The coronavirus disease-2019 (COVID-19) pandemic has brought unprecedented changes to our world and health-care system. Its high virulence and infectiousness directly infect people's respiratory system and indirectly disrupt our health-care infrastructure. In particular, ST elevation myocardial infarction (STEMI) is a clinical emergency emphasizes on the establishment of care system to minimize delay to reperfusion. As such, the impact of COVID-19 on STEMI care, ranging from disease severity, patient delay, diagnostic difficulty, triage to selection of reperfusion strategy and postoperative care, is immense. Importantly, not only we have to save our patients, but we must also need to protect all health-care workers and prevent environmental contamination. Otherwise, in-hospital transmission can quickly evolve into nosocomial outbreak with staff infection and quarantine which lead to health-care system collapse. In this article, we will discuss the challenges in various aspects of STEMI management during COVID-19, as well as the mitigation measures we can take to optimize outcome and our future.

**Keywords:** COVID-19; Percutaneous coronary intervention; ST-elevation myocardial infarction

### Challenges in Management of ST Elevation Myocardial Infarction during COVID-19 Pandemic

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**Abstract**

The coronavirus disease-2019 (COVID-19) pandemic has brought unprecedented changes to our world and health-care system. Its high virulence and infectiousness directly infect people’s respiratory system and indirectly disrupt our health-care infrastructure. In particular, ST elevation myocardial infarction (STEMI) is a clinical emergency emphasizes on the establishment of care system to minimize delay to reperfusion. As such, the impact of COVID-19 on STEMI care, ranging from disease severity, patient delay, diagnostic difficulty, triage to selection of reperfusion strategy and postoperative care, is immense. Importantly, not only we have to save our patients, but we must also need to protect all health-care workers and prevent environmental contamination. Otherwise, in-hospital transmission can quickly evolve into nosocomial outbreak with staff infection and quarantine which lead to health-care system collapse. In this article, we will discuss the challenges in various aspects of STEMI management during COVID-19, as well as the mitigation measures we can take to optimize outcome and our future.

**Keywords:** COVID-19; Percutaneous coronary intervention; ST-elevation myocardial infarction

### Introduction

Since its emergence in late 2019, the coronavirus disease-2019 (COVID-19) has resulted in an explosive outbreak of viral infection worldwide in a few months. The World Health Organization (WHO) declared COVID-19 as a public health emergency of international concern on January 30, 2020, and further characterized it as pandemic on March 11, 2020. As of September 2021, the disease has infected more than 200 million people and caused 4.5 million deaths. Cities were locked down and billions of lives were transformed which make COVID-19 as one of the most important subjects in human history. The causative agent severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) primarily infects the respiratory tract and leads to fulminant pneumonia. In addition, the virus can adversely affect the cardiovascular system directly and indirectly. All these place huge demand on hospitals, especially for intensive care facilities and personnel. The unprecedented disruption in health-care system and resource allocation not only affects COVID-19 patient care, but non-COVID-19 disease care is also immensely undermined.

In particular, the management of emergent conditions such as ST elevation myocardial infarction (STEMI) is the most vulnerable. STEMI is usually caused by abrupt occlusion of a major epicardial coronary artery resulting in myocardial ischemia and cell death. Immediate reperfusion is the treatment priority and has been shown to be life-saving. Modern STEMI management mandates the establishment of STEMI network for rapid diagnosis, transport, triage, and treatment to restore coronary blood flow expeditiously. In this article, we summarize the impact of COVID-19 on STEMI and the impact of STEMI on COVID-19 infection. Furthermore, the indirect effects of COVID-19 on STEMI system of care are also discussed.

