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COVID-19 pandemic: Challenges and solutions from the cardiology pharmacist's perspective

Kerry K. Pickworth Pharm.D., FCCP[1] | Danielle Blais Pharm.D.[1] | Aaron Bagnola Pharm.D.[2] | Robert Barcelona Pharm.D.[3] | J Michael Boyd Pharm.D.[1] | Heidi Brink Pharm.D.[4] | Maya Chilbert Pharm.D.[5] | Daniel Galipeau Pharm.D.[1] | Brooke Gengler Pharm.D.[6] | Anthony T. Gerlach Pharm.D., FCCP[1] | Charles Hayes Pharm.D.[7] | Joshua Jacobs Pharm.D.[8] | Hasan Kazmi Pharm.D.[9] | Rachel Lavelle Pharm.D.[1] | John Lindsley Pharm.D.[10] | Tracy E. Macaulay Pharm.D.[11] | Michael A Militello Pharm.D.[12] | Libby Orzel Pharm.D.[1] | Sajni Patel Pharm.D.[13] | Pamela Simone Pharm.D.[13] | Kristen Tasca Pharm.D.[14] | Sara Varnado Pharm.D.[15] | Sara Zoubek Pharm.D.[16]

[1]The Ohio State University Wexner Medical Center, Columbus, OH

[2]Inova Fairfax Medical Campus, Falls Creek, VA

[3]University Hospitals Cleveland Medical Center, Cleveland, OH

[4]University of Nebraska Medical Center, Omaha, NE

[5]University at Buffalo School of Pharmacy and Pharmaceutical Sciences, Buffalo, NY

[6]SSM Health St Louis University Hospital, St Louis, MO

[7]Saint Luke's Hospital of Kansas City, Kansas City, MO

[8]University of Utah Health, Salt Lake City, UT

[9]Carilion Roanoke Memorial Hospital, Roanoke, VA

[10]Johns Hopkins Hospital, Baltimore, MD

[11]University of Kentucky College of Pharmacy, Lexington, KY

[12]Cleveland Clinic, Cleveland, OH

[13]University of Chicago Medical Center, Chicago, IL

[14]Cedars-Sinai Medical Center, Los Angeles, CA

[15]Intermountain Healthcare Utah, Murray, UT

[16]The University of Kansas Health System, Kansas City, KS

Abstract

The recent coronavirus disease 2019 (COVID-19) pandemic caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) challenges pharmacists worldwide. Alongside other specialized pharmacists, we re-evaluated daily processes and therapies used to treat COVID-19 patients within our institutions from a cardiovascular perspective and share what we have learned.

To develop a collaborative approach for cardiology issues and concerns in the care of confirmed or suspected COVID-19 patients by drawing on the experiences of cardiology pharmacists across the country.

On March 26, 2020, a conference call was convened composed of 24 cardiology residency-trained pharmacists (23 actively practicing in cardiology and 1 in critical care) from 16 institutions across the United States to discuss cardiology issues each have encountered with COVID-19 patients. Discussion centered around providing optimal pharmaceutical care while limiting staff exposure.

The collaborative of pharmacists found for the ST-elevation myocardial infarction patient, many institutions were diverting COVID-19 rule-out patients to their Emergency Department (ED). Thrombolytics are an alternative to percutaneous coronary intervention (PCI) allowing for timely treatment of patients and decreased staff exposure. An emergency response grab and go kit includes initial drugs and airway equipment so the patient can be treated and the cart can be left outside the room. Cardiology pharmacists have developed policies and procedures to address monitoring of QT prolonging medications, the use of inhaled prostacyclins, and national drug shortages. Technology has allowed us to practice social distancing, while staying in

Correspondence
Kerry K. Pickworth, The Ohio State University Wexner Medical Center, Columbus, OH, USA.
Email: kerry.pickworth@osumc.edu

close contact with our teams, patients, and colleagues and continuing to teach. Residents are engaged in unique decision-making processes with their preceptors and assist as pharmacist extenders.

Cardiology pharmacists are in a unique position to work with other pharmacists and health care professionals to implement safe and effective practice changes during the COVID-19 pandemic. Ongoing monitoring and adjustments are necessary in rapidly changing times.

KEYWORDS
arrhythmia, cardiology, COVID-19, myocardial infarction, pharmacists

1 | INTRODUCTION

While all health care providers have been challenged during the recent coronavirus disease 2019 (COVID-19) pandemic caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), pharmacists worldwide have faced unique situations requiring them to adapt to continue to provide excellent patient care. In response to the current circumstances, 23 cardiology pharmacists and 1 critical care pharmacist from 16 institutions across the United States joined on a conference call on March 26, 2020 to discuss and develop a collaborative approach for addressing cardiology issues and concerns in the care of suspected or confirmed COVID-19 patients. The purpose of this virtual call was to review pharmaceutical care for cardiovascular diseases, including common problems and solutions. These were further developed through electronic communications (eg, e-mail and telephone conversations) by this group of specialized pharmacists.

