Impact of Coronavirus Disease 2019 Pandemic on Cardiac Arrest and Emergency Care

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KEYWORDS

• Cardiac arrest • Emergency care • Out-of-hospital cardiac arrest • In-hospital cardiac arrest • COVID-19 pandemic

KEY POINTS

- The COVID-19 pandemic has increased the incidence of both out-of-hospital and in-hospital cardiac arrest.
- The increase in the incidence of cardiac arrest seems to be multifactorial and related to the severity of COVID-19 in the community, reduced access to health care, and patient delays in seeking care.
- During the COVID-19 pandemic, patient survival and neurologic outcome after both out-of-hospital and in-hospital cardiac arrest were reduced.
- The worse outcome may be related to a combination of factors including reduction in bystander cardiopulmonary resuscitation rates, delays in emergency medical system response times and transport, higher incidence of nonshockable rhythms, and reduced access to emergency and in-hospital care because of COVID-19-related hospitalizations.
- A better understanding of the mechanisms by which COVID-19 has disrupted the chain of survival can direct further effort to mitigate the negative impacts on cardiac arrest and patient outcome. Understanding how the system response to a pandemic can be modified to increase lives saved is essential.

INTRODUCTION

Cardiac arrest continues to be a major public health concern. In the United States, the incidence of out-of-hospital cardiac arrest (OHCA) and in-hospital cardiac arrest (IHCA) are approximately 350,000 and 200,000 per year, respectively.[1,2] Despite significant advances in other areas of cardiovascular medicine, survival from cardiac arrest remains low.[3] Effective treatment of cardiac arrest includes bystander cardiopulmonary resuscitation (CPR), early activation of emergency medical services (EMS), early defibrillation, advanced cardiovascular life support, and postresuscitation care that includes targeted temperature management and emergency coronary angiography with percutaneous coronary intervention in some cases.

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Since the emergence of COVID-19 and the global pandemic declared by the World Health Organization on March 11, 2020, there have been more than 230 million confirmed cases around the world with more than 4.8 million deaths.[4] The COVID-19 pandemic has affected the incidence, presentation, care, and outcome of time-sensitive medical conditions including cardiac arrest.[5] Beyond the direct mortality related to the respiratory infection, health care systems have been overwhelmed by COVID-19-related hospitalizations, disruptions to the work force because of infected health care personnel, and logistical challenges related to implementation of strategies to minimize disease transmission. A reduction in elective cardiovascular procedures, shortened length of hospital stay, and longer delays between symptom onset and hospital treatment have also been observed during the COVID-19 pandemic.[6] In this article, the effects of the COVID-19 pandemic on cardiac arrest are presented, considering data from recent clinical studies, with a focus on the contributing factors and implications for improving outcome.

OUT-OF-HOSPITAL CARDIAC ARREST

Incidence

During the COVID-19 pandemic, the incidence of OHCA significantly increased with multiple geographic regions throughout the world reporting similar trends.[7–12] In the United States, various regions noted an increase in OHCA. Rollman and colleagues[7] reported a 21% increase in the incidence of OHCA in Los Angeles County, CA, USA, a diverse population of approximately 10.1 million persons. Matthew and colleagues[9] found a 62% increase in Detroit, MI, USA, using data from the Cardiac Arrest Registry to Enhance Survival (CARES). Lai and colleagues[12] reported an approximately 3-fold higher incidence of OHCA in New York City, NY, USA, a particularly hard-hit area early in the pandemic, which is also among the largest EMS systems in the United States serving a population of approximately 8.4 million (**Fig. 1**). Similarly, in Europe, Baldi and colleagues[10] analyzed data from the Lombardi Cardiac Arrest Registry that included 4 providences in Italy and found a 58% increase in OHCA. Marion and colleagues[8] found a 2-fold increase in OHCA in Paris, France, and the surrounding suburbs. In a meta-analysis of 10 studies with more than 35,000 OHCA events in various geographic regions, Lim and colleagues[13] found a 120% increase in OHCA.

