REVIEW

Simulation-based medical education in clinical skills laboratory

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Abstract : Clinical skills laboratories have been established in medical institutions as facilities for simulation-based medical education (SBME). SBME is believed to be superior to the traditional style of medical education from the viewpoint of the active and adult learning theories. SBME can provide a learning cycle of debriefing and feedback for learners as well as evaluation of procedures and competency. SBME offers both learners and patients a safe environment for practice and error. In a full-environment simulation, learners can obtain not only technical skills but also non-technical skills, such as leadership, team work, communication, situation awareness, decision-making, and awareness of personal limitations. SBME is also effective for integration of clinical medicine and basic medicine. In addition, technology-enhanced simulation training is associated with beneficial effects for outcomes of knowledge, skills, behaviors, and patient-related outcomes. To perform SBME, effectively, not only simulators including high-fidelity mannequin-type simulators or virtual-reality simulators but also full-time faculties and instructors as professionals of SBME are essential in a clinical skills laboratory for SBME. Clinical skills laboratory is expected to become an integrated medical education center to achieve continuing professional development, integrated learning of basic and clinical medicine, and citizens' participation and cooperation in medical education. J. Med. Invest. 59 : 28-35, February, 2012

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INTRODUCTION

Clinical simulation is one of the procedures used in health-care education that is performed in a situation that mimics a clinical setting in order to learn the technical skills and competency required for health care (1-3). Desire for patient safety and quality in patient care as the driving force is accelerating the development of simulation-based medical education (SBME) around the world. Traditionally, "See one, Do one, and Teach one" has been proposed as the principle of clinical practice in the United States and Europe (4). SBME is an educational tool that is located between "See one" and "Do one". SBME has been proposed as a method to bridge the educational gap between them. The main objective of SBME is focused on obtaining clinical skills belonging to the psychomotor domain. Furthermore, it can be used for not only education of the cognitive domain, such as knowledge, but also education of the affective domain, for example, communication training by the session

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with simulated patients.

Many clinical skills laboratories have been established in medical institutions around the world including Japan as facilities for SBME. There are various types of simulators and rooms that mimic clinical settings in clinical skills laboratories. In Japan, the need for clinical skills laboratories is increasing for reforming undergraduate medical education, represented by Objective Structured Clinical Examination (OSCE) and clinical clerkship, and continuing professional development in postgraduate medical education. In this paper, we present an overview of SBME in clinical skills laboratories and discuss its effectiveness and problems.

EDUCATIONAL RESOURCES FOR SBME (TABLE 1)

Educational resources for simulations include simple plastic models for partial task training, mannequin-type simulators including dummy type and high-fidelity type, screen-based virtual-reality simulators, live or inert animals including isolated organs and human cadavers for surgical skill training, and simulated or standardized patients.

Table 1. Educational resources for simulation-based medical education

1. Plastic model for partial task training
2. Mannequin-type simulators
1) Dummy type
2) High-fidelity type
3. Screen-based virtual-reality simulators
4. Live or inert animals including isolated organs
5. Human cadavers for surgical skill training
6. Simulated or standardized patients

Plastic model for partial task training

Partial task trainers that are not controlled by computer have been mainly used for training in basic clinical skills. Partial task trainers include training models for diagnostic procedures with shame for patients, such as examination of the rectum, breast or vagina, and noninvasive or invasive clinical procedures, such as suture and ligation of skin, inserting a catheter into the stomach and bladder, catheterization into a peripheral or central vein, and lumbar puncture (Figure 1A, 1B). They are often believed to be only for personal task training. However, they can also be utilized for training in teamwork or communication with patients by using them

