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NURSE EDUCATION REPORT

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Evaluation of computer-based training and high-fidelity simulation to improve early recognition of sepsis on the adult general ward

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Abstract

This quality improvement project involved developing, implementing and evaluating an educational intervention using computer-based training (CBT) and high-fidelity simulation (HFS) to increase knowledge, confidence and compliance of nurses identifying sepsis. A one-group pretest-posttest design was used. Participants were nurses on a general ward of an academic medical centre. Study variables were measured over three timepoints: 2 weeks before, immediately after and 90 days after implementation. Data were collected from January 30, 2018, to June 22, 2018. SQUIRE 2.0 checklist for quality improvement reporting used. Improvements in knowledge of sepsis ($F_{(2,83)} = 18.14$, $p < 0.001$, $\eta_p^2 = 0.30$) and confidence in early recognition of sepsis ($F_{(2,83)} = 13.67$, $p < 0.001$, $\eta_p^2 = 0.25$) were found. Additionally, compliance with sepsis screening improved between the preimplementation and postimplementation period ($\chi^2 = 13.633$, df = 1, $p < 0.001$). Overall, the nurses evaluated their experience with the CBT and HFS as strongly positive. When designing and implementing an educational intervention on sepsis, a process for follow-up which provides reinforcement should be considered to retain nurses' knowledge.

KEYWORDS
education, high-fidelity simulation, knowledge, nurses, sepsis, simulation training

1 | INTRODUCTION

Worldwide, there were an estimated 11 million sepsis-related deaths in 2017, accounting for 19.7% of all globally reported deaths (Rudd et al., 2020). In US hospitals, sepsis is a leading cause of immediate death (Rhee et al., 2019). Likewise, it has been found to be a contributing factor in every two to three hospital deaths, depending on the criteria used for sepsis identification (Liu et al., 2014; Makic & Bridges, 2018). In the United States, it is also a leading reason for all-cause readmissions and the most expensive hospital condition (Fingar et al., 2017; Torio & Moore, 2016). Traditionally, providers and nurses in hospitals have focused on sepsis surveillance in emergency departments and intensive care units. Only in the last decade has focus shifted to early recognition on the general wards, where there is higher mortality compared to sepsis identified in emergency departments, likely due to the delay in sepsis recognition and treatment (Levy et al., 2015; Schorr et al., 2016). Since early interventions are critical in decreasing sepsis mortality, early recognition is of paramount importance (Rhodes et al., 2017).

At a large academic medical centre in Chicago, Illinois, sepsis screening had been established for less than a year and was completed for all patients by bedside nurses during every shift on all adult, general wards. The nurses assess patients for systemic inflammatory response syndrome (SIRS) in combination with new or worsening infection to identify a "positive" screen. Previously, three members of this quality improvement (QI) project team were also part of the implementation team for the medical centre's nurse-driven sepsis screening process. They discovered during that time that many nurses lacked general knowledge of sepsis and struggled with determining whether new or worsening infection was present. These findings align with studies that have shown nursing knowledge on SIRS and sepsis is often deficient (Jeffery et al., 2014; Robson et al., 2007). The nurses also expressed a lack of knowledge and confidence in taking the appropriate actions once sepsis was suspected (i.e. drawing appropriate blood work or checking for broad spectrum antibiotics). Furthermore, the implementation team found many sepsis screens to be incomplete. At the time, there was no organizational curriculum designed to address these gaps. Therefore, the purpose of this QI pilot study was to develop, implement and evaluate an educational intervention composed of a computer-based training (CBT) module and high-fidelity simulation (HFS) to increase nurses' knowledge of sepsis, confidence in early recognition of sepsis and compliance with sepsis screening.

1.1 | Conceptual framework

HFS is an experiential method of teaching and has demonstrated efficacy in QI and research studies focusing on sepsis education, especially in conjunction with didactic methods (i.e. lectures) (Delaney et al., 2015; Schubert, 2012). Experiential learning is aligned with the concept of andragogy that asserts adults learn better in active learning situations because those are more meaningful and relevant to their lived experiences (Curran, 2014). In two meta-analyses looking broadly at nursing simulation education, the overall efficacy has been associated with medium-to-large effect sizes when compared to traditional modes of education or no intervention at all (Kim et al., 2016; Shin et al., 2015). When combining didactic methods with simulation, researchers found that physicians who received didactic preparation before a sepsis simulation demonstrated a statistically significant improvement in their test results after the simulation versus those who received didactic or simulation-only teaching (Li et al., 2012).

