The American Journal of Surgery 218 (2019) 237–242

Contents lists available at ScienceDirect

The American Journal of Surgery

journal homepage: www.americanjournalofsurgery.com

Simulation training results in improvement of the management of operating room fires—A single-blinded randomized controlled trial

Tomokazu Kishiki [a,b], Bailey Su [a,c,*], Brandon Johnson [a], Brittany Lapin [a], Kristine Kuchta [a], Laurie Sherman [a], JoAnn Carbray [a], Michael B. Ujiki [a]

[a] Department of Surgery, Section of Minimally Invasive Surgery, NorthShore University HealthSystem, 2650 Ridge Ave, Evanston, IL, 60201, USA
[b] Department of Surgery, Kyorin University School of Medicine, Tokyo, Japan
[c] Department of Surgery, Section of General Surgery, University of Chicago, 5841 South Maryland Ave, Chicago, IL, 60637, USA

ARTICLE INFO

Article history:
Received 3 January 2019
Received in revised form
7 February 2019
Accepted 28 February 2019

This study was presented at the following; Poster presentation, American College of Surgeons, Accredited Education Institutes, March 7, 2016 meeting, Chicago, Illinois

ABSTRACT

Background: Operating room (OR) fires are a preventable danger. Our aim is to examine the effectiveness of OR fire simulation scenarios as a supplement to classroom-based training for managing OR fires.
Methods: Eighty-two participants were randomly divided into 14 groups. Eight groups (Group S) participated in two simulations: one prior to the classroom-based fire training and another after the classroom. Six groups (Group D) participated in the identical classroom training, but only one simulation, which followed the classroom session. Confidence surveys were completed before classroom training and after the final simulation. All simulations were assessed by a blinded evaluator.
Results: Competency scores within Group S were significantly higher after the second simulation. Competency scores for Group S were significantly higher than Group D for the final test scenario. Prior to the classroom-based training, confidence scores regarding fire safety-related OR tasks were significantly higher in S group.
Conclusions: Simulation training significantly improves both the competency and confidence of medical professionals in managing fires in the OR, with more simulation training showing a greater degree of benefit.

1. Introduction

Operating room (OR) fires are a preventable danger that present a significant risk to patients undergoing surgery. The ECRI Institute estimates that as high as 20% of the 650 OR fires reported each year are directly harmful to patients, ranking intraoperative fires as the third most dangerous technology-related hazard occurring in a hospital setting.[1] Adverse outcomes associated with intraoperative fires have included major or minor burns, inhalation injuries, infection, disfigurement, and death.[2] Prevention of surgical fires requires a broad understanding of the risks accompanying such adverse events, as well as effective communication between surgical, anesthesia, and OR nursing staff. Successful resolution of an OR fire requires all of the team members to work simultaneously, with certain tasks being performed by certain personnel. For example, it is the first priority for the anesthesia provider to turn off the oxygen. The relative rarity of OR fires, however, makes it difficult to determine the level of readiness a surgical team might possess in order to address these events when they do occur. Simulation exercises are increasingly relied upon to allow OR staff to practice and improve their response to these unexpected and dangerous events.[3–5]

Directives from the Institute of Medicine, now the National Academy of Medicine, calls for teams that work together to be trained together in an effort to enhance cooperative action within the OR.[6] Simulations allow these teams to address specific learning objectives by using tailored scenarios to test technical skill, communication, teamwork, and the application of medical knowledge within a particular context.[7] In this way, simulation-based training acts as an important educational tool that can prepare healthcare professionals for complex situations that arise

* Corresponding author. Department of Surgery, Section of Minimally Invasive Surgery, NorthShore University HealthSystem, 2650 Ridge Ave, GCSI Suite B665, Evanston, IL, 60201, USA.