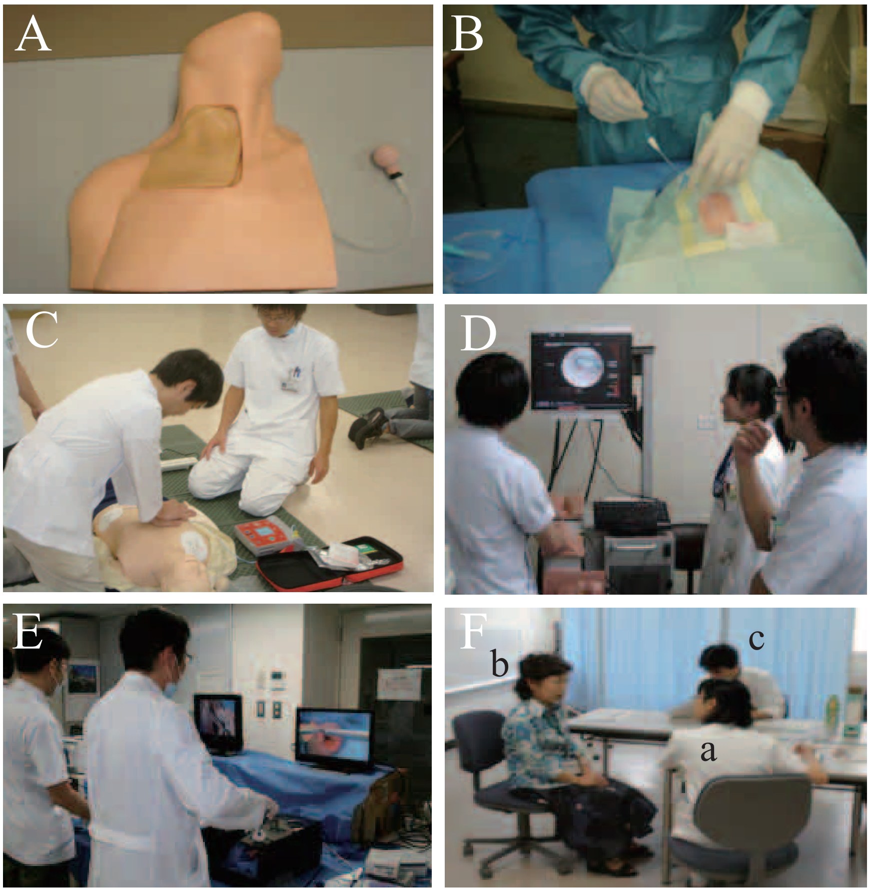

Figure. 1. Educational resources for simulation-based medical education.
A. Central venous catheterization trainer (Avice, Tokyo, Japan).
B : Task training of central venous catheterization using a trainer.
C. Simulation training in basic life support using AED Ressusi Anni training system (Laerdal, Norway).
D. Simulation training in bronchoscopy using a virtual-reality simulator “Endoscopy AccuTouch® System” (CAE Healthcare, Montreal, Canada).
E. Simulation training in laparoscopic skills and procedures using an isolated pig kidney and training box (B.Braun AESCULAP. Tokyo, Japan).
F. Training of medical interview by the session with a simulated patient. Medical students (a) can practice and improve communication skills by feedback provided from simulated patient (b) and teacher (c).

in a simulated clinical situation such as an emergency or examination room (5).

Mannequin-type simulators

The first mannequin-type simulator was developed in the 1950's to teach skills for resuscitation. Recently, many types of mannequin, such as Ressusi Anni (Laerdal, Norway), are used for training in basic life support (BLS) and advanced life support (ALS) such as endotracheal intubation and cardiac defibrillation (Figure 1C). Today, high-fidelity mannequin simulators controlled by a computer system are capable of presenting physical status such as blood pressure, heart rate, breath, heart and respiratory sounds, voice, pupil's diameter and movement of upper limbs. They can display changes in vital signs and parameters of cardiorespiratory function and respiratory gas exchange in response to physiological or pharmacological stimulation as in real patients. High-fidelity mannequin simulators have been mainly used for anesthesiologist training or education of pharmacology and physiology (6). Other types of mannequin simulators controlled by a computer system have been developed for training in diagnostic auscultation of normal and abnormal heart sounds or respiratory sounds or for physical assessment at the bedside such as reflex of pupils, blood pressure, arterial pulse, heart, respiratory and bowel sounds. Progress in the development of high-fidelity mannequin simulators has provided the opportunity to not only practice personal tasks but also perform team-based training in a full-environment simulation based on a clinical scenario (7).

Screen-based virtual-reality simulators

Advanced hardware and software technologies that are controlled by a computer can offer learners the more realistic training environment. First, a personal computer in which software for medical education presented is installed present medical information and questions on the screen, providing a one-way or interactive learning tool. The equipment is useful for gain problem-solving knowledge such as abilities for clinical reasoning or decision making, as well as recall or interpretation level of medical knowledge. Screen-type simulators, which are commonly used for self-learning, play a central role in both basic medicine such as anatomy and clinical medicine such as medical interviews or differential diagnosis.

