Utilizing Simulation Technology for Competency Skills Assessment and a Comparison of Traditional Methods of Training to Simulation-Based Training

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BACKGROUND: The respiratory care department of one campus within our health system evaluated simulation-based medical education for training and competency evaluation of the mini bronchoalveolar lavage (mini-BAL) procedure, with an emphasis on patient safety and procedure performance standards. METHODS: Training and competency evaluation occurred in 4 phases. In phase one, 24 staff respiratory therapists (RTs) were randomly chosen and individually underwent a simulation-based test of their mini-BAL performance, using a patient-simulator mannequin. Their performance on this test reflected the effectiveness of traditional training methods. In phase two, 83 staff RTs were given unlimited access to a Web-based curriculum on mini-BAL, including a video of a mini-BAL. They then took 2 tests: one online Web-based test, then a patient-simulator test. In phase three, the same 83 RTs attended a workshop that used the patient simulator for training and practice, then were re-evaluated with the patient-simulator test. Phase four was another simulator-based re-evaluation, 90 days after phase three, to study skills retention. RESULTS: The mean scores were: phase one 73 ± 10%, phase two 77 ± 11%, phase three 95 ± 5% ($p < 0.01$), phase four 92 ± 8%. CONCLUSION: Our results suggest that employing simulation technology within a comprehensive departmental program can enhance staff training. *Key words: training, bronchoalveolar lavage, simulator*. [Respir Care 2007;52(3):263–270. © 2007 Daedalus Enterprises]

Introduction

Like many respiratory care departments, we rely on medicine's traditional hands-on method of learning to train our staff. The apprenticeship model, often referred to as "see one, do one," is predominately used and, with varying degrees of supervision, clinical procedures are generally mastered via repeated practice on patients. This process has shortcomings. Patients can be put at risk, and sometimes skills do not fully develop. In-service/didactic training may be useful for instilling medical knowledge, but is often inadequate for teaching the psychomotor skills required to safely perform some medical procedures. Though clinical apprenticeship is indispensable, it does not ensure consistency in the information delivered or permit a standardized experience for all trainees. Also, despite various strategies such as "dedicated educators" and designated

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"competency days," objectively measuring staff performance can be difficult.

The 1999 Institute of Medicine report "To Err Is Human" identified inadequate education and training of clinicians as a key problem, and simulation was mentioned as an innovative approach to performance improvement and health-care training.[1] Simulation is a training and feedback method in which trainees can repeatedly practice tasks in lifelike circumstances without endangering patients. Although relatively new to medical education, simulation is well established in other disciplines. Examples include flight simulators for pilots and technical operations for nuclear power personnel. Anesthesiologists have used simulated clinical environments and computer-controlled full-body patient simulators since the mid-1990s for training in procedures, crisis management, and teamwork.[2–5] The latest generation of computer-based mannequins can simulate human physiology and a variety of pathologies and simulated scenarios that present a wide range of realistic events for training of both novices and experts. Evaluation techniques such as video review and post-simulation debriefing can provide immediate feedback. Some simulator programs also provide a timed log of the trainee's actions, which limits the subjectivity of performance evaluation.[6–8] The use of simulation as a means of objective skills assessment is well recognized, and studies indicate that simulation not only improves learning but is especially effective in developing procedural skills.[7,9]

We used simulation as a means of objective skills assessment and also investigated its use as a standardized, reproducible method of staff instruction for a specialized clinical procedure, the mini bronchoalveolar lavage (mini-BAL), which is currently performed by all respiratory therapists (RTs) in our institution. This project was part of a departmental quality improvement program. The objectives were: (1) to determine the staff's mini-BAL proficiency prior to implementing the new training and assessment procedures in order to determine the effectiveness of current traditional training; (2) to determine the effect of adding a Web-based didactic tutorial (that included a video of a mini-BAL) on objective measures of mini-BAL performance; (3) to determine the effect of a simulation-based training session on simulated mini-BAL performance; (4) to test skills retention 90 days after the simulation training.

