Brief Reviews

Looking to the Past to Improve the Future: A Narrative Review of Lessons Learned from Inpatient Cardiac Arrest Care During the COVID-19 Pandemic

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Abstract

Background

Inpatient cardiac arrest care had to be adapted to meet the needs of patients and providers during the COVID-19 pandemic. Providers working in the emergency department and in the inpatient setting have acquired extensive experience and expertise in caring for patients with COVID-19 related cardiac arrest. We summarize recent reports relevant to clinicians on inpatient cardiac arrest care, provider and patient safety, and effective use of resources.

Methods

We performed literature searches of the PubMed database on inpatient cardiac arrest, COVID-19, healthcare-associated coronavirus transmission, and others. The authors' collections of lived experience as inpatient care providers and clinically useful materials gathered during the pandemic were included.

Results

We summarize current knowledge about cardiac arrest in COVID-19 relevant to hospitalist practice, describe lessons learned to date, and provide practical guidance for addressing cardiopulmonary resuscitation for patients with COVID-19. We discuss literature on risk factors for cardiac arrest in patients with COVID-19; risk of infection for rescuers performing resuscitation in patients with COVID-19 and mitigation strategies; goals of care during cardiac arrest in a patient with COVID-19; reducing the risk of exposure to rescuers (including pre–cardiac arrest care); reducing cross-contamination during cardiac arrest in patients with COVID-19; prioritizing oxygenation and ventilation strategies with lower aerosolization risk; maximizing resources during cardiac arrest in patients with COVID-19; and post–cardiac arrest care.

Conclusions

Advances made in the care of inpatient cardiac arrest patients during the COVID-19 include domains of patient risk stratification, provider safety, advance directives, and others. Lessons in the management of inpatient cardiac arrest learned during this pandemic are likely to applicable to future pandemics.

BACKGROUND

Though epidemiologists had long warned of potential for pandemic illnesses, healthcare systems globally were underprepared for the speed, scale, and destructiveness of the COVID-19 pandemic. Hospitals in the United States were overwhelmed materially and logistically. Hospital providers had to make real-time modifications to care systems, including management of in-hospital cardiac arrest care. As the pandemic progressed, specialty organizations produced new cardiac arrest guidelines based on expert opinion in the absence of data, due to the novelty of COVID-19, as well as its unprecedented incidence, morbidity, and mortality.[1,2] Many existing procedures used to care for patients with cardiac arrest have been associated with increased risk of COVID-19 transmission to healthcare providers, though this risk can be mitigated with proper use of personal protective equipment (PPE).[2-4]

Although the number of admitted patients with COVID-19 decreased dramatically in 2022, intermittent future surges of the illness are expected (e.g., one in late 2022, a potential new surge in spring 2023).[5,6] In this narrative review, we focus on inpatient cardiac arrest, summarizing interventions that proved successful based upon review of the literature and our lived experience as hospital providers during the pandemic, and discuss how they might be deployed in a future pandemic context.

Though future pandemics will almost certainly include different presentations and disease courses from COVID-19, there may be commonalities: airborne transmission; severe respiratory illness with cardiovascular system involvement; high rates of transmission, morbidity, and mortality; cyclical/seasonal surges and overwhelm of health systems; disruption to supply chains; delays in development, deployment, and uptake of vaccines and novel treatments; and elevated risk to healthcare providers.[7] Utilizing hard-won knowledge from the COVID-19 pandemic may not prevent the next global pandemic, but may help mitigate harms to patients, providers, and systems.

METHODS

We performed a literature search of PubMed using a variety of search terms and permutations related to inpatient cardiac arrest and COVID-19 (see Supplemental Table for additional detail). We searched for related articles using PubMed's "Cited By" and "Similar Articles" features of papers determined to be highly salient. These findings were supplemented by the authors' lived experience, collections of useful material gathered during the course of the pandemic, and reviews of the reference sections of these papers.