2 | METHODS

2.1 | Study design

A one-group pretest-posttest design was used to measure changes in nursing knowledge of sepsis, confidence in early recognition of sepsis, and compliance with sepsis screening. There were three timepoints of measurement: 2 weeks prior to implementation (Time 1), immediately after implementation (Time 2) and 90 days after implementation (Time 3). The Standards for Quality Improvement Reporting Excellence (SQUIRE 2.0) checklist (Ogrinc et al., 2016) was used (Appendix S1).

2.2 | Participants and setting

The convenience sample consisted of 47 nurses working on a 40-bed general medical-surgical ward in a large academic medical center in Chicago, Illinois. The inclusion criteria were: (1) registered nurses (RN) whose home ward was on the target medical-surgical ward, and (2) RNs who had received sepsis education using a computer-based training (CBT) module and high-fidelity simulation (HFS). The exclusion criteria were: (1) RNs whose home ward was not on the target medical-surgical ward (i.e. float nurses and agency nurses), and (2) RNs who did not want to participate. Two conference rooms on the ward were used for the HFS. The HFS facilitators consisted of a telemetry ward Nurse Manager (herein, "QI leader"), the Rapid Response Team (RRT) Nurse Manager (herein, "RRT consultant"), and a Simulation Technical Specialist (herein, "STS"), who is the lead operator of the organization's simulation technology.

2.3 | Procedure

Communication to staff about the project started 2 months prior to the pretest survey and included emails and briefings by the QI leader at huddles and staff meetings on both day and night shifts. The nurses during this time also assisted in identifying optimal times for HFS sessions to occur. The general cadence for implementation was sequential without overlap: 2 weeks for pretest surveys, 2 weeks for CBT completion, 2 weeks to attend one 30-minute HFS session after which the first posttest survey was completed; and lastly, a second, 90-day posttest survey to assess any long-term changes in data.

Only nurses who completed the CBT were permitted to attend an HFS session. All surveys were anonymous and created using online survey software. Links to the surveys were accessible via email or via two mobile tablets provided at the time of the HFS. The nurses were instructed to take surveys alone and the first posttest survey was additionally proctored by the QI leader or RRT consultant to ensure individual results. Nurses who completed the CBT and HFS were awarded one nursing contact hour. Nurses who reported completing the 90-day posttest were entered in a raffle for one of seven, 25-dollar gift cards. Data were collected from January 30, 2018 to June 22, 2018.

2.3.1 | Computer-based training (CBT) module

The CBT module was developed using Microsoft PowerPoint and uploaded into the medical centre's electronic learning management

system. An expert in instructional design and technology reviewed the CBT module before being finalized. The contents of the final module are presented in Table 1.

2.3.2 | High-fidelity simulation (HFS)

The HFS used the International Nursing Association for Clinical Simulation and Learning (INACSL) "Standards of Best Practice: Simulation[SM]" as a guiding framework for the design, facilitation, and evaluation of the experience (INACSL Standards Committee, 2016). Through Plan-Do-Study-Action (PDSA) cycles, the QI leader created the simulation scenario, script and related documents by having multiple iterations reviewed and provided feedback by the RRT consultant, the STS, other members of the simulation lab team, a Clinical Nurse Specialist and two staff nurses, before being finalized. Lastly, the final documents were run through in a table-read and then tested in a simulation with a volunteer staff by the QI leader, RRT consultant and STS before final implementation approval. The main components (Table 1) included a prebrief, a simulation, debrief and an evaluation (first posttest survey). No session exceeded the 45-minute timeframe allotted to complete all components. The nurses performed the HFS in pairs or groups of three. Table 1 summarizes the content of the CBT and HFS educational intervention.