In contrast to the aforementioned studies, several studies found no increase in OHCA.[11,14–16] Huber and colleagues[11] found no significant increase in OHCA within a community in Germany with a low prevalence of COVID-19 infection. Elmer and colleagues[15] also reported no significant increase in OHCA in Pennsylvania, USA, where the prevalence of COVID-19 was low. Chan and colleagues[17] observed communities with different COVID-19 mortality rates and found the incidence of OHCA was higher largely in communities with high COVID-19 mortality. Although these studies in aggregate suggest that the incidence of OHCA is related to the prevalence of COVID-19 infection within the community, it does not follow that patients experiencing OHCA were predominately COVID-19 positive.[18]

Patient and Arrest Characteristics

During the COVID-19 pandemic, there were also notable changes in baseline patient characteristics among those experiencing OHCA. Lai and colleagues[12] found that patients were older, less likely to be white, and more likely to have comorbid conditions, including diabetes mellitus and hypertension, compared with a prepandemic control group. Nonshockable rhythms (asystole and pulseless electrical activity) were also more common. Sultanian and colleagues[19] further evaluated the association between COVID-19 and the initial arrest rhythm; patients with confirmed COVID-19 were less likely to have a shockable rhythm compared with patients who were known to be COVID-19 negative. While Marijon and colleagues[8] did not note significant differences in baseline characteristics, the investigators observed higher rates of OHCA occurring at home, less frequent bystander CPR, and less frequent shockable rhythms. Two systematic reviews, one by Scquizzato and colleagues[20] that included 6 studies and another by Lim and colleagues with many of the same and totaling 10 studies found lower rates of shockable rhythm, lower rates of witnessed arrests, and lower rates of bystander CPR.[21]

Out-of-Hospital Arrest Management

OHCA is a time-critical emergency, with reduced chance of survival for every minute of delay. Multiple studies documented increased EMS response and transport times during the COVID-19 pandemic.[6,8,18,20,22,23] Use of personal protective equipment (PPE) to ensure health care provider safety and reduce transmission of COVID-19 during on-scene resuscitation likely contributed to delays in treatment and transport.[24] Furthermore, workforce reduction due to illness and overwhelmed health care systems leading to longer

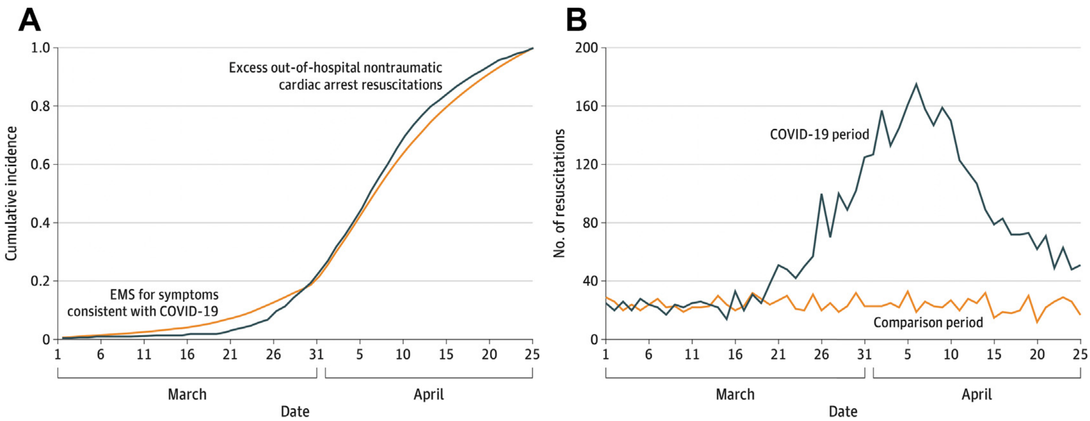

Fig. 1. New York City out-of-hospital nontraumatic cardiac arrest resuscitations, March 1 through April 25, 2020. (*A*) Temporal association between the cumulative percentage of EMS calls for fever, cough, dyspnea, and virallike symptoms consistent with coronavirus disease 2019 (COVID-19) and the number of excess out-of-hospital nontraumatic cardiac arrest resuscitations occurring in New York City in 2020. Excess cases were defined as the daily difference between the number of 2020 and 2019 cases; days with a negative difference were recoded as 0 for graphic presentation. (*B*) The number of daily out-of-hospital nontraumatic cardiac arrest resuscitations. (*From* Lai, P.H., et al., Characteristics Associated With Out-of-Hospital Cardiac Arrests and Resuscitations During the Novel Coronavirus Disease 2019 Pandemic in New York City. JAMA Cardiol, 2020. 5(10): p. 1154-1163.)

