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First-Year Residents Outperform Third-Year Residents after Simulation-Based Education in Critical Care Medicine

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Abstract

Introduction—Prior research shows that gaps exist in internal medicine residents' critical care knowledge and skills. The purpose of this study was to compare the bedside critical care competency of first-year residents who received a simulation-based educational intervention plus clinical training to third-year residents who received clinical training alone.

Methods—During their first three months of residency, a group of first-year residents completed a simulation-based educational intervention. A group of traditionally-trained third-year residents who did not receive simulation-based training served as a comparison group. Both groups were evaluated using a 20-item clinical skills assessment at the bedside of a patient receiving mechanical ventilation at the end of their medical intensive care unit rotation. Scores on the skills assessment were compared between groups.

Results—Simulator-trained first-year residents (n=40) scored significantly higher compared to traditionally-trained third-year residents (n=27) on the bedside assessment, 91.3% (95% CI 88.2% to 94.3%) vs. 80.9% (95% CI 76.8% to 85.0%), $P = <.001$.

Conclusions—First-year residents who completed a simulation-based educational intervention demonstrated higher clinical competency than third-year residents who did not undergo simulation training. Critical care competency cannot be assumed after clinical ICU rotations; simulation-based curricula can help ensure residents are proficient to care for critically ill patients.

Introduction

Acuity and complexity of illness, high patient volume, and duty-hour restrictions leave limited time for dedicated critical care education in the medical intensive care unit (MICU) during internal medicine residency.¹ As a result, residents demonstrate a wide range of critical care knowledge and competency even in their final year of training.² Effective

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critical care education and competency assessment during internal medicine residency is vital because intensivists manage only a fraction of critically ill patients in the United States.^{3,4}

Multiple studies have shown that simulation-based education is an effective method to boost clinical skills of postgraduate medical trainees.⁵ High-fidelity patient simulators provide an opportunity for inexperienced learners to train in a controlled and safe environment.⁶ Simulation-based curricula improve skills in complex emergent situations including advanced cardiac life support⁷⁻⁹, obstetrics^{10,11}, airway management¹², and trauma resuscitation^{13,14}. Procedural skills in minimally-invasive surgery¹⁵⁻¹⁷, endoscopy¹⁸, bronchoscopy¹⁹, and central venous catheter (CVC) insertion²⁰⁻²² are also enhanced by simulation training. The American Board of Internal Medicine (ABIM) recommends that residents undergo simulation training prior to performing invasive procedures.²³

Little is known about the role of simulation-based education to improve cognitive skills such as patient care in the MICU. Prior studies have shown that simulation training improves performance in simulated scenarios of medical critical illness.^{24,25} A randomized trial from our institution demonstrated that first-year residents who receive a simulation-based curriculum perform better on standardized assessments in the MICU than those who receive traditional clinical training alone.²⁶ However, it remains unknown if senior residents eventually attain a similar level of competency in the MICU with additional traditional clinical training. It is necessary to compare first-year residents who receive a simulation-based curriculum with third-year residents who receive only traditional clinical training in order to justify the use of simulation training for MICU patient care skills.

The aim of this study was to compare the bedside critical care competency of first-year residents who completed a simulation-based intervention to traditionally-trained third-year residents who completed clinical training alone.

Methods

From July 2010 through June 2011, we conducted a prospective cohort study comparing traditional clinical training with a simulation-based educational intervention to traditional clinical training alone. This study period allowed all residents in both groups to be assessed during their clinical rotation. Figure 1 outlines the study design.

First-year residents (the intervention group) received traditional clinical training plus a simulation-based curriculum; third-year residents comprised the traditionally-trained comparison group. All study subjects were recruited prior to a clinical rotation in the 23-bed MICU of Northwestern Memorial Hospital (NMH): a large, urban, university-affiliated teaching hospital. The Northwestern University Institutional Review Board approved the study, and all participants provided informed consent before participation.

All first- and third-year residents in the study completed a four-week rotation in the NMH MICU as part of a team consisting of one or two first-year residents, one senior resident, one pulmonary and critical care fellow, and one ABIM-certified attending physician from the Division of Pulmonary and Critical Care Medicine. Residents who participated in our previous study of simulation-based education²⁶ were not included in either study group. Resident teams admitted new patients every fourth day; bedside teaching rounds occurred daily. Small group formal teaching took place at the discretion of the team fellow and attending. All residents participated in didactic activities including 10 critical care lectures focusing on mechanical ventilation and evaluation of circulation. These lectures were archived on the residency website.

The intervention group received a four-hour standardized intervention regarding MICU knowledge and patient care during a “boot camp” experience in their first three months of residency. The intervention consisted of hands-on deliberate practice²⁷ of clinical scenarios of circulatory shock, respiratory failure, mechanical ventilation, and spontaneous breathing trial readiness. A senior educator and former MICU medical director in the Division of Pulmonary and Critical Care Medicine (TCC) led each session. All sessions occurred in the NMH Patient Safety Simulator Center using a high-fidelity human patient simulator (Medical Education Technologies, Inc., Sarasota, FL) that features a realistic pulse, blood pressure, and cardiac rhythm, and is ventilator compatible.

