Original Article

The role of simulation-based training in healthcare-associated infection (HAI) prevention

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Abstract

Objectives: To perform a review of the literature on the role of simulation-based training (SBT) in healthcare-associated infection (HAI) prevention and to highlight the importance of SBT as an educational tool in infection prevention.

Methods: We reviewed English language publications from PubMed to select original articles that utilized SBT as the primary mode of education for infection prevention efforts in acute-care hospitals.

Results: Overall, 27 publications utilized SBT as primary mode of education for HAI prevention in acute-care hospitals. Training included the following: hand hygiene in 3 studies (11%), standard precaution in 1 study (4%), disaster preparedness in 4 studies (15%), central-line–associated blood stream infection (CLABSI) prevention in 14 studies (52%), catheter-associated urinary tract infection (CAUTI) prevention in 2 studies (7%), surgical site infection prevention in 2 studies (7%), and ventilatory associated pneumonia prevention in 1 study (4%). SBT improved learner’s sense of competence and confidence, increased knowledge and compliance in infection prevention measures, decreased HAI rates, and reduced healthcare costs.

Conclusion: SBT can function as a teaching tool in day-to-day infection prevention efforts as well as in disaster preparedness. SBT is underutilized in infection prevention but can serve as a crucial educational tool.

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Simulation-based training (SBT) utilizes artificial representation of real-world processes to allow for learning with approximation of practice. It is an educational technique, not a technology, that facilitates learning through immersion, reflection, feedback, and practice in a controlled environment with minimal risk to patients. The Institute of Medicine’s “To err is human” highlighted medical errors and their consequences, emphasizing the need for patient safety through the design of a safer health system.1 Common root causes of preventable medical errors were communication breakdowns, faulty systems of care, lack of standardization in practice, and insufficient knowledge.1,2 By allowing practice in a realistic and interactive setting with minimal risk to patients, SBT can help minimize medical errors by acquiring clinical skills through practice, improving communication skills, defining team structures, and refining protocols.3,4

According to the Centers for Disease Control and Prevention (CDC), 1 in 31 hospitalized patients developed at least 1 healthcare-associated infection (HAI) in 2018.5 Most HAIs are related to invasive devices or procedures: catheter-associated urinary tract infection (CAUTI), central-line–associated bloodstream infection (CLABSI), surgical site infection (SSI), and ventilator-associated pneumonia (VAP). Evidence-based prevention strategies can reduce HAIs but are insufficiently implemented. Education is a key component of infection prevention efforts and traditional methods of teaching include lectures, videos, and fact sheets with some opportunities for hands-on practice.6 With growing recognition of SBT in healthcare education, SBT can also be used as an important adjunct to traditional teaching and assessment methods in infection prevention. In this study, we performed a focused literature review on the use of SBT in HAI prevention and highlight the importance of SBT as an educational tool in infection prevention.