patient offload times at the hospital resulted in less available resources to respond to time-sensitive emergencies. Changes in resuscitation protocols during the COVID-19 pandemic by various EMS systems in response to resource limitations as well as uncertainties early in the pandemic may have affected prehospital management, response, and transport times.[22,25] Early recommendations, when PPE was scarce, included limiting personnel during the resuscitation, which could have had implications for outcome, and considering the appropriateness of initiation resuscitation.[26] Congruent with the observation of less frequent shockable rhythms, rates of defibrillation were significantly lower during the COVID-19 pandemic.[7] Studies also documented a reduction in attempted resuscitation measures[8]; this was again likely driven by the increase in unfavorable prognostic factors, although a fear of disease transmission by first responders, lack of EMS and hospital resources, and a perception of poor prognosis for COVID-positive patients experiencing OHCA may have contributed.

Outcome

Studies reporting outcome events during the COVID-19 pandemic were consistent and documented lower rates of return of spontaneous circulation (ROSC), less frequent survival to hospital admission, lower survival to hospital discharge, and worse neurologic outcome.[8,9,12,13,20] The prevalence of COVID-19 infection within the community also seems to be associated with worse outcome for those experiencing OHCA.[17] Chan and colleagues[17] used data from CARES throughout the United States to evaluate the association between OHCA outcomes and the COVID-19 disease burden within geographic areas; whereas ROSC was lower regardless of COVID-19 burden, survival to hospital discharge was primarily lower in communities with moderate to very high COVID-19 mortality rates.

IN-HOSPITAL CARDIAC ARREST

Incidence

Although data are limited, the incidence of IHCA in the United States before the COVID-19 pandemic was estimated at 10 per 1000 admissions.[27] This incidence varies by county and region with reports from the United Kingdom, for example, estimating an incidence of 1.6 per 1000 admissions making comparisons with current pandemic rates challenging.[28] Most recent literature has focused on IHCA occurring among COVID-19-positive patients. The incidence of IHCA seems to have increased during the COVID-19 pandemic, driven by high mortality among patients with COVID-19 and a decrease in hospitalizations for other conditions.[29–33] At the onset of the pandemic, Shao and colleagues[29] reported that 20% experienced IHCA in a consecutive series of patients from Wuhan, China, who required hospitalization for COVID-19 pneumonia. Subsequently, reports from New York in the United States of hospitalized patients with COVID-19 found IHCA rates of 3% to 7%.[30,31] However, among critically ill patients with COVID-19 in the intensive care unit (ICU), IHCA was more frequent. In a multicenter study from the United States of more than 5000 critically ill patients with COVID-19, 14% suffered IHCA.[32]

The few reports evaluating IHCA rates in non-COVID patients are mixed.[33] In a separate analysis from the aforementioned study, Roedl and colleagues[33] reported a decline in overall hospital admission in Germany during the peak of the pandemic, with an increase in IHCA among all hospitalized patients from the prepandemic era of 4.6% to 6.6% during the pandemic. However, both COVID-positive and COVID-negative patients were included in this study. In a study of only COVID-negative patients in Hong Kong, Tong and colleagues[34] found a decline in IHCA from 1.6 to 1.4 per 1000 admissions before and during the pandemic.

