Simulation-based Assessment of Critical Care 'Front-Line' Providers

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Abstract

Objective—Develop a standardized simulation method to assess clinical skills of ICU providers

Design—Simulation assessment

Setting—Simulation laboratory

Subjects—Residents, CCM Fellows, ACNP students

Interventions—Performance scoring in scenarios from multiple CCM competency domains.

Measurements and Main Results—384 performances by 48 participants were scored using checklists (% correct) and holistic 'global' ratings [1(unprepared) to 9(expert)]. 180 were scored by two raters. Mean checklist and global scores(±SD) ranged from 65.0%(±16.3%) to 84.5% (±17.3%), and 4.7(±1.4) to 7.2(±1.2). Checklist and global scores for CCM Fellows and senior ACNP students (Experienced Group, n=26) were significantly higher than those for the Novice ACNP students (Novice Group, n=14) (75.6±15.6% vs.68.8±21.0%, and 6.1±1.6 vs. 5.4±1.5, respectively; p<0.05). Residents (Intermediate Group, n=8) scored between the two (75.4±18.3% and 5.7±1.7). 38.5% of the Experienced Group scored in the top quartile for mean global score, compared to 12.5% of the Intermediate and 7.1% of the Novice Groups. Conversely, 50% of the Novice Group scored in the lower quartile (<5.3), compared to 37.5% of the Intermediate and 11.5% of the Experienced Groups. Psychometric analyses yielded discrimination values >0.3 for most scenarios, and reliability for the 8-scenario assessments of 0.51 and 0.60, with inter-rater reliability of 0.71 and 0.75, for checklist and global scoring, respectively.

Conclusions—The simulation assessments yielded reasonably reliable measures of CCM decision-making skills. Despite a wide range of performance, those with more ICU training and experience performed better, providing evidence to support the validity of the scores. Simulation-

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based assessments may ultimately prove useful to determine readiness to assume decision-making roles in the ICU.

Keywords

Introduction

Several million people in the United States admitted annually to the intensive care unit (ICU) rely on the skill of ICU clinicians for life-saving interventions during their ICU stay (1–4). As ICU admissions continue to rise (2), there has been a parallel increase in the demand for qualified ICU providers (3–6). For physician specialists ('intensivists'), this demand has been amplified by consumer advocacy for intensivist-led ICU care, which has been shown to reduce ICU mortality and lengths of stay (1–3, 7–9). The result has been a growing shortage of intensivists which has been exacerbated by safety-related work hour restrictions for physician trainees, who served as 'front line' ICU providers to manage the intensivist supply-demand gap (10–12). A rapid expansion of the critical care work force has ensued to now include a large number of non-physician 'advanced practice' ICU providers (APPs) (13–15), largely comprised of acute care nurse practitioners (ACNPs) and physician assistants (PAs) with ICU training and experience. In collaboration with intensivists, these new 'front line' ICU providers are responsible for moment-to-moment coverage and management decisions in the ICU (14–16), and are thus essential to produce the improved ICU outcomes with intensivist-led ICU care (7, 8, 17, 18).

The educational preparation of physician trainees, ACNPs, and PAs who fill front line ICU provider roles differ considerably, but all must be able to promptly recognize and respond appropriately to changes that portend a serious deterioration in a patient's condition (13–15). The often limited ICU exposure during their professional education (19–20), however, can lead to early learning-based errors, which can have devastating for patients, and often for the provider(s), whose negative experience leads them to believe they are unsuited for ICU work, and drop out of the ICU workforce (21).

Simulation provides an experiential learning environment that improves health care professional preparation while eliminating the potential for patient harm (22–25). Simulation may also offer a potential means to assess providers clinical decision-making skills using a standardized approach and environment (26).

The aims of the study were 1) to develop an inventory of simulated ICU conditions (scenarios) that could be used to assess whether participants have acquired the cognitive skills necessary to assume 'front line' ICU provider roles, and 2) to gather evidence to support the psychometric adequacy of the performance metrics for the scenarios. From a validity perspective, we hypothesized that participants with more ICU experienced would perform better. The longer term goal was to develop a standardized simulation methodology that can be used to reliably assess provider readiness to manage patients in the ICU.

