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SHORT REPORT

Improving Resident Comfort with Central Venous Catheter Supervision: Use of an Error Management Training Approach

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Background: Simulation is a well-established component of central venous catheter (CVC) training. However, there is little published regarding how to train residents to supervise CVC insertion.

Purpose: We describe a curriculum designed to help trainees identify potential procedural errors and improve their comfort with supervising CVC insertion.

Patients and Methods: We conducted a one-group, pre-post-posttest study. All participants completed a pre-simulation assessment (Time 1) that evaluated residents' ability to identify potential complications with CVC insertion and their procedural completion and procedural supervision comfort. Residents then participated in a simulation in which they supervised a mock proceduralist insert a CVC and commit five pre-specified errors. Participants completed the same comfort assessment immediately following the simulation (Time 2) and repeat knowledge and comfort assessments five months later (Time 3).

Results: Forty-seven interns participated in the study. Relative to Time 1 (M = 3.00, SD = 1.02), interns were significantly more comfortable supervising CVC insertion at Time 2 (M = 3.75, SD = 0.85) and at Time 3 (M = 4.08, SD = 0.58).

Conclusion: We describe a simulation designed to help residents identify errors when supervising CVC insertion. Due to a poor survey response rate, no comparisons between pre- and post-simulation error identification could be determined. However, following our CVC supervisor simulation, participants reported immediate and sustained increases in their comfort supervising CVC placement.

Keywords: error management training, simulation, supervision, procedure training, central venous catheter training, graduate medical education

Introduction

Central venous catheter (CVC) insertion is a common bedside procedure. However, this procedure involves inherent risk.[1–5] In one simulation-based evaluation of CVC insertion, only 24% of surgical residents performed the procedure without any errors.[6] Moreover, medical students and residents alike report minimal experience and comfort with bedside procedures such as CVCs.[7,8]

To improve mastery of CVC insertion, many programs use simulation to evaluate competency, provide additional instruction, and improve rates of procedure success.[9–15] At our institution, all incoming interns participate in a simulation-based mastery learning curriculum for CVC insertion during orientation similar to the model described by McGaghie et al.[16] To augment procedure training and minimize skills decay, some programs also incorporate error management training. This training ensures exposure to common errors during the initial teaching so that participants learn to identify mistakes and perform appropriate corrective actions.[17]

Despite well-described CVC training curricula that focus on the role of the proceduralist, there is a paucity of literature detailing how to train residents to supervise one another. This gap is of particular importance given that much of the real-time CVC insertion supervision and training is completed by residents.[8,18]

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We aimed to develop a supervision simulation for CVC insertion that incorporated elements of error management training. Secondly, we aimed to evaluate the impact of this training program on trainees' comfort supervising CVC placement.

Materials and Methods

Study Setting

We scheduled all internal medicine interns at our tertiary care, academic medical center to participate in the CVC insertion supervision simulation as part of their required residency education. We randomly grouped interns into pairs to complete the simulation exercise. Prior to the start of the simulation session, we invited all interns to scan a QR code to learn about the associated research aspect of the simulation. Residents who were interested in participating in the associated research study provided informed consent via the QR code. Consenting residents were prompted to complete a survey before and after the simulation and agreed to being contacted three and six months after the simulation for follow-up surveys and assessments. This study and the consent process was approved by The Ohio State University Behavioral and Social Sciences Institutional Review Board (IRB 2020B0136). We conducted the simulation on six dates between the spring and fall of 2021.

Simulation

At the beginning of the simulation, we presented each intern with a case study of a patient about to undergo CVC insertion. The case included a narrative description of an adult patient as well as an image previously published in error management training[6] (Appendix A). We instructed each intern to individually list all anticipated difficulties or potential complications based on the patient's history and the associated image. We also asked each intern to complete a comfort measure related to performing and supervising CVCs.[8]

Once the interns completed individual error assessment and comfort measures, we started the simulation. During this mock procedure, a trained senior resident played the role of a new proceduralist and committed five pre-specified errors. Interns were responsible for providing necessary supervision and coaching for the mock proceduralist and intervening, as necessary. At the conclusion of the case, a member of the research team provided feedback to the intern pair regarding their performance.