The QI leader and RRT consultant interchanged who performed the facilitator role (narrated and moved the simulation forward) and played the roles of other clinicians in the simulation. The STS played a standardized patient and controlled the vital signs monitor via remote control; he also used two mannequin arms from which blood could be drawn. Each QI team member had a script of the scenario. In addition, the facilitator followed a learning objectives checklist to ensure all major components of the education were delivered. The "playground" environment of the hospital's electronic health record (EHR) was utilized to produce simulated laboratory results and allowed participants to enter laboratory orders. The hospital call centre was involved in taking simulated rapid response calls. Lastly, the mannequin arms were utilized for demonstrating blood specimen collection for the venous blood gas lactate.

TABLE 1 Content of the intervention (CBT and HFS).

Category	Content
Computer-based training (CBT) module	Sepsis pathophysiology and identification
	Communication to providers
	Care interventions
	Hospital's existing sepsis protocol
	Blood specimen collection for a venous blood gas lactate (Video)
	Two case-study exercises
High-fidelity simulation (HFS)	Standardized patient with mannequin arms
	Prebrief (5 min): orientation to the environment and simulation components
	Simulation (20 min): assessment, identification, and interventions in a septic patient
	Debrief (5 min): review of participants' performances and key lessons

2.4 | Measurements

The QI leader created the survey to measure knowledge of sepsis and confidence in early recognition of sepsis based on a literature review and hospital procedures. The evaluation survey for the simulation used questions from the Simulation Design Scale (SDS) (student version) from the National League for Nursing (2019). Included with the SDS questions were two additional questions created by the QI leader to evaluate the CBT. An education specialist for the organization's simulation centre reviewed the evaluation questions for the HFS and CBT. All surveys achieved content validity through review by the QI leader's project committee and the hospital's nurse scientist. Through PDSA cycles, each survey went through multiple iterations after feedback was provided from the latter. In addition, two staff nurses from the QI leader's home unit assisted in providing feedback on survey question relevance, clarity and importance after reviewing the CBT.

2.4.1 | Knowledge of sepsis

Knowledge of sepsis was measured with the sepsis knowledge scale developed for this study. This scale consists of 12 items. Each item is recorded as "correct" or "not correct." The sum of correct questions was divided by the total number of questions, ranging from 0% to 100%.

2.4.2 | Confidence in early recognition of sepsis

Confidence in early recognition of sepsis was measured with the confidence scale developed for this study. This scale consists of five items. Each item is rated on a 4-point Likert scale, with "a" (not confident) to "d" (highly confident).

2.4.3 | Compliance with sepsis screening

Data on sepsis screening compliance were collected via an EHR report already established through the hospital's data analytics team.

Compliance was measured as the total number of sepsis screens completed in the EHR over the total number of screening opportunities. Each 12-hour shift had one opportunity to fill out a screen, and a screen was considered complete if it answered the questions pertaining to the presence of any SIRS indicators and whether the new or worsening infection was suspected.

2.4.4 | Evaluation of the CBT and HFS design and experience

The CBT and HFS design and experience was evaluated with seven items using a -point Likert scale (strongly agree/agree/disagree/strongly disagree) and one open-ended question.

2.5 | Data analysis

The data were analysed using the Statistical Package for the Social Sciences (SPSS), version 26.0. Descriptive statistics were used to obtain the percentage, frequency, means and standard deviation. The normality of the data was assessed and confirmed using the Shapiro–Wilk test. A one-way repeated-measure ANOVA with *post hoc Tukey's test* was conducted to assess the effect of the intervention on study variables. The *effect size partial eta squared* (η^2_p) was calculated. A result with a *p*-value of <0.05 is considered to be significant. The comments from one open-ended question about the participants' CBT and HFS experiences were *analysed* using content *analysis*.

2.6 | Ethical consideration

On December 2, 2017, this QI pilot project was formally evaluated using a QI checklist and determined not to be human subjects research by an internal review process at Duke University School of Nursing. All participants who volunteered to participate in this study were informed about the study aims, and their rights to refuse and assured confidentiality of the information they provided. The requirement for informed consent was waived because of anonymized and aggregated data.

