Int J Emerg Med (2008) 1:73–77
DOI 10.1007/s12245-008-0034-2

REVIEW ARTICLE

The use of simulation in the education of emergency care providers for cardiac emergencies

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Received: 10 April 2008 / Accepted: 2 May 2008 / Published online: 5 June 2008

Abstract
Background Traditional methods of educating residents and medical students using lectures and bedside teaching are no longer sufficient. Today's generation of trainees grew up in a multimedia environment, learning on the World Wide Web instead of reading books. It is unreasonable to expect the educational model developed 50 years ago to be able to adequately train the medical students and residents of today. One area that is difficult to teach is the diagnosis and management of the critically ill patient, specifically cardiac emergencies and cardiac arrest.
Rationale In the management of a patient in cardiac arrest, it is sometimes the least experienced provider giving chest compressions, intubating the patient, and running the code during the most crucial moment in that patient's life.
Methods Patient simulation has emerged as an educational tool that allows the learner to practice patient care, away from the bedside, in a controlled and safe environment, giving the learner the opportunity to practice the educational principles of deliberate practice and self-refection. We performed a qualitative literature review of the uses of simulators in medical training with a focus on their current and potential applications in cardiac emergencies.

The views expressed in this paper are those of the authors and not those of the editors, editorial board, or publisher.

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Keywords Patient simulation · Graduate medical education · Emergency medicine · Cardiology

Introduction

Medical student and resident training has changed dramatically in the twentyfirst century because of a dynamic shift in the attitudes of our patients and learners, as well as the creation of information technology. Patients today are no longer passive in their healthcare but are fully engaged using tools such as the Internet, to make their own care decisions. Patients also have an increased awareness to medical errors, calling into question the century-old practice of "see one, do one, teach one" [1]. Learner expectations have also changed in the current, fast-paced, technological environment: In the past, trainees would read about unfamiliar disease processes, sit passively in a lecture, and observe skilled clinicians prior to practicing on a patient. This form of learning is not conducive to adult learning or to current practice environments. Research specific to medical education has shown that adults learn faster and have greater retention of knowledge when they participate in an interactive setting [2]. Patient simulation has been suggested as an ideal tool for teaching in this new generation of learners, allowing them to engage actively in their learning process while doing no harm to their patients.

One area of medicine needing a fundamental shift in the teaching model is in the training of cardiac emergencies. A recent study by Pebedy et al. of 58,593 cardiac arrest patients demonstrated a significant decline in survival rates for in-hospital cardiac arrests during nights and weekends for all areas of the hospital except the emergency department (ED) and trauma service [3]. The authors theorized that this was likely due to less direct supervision by senior staff in areas of the hospital outside of the ED and trauma center.

In the USA, the current model for training in cardiac emergencies is usually initiated at the beginning of internship with the Advanced Cardiac Life Support (ACLS) course. After taking the 2-day course, the physician becomes certified in the initial management for most cardiac emergencies such as cardiac arrest and unstable arrhythmias. Though ACLS certification has become a standard process for ensuring minimum competency for practitioners responding to cardiac emergencies, it does not require a mastery of the knowledge and skill needed to handle the complexities of advanced clinical decision-making. With evidence correlating increased patient survival to factors such as rate and quality of chest compressions and early recognition of ventricular fibrillation and defibrillation, it becomes evident that instruction through passive lectures and a one-time skills station is inadequate for providing optimal survival opportunities for these patients [4–6].

Research in instructional science has demonstrated that, in order to ensure acquisition and maintenance of a skill at the expert level, the deliberate practice of the educational objective must be employed [7]. Simulation is an ideal educational tool for the training of these high-stakes patients.

Gaba defines simulation as an instructional process that substitutes real patient encounters with artificial models, live actors, or virtual reality patients with the goal of replicating patient care scenarios in a realistic environment for the purposes of feedback and assessment [8]. Currently, no standardized classification in simulation exists, but it is often divided into four areas by the educational tool: the standardized patient, screen-based computer, partial-task, and high-fidelity simulator. Standardized patients are actors trained to give specific responses to a certain medical condition that can be reliably replicated between learners. Computer simulation is an interactive program that allows the learner to practice patient care and receive feedback on their medical management. Part-task simulation is a device used to teach a specific skill or procedure such as the placement of a chest tube or delivery of a baby. The high-fidelity mannequin simulator (HFMS) is a dynamic, computer-controlled, full-sized, simulated mannequin capable of giving a history, recreating physical exam findings such as normal and abnormal heart sounds, lung sounds, and pupil findings, as well as physiologic changes including blood pressure, heart rate, and breathing. Some HFMS are even capable of physiologically responding to medication and oxygen administration, receiving electrical cardioversion and procedures such as diagnostic peritoneal lavage and central lines.