E-mail addresses: kishikitomokazu@yahoo.co.jp (T. Kishiki), Bailey.Su@uchospitals.edu (B. Su), BJohnson3@northshore.org (B. Johnson), BLapin@northshore.org (B. Lapin), KKuchta@northshore.org (K. Kuchta), LSherman@northshore.org (L. Sherman), JCarbray@northshore.org (J. Carbray), MUjiki@northshore.org (M.B. Ujiki).

https://doi.org/10.1016/j.amjsurg.2019.02.035
0002-9610/

during the course of patient care.[8] Additionally, such training may also serve to improve the culture of care within a hospital setting, shedding new light on areas such as medical decision-making, surgical safety risks, and patient outcomes that can be difficult to predict.[9] The aim of this study was to examine the utility of OR fire simulation scenarios, in addition to traditional didactic teaching, as training tools to improve the confidence and competency of OR teams in response to a simulated OR fire.

2. Methods

2.1. Study design

Between June and December 2015, 82 participants volunteered to participate in a training curriculum for managing an "OR catastrophe". Participants were divided into groups, within which a surgeon and anesthesiologist role were specifically assigned. The surgeon role was usually filled by an attending surgeon, however on rare occasion this role was filled by a surgical physician assistant (PA). Similarly, the anesthesiologist role was usually filled by an attending anesthesiologist, anesthesia resident or Certified Registered Nurse Anesthetist (CRNA), but occasionally filled by a surgical PA. Groups were then randomly assigned to either simulation (Group S) or didactic (Group D) curriculums (Fig. 1). Eight simulation groups participated in two hands-on simulation training exercises, one prior to the classroom-based fire safety overview and one following it. Six didactic groups underwent the same classroom-based fire safety overview, but participated in only one hands-on simulation training exercise, which followed the classroom session. An initial confidence survey was given to each participant prior to the classroom-based portion of the training. For Group S, the initial confidence survey was not provided at the beginning (ie: prior to the practice simulation) so they would be completely naive to the simulation scenario.

After finishing all simulation exercises, participants in both groups completed a final confidence survey and evaluation. They also completed a "retention quiz" between three to six months after the study, which tested retained knowledge of fire safety procedures in the OR. As detailed in the following section, teams were also evaluated during the simulation exercises in order to gauge their success in completing several fire safety-related tasks, which were deemed to be critically important when identifying and controlling an OR fire.

2.2. Assessment

All simulations were recorded. An independent surgeon, who was blinded to each team's designation, carefully evaluated each simulation and scored each team (scale from 1 to 5) for successful completion of each step of the Critical Action Checklist:

1. Fire risk assessment
2. Fire recognition and communication
3. Identifying/controlling the ignition source
4. Turning off oxygen
5. Removing burning items from the patient
6. Extinguishing the fire
7. Event follow-up

Study participants were also blinded to the type and number of simulations performed by other teams until after the study was complete.

The primary metric in the critical action checklist was time to completion, which was defined as the interval between recognition of a significant risk factor during an OR fire event and its resolution through coordinated action undertaken by the OR team. The time to completion was measured by the blinded independent surgeon. Team members were instructed to perform their fire management tasks as quickly as possible during the scenario. In addition, all members of the team were advised to help perform tasks that remained incomplete as the OR fire simulation progressed. Timely completion of these tasks, which commonly contribute to the successful resolution of fire events in the OR, was taken as a proxy measure of whether or not the simulated fire had been appropriately controlled.[10] Higher scores indicated better management of a given risk in the OR.

2.3. Training setting and scenario

Our hospital-based simulation center has designated two ORs for in-situ simulation-based training. With few exceptions, all equipment, drugs, and supplies are real and exactly the same as would be found in a functional OR setting. The "patient" in this simulation was a SimMan Essential High-Fidelity patient simulation mannequin (Laerdal Medical, Stavanger, Norway) whose changing physical characteristics and vital signs are controlled from an observational room separated by one-way glass.