3 | RESULTS

3.1 | Sample characteristics

A total of 36 staff nurses completed the pretest survey (78% total response rate), of whom 29 completed the full education (CBT and HFS) and immediate posttest survey (81% relative response rate); and 21 completed the 90-day posttest survey (72% relative response rate). No demographic information was collected.

3.2 | Effects of intervention

3.2.1 | Knowledge of sepsis

There was a statistically significant difference in the mean percentage scores for knowledge of sepsis between the three timepoints, $F_{(2,83)} = 18.14$, $p < 0.001$, $\eta_p^2 = 0.30$. Post hoc testing using Tukey's test revealed statistically significant differences between Time 1 and Time 2 ($p < 0.001$) but not between Time 1 and Time 3 ($p = 0.125$) (see Table 2).

3.2.2 | Confidence in early recognition of sepsis

There was a statistically significant difference in the mean scores of confidence in early recognition of sepsis between the three timepoints, $F_{(2,83)} = 13.67$, $p < 0.001$, $\eta_p^2 = 0.25$. Post hoc testing using Tukey's test revealed statistically significant differences between Time 1 and Time 2 ($p < 0.001$) and Time 1 and Time 3 ($p = 0.005$) (see Table 2).

3.2.3 | Compliance with sepsis screening

There was a statistically significant difference in the proportion of completed and not-completed sepsis screens for all staff nurses on the target unit when comparing the preimplementation period (90 days before CBT and HFS, 87.52% completion rate in 7181 screenings) with the postimplementation period (90 days after CBT and HFS, 89.48% completion rate in 7427 screenings), $\chi^2 = 13.63$, df = 1, $p < 0.001$ (see Table 2).

TABLE 2 Effects of CBT and HFS intervention on study outcomes.

Study variables	Time 1[a] (*n* = 36)	Time 2[b] (*n* = 29)	Time 3[c] (*n* = 21)	F/χ^2	Sig
Knowledge of sepsis M ± SD %	59.39 ± 12.17	81.30 ± 13.09	67.32 ± 19.72	18.14	<0.001 b > a
Confidence in sepsis early recognition M ± SD	3.02 ± 0.52	3.70 ± 0.45	3.48 ± 0.58	13.67	<0.001 b, c > a
Compliance with sepsis screening %	87.52		89.48	13.63	<0.001 c > a

Note: [a] - Time 1 = Pretest; [b] - Time 2 = Posttest; [c] - Time 3 = Follow up (90 days after intervention).
Abbreviations: CBT, computer-based training; HFS, high-fidelity simulation.

3.2.4 | Evaluation of the HFS and CBT design and experience

Participants evaluated the CBT and HFS experience at time 2. No participants disagreed or strongly disagreed with any of the evaluation statements. The post surveys were administered by one of the HFS facilitators immediately after the HFS via electronic tablets or mobile computer stations. The results are presented in Figure 1. The participants highly rated the five dimensions (information, support, problem solving, feedback/guided reflection and fidelity [realism]) of the simulation design. The highest rating was given to the dimensions of support and problem solving.