Methods

We reviewed English language publications from PubMed using combinations of keywords “simulation,” “infection prevention,” “healthcare-acquired infections,” and “disaster preparedness.” From this, we selected original articles that utilized SBT as the primary mode of education for infection prevention efforts in acute care hospitals. We defined simulation as the mode of training that utilized imitation or representation of one act or system by
| Infection Prevention Measure | Trainer | Learner | Training | Outcome | Reference |
|------------------------------|---------|---------|----------|---------|-----------|
| **General**                  |         |         |          |         |           |
| Hand Hygiene                 | Critical care physicians, hygienist nurses | Second- and third-year medical students | Application of fluorescent alcohol-based hand rub under UV-C | Improvement in complete application of alcohol hand rub | Dray et al⁷ |
| Does not specify             | Residents, nurses, nursing assistants | | | | Ghazali et al⁸ |
| Chief nurses                 | Healthcare workers | | | | Lehotsky et al⁹ |
| Standard precautions         | Does not specify | Nursing students | Donning and doffing of PPE; performing nursing practices on standardized patients or peer role play | Increase in knowledge, awareness of standard precaution and infection control performance | Kim et al¹⁰ |
| Disaster/outbreak preparedness |          |         |          |         |           |
| PPE                          | Educator, director of infection control | Nurses, physicians, respiratory therapists | Cardiac arrest scenario in patient with SARS | Identified errors in infection control measures | Abrahanson et al¹¹ |
| Does not specify             | Physician, nurses, technicians | | | Improvement in post-intervention score | Abualenain et al¹² |
| Physicians                   | Multidisciplinary healthcare workers | Application of PPE; practice of various procedures on patient with Ebola | | Increasing sense of security, predisposition, and confidence | Carvalho et al¹³ |
| Hand Hygiene, PPE            | Nursing champions, simulation team | Nurses, physicians, respiratory therapists | Tracking of surface contamination using UV-C luminescent spray during MRSA outbreak | No new episodes of colonization or infection | Gibbs et al¹⁴ |
| **CAUTI**                    |         |         |          |         |           |
| Urinary catheter Insertion   | Nurse educator | Medical students | Aseptic technique during insertion of urinary catheter | Lowest CAUTI rate among medical students | Barnum et al¹⁵ |
| Simulation fellow, senior general surgery residents | Second year medical students | Simulated germs for hand washing, maintenance of aseptic technique during urinary catheterization | Maintained better sterility and had higher technical proficiency score during urinary catheterization | Mittal et al¹⁶ |
| **CLABSI**                   |         |         |          |         |           |
| Central venous catheter insertion | Vascular access nurse or physician | Attending physicians, residents | Hands-on practice of insertion of central venous catheter | Decrease in CLABSI rate | Allen et al¹⁷ |
| Critical care fellows, attending physician | Residents | | | | Burden et al¹⁸ |
| Neonotologists               | Attending physicians, residents | | | | Steiner et al¹⁹ |
| Does not specify             | Internal medicine emergency medicine residents | | | Fewer CLABSI after intervention | Barsuk et al²⁰ |
| Does not specify             | Residents in anesthesia | | | Increased cost savings | Cohën et al²¹ |
| Emergency medicine and critical care attendings | Emergency medicine residents | | | Improvement in compliance on catheter insertion checklist | Cartier et al²² |
| Does not specify             | Second- and third-year medical residents | | | Improvement in sterile technique performance scores | Hoskote et al²³ |
| Anesthesiologist, Pulmonary/critical care physician | Interns, residents, nurse anesthetists | | | Improvement in sterile technique score | Khouli et al²⁴ |
| Infection control practitioners, hospital epidemiologist | Medical students, interns | | | Increase in Likert-scale ratings on aseptic technique | Latif et al²⁵ |
|                             |         |         |          |         | Increased use of full-size sterile drapes, decrease in rate of catheter-related infection, cost savings | Sherertz et al²⁶ |

(Continued)
another. The references for each relevant paper were additionally reviewed.

**Results**

We retrieved 138 English language publications from PubMed, of which 111 were excluded because simulation was not utilized for infection prevention education in acute-care hospitals. We then performed a detailed review of 27 publications that utilized simulation as primary mode of education for HAI prevention in acute care hospitals (Table 1).

Trainers included the following: physicians in 8 studies (30%), nurses in 7 studies (26%), infection preventionists in 3 studies (11%), and simulation center staff in 2 studies (7%). Learners included the following: residents in 10 studies (37%), nurses in 9 studies (33%), medical students in 7 studies (26%), and physicians in 5 studies (19%). Nursing students, technicians, and respiratory therapists made up a minority of learner types.

Furthermore, 3 studies focused on SBT for hand hygiene using the application of fluorescent alcohol-based hand rub under ultraviolet C light with all studies demonstrating improvement in complete application of alcohol hand rub7–9. In addition, 3 studies used SBT to recreate clinical scenarios pertaining to suspected Ebola and severe acute respiratory syndrome (SARS) cases11–13 with identification of errors in infection control measures11 and improvement in both postintervention score12 and learners’ sense of confidence.13 Also, 13 studies utilized SBT for CLABSI prevention, and 10 studies focused on aseptic technique pertaining to central venous catheter (CVC) insertion17–26 with improvement in skin preparation20–27 and CLABSI rate.17–19 We identified 4 studies that focused on CVC maintenance27–30 with improvements in compliance in bundle usage28 and decrease in CLABSI rates.30–32 We identified 2 studies that utilized SBT for Foley catheter insertion15,16 with improvement in sterile technique16 and decreased CAUTI rates.15 Finally, 2 studies focused on SSI prevention with surgical hand washing technique and preparation of the surgical field.31,32

