Simulation-based medical teaching and learning

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ABSTRACT

One of the most important steps in curriculum development is the introduction of simulation-based medical teaching and learning. Simulation is a generic term that refers to an artificial representation of a real world process to achieve educational goals through experiential learning. Simulation based medical education is defined as any educational activity that utilizes simulation aides to replicate clinical scenarios. Although medical simulation is relatively new, simulation has been used for a long time in other high risk professions such as aviation. Medical simulation allows the acquisition of clinical skills through deliberate practice rather than an apprentice style of learning. Simulation tools serve as an alternative to real patients. A trainee can make mistakes and learn from them without the fear of harming the patient. There are different types and classification of simulators and their cost vary according to the degree of their resemblance to the reality, or 'fidelity'. Simulation-based learning is expensive. However, it is cost-effective if utilized properly. Medical simulation has been found to enhance clinical competence at the undergraduate and postgraduate levels. It has also been found to have many advantages that can improve patient safety and reduce health care costs through the improvement of the medical provider’s competencies. The objective of this narrative review article is to highlight the importance of simulation as a new teaching method in undergraduate and postgraduate education.

Key words: Clinical skills, medical education, medical simulation, simulators

INTRODUCTION

Medical education has undergone significant changes all over the world. One of the reasons for the changes is concern for the patient's safety. "To Err Is Human", a landmark report released by the Institute of Medicine (IOM) in 1999 estimated that medical errors cause injury to approximately 3% of hospital patients and results in a minimum of 44,000 and perhaps as many as 98,000 deaths per year in the United States. Another important finding came from the Harvard Medical Practice Study I, in which the authors reviewed over 30,000 randomly selected hospital records at New York State in 1984 as part of an interdisciplinary study of medical injury and malpractice litigation. They found that injuries from adverse events occurred in 3.7% of hospital admissions, 27.6% of which were due to negligence and in which 13.6% led to death. Medical errors also contribute to the cost of medical care throughout the world. The annual cost attributable to all adverse drug events and preventable adverse drug events for a 700-bed American teaching hospital was estimated by one study as $5.6 million and $2.8 million respectively. Though it is expected that such medical errors occur in Saudi Arabia, there are no studies on their extent in Saudi hospitals.

Calls for a change in the instructional methods have resulted in innovative medical curricula. The new curricula stress the importance of proficiency in several clinical skills by medical graduates rather than mere acquisition of knowledge. As evidenced by their endorsement by many of the international bodies and medical schools, it is universally accepted that clinical skills constitute an essential learning outcome. The acquisition of appropriate clinical skills is key to health education; however, students sometimes complete their educational programs armed with theoretical knowledge but lack many of the clinical skills vital for their work. A major challenge for medical undergraduates is the application of theoretical knowledge to the management of patients. Some medical schools in the Middle East have changed their curricula and adopted such educational strategies as problem-based learning. Also many medical schools have started to utilize clinical skills laboratories for training. However, simulation-based learning is not yet well established in this region. The objective of this narrative review article is to highlight the
importance of simulation as a new teaching method for undergraduate and postgraduate education.

**MATERIALS AND METHODS**

This is a narrative review of literature on a medical simulator and the use of simulation in medical education. A literature search of MEDLINE/PubMed database for English-language publications and reference lists from relevant articles published between 1990 and August 2009 was conducted. The main search terms were medical simulation, medical simulator, medical education, and clinical skills. All articles thought to be relevant to the title and/or abstracts were retrieved. These articles were reviewed if they were considered relevant to the search.

**CLINICAL COMPETENCE**

Medical training programs should ensure that students have the necessary learning opportunities and assessed by the appropriate methods. Clinical skills competencies including communication skills, history-taking, professional attitudes, awareness of ethical basis of healthcare, physical examination, procedural skills, clinical laboratory skills, diagnostic skills, therapeutic skills, resuscitation skills, critical thinking, clinical reasoning, problem solving, team-work, organization skills, management skills, and information technology skills should be part of the core undergraduate curriculum. Traditionally, the acquisition and ongoing improvement of high level psychomotor skills required by future physician take place in an apprentice-style model of 'See One, Do One, Teach One.' This apprentice-style of learning is no longer considered acceptable because of the increasing concern for the quality of patient care and safety and change in health care systems. The pressure of managed care has shaped the forms and frequency of hospitalization and led to a higher percentage of acutely ill patients and shorter inpatient stays. This has resulted in fewer opportunities for the medical learner to access a wide variety of diseases and physical findings. Relying on exposure to real hospital patients during training years may result in an ad-hoc method of learning clinical skills, as this depends on the availability of cases, and consequently to less than optimal development and performance of clinical skills. There are many reports that indicate concerns for the level of skills medical graduates even in western countries possess.