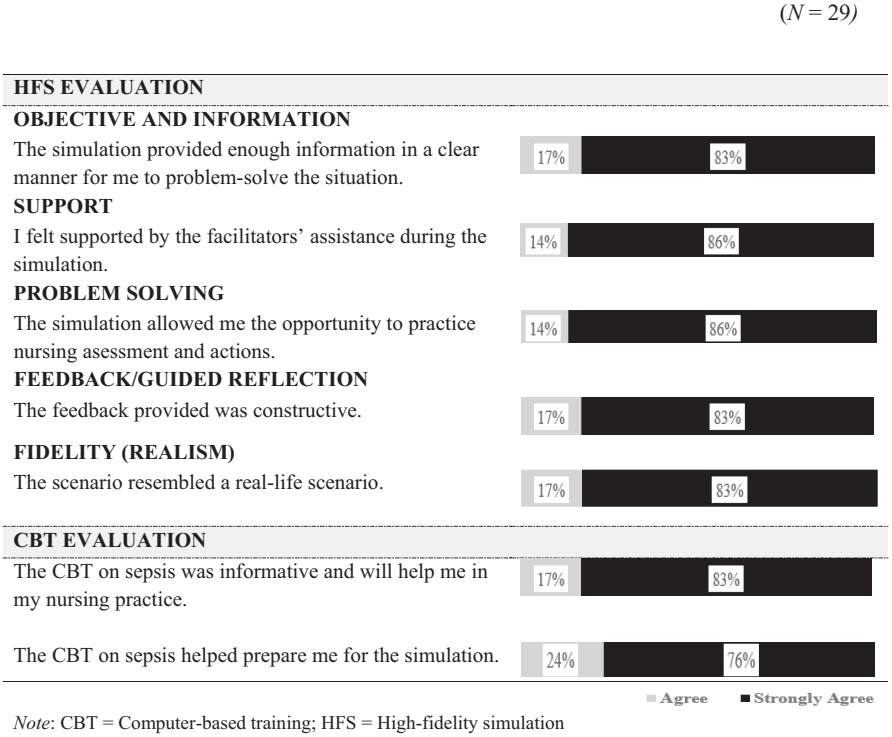
Open-ended feedback was organized by categories from the Simulation Design Scale (student version) with the addition of a "general experience" category (National League for Nursing, 2019). Eighteen of the 29 participants responded to the open-ended question, which asked for general feedback related to the CBT and HFS (62% response rate). Most of the comments made were short, nonspecific and largely addressed the general experience, which all participants who responded rated as positive. Other comments aligned with the following areas (respondents [%]): adequacy of information (39%), feeling supported (11%), problem-solving (17%) and fidelity (18%).

4 | DISCUSSION

This study aimed to develop, implement and evaluate an educational intervention composed of a CBT module and HFS to increase nurses' knowledge of sepsis, confidence in early recognition of sepsis, and compliance with sepsis screening. This study indicates that a CBT in conjunction with HFS can improve and sustain sepsis screening compliance and confidence among nurses identifying sepsis on a general ward. This is relevant because the bedside nurse is recognized as a key component for alerting providers to potential sepsis concerns, as was concluded in a systematic review by Alberto et al. (2017) on sepsis screening processes for general hospitalized patients. Additionally, bedside nurses have been found to suspect sepsis earlier and more often than their physician colleagues in patients later transferred to the intensive care unit (Bhattacharjee et al., 2017). Therefore, the most vital outcome of this QI intervention was demonstrating statistical significance and a large effect size for the improvement of nursing confidence in early recognition of sepsis.

Participants' compliance with sepsis screening was also significantly improved after the intervention which indicates it could be recommended to promote the quality of nursing care, particularly, for the completion of sepsis screening. Given the high economic and social burden of sepsis (Arefian et al., 2017; Chen et al., 2020; Jones et al., 2015; Rudd et al., 2018), improving nurses' compliance with screening for the early recognition of sepsis could improve patient outcomes and decrease the cost of sepsis-related care. However, approximately 10% of sepsis screens were incomplete. Thus, it is recommended that further studies focusing on modifying this QI intervention should seek to increase the rates of nurses' compliance with sepsis screening by exploring barriers and factors facilitating sepsis screening at both the individual and organizational levels.

At baseline, the participants' knowledge of sepsis before the intervention was not sufficient. Thus, it was encouraging that



Note: CBT = Computer-based training; HFS = High-fidelity simulation

FIGURE 1 Evaluation of the Design of the Computer-Based Training (CBT) Module and High-Fidelity Simulation.

knowledge of sepsis initially had statistically significant improvements with large effect size, but those improvements were not sustained over 90 days. This indicates the need for a reinforcing learning activity during that period. For example, researchers demonstrated nursing knowledge retention after 90 days when they reinforced content through summaries sent via email every 2 weeks and discussions at staff meetings or team huddles opposite the week of the emails (Mahramus et al., 2014). This emphasizes that follow-up for reinforcement of content must be considered when planning an educational intervention to improve nurses' knowledge of sepsis. Additionally, a previous study on nursing students' knowledge of sepsis demonstrates that education about sepsis must be included in the nursing curriculum (Valičević et al., 2021). More broadly, nursing education regarding sepsis should be strengthened at multiple levels to ensure proficiency (e.g. nursing school, orientation programs for new nurses and continuing education).