Mini-BAL is a blind (nonbronchoscopic) procedure for obtaining lower-respiratory-tract samples for diagnosing ventilator-associated pneumonia.[10] The mini-BAL procedure performed at our institution uses a sterile prepackaged, commercially available telescoping catheter (BAL Cath, Ballard Medical Products, Draper, Utah) (Fig. 1). The telescoping catheter is passed through the endotracheal or tracheostomy tube, using an accompanying prepackaged access port adapter. With the curved tip of the catheter directed toward the desired lung, the outer catheter is advanced into the left or right bronchus. The inner catheter is advanced into a wedged position. Then sterile, physiologic saline solution is injected through the catheter into the airway, and then suctioned out. The lavage sample is sent to the microbiology laboratory for quantitative analysis.[11]

Fig. 1. Mini bronchoalveolar lavage procedure performed on a full-body patient simulator.

The mini-BAL program at our institution was implemented in April 2002. Our traditional mini-BAL training was via in-services, procedure demonstration, and apprenticeship, which consisted of bedside mentoring by a peer(s) or instructor for 3 consecutive mini-BALs prior to operating independently. Once apprenticeship was completed, the staff member could act as a mentor. All staff were required to demonstrate the mini-BAL to a designated instructor(s) for yearly competency validation.

Methods

The study was approved as a quality improvement project by the Total Quality Council of the University of Pittsburgh Medical Center Presbyterian Hospital. All simulation-based medical education occurred at the Winter Institute for Simulation Education and Research, a medical simulation and education center affiliated with our health system. The simulation center incorporates Web-based curriculum, simulation-based training, video of the trainee's performance, data collection, and post-simulation debriefing.

Our focus was on proper procedure and individual psychomotor skills, both of which can impact sample quality

Fig. 2. Competency evaluation of the mini bronchoalveolar lavage procedure.

and patient safety. To mimic clinical reality, the simulation room was configured to resemble an intensive care unit patient room (Fig. 2).[12–16] We designed one scenario involving an intubated and ventilated intensive care unit patient. Vital signs (heart rate, blood pressure, and pulse-oximetry reading) remained within acceptable limits throughout the procedure. The participants were required to properly screen the simulated patient as a candidate for mini-BAL, to appropriately manage the ventilator and airway, to perform the mini-BAL, and to monitor patient tolerance per procedure guidelines.

We used a computer-based full-body patient simulator (SimMan, Laerdal, Wappingers Falls, New York) because of its availability within our simulation center and because it contributed to the reality of the scenario.[16,17]

Evaluation Methods

Simulation was used to measure staff performance in all phases of this project. Phase two also included an online (Web-based) test. All participants were introduced to the simulated intensive care patient room and the patient simulator, given time to review equipment (ventilator, suction equipment, monitor, telescoping catheter, etc) and then asked to perform the mini-BAL. All participants were given the same scenario and patient information in a mock patient chart.

To objectively measure procedure and skills demonstration, the mini-BAL procedure was defined as a sequenced set of tasks (Table 1). Three educators from the respiratory care department were trained as facilitators. Two of the facilitators observed the procedures and used an electronic checklist to independently document each RT's actions. After each scenario simulation the 2 facilitators' checklists were compared for consistency.[18,19] If inconsistency occurred, a third facilitator reviewed the video for final determination of score. The video was also used for performance review and debriefing the test-taker, if appropriate. Tasks were scored 1 if correctly completed or 0 if not correctly completed, and the individual's total score was the percentage of the 20 checklist points that the RT correctly completed.

We also surveyed the RTs regarding their attitudes toward simulation training and their self-assessment of their confidence and competence in the procedure.