Methods

Scenarios

A list of common ICU conditions was developed through review of administrative databases and published critical care provider competencies (19, 20, 27). Academic intensivists (n=14) were surveyed using a Delphi technique to narrow the list to 16 conditions used to construct scenarios (28). The research team developed and refined the scenarios including the standardized patient behaviors and responses, and the scripted responses from the 'standardized nurse'. Patient findings were simulated using Meti HPS® and iStan® electromechanical mannequins. Additional laboratory and/or radiologic data were available upon request of the participant. Two 8-scenario forms ("A" or "B") were designed to be equivalent and completed in a session lasting 90-120 minutes (see Table 1).

Participants

The study was approved by the Institutional Review Board and informed consent was obtained from 48 participants. These included 14 novice and 4 senior ACNP students, 8 residents, and 22 CCM fellows. 21 were male and 27 were female. Average age was 32.7 years (range 26-52). The ACNPs completed undergraduate nursing programs between 1990 and 2012. The novice ACNPs were evaluated during the first 2 months, and the senior ACNPs in the last 2 months, of their year-long ACNP clinical training. The ACNP students had an average of 7.5 years (SD=6.2) of prior critical care nursing experience. The residents and CCM fellows graduated from medical school between 2003 and 2015. The residents included 7 PGY-1s and 1 PGY-2 from Anesthesiology or Surgery training programs. The CCM fellows completed residency programs in Anesthesiology (n=8), Emergency Medicine (n=8), or General Surgery (n=6). The residents had less than 3 months of critical care experience. Most CCM fellows (82%) had at least 8 months of critical care experience at the time of the simulation assessments. All participants had previous simulation experience.

Simulation Assessment

During each participant's assessment, an instructor, a 'standardized' nurse, and a simulation operator managed the standardized simulation experience. The instructors were certified critical care specialists and members of the critical care faculty and the research team. In a few instances, instructors had prior exposure to a participant. However, in no case did an instructor feel there was an issue with objectivity as a rater. The 'standardized' nurse, who acted as the 'bedside' ICU nurse, had 20 years of experience as a critical care nurse and 5 years of experience in simulation education. For each scenario, the participants were 'called' by the bedside ICU nurse who provided the scripted reason for the call (Table 1) and answered participant's questions with the scripted responses. In the control room adjacent to the simulation suite, the operator managed the mannequin interface in a standardized fashion, and the instructor scored the performance.

Checklist Scoring

The participants were scored analytically by the instructor during the live viewing of the performance using scenario-specific checklists that included items considered important for diagnosis and initial management (see Supplemental Data).

Global Performance Scoring

To assess overall management, participant performances were also 'holistically' scored by the instructor using a global rating scale from 1 ('unprepared') to 9 ('expert').

The 48 participants each completed an 8 scenario assessment (A or B) for a total of 384 individual performances. 180 were scored by a second rater from a video recording. Prior to viewing performances, raters reviewed the checklist scoring rubric and global rating scale.

Post-assessment survey

Participants completed post-assessment surveys regarding the simulation experience using a 5-point scale (1=strongly agree to 5=strongly disagree). Participants were asked about whether (1) the patient presentations and environment were realistic, (2) the scenarios were representative of practice, (3) the scenarios were relevant to practice, (4) the scenarios would be stress provoking in practice, and (5) the scenarios would improve clinical performance.

Participant Performance

Descriptive statistics were used to summarize performance by scenario. Scenario discrimination (D) values (the correlation between individual scenario scores and total scores across scenarios) were calculated to provide a measure of how well performance on a single scenario predicted the participant's overall performance.

Reliability

Variance components were calculated to estimate the reliability of checklist and global rating scores for an 8 scenario assessment with a single rater. Inter-rater reliability was calculated for the 180 scenarios scored by two raters.

Group and Scenario Comparisons

Comparisons were made between 'Experienced' (CCM fellows and senior ACNP students, n=26), 'Intermediate' (residents, n=8), and 'Novice' (novice ACNP students, n=14) Groups. Group performances were described with descriptive statistics. Quartiles were also determined for average global performance and used to compare performance by Group. Significant differences in performance related to scenario and Group were evaluated using repeated measures analysis of variance (RM-ANOVA) in which scenario and Group were the independent variables, and either checklist or global scores were the dependent variables. Post-hoc one-way ANOVA and Scheffe tests were employed to explore significant scenario and Group effects.

Quality of the Simulation Experience

Participants' responses to the post assessment survey were summarized (mean, SD, min, max).

Results

Scenario Performance

Average checklist and global scores, and discrimination (D) values, for each scenario are presented in Table 2. For most scenarios, discrimination (D) values were >0.30 and were higher for global scores compared to those for checklist scores.

