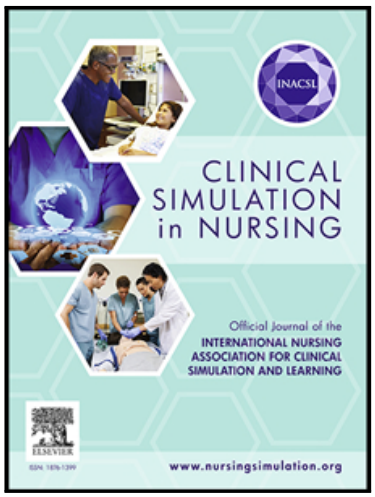

A Multimodal Approach to Training COVID-19 Processes Across Four Intensive Care Units

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PII: S1876-1399(22)00022-6
DOI: https://doi.org/10.1016/j.ecns.2022.03.001
Reference: ECSN 1317

To appear in: *Clinical Simulation in Nursing*

Please cite this article as: Katie M. Moynihan MBBS , Dorothy M. Beke RN, CPNP-PC/AC , Annette Imprescia RN, CCRN , Michael SD Agus MD , Monica Kleinman MD , Anne Hansen MD , Kevin Bullock MS, RRT-NPS , Matt Taylor MEd RN , Marlena Smith-Millman MPH , Traci Wolbrink MD , Peter Weinstock MD , Catherine Allan MD , A Multimodal Approach to Training COVID-19 Processes Across Four Intensive Care Units, *Clinical Simulation in Nursing* (2022), doi: https://doi.org/10.1016/j.ecns.2022.03.001

Highlights

- COVID-19 required urgent clinical changes to promote Intensive Care Unit staff safety
- Information dissemination and high-volume team training demands a multimodal approach
- We employed videos, webinars, superusers, small-group simulation and cognitive aids

A Multimodal Approach to Training COVID-19 Processes Across Four Intensive Care Units

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The work was performed at Boston Children's Hospital, Boston, MA, USA.

Funding: None.
Financial Disclosure: The authors have no financial relationships relevant to this article to disclose.
Potential conflicts of interest: The authors have no conflicts of interest relevant to this article to disclose.

Acknowledgements: All interdisciplinary staff across four ICUs (medical-surgical, medical, cardiac and neonatal) at Boston Children's Hospital. And all providers in the front-line facing this pandemic.

Abbreviations: Coronavirus disease (COVID-19), intensive care unit (ICU), aerosol generating procedures (AGPs), health care providers (HCPs), personal protective equipment (PPE), cardiopulmonary resuscitation (CPR), Extracorporeal membrane oxygenation (ECMO), crisis resource management (CRM).

Key Words: Intensive Care Units, Pediatric; Information Dissemination; COVID-19; Simulation Training; Communication; Aerosols; Intubation, Intratracheal

Abstract:
Coronavirus disease (COVID-19) required innovative training strategies for emergent aerosol generating procedures (AGPs) in intensive care units (ICUs). This manuscript summarizes institutional operationalization of COVID-specific training, standardized across four ICUs. An interdisciplinary team

collaborated with the Simulator Program and OpenPediatrics refining logistics using process maps, walkthroughs and simulation. A multimodal approach to information dissemination, high-volume team training in modified resuscitation practices and technical skill acquisition included instructional videos, training superusers, small-group simulation using a flipped classroom approach with rapid cycle deliberate practice, interactive webinars, and cognitive aids. Institutional data on application of this model are presented. Success was founded in interdisciplinary collaboration, resource availability and institutional buy in.

Introduction:

Coronavirus disease (COVID-19) has high morbidity and mortality and is highly transmissible via respiratory droplets or direct contact (CDC, 2020; WHO, 2020). Aerosol generating procedures (AGPs) such as bag mask ventilation, intubation and non-invasive ventilation increase health care providers' exposure (HCPs) to pathogens. To maintain HCP safety, specific infection control measures, procedural and systems-based modifications are recommended for AGPs in patients with confirmed/suspected COVID-19 infection (Abulebda et al., 2020; Balikai et al., 2021; CDC, 2020; Edelson et al., 2020; Feldman et al., 2020). Emergent AGPs present unique challenges: teams must implement effective clinical care while minimizing spread of aerosolized viral particles; personal protective equipment (PPE) adversely impacts verbal and non-verbal communication; providers must learn modified technical skills; and risk of personal exposure heightens stress inherent to resuscitation negatively influencing teamwork. The evolving global pandemic required HCPs, especially those in intensive care units (ICUs) where emergent AGPs are commonly performed, to make these significant practice changes and rapidly train to competency in new technical skills and team-based practices while adhering to social distancing regulations and simultaneously provide uninterrupted patient care (Bialek et al., 2020; CDC, 2020; Edelson et al., 2020).