Prior to the simulations, a fog machine was placed under the surgical drapes (fuel). Once activated from the control room, the fog machine produced "smoke" which indicated a fire outbreak. Two standardized scenarios based on actual cases were used in the simulation exercises. The first scenario was a cervical lymph node biopsy, in which nasally administered oxygen was ignited by monopolar cautery. In the second scenario, an incorrectly

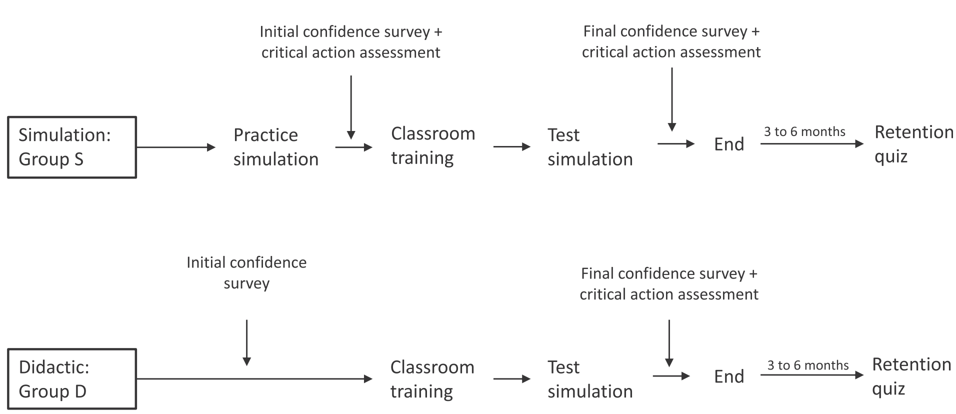

Fig. 1. Curriculum depending on randomization into Simulation (Group S) or Didactic Group (Group D).

assembled laparoscope with an exposed fiber optic light (ignition source) was left resting on the surgical drapes (fuel) and resulted in a fire outbreak.

2.4. Statistical analysis

Comparisons between group demographics were made using a chi-square test (Table 1). Comparisons of confidence surveys between groups were made using a Mann-Whitney U test (Table 2). Comparisons of critical action evaluations between the first and second simulations for Group S were made using the Wilcoxon signed-rank and McNemar's test. Comparisons of critical action evaluations between the second simulation for Group S and Group D were made using the Mann-Whitney U and Fisher's exact test (Table 3). A p-value of less than 0.05 was considered to be statistically significant. All analyses were conducted using SAS version 9.3 (SAS Institute Inc, Cary, NC).

3. Results

3.1. Participant demographics

There were no significant differences in demographics between the two groups, however Group S trended towards having more years of experience (Table 1). Only 7 (9%) of the study participants reported ever being involved in an OR fire, and 47 (57%) reported that they had reviewed OR fire safety protocols within the past year.

3.2. Confidence surveys

On the initial confidence survey done before classroom training but after one simulation session, Group S felt significantly more confident in performing critical fire safety tasks when compared to Group D, who had not yet completed a simulation (Table 2). Scores from Group S were significantly higher than those from Group D on a converted Likert scale ranging from 1 (not at all confident) to 5 (very confident) when recognizing and communicating fire presence (4.3 ± 0.8 vs. 3.7 ± 0.9, $p < 0.01$), identifying and controlling the ignition source (3.8 ± 1.0 vs. 3.3 ± 1.1, $p = 0.02$), recognizing the need to turn off oxygen (4.1 ± 1.1 vs. 3.6 ± 1.1, $p = 0.04$), removing burning items from the patient (4.1 ± 0.9 vs. 3.4 ± 1.2, $p = 0.02$), and extinguishing the fire (4.0 ± 1.0 vs. 3.5 ± 1.0, $p = 0.04$) (Table 2). In addition, Group S felt significantly more confident in performing follow-up after an OR fire, including evaluating the patient (4.0 ± 0.8 vs. 3.1 ± 1.0, $p < 0.01$), determining to proceed (3.6 ± 0.8 vs. 2.9 ± 1.1, $p < 0.01$), and reporting to family/risk/ERA (3.5 ± 1.0 vs. 3.0 ± 1.1, $p = 0.04$). Initial total confidence levels were also higher among Group S participants (after 1 simulation) than among Group D participants (with no simulations) (37.9 ± 7.2 vs. 32.3 ± 9.1, $p = 0.01$).