Reliability

The reliabilities of the 8-scenario assessments with a single rater were 0.51 and 0.60 for checklist and global scores, respectively, with an estimate of 0.67 and 0.75, respectively, for a full 16-scenario assessment. Based on the double scored scenarios, inter-rater reliabilities were 0.71 and 0.75 for checklist and global scoring, respectively.

Individual Participant Global Scores by Group

The mean global scores for participants in the Experienced, Intermediate and Novice Groups are shown in Figure 1. The Experienced Group had the highest mean global score (6.1 ± 1.6, Mean$\pm$SD), and accounted for 83% (10/12) of scores in the top quartile (>6.5) (38.5% of the Group). Notably, all of the senior ACNPs (n=4) scored in the top quartile. Mean global scores were lower in the Intermediate (5.7 ± 1.7) and Novice Groups (5.4 ± 1.5), with only 1 top quartile score from the Intermediate Group (12.5% of the group), and 1 from the Novice Group (7.1% of the group). Conversely, 58% (7/12) of scores in the lower quartile (<5.3) were from the Novice Group (50.0% of that group), compared to 3 from the Intermediate Group (37.5% of that group), and 3 from the Experienced Group (11.5% of that group).

Group and Scenario Comparisons

Mean checklist and global scores for the Experienced, Intermediate, and Novice Groups are shown in Table 3. Based on RM-ANOVA for checklist scores, there was a significant Group by scenario interaction effect ($F_{28,44}=1.63$, $p<0.05$), as well as significant Group ($F_{3,44}=4.23$, $p<0.05$) and scenario effects ($F_{14,44}=1.91$, $p<0.05$). For global scores, the RM-ANOVA did not demonstrate a significant Group x scenario interaction effect ($F_{28,44}=1.1$, $p>0.05$) but there were again significant Group ($F_{2,44}=4.13$, $p<0.05$) and scenario ($F_{14,44}=3.72$, $p<0.05$) effects identified. Post hoc analysis (ANOVAs and Scheffe's test) indicated significant differences for both checklist and global scores between the Experienced (75.8 ± 15.6, and 6.1 ± 1.6, respectively) and Novice Groups (68.8 ± 21.0 and 5.4 ± 1.5, $p<0.05$). Based on performance of the Experienced and Novice Groups, the effect sizes (ES) for the checklist and global score differences were 0.42 and 0.46, respectively. Differences in checklist and global scores between the Intermediate Group (75.4 ± 18.3 and 5.7 ± 1.7) and the other two Groups were not significant.

Quality of the Simulation Experience

The responses to the post-assessment survey questions are shown in Table 4. Average responses indicated that participants 'strongly agreed' that the scenarios were (1) representative and (2) relevant to practice, (3) stress provoking in the clinical setting, and (4) would improve their clinical performance (mean 4.7/5 to 4.8/5 ± 0.4-0.6, Table 4). Participants 'agreed' on average that scenarios were realistic (mean 4.0/5 ± 0.7), but responses of 'disagree' were recorded by some participants.

Discussion

This study is the first to use multi-scenario simulation to assess the performance of a diverse group of critical care providers. The results support the psychometric adequacy of the scores derived from the simulation assessment designed to measure cognitive decision-making skills of potential ICU 'front line' providers. Based on variance components analysis, 'holistic' global scores were more reliable than checklist scores. Using a holistic framework, the raters' ability to consider how the participant communicated and prioritized their management, something not captured by checklist scoring, likely contributed to the more precise measures of decision making ability. The high discrimination (D) values (≥ 0.6) for many scenarios indicate that the participant performance on these scenarios more effectively predicted overall performance. The lower D values (<0.3) for a few scenarios suggests that these scenarios may not differentiate along the ability continuum, perhaps because the scenario was too easy (e.g., 'Obstructed Foley'). For the future development of simulation-based assessments, there is a need to re-assess the constructs measured by the individual scenarios and whether the content is truly appropriate for all those being assessed. The individual scenario discriminations, combined with the moderate reliability estimates, highlight the need for multiple, content valid, scenarios to precisely estimate overall critical care ability. Similar to previous simulation-based assessments, we found that the reliability of the assessment scores was most dependent on the number of scenarios, not the number of raters per given scenario (23, 24, 26). Overall, the reliability of the eight scenario assessments was moderate (0.51-0.60), with sufficient precision for determining progress in training and providing formative feedback to front-line provider candidates. The simulation assessments in their present form may also be useful to identify training program gaps, and to potentially identify individual providers who may benefit from additional initial oversight when assuming ICU front line provider roles. A higher reliability estimate (r>=0.80) would be required to make licensing, credentialing or certification decisions (29).