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**COVID-19 Infection and Cardiovascular System**

SARS-CoV-2 virus is a member of the Coronaviridae family, which is an enveloped virus with non-segmented single-stranded, positive-sense ribonucleic acid (RNA) genome. SARS-CoV-2 utilizes the angiotensin-converting enzyme 2 (ACE2) protein for cell entry. Upon entry, the viral genome RNA is released and replicates leading to newly formed genomic RNA. SARS-CoV-2 is spread mainly through the respiratory tract by droplets, respiratory secretions, and direct contact. ACE2 is highly expressed in lung alveolar cells, human heart, and blood vessels. Figure 1 shows the interaction between COVID-19 and the cardiovascular system. First, SARS-CoV-2 may induce direct injury to the myocardium, possibly through entry ACE2 upregulation. Second, hyperinflammation associated with COVID-19 infection can cause cytokine release, leading to vascular injury, plaque instability, and myocardial inflammation. Third, COVID-19 infection disrupts endothelial function and promotes microangiopathy and thrombotic complications such as disseminated intravascular coagulation. Together with hypoxia secondary to severe lung infection and stress-induced myocardial overload, all these induce injury to cardiac myocytes and cause dysfunction. Pathologically, viral particles, interstitial inflammatory infiltration, cytokines, myocyte necrosis, microthrombi, and vascular inflammation can be found in autopsy specimen.

In addition, profound hemodynamic disturbance and inflammatory response of COVID-19 infection potentially trigger cardiovascular events in patients with underlying cardiovascular diseases such as heart failure, coronary artery disease, arrhythmias, or valvular heart diseases. Notably, acute respiratory infection has been shown to increase the incidence of subsequent myocardial infarction (MI), possibly due to plaque rupture. Furthermore, the use of angiotensin-converting enzyme inhibitors (ACEIs) or angiotensin receptor blockers (ARBs) has been implicated to upregulate ACE2 protein in tissues and promote viral entry. Nevertheless, it must be emphasized that up till now, there is no evidence that the use of ACEI or ARB is detrimental and routine therapy cessation is not recommended. Besides, although rare, pharmacological treatment of COVID-19 infection and COVID-19 vaccine may have cardiovascular sequelae. Last but not least, the impact of COVID-19 pandemic on patient behavior and health-care system disruption significantly affects care of various cardiovascular diseases. This will be explained in subsequent sections in this article.

**Impact of Active COVID-19 Infection on ST Elevation Myocardial Infarction Patients**

As discussed above, SARS-CoV-2 virus is capable to attack our cardiovascular system, causing myocardial injury, immune activation, hypoxia, and thrombotic complications. Together with its intrinsic high mortality in severely infected patients, it is expected that STEMI patients with active COVID-19 infection have worse outcomes. Using data from a nationwide registry of consecutive STEMI patients who underwent reperfusion...
therapy in 42 specific STEMI care networks in Spain during COVID-19 pandemic, Rodriguez-Leor et al. demonstrated that STEMI patients with COVID-19 had higher mortality, more cardiogenic shock, heart failure, and stent thrombosis than STEMI patients without COVID-19. The initial findings of prospective NACMI (North American COVID-19 MI) registry also showed that STEMI patients with COVID-19 had a higher incidence of cardiogenic shock and mortality. Interestingly, STEMI patients with COVID-19 seemed to have higher thrombus load, as shown by greater usage of mechanical thrombectomy and glycoprotein IIb/IIIa inhibitors. Besides, the incidence of in-hospital stent thrombosis was remarkably higher. The results were in line with another single-center report from the United Kingdom which showed that STEMI patients with COVID-19 had a higher incidence of multi-vessel disease and stent thrombosis. This is clinically important for physicians to notice as regards to the use of antithrombotic and meticulous intraprocedural care in STEMI patients with concomitant COVID-19 infection. Table 1 summarizes the impact of active COVID-19 infection on STEMI manifestations.

