



Case Selection During the COVID-19 Pandemic: Who Should Go to the Cardiac Catheterization Laboratory?

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Abstract

Purpose of review To summarize the best available evidence and recommendations regarding case selection for cardiac catheterization laboratory (CCL) during the coronavirus disease 2019 (COVID-19) pandemic with emphasis on ST segment elevation myocardial infarction (STEMI) management.

Recent findings The restructuring of cardiovascular services to preserve hospital beds and personal protective equipment during the COVID-19 pandemic had a profound effect on healthcare delivery around the world with unintended consequences. In the United States, a significant 38% reduction in CCL activations for STEMI was noted in the early phase of the pandemic. Similarly, a 34% decline in utilization of invasive angiography, an 18% reduction in primary percutaneous coronary intervention (PPCI), and a 19% increase in door-to-balloon (D2B) times were also observed. These trends coincided with a significant increase in out-of-hospital cardiac arrests and late MI presentations. A shift to

pharmacological reperfusion has been advocated in Asia, which resulted in increased morbidity and mortality.

Summary COVID-19 has negatively affected many aspects of STEMI care, including timely access to mechanical reperfusion, which has resulted in increased morbidity and mortality. Balancing optimal STEMI care with the risk of infection to healthcare workers during the pandemic is challenging. Recommendations provided by consensus documents are a helpful guidance.

Introduction

During the coronavirus disease 2019 (COVID-19) pandemic, caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the normal function of the cardiac catheterization laboratory (CCL) has been altered to minimize the risk of personnel infection and preserve hospital beds [1]. In the present manuscript, we

summarize the unintended consequences of these changes, present modified reperfusion strategies for ST segment elevation myocardial infarction (STEMI) patients during the pandemic, and discuss best available evidence regarding patient selection for cardiac catheterization during the pandemic.

Myocardial injury and COVID-19

The frequency of myocardial injury depends on the method of detection (fourth generation, high-sensitivity cardiac troponins (hs cTn), or cardiac magnetic resonance imaging), frequency of sampling, and illness severity. In the largest study to date [2], myocardial injury defined as cardiac troponin (cTn) increase above the 99th percentile was found in 36% of hospitalized patients with COVID-19 and was associated with higher incidence of adverse outcomes including mortality, a finding similar to other acute respiratory diseases [3•]. Nevertheless, the frequency of myocardial injury assessed by cardiac troponins in COVID-19 varies greatly between studies, ranging from 1% in COVID-19 survivors to 100% in patients with very severe forms of COVID-19 [3•]. This is likely due to inclusion of different patient populations in each study, given that patients with myocardial injury are more likely to be critically ill and have higher prevalence of chronic cardiovascular conditions.

Another study evaluated 100 patients recently recovered from COVID-19 infection with cMRI and found abnormal findings in 78% of them including abnormal CMR raised myocardial native T1 ($n = 73$), raised myocardial native T2 ($n = 60$), myocardial late gadolinium enhancement ($n = 32$), or pericardial enhancement ($n = 22$) [4].

With serial cTn measurements, myocardial injury due to COVID-19 can be classified as acute ($\Delta > 20\%$) or chronic ($\Delta < 20\%$). Acute injury cases can be either ischemic if there is a clinical correlate of myocardial ischemia (i.e. wall motion abnormality) or nonischemic, such as acute heart failure, pulmonary embolism [5], or less commonly stress cardiomyopathy [6] or myocarditis. Chronic injury manifests as mild cTn elevation and is typically seen in patients with pre-existing cardiovascular conditions such as heart failure and hypertension and portends a bad prognosis [3•]. In an echocardiographic assessment of

consecutive hospitalized COVID-19 patients, myocardial injury correlated with higher prevalence of right and left ventricular diastolic dysfunction; however, the left ventricular ejection fraction remained normal in most patients with elevated cTn, indicating that lung disease causing right heart failure is the main contributor of troponin elevation in COVID-19 patients [7]. Indeed, in a study involving 799 moderately to severely ill COVID-19 patients, clinical heart failure complicated the hospitalization of 24% and amino-terminal pro-B-type natriuretic peptide levels (BNPs) were elevated in 23% of all patients [8]. Also, in an autopsy study of 21 COVID-19 patients, the principal cardiac pathological changes were diffuse macrophage infiltration (possibly due to COVID-19-induced inflammation or due to underlying conditions) and right ventricular strain, with lymphocytic myocarditis being a less common finding [9]. Experts recommend serial testing with hs-cTn and BNP in all hospitalized patients with COVID-19 infection for risk stratification and prognosis [3•].