The structured assessment development process for the scenarios, based on actual clinical management problems, provides evidence to support the scoring and generalization inferences in Kane's validity framework (29). The relationship between participants' prior ICU experience and performance on the simulation assessment provides additional 'criterion' validity evidence, and supports the extrapolation inference in the Kane framework; namely, that the simulation performance scores reflect ability in actual 'real life' ICU provider roles (29). In this regard, it was notable that 100% of the senior ACNPs scored in the top quartile for overall global scores, in comparison to 27.3% of critical care fellows, 12.5% of the residents, and 7.1% of the novice ACNP students. This finding is consistent

with prior clinical trials which have demonstrated that fully trained ACNPs compare favorably to residents and critical care fellow using objective clinical outcome measures in actual ICU settings (14, 16, 30, 31). While derived from a relatively small sample, this finding strengthens the extrapolation validity argument, and further supports the utilization of ACNPs in these roles (10, 13, 15).

The long term goal of this research is to provide an assessment methodology that transcends the various training pathways of ICU providers. In this regard, there are six separate training and certification pathways for physician intensivists, and equally diverse pathways for ACNPs and PAs, with programs that differ considerably with respect to training and experience. As noted by Kaplan et al., the separate credentialing and certification processes "creates confusion among practitioners and patients, and establishes a barrier to practice and credentialing standardization" (20). The simulation approach presented here provides a standardized method to assess performance. Refinements to the simulation assessment tool (e.g., additional and/or more discriminating scenarios) to decrease measurement error should allow for more precise estimates of ability that could ultimately meet the high psychometric standards required for summative assessments such as those used for certification (29, 32). The addition of some form of criterion-referenced standard setting would be an additional next step to develop a minimum performance standard that could be used to make valid competency decisions about an ICU front-line provider's decision-making skills (33).

There are limitations of our study. The simulation assessment employed a set of scenarios directed at cognitive skills involved in early recognition and management and did not assess procedural skills or abilities for developing longer term care plans. The simulation setting may also not perfectly reflect the provision of care in ICU settings. The scenarios were purposely shortened to allow for greater sampling of provider performance, and the simulation scenarios were not designed to capture the complex prioritization realities often required to effectively manage patients in the ICU. Finally, it is recognized that individual participant's performance in an actual clinical environment may be different than that in the simulation environment.

This study adds to a growing body of knowledge that advanced simulation methods may provide a means to assess clinical competence (24, 26). Further refinements should ultimately produce a standardized competency-based assessment tool that could be used to determine whether individuals with a range of training and experience are adequately prepared for ICU provider roles. Ultimately, the goal is to improve patient safety and optimize outcomes of ICU patients by assuring that providers assigned to roles as front line providers in the ICU are adequately prepared.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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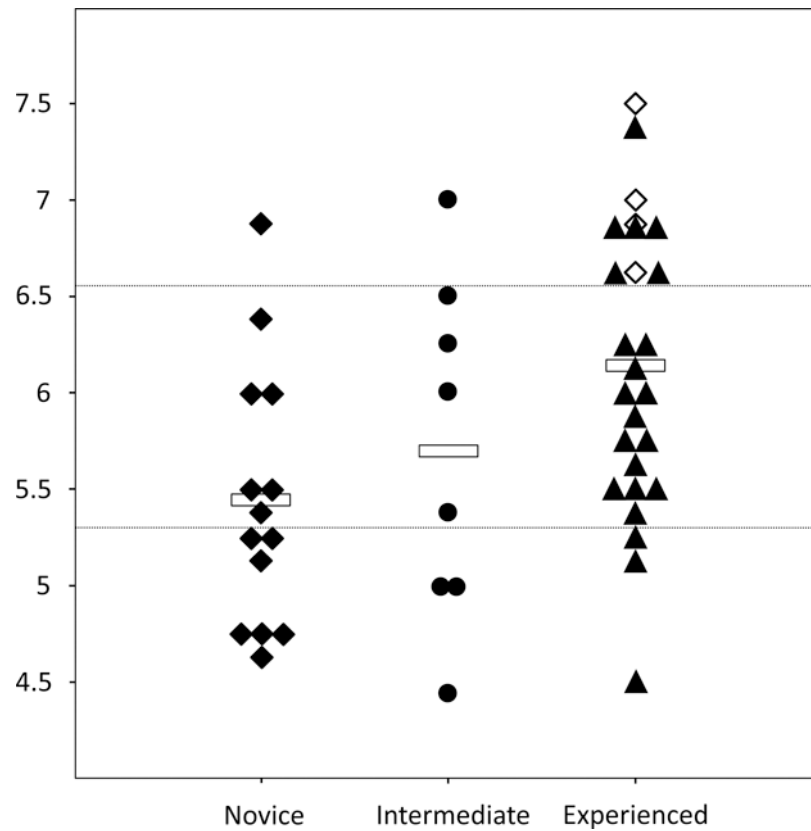
Figure 1. Global Score by Group and Quartile