**Impact of ST Elevation Myocardial Infarction on Patients Suffering from Concurrent COVID-19 Infection**

On the other hand, patients suffering from COVID-19 infection can develop STEMI due to the aforementioned factors. Studies have shown that COVID-19 patients with myocardial injury and raised troponin had higher mortality rates. Theoretically, COVID-19 patients complicated with STEMI should be at higher risk of death. One important thing to note is the diagnostic difficulty of ST elevation on electrocardiography (ECG) and type I MI in COVID-19 patients. An early report in Italy including 28 COVID-19 patients with ST elevation ECG demonstrated that despite the presence of regional wall motion abnormalities on echocardiogram, a significant portion of them did not have a culprit lesion (defined by more than 50% stenosis) on coronary angiogram. This generates important diagnostic and therapeutic implications including use of potent antithrombotic, fibrinolysis, and triage for primary percutaneous coronary intervention (PPCI). The underlying reasons of this ST elevation type myocardial injury instead of typical type I MI secondary to plaque rupture and coronary thrombosis may include inflammatory myocarditis, ischemia due to microvascular dysfunction, microthrombi, and type II MI due to oxygen demand–supply imbalance. Nonetheless, COVID-19 patients with any type of myocardial injury or MI had worse outcomes. Occasionally, the damages can be subclinical, as evident by worse left ventricular global longitudinal strain and diastolic function in patients recovered from COVID-19 infection. These may have long-term consequences given the huge number of COVID-19 survivors and the pandemic seems to be long lasting.

**Table 1: Impact of coronavirus disease-2019 on ST elevation myocardial infarction manifestations**

| Procedural                                      | COVID-19 infection and STEMI manifestations |
|------------------------------------------------|---------------------------------------------|
| Higher thrombus grade                          | Higher thrombus grade                        |
| More multi-vessel thrombosis                   | More multi-vessel thrombosis                |
| More stent thrombosis                          | More stent thrombosis                       |
| Worse TIMI flow and myocardial blush grade post-PCI | Worse TIMI flow and myocardial blush grade post-PCI |
| More use of mechanical thrombectomy            | More use of mechanical thrombectomy         |
| More use of glycoprotein IIb/IIIa inhibitors   | More use of glycoprotein IIb/IIIa inhibitors |
| Clinical                                        | Clinical                                    |
| More heart failure and cardiogenic shock        | More heart failure and cardiogenic shock     |
| More stroke                                    | More stroke                                 |
| Longer length of intensive care unit stay      | Longer length of intensive care unit stay   |
| Longer length of in-hospital stay              | Longer length of in-hospital stay           |
| High mortality                                 | High mortality                              |

STEMI: ST elevation myocardial infarction, COVID-19: Coronavirus disease-2019, TIMI: Thrombolysis in myocardial infarction, PCI: Percutaneous coronary intervention
When a STEMI patient with COVID-19 is admitted to the hospital for treatment, he/she may transmit the virus to other persons (other patients/relatives/friends/medical staff) who are without protection and contaminate the environment [Figure 2]. The cycle repeats itself and results in multiple generations of transmissions. The uncontrolled outbreak will cause death, place more demand on medical resources, medical personnel absence, and quarantine which mandate shut down of facilities and services. Eventually, this will lead to health-care system collapse. Therefore, not only we have to treat our STEMI patients, but we also need to protect our staff and the environment at the same time. This is even more challenging in the context of STEMI, as speed is our concomitant priority. Detailed assessment of individual patient’s COVID-19 status, including nucleic test result availability, may not be feasible before we decide on the immediate triage and treatment of acute STEMI patients. Hence, different hospital systems should devise their own protocols for the management of patients presented with STEMI.

**ST Elevation Myocardial Infarction Management Protocol Considerations**

**Initial assessment of COVID-19 status**

As most of the STEMI patients present from the community, their COVID-19 status is unknown in the beginning. The gold standard SARS-CoV-2 nucleic acid test result usually takes at least several hours to become available and a single negative SARS-CoV-2 nucleic acid test cannot completely rule out COVID-19 infection. Other circumstantial factors that can be taken into considerations include local COVID-19 outbreak situation, patients’ contact history, symptomatology, radiological (chest X-ray, computed tomography), and serological tests. Another novel approach is the use of a point-of-care ultra-rapid diagnostic test which has a turnaround time for 10–20 min for immediate decision making. One must be aware all these measures may have false negatives. Consequently, all STEMI patients should be initially managed as if they are potentially infected, while hospital and staff should have appropriate personal protective equipment (PPE) when they come into contact with patients. They should be segregated from other non-COVID-19 patients and managed in suitable isolation facilities. SARS-CoV-2 nucleic acid test should be taken upon initial patient encounter as when results come back, they can help further triage and care in the hospital. In addition, the test should be repeated if there is any clinical suspicion.