Patient and Arrest Characteristics

Baseline characteristics for patients with IHCA were different during the COVID-19 pandemic compared with the prepandemic era. Studies within the United States found an increased prevalence of IHCA among minorities (black and Hispanic patients) during the COVID-19 pandemic compared with earlier control periods.[30] In addition, studies from multiple geographic regions consistently found a higher prevalence of cardiovascular disease and cardiovascular risk factors in patients with IHCA during the COVID-19 pandemic compared with control periods.[29,31–33] In an evaluation before the pandemic, Andersen and colleagues[28] reported that the underlying cause of arrest was primary cardiac (50%–60%) followed by respiratory. In contrast, the most common cause for arrest in most studies during the pandemic was respiratory and most patients were intubated before the arrest.[29,31,35] Most studies found low rates of a shockable rhythm during the COVID-19 pandemic, ranging from 3% to 18%, similar to prepandemic data.[19,29–32,36] Rates of CPR within the aforementioned studies varied from 50% to 90%.[29,32] In general, time to treatment and resuscitation times were similar during the COVID-19 period compared with prior years.[31,33] When comparing the pandemic period to prepandemic, IHCA more commonly occurred in a general medical ward (as opposed to ICU) in some studies,[29,31] although other studies found higher rates of ICU IHCA during the pandemic.[33] Although location of the arrest has implications for recognition and response time, it may also reflect hospital overcrowding and conversion of non-ICU beds to a semi-ICU setting in some hospital systems and, therefore, would vary by region.

In-Hospital Cardiac Arrest Management

Early in the pandemic, there were little data to inform management. Prone positioning of patients with severe COVID-19, as well as the logistics of maintaining isolation precautions, added further challenges to achieving rapid response and high-quality resuscitation. Several novel treatment approaches were suggested for IHCA during the COVID-19 pandemic, including increased use of mechanical CPR devices, performance of prone CPR, and application of extracorporeal membrane oxygenation (ECMO).[37–39] Each of these presents its own challenges and are not feasible in all health care settings. There are limited data on outcome from prone CPR; however, it has the advantage to reduce delays to initiation of compressions as well as minimizing the complications that could occur from attempting repositioning in the prone patient.[38] ECMO rapidly became a limited resource given the high burden of COVID-19 in many communities and the need for specialty centers with expertise to manage these complicated patients. As such, use of ECMO has been limited to patients with COVID-19 not in cardiac arrest or patients with other causes of IHCA with an overall better prognosis and/or a clear, treatable underlying condition.[37,40]

Outcome

IHCA has a high mortality.[28] Similar to the findings for OHCA, studies reporting outcome events for IHCA during the COVID-19 pandemic were consistent and documented lower rates of ROSC, lower survival to hospital discharge, and worse neurologic outcome.[29,31,32] Survival to hospital discharge ranged from 0% to 14%.[31,32,36] During the peak of the COVID-19 pandemic in Wuhan, China, Shao and colleagues[29] reported 30-day survival of only 2.9%. Hayek and colleagues[32] reported data from a large multicenter registry from the United States and found that survival to hospital discharge was associated with patient age; for those younger than 45 years, survival was 21% compared with only 3% for those older than 80 years. A meta-analysis by Ippolito and colleagues[41] that included 7 studies, with all patients receiving attempted resuscitation, found an in-hospital survival rate of approximately 4%. These low survival rates have led some to question the benefits of performing CPR on patients with COVID-19.[33,42] However, the ability to predict outcome for patients with IHCA is challenging. The GO-FAR Score (Good Outcome Following

Attempted Resuscitation) is a validated scoring system that uses prearrest variables to predict the probability of survival to hospital discharge following IHCA.[43] In the aforementioned study by Aldabagh and colleagues[30] actual survival was compared with the GO-FAR score in 450 patients with IHCA. Unfortunately, COVID-19-positive patients had lower observed survival than predicted by the GO-FAR Score. However, lower survival rates are not entirely consistent across studies; Roedl and colleagues[33] found higher survival in COVID-positive versus COVID-negative patients with IHCA due to respiratory failure, albeit among a small cohort of 43 patients.

The low survival rates for IHCA seems to be multifactorial, related to the presence of the underlying illness at the time of arrest (mechanical ventilation, kidney replacement therapy, or vasopressor support), a high percentage of nonshockable rhythms, lack of therapies to treat the underlying disease process, and potential delays in response time because of isolation procedures, the need to use PPE, and restricted access to COVID-19 units. Improving outcomes of IHCA in patients with COVID-19 will be challenging, because many of the factors associated with poor outcome may not be modifiable. Further investigation into the risks and benefits of performing prolonged CPR in this subset of patients is needed, especially related to the concern for increased aerosolization of viral particles that places health care personnel at increased risk of contracting the infection.

