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Leveraging Telemedicine for Quality Improvement Video Review of Critical ICU Events: A Novel Multidisciplinary Form of Education

Andrew K. Gold, MD[1]

Ann Huffenberger, RN[2]

Meghan Lane-Fall, MD, MSHP, FCCM[1]

Jose L. Pascual Lopez, MD, PhD[3]

Kristen C. Rock, MD[1]

OBJECTIVES: The objectives of this study were to codify the events triggering bedside recording and to report the types of performance issues identified that were then used to inform dedicated ICU quality improvement efforts.

DESIGN: This is a retrospective descriptive analysis of a video review program conducted at a single institution from July 2016 to November 2019.

SETTING: Surgical and Trauma ICU at a single urban academic quaternary care center.

PATIENTS: All patients admitted to the surgical and trauma ICU between July 2016 and November 2019 were eligible for the study as all ICU beds in our health system institutions are equipped with closed circuit video/audio monitoring. Through an institutional review board approved program, any event triggering the immediate bedside presence of a provider in the ICU is routinely recorded at the discretion of the care team or tele-intensivist.

INTERVENTIONS: A database of these events was created over a 3-year period, and cases were reviewed for content, quality improvement, and educational opportunities. Select recordings were analyzed and shared at multidisciplinary/multiprofessional video review sessions.

MEASUREMENTS AND MAIN RESULTS: There were 286 critical events video recorded and reviewed in the ICUs between July 2016 and November 2019. The most commonly recorded events included: cardiopulmonary arrests ($n = 75$), intubations ($n = 71$), and acute clinical decompensation triggered by nonreassuring vital signs ($n = 57$) or arrhythmias ($n = 13$). Of these recordings, 59 were shared at video review conferences, where quality of care was assessed and thematic opportunities for improvement were characterized. Recurrent quality improvement themes that were identified included adherence to protocols, the importance of teamwork and closed-loop communication, clearly designated team leadership, and the use of universal precautions.

CONCLUSIONS: Video review in the ICU is feasible and presents valuable opportunities for quality improvement and educational discussions.

KEY WORDS: intensive care; medical education; patient safety; quality improvement; telemedicine

Video review of critical events using telemedicine has been used as a quality improvement (QI) and educational tool in many clinical settings (1–14), such as the trauma bay (1, 3, 7–9), labor and delivery (14), and in neonatal resuscitation (5). Multiple published reports have demonstrated improved provider performance when using video review for teaching (1–14). The National Academy of Medicine (formerly the Institute of Medicine) describes telemedicine as the real-time transmission of medical information

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using technologies such as video imaging and telecommunication devices to aid the provision of healthcare services at a distance (2, 15). Telemonitoring is defined as the ability of an expert to assist another person from a remote location through real-time, live interactions in executing their task (15). Catalyzed by the coronavirus disease 2019 pandemic, telemedicine technology is increasingly present in academic and community ICUs, most often utilizing in-room, hardwired, one or two-way cameras, and microphones, allowing video imaging and telecommunication between remote providers and bedside staff. Since 2012, the University of Pennsylvania ICUs have used bedside telemedicine and telemonitoring technology to video record critical patient events in the general surgical and trauma ICUs. The uniqueness of this video review program is two-fold. First, to our knowledge, the University of Pennsylvania is the only institution that has implemented this process in our ICU, a feat that has been previously described as insurmountable due to the costs, logistics, and infrastructure needed to create such a system in the ICU setting (1). Second, our telemedicine video review model not only captures critical events allowing for subsequent review but also incorporates telemonitoring via the presence of a tele-intensivist during the event. The tele-intensivist is another consultant available during these critical events, serving as an eye in the sky that is able to conference into the room to give clinical guidance, gather additional information, or facilitate additional advancements in care while the critical care providers remain hands-on at the bedside. The objectives of this study were to codify the events triggering bedside recording and to report the types of performance issues identified that were then used to inform dedicated ICU QI efforts.

