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Simulation to Train Pediatric ICU Teams in Endotracheal Intubation of Patients with COVID-19

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Abstract

Introduction: To prevent transmission of severe acute respiratory syndrome coronavirus 2 to healthcare workers, we must quickly implement workflow modifications in the pediatric intensive care unit (PICU). Our objective was to rapidly train interdisciplinary PICU teams to safely perform endotracheal intubations in children with suspected or confirmed coronavirus disease 2019 using a structured simulation education program. **Methods:** We conducted a quality improvement study in a tertiary referral PICU. After developing stakeholder-driven guidelines for modified intubation in this population, we implemented a structured simulation program to train PICU physicians, nurses, and respiratory therapists. We directly observed PICU teams' adherence to the modified intubation process before and after simulation sessions and compared participants' confidence using the Simulation Effectiveness Tool-Modified (SET-M, Likert scale range 0: do not agree to 2: strongly agree regarding statements of confidence). **Results:** Fifty unique PICU staff members participated in 9 simulation sessions. Observed intubation performance improved, with teams executing a mean of 7.3–8.4 out of 9 recommended practices between simulation attempts ($P = 0.024$). Before undergoing simulation, PICU staff indicated that overall they did not feel prepared to intubate patients with suspected or confirmed SARS-CoV-2 (mean SET-M score 0.9). After the simulation program, PICU staff confidence improved (mean SET-M score increased from 0.9 to 2, $P < 0.001$). **Conclusion:** PICU teams' performance and confidence in safely executing a modified endotracheal intubation process for children with suspected or confirmed SARS-CoV-2 infection improved using a rapidly deployed structured simulation education program. *(Pediatr Qual Saf 2021;6:e373; doi: 10.1097/pq9.0000000000000373; Published online December 28, 2020.)*

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INTRODUCTION

On March 11, 2020, the World Health Organization declared the outbreak of coronavirus disease 2019 (COVID-19) caused by the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) as a global pandemic.[1] As of this writing, the virus has caused 22.1 million infections and 780,000 deaths worldwide.[2] This virus is highly infectious, which has led to alarming numbers of infected healthcare workers (HCWs). In March 2020, Italy and Spain reported an estimated 9% and 12% infection rate among healthcare professionals, respectively.[3] An estimated 3,000 HCWs in China[4] and 9,200 HCWs in the United States[5] have been infected. Among 185 pediatric intensive care units (PICUs) in North America, there are 166 reported COVID-19-positive PICU staff.[6]

Infections among HCWs have mainly been attributed to inadequate personal protection. At the beginning of the pandemic, this was due to poor awareness of the pathogen's mechanism of transmission.[7] Later, HCWs remained vulnerable due to shortages in personal protective equipment (PPE), inadequate training in appropriate PPE use (eg, use for specific patients and procedures), slow implementation of changes to patient flow (eg, cohorting patients with respiratory symptoms), and slow adoption of protective modifications to common procedures (eg, use of video laryngoscopy for endotracheal intubation).[7]

Healthcare institutions, professional organizations, and public health agencies have recognized an urgent need to be better prepared to care for patients with suspected or confirmed COVID-19 while protecting the healthcare workforce. Since then, recommendations have been issued to render high-risk aerosol-generating procedures (AGPs) safer and lessen the risk of virus transmission to HCWs.[8–10] At the University of Iowa Stead Family Children's Hospital PICU, we anticipate that the most common and highest risk AGP procedure we would need to perform on patients with suspected or confirmed COVID-19 is endotracheal intubation. We realized a need to rapidly adapt existing COVID-19 intubation guidelines to our setting and train our interdisciplinary teams to perform a modified endotracheal intubation process to ensure our staff's safety. This project's objective was to rapidly train interdisciplinary PICU teams to safely perform endotracheal intubations in children with suspected or confirmed COVID-19 using a structured simulation education program.

MATERIALS AND METHODS

To rapidly train PICU teams to safely perform endotracheal intubations in children with suspected or confirmed COVID-19, we used a simulation-based educational intervention since the evidence shows that simulation can result in rapid acquisition of procedural and teamwork skills,[11] improve clinical performance,[12] and enhance team communication.[13] We reported this project following SQUIRE14 and healthcare simulation research reporting guidelines.[15] This work was reviewed and determined to be exempt from human subjects research oversight by the local Institutional Review Board.