MECHANISM FOR INCREASED CARDIAC ARREST

Multiple different mechanisms have been proposed to explain how the COVID-19 pandemic may have led to the increased incidence and worse outcomes from cardiac arrest. A dichotomy that includes both the direct and indirect effects of COVID-19 is a useful framework to understand this complex interaction[18] (**Table 1**).

Table 1
Direct and indirect effects of coronavirus disease 2019 on cardiac arrest

Direct Effects	Indirect Effects
• Respiratory illness leading to hypoxia • Endothelial inflammatory illness • Exaggerated immune response • Cytokine storm • Vascular thrombosis • Myocarditis • Arrhythmias • Prothrombotic state triggering pulmonary embolism and acute coronary syndrome • Drug treatment causing risk for arrhythmias	• Stringent lockdown measures • Stay-at-home order • Health care reorganization • Reduction in preventive and emergent diagnostic testing and procedures • Overwhelmed EMS and hospital systems • Use of personal protective equipment • Reduction in hospital work force • Delay in patient care • At-risk patients alone more often

Abbreviation: EMS, emergency medical system.

Direct Effects of COVID-19

COVID-19 can lead to the occurrence of cardiac arrest throughout multiple pathways. First, the respiratory illness itself with progressive hypoxia from ongoing pneumonia and acute respiratory distress syndrome can trigger cardiac arrest. In addition, particularly in the advanced stages of disease, COVID-19 progresses to a systemic endothelial inflammatory illness with an exaggerated immune response and cytokine storm.[44,45] In patients with preexisting cardiac conditions, this high inflammatory burden may induce vascular thrombosis, myocarditis, and cardiac arrhythmias.[46] Even in patients without predisposing conditions, a significant prothrombotic state has been associated with COVID-19 infections with an increased incidence in thromboembolic events including pulmonary embolism and acute coronary syndrome, possibly increasing the risk of cardiac arrest, particularly in the setting of concomitant inflammation.[47,48] Various drug treatments including hydroxychloroquine and azithromycin may further increase the risk of cardiac arrest, particularly in patients with preexisting cardiac conditions.[49]

Indirect Effects of COVID-19

Despite the potential direct effects of COVID-19 on cardiac arrest, the proportion of patients with OHCA with active and/or confirmed COVID-19 infection seems to be relatively low. For example, confirmed and suspected cases of COVID-19 in a French population accounted for only 30% of the observed increase in the incidence of OHCA.[8] Data from the Victorian Ambulance Cardiac Arrest Registry cross-referenced with the Victorian Department of Health and Human Services COVID registry demonstrated less public arrest, less public access defibrillation, lower rates of resuscitation by EMS, longer time to key intervention (defibrillation, epinephrine), and a 50% reduction in survival despite none of the patients in the registry testing positive for COVID-19.[50] These data suggest that the indirect effects may play an equal or even more important role in the increased incidence in and worse outcome from cardiac arrest observed during the COVID-19 pandemic. The potential indirect effects include stringent lockdowns and stay-at-home messaging, health care reorganization, reductions in preventive and emergency procedures, and overwhelmed EMS and hospital systems.

Lockdowns and movement restrictions, along with fear of seeking medical care due to potential exposure to COVID-19, made patients reluctant to seek emergency services, resulting in delayed care and worse outcome. Social restrictions and self-isolation during the pandemic likely caused at-risk patients to be alone more often, thus reducing the occurrence of witnessed arrests and reducing the possibility of bystander CPR[18,51]; this is consistent with a prior study that documented that those living alone were more likely to present with severe complaints and have an increased risk for early mortality.[52] Friedman and Akrenoted a striking increase in overdose-related deaths early in the pandemic, likely due to social isolation leading to both an increased use of substances due to stressors and use of substances while alone.[53]