The acquisition of expertise in clinical medicine requires the learner's engagement in deliberate practice of desired learning outcomes. According to Issenberg et al (2002) "Deliberate practice involves (a) repetitive performance of intended cognitive or psychomotor skills in focused domain, coupled with (b) rigorous skills assessment, that provides learners (c) specific, informative feedback, that results in increasingly (d) better skills performance, in a controlled setting." Concerns about patient safety and fewer available patients for learning, and many other factors have led to the introduction of simulation and the development of simulation centers and clinical skills laboratories in medical education.

**SIMULATION**

Aviation and aerospace industries have been using simulation as a teaching tool for many years. Simulators are now widely used in education and training in a variety of high risk professions and disciplines, including the military, commercial airlines, nuclear power plants, business and medicine. Recently, the inclusion of clinical skills training into the curricula of medical students has seen significant growth. There are many examples of curricular reform that include clinical skills training, the use of simulators, and the creation of clinical skills centres. Simulation has been defined as a situation in which a particular set of conditions is created artificially in order to study or experience something that is possible in real life; or a generic term that refers to the artificial representation of a real world process to achieve educational goals via experimental learning.

A simulator is defined as a device that enables the operator to reproduce or represent under test conditions phenomena likely to occur in actual performance. On the other hand, simulation based medical education can be defined as any educational activity that utilizes simulative aides to replicate clinical scenarios. Simulation tools serve as an alternative to the real patient. Trainers can make mistakes and learn from them without the fear of distressing the patient. Experiential learning, which is a part of the definition of simulation, is an active process during which the learner constructs knowledge by linking new information and new experience with previous knowledge and understanding. Experiential learning or learning from experience during simulation based training sometimes involves the use of clinical scenarios as the bases of learning. The practice of scenarios can be done individually, but it is mostly carried out by a team from the same or different specialties or professions in a simulated environment made to resemble the intended environment as closely as possible in order to immerse students in an experience closest to real life. The practice of a scenario can be videotaped for immediate feedback to participants during the debriefing sessions.

Debriefing after a scenario is an important component of full-scale simulation. Video recording of the scenario is also used to initiate discussion and to make sure that all
learning objectives were covered. Debriefing can focus both around the cognitive process involved in the recognition of the problem and the implementation of the management guidelines and the technical level at which the ability of the learner to apply rules and appropriate responses in a stressful situation is evaluated. 

During the full scale scenario-based training, the learner can acquire such important skills as interpersonal communication, teamwork, leadership, decision-making, the ability to prioritize tasks under pressure, and stress management. However, training through simulation should be viewed as an adjuvant and not a replacement for learning with real patients. Simulation is not intended to replace the need for learning in the clinical environment, so it is important to integrate simulation training with the clinical practice during curriculum development.

**SIMULATOR**

Simulators are classified into different categories. An example of the classification of simulators is shown in Table 1. Simulators can be classified according to their resemblance to reality into low-fidelity, medium-fidelity and high-fidelity simulators. Low-fidelity simulators are often static and lack the realism or situational context. They are usually used to teach novices the basics of technical skills. Example of a low-fidelity simulator is the intravenous insertion arm [Figure 1] and Resusci-Anne [Figure 2]. Moderate fidelity simulators give more resemblance of reality with such features as pulse, heart sounds, and breathing sounds but without the ability to talk and they lack chest or eye movement. They can be used for both the introduction and deeper understanding of specific, increasingly complex competencies. An example of a moderate fidelity simulator is the "Harvey" cardiology simulator [Figure 3]. High fidelity simulators combine part or whole body manikins to carry the intervention with computers that drive the manikins to produce physical signs and feed physiological signs to monitors. They are usually designed to resemble the reality. They can talk, breathe, blink, and respond either automatically or manually to physical and pharmacological interventions. Good examples of high-fidelity simulator is the METI Human Patient Simulator (HPS) which is model driven [Figure 4] and the "Noelle" obstetric simulator which is instructor driven. In general, the higher the fidelity, the more expensive it is.