Environment and Context

We conducted the project at the University of Iowa Stead Family Children's Hospital PICU, a 28-bed unit accommodating ~1,200 admissions per year, of patients 0–21 years old. It serves as the only academic tertiary referral center in Iowa and admits patients from other nearby states. The PICU staff admit critically ill pediatric patients up to 21 years old with COVID-19. At the time of this writing, there is no dedicated pediatric intubation team for patients with suspected or confirmed COVID-19. Thus, the PICU team will perform intubations for these patients. Of note, some PICU staff have completed simulation programs previously as part of specific clinical certification programs (eg, extracorporeal membrane oxygenation training).

Project Design and Implementation

We conducted the project in 3 stages:

1) development of PICU guidelines for a modified endotracheal intubation process in patients with suspected or confirmed COVID-19;
2) implementation of a structured simulation education program directed at interdisciplinary PICU intubation teams; and
3) pretraining and posttraining assessment of simulation effectiveness (Fig. 1).

Development of PICU Intubation Guidelines

We convened an interdisciplinary working group of PICU stakeholders composed of physician, nursing, and respiratory therapy leadership to develop consensus intubation guidelines for PICU patients with suspected or confirmed COVID-19. These guidelines aim to balance patient care with the prevention of viral transmission to PICU staff. We reviewed published research,[16–18] guidelines from professional organizations (the Society for Critical Care Medicine,[10] the American College of Emergency Physicians,[19] the American Society of Anesthesiology,[20] other medical societies in the United Kingdom[21]), recommendations from public health agencies (World Health Organization[22]), and other institutions' intubation policies (University of Washington[23] and Children's Hospital of Philadelphia[24]). We adapted these recommendations based on available staffing and resources of our PICU and hospital infection control policies regarding PPE use. We obtained feedback from our anesthesiologist colleagues (who perform difficult intubations in the PICU) to ensure that the guidelines are in line with their practice.

We evaluated the prototype intubation procedure via a rapid series of simulations with a test group of PICU physicians, nurses, and respiratory therapists. Testing revealed optimal in-room staff configuration, specific personnel roles to ensure smooth task performance, and ideal patterns of team communication. For example, to more quickly and efficiently complete tasks, we determined that the bedside nurse should control the oxygen flow meter (a task that the respiratory therapist usually performs) because of her proximity to the equipment and other more pressing tasks that the respiratory therapist is required to perform at the same moment. After arriving at a final working version of the guidelines, we then produced training videos depicting the test PICU staff performing the modified intubation procedure (Fig. 1). We were able to develop and finalize the guidelines and create training videos in 7 days.

We incorporated these main modifications into our usual endotracheal intubation workflow (**Supplemental Digital Content 1**, which describes University of Iowa Stead Family Children's Hospital Pediatric Intensive Care Unit Guidelines for endotracheal intubation of patients