A literature review revealed the application of numerous pedagogical innovations to meet urgent training needs during the COVID-19 pandemic involving technology and simulation-based teaching. Internationally, simulation was relied upon to both prepare HCP and identify latent safety threats in COVID-19 care processes and environments (Dubé et al., 2021). Adult centers in Saudi Arabia and France reported use of online modules, practical skill stations and an in-situ training program using a

modified Peyton's approach with rapid cycle deliberate practice (RCDP) (Buléon et al., 2020; Lababidi et al., 2021). Similarly, tabletop exercises, structured in-situ simulation sessions and debriefing resulted in improved performance and compliance with protocol modifications and increasing procedural confidence (Balikai et al., 2021; Daly Guris et al., 2020; Sharara-Chami et al., 2020). In a national preparedness survey of 22 US pediatric ICUs with simulation capabilities, reported training modalities included 'simulation-based' (82%), video (73%), didactic (55%) and online modules (45%) (Abulebda et al., 2020). The International Pediatric Simulation Society maintains a collaborative document of simulation efforts relating to COVID-19 (https://www.ipssglobal.org/community_resources_covid). However, we identified no published overarching description of practical implementation and integration of multiple modalities in a pediatric center.

This manuscript outlines the multimodal approach established at our large urban academic quaternary pediatric institution to develop safe approaches to emergent AGPs and to train large numbers of staff in new practices across four ICUs (Figure 1). The goal was to provide high-quality care without compromising HCP safety (Edelson et al., 2020).

Implementation Team:

The work of developing new care processes for safe conduct of emergent AGPs and subsequent training of front-line team members was conducted by a multidisciplinary team made up of clinical experts (ICU nurses, physicians, respiratory therapists), Simulator Program personnel (curriculum developer, simulation engineers), representatives from OPENPediatrics (a web-based, educational platform), and unit-based clinical educators with specific expertise in simulation and debriefing. Implementation of training built on the established culture of in-situ simulation and strong foundation in crisis resource management principles present across all 4 ICUs in the institution.

Development of COVID-19 Safe AGP Practices for Implementation:

To standardize the institutional ICU approach to emergent AGPs, key interdisciplinary stakeholders from four ICUs (cardiac, medical, medical/surgical and neonatal) partnered with the Simulator Program to address three high-risk scenarios: intubation, cardiopulmonary resuscitation (CPR) and extracorporeal membrane oxygenation (ECMO) cannulation. The collaborative response addressed modified team resuscitation practices and acquisition of new technical skills to provide high-quality care, effective teamwork and overcome COVID-19 related challenges (CDC, 2020; Edelson et al., 2020). Draft procedures were developed based on emerging literature, recommendations from prior pandemics and interdisciplinary clinical expertise. Process maps were created and subsequently refined via procedural walkthroughs in the clinical space and room diagrams were constructed (Figure 2). Cycles of high-fidelity in-situ simulation, debriefing, process modification, and repeat simulation and debriefing were leveraged to test and refine processes, optimize sequences of steps, team roles, provider physical location in the room, and order as well as timing of entry of equipment into the room. Debriefings focused on identifying and solving challenges to implementation of processes using the Promoting Excellence and Reflective Learning in Simulation framework (Balikai et al., 2021; Daly Guris et al., 2020; Edelson et al., 2020; Sharara-Chami et al., 2020). Specific process-based changes included alterations to standard intubation (immediate cuff inflation and direct ventilator connection *prior* to initiation of positive pressure) and CPR (use of a mechanical CPR device) (Balikai et al., 2021; Edelson et al., 2020; Sharara-Chami et al., 2020). Each unique ICU setting also instituted population specific modifications; for example, the neonatal ICU used inline suction due to endotracheal tube size.

