The Benefits of a Human Simulator Training Course for Initial First-Year Anesthesia Residency Education[§]

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Abstract: *Introduction*: Simulator training offers an opportunity to safely educate new residents in a conducive learning environment.

Methods: New, first-year anesthesia residents received a 3-day training course prior to beginning clinical training. Instruction focused on developing knowledge and skills for operating room preparation, general anesthesia induction, airway and anesthesia management, and post-operative transfer of care. Before training, residents rated their confidence for performing basic anesthesia skills and completed a knowledge test. At course completion, residents performed operative management for a simulated healthy patient undergoing uncomplicated general anesthesia and repeated the confidence and knowledge tests.

Results: Forty-five new, first-year residents enrolled in and completed the simulator course. Prior to training, residents were neutral about their confidence for performing laryngeal mask airway placement, operating room preparation, general anesthesia induction, or transfer of patient care. They were confident that they could perform bag-mask ventilation and direct laryngoscopy prior to training. Mean percentage of correct answers on the knowledge test was 53% before training. After training, confidence for performing each of the six assessed anesthesia skills increased numerically, with residents expressing confidence in performing every skill. Increases achieved statistical significance ($P<0.01$) for all skills except for bag-mask ventilation. Mean correct responses on the knowledge test after training increased to 69%.

Conclusions: A brief, 3-day didactic and simulator training course for new, first-year anesthesia residents can improve resident confidence and competency to begin clinical anesthesia training.

Keywords: Airway management, anesthesia resident, comfort, simulator, training.

OVERVIEW

- What is already known

Human simulators provide an effective tool to assess clinical skill base and facilitate training of healthcare personnel across a variety of fields.

- What this study adds

Pre-training with a human simulator course prior to actual clinical patient exposure improves comfort with basic operative management and knowledge base for new, first-year, anesthesia residents.

- Suggestions for future research

Future research should compare clinical skill and knowledge acquisition between residents who received pre-clinical exposure to simulator training and those initiating training with traditional clinical exposures.

INTRODUCTION

Human simulators have been used to reliably assess medical skill competency [1] and provide an invaluable tool for teaching new or improved techniques to medical personnel in a variety of backgrounds [2, 3]. A survey of program directors from urological residency programs showed that the majority believed simulators were realistic, easy to use, and provided a good educational tool for a variety of surgical procedures [4]. While all directors endorsed an important role for simulators in residency training and 96% believed simulators would reduce patient risk and complications, only 46% believed that simulators could replace hands-on clinical instruction.

Simulator training improves performance when used as the initial exposure to surgical techniques for trainees. Early simulator exposure is not designed to replace the need for clinical training, but rather provide a foundation of experience to improve trainees' ability to master complex skills in the clinical environment. Two randomized, controlled studies showed improved performance for new surgical residents exposed to laparoscopic surgery and minimally-invasive catheter-based surgical interventions [5, 6]. Pre-training with simulators before actual clinical exposure should help accelerate student learning when clinical training occurs and minimize patient safety risks.

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Early application of simulator training of anesthesia residents similarly showed improved clinical performance among those initially using simulators [7]. In a randomized study, endotracheal intubation skill was assessed in ten new residents, half of whom were trained with a simulator over 2 weeks and the other half taught with traditional methods. Residents receiving simulator training reached competency levels in the operating room sooner than those that did not, although most between-group comparisons failed to achieve statistical significance. Since this early study, others have demonstrated the ability of simulators to enhance clinical medical education; in anesthesiology they have typically evaluated residents who have already achieved some clinical expertise [8-10].

Newly enrolled, first-year anesthesia residents are uniformly uncomfortable with the process of delivering anesthesia. In particular, new residents lack exposure to anesthesia machines, which are complex and require many checks to ensure patient safety and the effective delivery of anesthesia. Simulator training allows complex tasks to be broken down into individual components. With a simulator, trainees can successfully master parts of the anesthesia machine before needing to understand the whole unit. In the operating room, conversely, the entire machine must function properly to ensure patient safety.