2 | CARDIOVASCULAR AND CARDIOTHORACIC CRITICAL CARE

In the face of the COVID-19 pandemic, some institutions have reconsidered cardiac catheterization laboratory (CCL) operations focusing on what is best for the patient as well as the health care professionals caring for the patient. Patients with acute coronary syndromes, cardiogenic shock requiring temporary mechanical circulatory support (TMCS), and pulmonary embolism requiring catheter-directed thrombolytics are often cared for in a cardiology or medical intensive care unit (ICU). Pharmacists, physicians, nurses, and staff working in the CCL and ICU are trained to care for these specific patient populations. Concerns over the high contagion factor with COVID-19 led to changes in CCL operations to preserve resources and decrease patient exposure to COVID-19. With the potential for increased numbers of critically ill COVID-19 cases, elective cases may be delayed. For cases that cannot be delayed, limiting staff exposure can be challenging for multiple reasons. First, staff is in close proximity to each other as well as the patients in the CCL. The patients can be hemodynamically unstable, requiring more time at the bedside titrating vasopressors and inotropes and managing support devices (Swan-Ganz Catheter, Intra-Aortic Balloon Pump, TMCS including Extracorporeal Life Support [ECLS]). Negative airflow rooms and personal protective equipment (PPE) may be limited, so other strategies should be available.[1]

2.1 | ST-elevation myocardial infarction

For the ST-elevation myocardial infarction (STEMI) patient, the amount of myocardium affected is decreased by getting patients to the CCL quickly. Primary percutaneous coronary intervention (PCI) is the preferred strategy if the door-to-balloon or door-to-door-to-balloon time is less than 90 or 120 minutes, respectively. Primary PCI is associated with a higher rate of normal coronary blood flow and reduced bleeding complications compared with systemic thrombolytics.[2] Systemic thrombolytics are reserved for those patients who are unable to meet the previously stated door-to-balloon times.[2-4] At the institutions represented by the collaborative, many have field-activated STEMI programs that allow emergency medical services to bring patients directly to the CCL and bypass the emergency department (ED).

Problem: Since the outbreak, some field-activated STEMI alerts have been suspended and patients are screened by the ED staff to determine their COVID-19 status as well as determine any additional supportive care prior to proceeding to the CCL. As the turnaround time for COVID-19 testing and ED operations evolve, it will be important to track goal door-to-balloon times.[5]

Solution: Primary PCI should remain the preferred treatment option for patients presenting with STEMI, but thrombolytics may be considered for hemodynamically stable STEMI patients with signs and symptoms suggestive of COVID-19 until testing has resulted.[1] In determining the most appropriate thrombolytic therapy for STEMI, our institutions have considered several factors. First, ease of administration and minimization of direct nursing time are a priority in suspected or confirmed COVID-19 patients. Tenecteplase, which is given as a weight-based bolus over 5 seconds, is the preferred agent from this perspective. Reteplase is administered over 2 minutes as a double bolus 30 minutes apart, while alteplase regimens are more complex and can take 1.5 to 3 hours to administer.[2,3] The more fibrin-

TABLE 1 Summary of the concomitant medications administered with thrombolytics for ST-elevation myocardial infarction (STEMI)

Medication		Dosing
Thrombolytics[2,3]		
Give within 30 min of hospital arrival		
Tenecteplase		*Single intravenous bolus given over 5 s*[a]:
		<60 kg: 30 mg
		≥60 to <70 kg: 35 mg
		≥70 to <80 kg: 40 mg
		≥80 to <90 kg: 45 mg
		≥90 kg: 50 mg
Reteplase		*Double intravenous bolus given over 2 min*:
		10 units followed by a second dose 30 min later of 10 units
Alteplase		*Accelerated regimen (weight-based)*:
		>67 kg: total dose: 100 mg over 1.5 h; 15 mg IV bolus over 1-2 min followed by infusions of 50 mg over 30 min, then 35 mg over 1 h
		≤67 kg: Infuse 15 mg IV bolus over 1-2 min followed by infusions of 0.75 mg/kg (not to exceed 50 mg) over 30 min then 0.5 mg/kg (not to exceed 35 mg) over 1 h. Maximum total dose: 100 mg
Aspirin[2,3]	*Loading*	324 mg
	Maintenance	81 mg by mouth daily
Clopidogrel[7-10]	*Loading*	*At the time of thrombolytics*
		Age ≤75 y: 300 mg
		Age >75 y: 75 mg
		At the time of PCI
		Thrombolytic ≤24 h ago: total of 300 mg (regardless of age)
		Thrombolytic >24 h ago: total of 600 mg (regardless of age)
	Maintenance	75 mg by mouth daily
Unfractionated Heparin [2-3,10]	*Loading*	60 units/kg (maximum of 4000 units)
	Maintenance	Initiate at 12 units/kg/h (maximum of 1000 units/hour and titrate to institutional protocol)
Enoxaparin[2-3,10]	*Loading*	Age <75 y: Single IV bolus of 30 mg
		Age ≥75 y: No IV bolus is administered
	Maintenance	Age <75 y: 1 mg/kg (maximum: 100 mg for the first 2 doses only) subcutaneously every 12 h or if CrCl less than 30 mL/min 1 mg/kg subcutaneously every 24 h. First dose to be given with the IV bolus
		Age ≥75 y: 0.75 mg/kg (maximum: 75 mg for the first 2 doses only) subcutaneously every 12 h or if CrCl less than 30 mL/min 0.75 mg/kg subcutaneously every 24 h