Three key systems-based changes were also devised and implemented to facilitate safe execution of AGPs: 1) Three distinct clinical care zones with differing PPE requirements were designated based on proximity to AGPs (Figure 2); 2) teams were divided into sub-teams and roles based on clinical care zones (Table); and 3) novel communication strategies were implemented to facilitate communication between teams inside and outside the room when room doors were closed (Table) (Howard et al., 1992).

Multimodal training strategies

Implementation of the newly developed technical and system-based changes into clinical practice across four ICUs faced important challenges. Coordinated distribution of information and trainings of such processes needed to: 1) adhere to social distancing requirements; 2) rapidly train large numbers of practitioners to acquire 'muscle memory' in new physical skills while simultaneously engaged in active patient care; 3) provide asynchronous training opportunities for staff infrequently on-site; 4) make just-in-time or refresher training available for high-risk procedures; 5) revise Crisis Resource Management (CRM) principles with novel applications in the context of the pandemic and 6) harmonize across ICU settings, as many staff work across multiple ICUs. A multimodal strategy was applied including video-based training modules for introduction of new skills and processes (Moynihan, Zackin, Agus, et al., 2020; Moynihan, Zackin, Bullock, et al., 2020), hands-on simulation using rapid cycle deliberate practice (RCDP) (Lemke et al., 2019; Perretta et al., 2020) for development of proficiency in new technical skills, webinar-style training, creation of durable cognitive aids, and hands-on refresher trainings (Figure 1). The design and conduct of in situ simulations conformed to INACSL Healthcare Simulation Standards (Watts et al., 2021). Simulation activities were preceded by a structured pre-brief. Super-users trained in the new protocols facilitated operationalization of practical training to large numbers of staff.

Instructional Videos

Instructional videos introduced large numbers of staff to new practices and processes, overcoming social distancing restrictions and permitting asynchronous and just-in-time learning. Developed as a collaboration between clinicians, the Simulator Program, and OPENPediatrics, three separate narrated videos of high-fidelity simulations performed in situ by experienced multidisciplinary teams provided instruction on intubation, resuscitation (including use of a mechanical CPR device), and emergency ECMO cannulation. Videos were made available on the OPENPediatrics platform and through links provided to all staff. Clinicians were encouraged to view videos both on their own time or at the bedside for just-in-time review of practices prior to anticipated high risk events.

Rapid Cycle Deliberate Practice

New technical skill acquisition requires hands-on practice. Applying a flipped classroom approach, nurses, attending physicians, fellows, and respiratory therapists watched instructional videos then received training from super-users using a RCDP approach (Lemke et al., 2019; Perretta et al., 2020). These sessions focused on technical aspects of intubation with COVID-19 precautions and mechanical CPR device use. To maintain social distancing, participants were trained in groups of 4 at an off-site simulation center, replicating ad-hoc team structure for real-life intubation events. Training sessions progressed from hands on instruction in technical skill components of modified COVID-specific intubation with a competency learning approach followed by a high-fidelity team simulation for consolidation. Training sessions began with hands on instruction in technical skill components of modified COVID-specific intubation protocols, with the expectation that learners would demonstrate competency in the skills before progressing to a scenario-based team simulation for consolidation of skills.

Structured Interactive Webinars and Video-based Simulation

To train large numbers of staff in new team-based approaches to intubation, resuscitation/CPR and emergent ECMO cannulation in the COVID-19 era webinar-style trainings were offered. Staff were encouraged to view instructional videos prior to participation. Webinars were run using a 'live', interactive zoom platform with a proportion of participants on site in a conference room maintaining social distancing, and others dialing in. Webinars encompassed brief revision of CRM principles, didactic instruction on care zones, roles of team members "inside" and "outside" room, and communication strategies followed by viewing of a video-recorded crisis simulation demonstrating these concepts. Learners participated in a debriefing focused on enhancing understanding of COVID-specific practices and trouble-shooting challenges of implementation of these practices. The rich interdisciplinary nature of participants was leveraged to troubleshoot practical implementation challenges and identify solutions.

Durable Cognitive Aids

To facilitate care at the bedside, cognitive aids were created and distributed throughout the ICUs providing streamlined instructions related to COVID-specific safety practices for intubation and team-based care for just-in-time reference. Visual references were laminated for decontamination available on all code carts also included room maps demonstrating zones of care (Figure 2) and associated PPE requirements.

