Impact of Cardiovascular Care of COVID-19: Lessons Learned, Current Challenges, and Future Opportunities

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Conflicts of interest are listed at the end of this article.

COVID-19 has disrupted traditional cardiovascular care pathways leading to significant challenges; with these challenges have also come opportunities to iterate our testing strategies to ensure they are patient centered and also that they are most appropriate and best align with infection protection protocols.

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Severe acute respiratory syndrome coronavirus 2, the causative agent of coronavirus disease 2019 (COVID-19), is a single-strand, positive-sense, enveloped RNA virus. It has spike proteins on the outside of membrane, which helps it attach to human cells. Coronavirus has been identified in avian hosts and mammals, which include camels, bats, mice, dogs, and cats. The initial disease outbreak as an unidentified pneumonia started in Wuhan, China, in December 2019. The first fatality from this viral infection was reported in China on January 11, 2020. The first U.S. case was reported in Washington state on January 21, 2020. The World Health Organization declared COVID-19 a pandemic on March 11, 2020. To date, the United States is leading the world with the total confirmed cases at 760,245, and New York City has the highest fatality rate in the country with 14,451 deaths (1–3).

The COVID-19 pandemic has rapidly and profoundly impacted the global economy and nearly all aspects of our personal lives. These sweeping societal effects have not spared health care. Procedure-based care has been largely suspended for all but the most acute circumstances, owing to the need to create capacity in the health care system and the intent to avoid unnecessary risks of infection for our patients and members of our health care teams. Similarly, diagnostic evaluations and follow-up care have been either postponed or rethought in approach.

Relative to other disciplines, the time domain for making care decisions is often more acute within cardiovascular medicine. Moreover, results stemming from any delays in care are often more consequential. Thus, practicing cardiovascular medicine amid the COVID-19 pandemic has presented particular clinical challenges. We present perspectives herein as to how those practicing in the midst of the COVID-19 pandemic are approaching these issues.

Lessons from New York City

The epicenter of this global pandemic migrated from its origin in Hubei province through Italy and on to New York City. The reasons for this are beyond the scope of this document, but the impact on health care provision in New York City was sudden and severe. The first response to COVID was to create acute care capacity by halting all elective procedures and diagnostic testing. Within the Division of Cardiology at Lenox Hill Hospital, this involved the stopping of all elective diagnostic angiography, percutaneous intervention, and noninvasive imaging procedures. While this was effective to create needed bed capacity and to preserve vital personal protection equipment (PPE), it created challenges in providing care for patients with chest pain who had presented either to the emergency department or in the outpatient setting and who have intermediate pretest likelihood of coronary artery disease. With these outpatients, screening tools using clinical history and electrocardiography (ECG) often can allow for safely deferring diagnostic evaluation, but for how long? What if a patient has undiagnosed left main disease, as was seen in over 5% of those in the ISCHEMIA trial (4)? And in the emergency department, the issue isn’t about whether to test but more so about how to test these patients.

Our system has moved toward using coronary CT angiography as the primary means for evaluating chest pain symptoms in such patients. Coronary CT angiography is a well-established clinical modality, with class 1 recommendation for chest pain in the emergency department and in the ambulatory setting. While other testing modalities are also indicated, in the COVID clinical environment we believe that coronary CT angiography offers superior clinical advantages. It is highly accurate, with a very high negative predictive value, and most importantly, it can be performed more rapidly and with far less personal contact with care providers than traditional stress testing. Given these benefits, we are aware that many other institutions have shifted to coronary CT angiography as their first-line testing strategy in evaluating patients with chest pain.

The Western Region of Northwell Health includes a tertiary hospital (449 beds), two community hospitals (Phelps Memorial Hospital and Northern Westchester...
Community Hospital, with 220 and 195 beds, respectively, and an outpatient health annex, which provides both emergency department and outpatient imaging services to the Southern Manhattan district of New York City. Our region has been relying completely on coronary CT angiography to triage inpatient and emergency department acute chest pain, to minimize the number of tests required to get the most and accurate information possible during this crisis situation (Table 1).

Historically, coronary CT angiography has been used for triple-rule-out (TRO) of acute chest pain for the assessment of acute pulmonary embolism, acute coronary syndrome, and acute thoracic aortic dissection.