Abbreviations: CrCl, creatinine clearance; IV, intravenous; PCI, percutaneous coronary intervention.
[a]Consider reducing weight-based dose by 50% for patients greater than or equal to 75 years of age.[29]

specific thrombolytics, including tenecteplase, may have a lower risk of major bleeding than other agents.[6] Given the noted benefits of tenecteplase, many of our institutions have emergently added this agent to formulary and/or increased their onsite stock. Given that thrombolytics are infrequently administered for STEMIs, and in order to meet the goal door-to-needle time of 30 minutes, we recommend use of a patient eligibility checklist in order to efficiently determine whether a presenting STEMI patient meets criteria for use. Guidance for the absolute contraindications, warnings, and precautions differ from the more common use of thrombolytics such as acute ischemic stroke and are located in the American College of Cardiology (ACC) and European Society of Cardiology guidelines, as well as the package insert for each medication.[2,3] One additional consideration is to have an adequate supply of thrombolytics in the ED to facilitate this new workflow, shorten door-to-needle times, and accommodate this added indication for thrombolytics. Because many institutions have alteplase on formulary, having a dosing guide available with instructions including how to prepare and administer a different thrombolytic will facilitate safe and efficient use. Concomitant medications with thrombolytics will need to be addressed including aspirin, unfractionated heparin (UFH), or enoxaparin as well as $P2Y_{12}$ inhibitors (Table 1). Studies have demonstrated the risk of intracranial hemorrhage with thrombolytics is less than 1%.[7-10]

One anticoagulant consideration, for a patient with COVID-19, is the nursing time spent in the room monitoring and adjusting UFH vs the ease of giving subcutaneous enoxaparin. For both agents, anticoagulation is started 15 minutes before to 30 minutes after the initiation of thrombolytic therapy. Anticoagulation is continued until revascularization or for 48 hours or 8 days for UFH or enoxaparin, respectively.[2,10] In the absence of renal dysfunction, enoxaparin may be a more favorable choice because of the decreased laboratory monitoring and times for the nurse to draw the activated partial thromboplastin time and make dose adjustments. Clopidogrel is the only $P2Y_{12}$ inhibitor utilized as pretreatment or given concomitantly with thrombolytics.[7,8,10] In the TREAT trial, STEMI patients less than 75 years of age who received thrombolytics were primarily pretreated with clopidogrel and could be transitioned to ticagrelor with a recommended 180 mg loading dose within 24 hours of randomization.[9] The rates of intracranial hemorrhage in this study were similar between groups. In the TRITON-TIMI-38 trial, patients who received thrombolytics were excluded from the trial, thus limited data on

prasugrel with thrombolytics is available, but caution is recommended due to a potential higher risk of bleeding.[11] Of course, none of the aforementioned studies included patients with COVID-19, so the current pandemic requires extrapolation of these treatment recommendations to a novel population.

Last, development of a computer order entry set is prudent to make sure the medications, nursing instructions, and laboratory monitoring are easy to enter and can be followed by the nurse. Because thrombolytics are not frequently used in this setting, education for impacted medical, nursing, and pharmacy staff is necessary. Recorded or online educational platforms can assist in rapidly disseminating the information. In addition, a podcast "Return of the Lytics" is posted on CardioScripts, which may be found on Spotify, Apple, or Stitcher.

2.2 | Non-ST-elevation myocardial infarction

Problem: Patients with unstable angina and non-ST-elevation myocardial infarction (NSTEMI) may experience a longer duration between the time of presentation and cardiac catheterization to allow for determination of COVID-19 status, especially due to the increased probability of a Type 2 NSTEMI where CCL intervention provides minimal benefit.[1]

Solution: Anticoagulants, such as UFH and enoxaparin, are utilized in the setting of an early invasive or ischemia-driven treatment strategy.[2] With equivalent efficacy, enoxaparin may be a more favorable choice because of decreased laboratory monitoring compared to the times for the nurse to draw the activated partial thromboplastin time (PTT) and make dose adjustments with heparin.[12] Because waiting times for the CCL may be prolonged until COVID-19 testing results, upfront use of dual antiplatelet therapy with aspirin plus ticagrelor or clopidogrel, even in medically managed patients, will be important. Hopefully this strategy will reserve use of glycoprotein (GP) IIb/IIIa inhibitors for patients with rising troponins or ongoing chest pain. The use of some anticoagulants and antiplatelets could be complicated by renal dysfunction in patients with COVID-19 requiring pharmacists to carefully dose and monitor enoxaparin and GP IIb/IIIa inhibitors. Some of these aforementioned strategies require more vigilant monitoring for access site complications and bleeding. Depending on the familiarity with GP IIb/IIIa inhibitors, if the utilization of these agents increases, having resources available and education of staff who may not be as familiar with these agents will be important.

2.3 | Temporary mechanical circulatory support

For patients undergoing PCI or with cardiogenic shock, temporary mechanical circulatory support (TMCS) can be used to improve their hemodynamics.