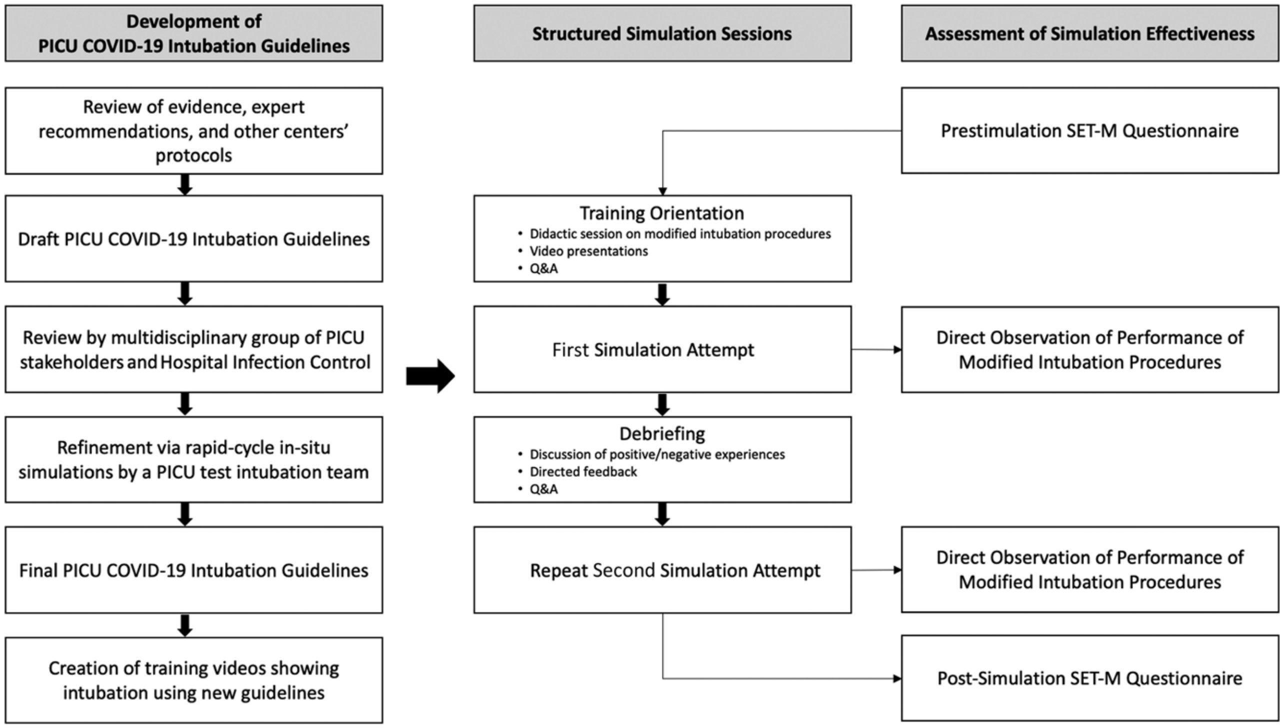

Fig. 1. Design and evaluation of a quality improvement project using simulation to train pediatric intensive care unit teams in endotracheal intubation of patients with suspected or confirmed SARS-CoV-2 infection.

with suspected or confirmed COVID-19, ***http://links.lww.com/PQ9/A228***).

1) Minimize personnel in the patient's room during the procedure (prototype testing revealed that five would be the minimum number needed to perform all tasks efficiently).
2) Use appropriate airborne PPE.
3) Have an experienced airway operator (attending physician or senior PICU fellow) perform intubation.
4) Routinely use video laryngoscopy (already used frequently in our unit).
5) Use a modified rapid sequence technique to avoid delivering bag-mask breaths.
6) Use a 2-person bag-mask technique with a filter if manual ventilation is needed.
7) Inflate the endotracheal tube (ETT) cuff immediately after intubation.
8) Connect to the ventilator immediately after intubation and minimize disconnections from the ventilator circuit.
9) Dispose of biohazards appropriately.

Implementation of Structured Simulation Training Sessions

We conducted structured simulation training sessions led by two authors who are local experts in simulation-based medical education (S.B.) and quality improvement (C.C.). Each session was 1.5–2 hours long and was directed at an ad hoc PICU intubating team composed of 2 PICU physicians, 3 nurses, and 1 respiratory therapist. Most of them were already on shift at the time (some physicians came in from home). The simulation training sessions were structured as follows (Fig. 1):

1) Training orientation: We first conducted a didactic session to discuss changes to the usual intubation process, expected team member roles, and rationales behind the modifications. We presented the training videos to illustrate the necessary intubation steps and situations that may be encountered by the team.
2) First simulation: We conducted all simulations in situ in a PICU patient room. We used a low-technology intubation mannequin (Gaumard S150 pediatric 5-y nursing care simulator) with actual clinical equipment, including a video laryngoscope, a mechanical ventilator, a circuit, and other usual intubation supplies. Each PICU team attempted to perform the modified intubation procedure. Teams ran through a complete simulation scenario from donning PPE to postintubation biohazard disposal.
3) Debriefing: After the first simulation was completed, a trained facilitator (S.B.) debriefed the team by providing directed feedback and leading a discussion of processes and teamwork dynamics that went well or could be further improved.
4) Repeat simulation: After debriefing, the PICU team again performed the modified intubation process incorporating feedback received and their reflections on improving team performance.

Assessment of Simulation Effectiveness

We assessed the structured simulation education program's effectiveness in increasing (1) PICU teams' adherence to recommended modified intubation procedures and (2) PICU staff's confidence and comfort in intubating patients with suspected or confirmed COVID-19 (Fig. 1).

We directly observed PICU teams' performance of recommended intubation procedures during the first and repeat simulation attempts. We developed a checklist of 9 items by consensus of the interdisciplinary PICU working group, consisting of the most relevant intubation modifications essential to protecting our staff. The simulation facilitator, a pediatric intensivist and simulation expert who also helped developed the checklist (S.B.), directly observed and rated the 2 simulation sessions, capturing the extent to which each PICU team was able to adhere to recommended intubation practices before and after the debriefing session. The same single rater performed all assessments for all teams in real time (**Supplemental Digital Content 2**, which displays endotracheal intubation observation checklist, ***http://links.lww.com/PQ9/A228***). Using Kane's validity framework,[25] we have evidence regarding the validity of our assessment strategy for 2 of 4 key validity domains—scoring and generalization. As described, we had a single rater who also helped develop the tool, eliminating challenges with rater familiarity with the instrument. The tool was also developed after broad consultation with the interdisciplinary PICU working group.