Management of ST segment elevation myocardial infarction during the COVID-19 pandemic

Prior to COVID-19, primary percutaneous coronary intervention (PPCI) was considered the treatment of choice for STEMI patients presenting to a PCI-capable hospital or who could be transferred to and treated in a PCI-capable hospital within 120 min of presentation [10].

The need to protect CCL personnel and patients from COVID-19 coupled with shortages of personnel protective equipment (PPE) and lack of rapid testing to confirm COVID-19 infection has significantly disrupted STEMI systems of care. Given these considerations, cardiology societies around the globe have taken different approaches to STEMI management during the pandemic. The American College of Cardiology (ACC)/American Heart Association (AHA) and Society for Cardiac Angiography and Interventions (SCAI) continue to recommend PPCI for patients with STEMI (Fig. 1).

In contrast, experts in China, Jordan, Palestine, and Iran recommend prioritizing thrombolytic therapy for most patients with unconfirmed COVID-19 status [11]. The Chinese experience with this modified approach has recently been published [11]. In Hubei province, the percentage of patients receiving PPCI dropped by 50% and the probability of receiving thrombolytic therapy increased sharply during the outbreak (odds ratio 4.78, 95% CI: 2.45–9.33, $p < 0.001$). Overall, the proportion of patients receiving timely reperfusion decreased from 59 to 51% and among patients receiving PPCI, a 20-min delay was noted in Hubei. In-hospital mortality increased from 4.6 to 7.3% and risk of heart failure also increased from 14.2 to 18.4% in Hubei during the outbreak.

In the United States (US), a significant 38% reduction in CCL activations for STEMI was documented in the early phase of the pandemic [12•]. A follow-up, expanded analysis that included 18 healthcare systems in the US showed that the number of CCL activations leading to angiography dropped by 34% and number of CCL activations leading to PPCI dropped by 20% whereas the average door to balloon time increased by 20% [13]. These negative trends in STEMI care coincided with

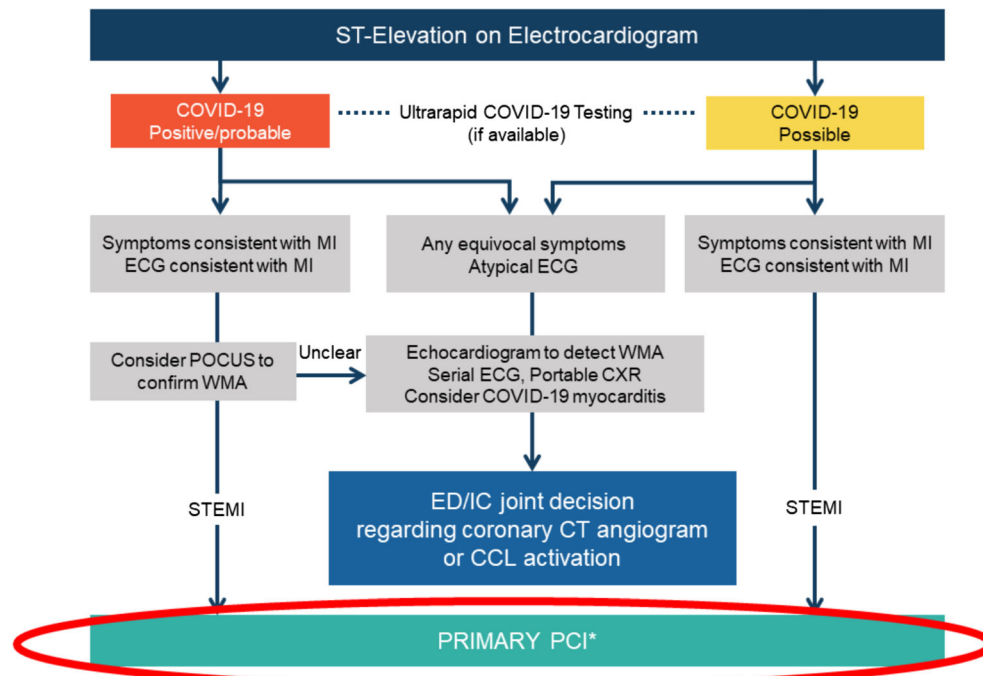


Fig. 1. Pathways for management of patients with suspected ST-Segment elevation myocardial infarction (STEMI) during the pandemic. Primary PCI (PPCI) remains the preferred reperfusion modality

a significant increase in the number of out-of-hospital cardiac arrest (OHCA) in various cities affected by COVID-19 lockdowns [14, 15]. The underlying reasons for these unexpected trends are not entirely clear and multiple factors may be playing a role including patients not seeking care out of fear of contracting COVID-19, inability to see doctors during the lockdown, and others. As the US prepares for a second wave of COVID-19 in the fall and winter, it is imperative to educate the public, preserve essential services to care for non-COVID patients with acute cardiovascular emergencies, and continue to observe these trends periodically.