**Reperfusion therapy: Primary percutaneous coronary intervention versus fibrinolysis**

Conventionally, PPCI is the preferred strategy if it can be performed expeditiously by an experienced team. Compared to fibrinolysis, PPCI has better diagnostic ability, efficacy, and lower risk of hemorrhage. In the era of COVID-19 pandemic, there has been intense debate on which strategy is more appropriate for the overall benefit of patients, staff, and health-care system. The pros and cons of both strategies are depicted in Table 2.

Depending on local outbreak situation and resource availability, institutions ought to adopt their own protocols for emergent reperfusion for eligible STEMI patients. The maximum delay from STEMI diagnosis to reperfusion of 120 min should still remain the goal. Besides, the protocol has to be periodically reviewed and modified accordingly. On the whole, there was an increase in the use of fibrinolysis as reperfusion strategy in view of resource implication. A survey by the European Association of Percutaneous Coronary

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**Figure 2: Nosocomial outbreak of COVID-19 can lead to health-care system collapse.**

STEMI patient with COVID-19 can transmit the virus to medical staff, other patients and contaminate the environment. Subsequent generations of transmissions can quickly evolve into outbreak and collapse the system.

STEMI: ST elevation myocardial infarction, COVID-19: Coronavirus disease-2019, ICU: Intensive care unit
Table 2: Pros and cons of fibrinolysis and primary percutaneous coronary intervention as reperfusion for ST elevation myocardial infarction

| Pro-fibrinolysis | Pro-PPCI |
|------------------|----------|
| Most catheterization laboratories do not have dedicated isolation facilities | There are multiple absolute or relative contraindications for fibrinolysis |
| PPCI causes contamination to environment | PPCI is both diagnostic and therapeutic |
| PPCI increases the risk to staff, especially if there is aerosol-generating procedure(s). For example, resuscitation and intubation | For COVID-19 patients with STEMI, some of them are not having coronary thrombosis in which fibrinolysis has no benefit but risk. For example, risk of hemorrhagic myopericarditis |
| Catheterization laboratory service may be undermined if staff and environment are deficient | Fibrinolysis may have a higher risk of bleeding or thrombotic complications in COVID-19 patients. For example, alveolar hemorrhage secondary to acute respiratory distress syndrome[24,30] |
| Immediate fibrinolysis minimizes delay associated with awaiting a decision on whether to proceed to PPCI | STEMI patients may present late and efficacy of fibrinolysis is limited |
| Fibrinolysis is a well-recognized treatment option for acute STEMI. Pharmaco-invasive approach is not that bad | Use of fibrinolysis may increase length of hospital stay and resource utilization[39] |
| For patients with successful or unsuccessful fibrinolysis, PPCI can then be performed with known COVID-19 status | |

PPCI: Primary percutaneous coronary intervention, STEMI: ST elevation myocardial infarction, COVID-19: Coronavirus disease-2019

Interventions (EAPCI) showed that 22% of participants reported the use of fibrinolysis due to logistic reasons.[32] Early experience from a large cardiovascular center in China suggested that fibrinolysis-first strategy increased the rates of recurrent ischemia, cardiogenic shock, and exacerbated heart failure but without worsened in-hospital net adverse clinical events.[35] Inevitably, this study had multiple confounding factors for which it is premature to conclude which reperfusion approach is superior in COVID-19 era.[36]

Catheterization laboratory consideration for primary percutaneous coronary intervention during COVID-19