To assess the confidence and comfort of PICU staff in intubating patients with suspected or confirmed COVID-19, we adapted the Simulation Effectiveness Tool-Modified (SET-M), a questionnaire developed to assess the effects of simulation interventions on learners.[26] The SET-M has been previously used in simulation to assess neonatal resuscitation by healthcare teams[27] and measure nursing students' self-confidence and learning.[28] We administered the tool to simulation participants before the training orientation and after the repeat simulation attempt. Both questionnaires assessed participants' agreement with statements of confidence or comfort in intubation for this particular patient population. The postsimulation questionnaire contained statements to determine whether specific components of the simulation session were perceived to facilitate participants' learning (**Supplemental Digital Content 3**, which describes presimulation effectiveness questionnaire, **http://links.lww.com/PQ9/A228**) (**Supplemental Digital Content 4**, which postsimulation effectiveness questionnaire, **http://links.lww.com/PQ9/A228**).

Statistical Analysis

We reported the proportions of PICU teams performing each of the recommended intubation procedures before and after the first and repeat simulation attempts. Participants' responses to simulation effectiveness questionnaires were scored on a Likert scale (0: do not agree, 1: somewhat agree, 2: strongly agree). The mean score per item was reported for the 2 questionnaires before and after simulation sessions and across PICU staff roles. For the postsimulation effectiveness questionnaire, we reported proportions of each response on the Likert scale, indicating staff's perceptions of the educational benefit of simulation.

We compared the mean number of modified intubation procedures performed between the two simulation attempts using the Student's t test. *We also compared participants' mean responses to the simulation effectiveness questionnaire before and after simulation using the paired Student's t* test. Finally, we compared mean responses across PICU staff roles using one-way ANOVA. A P value <0.05 was considered statistically significant. We performed statistical analysis using STATA 14.2 (StataCorp, College Station, Tex., 2015).

RESULTS

The modified endotracheal intubation guidelines and simulation program were developed and ready for implementation within one week. After another week, we had already trained a total of 50 PICU staff members (100% of PICU physicians, 34% of nurses, and 33% of respiratory therapists). Simulation sessions continued to be held after data collection was completed.

Simulation Participants

Over 8 days, a total of 50 unique PICU staff members participated in nine simulation sessions. Participants included 13 PICU physicians (8 attendings and 5 fellows), 28 nurses, and nine respiratory therapists. Each simulation session was composed of an ad hoc PICU intubation team which, on average, was composed of 6 members: 2 PICU physicians (airway operator and team leader), 3 nurses (for medication administration, documentation/biohazard disposal, and additional support), and one respiratory therapist. Five PICU team members were inside the patient room, whereas the support nurse remained outside on stand-by.

Observed Performance of Modified Intubation Practices

During the first simulation attempt, 4 of 9 PICU intubation teams performed all recommended intubation procedures. The most commonly missed procedures included inflating the ETT cuff before giving breaths, using end-tidal CO2 capnography to confirm intratracheal ETT placement, and removing the top layer of gloves after the airway is secure. However, during the repeat simulation attempt, the performance of recommended intubation practices markedly improved, with 7 of 9 teams performing all recommended procedures (Table 1). Team performance improved from executing a mean of 7.3–8.4 out of 9 recommended procedures between the first and repeat simulation attempts ($P = 0.024$).

Confidence of PICU Staff in Intubating Patients with Suspected or Confirmed COVID-19

Before undergoing the simulation program, PICU staff indicated that they did not feel prepared to provide care to a patient with suspected or confirmed COVID-19 requiring intubation (mean SET-M score 0.9). They expressed only moderate confidence in their ability to follow specific recommendations for COVID-19 intubations (mean score 1.1) and their skills as a member of a COVID-19 intubation team (mean score 1.1). They particularly expressed discomfort with performing recommended biohazard disposal practices during and after intubation (mean score 0.9) (Table 2). Sixteen participants indicated that their most common concern was the appropriate use of PPE and other methods to protect staff from aerosolized secretions.