Individual participant (n=48) average global scores in the Novice (◆ novice ACNP students, n=14), Intermediate (• resident physicians, n=8) and Experienced Groups (▲ critical care fellows, n=22;   senior ACNP students, n=4). () ▭ Mean for Groups; (------) upper/lower quartile demarcation lines.

Table 1

Critical Care Scenarios

Simulated ICU conditions and information provided to participants at the beginning of each scenario.

Form A Scenarios	Form B Scenarios
1. 3rd Degree Heart Block. 75 year old patient admitted after treatment of ventricular tachycardia with cardioversion. Amiodarone is infusing. HR 40, BP 80/40, RR 12, O2 sat 92%. Patient is responsive, but disoriented.	**1. Atrial Fibrillation.** 75 year old female patient 12 hours following posterior cervical spinal fusion for atlantoaxial subluxation. HR 140, BP 80/40, RR 12, 02 Sat 92%. Patient is responsive, but disoriented.
2. ARDS. 60 year old male intubated and ventilated for 24 hours following colectomy, now with worsening blood gases. FiO2 is 100%, O2 Sat is 89, increasing dyspnea and hypoxia. HR 130, BP 110/80, RR 28, O2 sat 88%. Patient appears dyspneic.	**2. Pulmonary Embolus.** 60 year old male admitted to ICU 48 hours following colectomy with increasing dyspnea and hypoxia. HR 130, BP 110/80, RR 28, O2 sat 88%.
3. Asthma. 40 year-old patient in the ICU 12 hours after total colectomy and end ileostomy. HR 120, BP 120/85, RR 24, O2 sat 89% on 2 liters Nasal Cannula. Patient is alert, dyspneic and complains of incisional pain.	**3. Atelectasis.** 40 year-old patient in the ICU 36 hours after total colectomy and end ileostomy. HR 120, BP 120/85, RR 24, O2 sat 89% on 2 liters Nasal Cannula. Patient is alert, dyspneic and complains of incisional pain.
4. Low Urine Output (Obstructed Foley) 45 year-old patient 24 hours after non-anatomic liver resection. HR 110, BP 130/90, RR 16, O2 sat 95%. Patient is complaining of abdominal pain. Urine output is absent for 2 hours.	**4. Low Urine Output (Hypovolemia)** 45 year-old patient 24 hours after non-anatomic liver resection. HR 110, BP 80/40, RR 12, O2 sat 92%. Urine output has been 10 ml for the last three hours. A fluid bolus was administered an hour earlier.
5. Cardiogenic Shock. 50-year-old male. Transferred from floor to ICU. One week after perforated diverticulitis and colectomy with primary anastomosis. HR 40, BP 80/40, RR 12, O2 sat 95%. Patient is responsive, but disoriented.	**5. Septic Shock.** 50-year-old male. Transferred from floor to ICU. One week after perforated diverticulitis and colectomy with primary anastomosis. HR 40, BP 80/40, RR 12, O2 sat 95%. Patient is responsive, but disoriented.
6. Endotracheal Tube Cuff Leak. 62-year-old ventilated patient in the ICU on POD 1 after resection of abdominal wall tumor. Ventilator is alarming (low pressure). HR 115, BP 100/70, RR 12, O2 sat 86%. Patient is responsive, but disoriented.	**6. Mucus Plug.** 62-year-old ventilated patient in the ICU on POD 1 after resection of abdominal wall tumor. Ventilator is alarming (high pressure). HR 115, BP 100/70, RR 12, O2 sat 86%.
7. Hyperkalemia due to Pulseless Leg. 25-year-old ICU POD 1 after ORIF right leg, soft tissue and extensive vascular repair secondary to MVA. HR 110, BP 110/70, RR 12, O2 sat 95%. Patient is responsive, but disoriented. Monitor tracing indicates peaked T waves. Patient is responsive, but disoriented. Potassium returns 7.4 meq/dL	**7. Hyperkalemia due to Crush Injury.** 25-year-old ICU POD 1 after ORIF right leg, soft tissue and extensive vascular repair secondary to MVA. HR 110, BP 110/70, RR 12, O2 sat 95%. Monitor tracing indicates peaked T waves. Patient is responsive, but disoriented. Potassium returns 7.4 meq/dL
8. Ischemic Stroke. 65 year old patient in the ICU on POD 1 after duodenal resection. HR 90, BP 130/70, RR 12, O2 sat 95%. Patient is responsive, but disoriented. On neurologic examination, patient has right-sided weakness.	**8. Opioid Overdose.** 65 year old patient in the ICU on POD 1 after colonic resection. HR 70, BP 100/60, RR 6, O2 sat 88%. Patient is responsive, but disoriented. Pupils are 2mm.

