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Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Repurposing Video Review Infrastructure for Clinical Resuscitation Care in the Age of COVID-19

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Within the context of the coronavirus disease 2019 (COVID-19) pandemic, minimizing health care worker exposure to the novel coronavirus has become a paramount part of the provision of health care in all settings across the world. Limited supply of personal protective equipment, personnel shortages as a result of exposure, and ensuring the safety and health of workers have all dictated the need to minimize the number of health care workers with direct patient contact. In resuscitation events, there is high likelihood of multiple aerosol-generating procedures and increased risk of viral transmission; therefore, limiting personnel is of particular importance. The development of creative solutions to allow vital team contributions to occur outside of the direct patient care space whenever possible is critical.

The use of video recording and video review during resuscitative care has been described in several recent studies from pediatric emergency departments (EDs).[1-3] Members of our group have reported on the use of video review as a means of assessing performance during cardiopulmonary resuscitation (CPR) and intubation.[4-7] Since 2012, the ED at the Children's Hospital of Philadelphia has maintained a robust video-based quality improvement program. All resuscitations (both medical and trauma) are recorded with a multicamera video system (B-Line Medical, Washington, DC), which uses a combination of 3 video angles, 2 audio feeds, and the vital sign monitor (Figure 1). These can be reviewed in simultaneously streaming windows. To allow capture of video-assisted laryngoscopy, one video feed is replaced with the laryngoscope view when actively in use. As part of the resuscitation quality improvement program, we collect prospective data from the resuscitation physician leader immediately after each event. Primarily, this creates a complete database of demographics, diagnoses, and procedures, but also allows the leader to self-identify a given video to be reviewed. With the use of a learning health care system approach, videos are reviewed every 2 weeks in an open meeting focused on objective, systematic data collection with simultaneous goals of identification of near misses, safety events, or areas for improvement in care delivery; evaluation of work flows to determine interventions likely to affect identified areas of weakness; and assessment of changes in care delivery after identified interventions are implemented.

Within secure firewalls, B-Line LiveCapture software can be used in a live-stream fashion to view the events in real time. This functionality has been essential to the setup of a resuscitation command center in the ED in the era of COVID-19. Given that medical and trauma resuscitation patients are considered COVID-19 unknown and are at high risk of requiring aerosol-generating procedures, team members not providing direct patient care have been moved into the resuscitation command center (Figure 2) to minimize exposure as appropriate. The following roles have been transitioned to work remotely from the command center:

- Patient care associate: Completes registration, prepares identification bands and patient labels, and pages consultants.
- Documenting nurse: Records the resuscitation events in real time, providing key guidance to the team on timing of medications, missing clinical information, and vital sign reassessments.
- Frontline ordering clinician: Places orders necessary for continuity of care, communicates with consulting services, and documents clinical care notes and updates in the electronic medical record.
- Charge respiratory therapist: Assists in gathering necessary equipment and supporting movement of the patients receiving respiratory support to their subsequent care area. Can be called into the direct patient care area as needed to support the first responding respiratory therapist.

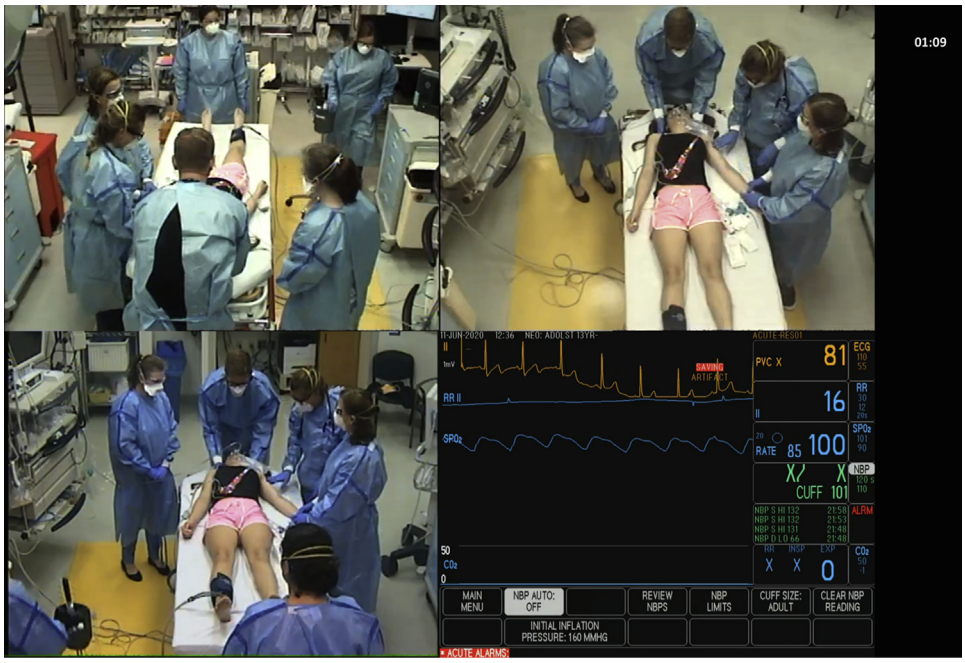

Figure 1. Video review platform using the B-Line LiveCapture system, displaying 3 camera views available in addition to the patient monitor. One camera view is replaced by the video laryngoscope feed during intubation. (Patient actor in simulated resuscitation.)