After undergoing the simulation program, PICU staff's confidence markedly improved, showing an increase in the mean score by 1.1 for perceived preparedness to provide care to patients with suspected or confirmed COVID-19 requiring intubation ($P < 0.001$). All items on the postsimulation effectiveness questionnaire showed statistically significant increases in mean scores ($P < 0.001$) (Table 2). Thirty-six participants indicated that simulation was helpful because it provided an opportunity to practice recommended intubation procedures in real time as a member of an actual PICU intubating team. Participants noted improved teamwork and communication since they better understand each other's roles during intubation.

Before undergoing the simulation program, there was a significant difference across PICU staff roles in perceived preparedness, with mean scores of 0.9 for physicians, 0.7 for nurses, and 1.4 for respiratory therapists ($P = 0.017$). Otherwise, there were no other significant differences in the rest of the presimulation effectiveness questionnaire items. After undergoing simulation, there were no longer differences in confidence across PICU staff roles.

Perceived Effectiveness of Structured Simulation Program

Overall, the PICU staff agreed that the simulation program's structure significantly increased their learning, confidence, and comfort. All staff agreed that conducting a presimulation training orientation facilitated their learning, that debriefing facilitated opportunities for constructive feedback and self-reflection, and that the repeat simulation attempt helped solidify concepts and increased their comfort as a member of the intubating team (Table 3).

DISCUSSION

We were able to rapidly train PICU teams to safely perform endotracheal intubations in children with suspected or confirmed COVID-19. We also showed that a modified endotracheal intubation guideline could be rapidly developed and effectively implemented via a structured simulation program, improving PICU teams' observed performance and reported confidence in executing recommended COVID-19 intubation procedures.

All PICU teams performed the majority of modified intubation procedures at the end of simulation training. Timeouts and removal of the top layer of gloves were the only procedures not performed consistently. We have expanded our timeouts to include specifics of the modified intubation process (eg, equipment in the room, staff roles). Thus teams may have found adherence to this more challenging. It is unclear why staff inconsistently removed the top layer of gloves, though this was done near the end and may have been neglected at the end of the scenario. Presimulation, respiratory therapists were most confident in their ability to care for patients with COVID-19 requiring intubation. Their comfort may stem from experiences they've already had in intubating adult patients with COVID-19 (most therapists cross-cover the adult ICUs). This variation in confidence across different PICU staff disappeared after simulation training.

Simulation improves participants' knowledge of and comfort with a wide variety of medical situations.[25] Simulation has also been used to prepare the workforce for infectious disease outbreaks, including simulated patient triage/management and the performance of essential procedures.[29] By closely approximating expected working circumstances, simulation helps hone participants' skills

Table 1. Observed Performance of Modified Intubation Procedures for Pediatric Patients with Suspected or Confirmed COVID-19

	Proportion of Intubation Teams Performing Procedure Correctly, n (%)	
	First Simulation Attempt	Repeat Simulation Attempt
Modified Intubation Procedures	n = 9	n = 9
All in-room staff donned PPE appropriately	9 (100)	9 (100)
Time out was performed	7 (78)	8 (89)
All needed equipment/medications were present inside the room	8 (89)	9 (100)
A filter was placed between bag and mask	9 (100)	9 (100)
No unintentional bag-mask breaths were provided before intubating	9 (100)	9 (100)
Video laryngoscopy was used to intubate	9 (100)	9 (100)
ETT cuff was inflated before attaching to the ventilator/giving breaths	5 (56)	9 (100)
End-tidal CO_2 continuous capnography was used to confirm ETT placement in trachea	6 (67)	9 (100)
Team members removed top layer of gloves after intubation	4 (44)	5 (56)

Table 2. Overall Confidence of Pediatric Intensive Care Unit Staff in Intubating Pediatric Patients with Suspected or Confirmed COVID-19

	Mean Scores*			
	Before Simulation Session	After Simulation Session		
Staff Confidence in Intubation	n = 50	n = 50	Mean Change	*P*†
I am prepared to provide care to a PUI/COVID-19-positive patient requiring intubation	0.9	2.0	1.1	<0.001
I have a good understanding of the rationale behind recommended practices for intubating a PUI/COVID-19-positive patient	1.4	2.0	0.6	<0.001
I am confident that I can follow the current recommendations for the intubation of a PUI/COVID-19-positive patient	1.1	2.0	0.9	<0.001
I am confident of my skills as a member of the intubating team for a PUI/COVID-19-positive patient	1.1	1.9	0.8	<0.001
I am confident in communicating with other members of the intubating team for a PUI/COVID-19-positive patient	1.4	2.0	0.6	<0.001
I am confident in my knowledge of recommended PPE for intubating a PUI/COVID-19-positive patient	1.2	1.9	0.7	<0.001
I am comfortable performing recommended practices for disposing of and/or decontaminating equipment after intubation of a PUI/COVID-19-positive patient	0.9	1.9	1.0	<0.001