As discussed above, the goal of performing invasive procedures in a catheterization laboratory is to save the patient and simultaneously protect the staff and environment. Ideally, the site should be a dedicated facility consists of negative pressure control room and gowning de-gowning room with adequate air exchange. All hardware and consumables inside the room have to be protected and disinfected in between every case. Nevertheless, most catheterization laboratories are not designed to operate under strict isolation purposes and in contrast, many of them have positive air pressure which can contaminate the surrounding environment extensively in case of COVID-19-infected patients. Nowadays, a number of measures can be instituted for the environment, patient, and staff in order to reduce the likelihood of disease transmission [Table 3]. Temporary methods to reduce respiratory droplets transmission include airflow change or use of high-efficiency particulate air (HEPA) filter. Thorough disinfection is mandatory after each case as per institutional infection control protocol. At the same time, aerosol-generating procedures should be avoided inside catheterization room as far as possible. As such, the threshold for airway intubation is lower in patients with respiratory distress or anticipated deterioration. The intubation should be performed in designated places by experienced hands and a close-circuit ventilation can be established before entering the catheterization room. In case if cardiopulmonary resuscitation is needed during PPCI, early use of automated chest compression device and airway management by an experienced and well-protected team are recommended. For the staff, full PPE including but not limited to medical protection mask (N95, FFP2, FFP3), disposable surgical cap, gown, disposable surgical gloves, goggles, face shield, and/or powered air purifying respirators should be provided. An area for gowning and de-gowning is also essential.

In the context of risk management, a contingency protocol has to be devised in case of a COVID-19 patient underwent an aerosol-generating procedure inside the catheterization laboratory. This will include the need for staff evacuation in the surrounding area, environmental protection, and the extent of disinfection required after procedure. All the aforementioned measures aim to reduce the chance of health-care providers contracting COVID-19 or mandating compulsory quarantine measures which may severely undermine invasive cardiology service.

Postreperfusion care

As all patients undergoing PPCI are regarded as potentially COVID-19 positive, they should care in appropriate isolation facilities before SARS-CoV-2 nucleic acid test comes back to be negative. Intensive care unit (ICU) isolation room is usually the preferred place, but they are unlikely to be easily available
during COVID-19 pandemic. Besides, coronary care unit (CCU) or bed with telemetry unit can be temporarily modified (use of HEPA filter or adjustment in airflow if feasible) to care for postreperfusion patients if they are stable. This may preserve ICU beds for other patients in the pandemic. Needless to say, the checking of SARS-CoV-2 nucleic acid test during the initial patient encounter is extremely useful for postreperfusion patient triage and disposal when the test result is available. On the other hand, patients who received fibrinolysis should also care in isolation facilities before COVID-19 status is known. Once the result is negative, they can be triaged to non-COVID-19 area or considered to proceed to revascularization as appropriate.

**Evidence of Impact of COVID-19 on ST Elevation Myocardial Infarction System of Care**

**ST elevation myocardial infarction and primary percutaneous coronary intervention numbers**

Especially in the early phase of COVID-19 pandemic, multiple reports from worldwide showed that there was reduction of STEMI diagnosis, admissions, catheterization laboratory activation, and PPCI.[33,37-45] A report of 1372 chest pain centers (n = 28,189) in China revealed that there was an approximately 26% drop in the weekly total number of hospitalized STEMI cases during the COVID-19 outbreak nationwide, and an approximately 62% drop in Hubei province which was the area most severely hit.[33] Subsequently, studies from other parts of the world revealed similar findings [Table 4]. There are a number of possible underlying reasons. First, city lockdown remarkably reduced human activities and social interaction. People staying at home may have a lower chance of triggering an acute coronary event. Second, social distancing and infection control measures markedly cut down the incidence of influenza and other respiratory viral infections which are known precipitating factors of cardiovascular events.[48] Besides, a more worrisome reason is concerning health-care avoidance. Patients are reluctant to seek medical advice even if they have symptoms of MI and this may be linked to worse outcomes. The increase in out-of-hospital cardiac arrest during the early COVID-19 pandemic was alarming and some of them might be suffering from MI for which they would never have been diagnosed.[49-51] Although not all out-of-hospital cardiac arrests could be attributed to acute cardiac disease, some of them might be preventable if prompt medical attention was sought. Furthermore, if a STEMI patient presents to the hospital out of revascularization window, PPCI will not be activated which can explain the reduction in catheterization laboratory activation and PPCI numbers. These delayed STEMI patients are prone to develop acute or chronic post-MI complications.

