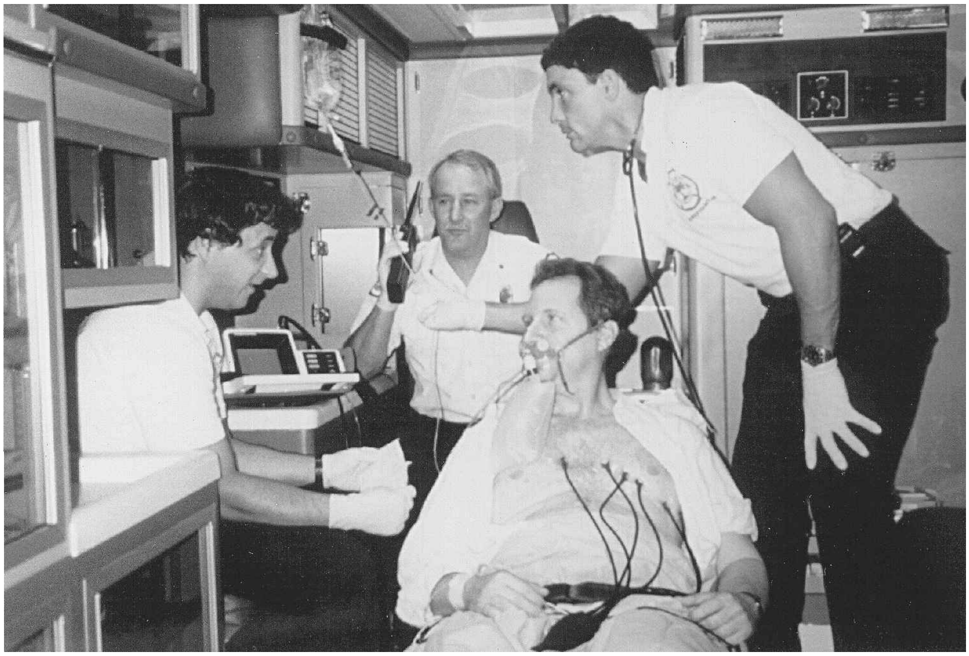

Figure 3. Caring for the patient in the rescue unit housed at the CRME.

and advanced ECG interpretation. This course has successfully utilized nearly all of the available advanced technical and computer simulations combined with live standardized patients to more closely simulate complex patient presentations.

Evaluation

The CPS has undergone extensive use and testing of its teaching effectiveness at multiple medical centers. 'Harvey' teaches small and large groups at multiple levels including medical students, nurses, house officers, primary care physicians and cardiologists. A rigidly controlled and comprehensive study, supported and independently evaluated by the National Heart, Lung and Blood Institute has been carried out. It involved 208 learners at Miami, Emory, Duke, Arizona and Nebraska over a 1 year period, and demonstrated that those trained with the simulator scored significantly higher on cognitive and skills test, including cardiac examinations involving real patients (Ewy *et al.*, 1987). These patients also noted no differences in the humanistic qualities displayed by learners trained with live patients compared with those trained with 'Harvey'. Another study conducted in association with the American Academy of Family Physicians during continuing medical education programs found that the participants were nearly unanimous that the CPS accurately simulated cardiac bedside findings and was a valuable teaching tool (Gordon *et al.*, 1981).

The first national multicenter study of UMedic was carried out during the 1991–92 academic year. It involved 182 senior medical students at Arizona, Duke, Emory and Miami and revealed that 96% of them felt the programs improved their bedside skills (Waugh *et al.*, 1995). This study demonstrated that the system is well received, easy to use and reliable. Another multicenter study demonstrated that this system could be integrated into the entire 4-year curriculum of medical education. A total of 1586 students at Duke, Emory, Florida, Miami, Illinois and Iowa medical schools completed 6131 programs and favorably rated the educational value of the system compared to other learning materials (Petrusa *et al.*, 1997). The study resulted in a recommended 4-year curriculum plan for the UMedic system (Table 1). An analysis of a 77 item randomized test taken by 122 senior medical students at two institutions yielded a reliability coefficient of 0.94 (Issenberg *et al.*, 1998). A current national multicenter study involving senior medical students at six institutions is comparing the UMedic system with traditional methods for teaching bedside skills in cardiology.