*Each survey item was scored based on the participant's Likert scale response (0: do not agree, 1: somewhat agree, 2: strongly agree), and the mean score per item was calculated. The minimum possible score is 0, whereas the maximum possible score is 2.
†Mean scores were compared before and after simulation sessions using the paired Student's *t* test.

Table 3. Pediatric Intensive Care Unit Staff's Perceptions of Effectiveness of Simulation Training Session

	Participant Responses n = 50, n (%)		
Perception of Components of Simulation Session	**Strongly Agree**	**Somewhat Agree**	**Do Not Agree**
Presimulation Briefing			
The presimulation briefing increased my confidence.	49 (98)	1 (2)	0
The presimulation briefing was beneficial to my learning.	50 (100)	0	0
Debriefing			
Debriefing contributed to my learning	47 (94)	3 (6)	0
Debriefing was valuable in helping me improve my clinical understanding of intubation recommendations	49 (98)	1 (2)	0
Debriefing provided opportunities to self-reflect on my performance during simulation	50 (100)	0	0
Debriefing consisted of a constructive evaluation of the simulation	50 (100)	0	0
Repeat simulation attempt			
Repeating the scenario was helpful in solidifying concepts related to intubation of a PUI/COVID-19-positive patient	50 (100)	0	0
Repeating the scenario was helpful to better understand each team member's role in intubation	48 (96)	2 (4)	0
Repeating the scenario helped me feel more comfortable in my role as a member of the intubating team	50 (100)	0	0

and teamwork to deliver optimal care and maintain staff safety even under high-risk conditions.[30] Because the COVID-19 pandemic was declared, similar studies have been performed in critical care units, wherein simulations were conducted to evaluate the ICU team's operational readiness for high-risk procedures for patients with COVID-19. Similar to our rapid simulations approach to develop and refine our modified endotracheal intubation guidelines, other simulation teams have identified active failures and latent hazards (eg, inappropriate PPE use, and inappropriate intubation checklist)—information that was used to modify existing unit protocols.[31,32] One simulation study illustrated the need for more extensive PPE given aerosol contamination patterns observed during simulated COVID-19 intubations.[33] Our work builds upon the results of these studies. We focused primarily on teaching PICU staff how to perform a modified intubation process to prevent viral transmission. We emphasized excellent team dynamics and communication so that PICU staff can implement these recommendations effectively.

This work has several limitations. At the end of data collection, we had not completed training all staff, so reported results are not reflective of our entire PICU team. We encountered some difficulty scheduling nurses and respiratory therapists due to the low PICU census (in anticipation of a COVID-19 surge) with less staff readily available to participate. We were unable to perform simulations with full PPE, using surgical masks instead of N95 respirators or controlled air-purifying respirators, due to our hospital's mandate to conserve supplies. Though we were unable to perform simulations in a negative air-pressure room because these were in short supply, this did not affect simulation fidelity because the layout and equipment in a regular room are identical. Although we used a low-technology mannequin to perform simulations, we still created a highly realistic intubation environment. Literature shows that high-fidelity mannequins are unnecessary if the simulation's primary objective is to improve teamwork and communication for specific tasks.[34,35] Finally, our results do not account for skill fade over time. We will address this by conducting refresher training later on.

It remains to be seen if our findings can be extrapolated to real-world performance, which we plan to assess once modified intubations are performed on actual patients. We plan to monitor each COVID-19 intubation performed in our unit using the same performance checklist to determine whether the PICU team appropriately executed the guideline's recommendations, paying particular attention to commonly missed procedural steps during debriefing (eg, timeouts and removal of the top layer of gloves).

CONCLUSIONS

PICU teams' performance and confidence in safely executing a modified endotracheal intubation process for children with suspected or confirmed SARS-CoV-2 infection improved using a structured simulation education program. We recommend using simulation as a rapid and effective method to train interdisciplinary teams to perform complex interventions in the PICU as an integral part of preparations to provide excellent patient care while protecting the healthcare workforce during the current COVID-19 pandemic.

DISCLOSURE

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