After each group completed its final simulation exercise, confidence surveys were re-administered. Significant differences were no longer found between Group S and Group D in any of the categories. Overall confidence levels also no longer showed a significant difference between the groups, although both groups demonstrated an improvement in total confidence scores, when comparing their initial and final surveys (Group S: 37.9 ± 7.2 vs. 45.7 ± 4.6, $p < 0.01$; Group D: 32.3 ± 9.1 vs. 45.2 ± 4.6, $p < 0.01$).

3.3. Critical action assessment scores

After all simulation exercises were complete, the Critical Action Assessment (CAA) scores from Group S were significantly higher than Group D in fire recognition and communication (5.0 ± 0.0 vs. 3.7 ± 0.8, $p < 0.01$), identifying and controlling the ignition source (4.4 ± 0.7 vs. 2.8 ± 1.0, $p < 0.01$), removing burning items from the patient (4.9 ± 0.4 vs. 2.3 ± 0.1, $p < 0.01$), and extinguishing the fire (4.5 ± 0.8 vs. 3.2 ± 0.4, $p < 0.01$) (Table 3). Total scores for Group S were also significantly higher (32.5 ± 1.8 vs. 23.3 ± 2.9, $p < 0.01$). No significant differences were seen between groups in initial fire risk assessment, turning off the oxygen, or event follow-up after an adverse event. Within Group S, CAA scores improved significantly from the first to the second simulation exercise in all categories ($p < 0.01$)(Table 3).

3.4. Time to complete critical action steps

Within Group S, time-to-completion significantly improved from the first to the second simulation in regards to recognizing and communicating a fire event (4 ± 1 s vs. 2 ± 1 s, $p = 0.02$), turning off the oxygen (9 ± 3 s vs. 3 ± 1 s, $p = 0.04$) and extinguishing the fire (35 ± 5 s vs. 6 ± 1 s, $p < 0.01$) (Table 3). There was no statistically significant difference in times to complete identification and control of the ignition source or removal of burning items from the patient. After all simulation exercises were completed, times were significantly different between Group S and Group D when recognizing and communicating a fire event (2 ± 1 s vs 4 ± 1 s, $p = 0.02$) and extinguishing the fire (6 ± 1 s vs 28 ± 6 s, $p < 0.01$). No significant differences were found with controlling the ignition source, turning off the oxygen or removing the burning

Table 1
Group demographics.

	Total N (%)	Simulation – Group S N (%)	Didactic – Group D N (%)	P-Value
Total Number of Participants	*82*	*53 (64.6)*	*29 (35.4)*	
Total Number of Groups	*14*	*8*	*6*	
Profession				0.96
Surgeon	11 (13.9)	7 (14.0)	4 (13.8)	
PA	17 (21.5)	10 (20.0)	7 (24.1)	
Anesthesia	11 (13.9)	8 (16.0)	3 (10.3)	
OR Nurse	35 (44.3)	22 (44.0)	13 (44.8)	
Surgical Tech	5 (6.3)	3 (6.0)	2 (6.9)	
Years of Experience in Profession				0.052
0–2 Years	14 (17.3)	5 (9.6)	9 (31.0)	
2–5 Years	19 (23.5)	14 (26.9)	5 (17.2)	
5–10 Years	16 (19.7)	9 (17.3)	7 (24.1)	
10 + Years	32 (39.5)	24 (46.2)	8 (27.6)	
Involved in an OR Fire Event	7 (8.6)	6 (11.3)	1 (3.6)	0.41
Reviewed OR Fire Safety in Past Year	47 (57.3)	32 (60.4)	15 (51.7)	0.45

Table 2
Confidence levels by group.