Virtual reality can also be incorporated into the simulators (mostly part-task simulators) to enhance learning. Virtual reality is best described as a concept of advanced human-computer interaction. Virtual reality varies greatly according to its level of sophistication in its level of realism and of the user's interaction with the virtual environment. A common form of virtual reality involves the use of haptic (touch) feedback to produce a feeling of resistance when using instruments in a simulated environment. This technology is frequently used in endoscopic and laparoscopic dexterity training. High-fidelity and virtual reality simulations can bridge the gap between theory and practice by immersing the learner in a realistic, dynamic, complex setting.

Nonetheless, simulation can only imitate but not replicate reality. The recreation of "reality" or "fidelity" is important for the success of simulation and for the participant. Since some simulators can be used to encourage independent or self-directed learning, they should be integrated into the overall curriculum. However, to make learning effective, important conditions are necessary during simulation practice. The intended outcomes should be predefined and the training carried out in a controlled environment. Effective learning requires repetitive practice and feedback during the learning experience. Issenberg et al performed an excellent systematic review and identified ten features of high-fidelity medical simulation that can lead to effective learning. Those ten features are listed in Table 2.

### Table 1: Classification of simulators

| SIMULATOR                        | Example                                                                 |
|----------------------------------|-------------------------------------------------------------------------|
| Part task trainer                | Plastic-based non dynamic trainers                                      |
| Plastic-based dynamic trainer    | Virtual reality trainer with low-fidelity haptics                       |
| Virtual reality trainer with high-fidelity haptics |                                                            |
| Computer-based system            | Simulated patients                                                      |
| Simulated environments           | Instructors driven simulators                                           |
| Integrated simulators            | Model driven simulators                                                 |

### Table 2: Features of high fidelity simulation that lead to effective learning

- Integrate simulators into the overall curriculum
- Clearly define outcomes and benchmarks for the learners to achieve using simulators
- Learners should repetitively practice skills on the simulator
- Learners should practice with increasing levels of difficulty if available
- Provide feedback during the learning experience with the simulator
- Adapt the simulator to complement multiple learning strategies
- Ensure the simulator provides for clinical variation if available
- Learning should occur in a controlled environment
- Provide individualized (in addition to team) learning on the simulator
- Ensure the simulator is a valid learning tool
Simulation can be used to resemble existing curricular material. The simulated scenarios are realistic enough to engage the students emotionally, thus providing a unique learning experience, where the high-fidelity simulator "patient" actually talks, breathes, blinks, and moves like a real patient. Simulation can be adapted to accommodate the need of various medical specialties such as anesthesia, emergency medicine and trauma, intensive care medicine, obstetrics, pediatrics, and radiology as well as for the use of other professionals such as nurses, paramedics, and respiratory therapists.\textsuperscript{[13,24,25]}

Simulation laboratories are quite costly. A single high-fidelity simulator with its monitoring system and other necessary equipment may cost up to $200,000. In addition, synthetic body fluids, replacement skins, bandages, syringes and other supplies are necessary to simulate the experience of treating real patients in a real hospital. The ability to practise without risk must be weighed against the cost of this new technology. Simulation has many advantages, for it results in highly trained medical graduates who are less likely to make life-threatening or costly medical errors.\textsuperscript{[21,23]}

Some of the advantages of simulation are listed in Table 3. Employing medical simulation techniques can help move medical training from the old "See One, Do One, Teach One" method into a "See One, Practice Many, Do One" model of success.\textsuperscript{[29]} Simulation-based teaching has proved to reduce risks to both patients and learners.\textsuperscript{[27,28]} It has also proved to be effective in both undergraduate and postgraduate education as well as faculty development.\textsuperscript{[29,30]}