Phase One: Mini-BAL Simulation Performance With Only Traditional Training

To establish a departmental performance benchmark, 24 staff RTs (which was 23% of the total department staff at the time) were randomly chosen and individually simulation-tested to study their current mini-BAL performance. Random selection was based on availability of staff members present during 3 shifts when the simulators were available for testing. All 24 RTs had received the standard departmental training in mini-BAL and were deemed competent via traditional methods, which consisted of physi-

Table 1. Mini-BAL Procedure Performance Checklist*

1. Reviewed and confirmed order for mini-BAL
2. Confirmed that hematology results were within established thresholds
3. Reviewed contraindications and cautions and assessed patient for contraindications
4. Pre-oxygenated the patient with 100% oxygen
5. Used universal precautions
6. Suctioned patient airway
7. Set up suction equipment and sputum trap
   a. Replaced existing suction tubing with sterile tubing
   b. Attached sputum trap to suction tubing
8. Patient pre-assessment
   a. Reviewed baseline vital signs and ICP
   b. Reviewed baseline ventilator parameters
9. Catheter preparation
   a. Attached suction adapter to stopcock
   b. Passed catheter 1.5 inch through ETT elbow
10. Avoided contaminating catheter tip when attaching catheter to ETT
11. Directed catheter to correct lung
12. Advanced outer catheter to 38 at blue lock
13. Confirmed direction and advanced 3–5 cm
14. Safely advanced catheter into wedge position
15. Locked outer catheter in position
16. Lavage
   a. Infused saline in 20-mL aliquots
   b. Aspirated sample after each aliquot
   c. Demonstrated accurate lavage volume
17. Preserving sample
   a. Turned off suction
   b. Removed sputum trap
18. Catheter withdrawal
   a. Retracted catheter from airway
   b. Reattached ETT to ventilator
19. Patient post-assessment
   a. Reviewed vital signs and ICP
   b. Reviewed ventilator parameters
20. Correct lung sampled

*Scoring system: 1 = completed. 0 = not completed.
BAL = bronchoalveolar lavage
ICP = intracranial pressure
ETT = endotracheal tube

cian lecture, initial demonstration of skill by an instructor, demonstration of skill by the trainee, and bedside mentoring by peers and instructors.

The 24 RTs tested in phase one had an average of 13 years experience within our health system, and they had performed an average of 25 prior mini-BALs each (Table 2). All participants were registered RTs or were registry-eligible at the time of the evaluation. The evaluation results were not discussed, procedure errors were not corrected, and no simulation training occurred before the phase-one test.

Phase Two: Web-Based Training, Online Test, and Simulator Test

In phase two, 83 staff RTs were given access to a Web-based presentation (PowerPoint, Microsoft, Redmond, Washington) on the mini-BAL and a video of the procedure. All 83 RTs had received prior training and were deemed competent via traditional methods. None of these 83 RTs had participated in the phase-one evaluation. The Web-based presentation described the need and rationale for mini-BAL invasive diagnosis and management of ventilator-associated pneumonia. It also included indications, contraindications, equipment required, and procedural steps. All 83 RTs were required to view the Web site and complete an online multiple-choice test. The RTs had unlimited access to the material and video for frequent review if desired. After completion of the online test, staff were scheduled for the mini-BAL simulation workshop. At the simulation center, each RT individually took the simulation test, prior to the phase-three training. The evaluation results were not discussed, procedure errors were not corrected, and no simulation training occurred before the phase-two simulation test. Phase two was designed to measure the impact of the Web-based curriculum alone.

Phase Three: Web-Based Training Plus Simulation Training

Immediately following phase-two testing, the same 83 RTs attended a workshop that employed simulation-based training and practice. The workshop included individual instruction and hands-on practice with the patient simulator. Following the workshop, each RT was individually tested with the simulator. Any deficiencies discovered were addressed privately with each RT, and additional training was completed if necessary to ensure safe and standard mini-BAL performance. Six RTs were new employees and received only the simulation training in mini-BAL.

Phase Four: 90-Day Skills Retention

To assess the impact of simulation training on skills retention, 24 RTs were randomly selected to be re-tested via simulation 90 days after the phase-three test.

Results

The mean score for phase one was 73 ± 10%, which represented traditional training methods. Interestingly, the number of prior mini-BALs an RT had performed did not correlate to performance score (Fig. 3).