Advances in computer technology have made it possible to output interactive information with visual and touch sense for training noninvasive and invasive procedures (8). Recently, simulators that can show computer-controlled ultrasound images of organs have also been developed for training in trans-thoracic or trans-esophageal echocardiography and abdominal echography. Furthermore, more advanced virtual-reality simulators have been used for training in invasive or surgical technique such as cerebral or cardiovascular angiography and intervention, bronchoscopy or gastrointestinal endoscopy, laparoscopic surgery of gastroenterology, urology or gynecology, otolaryngologic surgery, orthopedic surgery and robotic surgery using a da Vinci system (Figure 1D). Trainees can practice these procedures feeling visual and touch sense like a real setting as well as correct anatomic and physiologic responses during the procedures by using virtual-reality simulators. In addition to feedback from instructors to trainee after the trainings, the equipment itself provides performance evaluation and debriefing for trainees after the procedure. These functions of virtual-reality simulators are highly effective for evaluating and improving procedure levels of trainees. Iwata *et al.* demonstrated that LapVR (Immersion Medical, San Jose, CA, USA) has construct validity to discriminate between novice and experienced laparoscopic surgeons (9). Patel *et al.* reported that a learning curve of a carotid angiogram with improved performance was demonstrated on the Vascular Interventional System Trainer (VIST) VR simulator (Mentice AB, Gothenburg, Sweden) (10).

Thus, virtual-reality simulators are usually used to train residents or specialists in postgraduate and continuing medical education. However, they can provide opportunities to study early clinical exposure or integration of basic medicine and clinical medicine for medical students of lower grades. Simulation training using virtual-reality simulators will be highly effective for obtaining an anatomical, physiological and pharmacological understanding that is required to perform a clinical technique. Morgan *et al.* demonstrated that undergraduate education using high-fidelity simulation is a valuable learning experience and bridges the gap between theory and practice. New types of virtual-reality simulators for training in various invasive or surgical techniques will be developed in the future (11).

Live or inert animals including isolated organs

Isolated animal organs have been used for training in surgical procedures such as bowel anastomosis, coronary bypass or prosthetic valve replacement.

By using a box-type simulator, they can also be used for training in laparoscopic techniques (Figure 1E). Surgical training using live animals is very practical and is used for training in gastroenterologic surgery, cardiovascular surgery and catheter coronary intervention (8). The training requires the management of animal anesthesia and operating rooms for animal surgery. Therefore, the running cost for live animal training is very high. In addition, live animal training must be approved by an animal committee, as in the case of animal experiments, from the point of view of animal welfare.

Human cadavers for surgical skill training

There is an increasing need for surgical skill training that does not involve patient. Cadavers provide a realistic model for training in surgical skills (8). Cadavers have been widely used in postgraduate surgical training in the US. Anastakis *et al.* showed by using randomized controlled trials that a cadaver-trained group showed better performance in 6 surgical tasks than did a standard training group in which a manual was used for learning though it was not stated whether these differences were statistically significant (11). Evidence for the effectiveness of cadaveric surgical training is currently limited because there has been little research to clarify whether such training improves the performance of surgical trainees compared with other training methods. However, Gilbody *et al.* reported in their review article that both trainees and assessors hold cadaveric surgical training in high regard and feel that it helps to improve operative skills (12).

Simulated or standardized patients

A simulated patient or standardized patient (SP) is an individual who is trained to act as a real patient in order to simulate symptoms or clinical problems including mental status, living situation and physical status. SPs have been successfully used in medical education to teach students about medical interviews for taking a history or obtaining informed consent and in some cases basic physical examinations such as auscultation and palpation (13, 14). Medical students can practice and improve their clinical skills by sessions with SPs and by feedback provided from teachers and SPs before encounter with real patients (Figure 1F). The feedback from SPs to medical students in medical interview should be focused on patient's emotion in response to interview, which is often difficult to be taught and evaluated by only teachers. SPs can provide various cases that are needed at the time when they are needed. SPs are also used for testing clinical skills of students, such as an Objective Structured Clinical Examination. However, there are several limitations for use of SPs in medical education. First, the recruitment and training of SPs for standardization needs a long time and effort of the faculty, especially if civilians become SPs as volunteers. Employment of actors for SPs is excellent in terms of standardization but usually expensive. In addition, SPs cannot simulate physical signs such as heart murmurs or breath sounds.