Simulation can be used in the primary health care setting to improve confidence in performing life-saving skills,\textsuperscript{[31]} clinical skills,\textsuperscript{[32,33]} communication skills,\textsuperscript{[34]} and the quality
of care for patients with chronic diseases such as diabetes mellitus and bronchial asthma.\textsuperscript{35,36} Such simulators as part task trainers, computer-based systems, virtual reality and the haptic system, simulated patients, simulated environment, and integrated simulators have been used also effectively to assess and evaluate clinical skills.\textsuperscript{10,37,38} The major challenge to medical simulation is the fact that evidence to date is weak in methodology. Most of the published work is descriptive and limited in generalisability. The assumption that such learning is directly transferable to the clinical context is often untested.\textsuperscript{10} Only a few studies have shown a direct positive impact in the clinical outcome from the use of simulation for medical training.\textsuperscript{10}

In conclusion, the promise of simulation-based medical training offers useful opportunities to reduce risks to patients and learners, improve learners’ competence and confidence, increase patient safety, and reduce health care costs in the long run. However, robust research is needed to see if simulation training does actually improve patient outcomes.

REFERENCES

1. Kohn LT, Corrigan JM, Donaldson MS. To err is human: Building a safer health system. Washington DC: National Academy Press; 1999.
2. Brennan TA, Leape LL, Laird NM, Hebert L, Localio AR, Lawthers AG, et al. Incidence of adverse events and negligence in hospitalized patients: Results of the Harvard Medical practice Study I. N Engl J Med 1991;324:360-76.
3. Bates DW, Spell N, Cullen DJ, Burdick E, Laird N, Petersen LA, et al. Cost of adverse drug events in hospitalized patients. Adverse drug events prevention study group. JAMA 1997;277:307-11.
4. Smith SR, Dollas R. AMEE Guide No 14: Outcome-based education: Part 2- Planning, implementing, and evaluation of competency-based curriculum. Med Teach 1999;21:15-22.
5. Ledingham McA, Harden RM. Twelve tips for setting up a clinical skills training facility. Med Teach 1998;20:503-7.
6. Langdell LA, Schaad D, Wipf J, Marshall S, Vontver L, Scott CS. Preparing Graduates for the First Year of Residency: Are Medical Schools Meeting the Need? Acad Med 2003;78:39-44.
7. Jones A, McArdle PE, O’Neill PA. How well prepared are graduates for the role of pre-registration house officer? A comparison of the perceptions of new graduates and educational supervisors. Med Educ 2001;35:578-84.
8. Issenberg SB, McGaghie WC, Gordon DL, Symes S, Petrusa ER, Hart IR, et al. Effectiveness of a Cardiology Review Course for Internal Medicine Using Simulation Technology and Deliberate Practice. Teach Learn Med 2002;14:223-8.
9. Al-Elq AH. Medicine and Clinical Skills Laboratories. J Fam Community Med 2007;14:59-63.
10. Scalese RJ, Obeso VT, Issenberg SB. Simulation Technology for Skills Training and Competency Assessment in Medical Education. J Gen Intern Med 2008;23:46-9.
11. Issenberg SB, Gordon MS, Gordon DJ, Safford RE, hart IR. Simulation and new learning technologies. Med Teach 2001;16:16-23.
12. Dent JA. Current trends and future implications in the developing role of clinical skills centres. Med Teach 2001;23:483-9.
13. Flanagan B, Nestel D, Joseph M. Making patient safety the focus: Crisis resource management in the undergraduate curriculum. Med Educ 2004;38:56-66.
14. Ziv A, Ben-David S, Ziv M. Simulation Based Medical Education: An opportunity to learn from errors. Med Teach 2005;27:193-9.
15. Cannon-Bowers JA. Recent advances in Scenario-based training for medical education. Curr Opin Anaesthesiol 2008;21:784-9.
16. Yaeger KA. Arafeh JM. Making the move: From traditional neonatal education to simulation-based training. J Perinat Neonatal Nurs 2008;22:154-8.