Simulation Evaluation

To evaluate the initial effectiveness of the supervisor simulation in an applied educational environment, we conducted a one-group, pre-post-posttest study. Immediately prior to the simulation, participants completed the comfort and error identification as well as prior experience with CVC insertion (ie number of attempted and successfully placed CVCs) (Time 1).

Following the simulation debriefing, participants completed a repeat comfort assessment (Time 2). Five months after the simulation experience (Time 3), we emailed all interns who consented to participate in the study and asked them to complete repeat comfort and error identification assessments (Table 1).

To assess participants' appropriate error identification at both Time 1 and Time 3, two members of the research team (one pulmonary/critical care attending and one pulmonary/critical care fellow) independently assessed all listed potential

Table 1 Study Design with Assessments

	Time 1 ***Pre-simulation Assessment***	→	**Training**	→	**Time 2** ***Post-simulation Immediate Assessment***	→	**Time 3** ***Post-simulation Delayed Assessment***
Previous Experiences Inventory	x						
Error Training Assessment	x						x
Procedural Comfort	x				x		x

complications for accuracy. If the two raters disagreed on a response, they discussed the item until they reached consensus. We added the total number of correct and incorrect responses for each participant.

To assess participants' comfort performing and supervising CVC insertion, we adapted the instrument previously described by Mourad et al to include only items related to CVC training. Participants indicated their comfort with performing and supervising CVCs on a 5-point Likert scale (Appendix B).

Statistical Analyses

We completed descriptive statistics for participants' correct and incorrect error identification and for their baseline exposure to and comfort with CVC insertion. We utilized a series of one-way, repeated measures analyses of variance (ANOVAs) to assess changes in comfort performing and supervising CVCs across time. We evaluated significant differences between each time point by completing post hoc analyses with Bonferroni adjustments.

Results

Forty-seven out of 58 interns (81%) who participated in the CVC procedure training consented to participate in the research.

On average, interns reported completing less than one successful CVC insertion prior to their internship ($M = 0.60$, $SD = 1.97$). Interns reported an average of 6.13 (SD = 2.73) successful CVC insertions and 2.06 (SD = 2.31) unsuccessful insertions during their intern year.

Initial Error Training Assessment

At Time 1, interns correctly identified an average of 3.58 (SD = 1.40) aspects of the clinical history that could lead to difficulties or potential complications when completing the procedure (see Table 2). Nearly 45% of interns also *incorrectly* identified one or two anticipated difficulties or complications which would not be expected as determined by the two reviewers (M = 0.57, SD = 0.55).

Table 2 Error Identification Table

Contributors to Procedural Difficulty	Number of Interns who Correctly Identified Contributor to Procedural Difficulty (%)
Altered Mental Status	48 (94)
Obesity/Body Habitus	25 (49)
CPAP	22 (43)
Cirrhosis Coagulopathy/Bleeding	22 (43)
Heart Failure	18 (35)
Neck Circumference	13 (25)
COPD/Emphysema	13 (25)
Hypoxia/Desaturation	10 (20)
Hypovolemia/Hypotension	6 (12)

Abbreviations: CPAP, continuous positive air pressure; COPD, chronic obstructive pulmonary disease.