In studies of EMST, the Miami Cardionet Project Study found that paramedics trained at our Center were able to accurately interpret 12 lead ECGs for acute myocardial ischemic events with minimal decline in retention (Schrank *et al.*, 1993). Post-course evaluations by the paramedics taking hands-on scenario-based programs showed that more than 98% of the trainees felt the course prepared them to

Table 1. Recommended use of UMedic cardiology modules in 4 year curriculum.

Year	Learning Goals	Course	Modules	Format	Time*
I	Normal cardiovascular physiology and bedside examination	Physiology and/or	Normal (bedside only)	Instructor mode (Lecture setting)	1½ hours
		Early Clinical Skills	Normal (bedside only)	Self-learning mode	1½ hours per class (Total=3 hours)
II	Review normal and add the four classic valve lesions: pathophysiology and bedside examination	Pathophysiology and/or	Review Normal Highlight MR, AS, AR, MS (bedside only)	Instructor mode (Lecture setting)	2 hours
		Introduction to Clinical Medicine	MR, AS, AR, MS (bedside only)	Self-learning mode	6 hours per class (Total=8 hours)
III	Review common diseases, including management: pathophysiology, the bedside examination, laboratory evaluation and treatment	Medicine clerkship	Angina Pectoris Acute Inferior Infarction Acute Anterior Infarction Hypertension Cardiomyopathy (entire program)	Self-learning mode	7½ hours per 3 month clerkship
IV	Comprehensive review of cardiovascular curriculum	Adult and/or Pediatric Cardiology Electives	Up to All 10 modules (entire program)	Self-learning mode	Up to 15 hours per 4 week elective

Notes: MR = mitral regurgitation, AS = aortic stenosis, AR = aortic regurgitation, MS = mitral stenosis.
*Self-learning time estimates presume groups of five students reviewing each module for 1½ hours.

effectively treat heart attack victims in the field. Initial results of a current study in our acute stroke course involving pre-hospital providers shows significant gain in cognitive knowledge on post-tests. Future studies will evaluate skills using standardized patients and multimedia computers.

Discussion

The implementation of simulation technology and computer-based methods of teaching and testing specifically addresses recent concerns related to the bedside skills training of young physicians. Although the accurate bedside examination of cardiac patients is cost effective (Roldan *et al.*, 1996), a nationwide survey indicates less frequent teaching of these skills (Mangione *et al.*, 1993). This decline in bedside skills training was recently re-emphasized in a study demonstrating that house officers often have difficulty identifying common cardiac findings (Mangione & Nieman, 1997). The authors concluded that "alternative strategies to provide additional and structured auscultatory teaching may be needed", that "learners may need to rely on electronic sounds or simulators" and that "teaching without testing may not suffice". While simulation techniques are not intended to take the place of a real patient, they solve many of the problems associated with the limitations of teacher time and patient availability. These systems use high technology to teach 'low technology' bedside diagnostic skills that are accurate and cost effective. The skills learned enhance student efficiency and confidence when examining real patients, resulting in less anxiety and more time to communicate with the patient.

We have demonstrated that a simulator and a standardized multimedia computer instruction system can be successfully integrated into all years of the medical school curriculum and can also be used for multiprofessional training. Implementation of such curricular innovations is too often slow and difficult. Inertia has been suggested as the most powerful force in current medical education (McGaghie, 1994). The most important requirement for curriculum innovation is leadership and a willingness to change. An equally important requirement is testing outcomes.

Conclusion

Our experience and outcomes studies at the University of Miami CRME have demonstrated that bedside skills learned through simulation can be effectively transferred to real patients. We believe that the expanded use of such simulation and multimedia computer technology systems in medical education is inevitable. Those systems that can be used by multiple populations and levels of learners will be the most valuable and cost effective. We are also convinced that simulation technology in medical education is the key to 'hand-on' skills training, that multimedia computer systems will be a central method for medical education and that these systems will be used for certification and recertification of all medical professionals.

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