The COVID-19 pandemic shifted the focus of health care to treatment of those afflicted with the acute respiratory infection while attempting to minimize the spread; this required changes to non-COVID medical care. Health care systems reorganized to accommodate the massive surge of patients with a highly infectious disease. Elective procedures including echocardiograms, cardiovascular stress tests, and coronary angiography were canceled to reallocate resources to COVID-19 treatment, as well as to avoid unnecessary exposure to stable and at-risk patients. During the pandemic, hospitalization rates for congestive heart failure, acute myocardial infarction, and arrhythmias were all lower than those during pre-COVID control periods.[54] Without timely hospitalization and/or prompt medical care, these cardiovascular conditions would be assumed to portend a higher risk for cardiac arrest (**Fig. 2**). Furthermore, early in the pandemic, limitations in PPE and lack of rapid testing availability led to changes to emergency procedures including delaying percutaneous coronary intervention for some patients with ST segment elevation myocardial infarction.[55,56] The psychosocial stress and reluctance to seek care in addition to the limitation of outpatient medical visits and the reduction in elective procedures are all likely contributors to the increased incidence of cardiac arrest.[11,18]

Finally, overwhelmed health care systems experienced challenges in handling the demands of hospitalized patients with COVID-19, in-hospital allocation of resources, and shortages in critical care services, including medical teams, equipment, and ICU bed availability.[6] With less available hospital resources during the pandemic, a higher threshold for hospital admission could have led to more at-risk patients for cardiac arrest being discharged from emergency departments. Response times for EMS were delayed, likely related to an overwhelmed EMS response system, emergency department overcrowding, and the need to use PPE during resuscitation.[12,51] There were also higher rates of nontransport in EMS systems, leaving patients potentially at risk for clinical deterioration.[57]

FUTURE CONSIDERATIONS

Cardiac Arrest Management

Current evidence is uncertain as to whether chest compressions or defibrillation can cause aerosol generalization and increase disease transmission to providers.[58] Airway management is an aerosol-generating procedure most commonly performed by EMS during cardiac arrest resuscitation. Therefore, a careful balance is necessary between the benefits of early resuscitation and the potential for harm to health care providers during resuscitative efforts. Consensus statements from multiple committees agree that chain of survival should be maintained including bystander CPR and public access defibrillation.[58–60] Furthermore, the use of PPE is recommended to ensure the safety of health care professionals during resuscitation, although defibrillation may be considered before donning airborne PPE.

The pandemic has led some to suggest modifications to cardiac arrest care including (1) use of field point-of-care ultrasonography to assess for cardiac standstill as means to supplement prognostication[25]; (2) reduction in the duration of CPR cycle from 2 to 1 minute, given the deterioration in the quality of chest compressions among rescuers wearing PPE[61]; and (3) placement of a towel or mask over the patient's mouth and nose during cardiac resuscitation with compression-only CPR.[60] These modifications may be reasonable as long as they do not interfere with high-quality CPR.