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Table 3 Comfort Performing and Supervising CVCs

	M (SD)			F	df	p	$\eta^2_{partial}$
	Time 1	Time 2	Time 3				
Performing with supervision	4.50 (0.66)[a]	4.71 (0.55)	4.88 (0.34)[a]	4.692	1.539, 35.403	0.023	0.169
Performing independently	3.54 (1.10)[a,b]	3.88 (1.04)[a]	4.38 (0.77)[b]	9.604	1.399, 32.181	0.002	0.295
Supervising	3.00 (1.02)[a,b]	3.75 (0.85)[a]	4.08 (0.58)[b]	20.53	2, 46	<0.001	0.472

Notes: [a,b]Superscripts within each row denote pairwise comparisons that were statistically significantly different.
Abbreviations: CVC, central venous catheter; M, mean; SD, standard deviation; F, F statistic for analysis of variance; df, degrees of freedom; p, probability statistic.

Comfort with Procedural Supervision

Interns reported significant improvements in comfort supervising CVC insertion over time ($F(2,46) = 20.53$, $p < 0.001$, $\eta 2partial = 0.47$). Relative to Time 1 (M = 3.00, SD = 1.02), interns were significantly more comfortable supervising CVC insertion at Time 2 (M = 3.75, SD = 0.85) and at Time 3 (M = 4.08, SD = 0.58; Table 3).

Though not the primary focus of our study, interns also reported significant improvements in performing CVCs with supervision and independently at T3 compared to T1 (Table 3).

Discussion

Though residents perform much of the real-time CVC insertion supervision, they are not necessarily comfortable fulfilling this role.[8] We found that immediate post-simulation comfort scores with respect to supervision were significantly higher than pre-simulation assessments. This suggests that simulation training alone can increase comfort with procedural supervision. Additionally, increased comfort with CVC supervision was sustained up to five months after the initial simulation. Though we acknowledge that skill in supervising CVC insertion is paramount, increasing resident comfort with supervision is also meaningful – especially given the number of CVCs that residents supervise and the discomfort many residents experience when faced with this task.

Additionally, through our description of this simulation, we provide a framework for how error management strategies might be utilized in CVC supervisor training. A recent position statement from the Society of Hospital Medicine recommended that CVC training should include a combination of simulation-based practice, supervised insertion on real patients, and cognitive training including detection and management of procedural complications.[19] Though error management strategies have been utilized in a number of bedside procedure training simulations[6,15,20] to our knowledge, this is the first description of a CVC simulation that utilizes error training to teach trainees how to be better procedural supervisors.

We acknowledge that our investigation has several limitations. First, prior literature suggests that increased procedural exposure is associated with trainees' perceived competence.[21,22] Due to the nature of our study design, we cannot determine whether residents' increased procedural comfort over time was solely a result of their participation in the simulation or if this was confounded by possible increased exposure while on the wards during the same time period. Second, we acknowledge the limitations of survey data. To maximize the validity of the self-report data, we utilized a previously published survey instrument specifically designed to assess procedural comfort as well as a previously published case illustration. Most importantly, we acknowledge that comfort does not equate proficiency. To measure procedural knowledge, we included an error management component as well as a formative, objective assessment of error management. However, we did not make this aspect of the five-month post-survey mandatory. Due to a poor response rate on the Time 3 formative assessment, we were unable to draw any conclusions regarding an improvement in error identification following residents' participation in the CVC simulation. Though we believe our framework can serve as a model for other institutions hoping to develop a CVC insertion supervision simulation, we recognize that our study was completed at a single academic center and our results may not be generalizable. Similarly, though all trainees would likely benefit from this training, only interns were included in the simulation due to space and time constraints.

Future studies are needed to investigate the effect of an error management training more objectively during CVC supervisor training simulations to assess whether this type of training is associated with increased knowledge and error identification post-simulation. More importantly, we need to assess whether procedural supervision simulations are associated with objective improvement in procedural supervision – as measured either via direct observation in simulation centers or by monitoring complications in actual patients.

Conclusion

Following our CVC supervisor simulation, participants reported immediate and sustained improvements in comfort supervising CVC insertion. The description of this supervisor training simulation provides a framework for other programs as they develop procedural supervision curricula.

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Disclosure

The authors report no conflicts of interest in this work.

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