Confidence Level,[a] Mean ± SD	Simulation – Group S (n = 53)		Didactic – Group D (n = 29)		Comparison of Initial Surveys (P-Value)	Comparison of Final Surveys (P-Value)
	Initial	Final	Initial	Final		
Discussing fire risk during Timeout	3.2 ± 1.4	4.6 ± 0.6	3.4 ± 1.1	4.5 ± 0.6	**0.60**	0.73
Recognizing and communicating fire	4.3 ± 0.8	4.8 ± 0.4	3.7 ± 0.9	4.7 ± 0.5	**<0.01**	0.37
Identifying/controlling ignition source	3.8 ± 1.0	4.6 ± 0.5	3.3 ± 1.1	4.6 ± 0.6	**0.02**	0.60
Recognizing need to turn off O2	4.1 ± 1.1	4.8 ± 0.4	3.6 ± 1.1	4.7 ± 0.5	**0.04**	0.27
Removing burning items from patient	4.1 ± 0.9	4.7 ± 0.4	3.4 ± 1.2	4.6 ± 0.5	**0.02**	0.31
Extinguishing fire	4.0 ± 1.0	4.8 ± 0.4	3.5 ± 1.0	4.7 ± 0.5	**0.04**	0.37
Follow up after OR fire event:						
Resume use of O2	3.5 ± 1.0	4.5 ± 0.6	3.1 ± 1.2	4.3 ± 0.7	**0.09**	0.49
Evaluate the patient	4.0 ± 0.8	4.6 ± 0.5	3.1 ± 1.0	4.5 ± 0.6	**<0.01**	0.31
Determination to proceed	3.6 ± 0.8	4.5 ± 0.6	2.9 ± 1.1	4.4 ± 0.7	**<0.01**	0.63
Reporting: family/risk/ERA	3.5 ± 1.0	4.6 ± 0.6	3.0 ± 1.1	4.4 ± 0.7	**0.04**	0.24
TOTAL CONFIDENCE LEVEL	*37.9 ± 7.2*	*45.7 ± 4.6*	*32.3 ± 9.1*	*45.2 ± 4.6*	**0.01**	0.65

[a] Scores range from 1 = not at all confident to 5 = very confident.

Table 3
Critical action assessment.

	Group S (1st Sim)	Group S (2nd Sim)	Group D	P-Value 1st Sim vs 2nd Sim	P-Value 2nd Sim vs D group
Number of Groups	*8*		*6*		
Scores (from 1–5), mean ± sd					
Fire Risk Assessment	1.0 ± 0.0	4.5 ± 0.8	3.3 ± 2.0	**<0.01**	0.32
Fire Recognition and Communication	3.0 ± 0.5	5.0 ± 0.0	3.7 ± 0.8	**<0.01**	**<0.01**
Identifying/Controlling Ignition Source	1.9 ± 1.2	4.4 ± 0.7	2.8 ± 1.0	**<0.01**	**<0.01**
Turning off O2	2.5 ± 1.1	4.5 ± 0.8	3.8 ± 0.8	**<0.01**	0.11
Removing burning items from patient	2.4 ± 0.5	4.9 ± 0.4	2.3 ± 1.0	**<0.01**	**<0.01**
Extinguishing Fire	3.0 ± 0.5	4.5 ± 0.8	3.2 ± 0.4	**<0.01**	**<0.01**
Event Follow-Up	2.6 ± 1.1	4.8 ± 0.5	4.2 ± 1.0	**<0.01**	0.23
Total	16.4 ± 3.5	32.5 ± 1.8	23.3 ± 2.9	**<0.01**	**<0.01**
Completion of Critical Action Steps Time to completion					
Fire Recognition and Communication completed, N (%)	8 (100)	8 (100)	6 (100)	-	-
Time (seconds), mean ± sd	4 ± 1	2 ± 1	4 ± 1	**0.02**	**0.02**
Identifying/Controlling Ignition Source completed, N (%)	3 (37.5)	8 (100)	5 (83.3)	**0.03**	0.43
Time (seconds), mean ± sd	4 ± 2	2 ± 1	7 ± 3	0.33	0.15
Turning off O2 completed, N (%)	6 (75.0)	8 (100)	6 (100)	0.47	-
Time (seconds), mean ± sd	9 ± 3	3 ± 1	2 ± 1	**0.04**	0.60
Removing burning items from patient completed, N (%)	8 (100)	8 (100)	6 (100)	-	-
Time (seconds), mean ± sd	6 ± 1	3 ± 1	7 ± 2	0.051	0.07
Extinguishing Fire completed, N (%)	8 (100)	8 (100)	4 (66.7)	-	0.16
Time (seconds), mean ± sd	35 ± 5	6 ± 1	28 ± 6	**<0.01**	**<0.01**
All Steps completed, N (%)	3 (37.5)	8 (100)	3 (50.0)	**0.03**	**0.03**
Total Scenario Time (seconds), mean ± sd	64 ± 7	15 ± 2	48 ± 8	**0.01**	**0.01**