MATERIALS AND METHODS

ICU Video Review Program and Research

This is a retrospective descriptive analysis of a video review program conducted at a single institution from July 2016 to November 2019. Each University of Pennsylvania ICU bed is equipped with 24-hour closed-circuit video monitoring, providing a live feed to a central location staffed overnight by intensivists and 24 hours a day by ICU nurses. The video review program is limited to general surgical and trauma ICU or general surgical or trauma ICU patients boarding in other units per institutional review board (IRB) approval. Both the general surgical and trauma ICUs are staffed 24 hours a day by critical care fellows, and thus, the critical care fellows were ubiquitously present at the recorded events. Residents are present 24 hours per day in the general surgical ICU, while the advanced practice providers are present 24 hours per day in the trauma ICU. Attending critical care physicians are present in both units during daytime hours and take home call overnight. Per institutional policy, any event in the general surgical or trauma ICUs that requires an immediate physician or advanced practice provider presence at bedside can be video recorded at the request of the tele-intensivists or bedside providers, or at the discretion of the tele-ICU nurses. Tele-intensivists and bedside providers are encouraged to request a video recording if they believe in real time that the event could be of educational significance, could contribute to ICU QI efforts, or if the event is an unusual clinical scenario (as defined by the bedside or telemedicine clinicians). The video is recorded at a single remote computer using third-party software (Camtasia Studio Academic V7.1; TechSmith, Okemos, MI) in the telemedicine suite and saved on a password and firewall-protected hard drive for a maximum of 28 days. Videos may not be used for any other purpose other than for the video review program. These activities are conducted under strict institutional legal and privacy policies. Viewing and analyzing of these videos for research purposes can be conducted within the policy guardrails and has been authorized under the auspices of a University of Pennsylvania umbrella IRB approval (Protocol Number: 813837). Our institution uses posted signs stating filming is underway in compliance with the Joint Commission of Accreditation of Hospital Organizations regulations for video recording in hospitals (1, 4). In addition, our ICU consent forms include a section informing patients that their care may be recorded and gives them the opportunity to opt out. Since the inception of our program, we have not had any patients opt out of the video recording process.

Critical Events Database

Starting in July 2016, we created a database of all critical events that had triggered a recording in any of the selected ICUs. Each recording was reviewed by two providers: the director of the video review program and an anesthesia critical care fellow. All fellows received an introductory training course designed to standardize the review process prior to serving in this

role. Over the 3-year study period, a total of 18 anesthesia critical care fellows were involved in the review process. On average, each fellow reviewed 2 months' worth of recorded videos with an average of seven recordings per month. All of the fellows involved had a background training in anesthesiology and were involved with the review program during their 1-year critical care fellowship. For each video recording, the nature of the triggering event, time of day, duration of the video, ICU location, and team members present were documented in a standardized encrypted database. In addition to objective data for each video, the reviewing physicians included a subjective analysis of elements of the video that they considered either was conducted well or that could be improved upon. This subjective analysis compared with the care depicted in the video to current local or universal ICU standards in practice in the unit where the video was recorded.

Monthly Quality Improvement Video Review Sessions

During monthly review of all database videos, the reviewers selected certain recordings that they ascertained to have the most educational value or opportunity for QI, to be shared in a multidisciplinary (anesthesia, surgery, and emergency medicine providers) and multiprofessional (attending physicians, residents/fellows, ICU nurses, advanced practice providers, pharmacists, and respiratory therapists) video review QI session. All ICU providers and caregivers and those rotating through the ICU that given month are invited to attend these monthly video review sessions, during which select footage of these events is viewed, discussed, and recurrent themes are identified as a group to improve systems-based care. These video review sessions occur under the auspices of Health System QI efforts as described above and serve as a heavily favored educational tool for house staff and other trainees as well as for active providers and faculty. Videos are destroyed within 28 days of creation as per policy.