We conducted a systematic review of the literature on the use of simulators in the training of cardiac emergencies. PUBMED was searched using the terms “simulation,” “training,” and “cardiology.” A summary of our findings is presented with a discussion of both the advantages and disadvantages of applied simulation to training.

Simulator types

Cardiopulmonary resuscitation simulator

The Resusci-Annie™, developed in 1960, was the earliest form of medical simulation [9]. This part-task simulator was developed from the need for a realistic model for training in basic cardiopulmonary resuscitation (CPR).

In a series of studies performed on curarized volunteers, Elam and Safar demonstrated that mouth-to-mouth ventilation could provide adequate oxygenation and elimination of carbon dioxide. Safar later met a toymaker named Asmund Laerdal, who was renowned for his lifelike toy dolls, and commissioned him to create the first CPR manikin, the Resusci-Annie™. Currently, the Resusci-Annie™ is used for basic life support and ACLS training internationally. While this is a powerful tool for basic life support training, it lacks the haptic feedback plus diagnostic and treatment cues of modern simulators.

Harvey cardiology simulator

Cardiologists were some of the first teachers in the medical field to recognize the limitations of relying only on direct patient encounter to teach all of the various cardiovascular diseases. Using this model of teaching, the instructor would need to find a patient for every disease during a limited encounter with a resident or medical student.

In 1968, under the direction of Dr. Michael Gordon at the University of Miami, work was started on developing a cardiology patient simulator (CPS) that would allow learners to engage in a reproducible simulated patient encounter of 20 diseases. In 1976, the first prototype was completed and named after Dr. W. Proctor Harvey, a Professor from Georgetown University, for his innovations in education and teaching.

The “Harvey” CPS is a life-size manikin torso capable of reproducing bedside physical findings of a multitude of cardiovascular diseases. Physical findings include jugular venous pulsations, precordial pulsations, respiratory sounds, pulses, and heart sounds that correspond to these diseases. The current CPS is able to reproduce 30 conditions ranging from the simple findings of mitral valve prolapse to the critically ill patient with acute inferior myocardial infarction.

A multicenter study from 1981, involving 208 medical students at five medical schools, demonstrated a significant improvement in clinical knowledge and patient skill when the CPS was used during a fourth-year cardiology clerkship [10]. During the clerkship, half of the students were taught using conventional bedside teaching while the other half was taught with both conventional teaching and CPS. After the rotation, the CPS group scored significantly higher on exams testing clinical skills and knowledge. Similar findings were found in training house staff using the CPS [11, 12]. Despite these impressive findings, the use of CPS did not mainstream effectively into medical education, yet the need for this, and other, technology is of utmost importance. Recent studies have demonstrated a deficiency in cardiology skills in graduating residents, as well as attending physicians. Two separate studies involving internal medicine residents and emergency medicine residents showed correct diagnosis of heart murmurs using the CPS to be 52% (mitral regurgitation), 37% (mitral stenosis), 54% (aortic regurgitation) and 59% (aortic regurgitation), 48% (mitral regurgitation), and 17% (mitral stenosis), respectively. This is likely do to a lack of exposure to the diseases during their medical school and residency training. These numbers did not vary with level of training.

The CPS is a powerful tool for physical diagnosis training. Its cost has been one limiting factor in its widespread application. In addition, it lacks the ability to simulate therapeutic interventions and physician–patient interactions. Regardless, it is an excellent assessment tool and provides a valuable adjunct to medical education.

Procedural simulators

Simulation can also be used for training in emergency cardiac procedures. Although several mannequin-based simulators on the market today are equipped with the capacity to perform pericardiocentesis, there is no study evaluating a simulation platform as a teaching tool. One report described practicing emergency procedures on the recently dead. However, this method of teaching is falling out of favor [13]. Sanchez and colleagues described increase confidence to perform pericardiocentesis autonomously in practitioners who had received instruction in an animal lab [14]. This study failed to provide a formal analysis of increased competence in the participants of the animal lab. Furthermore, increased regulations and restrictions on the use of animal subjects for training purposes make this a difficult and costly method to employ. Another reference outlined the adaptation of a virtual reality intravenous line simulator for the performance of pericardiocentesis [15]. However, no data regarding the use of this simulator for teaching students or clinicians is provided. Future applications of current technologies for training in emergency pericardiocentesis will likely be useful in this arena.