Hands on Refresher Trainings

Following initial live and virtual trainings, in situ simulation-based mock codes were run on a weekly basis, emphasizing rapid correct donning of PPE, utilization of clinical care zones, and management of communication strategies between inside and outside the patient room. Simulations adhered to all institutional social distancing guidelines. The majority of staff arrived at simulation events with PPE allotted for that day of work. For those who responded without PPE, N95 masks and face shields crafted by simulation center engineering staff for simulation use only (not approved for patient use) were provided to avoid depletion of hospital PPE resources. A prebrief oriented participants to the specific objectives of the simulation. Novel COVID-19 protocols were reviewed, including use of designated zones of care, protocols for communication from inside to outside the room, and expectations for PPE use during an emergency. Finally, team member roles were assigned and participants were given ample time to ask clarifying questions regarding new COVID-19 protocols. Simulations were facilitated by multidisciplinary clinical faculty with specific training in simulation and debriefing. In each one-hour session staff completed the same simulation scenario twice followed by debriefing to reinforce and clarify safety practices. Debriefing applied a systems improvement lens to identify strategies for managing challenges to adhering to COVID-19 best practices and application of CRM principles as relevant to clinical modifications for the pandemic.

Uptake of Training Opportunities:

HCP were required to be well-versed in procedures/protocols around AGPs, infection control, safety and appropriate use of PPE. Our multimodal approach was designed to allow access to training to the largest number of staff possible through either virtual or live interactive activities while adhering to social distancing policies. RCDP training on intubation procedures were assigned to all attending ICU physicians and respiratory therapists, the group most likely to engage in these activities and face risk of exposure during clinical practice. In situ simulations were offered to ICU nurses, physicians, and respiratory therapists as part of their workdays in order maximize opportunities for participation. Online learning modules and webinars were available to individuals and allowed for both participation by greater numbers and opportunity to repeatedly reinforce new material.

Clinical Applications, Limitations and Future Directions

Overall, 169 ICU staff, including nurses, nurse practitioners, respiratory therapists and physicians, trained with in-person small group skills-based simulations. Post-training surveys of participants revealed they perceived increased preparedness and reduced anxiety. Additionally, 145 interdisciplinary staff participated in webinars, with surveys confirming increased perceived preparedness and improved clarity on application of CRM principles during COVID-19 safety protocols. Finally, 87 staff (nurses, nurse practitioners, respiratory therapists and physicians) participated in simulation-based refresher trainings. Intubation and resuscitation training videos were also made available beyond our institution through OPENPediatrics, the free, on-line, open access knowledge exchange platform, recording greater than 283,000 views across 53 countries (Moynihan, Zackin, Agus, et al., 2020; Moynihan, Zackin, Bullock, et al., 2020). Practical solutions to overcome clinical challenges identified during debriefings of simulation events were implemented, such as placement of a face shield and N95 under the resuscitation alarm-bell to facilitate expedited donning prior to CPR initiation. While no direct causality can be inferred, only 4 out of 934 (<0.5%) critical care staff acquired COVID-19 infection because of COVID-positive patient

exposures in critical care areas during the pandemic (3.2020-7.2021) at a time in which the patient infection rate was 1.37% admissions.

Generalizability of this approach has several caveats; implementation relied on a strong, collaborative relationship between the Simulator Program and clinical departments, established culture of in-situ simulation training, key stakeholder and institutional buy-in, and resource availability. However, we envisage an important role for simulation training in future emerging healthcare crises. Integration of multiple modalities applying social education theory and targeted practical training to urgently support skill acquisition and team-based system changes will likely be required again. Lessons learned may guide future endeavors. We emphasize the importance of early, interdisciplinary collaborative planning and harmonization across settings where HCPs crossover. Success was grounded in iterative processes, applying innovative pedagogic simulation-based strategies and multimodal training approaches to enhance planning of training that addresses human factors, team communication, equipment choice, and prioritizes HCP safety while providing high-quality patient care.

Conclusion

This manuscript outlines the multimodal approach utilized at our institution during the COVID-19 pandemic to develop new processes for both technical skill acquisition and systems-based changes unified across four ICUs to facilitate safe execution of AGPs. Our system rapidly trained a large number of busy multidisciplinary staff using a multimodal approach to incorporate changes into clinical practice while providing uninterrupted patient care and adhering to social distancing restrictions. The training strategy leveraged multiple educational methodologies, including videos, a flipped classroom approach to introduce new material, RCDP technical skills training, traditional hands-on simulation for skill and team training, webinar-style training and cognitive aids for bedside use. We demonstrate successful implementation of this strategy through strong interdisciplinary collaboration harmonizing of work across

four ICUs, partnership with a well-established hospital-based Simulator Program, and resource availability with institutional buy-in.