RESULTS

There were 286 critical events recorded in the ICUs over the 3-year study period. Most common event categories included: cardiopulmonary arrests (n = 75), endotracheal intubations (n = 71), and acute clinical decompensation triggered by nonreassuring vital signs (n = 57) or arrhythmias (n = 13) (**Fig. 1**). Bedside procedures including exploratory laparotomy (n = 10), extracorporeal membrane oxygenation cannulation (n = 10), bronchoscopy (n = 6), tracheostomy (n = 7), chest tube placement (n = 5), proning (n = 5), and central venous line placement (n = 3) were also recorded (**Fig. 2**). Most of the events triggering video recording occurred in the general surgical ICU (n = 164, 57%) followed by the trauma ICU (n = 88, 30%); the remaining events were recorded in other ICUs boarding either general surgery or trauma ICU patients. The majority of events were considered unplanned (n = 200; 70%) versus planned (n = 66; 23%), with 20 of the event recordings unclear as to whether the ICU providers had planned and prepared for the event. Of events with a viable timestamp, more were recorded during the daytime (07:00–18:59; n = 146) compared with nighttime (19:00–06:59; n = 103). The time of day could not be determined in 37 of the recordings. From our video database, 59 of the recorded critical events were used for monthly video review sessions (**Fig. 3**).

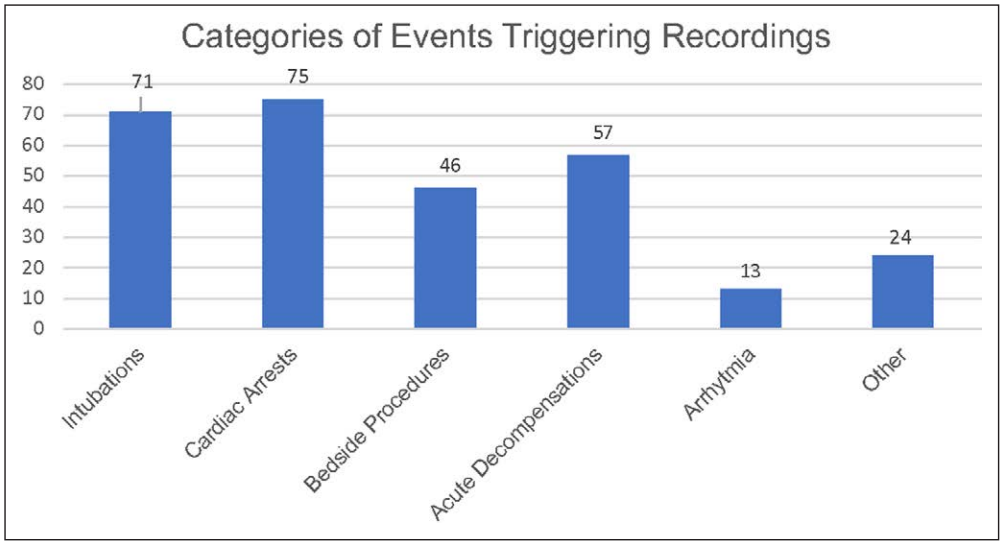

Figure 1. Categories of events triggering recording.

To identify recurrent themes, assessing for areas of strength and areas with opportunity for