The mean score for phase two was 77 ± 11%, which represented the impact of the Web-based curriculum.

Table 2. Clinical Experience and Mini-BAL Procedures Previously Performed

	Mean ± SD	Median	Maximum	Minimum
Phase I				
Years of experience	13.4 ± 11.1	15.9	36.7	0.1
Number of mini-BAL procedures performed	25.6 ± 23.2	15.0	73.0	0.0
Phases II and III				
Years of experience	9.1 ± 9.9	3.4	37.3	0.1
Number of mini-BAL procedures performed	14.9 ± 22.1	5.0	115.0	0.0
Phase IV				
Years of experience	13.2 ± 11.3	15.7	36.7	0.1
Number of mini-BAL procedures performed	26.6 ± 24.3	16.0	78.0	1.0

BAL = bronchoalveolar lavage

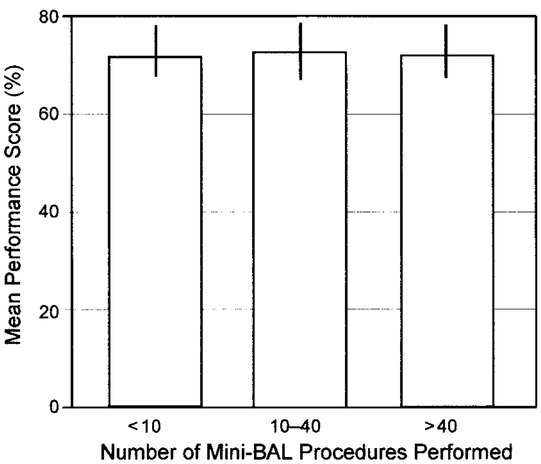

Fig. 3. Phase one mean performance score on the simulation tests for the mini bronchoalveolar lavage procedure, in relation to the number of mini bronchoalveolar lavage procedures the test-takers had previously performed. The number of prior procedures performed did not significantly correlate to performance score in the phase one evaluation.

The mean score for phase three was 95 ± 5% ($p < 0.01$), which represented the effect of the simulation-based training. The mean score on critical tasks that require psychomotor function improved from 49% in phase one to 93% in phase three (Table 3). The 6 new employees who received only simulation training in mini-BAL had a mean score of 96 ± 4%.

The mean score for phase four was 92 ± 8%, which reflected skills retention after 90 days (Table 4 and Fig. 4).

The survey results (Table 5) indicate that the RTs' self-evaluation of their procedure competence significantly improved after simulation training (Fig. 5), and the number of RTs who felt uncomfortable with simulation-based training and testing fell from 28% to zero. Most of the RTs (76%) believed that simulation will be a necessary part of re-credentialing in the future.

Discussion

A comparison of the phase-one and phase-two scores (73% and 77%, respectively) implies that the Web-based curriculum and video did not significantly impact procedure performance. This would seem to indicate that the on-line material was ineffective, although the scores from the on-line test in phase two did validate the participants' conceptual understanding. A probable cause of this lack of improvement could be the number of times that the RTs accessed the Web-based curriculum. We do not know how often the Web-based materials were reviewed, because the system was not configured to measure how often the staff accessed the Web material beyond the initial review and online test completion.

The complexity of many clinical procedures is not well understood without first-hand experience. Although mini-BAL is a relatively common procedure in our institution, some staff may get limited and inconsistent opportunities for the repetition required to fully develop and maintain mini-BAL skill. Even the number of mini-BALs that should be required to complete training is not well defined, and the number differs among institutions. The simulation training in phase three improved mean staff score to 95%, and the mean score on tasks that require psychomotor function improved, which suggests that this aspect of mini-BAL training can be enhanced with simulation (see Table 4). These psychomotor tasks are critical and can impact sample quality and patient safety.