BENEFITS OF SBME

Simulation training is based on active and adult learning theories. Dale *et al.* demonstrated that the learning curve of active learning is higher than that of passive learning and that learners can generally remember 90% of what they do by active learning (Dale's cone of experience) (15). Bryan *et al* reported the following five principles in medical education : 1) Adult learners need to know why they are learning., 2) Adult learners are motivated by the need to solve problems., 3) Previous experiences of adult learners must be respected and built upon., 4) The educational approach should match the diversity and background of adult learners., and 5) Adults need to be involved actively in the process (16). SBME is also superior to the traditional style of medical education from the viewpoint of the adult learning principles.

The benefit of SBME is that simulation training offers both learners and patients a safe environment for practice and error (3, 5). A public magazine of University of Texas Houston Medical School introduced the message "No patients were harmed in the making of this physician" by Darla Brown as a slogan of a new skills laboratory (17). Medical learners are allowed to fail a procedure and make mistakes, and they can try a procedure repeatedly until they master it. Since various types of cases or clinical situations can be freely set for simulation training, learners can experience important or rare cases that should be encountered from the viewpoint of medical safety.

It should also be noted that medical learners can obtain not only technical skills but also non-technical skills by SBME. Technical skill is defined by as an individual skill that is required for the accomplishment of a specific task such as a diagnostic or therapeutic procedure. However, since clinical working is usually team-based and requires decisions for indication of procedures, if learners have acquired only technical skills, they cannot properly and safely use these skills in a clinical setting. Non-technical skills has been reported to consist of leadership, team work, communication, situation awareness, decision-making, and awareness of personal limitations such as a management of stress and fatigue, which are also important for medical safety (18). Full-environment simulation, for example, an emergency, is designed to reproduce realistic settings based on a clinical scenario using high-fidelity mannequin simulators, SPs, and replicated equipment and supplies (Figure 2A). Full-environment simulation is an ideal environment to learn non-technical skills (7, 19). Continuous creation of new scenarios based on clinical settings such as incident cases in hospitals is necessary for effective utilization of full-environment simulation.

In addition, SBME can provide a learning cycle of debriefing and feedback for learners as well as assessment and certification for procedures and competency (20, 21) (Figure 2B). Savoidelli *et al.* reported that simulation without debriefing resulted in no improvement in non-technical skills and that either oral or videotape-assisted feedback resulted in significant improvement (22). Both training and evaluation based on a common protocol throughout medical institutions or health care professions, for example, BLS or ICLS, can contribute to maintenance and improvement of medical level (23, 24). Recently, for a technique with a high rate of fatal complications, such as central venous catheterization, trainees are required to attend a training program and pass a skill examination (25). In undergraduate education of Japan as well as other countries, medical and dentistry schools in 2005 and pharmacy schools in 2009 started to conduct OSCEs in order to ensure ability of clinical skills before starting clinical practice in a hospital.

Figure 2. Full-environment simulation
A : Simulation training in crew resource management skills. Emergent situation in bedside is designed to the realistic setting based on a clinical scenario using a mannequin simulator and replicated equipment and supplies.
B : Videotape-assisted feedback after the performance. Learners can obtain not only technical skills but also non-technical skills such as team work.

SBME is also effective for integration of clinical medicine and basic medicine (3). For example, by simulation training using a virtual-reality simulator, learners can obtain knowledge of anatomy and physiology in relation to clinical skills. In addition, early clinical exposure for undergraduate medical students using virtual-reality simulators will enhance their motivation for learning basic medicine.

Taken together, SBME is expected to improve educational and clinical outcomes in comparison with no intervention. Cook *et al.* reported that technology-enhanced simulation training in health profession education is consistently associated with large effects for outcomes of knowledge, skills, and behaviors and moderate effects for patient-related outcomes (26).