The potential advantages of initial simulator exposure include the ability to repeat training to achieve skill acquisition without risk to patients and training in a controlled environment. While all testing environments are inherently stressful, stress should be reduced for both trainee and instructor with simulated patients because of the absence of actual risk to human life. The current study was designed to evaluate trainee confidence in performing and knowledge of basic anesthesia skills after starting residency training with simulation. In this study, training benefits were evaluated by measuring both perceived self-confidence with and knowledge of necessary anesthesia skills.

METHODS

This prospective analysis was conducted as part of an assessment of new resident training with simulator scenarios in July of 2004, 2005, and 2006. This study was determined to be exempt from evaluation by the local Institutional Review Board.

Study Design

All new, first-year anesthesia residents entering a university training program were required to participate in a 3-day simulator training course prior to beginning clinical instruction. Trainees were required to successfully complete a skills acquisition clinical scenario assessment before graduating to clinical training. Prior to receiving simulator training, trainees provided information about previous clinical experiences: years of clinical practice (counting internship and residency), whether they had ever managed an airway in a clinical scenario, and how many times during the preceding 12 months they had bag-mask ventilated a patient, placed a laryngeal mask airway, and/or used direct larnygoscopy to place an endotracheal tube. They also completed a questionnaire assessing their confidence for performing six typical anesthesia skills: preparing the operating room for anesthesia, inducing general anesthesia, performing bag-mask ventilation, placing a laryngeal mask airway, performing direct laryngoscopy, and transferring patient care in the postoperative recovery suite. Trainees were asked to respond to the statement that they were confident they could perform each skill, using a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree) (Table **1**). Trainees were also asked to complete a 20-question anesthesia knowledge-based test (Appendix). This knowledge questionnaire was designed by the faculty administering the classes and all information needed to correctly answer each question was provided during the 3-day seminar. The pre-training knowledge test was used to evaluate baseline knowledge and also potentially focus trainees on important areas of anesthesia training that would be covered during the brief course.

After completing their baseline questionnaires, trainees began the simulator course, which included three 8-hour sessions. At each session, two hours were spent receiving didactic lectures and six hours were spent in simulator training. Topics covered during didactic and simulator sessions included preparation of anesthesia equipment in an operating room, airway management, induction of general anesthesia, and post-anesthesia care transfer. After completing the three days of education, each trainee was required to complete a simulated patient test in which one of three possible scenarios was provided to the trainee. Each scenario described an uncomplicated, healthy patient who was being prepared for a surgical procedure requiring general anesthesia (Box **1**). Scenarios were presented to trainees in random order. Performance was assessed by a faculty anesthesiologist actively engaged in clinical anesthesia care. Trainees were required to successfully perform a list of tasks to demonstrate competence for operating room preparation, general anesthesia induction, airway and anesthesia management, and postoperative transfer of care. Within each category, skills could be performed in any order. A total of 29 individual skills

Table 1. Perceived Confidence in Anesthesia Skills Questionnaire

Statement: I Am Confident that I Can …	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Bag-mask ventilate a human patient	1	2	3	4	5
Place a laryngeal mask airway in a human patient					
Perform direct laryngoscopy on a human patient					
Prepare an operating room to deliver general anesthesia					
Perform induction of general anesthesia					
Transfer a patient's care to a recovery room nurse					

were tested (Box **2**). If trainees failed to complete any of the 29 necessary tasks, the examiner was permitted to provide verbal prompts as reminders of necessary skills. The course instructors established an *a priori* level of >5 prompts to indicate that the trainee exhibited insufficient skill level to safely manage the patient in the scenario. In that case, trainees would be required to start another case and successfully complete it without excessive prompting. After successfully completing the simulated case testing scenario, trainees were asked to again complete the skill comfort questionnaire as well as the fund of knowledge questionnaire. Repeating evaluation with the same test used as pre-test assessment has been shown to effectively measure clinical knowledge acquisition [11-13].

Data Analysis

Demographics of course participants, responses to the knowledge test, and simulator testing were evaluated using descriptive statistics. Group mean scores were calculated for pre- and post-training confidence level for each of the six skill areas. Pre- and post-training confidence score comparisons were conducted using a Wilcoxon rank-sum test. Pre- to post-training knowledge scores were evaluated with paired t-tests. For all testing, significance was set at $P<0.05$.

Box 1. Case Scenarios

1. A 36 year old healthy male presents for arthroscopic right knee surgery. He had an uneventful tonsillectomy/adenoidectomy at age seven and currently takes no prescription medications. He has no known allergies. Physical examination is unremarkable. The patient requests general anesthesia.
2. A healthy 29 year old woman presents for elective, laparoscopic tubal ligation. She has had two full-term, uncomplicated vaginal deliveries. Her medical history is only remarkable for seasonal allergies treated with Claritin as needed. Her only other medication is oral contraceptives and she has no medication allergies. Her last menstrual period was last week. She had wisdom tooth extraction with general anesthesia uneventfully at age 19. Her physical examination is unremarkable. Lab values the day of surgery include a hemoglobin of 12.5 mg/dL and a negative pregnancy test. She is scheduled for general anesthesia.
3. A healthy 33 year old man presents for repair of a distal radial fracture. Medical history is remarkable for hypercholesterolemia, treated with Lipitor. He had an uneventful right inguinal herniorrhaphy at age 3 and has no medication allergies. Physical examination is unremarkable. Patient requests general anesthesia.

Box 2. Simulator Case Performance Assessment Criteria

1. Operating room preparation skills
   - ☐ Turn on machine
   - ☐ Check oxygen supply
   - ☐ Check fail-safe valve
   - ☐ Check low pressure system
   - ☐ Check oxygen analyzer
   - ☐ Check circle system
   - ☐ Check suction
   - ☐ Prepare basic ASA monitors
   - ☐ Prepare airway equipment (e.g., oral and laryngeal mask airways) and check endotracheal tubes
   - ☐ Prepare emergency medications
   - ☐ Achieve ready position with adjustable pressure-limiting valve open, selector switch to bag, and all flow meters to minimum
2. General anesthesia induction skills
   - ☐ Prepare anesthetic medications
   - ☐ Place basic monitors
   - ☐ Place patient in sniffing position
   - ☐ Establish adequate pre-oxygenation
   - ☐ Administer appropriate doses of propofol or pentothal and succinylcholine
3. Airway and anesthesia management skills
   - ☐ Perform bag-mask ventilation
   - ☐ Perform laryngeal mask airway placement and ventilation
   - ☐ Perform direct laryngoscopy and endotracheal tube placement
   - ☐ Confirm endotracheal tube placement
   - ☐ Activate ventilator and adjust settings
   - ☐ Begin maintenance of general anesthesia
4. Post-operative transfer of care skills
   - ☐ Provide patient and procedure information
   - ☐ Provide pertinent past medical history
   - ☐ Provide patient medication and allergy information
   - ☐ List anesthetics administered
   - ☐ Report volume status, including fluids transfused and estimated blood loss
   - ☐ Describe intraoperative course
   - ☐ Write simple post-operative orders

Trainees were required to successfully complete each skill in every task category.

RESULTS

Participants

A total of 45 new first-year anesthesia residents participated in this course, 13 during July 2004, and 16 each during July of 2005 and 2006. Trainees included 31 males and 14 females, with a mean age of 29.6 ± 4.6 years. The mean years of clinical experience at the time of participation was 3.0 ± 3.7 years, with a range of 1-17 years. The most common number of clinical experience years was a single (internship) year, which was the level of previous clinical experience for 19 residents (42%). A total of 42 participants answered questions about previous experience with airway management, with 36 reporting prior experience and 6 reporting no experience. The number of times participating in different forms of airway management varied widely among trainees. Previous exposure to bag-mask ventilation was reported for an average of 29.9 exposures (range 0-350), laryngeal mask ventilation an average of 2.2 exposures (range 0-25), and direct laryngoscopy an average of 22.6 experiences (range 0-300).

All trainees completed the post-course testing scenario. Each trainee successfully completed the first case presented, with none requiring more than one case to pass the scenario testing. None of the residents required more than five prompts during his/her simulated case scenario.

Pre- and Post-Course Confidence with Anesthesia Skills

As expected, average scores for confidence to perform anesthesia skills before training indicated that the trainees did not agree that they were confident with most skills (Table **2**). Most pre-course scores were around 3, suggesting that they neither agreed nor disagreed with statements that they were confident they could perform the required skills, with the exception of bag-mask ventilation and ability to perform direct laryngoscopy. After completing the training course, confidence levels increased so that the mean scores for every skill were around 4, meaning that the trainees agreed they were confident in their ability to perform the required skill.

A secondary analysis was performed for those participants registering only a single year of previous clinical experience (internship). Confidence scores for this subgroup for pre- *vs* post-course statements were 4.0 ± 0.6 *vs* 4.3 ± 0.6 for bag-mask ventilation, 3.4 ± 1.1 *vs* 4.2 ± 0.6 for laryngeal mask airway placement, 3.8 ± 0.8 *vs* 4.2 ± 0.7 for direct laryngoscopy, 2.8 ± 1.4 *vs* 4.1 ± 0.7 for operating room preparation, 2.9 ±1.2 *vs* 4.2 ± 0.6 for general anesthesia induction, and 2.7 ± 1.1 *vs* 4.0 ± 0.8 for patient care transfer. Scores for the least experienced among the trainees, therefore, were similar to those for the entire group.

Pre- and Post-Course Knowledge Testing

Knowledge tests were completed by 44 participants (96%) before simulator training and 42 participants (91%) at course completion. The mean group percentage of correct answers was 53% ± 13% on the pre-test and 69% ± 9% on the post-test. This difference was significant ($P<0.001$). Percentages of correct scores on pre-and post- testing were similar among the three years. On pre-course testing, 27% of trainees scored ≥65% correct, 7% ≥75% correct, and 2% ≥80%. After completing training, scores improved, with 71% scoring ≥65% correct on post-course testing, 31% scoring ≥75%, and 21% scoring ≥80%.

Eight of the 20 knowledge questions (40%) were missed by over half of the trainees on the pre-test: question 2 (91% missed), question 3 (64%), question 6 (63%), question 9 (84%), question 15 (70%), question 18 (80%), question 19 (61%), and question 20 (59%). Three of the 20 questions (15%) were missed on the post-test by at least half of attendees: question 2 (69% missed), question 3 (52%), and question 9 (62%).

DISCUSSION

Prior to simulator or clinical training, new, first-year anesthesia residents are not confident that they can perform most necessary anesthesia skills when they begin their residency training. Lack of confidence in their skills was supported by pre-course accuracy on the knowledge test, with almost one in three trainees scoring below 65% accuracy. Completing the 3-day simulator training course resulted in significant increases in confidence and performance on the knowledge test. After course completion, trainees agreed that they were confident to perform all of the six evaluated anesthesia skills. This confidence was supported by all trainees successfully completing the clinical scenario on their first attempt after course completion. In addition, over 70% scored ≥65% on the knowledge test after the brief simulator training course. Only one in three participants scored ≥75%, supporting the use of this course as pre-training to supplement rather than replace additional didactic and hands-on clinical training. Clearly, this brief course is inadequate to thoroughly train new anesthesia residents in necessary basic anesthesia management skills. Improvement in knowledge and confidence in anesthesia, however, may help facilitate subsequent clinical training.

Table 2. Confidence in Performing Routine Anesthesia Skills (Mean ± Standard Deviation)

Statement of Confidence	Pre-Course	Post-Course	*P*-Values
Bag-mask ventilate a human patient	4.1 ± 0.8	4.4 ± 0.6	0.0911
Place a laryngeal mask airway in a human patient	3.4 ± 1.1	4.2 ± 0.7	0.0024
Perform direct laryngoscopy on a human patient	3.9 ± 1.0	4.4 ± 0.6	0.0098
Prepare an operating room to deliver general anesthesia	3.1 ± 1.5	4.2 ± 0.7	0.0017
Perform induction of general anesthesia	3.2 ± 1.4	4.2 ± 0.7	0.0004
Transfer a patient's care to a recovery room nurse	3.1 ± 1.3	4.1 ± 0.8	0.0008

Data from this study support and extend findings from earlier studies showing benefit in residents with previous clinical anesthesia residency training. The current study supports that new residents can improve their knowledge of and comfort level with performing a variety of necessary daily tasks performed during patient management in the operating room with pre-clinical exposure to a brief, simulator training program. Skill and knowledge acquisition can successfully occur prior to actual patient care experiences in the training program; future studies are needed to support that this initial performance benefit may expedite training in the operating room and improve patient safety.

Unexpectedly, untrained residents on average neither agreed nor disagreed that they were confident in performing anesthesia skills. Although new residents as a group did not agree that they were confident in performing most anesthesia skills before completing the simulator course, they also did not disagree that they were confident with performing any of the six anesthesia skill categories before the course, despite the large number of errors identified on the knowledge test. It was also interesting that confidence with skills was not substantially lower in those trainees who reported having only a single year of previous clinical training. This discrepancy in skill perception and performance supports training new residents in a safe environment to raise skill performance to a comparable level to their confidence before residents apply skills to actual patients.

Collecting data on knowledge acquisition can be used to help improve subsequent training sessions. Information was included in didactic lectures to correctly answer each of the proposed questions on the knowledge test. Failure of the majority of trainees to correctly answer most of the questions suggests a need to incorporate additional educational tools, such as additional visual aids, repetition of essential material, etc., to improve knowledge acquisition. In addition, identifying those questions incorrectly answered after training by the majority of participants further highlights areas where course modification is needed. Subsequent studies may wish to use a modified test after training to ensure trainees have successfully acquired knowledge of concepts rather than memorized answers to questions.

This study is limited by a relatively small sample size, which precludes subanalyses of trainee groups to help identify those residents for whom simulator training would be most beneficial. Furthermore, confidence in skills and success on a knowledge test and simulator scenario do not necessarily translate to improve performance in an actual operating room. Similar to the early trial by Abrahamson [7] in new residents, future studies should similarly evaluate operating room performance of residents who have and have not experienced simulator training. The operating room offers may additional challenges that cannot be replicated with simulator training; therefore, future studies might evaluate whether pre-clinical exposure to a simulator course improves ability to master skills on actual patients in the operating room. Future studies may also wish to evaluate the benefits of shorter duration training, as well as the full 3-day program supplemented with additional simulator training after new residents have initiated clinical rotations.

In summary, a brief, 3-day simulator-based training program can improve knowledge base and comfort with performing necessary operating room skills in new, first-year anesthesia residents. Implementing a training program before actual clinical care has begun helps ensure an adequate knowledge base to facilitate learning once residents begin actual patient care. Simulator training, therefore, may be incorporated into the pre-clinical training regimen for new anesthesia trainees.

APPENDIX. NEW ANESTHESIA RESIDENT KNOW-LEDGE-BASE QUESTIONNAIRE

1. Which of the following drugs would you most likely withhold on the day of surgery:

a. metoprolol
b. clonidine
c. furosemide
d. levothyroxine
e. ranitidine

2. Which of the following is not an intermediate clinical predictor per the ACC/AHA guidelines:

a. previous myocardial infarction
b. history of CVA
c. diabetes
d. creatinine >2mg/dL
e. history of CHF

3. The following are parts of the emergent pathway in the ASA difficult airway algorithm, except:

a. LMA
b. combitube
c. fiberoptic intubation
d. transtracheal jet ventilation
e. cricothyrotomy

4. The following things are part of a routine room set up, except:

a. machine check
b. monitor check
c. electrical check
d. airway equipment check
e. drug setup check

5. ASA standards for basic anesthesia monitoring state that all of the following shall be continually evaluated, except:

a. oxygenation
b. level of awareness
c. temperature
d. circulation
e. ventilation

6. Which of the following is not a potential side effect of opioid premedication:

a. bradycardia
b. respiratory depression
c. pruritis
d. orthostatic hypotension
e. delayed gastric emptying

7. A patient with systemic hypertension and evidence of LVH on EKG is:

a. ASA class 1
b. ASA class 2
c. ASA class 3
d. ASA class 4
e. ASA class 5

8. A healthy patient who is a marathon runner and smokes 1 pack/day is:

a. ASA class 1
b. ASA class 2
c. ASA class 3
d. ASA class 4
e. ASA class 5

9. According to the ACC/AHA guidelines, which of the following procedures is not an intermediate surgical risk:

a. carotid endarterectomy
b. neck dissection
c. pulmonary wedge resection
d. prostatectomy
e. popliteal-distal bypass

10. The basic functions of anesthetic drugs include all of the following, except:

a. analgesia
b. pyrexia
c. amnesia
d. muscle relaxation
e. sympathetic modulation

11. The treatment of hypotension may include all of the following, except:

a. fluid bolus
b. ephedrine
c. phenylephrine
d. phentolamine
e. decrease inhaled anesthetic concentration

12. The triple airway maneuver includes the following, except:

a. mouth opening
b. head tilt
c. jaw thrust
d. cervical spine flexion

13. Which of the following has the most direct myocardial depression:

a. isoflurane
b. enflurane
c. desflurane
d. sevoflurane
e. halothane

14. The following are correct about Mallampati classification, except:

a. if the entire uvula is seen, it is class I
b. the patient should be asked to say "ahhh"
c. there are four classes
d. if the soft palate is the most you see, it is class III
e. it correlates with predicting ease of intubation

15. All of the following help prevent delivery of a hypoxic mixture, except:

a. link between vaporizer and oxygen flow
b. fail safe valve
c. oxygen analyzer
d. link between oxygen and nitrous flows
e. presence of vigilant anesthesiologist

16. In a healthy 25 year old, the PaO2 on room air should be approximately:

a. 21 mm Hg
b. 60 mm Hg
c. 90 mm Hg
d. 250 mm Hg
e. 760 mm Hg

17. The following conditions describe a full E-cylinder of oxygen:

a. 1600 PSI, 625 L
b. 2800 PSI, 400 L
c. 1800 PSI, 350 L
d. 2200 PSI, 625 L
e. 1400 PSI, 335 L

18. One should never, never:

a. turn down the oxygen and nitrous oxide flowmeters
b. depress the oxygen flush valve during the inspiratory cycle of mechanical ventilation
c. completely close the "pop-off"valve while mask ventilating with the circle system
d. disconnect the central oxygen supply on the anesthesia machine
e. turn off the mechanical ventilator and "hand-bag" during a central oxygen supply failure

19. The fail safe device:

a. alarms when the patient becomes hypoxic
b. alarms at the loss of pipeline oxygen flow
c. is part of the low-pressure system in the anesthesia machine
d. shuts off nitrous oxide supply in the event of low oxygen supply pressure
e. is checked by pressurizing the circle system

20. An inappropriate induction agent medication in an anephric patient presenting for kidney transplant would be:

a. succinylcholine
b. MSO4
c. etomidate
d. pancuronium
e. nitrous oxide

Answer Key: 1c, 2b, 3c, 4c, 5b, 6a, 7c, 8b, 9e, 10b, 11d, 12d, 13e, 14b, 15a, 16c, 17d, 18b, 19d, 20d

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