items from the patient. Overall, in cases where all fire safety actions were successfully performed, the average time to complete the scenario for Group S significantly improved from the first to second simulation (64 ± 7 s vs 15 ± 2 s, p = 0.01). Additionally, the total scenario time for Group S was significantly less than Group D (15 ± 2 s vs 48 ± 8 s, p = 0.01) (Table 3).

3.5. Retention quiz

A retention quiz was sent electronically to all participants between three to six months after the study was complete, in order to measure retention of essential fire safety concepts. Fifty-one out of 82 participants (62%) returned a completed quiz. No significant differences were found between groups in the frequency of correct answers to questions 1–7 or 9, but participants in Group S answered question 8 correctly more often than Group D [Question 8: If a fire occurs in the surgical field, immediate actions include which of the following: a) stop airway gases/get fire extinguisher/activate fire alarm, b) stop airway gases/turn off ignition source/smother fire with towel, c) turn off ignition source/get fire extinguisher/stop airway gases, d) turn off ignition source/smother fire with towel/activate fire alarm (30 correct (83.3%) vs. 8 correct (53.3%), p = 0.04). The correct answer to this question was "b"].

3.6. Course evaluations

After both groups completed the simulation exercises, each participant was given a post-study evaluation and asked to assess the value of their experience. Participants rated the workshop very highly (mean ± sd, 4.5 ± 0.6 out of 5 points), with 93% of participants indicating they would like to engage in future simulations (data not shown). Team members found learning communication practices, understanding each team member's role in fire prevention and management, and performing hands-on practice with real smoke to be the most helpful parts of the simulation exercises. No significant differences were found in the workshop evaluation results between the groups (data not shown).

4. Discussion

OR fires have been identified as a key safety problem by many patient advocacy organizations, including The Joint Commission, the ECRI Institute, the American Society of Anesthesiologists, and the Anesthesia Patient Safety Foundation.[11] Even with this acknowledgement, the number of OR fires likely remains underestimated and underreported. Many organizations concerned with addressing and improving intraoperative safety have published materials and recommendations specifically targeted toward reducing overall fire risk in a hospital setting. Despite these efforts, OR fires still continue to present a significant danger in the OR. The heightened awareness of the medical staff as a result of these educational campaigns has not yet translated into elimination of the central problem. Recent studies conducted by Dr. Liane Feldman and colleagues, when assessing the need for the newly-developed Fundamental Use of Surgical Energy (FUSE) curriculum, found that safe use of electrical devices in an OR setting included “knowing which corrective actions to take in the event of an operating room fire”, but that regular training of surgical and ancillary OR staff lacked a competency requirement in the use of such devices.[12] Feldman's study goes on to point out that even experienced surgeons may not be aware of best practices when using such devices, and this lack of knowledge may contribute to a higher rate of fire outbreak and injury in the OR.[12] With further study, simulation exercises might serve as a regular educational tool that could be used to assess and improve competency and confidence in preparation for an adverse event, thus addressing the perceived gap in current training regimens of OR staff.