STEMI in patients with confirmed COVID-19 infection

A summary of published studies including STEMI patients with COVID-19 at the time of this writing is presented in Table 1. As noted in the table, wide variations in mortality have been reported likely due to variations in patients included, reperfusion strategies, and utilization of invasive angiography.

To overcome some of these limitations, SCAI and the Canadian Association of Interventional Cardiology (CAIC) in conjunction with the ACC Interventional Council have collaborated to create a multi-center observational registry, North American COVID-19 ST Segment Elevation Myocardial Infarction (NACMI). This registry is enrolling confirmed COVID-19 patients and persons under investigation (PUIs) with new ST segment elevation or new-onset left bundle branch block (LBBB)

Table 1. ST-segment elevation myocardial infarction in COVID-19 literature review

STEMI series in COVID-19—literature review		New York series [17], n = 18	Lombardy series [18], n = 28	London series [19], N = 39	French series [51], n = 11	International [52], n = 78	Chinese series [11], n = 25,150
Population	6 hospitals in New York, USA, n of 18	All PCI capable hospitals (?n) in Lombardy, Italy n of 28	115 consecutive STEMI patients at Barts Heart Centre (39 positive for COVID-19)	83 consecutive STEMI patients at University Hospital of Nancy, France (11 positive for COVID-19)	Lithuania, Italy, Spain, and Iraq	China Chest Pain Center (CCPC) Database	
Time frame	March 2020	Feb 20–March 30, 2020	March 1 to May 20, 2020	February 26 to May 20, 2020	February 1 to April 15, 2020	December 27, 2019, to February 20, 2020	
Demographics	Median age 63, 83% male, 67% intubated	Mean age 68, 71% male	Mean age of 62, 85% male, 13% intubated	Mean age 63.6, 64% male	Median age of 65, 63% men	Hubei sample:	
COVID-19 diagnosis	N/A	Reverse transcriptase PCR	Reverse transcriptase PCR OR symptoms + positive chest imaging	Reverse transcriptase PCR OR symptoms + positive chest imaging	Confirmed-positive result on PCR testing of a nasopharyngeal sample	NA	
Chest pain as initial symptom	6/18 (33%) had chest pain	22/28 (79%)	11/39 had cardiac arrest as initial presentation	4/11 had cardiac arrest as initial presentation	18% were intubated	NA	
Strength of the study	First paper to describe STEMI		Looked at thrombus grade for grade 5 thrombus, TIMI flow, Blush score 3 interventionalists	2 angiographers scored angiograms for thrombotic	Multi-center	Multi-center	

on electrocardiogram (ECG). The primary objective of this registry is to compare demographics, comorbidities, and pertinent diagnostic and management data between COVID-19 confirmed STEMI patients with a historical cohort of STEMI patients prior to the COVID-19 crisis. The primary endpoint is in-hospital and 1-year major adverse cardiovascular events (MACEs) defined as composite of all-cause mortality, stroke, recurrent MI, and repeat unplanned revascularization [16].

Angiographic findings

Of 18 COVID-19-positive patients presenting with ST segment elevation to 6 New York City hospitals, 8 were classified as having a typical STEMI on the basis of clinical presentation and angiographic findings whereas 10 had non coronary myocardial injury [17]. Of note, this diagnosis was made on the basis of clinical presentation, biomarkers, and echocardiography since only 9 (50%) underwent invasive angiography. Importantly, only 33% had chest pain, 39% had shock, and 11% cardiac arrest. In-hospital mortality was 72%.

Similarly, among 28 COVID-19 patients with chest pain and localized ST elevation in Northern Italy, 11 (39.3%) did not have obstructive coronary artery disease [18]. Among 115 STEMI patients admitted during a 12-week period at Barts Health Centre, 39 were COVID-19-positive, and COVID-19 positivity was associated with higher D-dimer levels (median, 1.86; interquartile range [IQR], 0.98–6.6 vs median, 0.52; IQR 0.40–1, $p = 0.0012$), and higher rates of multivessel thrombosis (17.9% vs 0%, $p = 0.0003$), stent thrombosis (10.3% vs 1.2%, $p = 0.0445$), and modified thrombus grade (4–5) (75% vs 31.4%, $p = 0.0006$) [19]. In-hospital mortality was numerically higher in COVID-19 patients (17.9% vs 6.5%, $p = 0.1$), who also had higher rates of cardiovascular comorbidities such as diabetes mellitus and hypertension [19].