References

Abulebda, K., Ahmed, R. A., Auerbach, M. A., Bona, A. M., Falvo, L. E., Hughes, P. G., Gross, I. T., Sarmiento, E. J., & Barach, P. R. (2020). National preparedness survey of pediatric intensive care units with simulation centers during the coronavirus pandemic. *World Journal of Critical Care Medicine*, *9*(5), 74–87. https://doi.org/10.5492/wjccm.v9.i5.74

Balikai, S. C., Badheka, A., Casey, A., Endahl, E., Erdahl, J., Fayram, L., Houston, A., Levett, P., Seigel, H., Vijayakumar, N., & Cifra, C. L. (2021). Simulation to Train Pediatric ICU Teams in Endotracheal Intubation of Patients with COVID-19. *Pediatric Quality & Safety*, *6*(1), e373. https://doi.org/10.1097/pq9.0000000000000373

Bialek, S., Boundy, E., Bowen, V., Chow, N., Cohn, A., Dowling, N., Ellington, S., Gierke, R., Hall, A., MacNeil, J., Patel, P., Peacock, G., Pilishvili, T., Razzaghi, H., Reed, N., Ritchey, M., & Sauber-Schatz, E. (2020). *Severe outcomes among patients with coronavirus disease 2019 (COVID-19) - United States, February 12-march 16, 2020*. Morbidity and Mortality Weekly Report. https://doi.org/10.15585/mmwr.mm6912e2

Buléon, C., Minehart, R. D., & Fischer, M. O. (2020). Protecting healthcare providers from COVID-19 through a large simulation training programme. *British Journal of Anaesthesia*, *125*(5), e418–e420. https://doi.org/10.1016/j.bja.2020.07.044

CDC. (2020). *Interim Infection Prevention and Control Recommendations for Patients with Suspected or Confirmed Coronavirus Disease 2019 (COVID-19) in Healthcare Settings*. National Center for Immunization and Respiratory Diseases Division of Viral Diseases. Center for Disease Control (CDC).

Daly Guris, R. J., Doshi, A., Boyer, D. L., Good, G., Gurnaney, H. G., Rosenblatt, S., McGowan, N., Widmeier, K., Kishida, M., Nadkarni, V., Nishisaki, A., & Wolfe, H. A. (2020). Just-in-Time Simulation to Guide Workflow Design for Coronavirus Disease 2019 Difficult Airway Management∗. *Pediatric Critical Care Medicine*, *21*(8), E485–E490. https://doi.org/10.1097/PCC.0000000000002435

Dubé, M., Kaba, A., Cronin, T., Barnes, S., Fuselli, T., & Grant, V. (2021). Correction to: COVID-19 pandemic preparation: using simulation for systems-based learning to prepare the largest healthcare workforce and system in Canada. *Advances in Simulation*, *6*(1), 1–12. https://doi.org/10.1186/s41077-021-00165-1

Edelson, D. P., Sasson, C., Chan, P. S., Atkins, D. L., Aziz, K., Becker, L. B., Berg, R. A., Bradley, S. M., Brooks, S. C., Cheng, A., Escobedo, M., Flores, G. E., Girotra, S., Hsu, A., Kamath-Rayne, B. D., Lee, H. C., Lehotzky, R. E., Mancini, M. E., Merchant, R. M., … Topjian, A. (2020). *Interim Guidance for Basic and Advanced Life Support in Adults, Children, and Neonates With Suspected or Confirmed COVID-19:From the Emergency Cardiovascular Care Committee and Get With the Guidelines ® -Resuscitation Adult and Pediatric Task Forces of t*. Circulation. https://doi.org/10.1161/circulationaha.120.047463

Feldman, O., Meir, M., Shavit, D., Idelman, R., & Shavit, I. (2020). *Exposure to a Surrogate Measure of Contamination From Simulated Patients by Emergency Department Personnel Wearing Personal Protective Equipment*. JAMA - Journal of the American Medical Association. https://doi.org/10.1001/jama.2020.6633

Howard, S. K., Gaba, D. M., Fish, K. J., Yang, G., & Sarnquist, F. H. (1992). Anesthesia crisis resource management training: Teaching anesthesiologists to handle critical incidents. *Aviation Space and Environmental Medicine*.