Problem: The challenge during the COVID-19 pandemic with this approach is the limited number of TMCS devices, as well as staff knowledgeable and credentialed to place and care for these patients. In addition, patients with TMCS are often anticoagulated and may require transfusion of blood products. As a result of the pandemic, blood donations and availability have been strained.

Solution: Alternative approaches like inotrope and vasopressor support will need to be balanced with impending medication shortages as they start to occur. Pharmacists working collaboratively with their interventional cardiology, heart failure/transplant, and cardiac surgery physicians is imperative. Cardiology pharmacists play an important role in dosing and monitoring anticoagulation for patients with TMCS. The prothrombotic state of suspected or confirmed COVID-19 patients may make anticoagulation even more challenging.[13] In addition, some patients with COVID-19 may have an elevated PTT at baseline making monitoring of UFH more challenging for TMCS as well as other indications.[14] Currently, monitoring of UFH with PTT or anti-Xa levels is an area requiring further investigation.[15]

3 | EMERGENCY RESPONSE

At many institutions, pharmacists are part of the emergency response team, responding to cardiac arrests and STEMI alerts.

Problem: As directed by the code leader, pharmacists commonly compound emergency medications from the drugs housed within a locked code cart. The pharmacist's knowledge of the contents of the code cart allows them to assist the team by efficiently preparing and dosing medications. During an arrest, the crash cart and defibrillator are commonly placed in close proximity to the patient's bed to enhance the closed loop dialog which occurs among the team members.

Solution: During the COVID-19 outbreak, code blue committees have reevaluated how the members of the code blue team interface with the patient in order to decrease potential exposure and limit the number of staff in the room. Most institutions have moved the pharmacist and code cart outside of the patient's room limiting the zone of contagion. This small maneuver decreases the need for pharmacy personnel to be fitted for PPE and increases the availability for the front-line staff. Another unique idea a few institutions have employed is preparing a grab and go kit which contains the first few items commonly needed during an arrest, which is situated on top of the code cart. The contents of these kits may vary between centers, but most often contain epinephrine syringes along with supplies for intubation, defibrillation pads, normal saline, flushes, and an arterial blood gas kit. First responders can easily access the kit and take it to the patient bedside for early drug administration. The kit prevents the code cart from being brought into the patient's room limiting the amount of time the door remains open and the need for the code cart to be disinfected if it is not used. While the pharmacist still manages and prepares the medication from the cart, some centers have designated a team member to work with the pharmacist to hand items to staff inside the patient room.

Other equipment, in addition to the code cart, which may need to be addressed in areas like the CCL, are automated dispensing cabinets which improve access to medications. The dispensing cabinet may need to be moved outside of the CCL; alternatively, centers may

designate CCL staff not in contact with the patient to get the medications out of the dispensing cabinet. In some places like the CCL, the defibrillators are regularly placed on top of the code carts, placing the pharmacist managing the cart in close proximity to the patient. By moving the defibrillators off of the code carts, the cart can then be moved outside of the CCL.

4 | MEDICATION MANAGEMENT

4.1 | QT prolonging drugs

Problem: Agents such as chloroquine and hydroxychloroquine have been studied for use in COVID-19 patients. These agents inhibit rapid potassium ion channels, causing a mild QT prolongation and the potential for torsades de pointes (TdP), a lethal ventricular arrhythmia.[16] Although these antimalarial drugs have been used for decades, the incidence of ventricular arrhythmias is unknown. COVID-19 patients are commonly prescribed concomitant antimicrobial agents, such as azithromycin and fluoroquinolones, to cover bacterial pneumonias. These agents augment the risk of lethal arrhythmias in some individuals. Risk factors for TdP include female sex, structural heart disease, electrolyte disturbances, hepatic/renal failure, and congenital long QT syndromes. Patients with COVID-19 are older on average, and there is a higher prevalence of structural heart disease.[13] Using a scoring system as described by Tisdale and colleagues may assist in determining who is at the highest risk.[17] When these agents are given to those at risk, combined with other QT prolonging medications such as azithromycin, the risk of lethal arrhythmias escalates.

Solution: Prior to the recent revoking of emergency use of hydroxychloroquine for COVID-19 patients, cardiology pharmacists and electrophysiologists developed ECG monitoring parameters for these medications to protect the patient from adverse events. Most specialists agreed patients should have a baseline 12-lead ECG and another ECG 2 to 3 hours after the subsequent dose, paying particular attention to the QTc interval.[18,19] Timing of the 12-lead ECG can be altered to limit the number of times health care personnel enter the room of a COVID-19 positive patient. If the baseline QTc is prolonged (>500 msec) or the patient is deemed high risk, pharmacists should suggest alternative therapies.[19] Pharmacists can review the medication profile and recommend discontinuing unnecessary QT prolonging medications to decrease risk. Nurse-driven electrolyte replacement protocols allow for optimization of potassium to greater than 4 mEq/L and magnesium greater than 2 mg/dL to further minimize risk.[19]

4.2 | Inhaled prostacyclin products

Some cardiology pharmacists are involved in providing care to patients with pulmonary hypertension (PH).