**Patient presentation**

Owing to COVID-19 outbreak, when STEMI patients start to experience symptoms, they may not go to the hospitals immediately. It may be due to the fact that they are afraid of contracting the virus in health-care facilities or they believe that the health-care resources are so scarce and should be reserved for COVID-19 patients. Lockdown and social distancing measures may also
### Table 4: Studies concerning the impact of coronavirus disease-2019 on ST-elevation myocardial infarction metrics and outcome

| Study design                     | Control cohort                                  | STEMI number         | Patient delay                                      | System delay                                      | Outcome                                                                 |
|---------------------------------|------------------------------------------------|----------------------|---------------------------------------------------|--------------------------------------------------|------------------------------------------------------------------------|
| Tam et al.[46,47]               | Single-center, retrospective (Hong Kong, China) | Single-center        | ↓Symptom onset to FMC time                         | ↑Doctor-to-device time                             | ↑ Composite endpoint of in-hospital death, cardiogenic shock, malignant arrhythmia, and use of mechanical circulatory support |
| Xiang et al.[33]                | Multi-center, retrospective (China)             | Multi-center         | ↓STEMI                                            | ↑Fibrinolysis                                     | ↑FMC to wire (non-Hubei sample)                                         |
| Wilson et al.[44]               | Single-center, retrospective (UK)               | Single-center        | ↓STEMI activation                                  | ↓PPCI                                            | ↑In-hospital mortality (non-Hubei sample)                                 |
| Kwok et al.[41]                 | Multi-center, retrospective (UK)                | Multi-center         | ↓Symptom onset to admission time                   | ↑Doctor-to-balloon time                            | Composite endpoint of death, re-infarction, and PCI                    |
| De Luca et al.[37]              | Multi-center, retrospective (Europe)            | Multi-center         | ↓Percentage of patients with total ischemic time <120 min | ↑Percentage of patients with door-to-balloon time >30 min | ↑In-hospital mortality                                                   |
| Kite et al.[40]                 | Multi-center, retrospective (International)     | Multi-center         | ↓Symptom onset to admission time                   | ↑Doctor-to-balloon time                            | In-hospital mortality and cardiogenic shock                              |
| Garcia et al.[21]              | Multi-center, retrospective (USA)               | Multi-center         | ↓STEMI                                            | ↑PPCI                                            | ↑In-hospital mortality and cardiogenic shock                              |
| Primessnig et al.[42]           | Single-center, retrospective (Germany)          | Single-center        | ↓STEMI admissions                                  | ←Door-to-balloon time                              | Composite endpoint of cardiopulmonary resuscitation, cardiogenic shock, and life-threatening arrhythmia |
| Scholz et al.[45]               | Multi-center, retrospective (Germany)           | Multi-center         | ↓STEMI admissions                                  | ←Door-to-balloon time                              | In-hospital mortality                                                    |
| Rodriguez-Leor et al.[45]       | Multi-center, retrospective (Spain)             | Multi-center         | ↓Symptom onset to FMC time                         | ↑FMC to reperfusion time                          | In-hospital mortality                                                    |

COVID-19: Coronavirus disease-2019, STEMI: ST elevation myocardial infarction, FMC: First medical contact, PPCI: Primary percutaneous coronary intervention, PCI: Percutaneous coronary intervention

Somehow encourage patients to stay at home to await their symptoms to resolve. Altogether, there was an increase in symptom onset to first medical contact (FMC) time which directly increased the STEMI total ischemic time. The first report from a handful of cases in Hong Kong, China, demonstrated a marked surge of symptom onset to FMC time from January to February 2020[46]. Thereafter, similar delays were seen in data from China chest pain centers and registries from the USA, Europe, and other countries[33,37,40,41,44,45] [Table 4]. The reality is that this pandemic changed human health-seeking behavior which led to treatment delays in STEMI care.