Lababidi, H. M. S., Alzoraigi, U., Almarshed, A. A., Alharbi, W., Alamar, M., Arab, A. A., Mukahal, M. A., Alasmari, F. A., Mzahim, B. Y., Alharastani, H. A. M., Alammi, S. S., & Alawad, Y. I. (2021). Simulation-based training programme and preparedness testing for COVID-19 using system integration methodology. *BMJ Simulation and Technology Enhanced Learning*, *7*(3), 126–133. https://doi.org/10.1136/bmjstel-2020-000626

Lemke, D. S., Fielder, E. K., Hsu, D. C., & Doughty, C. B. (2019). Improved Team Performance During Pediatric Resuscitations After Rapid Cycle Deliberate Practice Compared With Traditional

Debriefing: A Pilot Study. *Pediatric Emergency Care*. https://doi.org/10.1097/PEC.0000000000000940

Moynihan, K., Zackin, B., Agus, M., Bullock, K., Imprescia, A., Kleinma, n M., & Allan, C. (2020). *Cardiopulmonary Resuscitation in the ICU with COVID-19 Considerations*. OPENPediatrics. https://youtu.be/M8MWOFjK2Ow

Moynihan, K., Zackin, B., Bullock, K., Kleinman, M., Mehta, N., & Agus, M. (2020). *COVID-19 Airway Management in the Intensive Care Unit*. OPENPediatrics. https://youtu.be/V-FEi9NEYtQ

Perretta, J. S., Duval-Arnould, J., Poling, S., Sullivan, N., Jeffers, J. M., Farrow, L., Shilkofski, N. A., Brown, K. M., & Hunt, E. A. (2020). Best Practices and Theoretical Foundations for Simulation Instruction Using Rapid-Cycle Deliberate Practice. *Simulation in Healthcare : Journal of the Society for Simulation in Healthcare, 15*(5), 356–362. https://doi.org/10.1097/SIH.0000000000000433

Sharara-Chami, R., Sabouneh, R., Zeineddine, R., Banat, R., Fayad, J., & Lakissian, Z. (2020). In Situ Simulation: An Essential Tool for Safe Preparedness for the COVID-19 Pandemic. *Simulation in Healthcare*, *15*(5), 303–309. https://doi.org/10.1097/SIH.0000000000000504

Watts, P. I., McDermott, D. S., Alinier, G., Charnetski, M., Ludlow, J., Horsley, E., Meakim, C., & Nawathe, P. A. (2021). Healthcare Simulation Standards of Best PracticeTM Simulation Design. *Clinical Simulation in Nursing, 58,* 14–21. https://doi.org/10.1016/j.ecns.2021.08.009

WHO. (2020). *Naming the coronavirus disease (COVID-19) and the virus that causes it*. World Health Organization (WHO).

Glossary of Expanded Definitions and Terms

The Simulator Program (https://simpeds.org/program/): Boston Children's Hospital Simulator Program (*SIMPeds*) was established in 2001, with the mission to apply state of the art experiential techniques to optimize human-human and human-technology relationships to reduce risk, fear and anxiety – creating quality experiences and outcomes in healthcare. Focused on improving preparedness and high quality, high volume pediatric care, the SIMPeds team span healthcare, biotech, engineering and education disciplines as a quality improvement resource, preparation and testing system. SIMPeds run >100 courses designed to train participants across the full spectrum of expertise gradients including sustainable on-site support activities for local, regional and international partnering institutions, participate in research, quality improvement and safety initiatives as well as development and manufacturing of simulation devices.

OPENPediatrics (https://www.openpediatrics.org/aboutus): OPENPediatrics is a free, global, open access online knowledge-exchange platform for healthcare providers from all resource settings involved in the care of sick children. This digital learning resource shares peer-reviewed content on best practices from around the world in the form of courses, expert lectures and demonstrations, interactive device simulators, protocols and medical calculators.