**Discussion**

SBT is underutilized in infection prevention, but it can serve as an important adjunct to traditional educational tools. It can target learners ranging from students to nurses, physicians, and other ancillary staff. SBT programs in infection prevention can vary widely from disaster preparedness of high acuity to low-frequency clinical scenarios to day-to-day infection prevention measures. SBT can improve learner’s sense of competence and confidence,11–13 increase patient safety through improved compliance in infection prevention measures16,22–26,28,32 and increase in knowledge29,33 improve HAIs rates15,17–20 and reduce healthcare costs.21 Simulation modalities can offer a realistic imitation under test conditions. Different simulation modalities and environments are classified as low fidelity, medium fidelity, and high fidelity, with the highest fidelity modality or environment most accurately representing the real environment. Various simulation modalities have been integrated into infection prevention efforts, each with its own advantages and disadvantages (Table 2). Task trainers (low-fidelity simulators) have been predominantly utilized to help learners practice specific psychomotor skills such as aseptic technique in the insertion of central venous catheters17–26 and indwelling urinary catheters.15,16 Standardized patients, which are real people portraying the role of patients, have been utilized to practice standard precautions and interpersonal skills.10 Virtual reality (high fidelity) has also taught healthcare personnel to safely don and doff PPE, as virtual reality help learners to gain knowledge on the proper process of a procedure in a scalable fashion. In prior outbreaks, mid- and high-fidelity manikins, which are full-body manikins, were utilized to mimic patient encounters with rare communicable diseases like Ebola and SARS, aiding in the identification of errors in infection control measures.11–13

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**Table 1. (Continued)**

| Measure | Trainer | Learner | Training | Outcome | Reference |
|---------|---------|---------|----------|---------|-----------|
| Central venous catheter maintenance | Nurses | Student nurses | Hands-on practice of maintenance of central venous catheter | No difference in posttest score for lecture-based vs simulation based | Aloush et al27 |
| Investigator | Nurses | | | Improvement in compliance bundle score | Hebbard et al28 |
| Nurses | Parents of children with cancer | | | Difference in knowledge score pre-and post-test | Rosenberg et al29 |
| Clinical educators | Nurses | | | Decrease in CLABSI rate | Scholtz et al30 |

**SSI**

| Surgical hand disinfection, preparation of surgical field | Surgical nurse, infection preventionist | Medical students, operating room technician trainees | Hands-on practice of operating room entry procedure, surgical hand disinfection, skin preparation | High satisfaction among learners | Breckwoldt et al31 |

| Surgical hand rub technique | Does not specify | Medical students | Fluorescent solution, hands placed under UV-C light | Improvement in compliance and efficacy of surgical hand rub | Vanylos et al32 |

**VAP**

| Oral care | Does not specify | Critical care nurses | Hands-on practice of ventilator bundle related to oral care practices | Increase in knowledge score | Jansson et al33 |

Note. UV-C, ultraviolet C; PPE, personal protective equipment; SARS, severe-acute respiratory syndrome; MRSA, methicillin-resistant Staphylococcus aureus; CAUTI, catheter-associated urinary tract infection; CLABSI, central-line-associated bloodstream infection; SSI, surgical site infection; VAP, ventilator acquired pneumonia.
These simulators can replicate a patient’s physiology modeling through the programming of vitals, breathing, or other patient presentations. They enable a team to work collectively to deliver care (eg, intensive care unit setting with in full hazmat suit) while performing a certain set of procedural tasks (eg, intubation) in a physical environment. This enables teams to practice not only individual skills, but also critical teamwork and communication skills.

Ultimately, simulation experts match the learning objectives to the most effective modality. For effective learning, SBT should be offered as part of a curriculum to supplement and complement other educational methods with clearly defined objectives and benchmarks for learners to achieve. The program should provide individualized and team learning and should allow for repetitive practice with clinical variation such as varying levels of difficulty if feasible. Expert trained facilitators should provide feedback during or after a learning experience through rapid cycle deliberate practice to develop procedural competence and immediate constructive debriefing, based on learning objectives.

SBT in infection prevention has predominantly focused on central venous catheter insertion and maintenance with various studies reporting significant improvement in compliance with sterile techniques and decrease in CLABSI rate. However, despite its proven effectiveness in CLABSI prevention, SBT has remained underutilized in other realms of infection prevention. Through repetitive and deliberate practice to develop procedural competence and immediate constructive debriefing by an expertly trained debriefer, SBT can allow for standardization of routine infection prevention measures and proper implementation of evidence-based prevention strategies to reduce HAI rates. In addition, SBT can play a role in understanding and optimizing workflows and bottlenecks in high-acuity, low-frequency encounters for disaster preparedness. Centralized SBT that promotes competency-based education can yield a large return on investment by reducing overall healthcare costs through improved quality of care, reduced HAI penalties, mitigation of readmissions, and decreased lengths of stay.

In summary, SBT is underutilized in infection prevention but can serve as a crucial educational tool. The coronavirus disease 2019 (COVID-19) pandemic has exposed our inadequacy in infection prevention teaching and argues for continued innovation.

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