Table 2

Performance on Form A and B Scenarios

Number of assessments for each scenario (n), Mean Checklist and Global scores (±SD), and Discrimination (D) values.

Form A Scenarios	Checklist (%) Global (1-9) (Mean±SD)	D*	Form B Scenarios	Checklist Global (Mean±SD)	D*
3rd degree HB (n=23)	69.6±16.8 5.2±1.5	0.47 0.55	**A Fib** (n=25)	70.2±28.0 5.0±2.2	0.66 0.53
ARDS (n=23)	71.5±18.6 5.41±1.9	0.60 0.71	**PE** (n=23)	65.0±16.3 5.5±1.5	0.68 0.24
Asthma (n=25)	70.5±15.7 6.0±1.1	0.57 0.61	**Atelectasis** (n=25)	78.70±13.2 6.0±1.3	0.47 0.70
Obstructed Foley (n=23)	76.3±15.8 7.2±1.2	0.02 0.35	**Hypovolemia** (n=25)	76.2±18.8 6.4±1.0	0.32 0.61
Cardiogenic shock (n=23)	72±10.9 4.7±1.4	0.23 0.65	**Septic Shock** (n=25)	81.4±10.3 6.0±1.1	0.12 0.42
Cuff Leak (n=25)	70.2±22.6 6.1±1.9	0.40 0.48	**Mucus Plug** (n=23)	69.1±15.7 5.5±1.6	0.60 0.45
Pulseless Leg (n=25)	74.7±19.9 5.8±1.9	0.63 0.74	**Crush Injury** (n=23)	84.5±17.3 6.6±2.0	0.60 0.55
Stroke (n=25)	71.0±19 6.2±1.2	0.54 0.34	**Opioid OD** (n=23)	76.2±14.1 6.0±1.3	0.37 0.40

*
D Discrimination-Correlation of Mean Score on Scenario with Overall Mean Performance

Table 3

Performance by Group

Mean of average checklist score (% correct) and average global scores by Group (±SD), and range of individual scenario scores.

Group	Scores	N	Mean	Range
Experienced Group (Fellows/senior ACNP students)	Checklist (%) Global (1-9)	26	75.6±15.6[*] 6.1±1.6[*]	30.0-100 1.0-9.0
Intermediate Group (Residents)	Checklist (%) Global (1-9)	8	75.4±18.3 5.7±1.7	33.3-100 2.0-9.0
Novice Group (Novice ACNP students)	Checklist (%) Global (1-9)	14	68.8±21.0 5.4±1.5	11.1-100 1.0-8.0

[*] significantly different from Novice Group by 2-way repeated measures ANOVA and post-hoc Scheffe's test (see Text).

Table 4

Quality of the Simulation Experience

Mean response, SD, min and max for participant responses to post-simulation assessment survey (1=strongly disagree; 2=disagree; 3=neutral; 4 agree; 5 strongly agree).

Variable	Mean	SD	Min	Max
The simulated patient and environment were realistic	4.0	0.7	2	5
The selected simulation scenarios represented events that might occur in practice	4.8	0.4	4	5
The chosen scenarios were important to practice	4.8	0.4	4	5
The events included are stress provoking in clinical settings	4.7	0.6	3	5
Practice scenarios will improve my performance in clinical settings	4.7	0.5	3	5

1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree