ORIGINAL RESEARCH

Comparison between Simulation-based Training and Lecture-based Education in Teaching Situation Awareness

A Randomized Controlled Study

Alfredo Lee Chang[1], Andrew A. Dym[2], Carla Venegas-Borsellino[1], Maneesha Bangar[1], Massoud Kazzi[1], Dmitry Lisenenkov[1], Nida Qadir[1], Adam Keene[1], and Lewis Ari Eisen[1]

[1]Division of Critical Care Medicine, Department of Medicine, Montefiore Medical Center of Albert Einstein College of Medicine, Bronx, New York; and [2]Albert Einstein College of Medicine, Bronx, New York

Abstract

Rationale: Situation awareness has been defined as the perception of the elements in the environment within volumes of time and space, the comprehension of their meaning, and the projection of their status in the near future. Intensivists often make time-sensitive critical decisions, and loss of situation awareness can lead to errors. It has been shown that simulation-based training is superior to lecture-based training for some critical scenarios. Because the methods of training to improve situation awareness have not been well studied in the medical field, we compared the impact of simulation vs. lecture training using the Situation Awareness Global Assessment Technique (SAGAT) score.

Objectives: To identify an effective method for teaching situation awareness.

Methods: We randomly assigned 17 critical care fellows to simulation vs. lecture training. Training consisted of eight cases on airway management, including topics such as elevated intracranial pressure, difficult airway, arrhythmia, and shock. During the testing scenario, at random times between 4 and 6 minutes into the simulation, the scenario was frozen, and the screens were blanked. Respondents then completed the 28 questions on the SAGAT scale. Sample items were categorized as Perception, Projection, and Comprehension of the situation. Results were analyzed using SPSS Version 21.

Results: Eight fellows from the simulation group and nine from the lecture group underwent simulation testing. Sixty-four SAGAT scores were recorded for the simulation group and 48 scores were recorded for the lecture group. The mean simulation vs. lecture group SAGAT score was 64.3 ± 10.1 (SD) vs. 59.7 ± 10.8 (SD) ($P = 0.02$). There was also a difference in the median Perception ability between the simulation vs. lecture groups (61.1 vs. 55.5, $P = 0.01$). There was no difference in the median Projection and Comprehension scores between the two groups (50.0 vs. 50.0, $P = 0.92$, and 83.3 vs. 83.3, $P = 0.27$).

Conclusions: We found a significant, albeit modest, difference between simulation training and lecture training on the total SAGAT score of situation awareness mainly because of the improvement in perception ability. Simulation may be a superior method of teaching situation awareness.

Keywords: situation awareness; simulation-based training; lecture-based training; airway management; intensive care

(Received in original form December 1, 2016; accepted in final form January 30, 2017)

Author Contributions: A.L.C., A.A.D., L.A.E., and C.V.-B.: study concept and design; A.L.C., A.A.D., C.V-.B., M.B., M.K., D.L., N.Q., A.K., and L.A.E.: acquisition of data; A.L.C., A.A.D., A.K., and L.A.E.: statistical methods and statistical data analysis and interpretation; and A.L.C., A.A.D, N.Q., C.V.-B., and L.A.E.: manuscript preparation and drafting.

Correspondence and requests for reprints should be addressed to Alfredo Lee Chang, M.D., Division of Critical Care Medicine, Montefiore Medical Center–Albert Einstein College of Medicine, 111 East 210th Street, Bronx, NY 10467. E-mail: alfredoleechang@yahoo.com

Ann Am Thorac Soc Vol 14, No 4, pp 529–535, Apr 2017

DOI: 10.1513/AnnalsATS.201612-950OC
Internet address: www.atsjournals.org

The concept of situation awareness was introduced by Oswald Boelke during World War I as a method for gaining advantage over an enemy (1). This concept was revived in the 1980s, particularly in the aviation industry. Situation awareness is defined as the ability of an individual to maintain an adequate internal representation of the status of the environment in complex, dynamic circumstances (2). Measures of situation awareness have correlated with performance in fighter pilots, in that pilots with lower observer ratings of situation awareness during a combat scenario had a greater number of errors when compared with pilots with highly rated situation awareness (3). The complexity, dynamism, high information load, and risk in the medical field are comparable to those seen in the aviation industry.

Medical errors are a combination of human and system errors. These can occur at any step of patient management, including diagnosis, treatment, and prevention (4–6). To prevent errors, the practitioner must be able to perceive important information (level 1), comprehend events (level 2), and project the course of future events (level 3). These are the three hierarchical levels of situation awareness for maintaining an adequate awareness of the situation as described by Endsley (Figure 1) (7).

A review by Reader and coauthors (8) using the Anesthetist Non-Technical Skills behavioral marker system in the critical care environment found that a large proportion of the contributory factors underlying critical incidents could be attributed to nontechnical skills. Lack of situation awareness accounted for 20% of those events. These numbers attributed to loss of situation awareness could have been subject to reporting bias and may be even higher in practice (8).

In the field of critical care medicine, where decisions must often be made quickly, the failure to achieve optimal situation awareness may lead to preventable errors and patient harm. To date, there is scarce evidence in the literature regarding an effective way to teach situation awareness to health care providers (9).

Simulation-based training has been shown to be superior in teaching technical and nontechnical skills across multiple medical specialties (10–14). We hypothesized that simulation training would be superior for teaching situation awareness when compared with lecture-based teaching alone.

Some of the results of this study have been reported previously in the form of an abstract (15).

Methods

Study Overview

We conducted a single-center, randomized controlled trial of two training methods. The study was approved by the institutional review board of Montefiore Medical Center and Albert Einstein College of Medicine (Bronx, NY); all subjects gave informed consent before participating in the study.

Location and Participants

The study took place in the Simulation Center at Montefiore Medical Center, a primary teaching hospital of Albert Einstein College of Medicine in Bronx, NY. We included critical care fellows at the beginning of the year of fellowship training. Rotation schedules permitted 17 of our 27 critical care fellows to participate in the study (Table 1). They were randomly assigned to simulation-based training with a computerized patient simulator (n = 8) or to lecture-based training (n = 9) for skills in management of the critically ill patient in various situations. The lecture also covered the standard concepts of situation awareness (Figure 2).

Simulation-based Training

The simulator (SimMan Laerdal Medical Corporation, Wappingers Falls, NY) is a human-sized, high-fidelity mannequin. The mannequin can replicate realistic patient features, such as palpable pulses, chest wall excursions, audible breath sounds, different airway views and can simulate patient speech. Vital signs and images during the simulated scenarios were displayed on a bedside monitor. An experienced critical care faculty member operated the mannequin. The simulated scenarios consisted of eight cases, including shock (septic, obstructive, and cardiogenic), hypoxic respiratory failure (severe adult respiratory distress syndrome, cardiogenic pulmonary edema, and endotracheal tube dislodgement), elevated intracranial pressure, difficult airways (neck abscess, angioedema, and airway management in pregnancy), and malignant arrhythmias, focused on critically ill patients.

Each simulated scenario was run for approximately 20 minutes and was followed by a debriefing of 10 minutes, with a total simulation time of 5 hours per participants. During the scenario, one of the critical care faculty acted as an impartial nurse who provided the team with the medications and equipment requested by the study participants. The nurse followed the instructions of the team members only. The study participants assumed the roles of team leader, airway manager, and team helpers, and rotated among the various roles.

Lecture-based Training

The group assigned to lecture training received an initial 2-hour lecture session, which covered a general approach to the critically ill patients in scenarios similar to the ones used in the simulation training, but without any actual hands-on interactive simulation training. In addition, the concepts of situation awareness were reviewed, and strategies to maintain situation awareness during emergencies were discussed.

Testing Procedures

Eight new simulation scenarios were presented independently to both groups of participants. The scenario began when a critical care faculty member acting as a nurse went outside the simulation room to call the testing group in as first responders to an emergency situation. The participating team chose which team roles each of the participants were to assume, on a rotating basis, with each participant fulfilling each role (leader, airway, and helper) for at least one of the eight scenarios.

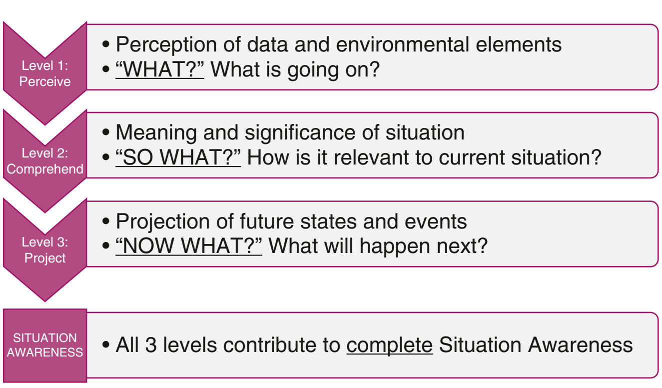

Figure 1. Hierarchical levels in achieving situation awareness (7).

Table 1. Demographics of participants

Participants	Simulation-based Training (*n* = *8 in total*)	Lecture-based Training (*n* = *9 tested*)
Sex		
Male	5 (62.5)	7 (77.7)
Female	3 (37.5)	2 (22.3)
Year		
Junior	7 (87.5)	3 (33.3)
Senior	1 (12.5)	6 (66.7)
Specialty		
IM/Pulmonary	4 (50)	5 (55.6)
IM/Renal	0	1 (11.1)
IM/Cardiology	1 (12.5)	0
IM/Critical care	0	1 (11.1)
IM/Pediatrics	1 (12.5)	0
Emergency medicine	2 (25)	2 (22.2)

Definition of abbreviation: IM = internal medicine.
Data are presented as n (%). Adapted by permission from Reference 33.

At a random time between 4 and 6 minutes into the simulation, the scenario was frozen, and the patient monitors were blanked. Participants then filled out the 28-item modified Situation Awareness Global Assessment Technique (SAGAT) scale (16–19), which included questions testing for perception, comprehension, and projection of the situation (Table 2). For categorical variables, an answer was considered correct when it agreed completely with the observer. For continuous variables, the answer was considered correct if it was within a 10% variation of the true value noted by the observer.

Outcome Measures

An overall situation awareness score was collected as per the SAGAT scale. The 28 questions from the SAGAT scale were further classified into the three aspects of situation awareness to individually evaluate perception, comprehension, and projection by two independent research staff. A third research staff member served as a tiebreaker for disagreements.

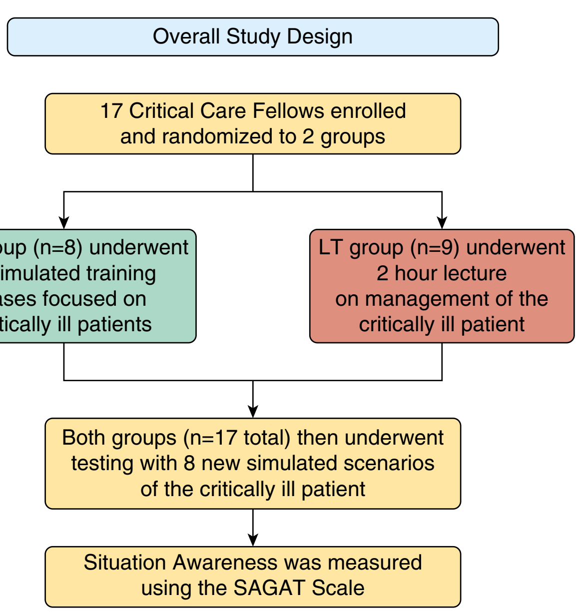

Figure 2. Study protocol. LT = lecture-based training; SAGAT = Situation Awareness Global Assessment Technique; ST = simulation-based training.

The primary outcome of the study was the overall SAGAT score in the simulation training vs. the lecture training group. Secondary outcomes measured were the difference in each hierarchical level of situation awareness (Perception, Comprehension, and Projection) in the simulation group vs. the lecture training group, change of situation awareness score during the progression of the cases, and difference in situation awareness by roles.

Statistical Analysis

SAGAT scale data was analyzed using SPSS, version 21 (IBM, Armonk, NY). Demographic and baseline characteristics of the participants were summarized by mean and SD for continuous variables and by numbers and percentages for categorical variables. The primary outcome of average SAGAT score was compared between the groups using a two-tailed *t* test. Secondary outcomes of medians in each domain were compared between the groups using the Mann-Whitney *U* test. A *P* value $\leq$0.05 was considered statistically significant.

Results

Seventeen fellows consented to participate in the study. Eight fellows underwent simulation-based training, and nine fellows underwent lecture-based training and testing (Table 1). Sixty-four SAGAT scores were recorded for the simulation group, and forty-eight SAGAT scores were recorded for the lecture group.

Regarding the primary outcome, a statistical difference was found in the overall mean SAGAT score for the simulation group 64.3 $\pm$ 10.1 (SD) vs. the lecture group 59.8 $\pm$ 10.8 (SD), $P = 0.02$ (Figure 3). None of the subjects were able to obtain a perfect score. In the secondary outcomes analysis, the situation awareness score tended to decrease slightly in both groups as cases progressed (Figure 4).

When the SAGAT score was divided into the three hierarchical levels of situation awareness, the perception ability score was higher in the simulation vs. the lecture group (61.1 [IQR, 16.7] vs. 55.5 [IQR, 22.2], $P = 0.01$). However, there was no difference in the median projection or comprehension scores between the two groups (50.0 [IQR, 50.0] vs. 50.0 [IQR, 50.0], $P = 0.92$, and 83.3 [IQR, 16.7] vs. 83.3 [IQR, 33.0], $P = 0.27$) (Figure 5).

Table 2. Modified SAGAT (Situation Awareness Global Assessment Technique) scale

SAGAT Query	Level of Situation Awareness
Part A	
Was the patient adequately pre-oxygenated?	Comprehension (level 2)
What is the current heart rhythm?	Perception (level 1)
What is the current heart rate?	Perception (level 1)
Has the rhythm changed over the last 2 min?	Perception (level 1)
What is the current oxygen saturation?	Perception (level 1)
Has the oxygen saturation gone up over the last 2 min?	Perception (level 1)
How long (in minutes) has the patient been receiving 100% oxygen?	Perception (level 1)
What is the current blood pressure?	Perception (level 1)
What medications have you administered thus far?	Perception (level 1)
What are the total doses of medications administered thus far?	Perception (level 1)
Are the patient's responses consistent with the medications given?	Comprehension (level 2)
Does the patient need more medication?	Comprehension (level 2)
How will the blood pressure develop in the next minute?	Projection (level 3)
How will the oxygen saturation develop in the next minute?	Projection (level 3)
How will the heart rate develop in the next minute?	Projection (level 3)
How long (in minutes) has this scenario lasted thus far?	Perception (level 1)
Part B	
How long (in seconds) did the intubation take from the time the intubation device was picked up to the time the airway was secured?	Perception (level 1)
How did the heart rate change during intubation?	Perception (level 1)
What is the current heart rate?	Perception (level 1)
What is the current heart rhythm?	Perception (level 1)
How did the oxygen saturation change during intubation?	Perception (level 1)
What is the current oxygen saturation?	Perception (level 1)
What has happened to the oxygen saturation since intubation?	Perception (level 1)
Is there symmetrical chest wall movement?	Perception (level 1)
Is there good air entry to both lung fields?	Comprehension (level 2)
Has the patient's hypoxemia responded as expected after intubation?	Comprehension (level 2)
Is the patient's airway secure at present?	Comprehension (level 2)
What do you expect to happen to the oxygen saturation over the next few minutes?	Projection (level 3)

Definition of abbreviation: SAGAT = Situation Awareness Global Assessment Technique.
Modified SAGAT scale questions classified with hierarchical levels. Adapted with permission from Reference 33.

When the SAGAT score was analyzed by specific team roles, there was no difference in the leader, airway, or helper roles in the total SAGAT scores (64.2 [IQR, 6.3] vs. 60.7 [IQR, 12.5], $P = 0.23$; 57.2 (IQR, 20.5] vs. 60.7 [IQR, 13.4], $P = 0.61$; and 62.6 [IQR, 16.96] vs. 58.9 [IQR, 14.3], $P = 0.11$ between the simulation and lecture groups, respectively). There was no difference in the three hierarchical levels of situation awareness between the leader and member roles within each group or training method, but there was a difference in the perception ability in the helper simulation vs. the helper lecture training groups (66.7 [IQR, 16.7] vs. 55.6 [IQR, 20.8], $P < 0.01$).

Discussion

Although the concept of situation awareness has been gaining momentum in the past 3 decades in other industries, its importance to the health care industry has been relatively underappreciated. Since the introduction of the concept of situation awareness to the medical field of anesthesia (20), several studies have demonstrated the importance of this concept in the health care industry (8, 21–33). Moreover, a recent systematic review concluded that more research is needed to establish the most effective method of teaching situation awareness (9).

Our study suggests that simulation-based training is superior to lecture-based training when teaching situation awareness to critical care fellows, as assessed using simulated clinical scenarios. We have also found higher perception scores in the simulation training group. These findings are similar to the study by Häsel and colleagues (34), in which 59 senior medical students underwent a simulated patient scenario involving postpartum septic shock. The situation awareness and clinical performance scores were compared among groups undergoing simulation training, a symposium on crew resource management, or no intervention. The investigators found that the simulation group had a better overall situation awareness score with an improvement in perception ability, but there were no difference in overall clinical performance. In comparison to the Häsel study (34), our study had an active control to ensure that both groups had familiarity with the concepts and practical applications of situation awareness.

In the aviation industry, failure to correctly perceive the situation (level 1) was the leading cause of errors when situation awareness was lost (35, 36). A recent review of 200 cases of critical incident reports in anesthesia and critical care medicine showed that situation awareness errors were distributed more homogenously among the three levels, with slightly higher rates on failure to perceive (level 1) (37).

It is unclear whether the improvement in perception ability (level 1) seen in our study could lead to improvements in comprehension (level 2) and projection abilities (level 3), but it is logical to believe that clinicians who perceive better will be able to make better decisions. Indirect evidence of this is provided by a study by Brady and associates (38). In their study, they created a system of care in which frequent patient screenings for clinical deterioration were designed to increase situation awareness and lead to a reduction of unplanned intensive care unit transfers. Unfortunately, Brady and coauthors (38) did not directly measure the improvement in total situation awareness or the improvement in the different levels of situation awareness. However, they were able to show indirectly that improving overall situation awareness led to a reduction in undesired outcomes.

We believe that the superiority of simulation-based training when compared

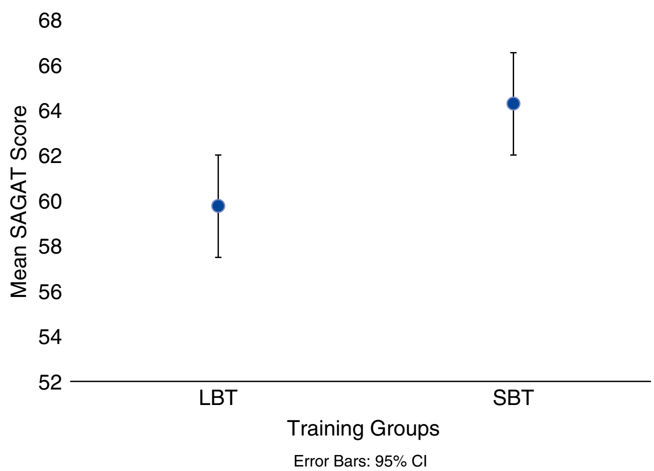

Figure 3. Comparison of overall Situation Awareness Global Assessment Technique (SAGAT) by training method ($P = 0.02$). CI = confidence interval; LBT = lecture-based training; SBT = simulation-based training.

with lecture-based training in teaching situation awareness could be a result of various factors. First, it is known that simulation training is a more efficient and effective teaching method when imparting medical knowledge and teaching communications and procedural skills. This could be true for teaching situation awareness as well. Second, it is possible that a failure of random assignment could have played a role in this small study, resulting in the simulation training group having higher baseline situation awareness skills. Baseline SAGAT scores could have resolved this issue; however, they are not available because we wanted to prevent repeat testing bias. Because there were more senior fellows in the lecture-based training group who were more clinically experienced, any bias in baseline abilities would probably have favored this group.

Third, repeat testing bias could have been present, potentially leading to higher test scores as cases went by. However, the data show that total SAGAT scores actually went down over time, possibly caused by fatigue, because it was observed in both groups. This should be explored in future studies. Fourth, the simulation group had more exposure to the simulator than did the lecture group. However, both groups had >15 hours of simulation training from prior educational endeavors, so neither was truly novice. Before the testing started, neither group was aware of which scale would be used for testing.

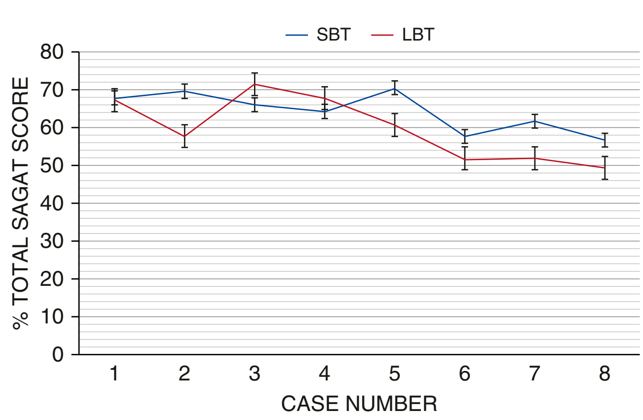

Figure 4. Comparison of hierarchical levels by training method ($P = 0.01$). CI = confidence interval; LBT = lecture-based training; SAGAT = Situation Awareness Global Assessment Technique; SBT = simulation-based training.

When situation awareness scores were compared by team role, there was no difference by role within a given training team. When each team role was compared across the two training groups, there was no difference in the situation awareness of the leader or the airway role in either group. However, the helpers in the simulation group did have better perception ability compared with the helpers in the lecture group. This could mean that the helpers in the situation group were more attentive to the surroundings, which could have led to a positive effect on overall situation awareness. This could be a noteworthy finding, because it highlights the importance of each team member during a stressful scenario. It is to be hoped that effective communication would improve team situation awareness and reduce errors. This would require further study in light of the multiple comparisons performed in this study.

Strengths and Limitations

This study has several strengths. First, this is a novel study that directly compares simulation-based vs. lecture-based training for teaching situational awareness in multiple critical care scenarios. Second, unlike a prior study (34), we chose individuals experienced in the critical care environment, rather than novices. Third, both groups were tested using the same high-fidelity simulator, thereby subjecting them to the same testing standards. Fourth, participants annotated their own SAGAT scores, eliminating observer variability and subjectivity and providing real-time evaluation of situation awareness. Many scales rely on subjective observations of situation awareness, but the SAGAT scale has objective values (Table 2).

Our study has several limitations. The study was performed in a single center, and its external generalizability has not been proved. The SAGAT score questionnaire has more questions testing perception ability than those testing comprehension and projection. The true effect of simulation vs. lecture training in the latter hierarchical levels could be underestimated. Because ours is a multidisciplinary fellowship, the critical care fellows had different training backgrounds (emergency medicine, internal medicine, pulmonary medicine, nephrology, and cardiology), and we did

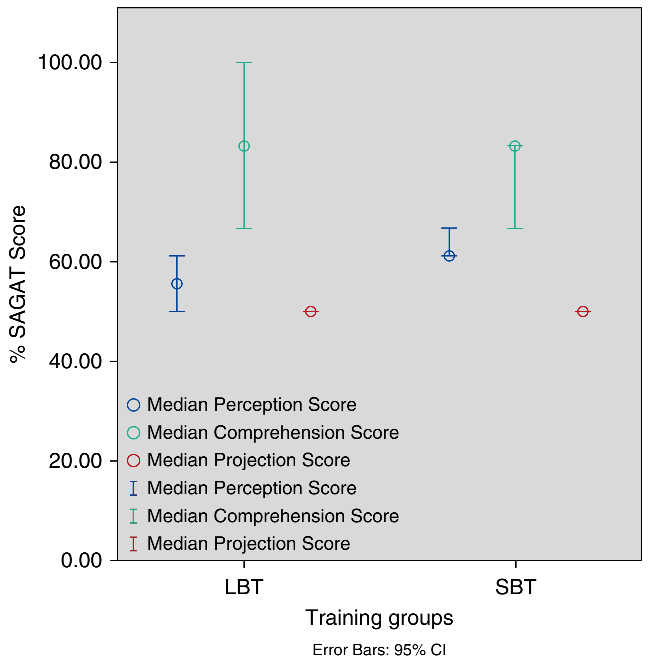

Figure 5. Mean Situation Awareness Global Assessment Technique (SAGAT) scores over time by training groups. CI = confidence interval; LBT = lecture-based training; SBT = simulation-based training.

not have sufficient numbers of participants to compare situation awareness among backgrounds and how that may affect situation awareness. Although this was a randomized trial, it was not double blinded because the learners were aware of the group to which they were assigned. Ten critical care fellows were not able to participate in the study because of scheduling conflicts (night float, vacations, or away electives). Although it is unclear how they would have affected the results, we believe that they would not have made a difference because their absence was a result of scheduling only and not because of any inherent characteristics of the subjects or subject choice. Finally, although differences in the SAGAT scores were statistically significant, the differences were modest in magnitude and thus of uncertain practical consequence.

Conclusions

Our study adds to the scarce literature on the effective teaching of situation awareness. We found that simulation-based training is superior to lecture-based training for learning overall situation awareness because it improves perception ability. Further research should be conducted focusing on the clinical impact of improving situation awareness and on the effect of comprehension and projection using other scales. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

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