RESULTS

Cardiac arrest is an acute event with high morbidity and mortality: 10 in 1,000 admitted patients go into cardiac arrest each year, and only 25% survive to hospital discharge.[8,9] Prior to COVID-19, there were 290,000 inpatient cardiac arrests per year, or 9–10 in-hospital cardiac arrests per 1,000 US admissions.[10] During the pandemic, these numbers rose dramatically worldwide. Shao and colleagues reviewed 761 reports of patients with severe COVID-19 and found 151 had an in-hospital cardiac arrest during the 90-day study period: 1 in every 5 patients admitted with COVID-19 pneumonia went into cardiac arrest, and among them, 96.3% underwent resuscitation.[11] In this study, 83.1% of cardiac arrests occurred in the general ward. Respiratory arrest was the reported cause of death in 87.5%, shockable cardiac rhythm in 5.9%, and pulseless electrical activity in 4.4% of patients. Only 2.9% of the patients who had cardiac arrests survived, and only 1 patient had a favorable neurological outcome at 30 days.[7,11]

Presentation and outcome of cardiac arrest in patients with COVID-19 is different from that observed in patients without COVID-19. In patients without COVID-19, the etiology of arrest is most often cardiac (50%–60%), followed by respiratory insufficiency (15%–40%).[12] The presenting rhythm is non-shockable (asystole or pulseless electrical activity) in 81% of non–COVID-19 patients.[10,12-14] Among all adult in-hospital cardiac arrests during 2000–2017, average survival to discharge was 25% for patients.[15,16]

Guidance for caring for COVID-19 patients safely has evolved with the pandemic. The World Health Organization (WHO) categorizes cardiopulmonary resuscitation (CPR) as an aerosol-generating procedure (AGP) requiring respirators, masks, and other PPE.[9,17] Risks associated with individual components of resuscitation attempts have not been clearly delineated.[8,18] Several conditions exacerbate the risk of CPR procedures during COVID-19: rescuers working in close proximity, lower levels of infection control practices because of the emergent nature of cardiopulmonary resuscitation, and global PPE shortages.[1] Current CPR guidance emphasizes rescuer safety, recommending that adequate PPE including N95 masks or positive airway pressure respirators be used, especially during AGPs.[19]

Risk Factors for Cardiac Arrest in Patients with COVID-19

Coagulation disorders—primarily pulmonary embolism (PE), ischemic strokes, and coronary thrombosis (generally venous or arterial thrombosis)[20]—are associated with cardiac arrests due to COVID-19 infection, which is considered a hypercoagulable state (Table 1).[21,22] Mechanisms include a host immune response contributing to vascular endothelial cell injury, inflammation, activation of the coagulation cascade via tissue factor expression, and shutdown of fibrinolysis. Patients may present with elevated serum D-dimer levels, low anti-thrombin levels, pulmonary congestion, and microvascular thrombosis: all increase risk of PE, which is itself a risk factor for acute respiratory distress syndrome and cardiac arrest.[20,23-25] Incidence of thrombosis in patients with COVID-19 who were admitted to the intensive care unit (ICU) ranged between 31% to 79% and was higher than among non-ICU patients, for whom the reported range was 9.2%-15%.[20,26-28] Pulmonary thromboembolism was the most frequently observed thrombotic complication.[20,28-30]

Data from China revealed myocardial injury in 27.8% of patients admitted with COVID-19; patients with elevated troponin levels had more frequent malignant arrhythmias (11.5% vs 5.2%) leading to cardiac arrest.[31] Shi et al. found cardiac injury in 20% of 146 patients hospi-

Table 1. Risk factors for cardiac arrest in patients with COVID-19[20-42]

Acute myocarditis including stress-induced cardiomyopathy
Arrythmias
Coagulopathies (pulmonary thromboembolism, coronary thrombosis, stroke)
Post myocarditis sequelae
Acute coronary syndrome
Hypoxia
High-grade systemic inflammatory state
Electrolyte imbalance
Cardiac tamponade
Underlying genetic predisposition

talized with COVID-19.[32] These patients had a higher mortality of 51.2% than patients with no cardiac injury (4.5%). Myocarditis or stress cardiomyopathy has been found in up to one third of patients admitted to ICU with COVID-19 in China and the United States.[33-35]

Life-threatening arrhythmias have been variably reported in 10-16% of patients hospitalized for severe COVID-19, most commonly in the setting of elevated troponin indicating myocardial injury.[36,37] Hypoxia has been reported as a major cause of fatal arrhythmias in COVID-19 due to direct viral lung involvement. Cardiac dysfunction, severe systemic inflammatory states, electrolyte derangements, intravascular volume imbalances, and drug side effects have been described as causes of arythmias in COVID-19 patients.[32]

Clinically significant heart blocks have been reported in patients with COVID-19.[36,38] Multiple factors influence this context, including hypoxia, acidosis, drug interactions, electrolyte abnormalities, and direct cardiac involvement in the form of myocarditis and acute coronary syndrome.[33-35]

Type II myocardial infarctions secondary to persistent hypoxia and consequent demand-supply mismatch are common and lead to myocardial injury.[39] Coronary artery dissection, cardiac tamponade, and uncovering of underlying channelopathies may explain hypoxia and arythmias leading to cardiac arrest in these patients.[40-42]

Risk of Infection for Rescuers Performing Resuscitation in Patients with COVID-19 and Mitigation Strategies

More than 3,600 U.S. health care workers died in the first year of the pandemic.[43] Healthcare workers who work with COVID-19 patients have the highest risk of transmission, especially in environments where AGPs take place. A number of strategies have been demonstrated that may reduce transmission during AGPs (summarized in Table 2).