Another potential use of simulators for emergency cardiac procedures is in the use of temporary and transvenous pacemakers. Murphy et al. conducted a survey of senior house officers and interns to assess the current training and practice of temporary transvenous pacemaker insertion [16]. All the surveyed trainees received instruction from fellows or senior house officers by the traditional methods of bedside teaching and observation on patients. Most house officers reported they had observed two temporary pacing procedures and performing two under supervision before being left unsupervised. Fifty-percent of the surveyed physicians were unhappy with their training in transvenous pacemaker insertion. A task force of physicians from the American College of Physicians, the American College of Cardiology, and the American Heart Association released a statement outlining the minimum competency for performing temporary transvenous pacing [17]. These recommendations were based on a panel of experts requiring a minimum of 10 supervised transvenous pacemaker procedures for competence. Indeed, the performance of temporary transvenous pacing is a necessary skill but is only sporadically performed in a clinical environment. Training in bedside cardiac procedures, such as the placement of a transvenous pacemaker and pericardiocentesis, is lacking and the development of such a platform appears to be needed.

High-fidelity mannequin simulators

Mannequin simulators provide some of the most realistic and high-yield environments for trainees. These simulators are computer-operated patients capable of recreating almost any disease entity. The first mannequin simulator was developed by Abrahamson and Denson in the early 1960s and was initially used for anesthesia training [5]. Today, these simulators are used in multiple other disciplines. Unlike the part-task simulators mentioned above, the mannequin simulator creates a comprehensive environment for trainees. Multiple studies have shown this method of training to be perceived as realistic and useful [18–22]. These simulators are physiologically modeled to respond appropriately to medications and inhaled gases. Participants speak to the patient, take a complete history and physical exam, and work in a team as they would in a real clinical encounter.

While some of the benefits of using this method of training are apparent, literature has outlined some specific advantages in the education of cardiac emergencies. Wayne and colleagues performed a retrospective evaluation of second-year internal medicine residents who received a simulation-based educational intervention with routine clinical education for cardiac arrest teams [23]. They developed checklists for six common American Heart

Association ACLS scenarios and abstracted adherence to these scenarios from the medical record. Simulator-trained residents were seven times more likely to adhere to the ACLS scenarios than non-simulator-trained residents. This study concluded that simulator-based education improved the quality of care delivered by cardiac arrest teams.

Another study reported an improvement in ACLS skills of residents following a simulator-based program [24]. This was a randomized control study that evaluated residents based on their adherence to ACLS protocols. Participants were randomized to either a traditional- or simulator-trained arm. They were evaluated at 3 and 6 months following training. Again, this study found an improvement in residents who participated in simulations. These improvements were sustained with little decay over the study period. In a separate study, no decay was seen in ACLS skills over a 14-month period following simulation-based training [25]. Based on this work, it appears that simulation enhances performance to a greater degree than clinical experience alone.

Mannequin simulators are generally accepted as valuable training tools. Equally important to training in education is the need to evaluate trainees. Mannequin simulators are being used increasingly in this capacity [26–28]. Simulated cases can be tailored to assess the individual Accreditation Council for Graduate Medical Education core competencies [29]. Some debate exists over which assessment methods are best. To date, there are no validated evaluation tools. At least one study suggests the objective structured clinical examination as a feasible method for trainee assessment [28]. This method showed comparable scores on simulator exams vs oral exam controls at various levels of training.

HFMS are also useful for team training. In 1999, the Institute of Medicine published the book *To Err Is Human*, which urged the establishment of multidisciplinary team training. Shapiro and colleagues conducted a study using emergency medicine attendings, residents, and nurses to evaluate the use of a simulator to improve team training [1]. Although no statistical differences between experimental and control groups were found, the experimental group showed a trend toward improved team behavior [30].

The use of mannequin simulators has not yet expanded into the field of cardiology. Other medical disciplines have been successful in using these simulators for education and training in cardiac-related conditions. Undeniably, the advantages of these high-fidelity simulators can mitigate the limitations of the part-task simulators described above and should be considered in future educational endeavors.

Conclusion

There are multiple areas where simulation appears to be used to train physicians in cardiac emergencies. The obvious use for decades has been to teach the lay public the techniques of basic life support using CPR mannequins. Other aspects of the cardiac physical exam are also well taught using the simulator, such as the diagnosis of a murmer and rub. There appears to be a lack of appropriate training models for the teaching of procedures necessary in cardiac emergencies. High-fidelity mannequin simulation appears to have the most promise in the training of physicians and may affect true patient outcome. Programs are using HFMS to train many of the skills needed during the resuscitation of the critically ill patient prior to going to the bedside.

Future uses of simulation in cardiology have extraordinary potential to improve the care delivered to cardiac patients. The standardization of simulation to train and maintain skills used in ACLS may improve care given to patients during times of decreased and less senior staffing. Creation of partial-task simulators to train procedures such as temporary transvenous pacemaker placement and pericardiocentesis would allow physicians to be competent in a skill they rarely perform but is critical when needed. Finally, HFMS can be used to ensure that all physicians training in the care for the acutely ill, such as emergency medicine, have received appropriate exposure and assessment in all relevant cardiac emergencies prior to their graduation.

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