Simulation-based training allows trainees to integrate basic procedure skills, such as ambidextrous maneuvers and hand-eye coordination maneuvers, into their clinical technique, and to repeatedly practice in a realistic manner and setting, with immediate feedback.[20,21] This cannot be easily done in traditional training with patients, given all their diversity and variability. Some skills follow immediately from conceptual knowledge, whereas others, such as complex psychomotor activities, must be developed. In the phase-one testing, which reflected traditional mini-

Table 3. Improvement in Mini-BAL Procedure Task Scores That Reflect Psychomotor Function

Psychomotor Skill	Phase I (mean % among 24 RTs)	Phase II (mean % among 84 RTs)	Phase III (mean % among 84 RTs)
Passed catheter 1.5 inch through ETT elbow	58	52	99
Did not contaminate catheter tip	21	30	93
Directed catheter to correct lung	46	59	93
Advanced catheter to 38 at blue lock	75	93	98
Safely advanced catheter into wedge	75	52	95
Correct lung sampled	21	52	80

BAL = bronchoalveolar lavage
RT = respiratory therapist
ETT = endotracheal tube

Table 4. Performance Scores on the Simulation Test for the Mini Bronchoalveolar Lavage Procedure

Phase	Mean ± SD %	Median %	Maximum %	Minimum %
I	73 ± 10	74	93	57
II	77 ± 11	79	100	50
III	95 ± 5	96	100	79
IV	92 ± 7	95	100	72

BAL = bronchoalveolar lavage

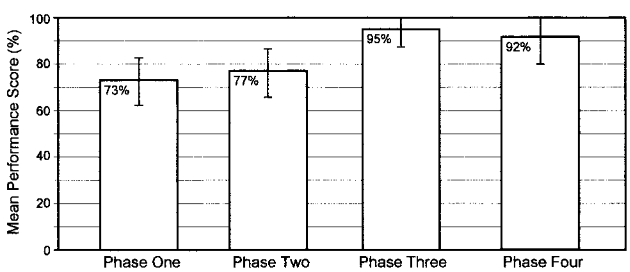

Fig. 4. Mean performance scores on the simulation test for the mini bronchoalveolar lavage procedure.

BAL training, the number of mini-BALs the RT had performed previously did not correlate to individual performance score (see Fig. 3), which may indicate that procedure performance is more a result of initial training than experience and that simulation may allow the trainee to climb the learning curve faster, as suggested by the 6 RTs who received only simulation training.

The issue of skills retention is intriguing; it is often difficult to determine how long clinicians maintain their skills. Knowledge gained via simulation is retained longer than knowledge gained via lecture.[18,22,23] Although a direct comparison of skills retention could not be made between the phase-one and phase-four evaluations, our data does indicate that, at least up to 90 days, skills retention is good after simulation training.

We acknowledge that this study was not designed as a controlled research trial but rather a quality-improvement project that had limitations. Our narrow focus on procedural steps and psychomotor skills excluded testing of cognitive information related to or beyond the procedure, although that might have identified clinically important differences between training methods. Our staff had prior training and bedside experience in mini-BAL, and we evaluated the impact of multiple technologies and training methods, which may have created confusion because of the potential additive effect of the technologies and methods and/or differences between them. However, we are convinced our program was effective, because it established simulation as an objective method of competency verification in our department, by focusing on the trainee's actual performance and excluding judgment differences between observers and the variability in patients and settings in clinical competency assessments. Furthermore, the survey results and changes in performance score indicate a positive effect on mini-BAL performance and staff attitude.

Completion of our mini-BAL training course does not necessarily correlate with improved clinical performance. Although there is currently little evidence that simulation training improves patient care, common sense would suggest that improved technical skills should lead to fewer complications and, in a sampling procedure such as mini-BAL, consistency in sample quality.

We learn best through activities that require our active participation. Through simulation, trainees are directly engaged and receive immediate feedback and reinforcement. We envision task-based simulation as a prelude to clinical practice and an adjunct to skills maintenance.