### Health-care response delay

Apart from patient delay, STEMI care system delay was also apparent during the COVID-19 pandemic. When STEMI patients present to the hospitals or any health-care providers, STEMI care system will be activated to triage the patients to appropriate facilities for reperfusion therapy. Depending on local infrastructure and resource availability, different STEMI care model has its own logistics, whereas the time to achieve reperfusion or so-called door-to-device time has long been regarded as an important quality indicator for STEMI care system. As the care chain depends heavily on close collaboration of various parties, it is extremely
vulnerable to resource disruption and behavioral change. In the context of COVID-19, hospitals may have a strict infection control policy to assess individuals’ COVID-19 status and time is needed to obtain specimen samples, radiological examinations, or symptomatology history. Staff may need time to gown, de-gown, and adequately disinfect the environment after every patient. Patients tend to present later with more severe diseases which require longer time for stabilization or even airway control before they enter the catheterization laboratory. These were elucidated by prolonged door-to-device time and catheterization laboratory arrival-to-device time in the early experience in Hong Kong, China.\[46\] The China chest pain center data also illustrated longer FMC-to-needle and FMC-to-wire time, while other studies worldwide echoed with prolonged door-to-balloon time\[21,33,40,41\] [Table 4]. Overall, it is undesirable but seems inevitable in the face of a novel infectious disease.

**ST elevation myocardial infarction patient outcome**

Given the increase in patient and system delay, patients suffering from STEMI unavoidably have prolonged ischemic time and their outcome is expected to be worse. Multiple registries showed that STEMI patients during COVID-19 pandemic had higher in-hospital mortality, rate of cardiogenic shock, use of mechanical circulatory support, heart failure, and malignant arrhythmia\[33,37,40-42,44,45,47\] [Table 4]. One must be aware that the true incidence of STEMI mortality may be even higher as some STEMI patients died before arriving at hospitals. In addition to treatment delay, some areas may have insufficient workforce and ICU/CCU capacity. Physicians may be more inclined to choose conservative management for some STEMI patients with borderline premorbid status. Furthermore, the delayed STEMI presentation precipitated a resurgence of post-MI mechanical complications such as ventricular septal defect, papillary muscle, and free-wall rupture\[52-54\] [Figure 3]. These invariably complicated patients’ in-hospital course and worsened outcomes.

**Mitigation Measures for ST Elevation Myocardial Infarction Management Delay Amid COVID-19 Pandemic**

COVID-19 has already been infecting millions of people and its collateral damage to non-COVID-19 care is evident, especially in acute STEMI care. The public health emergency response has led to increase in patient delay, system delay, and reduction in emergent reperfusion accessibility which probably resulted in worse outcomes. In addition to combating the infectious agents, cardiology community should strive to figure out how to improve the service model.

**Patient education**

Concerning the health-care avoidance behavior, public education is imminently required to let patients acknowledge that heart attack symptoms should not be ignored. They should seek immediate medical attention and hospitals are employing safety measures to protect them from contracting COVID-19. They should know that if they get care faster, they will recover faster with less damage. Indeed, there were campaigns in various countries to remind patients the importance of not to ignore heart attack symptoms. Hopefully, this will minimize patient delay in STEMI treatment.