- Social work: Provides remote assistance to family members by tablet video chat or face-to-face assistance to family members who may choose to leave the resuscitation room.
- Child life: Provides support to the patient by tablet video chat or transitions to in-room support when appropriate according to age-associated coping.
- Consultant(s): Report directly to command center to determine whether their presence is required in the resuscitation room or whether they can provide all necessary support virtually.

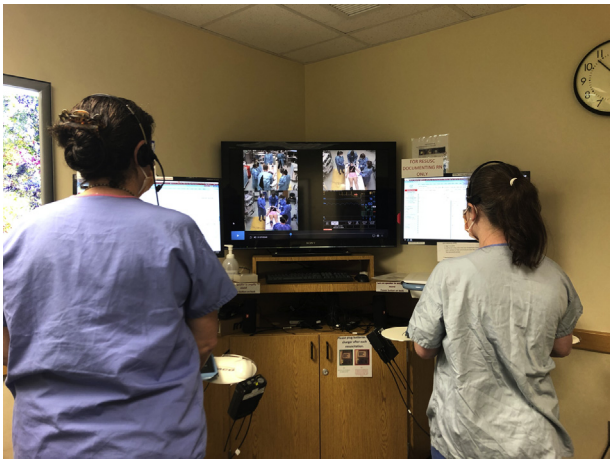

Figure 2. Resuscitation command center with frontline ordering clinician and nurse viewing live stream of resuscitation while using headsets for 2-way communication into the resuscitation room.

Using the B-Line LiveCapture live stream, clinicians view the resuscitation events as they unfold within the resuscitation command center, with minimal delay. To allow seamless communication between the 2 locations, key team members wear a hands-free, wireless headset with one ear speaker and attached articulating microphone (Telex PH Lightweight single-sided headset for RHS). Team members within the command center keep the microphone silent unless actively requesting or relaying information to prevent distracting background noises for team members in the resuscitation room. Team members within the resuscitation room keep their microphones on at all times to facilitate hands-free closed-loop communication of orders and patient assessments to the command center team while limiting potential contamination by touching the device. The communication system used was designed for use in medical diagnostic laboratories such as cardiac catheterization laboratories because the wireless signals can penetrate lead-lined walls, yet transmissions do not interfere with sensitive diagnostic equipment. Written guides on use of the B-Line audio/video and 2-way headset audio communication were created and published on a widely accessible Web-based pathway. In addition, at the beginning of the pandemic, twice-daily rounding occurred to support all of the process and system changes occurring in ED care delivery, and the use of the new resuscitation

Table 1. Communication methods tested to support out-of-room staff placement and minimize staff exposure during resuscitation in the era of the COVID-19 pandemic.

Communication Method	Benefits	Drawbacks
Audio/video live stream (such as B-Line LiveCapture)	Hands-free relay of video and audio from resuscitation room into command center Requires no setup or participation by clinical team in operation Allows full-room view of team and patient Allows legible view of monitor Allows video laryngoscope camera view during intubation Allows video recording of resuscitation during real-time event while live streaming to allow later quality review	Cost of initial setup (consider ultraportable or tablet-based options for low-overhead setup) No ability for 2-way communication into resuscitation room Slight lag between audio-only communication (headset or cellular telephone) and B-Line requires one to be used as primary audio source but does not affect timing of interventions for documentation
2-way headset communication	Allows hands-free 2-way audio communication between resuscitation room and command center Ability to have continual talk on for providers in resuscitation room to avoid repeated touching/self-contamination and ensure command center has complete audio information	Lack of video Leader often needs to turn volume down to prevent distraction
Cellular telephone	Easy to access because always carried by physician staff Bluetooth earbuds allow hands-free use Simple 1:1 communication	Not carried ubiquitously by nursing or technician staff Bluetooth earbuds need to be carried by the staff member at all times to be useful in unanticipated events Time to pair shared earbuds too long to be practical Variable comfort with use of Bluetooth ear buds among staff
Hospital-based telephone	All staff carry, allowing easy access and ubiquitous familiarity with use	Does not allow easy hands-free use Difficult to hear in resuscitation environment

Table 1. Continued.