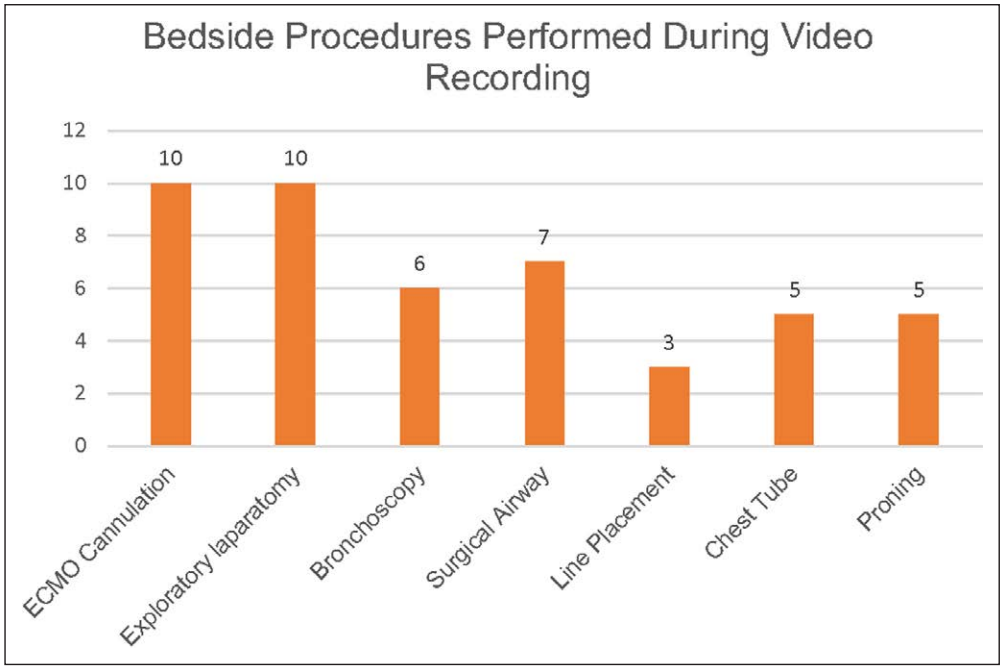

Figure 2. Bedside procedures performed during video recording. ECMO = extracorporeal membrane oxygenation.

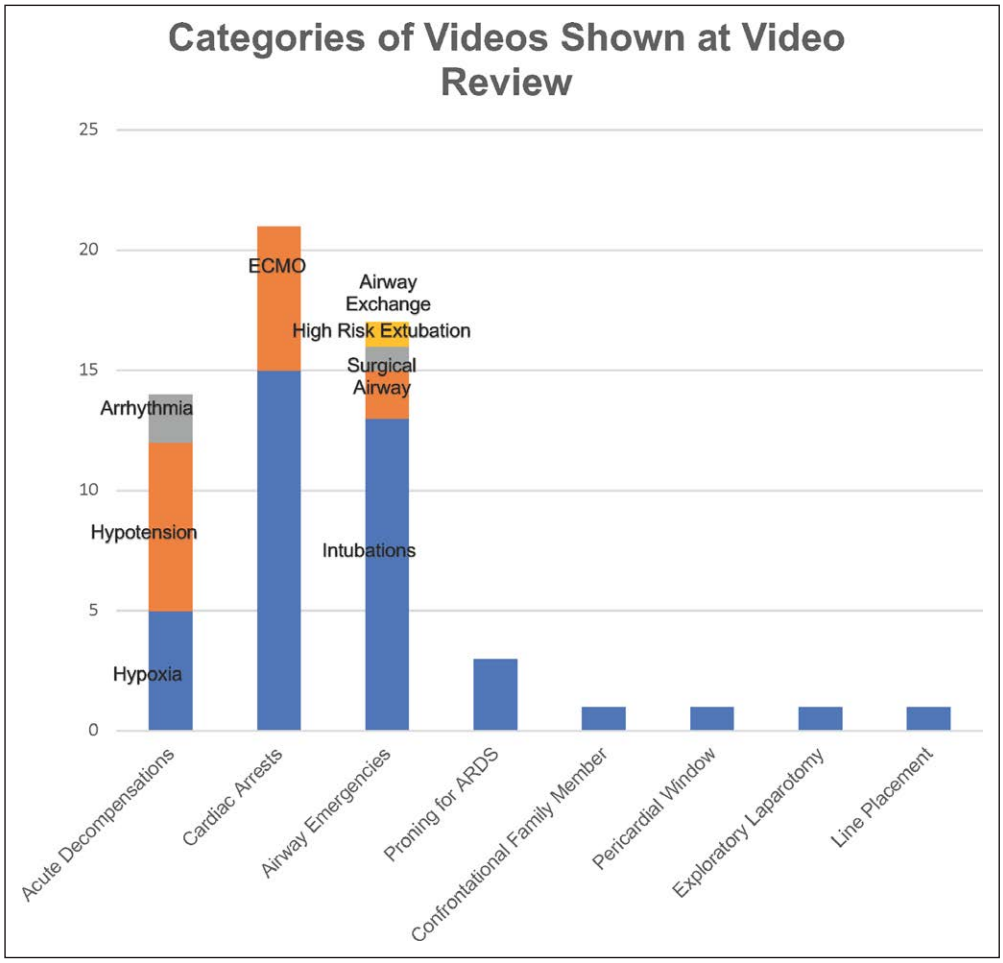

Figure 3. Categories of videos shown at video review. ARDS = acute respiratory distress syndrome, ECMO = extracorporeal membrane oxygenation.