Cardiogenic shock

In the Barts study, rates of cardiogenic shock were similar among STEMI patients with and without COVID-19 (15.4% vs 10.5%, $p = 0.549$) [19]. Nevertheless, STEMI with cardiogenic shock in patients with already established COVID-19 infection can be fatal [20]. Cardiogenic shock can also develop in COVID-19 patients with myocarditis, stress cardiomyopathy, or pulmonary embolism with unfavorable outcome [21].

Mechanical circulatory support

Extracorporeal membrane oxygenation (ECMO) may have a role in COVID-19-related acute respiratory failure with refractory hypoxemia [22]. However, initial reports of patients with COVID-19 requiring ECMO suggested mortality rates higher than 90% [23].

Schmidt et al. studied 83 patients that were treated for COVID-19 in the intensive care units in the Paris-Sorbonne University Hospital Network, including 61 patients who received ECMO. At 60 days post ECMO initiation, the

estimated probability of death was 31% (95% CI 22–42) [24].

Barbaro et al. [25] studied 1035 patients with COVID-19 who received ECMO support at 213 hospitals in 36 countries. Their study showed that the estimated cumulative incidence of in-hospital mortality 90 days after the initiation of ECMO was 37.4% (95% CI 34.4–40.4). The results were similar when only patients who were characterized as having acute respiratory distress syndrome (ARDS) (74% of the study cohort) were included in the analysis.

The ongoing COVID-19 Mechanical Circulatory Support (MCS) registry will provide more information into short- and long-term outcomes of these patients.

Myocarditis

Although most cases of myocardial injury in COVID-19 patients are not associated with myocarditis [26], myocarditis in patients with COVID-19 presenting with ST segment elevation has been described in isolated case reports [27–31].

Triage prior to coming to the cardiac catheterization laboratory

STEMI

The triage of STEMI patients during the pandemic comprises four pillars: (a) initial emergency department evaluation, with focused history and physical exam as well as chest x-ray and ultra-rapid COVID-19 testing (if available) to determine probability of COVID-19 infection; (b) use of point-of-care ultrasound to detect regional wall motion abnormalities prior to PPCI in positive/probable COVID-19 patients having clinical and electrocardiographic presentation consistent with STEMI; (c) immediate PPCI in COVID-19 possible patients having clinical and electrocardiographic presentation consistent with STEMI; and (d) use of echocardiogram, serial electrocardiograms, and cTn and possible computed tomography angiography in patients without typical clinical and electrocardiographic presentation [32•, 33, 34].

Upon decision for revascularization, all COVID-19-positive/probable patients should be transferred to a dedicated COVID-19 laboratory and then to an isolated intensive care unit [32•]. Fibrinolysis is not recommended by ACC/AHA/SCAI due to its suboptimal efficacy compared with PPCI [35–37] and potential need for rescue PCI, especially given that it can increase bleeding risk while having no benefit in a large proportion of COVID-19 patients with STEMI who have non-obstructive coronary arteries [18]. It could however be used as part of a pharmacoinvasive strategy [35] in cases when the patient is at a referral center and a long delay is anticipated [36], followed by repeat electrocardiogram and PCI.

Non-STEMI

The majority of patients with NSTEMI can undergo rapid COVID testing prior to coming to the CCL. High-risk non-STEMI patients (e.g., with hypotension/shock, refractory chest pain, acute heart failure, life-threatening arrhythmia) should be managed with early (<2 h)

angiography, while the remaining patients can either be transferred to the cardiac care unit and undergo catheterization within 1 day (if COVID-19-negative) or receive medical management with possible catheterization in a COVID-19 hospital if symptoms do not recede (COVID-19-positive or under investigation) [1].

Personal protective equipment

Personal protective equipment considerations for catheterization laboratory personnel

Ensuring adequate personal protection of all catheterization laboratory members is critical. Cardiovascular teams in China published in March 2020 an algorithm for performing procedures in the safest possible environment but the applicability of these policies is limited to cardiovascular systems with access to rapid testing protocols for the diagnosis of COVID-19 [38]. There are significant delays in COVID testing in some countries and situations where emergent activation of the catheterization laboratory is required. The Society for Cardiovascular Angiography and Interventions (SCAI), the American College of Cardiology (ACC), and the American College of Emergency Physicians (ACEP) published a consensus document stating that patients requiring emergent activation of the catheterization laboratory should be treated as COVID-19 possible [32•].