Problem: Medications to treat PH vary from oral calcium channel blockers, endothelin receptor antagonists, and phosphodiesterase type 5 inhibitor agents to inhaled or intravenous (IV) prostacyclin analogues. Inhaled treprostinil used in COVID-19 suspected or confirmed PH patients has the potential for spreading the virus because it is administered by nebulization.

Solution: Aerosolization of COVID-19 has been proven to remain viable in controlled environments for at least 3 hours, but when real-world implementation with proper protection and sanitation occurs, the transmission of COVID-19 via aerosolization was minimized.[20,21] Additionally, a previous study of SARS-CoV demonstrated viral transmission via a nebulizer.[22] Presently, the Centers for Disease Control and Prevention recommends to "minimize" the use of procedures or techniques that might produce infectious aerosols when feasible but categorizes nebulizer administration as an uncertain generator of aerosolization.[23] Out of an abundance of caution to minimize the risk of aerosolization, awareness of necessity and appropriate use of prostacyclin conversion strategies are necessary. Therefore, patients may have to be switched to an IV product until they are virus free. Pharmacists with the unique knowledge of the pharmacokinetic properties of these products have worked in conjunction with their physician colleagues to provide acceptable conversion strategies from inhaled to IV products in these situations.[24]

Some critically ill COVID-19 patients develop an acute respiratory distress syndrome, and multiple maneuvers are being employed to improve oxygenation. Providers may consider inhaled prostacyclins to enhance the dilation of the pulmonary artery, increasing blood flow to the lungs and potentially improving oxygenation; however, there are no studies to support this approach. Unless intubated, the use of inhaled prostacyclins increases the risk of viral transmission to the health care worker due to aerosolization using noninvasive positive pressure (heated high flow nasal cannula, Bilevel Positive Airway Pressure [BiPAP], etc). Unfortunately, the inhaled prostacyclin, treprostinil, is not ventilator compatible and is not an option for intubated patients. However, nitric oxide may be an option and can be given via nasal cannula without positive pressure.

4.3 | Angiotensin-converting-enzyme inhibitors/angiotensin II receptor blockers

Problem: As more information is learned about COVID-19, professionals continue to look for new opportunities to alleviate the severity of the disease. In animal models, the SARS-CoV-1 virus, which was at the center of the SARS outbreak in 2003, is known to bind to a receptor protein on the angiotensin-converting enzyme 2 (ACE2).[25,26] Recent information released shows the same is true for the SARS-CoV-2 virus causing the current pandemic. One concern is that ACEI/ARB may increase the expression of ACE2, which may lead to increased binding of the SARS-CoV-2 spike glycoprotein, producing a higher disease burden. In recent data, comorbidities such as diabetes, hypertension, heart failure, and ischemic heart disease have been associated with the highest death rates.[13] However, it is not known what underlying medications these patients were receiving. Therefore, it is unclear if these medications play a role or not.

Solution: Cardiology pharmacists are versed in the pharmacology of angiotensin-converting-enzyme inhibitors/angiotensin II receptor blockers (ACEI/ARBS) as well as the literature supporting their use in various cardiology disease states. Inhibition of the renin-angiotensin-aldosterone system has affected most cardiology disease states in a positive fashion, and these agents have been protective of end organ damage. As supported by a joint statement from the Heart Failure Society of America/ACC and American Heart Association, ACEI should not be stopped in patients with COVID-19. As cardiology pharmacists review home medications, they are in a prime position to prevent stopping of these life-altering medications, unless necessary due to hemodynamic or renal complications.[26] Pharmacists provide education to medical staff and patients around this issue so ACEI/ARBs, which are the cornerstone of cardiac care, are not inadvertently discontinued, resulting in an influx of decompensated patients entering the health care system during the pandemic.

4.4 | Drug interactions

Problem: As new therapies are investigated and utilized to prevent or treat COVID-19, looking for cytochrome P450 (CYP) and P-glycoprotein drug interactions will be important. For example, lopinavir/ritonavir was initially used for treatment of COVID-19 and is an inhibitor of the CYP enzymes, interfering with some common cardiac medications including, but not limited to ticagrelor, diltiazem, warfarin, apixaban, and most statins. For patients who are placed on ECLS, consideration must be given to the binding of the medications to the ECLS circuit and tubing including those therapies specifically being used to treat COVID-19.

Solution: Pharmacists should be involved in the development of evidence-based guidelines to help identify potential drug-drug interactions with various therapies being utilized to prevent or treat COVID-19.

4.5 | Cardiovascular medication shortages

Clinical pharmacists, including those in cardiology, are on the forefront to determine how to manage multiple drug shortages in their area.

Problem: Some current shortages include amiodarone, vasopressin, IV diuretics, and thrombolytics, but this list may vary depending on the institution's wholesale supplier.

Solution: With new shortages occurring daily, cardiology pharmacists use their expertise to identify alternative products or approaches to achieve a similar outcome. For example, some institutions have a shortage of small vials of IV loop diuretics, both furosemide and bumetanide. Many have advocated switching to oral products as soon as possible or utilizing combination regimens for synergistic nephron blockade earlier in the course of treatment. If the small IV vials are in limited supply, switching to a continuous infusion might achieve the necessary diuretic response while conserving the institution's supply.