improvement, the data were examined as a whole and in 6-month intervals in an attempt to identify trends or changes in trends over time. Teamwork, closed-loop communication, and team organization were consistently identified as strengths during these critical events. Over time, areas with opportunity for improvement included: adherence to best practice protocols (such as Advanced Cardiac Life Support [ACLS] algorithms), integration of evidence-based practice (e.g., use of continuous end-tidal carbon dioxide monitoring during cardiac arrest), recognition of changes in patient status via vital signs or alarms, improvement of procedural technique, and having readily available emergency resources (such as fiberoptic bronchoscopes or surgical airway trays) to avoid delays in care.

Certain themes changed over the study period. Sterility, the use of universal precautions, ambient noise level, and crowd control were often identified as areas for improvement early in the study period. However, both of these aspects of care in the review process became areas identified as strengths toward the end of the 3-year period of review. Incorporating the teleintensivist into the clinical event also became a more commonly identified area

of strength. A newly identified area for improvement over the last year of the study period was the use of ultrasound and Doppler technology during ACLS for monitoring and diagnostics supplementing pulse checks and/or echocardiography, which contributed to delays in resuming chest compressions.

The qualitative comments relating to the clear presence of a team leader evolved over the study period. Early on in the program, lack of a clear leader was occasionally identified as an area that could be improved upon. After July 2017, the presence of a clear leader has only been identified as a strength upon video review. During the 2017–2018 academic year, it was noted in multiple events that while there was a clear leader, the leader occasionally deviated from their role and became involved at performing other aspects of care rather than solely focusing on leading and coordinating the event. This was discussed during multiple video review sessions and all qualitative comments concerning the presence of a leader and staying in role were noted as an area of strength during the 2018–2019 academic year.

DISCUSSION

Using telemedicine technology to establish an ICU video review program is a novel initiative that can be leveraged to successfully enhance QI and educational activities. This study demonstrates the feasibility of establishing an ICU video review program and its early experience using existing technology. The types of emergent events that triggered bedside video recordings spanned a variety of critical bedside patient emergencies and procedures, most commonly cardiac arrests, endotracheal intubation, and unstable vital signs. The 3-year study period yielded a number of recurrent themes that became starting blocks for QI initiatives, including team dynamics and communication, use of best practices, increased and standardized access to emergency resources, and improvement of procedural technique.

QI in the management of critical clinical scenarios is traditionally reliant on chart review and debriefing sessions, which are vulnerable to discrepancies and recall bias (1, 3). "Near miss" events can be overlooked or even impossible to detect in patient medical records without being physically present at bedside or through video recording (6). Video review allows for the observation of visual and auditory critical events potentially in repeated fashion and by multiple reviewers including those not present at the initial event (1, 3, 4). This can greatly enhance and complement the fidelity of traditional retrospective analysis, improving both accuracy and completeness. Furthermore, video analysis can be a powerful adjunct to existing QI methodologies for understanding the context and the events leading to an adverse event (4). In particular, video review allows for analysis of nontechnical aspects of managing critical situations such as teamwork, closed-loop communication, leader performance, adherence to role responsibilities, and situational awareness (1, 4, 7, 10). These critical components of management of emergency situations in the ICU have been captured, reviewed, and discussed in our video review program. Outside of clinical medical practice, in disciplines such as aviation and sports, the practice of reviewing recorded data in order to analyze performance and identify mistakes is commonplace (6, 14). Within medicine, video review has been demonstrated to improve compliance with universal precautions, reduce deviations from best practice protocols, identify technical and procedural errors, and identify more errors in clinical judgment than chart review alone (1, 3, 5, 6). Although our thematic results are qualitative, they are consistent with these prior studies.

A few specific examples of QI initiatives that have resulted directly from these video review sessions included redesigning and stocking the airway carts in the ICU and creating an in-service educational session for the bedside nurses on the interpretation of pulmonary artery catheters and the basics of cardiogenic shock. In addition, occasionally, the general surgical ICU will board overflow patients from other ICUs; these patients continue to be covered by their native ICU physician team. A formalized brief physician to physician sign-out process was created after reviewing critical events occurring in these "off-service" ICU patients, with the goal of giving the physicians in the general surgical ICU anticipatory guidance and highlighting any concerns in the event that the general surgical ICU staff are the first to arrive at the bedside during an emergency situation or if requested by the bedside nurse.