Several practical questions must be addressed when assessing the feasibility and value of simulation training and testing, including cost, training needs, available resources, and number of staff to be trained. Costs will differ widely, depending on the application. Although trainees and course developers may prefer the "bells and whistles" of full-

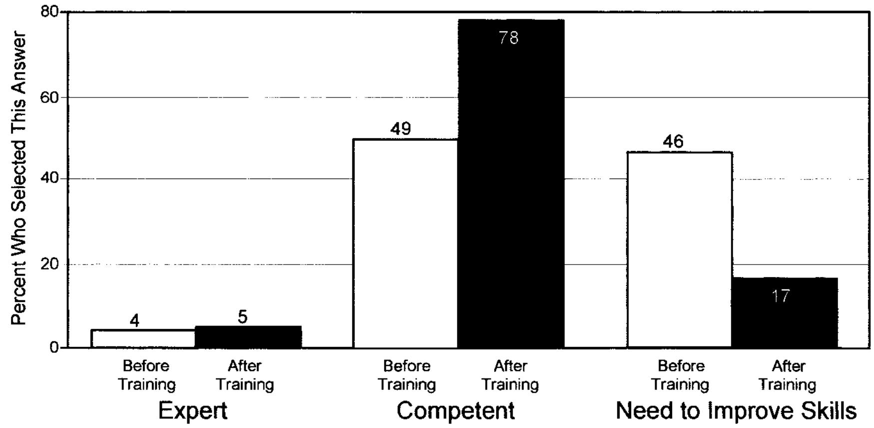

Fig. 5. Staff self-evaluation of competence in performing the mini bronchoalveolar lavage procedure.

Table 5. Staff Survey Responses Before and After Simulation Training

Self-Evaluation of Competence and Confidence	Percent Who Selected This Answer	
	Before Training	After Training
Competence		
I am an expert in this procedure	4	5
I am competent in this procedure	50	78
I need to improve my skill/competence in this procedure	47	17
Confidence		
I am very confident in this procedure	13	24
I am confident in this procedure	62	70
I am not confident in this procedure	25	7

Attitudes About the Simulation Training	Strongly Disagree (% before/after)	Disagree (% before/after)	Agree (% before/after)	Strongly Agree (% before/after)
In the future, simulation will be a necessary part of re-credentialing.	NA/0	NA/24	NA/76	NA/0
I am uncomfortable with simulation-based competency training.	24/76	50/24	19/0	7/0
I am uncomfortable with simulation-based competency because I do not believe it is valid form of skills assessment.	29/85	51/16	14/0	6/0

NA - not applicable, because this question was asked only after the training

body simulators, departments can maximize their resources by using "partial task trainers" specific to training goals. For example, a less expensive head-and-neck model may have been sufficient for our mini-BAL training, although it would not have provided a realistic feel of catheter advancement into the lung or monitoring and manipulation of physiologic variables.

There are no statutes that require competency verification for the respiratory care staff. However, the Joint Commission on Accreditation of Health Care Organizations and individual states expect that hospitals examine staff competency and evaluate the safety of the care they deliver. Whereas safety improvement and impact on patient outcome are difficult to assess, immediate improved performance of individuals can be readily discernable. The usefulness of simulation technology in training and documenting RT competency for quality assurance and accreditation should be considered and further studied.

Conclusion

Assessing clinical and procedural skills of RTs remains a challenge for many respiratory care departments, and needs to be a priority. Our results suggest that employing simulation technology within a comprehensive departmental program can enhance staff training, provide an objective measure of skill, and potentially improve skill retention.