This study was unique because it brought the simulation to the nurses on their home ward, and kept the experience compact enough that it could be completed during their regular shift hours. This created a comfortable environment for the nurses while gaining the support of administration as it did not entail accruing additional paid time. Overall, the positive regard for this learning experience aligns with applied adult learning principles: namely, the nurses were motivated to learn through an experiential process which focused on the relevance of sepsis to their everyday experiences on the ward and thus made the learning meaningful (Curran, 2014). Such experiential learning methods for sepsis are supported by van den Hengel et al. (2016) who found an association between experience with sepsis patients and increased knowledge about SIRS and sepsis. Furthermore, the nurses were given the opportunity to self-direct their learning, especially during the HFS where the facilitators created a nonjudgemental atmosphere and worked collaboratively with the nurses to navigate their path through the high-stakes scenario of a patient developing sepsis.

Given the demonstrated need for sepsis education in nursing; the positive results of this study in relation to knowledge, confidence and compliance in identifying patients with sepsis; and the strongly favourable evaluation of the CBT and HFS experiences; nurse leaders, educators, and other staff development specialists should consider using the methods described herein as a contemporary approach to sepsis education. It will be imperative to evaluate the efficacy of such methods, especially as the use of HFS and other simulation methods continues to expand through new technologies such as virtual reality. Lastly, conducting the simulation on the nurses' home ward should be considered rather than in a remote simulation centre. This allows the nurses to be near their actual patients which anecdotally offered psychological comfort had an actual clinical emergency taken place, and from a logistical standpoint made the learning opportunity convenient, flexible, and seemingly cost-effective.

5 | LIMITATIONS

This study is limited by the study design (one-group pretest-posttest design). The intervention groups were not paired, so there is a greater possibility that variation from each time point was the result of other factors; however, there was no staff turnover during the implementation period. Pre- and postimplementation screening rates included all nurses on the unit and not just those that participated in the study. Thus, the results may be attributable to other factors, such as the awareness of nonparticipants that a QI project focusing on sepsis was in process on the unit. There was a significant time investment on the part of the implementation team (approximately 30 h for each team member), and while a formal return-on-investment was not performed, just one sepsis case can cost $16,324 to $38,298 on average depending on severity (Paoli et al., 2018). Participating in the HFS during regular shift hours proved difficult for some nurses and eight who answered the pretest survey never went any further in the study. This study was conducted involving a single clinical ward with small samples. One of the major disadvantages to a small sample size is low statistical power. We suggest further studies with larger sample sizes, including control groups, to confirm the study findings. Lastly, there were no instruments with adequate psychometric properties for the assessment of study variables in this study. Thus, psychometrically unvalidated evaluation instruments were used, and further research is warranted to validate measures (knowledge and confidence in early recognition of sepsis) used in this study. Despite these limitations, the implementation team was satisfied overall with the level of nursing participation and engagement, and the impact this study could have on clinical outcomes.

6 | CONCLUSIONS

The negative impact of sepsis on hospital costs, readmissions and mortality is substantial. Identifying sepsis has shifted to the general wards where early recognition gives providers an opportunity to initiate early interventions. General ward nurses spend more time with patients than other caregivers so ensuring they have the knowledge and confidence to complete sepsis screenings, identify sepsis early, and take appropriate action, is paramount. As demonstrated in this pilot study, a CBT in conjunction with HFS has the potential to achieve those goals in an engaging, time-sensitive and cost-effective way. However, when designing and implementing an educational intervention related to sepsis, a process for follow-up which provides educational reinforcement must be considered in order to sustain an increase in nurses' knowledge.

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CONFLICT OF INTEREST STATEMENT

There are no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

Research data are not shared.

RESEARCH ETHICS COMMITTEE APPROVAL

This QI project has been formally evaluated using a QI checklist and determined not to be human subjects research by an internal review process at Duke University School of Nursing.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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