Rapid Cycle Deliberate Practice (RCDP): is a simulation-based teaching methodology in which individual or groups of learners engage in repeated performance of a simulation, task or procedure with debriefing by an expert facilitator who immediately identifies and corrects performance gaps. Repeated cycles of practice and feedback allow learners to achieve mastery learning.

Flipped Classroom: A flipped classroom is a pedagogical approach in which pre-class activities are emphasized, so as opposed to typical direct group learning and instruction in the form of lectures, this model moves prior learning to individual learning space thus transforming the group space into a more interactive, dynamic learning environment. For our participants, the instructional videos were required viewing prior to the webinar sessions.

Figure Legends

Figure 1 Summary of the institutional approach to developing new processes related to both technical skills and systems-based changes to facilitate safe execution of aerosol generating procedures in response to the COVID-19 pandemic. The multimodal strategy included a flipped classroom approach, rapid cycle deliberate practice, traditional hands-on simulation, and webinar-style trainings successful through strong interdisciplinary collaboration, partnership with a well-established hospital-based Simulator Program, and harmonizing of work across 4 ICUs.

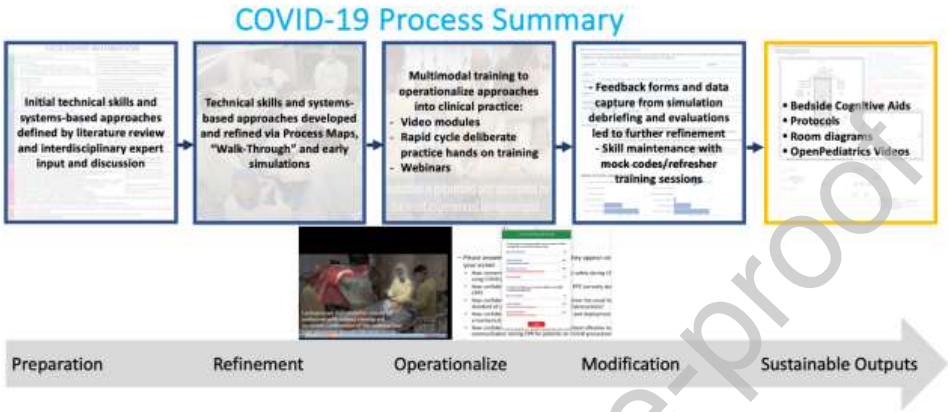

Figure 2 Room diagram depicting clinical zones. During an emergent response in the ICU setting, the surrounding clinical space was organized into three distinct zones based on patient proximity and exposure risk. 1) the "hot zone" inside the patient's room, required PPE including N95 or powered air-purifying respirator (PAPR), eye protection, gown and gloves, worn prior to any entry; 2) the "warm zone" including the anteroom and/or area immediately outside the patient's hallway door defined by temporary barriers; and 3) the "cold zone" outside the room. For early iterations, "warm zone" PPE included only a surgical ear-loop mask and eye protection. Observed frequent door openings for equipment entry in high-fidelity simulations raised concern about risk to nearby staff leading to adjustments to include same PPE as the "hot zone". "Full PPE = gown, gloves, N95 or powered air purifying respirator (PAPR), eye protection". Computer on wheels (COW), Respiratory Therapist (RT), Medical Doctor / clinician (MD), Nurse (RN), Nurse Practitioner (NP), cardiopulmonary resuscitation (CPR), Event Manager (EM), Clinical Assistant (CA).