During this COVID-19 crisis, we have added two more critical diagnoses which include COVID lung infection and acute viral perimyocarditis. Our protocol includes a gated noncontrast scan of the chest for the evaluation of COVID-19 lung disease and calcium score, followed by an ECG-synchronized CT angiography of the heart (5), heart and aorta, or heart, pulmonary arteries, and aorta (TRO). The clinical role of TRO remains modest but has been used in patients who have positive d-dimer or high clinical suspicion of having acute pulmonary embolism. There have been some reports suggesting that a delayed enhancement CT protocol may be helpful in aiding in the diagnosis of COVID myocarditis (6), as has been described previously for other causes of myocarditis. Although cardiac MRI is the preferred noninvasive technique for the detection of acute myocarditis and scarring, the clinical access to cardiac MRI during the acute crisis has been very limited; in addition, the lack of direct visualization of the coronary arteries limits the utility. During this COVID crisis, we found two positive cases of acute perimyocarditis using our protocol in 10 patients known to be positive for COVID. During this crisis, our standard CT protocol has included wide reconstructed field of view for the evaluation of the pulmonary parenchyma for the evaluation COVID lung disease in patients with cardiac symptoms and elucidating the etiology of atypical chest pain and dysrhythmia. The pulmonary findings have been interpreted in a standardized fashion as laid out in recent guidance documents (7). Instead of transesophageal echocardiography, coronary CT angiography has also become the noninvasive imaging of choice for the evaluation of the left atrial appendage thrombus during this crisis.

The challenges with performing coronary CT angiography in critically ill patients with COVID-19 with fever, shortness of breath, and coughing include tachycardia, unable to breath hold, and risk of exposing frontline workers to the risk of contracting the virus. Some modifications of the routine patient preparation and scanning procedures are often required. Prior to COVID-19, many centers have been providing oral heart rate control and beta blockade in triage or holding areas, but with a desire to keep time in the department to a minimum, we and others have expanded our use of outpatient prebeta blockade. Owing to a desire to optimize social distancing, every effort is made to lower the heart rate using a combination of oral (Table 2) 1 day or 2 days prior to the testing and intravenous beta blocker on the CT couch to achieve the best images with the least amount radiation exposure possible in accordance with Society of Cardiovascular Computed Tomography acquisition guidance (5,8). However, high heart rate as a result of fever and systemic infection may render heart rate control with either beta blocker or calcium blocker difficult. Due to the urgency of the scan, we may rely on wide acquisition windows covering the entirety of the cardiac cycle to help increase the likelihood of an interpretable scan. During the COVID-19 crisis, we also received approval from our administration to send coronary CT angiography cases from both the emergency department and inpatient cases to HeartFlow (Redwood City, Calif) for fractional flow reserve (FFR) analysis, if needed, to improve our positive predictive value.

We have also found utility in extending the use of coronary CT angiography in the evaluation of select higher risk patients, such as those presenting with chest pain and biomarkers indicating myocardial injury. The safety and efficacy of this approach was recently demonstrated in the VERDICT CT study (9), which evaluated the diagnostic performance and the potential clinical utility of coronary CT angiography in patients with non–ST-elevation myocardial infarction. The timing of the reporting of these findings is opportune, given the overlap between COVID cardiac disease and acute coronary syndrome. The experience in Northern Italy has been an unexpectedly high rate (approximately threefold) of finding nonobstructive coronary artery disease in patients positive for COVID presenting with acute coronary syndrome (10,11). This highlights the opportunity to integrate coronary CT angiography into care pathways.

### Table 1: Summary Data of the First 2 Months of using Coronary CT Angiography during COVID-19 in New York City

| Category | Count |
|----------|-------|
| Total no. of patients | 135 |
| Inpatient or ED patients | 85 |
| Known COVID test positive* | 10 |
| COVID lung disease per radiology report | 14 |
| Intubated | 0 |
| Prescan beta blocker oral or intravenous | 57 |
| Prospective scan | 21 |
| No SL NTG | 8 |
| Troponin positive | 5 |
| Triple rule out | 15 |
| Positive for acute pulmonary embolism | 3 |
| Average study quality (1 to 4 scale)† | 2.6 |
| Nondiagnostic scan | 1 |
| Renal insufficiency eGFR < 50 | 1 |
| Positive myocarditis | 2 |
| Recommend for HeartFlow | 10 |
| Accepted for HeartFlow analysis | 10 |
| Medium radiation dose (mSv) | 15 |