REFERENCES

1. Corrigan J, Kohn LT, Donaldson MS, editors. To err is human: building a better health system. Washington DC: National Academy Press; 1999.
2. Schaefer JJ, Gonzalez R. Dynamic simulation: a new tool for difficult airway training of professional healthcare providers. Am J Clin Anesth 2000;27(3):232–242.
3. DeVita MA, Schaefer J, Lutz J, Dongilli T, Wang H. Improving medical crisis team performance. Crit Care Med 2004;32(2 Suppl): S61–S65.
4. DeVita MA, Schaefer J, Lutz J, Wang H, Dongilli T. Improving medical emergency team (MET) performance using a novel curriculum and a computerized human patient simulator. Qual Saf Health Care 2005;14:326–331.
5. Grenvik A, Schaefer J. From Resusci-Anne to Sim-Man: the evolution of simulators in medicine. Crit Care Med 2004;32(2 Suppl): S56–S57.
6. Schwid HA, Rooke GA, Carline J, Steadman RH, Murray WB, Olympio M, et al; Anesthesia Simulator Research Consortium. Evaluation of anesthesia residents using mannequin-based simulation: a multiinstitutional study. Anesthesiology 2002;97(6):1434–1444.
7. Boulet JR, Murray D, Kras J, Woodhouse J, McAllister J, Ziv A. Reliability and validity of a simulation-based acute care skills assessment for medical students and residents. Anesthesiology 2003; 99(6):1270–1280.
8. Devitt JH, Kurrek MM, Cohen MM, Fish K, Fish P, Noel AG, Szalai JP. Testing internal consistency and construct validity during evaluation of performance in a patient simulator. Anesth Analg 1998; 86(6):1160–1164.
9. Grantcharov TP, Kristiansen VB, Bendix J, Bardram L, Rosenberg J, Funch-Jensen P. Randomized clinical trial of virtual reality simulation for laparoscopic skills training. Br J Surg 2004;91(2):146–150.
10. Kollef MH, Bock KR, Richards RD, Hearns ML. The safety and diagnostic accuracy of minibronchoalveolar lavage in patients with suspected ventilator-associated pneumonia. Ann Intern Med 1995; 122(10):743–748.
11. Delgado E, Tuttle R, Cohen M, Darby J. Effect of lavage volume on microbiological yield using blind bronchoalveolar lavage. Crit Care Med 2004;32(12 Suppl):A152.
12. Gaba DM, Howard SK, Flanagan B, Smith BE, Fish KJ, Botney R. Assessment of clinical performance during simulated crises using both technical and behavioral ratings. Anesthesiology 1998;89(1):8–18.
13. Dawson SL. A critical approach to medical simulation. Bull Am Coll Surg 2002;87(11):12–18.
14. Weller JM, Bloch M, Young S, Maze M, Oyesola S, Wyner J, et al. Evaluation of high fidelity patient simulator in assessment of performance of anaesthetists. Br J Anaesth 2003;90(1):43–47.
15. Issenberg SB, McGaghie WC, Hart IR, Mayer JW, Felner JM, Petrusa ER, et al. Simulation technology for health care professional skills training and assessment. JAMA 1999;282(9):861–866.
16. Friedrich MJ. Practice makes perfect: risk-free medical training with patient simulators. JAMA 2002;288(22):2808, 2811–2812.
17. Cioffi J. Clinical simulations: development and validation. Nurse Educ Today 2001;21(6):477–486.
18. Devitt JH, Kurrek MM, Cohen MM, Cleave-Hogg D. The validity of performance assessments using simulation. Anesthesiology 2001; 95(1):36–42.
19. Weller JM, Bloch M, Young S, Maze M, Oyesola S, Wyner J, et al. Evaluation of high fidelity patient simulator in assessment of performance of anesthetists. Br J Anaesth 2003;90(1):43–47.
20. Jacobs LM, Burns KJ, Luk SS. Advanced trauma operative management course introduced to surgeons in West Africa. Bull Am Coll Surg 2005;90(6):8–14.
21. Ost D, DeRosiers A, Britt EJ, Fein AM, Lesser ML, Mehta AC. Assessment of a bronchoscopy simulator. Am J Respir Crit Care Med 2001;164(12):2248–2255.
22. Devitt JH, Kurrek MM, Cohen MM, Fish K, Fish P, Noel AG, Szalai JP. Testing internal consistency and construct validity during evaluation of performance in a patient simulator. Anesth Analg 1998; 86(6):1160–1164.
23. Kneebone RL, Scott W, Darzi A, Horrocks M. Simulation and clinical practice: strengthening the relationship. Med Educ 2004;38(10): 1095–1102.