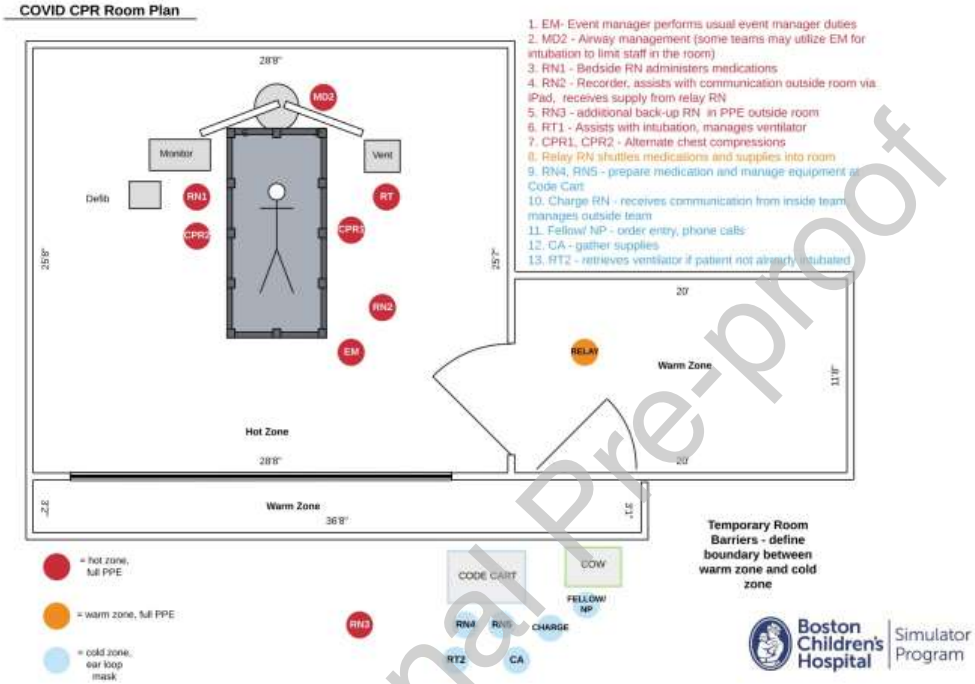

Table. COVID-19 Safe Aerosol Generating Procedures

A. Defined team roles for resuscitation

Sub-team	Team Member	Role	Zone
In-room team; delivers direct patient care	Event manager	Likely the ICU attending, who leads the team, maintains situational awareness and coordinates with the outside team[a]	Hot: highest risk of exposure given proximity to the patient so full PPE [b] must be worn prior to entry and in-room participants not directly involved in patient care maintain a distance of 6 feet from the patient when possible to reduce exposure
	Second physician or nurse practitioner	Present if intubation is required. Some teams may choose for the event manager to intubate to minimize the number of people in the room	
	Respiratory therapist	Assists with intubation and manages the ventilator	
	Bedside nurse	Administers medication and arranges monitoring	
	Resource nurse	Records events, receive supplies from the relay nurse, +/-sets up Zoom communication	
	Two staff members for compressions	Rotate chest compressions every 2 minutes; set up defibrillator and mechanical CPR device	
	Relay	Receives medications and supplies from outside and transfers them to a team member inside the patient room	Warm: wearing full PPE
Outside team; support in-room team efforts through preparation and gathering supplies [c].	Outside team leader (Charge nurse or attending)	Leads outside team, receives communication from inside team via Zoom, transmits requests and updates to the outside team; guide medication preparation and directs further staff to don to enter if unanticipated tasks arise [a]	Cold: no specific PPE [e]
	Fellow or nurse practitioner	Prepares airway equipment, enters orders and makes phone calls	
	Respiratory therapist (2^{nd})	Prepares the ventilator if not already in room	
	Code cart nurses	Prepare medication and equipment	

	Clinical assistant or nurse	Gathers equipment, supplies and resuscitation aids as needed (such as ventilator, defibrillator and mechanical CPR device)	
	Back-up team members	Set up the phones for communication and are available outside the room ready to don for rapid room entry if required to assist with unanticipated tasks [d]	
B. Communication Strategies Implemented			
Huddle	The event manager leads a team huddle while donning outside the room to rapidly delineate roles, and equipment and medication requirements		
Technology	Once the in-room team enters the "hot zone", communication takes place using phone devices, headsets and a HIPAA-compliant platform such as Zoom		
Verbal Communication techniques	Strict verbal closed-loop communication is essential given visual confirmation is nearly impossible; when requesting supplies, the outside team leader will reply "we are drawing up another round of resuscitation drugs". The inside team broadcasts key milestone events to maintain situational awareness and facilitate anticipation including both predictable events: "we have commenced skin incision"; and unpredictable events "there is significant blood loss".		

[a] To enable effective resuscitation the outside room team leader communicates with the in-room event manager. [b] N95 mask or PAPR, gown, gloves, eye protection. [c] including while the in-room team are donning to facilitate room entry and expedite resuscitation. [d] While the in-room team are donning, outside team members will set up the phones, initiating a zoom meeting and connecting headsets. Room-specific Zoom ID numbers and passwords exist for each ICU bed-space and log in occurs using the instructions posted on the door of room. [e] Standard surgical facemask.