Each simulation session was divided into three **35-minute** clinical cases designed to replicate common MICU clinical scenarios. The senior medical educator (TCC) provided debriefing and individualized feedback for **45 minutes** after each case. In the first scenario, residents were asked to assess and manage a patient with community-acquired pneumonia, acute hypoxemic respiratory failure, and septic shock. The simulated patient required aggressive resuscitation, intubation and mechanical ventilation, invasive monitoring with an arterial catheter and CVC, administration of antibiotics and vasopressors, and interpretation of laboratory data and chest x-ray imaging. The second scenario required residents to respond to a high peak pressure ventilator alarm, gather data, and present their findings and plan during simulated bedside rounds. Finally, the third scenario involved assessment and management of a patient who was appropriate for a spontaneous breathing trial and extubation.

Intervention group first-year residents also received a standardized small group 30-minute review of the curriculum, performed by an internal medicine chief resident (BDS) during the first week of their required MICU clinical rotation. This session was intended to boost retention of concepts introduced earlier in the academic year.

During the fourth week of their MICU clinical rotation, residents in both groups were assessed on MICU clinical knowledge and patient care. Bedside assessment was performed using a 20-item checklist (Figure 2), generated by augmenting an existing instrument previously validated in resident critical care education.²⁶ We developed the instrument using a modified Delphi procedure and checklist design methodology.²⁸ The checklist assessed skill in interpreting respiratory system mechanics, ventilator settings, spontaneous breathing trial readiness, and circulatory status. Three authors with expertise in MICU clinical care (TCC) and simulation-based education and checklist design (DBW, WCM) reviewed the instrument for accuracy and completeness. Criteria for spontaneous breathing trial readiness were modified from a published consensus document.²⁹ Each checklist item received equal weight and was scored as either correct or incorrect; failure to respond to an item was scored as incorrect.

Residents in both groups completed the clinical skills assessment at the bedside of a MICU patient receiving mechanical ventilation and undergoing continuous hemodynamic monitoring. The instrument was read verbatim to each subject; subjects were not prompted for answers. One examiner (BDS) performed all assessments. A random 30% sample was also observed and scored by a second rater to assess inter-rater reliability.

Statistical Analysis

Demographic differences between intervention and comparison group residents were assessed using Pearson's chi-square test and two-tailed independent samples t-tests. Between-group differences on the bedside clinical skills assessment score were evaluated using two-tailed independent samples t-tests. Checklist score reliability was estimated by calculating inter-rater reliability with the Kappa (κ) coefficient. Multiple regression analysis

was used to assess the effect of age, gender, United States Medical Licensing Examination (USMLE) Step 1 and 2 scores, and critical care clinical experience on the bedside assessment score. All analyses were performed using PASW Statistics software, version 18.0 (SPSS, Inc., Chicago, IL).

Results

Sixty-seven residents rotated through the MICU during the 9-month evaluation phase. There were 40 (59.7%) first-year residents and 27 (40.3%) third-year residents. Demographics of the intervention and comparison groups are shown in Table 1. The groups were similar except for age and prior critical care clinical experience. All 67 residents consented to participate in the study and completed the entire protocol.

Inter-rater reliability for the assessment was very high. The mean Kappa coefficient (κ) was .98.

The intervention group (n=40) scored significantly higher on the bedside clinical skills assessment than the comparison group (n=27) (91.3% [95% CI 88.2% to 94.3%] versus 80.9% [95% CI 76.8% to 85.0%], $P = <.001$) (Figure 3). When controlled for age, gender, USMLE Step 1 and 2 scores, and critical care experience, intervention status (simulator versus traditional training) remained a significant predictor of performance on the bedside clinical skills assessment ($P = .001$).

Discussion

First-year internal medicine residents who received a simulation-based educational intervention as an adjunct to traditional clinical training demonstrated higher clinical competency at the bedside of a critically ill patient than traditionally-trained third-year residents. This finding is despite the fact that the first-year residents had significantly less critical care clinical experience than their supervising third-year residents. The absolute difference in bedside scores (>10%) corresponds to approximately two more questions answered correctly on the bedside clinical skills assessment. The statistically significant difference suggests a greater mastery of clinical concepts in the intervention group, although the clinical impact of the difference was not assessed in our study. While it is disappointing that third-year residents with significantly more critical care experience showed worse performance than first-year residents, the results are not surprising based on the findings of two recent meta-analyses suggesting that clinical training alone is inferior to clinical training plus simulation-based education.^{5,30}

Prior studies have demonstrated that simulation-based education for procedural skills such as CVC insertion is associated with improved technical capability²², reduced complications²¹, and decreased hospital costs³¹. However, few studies have assessed the ability of a simulation-based curriculum to improve the medical knowledge and patient care competency of residents in the MICU. Our study extends what is known about the ability of simulation-based education to improve skills in critical care topics such as mechanical ventilation and circulatory shock. These topics are important competencies for internal medicine training, yet concerns have been raised on a national level about the adequacy of current training models.^{3,4} However, future studies are needed to determine if simulation-based education can be integrated into systems-level interventions that affect important clinical outcomes such as ventilator days, MICU length-of-stay, and mortality.

Our finding that first-year residents displayed higher bedside competency than third-year residents is timely, as new duty-hour regulations from the Accreditation Council for Graduate Medical Education restrict first-year residents to a maximum 16-hour duty period

effective July 2011.³² Even under less stringent regulations, residents and critical care faculty have raised concerns about the effectiveness of critical care education during internal medicine residency.^{1,4} Our results suggest that bedside competency is not solely a function of training time and lecture attendance because third-year residents in the comparison group had significantly more critical care and didactic experience yet scored lower on the clinical skills assessment. This study advances what is known about MICU clinical skill acquisition, as we show that additional clinical time is not a proxy for skill at the bedside. In other words, first-year residents will not “catch up” after ICU rotations and lectures and demonstrate satisfactory bedside proficiency as third-year residents. Based on these results as well as our earlier study of MICU clinical skills acquisition²⁶, we recommend use of simulation-based education for internal medicine residents prior to ICU clinical rotations. This approach boosts clinical skills in mechanical ventilation and circulatory shock and is an efficient and effective adjunct to traditional critical care education in a time-limited training environment.

Our study has several important limitations. First, we performed our study at a single center with a limited number of residents. Second, we assessed only a limited number of critical care competencies and our study was not powered to examine which individual competencies are improved by the simulation-based curriculum. Third, the primary examiner was not blind to training status, **which could introduce significant bias**. However, bias should be limited by the fact that the assessment items were objective questions with single correct answers, and we used a second rater who was not familiar with the study design. Fourth, variation in patient cases seen during ICU rotations may have impacted performance on the bedside skills assessment. Finally, while our study did assess resident critical care competency, it was not designed to measure actual patient outcomes. Further study is required to show the full impact of simulation-based education on patient outcomes.

This study demonstrates that simulation-based education develops critical care knowledge and patient care competency in first-year residents to higher levels than supervising third-year residents. New duty-hour regulations require medical educators to develop powerful interventions to ensure their trainees achieve clinical competency. Simulation-based education is an effective curriculum driver to teach and assess residents and should be used as an adjunct to current critical care curricula. Further study is required to assess the effect of simulation-based education on MICU clinical outcomes.

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Figure 1.
Flow of participants through the study.

Skill Key A=Done Correctly B= Done Incorrectly		
By using data from the ventilator, calculate the airways resistance.	A	B
By using data from the ventilator, calculate the static compliance of the respiratory system.	A	B
Does the expiratory flow tracing suggest auto-PEEP?	A	B
Describe the ventilator settings (DO NOT PROMPT)		
Mode	A	B
Rate	A	B
Tidal volume	A	B
Fraction of inspired oxygen (FiO ₂)	A	B
Positive end-expiratory pressure (PEEP)	A	B
Flow rate	A	B
Flow pattern	A	B
In this patient, what initiates the inspiratory flow?	A	B
In this patient, what terminates the inspiratory flow?	A	B
What is the pulse pressure?	A	B
What is the central venous pressure? (either from CVP strip or monitor)	A	B
What is the mean arterial pressure? (from monitor or calculated is acceptable)	A	B
What parameters would you need to identify so that this patient could undergo a spontaneous breathing trial? (DO NOT PROMPT)		
Adequate mental status (awake and following commands)	A	B
Hemodynamically stable	A	B
Minimal secretions (suctioning less than every 2 hours)	A	B
FiO ₂ ≤40%	A	B
PEEP≤5cm H ₂ O	A	B

Figure 2.
Bedside clinical skills assessment instrument.

Figure 3. Bedside clinical skills assessment performance (% correct with 95% confidence intervals) in traditionally-trained and simulator-trained residents

Table 1

Baseline characteristics of residents. Plus-minus values are means $\pm$ standard deviation.

	Simulator-Trained PGY-1 Residents n=40	Traditionally-Trained PGY-3 Residents n=27
Age—yr	26.8 $\pm$ 2.0	28.7 $\pm$ 1.8
Male sex—no. (%)	15 (37.5)	16 (59.3)
US Medical School Graduates— no. (%)	40 (100)	27 (100)
Previous ICU rotation—weeks	5.5 $\pm$ 2.7	21.1 $\pm$ 2.4