4.6 | Transitions of care

Pharmacists serve an important role in educating patients with cardiovascular disease in areas such as compliance with antiplatelet therapy, antiarrhythmics, and anticoagulation.

Problem: This can be more challenging in the setting of COVID-19, where family members or caregivers may have limited access to the hospital at the time of discharge.

Solution: Video conferencing or phone calls to the patients or family members can allow for patient education while reducing the need to physically see each patient. In addition, patients who are COVID-19 positive should be self-quarantined for at least 14 days, making it more difficult for them to get their medications in a timely manner. One way to maintain social distancing and prevent COVID-19 spread is to provide medications prior to discharge, thus eliminating a trip into the public, which may decrease risk of readmission.[27]

5 | STAFFING CHANGES

Cardiology pharmacists and their colleagues across the country have learned to adapt to meet the social distancing requirements without sacrificing the care of our patients.

Problem: Institutions placed social distancing requirements and maximum number of employees in offices and workspaces. At the same time, the number of critically ill patients in some cases were increasing exponentially.

Solution: Some medical teams have limited the number of health care professionals physically rounding face to face and seeing patients. Pharmacists have developed unique ways of communicating with the health care team to ensure that the safety and efficiency of the care we provide for our patients is not compromised. Cardiology and critical care pharmacists have worked together to meet the increasing demands for critically ill patients. Video conferencing or reviewing the patient census via telephone before and after rounds was one strategy to maintain a cohesive team. Pharmacists were cross-trained in various positions and operations in order to provide back up to their regular staff in case of illness. As for patient care, most of the groups have redesigned what direct patient care entails. Variability exists across the country on how quickly the COVID-19 surge has impacted patient care. For those institutions with an attenuated census, the condensed version of rounding has helped them to find time to read new literature and refine processes and procedures as they gear up for the surge of COVID-19 patients. With the requirements for physical distancing, video conferencing has been utilized to help staff stay in contact with pharmacy leadership and colleagues to make quick staffing decisions, keep up-to-date with rapidly evolving information, and help to decrease stress of the unknown.

As we better understand the risk of transmission of COVID-19 and necessary steps to decrease the spread of the virus, health care professionals, including pharmacists, have started to safely integrate themselves back into rounds.

TABLE 2 Summary of cardiology pharmacists' collaborative practices before and during the COVID-19 pandemic

	Before COVID-19	During COVID-19
STEMI	Patients admitted directly to CCL for intervention	Patients stop in the ED first Some will receive thrombolytic therapy instead of PCI
Adjunctive therapy for STEMI	Aspirin	Aspirin
	Ticagrelor, prasugrel, and clopidogrel	Clopidogrel (preferred with thrombolyitcs)
	Heparin or enoxaparin	Consider enoxaparin
Cardiogenic Shock	Inotrope/vasopressors TMCS	Balance availability of resources, staff, and drug shortages
Emergency response (Code blue, strokes, STEMI)	Pharmacists respond and draw up medications at bedside	Pharmacists attend but remain outside patient room providing medications
		Grab and go kits added to cart to provide easy access to initial ACLS drugs
QT prolongation drugs	Hospital policies center around anti-arrhythmic medications and monitoring	Developed new policies to cover chloroquine and hydroxychloroquine
		Education to staff who may not be as familiar with interpreting an EKG or medications that prolong QT
Pulmonary hypertension	May use inhaled treprostinil or epoprostenil	Converting to IV prostacyclins to decrease virus spread, unless intubated
		May use nitric oxide if available
ACEI/ARB	Proven effective to treat hypertension, heart failure, and coronary artery disease	Educating medical staff and patients
		Prevent discontinuation unless necessary due to hypotension or renal complication
Drug shortages	Amiodarone	Transition from IV to oral; Lidocaine
	Vasopressin	Consider phenylephrine or norepinephrine
	Thrombolytics	Consider order of preference
	Diuretics	Consider transition of oral, combination diuretics
Patient Education/ Medication Reconciliation/Transition Of Care	Provide face-to-face education on antiplatelet therapies, anticoagulation, transplant medications	Use video conferencing and phone calls to provide the same information before COVID-19
Staffing	Provide direct patient care in-house by interacting with medical staff	Remotely provide direct patient care via video/phone conferencing
	Provide education to medical staff and pharmacy residents	Cross training in various areas
	Develop processes /procedures for new treatment as they arise	Developing new processes/procedures for COVID-19 + patients
		Video conference for staff Education on these changes
Resident training	Provide patient care in-house by interacting daily with medical staff to optimize drug therapy	Remotely provide patient care
		Assist in developing new processes or treatments for various patient populations at risk
		Encourage layered learning to help PGY-2 residents refine precepting skills

Abbreviations: ACLS, advanced cardiac life support; CCL, cardiac catheterization lab; ED, emergency department; EKG, electrocardiogram; IV, intravenous; PCI, percutaneous coronary intervention; PGY-2, postgraduate year 2; STEMI, ST-elevation myocardial infarction; TMCS, temporary mechanical circulatory support.

6 | RESIDENCY TRAINING

Problem: Most cardiology pharmacists have a commitment and a desire to teach and train the next generation of pharmacy clinicians. Pharmacy residents rotate through various disciplines in order to gain experience and an understanding of the therapeutics used in different patient populations. There are many questions about how best to utilize residents in this unprecedented time.