17. Cheng A, Duff J, Grant E, Kissoon N, Grant VI. Simulation in paediatrics: An educational revolution. Paediatr Child Health 2007;12:465-8.
18. Robertson B, Schumacher L, Gosman G, Kanfer R, Kelley M, DeVita M. Simulation-based crisis team training for multidisciplinary obstetric providers. Simul Healthc 2009;4:77-83.
19. Rudolph JW, Simon R, Raemer DB, Eppich WJ. Debriefing as formative assessment: Closing performance gaps in medical education. Acad Emerg Med 2008;15:1010-6.
20. Seropian MA, Brown K, Galvanes JS, Driggers B. Simulation: Not just a Manikin. J Nurs Educ 2004;43:164-9.
21. Maran NJ, Glavin RJ. Low-to high-fidelity simulation – a continuum of medical education? Med Educ 2003;37:22-8.
22. Issenberg SB, McGaghie WC, Petrusa ER, Lee Gordon D, Scalese RJ. Feature and uses of high-fidelity medical simulations that lead to effective learning: A BEME systematic review. Med Teach 2005;27:10-28.
23. Ypinazar VA, Margolis SA. Clinical simulators: Applications and implication for rural medical education. Rural Remote Health 2006;6:527-38.
24. Cherry RA, Ali J. Current concepts in simulation-based trauma education. J Trauma 2008;65:1186-93.
25. Jeffries PR. A framework for Designing, Implementing and Evaluating Simulation Used as Teaching Strategies in Nursing. Nurs Educ Perspect 2005;26:96-103.
26. Vozenilek J, Huff JS, Reznik M, Gordon JA. See one, do one, teach one: Advanced technology in medical education. Acad Emerg Med 2004;11:1149-54.
27. Gordon JA, Wilkerson WM, Shaffer DW, Armstrong EG. Practicing medicine without risk: Students’ and educators’ response to high-fidelity patient simulation. Acad Med 2001;76:649-72.
28. Pian-Smith MC, Simon R, Minehart RD, Podraza M, Rudolph J, Walzer T, et al. Teaching residents the two-challenge rule: A simulation-based approach to improve education and patient safety. Simul Healthc 2009;4:84-91.
29. Weller JM. Simulation in undergraduate medical education: Bridging the gap between theory and practice. Med Edu 2004;38:32-8.
30. Margan PJ, Cleave-Hogg D. Simulation technology in training students, residents and faculty. Curr Opin Anaesthesiol 2005;18:199-203.
31. Toback SL, Fiedor M, Kilpela B, Reis EC. Impact of a Pediatric Primary Care Office-based Mock Code Program On Physician and Staff Confidence to Perform Life-saving Skills. Pediatr Emerg Care 2006;22:415-22.
32. Ramsey PG, Curtis JR, Pauuw DS, Carline JD, Wenrich MD. History-taking and Preventive Medicine Skills among Primary Care Physicians: An Assessment Using Standardized Patients. Am J Med 1998;104:152-8.
33. Costanza ME, Luckmann R, Quirk ME, Clemow L, White MJ, Stoddard AM. The Effectiveness of Using Standardized Patients to Improve Community Physicians’ Skills in Mammography Counseling and Clinical Breast Exam. Prev Med 1999;29:241-8.
34. Vaidya VU, Greenberg LW, Patel KM, Strauss LH, Pollack MM. Teaching Physicians How to Break Bad News. Arch Pediatr Adolesc Med 1999;153:419-22.
35. O’Connor PJ, Sped-Hillen JM, Johnson PE, Rush WA, Asche SE, Dutta P, et al. Simulated physician learning intervention to improve safety and quality of diabetes care: A randomized trial. Diabetes Care 2009;32:885-90.
36. Morrow R, Fletcher J, Mulvihill M, Park H. The asthma dialogues: A model of interactive education for skills. J Contin Educ Health Prof 2007;27:49-58.
37. Srinivasan M, Hwang JC, West D, Yellowlees PM. Assessment of clinical skills using simulator technology. Acad Psychiatry 2006;30:505-15.
38. Weinberg ER, Auerbach MA, Shah NB. The use of simulation for pediatric training and assessment. Curr Opin Pediatr 2009;21:282-7.
39. Gordon JA, Oriol NE, Cooper JB. Bringing good teaching cases "to life": A simulation-based medical education service. Acad Med 2004;79:23-7.
40. Okuda Y, Bryson EO, DeMaria S Jr, Jacobson L, Quinones J, Shen B, et al. The utility of simulation in medical education: What is the evidence? Mt Sinai J Med 2009;76:330-43.