Video review provides educational opportunities, particularly to providers in training or new to practice (13). Providers can have the opportunity to review their video recorded care without being dependent on memory to

recreate the events. This allows for more precise critique or self-critique making more apparent how performance can be improved when compared to discussion alone (4). Such feedback has been demonstrated to improve performance more quickly and is associated with sustaining more durable behavioral changes when compared with verbal feedback alone (6, 12). This program has also provided an educational opportunity for our critical care fellows to improve their pedagogical skills through their training to review the videos and proctor the monthly video review sessions.

Although ICU video review has been widely accepted at our institution, the program has its challenges. The review process and data collection are lengthy and labor intensive. The program requires financial and time investments from telemedicine, intensive care leadership, and a video review team. Setting up such a program requires initial investment into telemedicine equipment. We are limited to recordings being initiated by bedside or tele-providers, which does not always occur immediately upon recognition of a critical event, as we currently do not have the capability for continuous recording in every ICU bed. In addition, we are limited to reviewing what is captured within the camera's field of view and what audio input the microphone systems are able to detect in what can be a noisy environment. These challenges are consistent with other video review programs (4, 8). We are consistently striving to improve our own program via upgrading our video and audio technology, encouraging providers at all levels to take advantage of the presence of the tele-intensivist as another set of eyes, and coordinating protected time for teams from multiple disciplines to be present and take part in our video review sessions. In addition, we currently have a team conducting a research project investigating how providers value our video review program, incorporate feedback from these sessions into their clinical practice, and attempting to identify barriers to attending video review sessions.

Medico-legal concerns of privacy and confidentiality are also common concerns of video records (8). Our institution uses posted signs stating filming is underway in compliance with the Joint Commission of Accreditation of Hospital Organizations regulations for video recording in hospitals (1, 4). In addition, our ICU consent forms include a section informing patients that their care may be recorded and gives them the opportunity to opt out. With the increasing use of telemedicine technology, these challenges are becoming easier to meet and as telemedicine equipment in ICUs becomes increasingly mainstay, such leveraging of this technology to establish a video review program should be easily replicated at other institutions. Our own institution is currently planning to expand this program into ICUs other than the general surgical and trauma critical care units.

The study has certain limitations. The database contains some sections that are incomplete. Although there was a single consistent reviewer for all videos and critical care fellows were trained in a standardized manner, there is an inherently subjective component to the qualitative data collected. Since video recordings can be triggered by multiple different people with broad guidelines, the video recordings could be biased toward more intense, dramatic clinical scenarios, and not reflective of the general practice of the ICU. It is impossible to solely attribute the perceived improvements in team communication and use of universal precautions to the use of video review. This retrospective study is anticipated to be a starting point for more rigorous QI and educational initiatives utilizing review of footage from bedside events. Future directions of inquiry include using video review to implement specific ICU initiatives and to quantify successful implementation and to further characterize the educational benefit of an ICU video review program.

CONCLUSIONS

Video review of emergent bedside events in the ICU captured through telemedicine technology presents opportunities for QI and educational discussions. At our institution, these sessions have provided opportunities to optimize bedside management of critically ill patients while fostering multidisciplinary communication. The ability to combine video review capability throughout our ICUs with telemonitoring via the immediate availability of a tele-intensivist who can immediately communicate with the bedside team is novel. While this program is still in its infancy, it may be a model which other academic and community ICUs with telemedicine capacity could adopt.

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1 *Department of Anesthesiology and Critical Care, Hospital of the University of Pennsylvania, Philadelphia, PA.*

2 *Department of Nursing, Hospital of the University of Pennsylvania, Philadelphia, PA.*

3 *Department of Surgery, Hospital of the University of Pennsylvania, Philadelphia, PA.*

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For information regarding this article, E-mail: andrew.gold@pennmedicine.upenn.edu

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