Solution: As described above, residents have been able to maintain patient care duties by modeling their preceptors. The landscape is different, but due to the pandemic's timing in the residency year, residents are able to function more independently, as their preceptor may be deployed to other areas. Precepting activities should be shifted to remote learning platforms, in accordance with hospital policies, to ensure residents are meeting the established goals and objectives during their training. Residents on a rotation that involves layered learning should work with their preceptor to develop a syllabus and learning objectives for their trainee. This may include but may not be limited to guidance for patient profile review, medication management, appropriate and succinct patient presentations, formal drug information question response, journal clubs, joint topic discussions, and patient case presentations. During this time, the resident should work toward using the aforementioned activities in a web-based platform to effectively employ the preceptor roles by instructing, modeling, coaching, and facilitating skills in accordance to American Society of Health-System Pharmacists (ASHP) required competencies. Shifting to remote learning can help facilitate timely graduation for residents and students.

Although chaotic at times, consideration should be made to include pharmacy residents in departmental emergency preparedness, as they could play an integral role in direct patient care -related activities. Given the rapidly evolving body of evidence and the low overall quality of evidence surrounding COVID-19, including residents in emergency policy/protocol development would be a valuable learning opportunity. Furthermore, including residents in drug shortage management can teach them valuable skills on how to effectively identify a shortage, find alternative therapies based on literature, communicate shortage information to many disciplines, and assist with an implementation plan to mitigate the shortage. In many ways, these activities could help shape them as a clinician and provide them with the necessary steps to progress into a successful cardiology pharmacist.

Residency program directors should keep in close contact with preceptors and residents to determine what work is needed above and beyond rotation expectations and normal patient care responsibilities. Cancellation of national/regional conferences, research presentations, and traditional job searches can increase the stress and anxiety of the resident. It is the program director's responsibility to be aware of the residents resilience and mental health while maintaining appropriate duty hours.

7 | CONCLUSION

The COVID-19 pandemic has brought many changes in a short amount of time to the health care system. Cardiology pharmacists are in a unique position to work with other pharmacists and health care professionals to implement safe and effective practice changes. (Table 2) Ongoing monitoring and changes will be needed in these rapidly changing times by using updated national resources such as the ACC COVID-19 Hub.[28]

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ORCID

Kerry K. Pickworth https://orcid.org/0000-0003-4217-7261
Aaron Bagnola https://orcid.org/0000-0001-6538-2781
J Michael Boyd https://orcid.org/0000-0001-9427-0156
Anthony T. Gerlach https://orcid.org/0000-0001-5631-4218
Joshua Jacobs https://orcid.org/0000-0002-9621-9060
Sajni Patel https://orcid.org/0000-0003-2277-9564
Pamela Simone https://orcid.org/0000-0003-1070-0740

REFERENCES

1. Welt FGP, Shah PB, Aronow HD, et al. Catheterization Laboratory Considerations During the Coronavirus (COVID-19) Pandemic: From American College of Cardiology's (ACC) Interventional Council and the Society of Cardiovascular Angiography and Intervention (SCAI). *J Am Coll Cardiol*. 2020;75:2372–2375. https://doi.org/10.1016/j.jacc.2020.03.021.
2. O'Gara PT, Kushner FG, Ascheim DD, et al. ACCF/AHA guideline for the management of ST-elevation myocardial infarction: A report of the american college of cardiology foundation/American Heart Association Task Force of Practice Guidelines. *J Am Coll Cardiol*. 2013;614:e78–140. https://doi.org/10.1016/j.jacc.2012.11.019.
3. Ibanez B, James S, Agewall S, et al. 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). *Eur Heart J*. 2018;39(2):119–177. https://doi.org/10.1093/eurheartj/ehx393.
4. Keeley EC, Boura JA, Grines CL. Primary angioplasty versus intravenous thrombolytic therapy for acute myocardial infarction: A quantitative review of 23 randomized trials. *Lancet*. 2003;361:13–20.
5. Mahmud E, Dauerman HL, Welt FG, et al. Management of acute myocardial infarction during the COVID-19 Pandemic. *J Am Coll Cardiol*. 2020. https://doi.org/10.1016/j.jacc.2020.04.039. [Epub ahead of print].
6. Guillermin A, Yan DJ, Perrier A, Marti C. Safety and efficacy of tenecteplase versus alteplase in acute coronary syndrome: A systematic review and meta analysis of randomized trials. *Arch Med Sci*. 2016;12:1181–1187.
7. Sabatine MS, Cannon CP, Gibson CM, et al. Addition of clopidogrel to aspirin and fibrinolytic therapy for myocardial infarction with ST-Segment Elevation (CLARITY). *N Engl J Med*. 2005;352:1179–1189.
8. Chen ZM, Jiang LX, Chen YP, et al. Addition of clopidogrel to aspirin 45,852 patients with acute myocardial infarction: randomized placebo-controlled trial (COMMIT). *Lancet*. 2005;366:1607–1621.
9. Berwanger O, Lopes RD, Moia DF, et al. Ticagrelor versus clopidogrel in patients with STEMI treated with fibrinolytic therapy: TREAT Trial. *J Am Coll Cardiol*. 2019;73:2819–2828.
10. Antman EM, Morrow DA, McCabe CH, et al. Enoxaparin versus unfractionated heparin with fibrinolysis for ST-elevation myocardial infarction. *N Engl J Med*. 2006;354(15):1477–1488.
11. Wiviott ST, Braunwald E, McCabe C, et al. Prasugrel versus clopidogrel in patients with acute coronary syndromes (TRITON). *N Engl J Med*. 2007;357(20):2001–2015.
12. Ferguson JJ, Califf RM, Antman EM, et al. Enoxaparin vs unfractionated heparin in high-risk patients with non-ST-segment elevation acute myocardial coronary syndromes managed with an intended early invasive strategy: Primary results of the synergy randomized trial. *JAMA*. 2004;292:45–54.
13. Zhou F, Yu T, Du R, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: A retrospective cohort study. *Lancet*. 2020;395(10229):1054–1062.
14. Zhang y XM, Zhang S, et al. Coagulopathy and antiphospholipid antibodies in patients with COVID-19. *New Engl J Med*. 2020;382:e38. https://doi.org/10.1056/NEJMC2007575.