CPR, including chest compressions, defibrillation, and airway management, is recognized by WHO as an AGP.[17] Couper et al. found weak evidence that chest compressions and defibrillations generated aerosols, and no studies that showed statistical significance in transmission of the virus through these modalities.[45] Liu et al. during the 2009 SARS crisis reported an increased odds ratio of SARS transmission in healthcare workers involved in chest compressions but noted that those individuals were exposed to tracheal intubations and airway management of affected patients.[54] Thus, the risk of transmission more likely resulted from tracheal intubations than chest compressions.[54] Tran et al. found similar results with higher odds ratio of acute respiratory illness transmission in tracheal intubations and manual ventilation, including bag-mask ventilation.[55] These studies were done prior to COVID-19. Soni et al. looked at the risk of COVID-19 transmission for healthcare workers during AGPs and found that performing CPR while wearing appropriate PPE was not associated with increased transmission.[4]

In addition to donning PPE, health care workers can take several physical measures to further mitigate risks. There should be as few people in the room as possible during CPR to decrease exposure; clear plastic covering around the patient during AGPs should be considered to minimize risk of aerosols and transmission.[1,46]

During CPR, bag mask valves are common way to deliver breaths to patients prior to tracheal intubations. Making sure the mask is a tight fit and using the two-handed “C and E” technique to decrease leaks is likely effective to decrease transmission.[47] Making sure experienced personnel perform tracheal intubations and using video laryngoscopy will decrease the need for interruptions in chest compressions and minimize the amount of aerosolization during the procedure. Mechanical compressors may decrease direct rescuer exposure to the patient.[1]

Before entering the room to provide CPR, all healthcare workers should don PPE, which includes eye protection, gown, gloves, and well-fitting mask. During chest compressions, the adequate protection rate was lower, likely due to risk of mask slippage.[45] Despite this, donning appropriate PPE should not be neglected and should remain a top priority to help protect healthcare workers.

Goals of Care during Cardiac Arrest in a Patient with COVID-19

International societies like the International Liaison Committee on Resuscitation (ILCOR), American Heart Association (AHA), and United Kingdom Resuscitation Council have generated interim guidelines for resuscitation during COVID-19.[1,9,56-58] The main goals for resuscitation are to reduce provider exposure, prioritize oxygenation and ventilation strategies with lower aerosolization risks, and consider resuscitation appropriateness.[1,2,19] Advanced directives and care planning should be discussed on admission and updated throughout the patient’s hospitalization.

Table 2. Strategies to minimize provider risk during resuscitations

Strategy Type [Reference(s)]	Specific strategies
Planning and decision strategies[1,2,19,44]	Consider resuscitation appropriateness, ideally following a goals of care discussion with the patient Prioritize oxygenation and ventilation strategies with lower aerosolization risk
PPE use[4,8,45-48]	Appropriately don PPE according to guidance prior to entering the scene/room of cardiac arrest and ensure it is used correctly during AGPs Create a specific area for donning and doffing PPE During CPR using bag mask valves, ensure the mask is a tight fit and use the two-handed "C and E" technique to decrease leaks Place a clear plastic covering around the patient during AGPs
Personnel strategies[1,49,50]	Limit the number of personnel at the scene, in the room, and in transit (e.g., in elevators) Clearly define the roles and responsibilities of the code team members Engage the person who is most likely to ensure first-pass success for intubation or ventilation, likely the most experienced staff member
Mechanical/technological strategies[1,19,48-50]	Use mechanical chest compression devices Use video laryngoscopy if available for intubation Minimize close circuit disconnections and connect ventilator to a HEPA filter if the patient is already on a ventilator Utilize remote communication devices (e.g., baby monitors) for communications between code teams and other providers
Communication strategies[1,8,50-53]	Communicate COVID-19 status to any new providers if not clear based on patient's location Debrief after codes to discuss what can be done better