Note.—ED = emergency department, eGFR = estimated glomerular filtration rate, SL NTG = sublingual nitroglycerin.
* COVID antigen and polymerase chain reaction tests only became available in early May 2020.
† Study quality scale: 1 = diagnostic using images from 1 diastolic phase, 2 = diagnostic using images from adjacent diastolic phases, 3 = diagnostic using images from both systolic and diastolic phases, 4 = nondiagnostic.
Prior to proceeding directly to the catheterization laboratory, this approach mitigates PPE use and potentially avoids exposing invasive catheterization laboratory staff unnecessarily to patients with COVID.

In the setting of known or highly probable COVID-19, there is also a potential role for pre-catheterization evaluation of patients presenting with ST-segment elevation myocardial infarction (STEMI) (11,12). The experience in Northern Italy has raised awareness of fulminant COVID-associated myocarditis presenting as STEMI. In all, it is estimated that in the setting of widespread community COVID infection that as many as 60% of STEMI presentation may be related to COVID rather than an acute plaque rupture amenable to percutaneous coronary intervention. Many have suggested that point of care US examination may help to define those patients more likely to have myocarditis by virtue of lack of regional wall motion abnormality. While some have proposed the use of coronary CT angiography in advance of invasive coronary angiography (ICA) for those with suspected COVID infection who present with STEMI, it is important that logistical issues should not delay appropriate care in the patients with true epicardial obstruction.

Of particular note, in patients with atypical presentations, coronary CT angiography may be particularly helpful where the findings of ST elevation and transthoracic echocardiography are divergent. Further, the European Society of Cardiology provided guidance regarding testing in the COVID environment. CT angiography should be preferred to noninvasive functional testing during COVID-19 pandemic. In case coronary CT angiography is not possible or available, noninvasive testing should be postponed owing to the close contact between patients and personnel (stress echocardiography) (13).

**Considerations for Coronary CT Angiography in Cardiovascular Care Delivery**

While coronary CT angiography requires less patient contact than ICA, it is not without its own risks and constraints. It is therefore essential that the care be provided in a safe and thoughtful fashion. Where at all possible, beta blockade should be initiated prior to arrival in the hospital for outpatients; for stable inpatients, it should be initiated prior to patient transfer to the CT department. Ideally, one CT scanner in the department should be designated for use for patients with probable or confirmed COVID. Proper PPE in line with infection protection guidance and exposure is needed, as is limiting the number of staff exposed to these patients.

Coronary CT angiography protocols should be aligned with current acquisition guidance to ensure optimal image quality and accurate diagnosis. Along with beta-blockade, nitrroglycerin should be administered whenever possible. Widened acquisition windows to acquire multiple phases of the cardiac cycle is generally recommended to help ensure that studies are fully diagnostic, given the added complexity of repeat scanning in such patients. Acquiring such views may afford detection of COVID-related lung disease in these patients.

**Table 2: Beta Blockade for Outpatient**

| Heart Rate (beats/min) | Dose |
|-----------------------|------|
| 60–70                 | Metoprol succinate 50 mg  
1 tablet on the evening prior to examination and 1 tablet in the morning prior to the examination |
| 71–89                 | Metoprol succinate 100 mg  
1 tablet on the evening prior to examination and 1 tablet in the morning prior to the examination |
| 90+                   | Metoprol succinate 100 mg  
1 tablet two nights prior to examination, 1 tablet 10 am and 10 pm on the day prior to examination and 1 tablet in the morning prior to the examination |

**Table 3: Lessons Learned from COVID-19 and Future Opportunities for Coronary CT Angiography**

1. To minimize the risk of staff exposure to COVID-19, coronary CT angiography is the preferred noninvasive imaging test for the evaluation of stable and acute chest pain and for ruling out left atrial appendage thrombus.

2. With careful preprocedure beta blockade and retrospective ECG-gating, most coronary CT angiography scans including triple rule out and delayed iodine enhancement scan for detecting myocardial inflammation can be performed with high diagnostic quality and safety in both suspected and COVID positive patients.