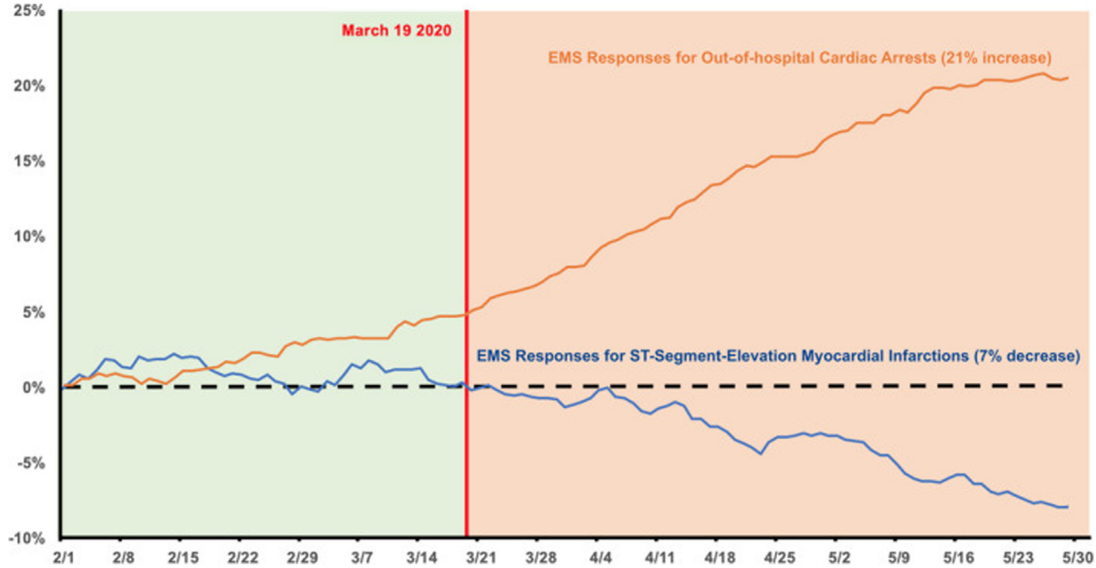

Fig. 2. Los Angeles county out-of-hospital nontraumatic cardiac arrest and ST segment elevation calls, March 19 to May 29, 2020. Significant increase in EMS calls for out-of- hospital cardiac arrest and a significant decrease in EMS call for ST segment elevation myocardial infarction in Los Angeles County, CA, USA. (*From* Rollman, J.E., et al., Emergency Medical Services Responses to Out-of-Hospital Cardiac Arrest and Suspected ST-Segment Elevation Myocardial Infarction During the COVID-19 Pandemic in Los Angeles County. J Am Heart Assoc, 2021. 10(12): p. e019635.)

Public Messaging

Particularly early in the pandemic, public health department messaging urged people to stay at home and lockdowns were implemented to reduce movement and potential exposure. Although a justifiable and important step to reduce the spread of infection, patients also avoided and minimized visits to outpatient clinics and to hospitals, likely due to this messaging as well as perceived risk of disease contagion. Studies published to date suggest that this resulted in worse outcome for time-sensitive cardiovascular medical conditions including cardiac arrest, ST segment elevation myocardial infarction, and stroke.[7] In response, multiple public messaging campaigns have been initiated.[62] Future messaging should continue to consider the impact on preventative and emergency care and to balance the concern for public and provider safety with the risk of delaying care for time-sensitive emergencies.

System-Level Pandemic Response

Many health care systems became overwhelmed with the surge of patients with acute respiratory illness and when baseline preventative health and emergency services broke down. Delays to both routine and emergency care led to increased severity of illness. Health care systems must consider how to maintain these services while responding to a pandemic surge. Many innovative programs to optimize resources were developed in response to the pandemic and can serve as models for expansion.[63] Building up telemedicine capabilities and mobile-integrated health programs can help to maintain standard medical care when access to hospital care is limited and/or public concern leads to changes in care-seeking behavior.[64] Dispatch support systems, use of advanced providers for triage, and alternate destinations for transport can optimize deployment of EMS resources to preserve rapid response for time-sensitive emergencies.

SUMMARY

During the COVID-19 pandemic both OHCA and IHCA have increased in incidence while outcomes among patients suffering cardiac arrest are worse. Direct effects of the COVID-19 illness as well as indirect effects of the pandemic on patient's behavior and health care systems have contributed to these changes. Understanding these potential factors offers the opportunity to improve future response and save lives. Fortunately, compared with the first wave of the COVID-19 pandemic, subsequent spikes in COVID-19 incidence seem to show an increase of lesser magnitude of cardiac arrest despite an overall increase in COVID-19 infections. As health care systems have adapted, experience gained from the first wave may have led to better management of patients with COVID-19, allocation of resources, and evaluation of non-COVID medical issues. Efforts at mass vaccination continue and will reduce the severity of disease leading to less severe complications for those with COVID-19. The adverse impact of delaying non-COVID medical care has become readily apparent, prompting the science and medical community to widely release public campaigns to encourage patients to pursue medical care despite the ongoing pandemic.

CLINICS CARE POINTS

- Clinicians should be aware that cardiac arrest incidence has increased during the COVID-19 pandemic.
- The chain of survival should be maintained, including bystander CPR and public access defibrillation.
- Healthcare professionals should use personal protective equipment to reduce risk of exposure during cardiac arrest resuscitation.
- It is important to maintain systems of care during respiratory pandemics in order to reduce harm of delayed access to routine and emergency care.

DISCLOSURE

There are no disclosures from any of the authors.

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