PCI for STEMI and out-of-hospital cardiac arrest are situations during which patients might require bi-level or continuous positive pressure ventilation, intubation/extubation, defibrillation with the need for cardiopulmonary resuscitation, and airway suctioning. In these circumstances, aerosol transmission can occur [39]; hence, healthcare workers performing PCI for these patients should wear personal protective equipment that minimizes potential aerosol transmission [32•].

Access to PPE

ACC's Interventional Council and SCAI's consensus document states that all catheterization laboratory personnel should be fit-tested for N95 masks, have eye masks, and receive training for doffing and donning equipment [40]. A multinational survey by Banerjee et al. conducted in April 2020 showed that, although access to personal protective equipment was universal (95%), the type of equipment available was diverse. For example, FIT-tested N95 or equivalent masks were not available to 30% of the respondents of this survey [41]. Universal masking at a large healthcare system in the United States was associated with significantly lower rate of SARS-CoC-2 infection among healthcare workers [42].

PPE

The World Health Organization recommends using medical masks for regular care of COVID-19 patients in the context of droplet and contact precautions and respirators for circumstances and settings where aerosol transmission can occur [43]. The individual components of PPE as used by an interventional cardiologist before a STEMI procedure can be found in SCAI, ACC, and ACEP guidelines [32•].

Table 2. Recommendations for cardiac catheterization utilization during the COVID-19 pandemic

Clinical situation	Preferred approach	Comments
STEMI	Primary PCI	Consider triaging of patients in the ED with POCUS and biomarkers
NSTEMI	Invasive strategy if high-risk features	Usually enough time for COVID-19 testing
Stable angina	High-risk imaging test, angina unresponsive to medical therapy	Outpatient COVID testing as per local practice Adjust volumes based on local disease prevalence and bed capacity
Cardiogenic shock	Mechanical circulatory support	Not universally available Consider transfer to dedicated MCS center
Refractory ARDS	VV ECMO	Not universally available Consider transfer to dedicated MCS center

Abbreviations: STEMI ST-elevation myocardial infarction, PCI primary percutaneous coronary intervention, ED emergency department, POCUS point-of-care ultrasound, NSTEMI non-ST-elevation myocardial infarction, COVID-19 coronavirus disease 2019, MCS mechanical circulatory support, ARDS acute respiratory distress syndrome, VV ECMO venous-venous extracorporeal membrane oxygenation

Other procedures

Apart from reduced STEMI procedures, other procedures have been affected. In the US, a national survey of catheterization laboratory directors and interventional cardiologists conducted in May 2020 showed that likelihood of deferral decreased as the urgency of the procedure increased and the majority deferred left atrial appendage closure and transcatheter mitral valve replacement. In the setting of deferred angiograms, the majority of the respondents of this survey reported that they were more likely to use imaging studies (nuclear perfusion scanning, coronary CT angiography, stress echocardiography) to risk stratify patients [44].

Safe reintroduction of cardiovascular services

The North American Society Leadership provided an ethical framework and guidance for safe reintroduction of cardiovascular procedures [45], based on recommendations from North American Cardiovascular Societies [20, 32, 46–50]. The authors' recommendations are summarized in Table 2.

Conclusion

Balancing optimal care while minimizing the risk of COVID-19 infection can be challenging. Recommendations provided by consensus documents are a helpful guidance. Ongoing observational registries such as NACMI have the potential to inform clinical decision-making and improve patient care.

Code availability

Not applicable

Authors' contributions

Literature search and drafting of the manuscript were performed by Evangelia Vemmou, Ilias Nikolakopoulos, and Santiago Garcia. All authors read, critically revised, and approved the final manuscript. Data availability Not applicable

Compliance with Ethical Standards

Conflict of Interest

Dr. Brilakis: consulting/speaker honoraria from Abbott Vascular, American Heart Association (associate editor Circulation), Amgen, Biotronik, Boston Scientific, Cardiovascular Innovations Foundation (Board of Directors), ControlRad, CSI, Ebix, Elsevier, GE Healthcare, InfraRedx, Medtronic, Siemens, and Teleflex; research support from Regeneron and Siemens. Shareholder: MHI Ventures. Dr. Garcia is a consultant for Edwards Lifesciences and Abbott Vascular. He has received institutional research grants from BSCI, Abbott Vascular, Edwards Lifesciences and Medtronic.

Evangelia Vemmou declares that she has no conflict of interest. Ilias Nikolakopoulos declares that he has no conflict of interest. Payam Dehghani declares that he has no conflict of interest.

Human and Animal Rights and Informed Consent

This article does not contain any studies with human or animal subjects performed by any of the authors.

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