Simulation training exercises were pioneered in the late 1980s by anesthesiologist Dr. David M. Gaba with the development of the Anesthetic Crisis Resource Management (ACRM) course.[13] Simulation training is now used with increasing frequency by a number of medical disciplines, including emergency medicine, surgery, ambulatory care, pediatrics, and obstetrics. Within surgical education, simulation training provides a high-fidelity environment that can adapt and evolve alongside current medical practice.[8]

The primary goal of our study was to assess the utility of simulation-based teaching, in addition to traditional didactic teaching, to improve the function of OR teams during a simulated intraoperative emergency by assessing their confidence levels and measuring their response times during a simulated OR fire. As a result, group members were not evaluated individually for specific skills, but rather as one functional entity. Additionally, the simplicity of the fire risk assessment score allows the results to be easily interpreted as well as reproduced.

Although both groups demonstrated greater confidence in performing critical fire response tasks after finishing their simulation exercises, the time taken to complete all tasks successfully was more than three times as long in Group D, after one simulation, than in Group S, after two simulations. Additionally, Group S was twice as likely to have completed all the steps when compared to Group D. This highlights the educational impact and efficacy of simulation training over traditional didactic training. Feedback from course evaluations reinforce this finding, with one participant stating, “The simulation was great to have hands-on experience for this situation. [It was] Better than just listening and watching a slide show.” Madani et al. had similar results when they examined the impact of simulation training on surgical trainees learning the FUSE curriculum. They found that test performance immediately following a simulation exercise was significantly better in the “Sim” group (structured hands-on training) than the control (unstructured, hands-on training), and that the difference in performance between the groups persisted at 3 months after the completion of the curriculum.[14]

There are some limitations to this study. By examining a relatively small number of participants, all of whom are part of a single institution, our study may be unable to clearly detect subtle differences between simulation-trained and didactic-trained teams that would be evident with broader participation. Larger, multi-site studies would be useful in confirming the impact of simulation training on fire safety within the OR. Apart from the retention quiz, our study did not investigate how well participants retained what they had learned during their simulation exercises and long-term follow-up to assess durability was not completed. Further assessment with additional simulation testing may uncover whether or not there was a true difference in retention between the groups. Additionally, although the groups were randomly assigned, five out of 53 members in Group S had two or fewer years of OR experience, compared to nine out of 29 members in Group D ($p = 0.02$). Additionally, on average, there were fewer members in the Group D teams compared to Group S teams. The greater distribution of team members with less than two years of experience in their typical roles into Group D, as well as having fewer members on average, may have impacted the time to completion of the fire scenarios in both groups. Finally, some challenges may present in generalizing our findings to smaller programs without developed simulation training capabilities. National studies investigating both community and academic programs would further serve to corroborate our conclusions.

Future research may include remediation for those that did not score well on the final simulation and/or retention quiz. It may also be interesting to look at what barriers or predictors for success exist in order to maximize the learning experience for all OR personnel.

5. Conclusion

Simulation training is a valuable tool that allows providers to practice emergency scenarios that are either relatively rare and/or unsafe to practice in real time. Teaching with simulation exercises appears to have a positive effect on the confidence and performance of OR team members when confronted with an adverse event, such as an OR fire. We recommend the use of simulation training, in addition to traditional didactic teaching, as a method for medical providers to enhance their performance in crisis situations. Perhaps most importantly, increased exposure to simulation training correlated with quicker critical task completion. In a situation such as an OR fire, where expedient resolution of the outbreak is of paramount importance to the safety of the patient and the OR staff, any training methodology that can be reliably shown to increase the ability of team members to efficiently take corrective action is worthy of consideration as a standardized safety training tool.

Disclosures

Tomokazu Kishiki, Bailey Su, Brandon Johnson, Brittany Lapin, Kristine Kuchta, Laurie Sherman, JoAnn Carbray and Michael Ujiki have no conflicts of interest or financial ties related to this study to disclose.

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