Communication Method	Benefits	Drawbacks
Video chat by tablet or cellular telephone	Allows audio and video communication Can be placed directly in front of monitor to allow live stream of vital signs to a command center team Can use multiple devices to obtain larger video picture of room (but must be careful with microphone/audio settings and placement of devices or there will be significant feedback) Can allow 1:1 communication between family and registration or social work for information and support (requires process to set up the device and give to the family)	Generally small area visible by video (difficult to see full team and patient) Very difficult to hear audio from the resuscitation room in the command center (improved with use of headphones) Nearly impossible to hear audio from the command center in the resuscitation room (improved with use of headphones but still difficult, and forces team member to be tethered to device or lose video of team if device moves with staff member)
2-way radio	Simple to use Can be easily passed between users	Generally not hands free Often difficult to hear in resuscitation environment Lack of video
Whiteboard	Simple to use if window available (held up to window between spaces) Low risk of technology failure Can be made easily accessible Excellent backup system when difficulties with other communication Useful for in-room decompensation events not moved to space where other devices available	Long time to write out questions/answers Risk of communication errors
Nurse call system	Speakers built into all rooms, including resuscitation room, previously used primarily for communication between family and nurse or clerk Preexisting and always available Allows 2-way audio communication Especially useful for in-room resuscitation events not moved to space where other devices available	Relatively low volume and inability to change location in room makes hearing difficult in ongoing resuscitation event

Table 1. Continued.

Communication Method	Benefits	Drawbacks
Wireless camera with 2-way audio	Considered and researched but not tested because of cost/setup Could allow 2-way communication through overhead speaker associated with camera between resuscitation room and command center	Distracting if direct information needed from 1 team member but have to interrupt entire team to obtain

command center devices was intermittently reviewed during these rounds. Additional technologies have been tested and are available as backup forms of communication, including tablets, walkie-talkies, telephones with Bluetooth earbuds, and the existing nurse call system intercoms. Although helpful to augment communication, each secondary device has inherent challenges, given the relatively loud environment, the requirement to actively hold the device during use, or both (Table 1). Although we did not prospectively set up data collection to monitor reliability of the live stream–based command center system, overall since the transition to the command center setup, we have had very few technical difficulties requiring command center team members to enter the resuscitation room because of lack of adequate audio/video connection. Built-in redundancies in communication have aided this, with tablet, cellular telephone, hospital telephone, 2-way radio, and nurse-call options available as needed. In comparing data between the number of patients cared for in the resuscitation room with the command center structure from March 19, 2020, to July 20, 2020, and the number of video-captured events (signaling that video was available and running in live stream during the event), we found only 5 of the 88 total events that did not have available video, further supporting the reliability of the system.

We recognize that our ED is uniquely situated, given our preexisting audio/video capability. However, similar strategies are possible without this substantial infrastructure. Although our main resuscitation space was previously outfitted with a permanent audio/video system, we also created a backup resuscitation space to allow simultaneous resuscitation of 2 patients. In this area, we used a B-Line ultraportable system, which involves placement of only 2 digital video cameras with built-in microphones connected to a laptop bearing the B-Line software. This allowed temporary setup of live-stream capabilities to support team members located in the command center when the backup space was in use and can still be controlled remotely from computers within the command center. Consideration of usefulness and drawbacks of other communication strategies that have been tested can be found in Table 1. Some EDs may have window visibility into resuscitation areas, which could allow some "outside room" knowledge and support of the bedside team, especially if augmented by a 2-way audio communication method. A video-based system like the one described here, however, adds the benefit of allowing that outside room team to be in a remote area that minimally affects ongoing patient care outside of the resuscitation and allows multiple camera angles, including vital signs monitoring, which may be difficult to achieve through window access.

Through this setup, we have successfully limited the in-room responding team to 2 bedside nurses or ED technicians, a lead physician, an airway physician, a physician trainee or advance practice nurse, a respiratory therapist, and a medication nurse. For rooms in which the setup allows easy transmission of objects in and out of the room (small delivery door, or door that can be opened slightly and closed again rapidly), it would be possible to also station the medication nurse outside the room. This was not an option for our team, given the presence of only one set of automatic swinging doors and the ultimate goal of maintaining a closed, negative-pressure environment. Additional personnel may enter the resuscitation room if specifically requested by the in-room team to support specialty direct patient care needs, such as delivery of CPR or complex invasive procedures. However, consultants responding to events can frequently provide necessary support from the command center; because vital signs and patient presentation can be visualized through the video stream, examination findings can be reported or redemonstrated, and collaboration of

care needs can be communicated with the physician leader by headsets.