Consider Resuscitation Appropriateness

The decision to initiate and continue resuscitative attempts is multifactorial and is influenced by patient-specific wishes and conditions in addition to physician experience. Resuscitation appropriateness is not an exact science for COVID-19 patients. Though COVID-19 can be associated with significant mortality, it is not a terminal disease in most cases. Having goals of care discussions upon admission to the hospital or earlier is especially important in COVID-19 patients due to the risks assumed by the resuscitation team. These early goals of care discussion should address code status and the use of CPR should the patient decompensate.[44] Palliative care consultation services, if available, should be engaged early for patients who have significant comorbid conditions and are at high risk of morbidity and mortality. The pandemic has highlighted the importance of implementing do-not-resuscitate (DNR) orders for hospitalized patients who are at high risk of decompensation; this is particularly salient for COVID-19 inpatients with COVID-19 who suffer cardiac arrest, given the low survival rates observed among those given CPR.[59,60]

In situations where direct knowledge of the patient's goals of care is not available, physicians require expert opinions and guidance. It is still unclear if incorporation biomarkers such as neuron-specific enolase, electrophysiology such as electroencephalographic reactivity, imaging tools such as diffusion-weighted magnetic resonance imaging (DWI), or algorithms to increase the accuracy of decisions in COVID-19 patients will be helpful. The presence of widespread ischemic damage detected by DWI performed between the second and fifth days after successful CPR can guide the prognosis.[61]

REDUCING THE RISK OF EXPOSURE TO RESCUERS (INCLUDING PRE—CARDIAC ARREST CARE)

As noted above, goals of care should be discussed with the patient, especially those hospitalized with COVID-19, and advance directives should be in place for every patient.[1] During the initial wave of COVID-19 in 2020 and the Delta variant wave in 2021, mortality in critically ill COVID-19 patients was as high as 30%.[62] Realistic expectations should be discussed with patients and loved ones when the patient has a cardiac arrest.

Cheruku et al. discussed measures for CPR in an ICU setting to deliver high-quality care in COVID-19 patients and protect healthcare workers from transmission of the virus.[63] One measure was to place invasive lines with extensions to allow laboratory draws and medication delivery outside the room with infusion pumps. Some ventilators could be separated from the console by ≤10 feet, allowing remote adjustment of settings. A schematic was set in place, each team member was assigned tasks to minimize confusion, and dedicated COVID-19 equipment was placed in a central location where it could be accessed by all team members.[63] During a cardiac arrest event, for non-intubated patients or those who did not have vascular access, 3–4 team members would start CPR, including an individual with airway management expertise and procedure skills, the patient's primary nurse and assistant nurse, and the respiratory therapist to set up the ventilator.[63] Once an airway was established, only those performing chest compressions would be in the room, although it is recommended to use mechanical compression devices if available.[1] Each healthcare worker would need to don PPE, including gown, gloves, face shield, head covering, and N95 mask prior to entering the room.

Ensuring a proper fit on masks is important: a main reason for diminished effectiveness of chest compressions is mask slippage and adjustment. In one report, approximately 35% of healthcare workers reported feeling that they had mask and goggle slippage during CPR although actual breach was uncommon.[4] After intubation, connecting the endotracheal tube to the ventilator instead of moving to bag ventilation would decrease exposure to aerosols.[64] Chest compressions should be paused during intubation.[1]

REDUCING CROSS-CONTAMINATION DURING CARDIAC ARREST IN PATIENTS WITH COVID-19

Several processes have been utilized by to reduce cross-contamination during cardiac arrest in COVID-19 patients. Ensuring appropriate PPE should be a priority when evaluating a patient with confirmed or suspected COVID-19 infection. Proper PPE includes N95 (powered air-purifying respirator), surgical mask, face shield or eye shield (goggles), gown, and double gloves as recommended by the Centers for Disease Control and Prevention (CDC) when performing AGPs such as bag-mask ventilation or endotracheal intubation during resuscitation.[48,49,65] These procedures should be performed in a negative pressure room if possible to reduce cross contamination by preventing viral particles from dispersing outside the room.[51] Maintaining designated donning and doffing areas lowers the risk of transmission amongst others as exposed areas are restricted to a specific location.[48]

Restructuring the code team reduces cross contamination by limiting the number of code team members and use of mechanical chest compression devices when possible.[49] Many institutions have reconfigured code teams. Providers typically in the room during a code event are the code team leader (physician), respiratory therapist, documentation nurse, medication nurse, and 2 CPR compressors.[49,66] Many institutions utilize short-range radio systems (e.g., baby monitors) and voice-activated smart badges for immediate, direct communication between code teams and providers outside the room/nursing station.[49]