**ST elevation myocardial infarction response system modification**

In view of anticipated delay in various steps of STEMI activation, stakeholders should constantly review their protocols and quality indicators to identify gaps and deficiencies. Ideally, non-COVID-19 patients should be segregated from COVID-19 or suspected COVID-19 patients. All STEMI patients should be regarded as potential COVID-19 positive, but they should receive adequate protection, and immediate assessment of COVID-19 status is essential. This can be expedited by systematic history taking, radiological examinations, serological tests and SARS-CoV-2 nucleic acid tests. Currently, the use of ultra-rapid antigen test may also allow immediate triage of patients if necessary. Hopefully in the future, there may be better diagnostic methods to identify COVID-19 patients. Hospital administrators are obliged to provide sufficient PPE for all staff and staff should be familiar with all equipment to reduce the time required for gowning and de-gowning. Disinfection protocol should be clearly defined for various clinical situations such that environmental contamination risk is minimized. If resources allow, hospitals can modify the infrastructure to allow transport of STEMI patients to catheterization laboratory with minimal contact with non-COVID-19 areas. Catheterization laboratory can also be refurnished and modified with airflow exchange [Figure 4]. All these measures aim to streamline the patient journey from door to device. With time and practice, the whole process can be expedited. Importantly, protocols have to be adjusted according to different outbreak situation and clinical needs.

**COVID-19 vaccine**

The widespread use of COVID-19 vaccine gives us hope to win the battle against the SARS-CoV-2 virus. In fact, COVID-19 vaccine effectively reduced the likelihood of severe COVID-19 infection even if someone
contracted the disease. This can lower the patients’ chance of admitting to hospitals or going into ICU. Theoretically, a vaccine is expected to lower the viral transmissibility and hospitals may be able to resume pre-COVID-19 activities after the staff receiving full doses of COVID-19 vaccine including easing hospital activity restriction and infective control measures. The initial experience among health-care workers in Israel showed that receiving BNT162b2 vaccine was associated with a lower incidence of symptomatic and asymptomatic SARS-CoV-2 infection. Nonetheless, with the emergence of SARS-CoV-2 variants and drop in efficacy of currently available vaccines, it is impossible to conclude that vaccines can eradicate COVID-19. A recent study showed that there was a resurgence of symptomatic COVID-19 infection among fully vaccinated health-care workers, with 75% of cases occurring in fully vaccinated individuals in July 2021. After all, vaccination is still capable of protecting someone from severe disease and ICU admissions, thus lessening the burden on health-care system. Therefore, health-care professionals are strongly recommended to take the vaccine for the sake of themselves, their patients, families, colleagues, and society.

**Future perspectives**

No one would deny COVID-19 pandemic has changed the lives of everybody on this planet. Although everyone suffers, it is gratifying to see everyone stay on the same boat to focus to fight against a single entity. Throughout these months, different measures including lockdowns, social distancing, contact tracing, case quarantine, and declaring state of emergency responses were utilized and eventually, we have vaccines which might have given us hope to win this battle. Millions of lives were lost and collateral damage is incalculable. At the same time, SARS-CoV-2 variants emerge and we know it is premature for humans to declare victory against COVID-19. It seems inescapable that the war will be long-lasting and we have to prepare how to adapt ourselves to cope with the disease. Hopefully not far from now, we will have better vaccines, medications, treatment strategies, diagnostic tests, and facilities for SARS-CoV-2 such that we can manage both COVID-19 and non-COVID-19 conditions effectively. Nevertheless, one must be aware that COVID-19 is not the only and certainly not the last infectious disease to affect humankind. Medical community has to devise measures to face the direct and indirect impact of communicable disease in future. Notably, this necessitates concerted effort from everyone and collaboration is the key to success for all.

**Conclusion**

COVID-19 pandemic has brought unprecedented influences on our world. In addition to being an infectious agent, it changes human behavior and health-care system which directly and indirectly undermines
various kinds of clinical services such as STEMI care. Treatment delay is apparent which leads to worse outcomes and we have to adapt to mitigate the risks for our people and society. There is a long way to go before we can defeat COVID-19 and cooperation is mandatory for humans to win this war.

Together, we prevail.

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