We performed an unadjusted univariate comparison of the number of providers present during events in which CPR or intubation was performed between baseline (pre–COVID-19) and after implementing the new strategy. Videos reviewed during traditional quality improvement meetings from December 7, 2019, to March 4, 2020 (pre–COVID-19; n=10), had an average number of personnel visible onscreen of 19.5 (SD 3.7; range 13 to 26). Consecutive videos reviewed from April 28, 2020, to May 15, 2020, had an average of 9.2 (SD 2.9; range 6 to 16; post–COVID-19 consecutive n=13). When limited only to those involving CPR or intubation to more closely mimic the videos that would be traditionally reviewed (available videos April 1, 2020, to May 23, 2020), the average number of personnel present was 10.5 (SD 2.8; range 6 to 16; post–COVID-19 severe n=11). Two-sided *t* test comparison of the difference between the pre– and post–COVID-19 severe resuscitations showed a significant difference of 9.04 (95% confidence interval 6.07 to 12.02). It is likely that the difference in personnel is actually much larger than reflected here; however, since pre–COVID-19 many people (observers, research associates, hospital leadership, pharmacy, radiology, etc) would also be in the resuscitation room within off-camera spaces, whereas post–COVID-19 only those visible on camera are allowed in the room.

Here, we have used video review to collect the data on provider presence, which was our typical method of quantifying staff presence even before the new resuscitation command center setup. Although it may be possible to collect information on provider presence by means other than video review (such as badge swipe attendance), these are not uniformly used in our setting and providers often enter without swiping their badges. Code sheet documentation lists only members directly involved in patient care and therefore does not account fully for number of providers present in the resuscitation room, and post–COVID-19 will list members (such as the documenting nurse and ordering clinician) who are in the command center and do not enter the resuscitation space. As an aside, the use of video review in this way has allowed us to have accurate contact tracing for all individuals involved in resuscitation events in which the patient ultimately was found to have COVID-19 because staff in the room may not otherwise be listed in the medical record (such as technicians performing compressions or supporting respiratory therapists setting up the ventilator).

To evaluate difference in clinical care outcomes associated with this new staffing model, we performed unadjusted univariate comparisons of intubation first-pass success and adverse events during intubation. In addition, to evaluate differences in clinical care processes, we performed unadjusted univariate comparisons of time to first blood pressure measurement, which had been a quality metric being tracked before the pandemic. We found that the decrease in staff present in the resuscitation room was not associated with obvious changes in clinical process or outcomes, as evidenced by supporting data listed in Table 2. As with the data presented earlier evaluating the effect of our intervention on number of providers present, data on intubation and vital sign metrics were collected through our ongoing video review process. The use of video for data collection has been shown to have superior accuracy to chart review[3] and is more feasible than in-person observation. Therefore, if video is implemented as a real-time feed to bolster out-of-room team support, it also brings the possibility of a secondary benefit of adding a rich data source for quality improvement through review or recorded videos.

Overall, by repurposing our video review quality improvement program to augment live, direct patient care, we have been able to limit the number of providers exposed to patients undergoing resuscitation, without deleterious effects on patient care processes or outcomes, thereby

Table 2. Clinical process and outcome metrics before and after novel command center implementation in the era of COVID-19.

	Pre–COVID-19	Post–COVID-19	Difference (95% CI)
Intubation, %	N=67	N=11	
First-attempt success	68.7	72.7	4.1 (−15.1 to 32.1)*
Desaturation events	16.4	18.2	1.76 (−26.8 to 25.2)*
Vital signs	N=56	N=42	
Time to blood pressure, min:s	4:47	5:03	22.74 s (−68.1 to 113.6)†

CI, Confidence interval.
*χ^2 Test of significance.
†Student's *t* test, comparison of means.

supporting the overarching goal of limiting staff contact with procedures at high risk of transmission in patients with unknown COVID-19 status. Although we benefited from a preexisting audio/video setup within our resuscitation space, the principle of allowing for clinical work by resuscitation team members outside of the closed resuscitation space through the use of audio and video communication can be adapted to other environments through use of the alternative methods discussed. In the ED, we face the unique risk combination of a patient population with an unknown COVID-19 status and yet relatively frequent requirement for aerosol-generating procedures, including resuscitation. We should continue to strive to implement creative solutions to decrease staff exposure. Evaluation of similar strategies implemented in EDs, including critical analysis of actual decrease in staff exposure and effect on clinical care, should continue as we are able to gather more data as this pandemic persists. In addition, adaptation of methods developed in the setting of COVID-19 should be considered as possible strategies for treatment of other high-risk patients such as those with Ebola and chemical exposure.

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