15. Bikdeli B, Madhavan M, Jimenez D, et al. COVID-19 and thrombotic or thromboembolic disease: Implications for prevention, antithrombotic therapy, and follow-up. *J Am Coll Cardiol*. 2020;75:2950–2973.
16. Credible meds. Available from https://urldefense.proofpoint.com/v2/url?u=http-3A__crediblemeds.org&d=DwIFaQ&c=k9MF1d71ITtkuJx-PdWme51dKbmfPEvxwt8SFEkBfs4&r=qAcUPdgKyX-VmKujiS3Ik3bZE0mnZTvrkM84qw2uSvQ&m=tan9LGcBJ0pY7gLxan8RTDV0pvXzt_AFbKHsPCquHKw&s=xFlycOySkhuG5_ebUoBvQ2NL4GGr5tpGJCUGgNVkO_w&e=
17. Tisdale J, Jaynes H, Kingery J, et al. Development and validation of a risk score to predict QT interval prolongation in hospitalized patients. *Circulation: Cardiovascular Quality and Outcomes*. 2013;6:479–487.
18. Simpson TF, Kovacs RJ, Stecker EC. Ventricular arrhythmia risk due to hydroxychloroquine-azithromycin treatment for COVID-19. Cardiology magazine; 2020. https://www.acc.org/latest-in-cardiology/articles/2020/03/27/14/00/ventricular-arrhythmia-risk-due-to-hydroxychloroquine-azithromycin-treatment-for-covid-19
19. Roden DM, Harrington RA, Poppas A, Russo AM. Considerations for drug interactions on QTc interval in explorator COVID-19 treatment. *J Am Coll Cardiol*. 2020;75(20):2623–2624.
20. van Doremalen N, Bushmaker T, Morris DH, et al. Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. *N Engl J Med*. 2020;382(16):1564–1567. https://doi.org/10.1056/NEJMc2004973.
21. Liu Y, Ning Z, Chen Y, et al. Aerodynamic analysis of SARS-CoV-2 in two Wuhan hospitals. *Nature*. 2020;582(7813):557–560. https://doi.org/10.1038/s41586-020-2271-3.
22. Wan GH, Tsai YH, Wu YK, Tsao KC. A large-volume nebulizer would not be an infectious source for severe acute respiratory syndrome. *Infect Control Hosp Epidemiol*. 2004;25(12):1113–1115. https://doi.org/10.1086/502353.
23. Centers for Disease Control and Prevention.Healthcare infection prevention and control FAQs for COVID-19. 2020. Available from https://www.cdc.gov/coronavirus/2019-ncov/hcp/infection-control-faq.html.
24. Ryan J, Melendres-Groves L, Zamanian R, et al. Care of patients with pulmonary arterial hypertension during the coronavirus (COVID-19) pandemic. *Pulm Circ*. 2020;10(2):1–7. https://doi.org/10.1177/2045894020920153.
25. Vaduganathan M, Vardeny O, Michel T, McMurray JJV, Pfeffer MA, Solomon SD. Renin-angiotensin-aldosterone system inhibitors in patients with COVID-19. *N Engl J Med*. 2020;382:1653–1659. https://doi.org/10.1056/NEJMsr2005760.
26. HFSA/ACC/AHA statement addresses concerns Re: Using RAAS antagonists in COVID-19. 2020. Available from accs-coronavirus-disease-2019-covid-19-hub.
27. Lash DB, Mack A, Jolliff J, et al. Meds-to-Beds: The impact of bedside medication delivery programs on 30-day readmissions. *JAACP*. 2019;2:674–680.
28. American College of Cardiology COVID-19 Hub. Available from https://www.acc.org/covid19#sort=%40fcommonsortdate90022%20descending
29. Armstrong PW, Gershlick AH, Goldstein P, et al. Fibrinolysis or Primary PCI in ST-Segment Elevation Myocardial Infarction. *N Engl J Med*. 2013;368:1379–1387.

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