3. Coronary CT angiography should not be used in COVID positive patients who are intubated or not able to breath hold for the duration of the scan. For nonintubated COVID positive patients who need supplemental oxygen, a nonbreather mask should be used to minimize aerosolization.

4. Coronary CT angiography could be used to help triage COVID positive patients with non–ST-segment elevation myocardial infarction with troponin leak.

**Potential Long-term Implications of Coronary CT Angiography in Cardiovascular Care Delivery**

Parallel to the uptake of coronary CT angiography, we have also seen use of telemedicine as a means to provide patient care yet limit the patient’s physical contact with the health care environment.

While imaging clearly cannot be done remotely, the COVID crisis nevertheless highlights the need for implementing the most efficient and direct approaches to diagnostic testing. During COVID, testing modalities that involve patients spending little time as possible in a hospital or outpatient department setting should be considered. Arguably, this objection should be maintained after the pandemic wanes. Coronary CT angiography meets this bar. For patients who arrive rate controlled,
coronary CT angiography will typically only require < 1 hour at the testing site (6). The comprehensiveness of the evaluation is as important as its applicability. In instances when coronary CT angiography identifies anatomic lesions of uncertain clinical relevance, posttest physiologic assessment by \( FFR_{CT} \) can be applied to guide downstream management.

While other testing strategies for evaluating patients with chest pain will undoubtedly resume in clinical practice when the pandemic passes, we believe that a “coronary CT angiography first” pathway should remain as the strongly favored approach. To do so, access to testing in outpatient facilities rather than only in hospital will be essential. In rationed health care systems, such as Canada and the UK, this is particularly challenging, as essentially all CT scanners are housed within hospital departments. In the United States, many states have certificate-of-need laws that limit acquisition of CT scanners, and reimbursement mechanisms greatly favor inpatient imaging centers. New CT platforms in lower cost care environments will need to be installed to meet clinical demand. Such obstacles will need to be addressed as we emerge from the acute crisis with a renewed focus on safe and effective care delivery.

**Concluding Thoughts**

The ongoing COVID pandemic has had significant impact on cardiovascular care delivery, with a marked reduction in elective diagnostic testing and face-to-face patient care. But it has also resulted an acute and necessary re-examination of how we deliver cardiac care. Too often our approaches to cardiac care delivery have been so deeply enmeshed into our clinical practice that we have not appropriately considered alternative approaches, those new ways to provide care that have been afforded by technical advances.

In many ways, the COVID crisis has been like a crucible: anything that is extraneous or unnecessary, anything that has gone on “just because” gets melted away, leaving left only that which is inherently of value and worth keeping (14). Just as up-take of telemedicine is showing us that indeed not every patient needs to present in person to have meaningful interactions that advance or safeguard care, our experience with an expanded clinical role of coronary CT angiography in ambulatory and acute care settings has been equally beneficial. Neither approach, however, will be sustainable in the future unless the regulatory and reimbursement systems that undergird care delivery prove receptive and adaptable to such innovative approaches.

To what extent these COVID-related shifts in approach to cardiac care will be maintained as we begin to transition into the “recovery” phase of the pandemic is as yet uncertain. But it would seem that those pathways that provide the most efficient answers to clinical questions in a manner that is the most patient-centric—those care pathways that create the greatest clinical value—will endure in the long run. And our patients deserve nothing less.

**Author contributions:** Guarantors of integrity of entire study, M.P., J.L., G.R.; study concept/strategy design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; agrees to ensure any questions related to the work are appropriately resolved, all authors; literature research, M.P., J.L., M.K., G.R.; clinical studies, M.P., M.K.; experimental studies, M.K.; statistical analysis, M.P.; and manuscript editing, M.P., J.L., M.K., F.W., G.R.

**Disclosures of Conflicts of Interest:** M.P. disclosed no relevant relationships. J.L. Activities related to the present article: disclosed no relevant relationships. Activities not related to the present article: author paid consultant for Circle CVI and HeartFlow; author received grants from GE and Edwards Lifesciences; author paid for lectures by Philips; author has stock in Circle CVI and HeartFlow. Other relationships: Institutional core lab contracts Edwards, Medtronic, Abbott, Neovasc. M.K. disclosed no relevant relationships. F.W. disclosed no relevant relationships. G.R. disclosed no relevant relationships.

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