PRIORITIZING OXYGENATION AND VENTILATION STRATEGIES WITH LOWER AEROSOLIZATION RISK

Managing airways in COVID-19 patients requires strategies to decrease risk of aerosolization; this includes attaching a high efficiency particulate air (HEPA) filter to any manual or mechanical ventilation device, as well the recommendation to intubate early using the most skilled and experienced provider and then place the patient on a ventilator.[50] If the patient is already intubated at the time of arrest, they should remain on a ventilator, as this provides a closed circuit. However, ventilator settings may need adjustment to ensure asynchronous ventilation, e.g., changing to pressure or volume control mode to deliver full breaths at a fraction of inspired oxygen (FiO2) of 1.0 and preventing the ventilator from auto-triggering with chest compressions. Patients in a prone position at the time of the arrest should optimally be turned to the supine position. If that is not feasible and the patient has an advanced airway in place, the medical team may proceed with CPR in the prone position by compressing over the T7/T10 vertebral bodies.[19] The efficacy of CPR in the prone position remains unknown. However, it is reasonable to judge prone resuscitation quality using end-tidal CO_2 and arterial pressure tracing.[67]

MAXIMIZING RESOURCES DURING CARDIAC ARREST IN PATIENTS WITH COVID-19

Institutions must implement safety procedures and checklists when caring for critically ill COVID-19 patients in the setting of CPR. This involves AGPs (chest compressions, intubation) associated with high risk for droplet exposure, and proper protocols need to be in place for protection of healthcare providers.[65] PPE should be provided for all personnel; training on PPE donning and doffing should be offered to all staff; care should be taken to ensure COVID-19 patients are in a negative pressure or single private room; the number of code team members should be limited to those required; and mechanical compression devices should be provided if possible. Code teams should debrief post-resuscitation to highlight positive outcomes and areas for improvement.[51] Open communication between code team members (and all other providers) with administration improves team dynamics and patient care.[51]

POST—CARDIAC ARREST CARE

After cardiac arrest, patients may need transport to ICUs, cardiac catheterization areas, or other areas for specialized care. Each healthcare system must have infection control measures for transportation based on the most current CDC guidelines and recommendations.[1] Transportation will likely require a team approach. There must be provider-to-provider sign out and nurse-to-nurse sign out prior to transportation. All parties involved in transportation must appropriately don PPE, and the patient should have at least a surgical mask on if they are not intubated.

Endotracheal tube placement and the end tidal CO_2 must be confirmed. Providers must ensure all airway equipment is in place and there are no leakages, and confirm all medications, equipment, and staff are available.

Receiving units must be notified prior to departure, and all concerns and anticipated problems should be addressed. Providers should utilize service elevators only, limit the number of personnel in the elevator, and complete debriefings once the patient is no longer in the area. Debriefing after cardiac arrest in COVID-19 patients improves patient outcomes.[8,52,53]

Though some patients may require extracorporeal membranous oxygenation (ECMO), currently, there is insufficient evidence that ECMO is beneficial to COVID-19 patients. The effectiveness of ECMO in different ages and populations has not been determined. ECMO in prone patients was widely used during the peak of COVID-19, though Yang et al. examined critically ill COVID-19 patients and found that five of six (83.3%) patients placed on ECMO did not survive.[35] While its use is currently not supported by several major organizations, who recommend against it given the potential for cross-contamination of staff, the significant consumption of PPE, and questionable risk-to-benefit ratio in patients with multiple co-morbidities or multiple organ failure, several groups have noted its effectiveness in certain populations (e.g., individuals with refractory hypoxemia) during other respiratory pandemics.[68-73] Urner et al. conducted a study that included 844 patients and found that ECMO was most effective in patients <65 years of age and with a PaO2/FiO2 <80 mm Hg or with driving pressures >15 cm H_2O during the first 10 days of mechanical ventilation.[74]

CONCLUSION

COVID-19 continues to challenge healthcare providers and healthcare systems in unprecedented ways. It is important to recall lessons learned during the height of the pandemic as hospital providers will almost certainly face new surges in COVID-19 (albeit different variants) or similar deadly outbreaks in the future. Advances made in care of patients with COVID-19 who develop cardiac arrest are a great asset for any future surges or similar pandemics. Meta-analyses of these repots to determine best practices and codification into guidelines could ensure maximal utility of this knowledge.

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- Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND
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SUPPLEMENTARY MATERIALS

Supplemental Table

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