PROBLEMS AND LIMITATIONS OF SBME

Simulation is not equal to reality. Even if learners can perform procedures in simulation, they cannot always do them as a clinical job. In addition, evaluation by simulation cannot completely predict performance in a clinical setting. Miller *et al.* proposed four stages, "Knows", "Knows How", "Shows How" and "Does", as levels of authenticity of clinical evaluation (27). Evaluation by simulation, such as OSCE, is focused on assessment of clinical skills that can be simulated, which is level of "Shows How", not level of "Does". It is difficult to evaluate clinical performance such as "Does" level that is related to work performance and attitudes in the real clinical field. Thus, passing the examination of clinical procedure and competency using simulation is not the ultimate goal for medical students (1). Medical teachers should clearly show learning objective in SBME to learners with consideration of difference between clinical setting and simulation.

In addition, many faculties often make the mistake that only setting-up of the simulator and free self-practice are effective for clinical training. Self-practice is effective for experts, but it is difficult for beginners to master a technique only by self-training because they cannot imagine a realistic situation. Without understanding the learning objective and relationship with clinical setting, learners might learn the wrong procedure by self-training using simulators (20). Also, it is a common situation that expensive facilities and equipment are not fully utilized for education because SBME takes much time and effort. To solve the above problems, full-time faculties and instructors who are familiar with simulation training and simulators are needed in clinical skills laboratories. The faculty in a skills laboratory can create educational programs and evaluation methods for simulation training in collaboration with clinical specialists. Instructors in a skills laboratory can prepare and maintain simulators according to the education program in collaboration with faculties and clinical specialists. Unfortunately, in Japan, facility of a clinical skills laboratory has been given priority, not human resources. However, faculties and instructors as professionals of SBME should also be assigned to a clinical skills laboratory.

COMPONENTS REQUIRED FOR SBME IN A CLINICAL SKILLS LABORATORY (TABLE 2)

Training area and lecture room

Both a training area and a lecture room are needed for a clinical skills laboratory because SBME consists of a pre-lecture, task or situation training, and debriefing by the trainee and feedback by the leader after the procedure (21, 22). To perform team-based training in a situation such as an emergency, the training space should be shielded from the surrounding so that learners can focus on performance in simulation training.

Simulators and equipment required in a clinical skills laboratory

Handmade equipment or simpler plastic simulators can be used for training in basic procedures. High-fidelity simulators controlled by a computer are needed for learning advanced procedures. In addition, recording devices or a Web camera system is useful for debriefing and feedback after performance (22).

To perform simulation training using isolated animal organs, hand-washing equipment, a washing machine for surgical instruments and a room ventilation system are required, and the material of the floor should be easy to clean if contaminated with blood and body fluids. For dealing with live animals, a clinical skills laboratory must have functions as an animal center. For dealing with human cadavers, functions for an autopsy room are necessary. However, it is difficult to construct a clinical skills laboratory in which all of these functions are integrated in one place.

Faculty, instructors, and administrative staff

Full-time faculty, instructors and administrative staff are essential for management of SBME in a clinical skills laboratory because a variety of works, such as program development, maintenance of equipment, recruitment and training of SPs, coordination of leaders and learners, booking services, setting preparation and clean up, are required for SBME (3, 13, 21).

Educational content

Educational content for trainees and teachers should be made by collaboration with educational staff of a clinical skills laboratory and specialists in each department of a medical school or hospital. The content must cover learning objectives, methods for practice including instruction manual of equipment and supplies that are needed for each training program, and evaluation system (24).

Budget

Expenses for purchase of equipment and supplies including repair costs should always be budgeted to maintain a clinical skills laboratory.

Table 2. Components required for simulation-based medical education in a clinical skills laboratory

1. Training area and lecture room
2. Simulators and equipment for simulation training
3. Full-time faculty, instructors, and administrative staff
4. Educational content
5. Budget

FUTURE PERSPECTIVES OF CLINICAL SKILLS LABORATORIES

Medical procedures and competency required for health care are constantly changing. A clinical skills laboratory is always evolving through the continuing collaboration with the clinical fields and settings. In addition, a clinical skills laboratory should become a facility to learn not only technical skills but also non-technical skills both in undergraduate and postgraduate education. It is expected that a clinical skills laboratory will become an integrated medical education center to achieve continuing professional development, integrated learning of basic and clinical medicine, and citizens' participation and cooperation in medical education, such as SPs.

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