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The cardiac intensive care unit and the cardiac intensivist during the COVID-19 surge in New York City

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Critical care cardiology has been impacted by the coronavirus disease-2019 (COVID-19) pandemic. COVID-19 causes severe acute respiratory distress syndrome, acute kidney injury, as well as several cardiovascular complications including myocarditis, venous thromboembolic disease, cardiogenic shock, and cardiac arrest. The cardiac intensive care unit is rapidly evolving as the need for critical care beds increases. Herein, we describe the changes to the cardiac intensive care unit and the evolving role of critical care cardiologists and other clinicians in the care of these complex patients affected by the COVID-19 pandemic. These include practical recommendations regarding structural and organizational changes to facilitate care of patients with COVID-19; staffing and personnel changes; and health and safety of personnel. We draw upon our own experiences at NewYork-Presbyterian Columbia University Irving Medical Center to offer insights into the unique challenges facing critical care clinicians and provide recommendations of how to address these challenges during this unprecedented time. (*Am Heart J* 2020;227:74-81.)

Background

The Cardiovascular Intensive Care Unit (CICU) was originally designed to take care of patients with mechanical complications and arrhythmias secondary to acute myocardial infarction. In recent decades the pathophysiology of cardiovascular disease has greatly expanded, ushering with it the emergence of the cardiac intensivist.^{1,2} This period has also seen an increase in the number of CICU patients present with primary non-cardiac illnesses but with underlying cardiac disease.^{3,4} In 2019, the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) which causes coronavirus disease-2019 (COVID-19) was described in Wuhan, China.⁵ Rapid spread of this virus has resulted in more

than 5,600,000 infections globally, prompting the World Health Organization to classify COVID-19 as a pandemic.⁶ As of May 27, 2020, there were more than 197,000 cases of COVID-19 in New York City, and New York State having more cases than most nations around the world.^{6,8} It is estimated that 3–6% of cases will become critically ill, requiring management in a critical care setting.^{9,11} The most common indication for intensive care admission is management of pneumonia or acute respiratory distress syndrome (ARDS). Many critically ill patients also progress to multisystem organ failure and overall mortality remains high.^{11,12}

Cardiovascular complications of COVID-19 have been reported and include myocarditis, stress-induced cardiomyopathy, acute coronary syndromes, arrhythmias, venous thromboembolic disease, and acute cardiogenic shock.¹³⁻¹⁵ In addition to keeping up with rapidly changing national and institutional clinical management and treatment protocols, critical care clinicians must address additional challenges.¹⁶ Finding solutions may require innovative thinking and developing new habits including organizational and structural changes, staffing and personnel changes, and addressing additional concerns regarding staff safety. In this context, the cardiac intensivist's role will expand beyond the domain of the typical CICU experience. Herein we discuss the evolving role of the cardiac intensivist and changes to the CICU in the era of the COVID-19 pandemic and provide

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recommendations based on our own experiences at New York-Presbyterian Columbia University Irving Medical Center.

Structural and organizational changes to facilitate care of patients with COVID-19

Consistent with predictions about the impact of a COVID-19 outbreak on New York City hospitals, hospitals throughout the New York metropolitan area have seen a surge in patient volumes. As patient volume increases within intensive care units, there are unique challenges that must be met so the CICU may rapidly respond to the COVID-19 pandemic.¹⁷ This includes optimization of physical space, attention to available resources, and an increased emphasis on identifying novel strategies to address what was previously routine management. Achieving these goals may involve bedside innovation including but not limited to: re-purposing existing equipment and physical spaces, improved anticipation and planning for clinical decompensation and, in some cases, a structural re-design to allow for higher patient volume. The COVID-19 pandemic has provided a unique opportunity for all staff members within the CICU to contribute meaningful and innovative ideas in order to meet the growing and complex needs of these patients. There are several domains across which innovation may occur including the physical layout of the CICU, the timing of laboratory and diagnostic studies, medication administration, clinical monitoring, and the management of cardiac arrests.

Optimization of physical space to accommodate the high volume of patients with COVID-19 in the CICU

While a typical critical care setting has one patient per room, the response to the surge of critically-ill COVID-19 patients nationally has included repurposing operating rooms and procedural spaces into intensive care units and utilization of single occupancy intensive care unit rooms to accommodate multiple intubated COVID-19 positive patients.¹⁷⁻¹⁹ Patient rooms within CICUs are utilized both for monitoring as well as a myriad of bedside procedures. Some procedures may be highly aerosolizing including bronchoscopy, intubating, and extubating, among others. Recommendations from the Centers for Disease Control and Prevention²⁰ suggest that negative pressure rooms be reserved for patients undergoing highly aerosolizing procedures. Although negative pressure rooms, or airborne infection isolation rooms, are ideal, few institutions are equipped to provide them for all COVID-19 patients. Knowing the ventilation of each patient care area of the CICU and planning to perform aerosolizing procedures in negative pressure rooms can help minimize staff exposure to COVID-19. Further, if a high volume of COVID-19 patients are anticipated, efforts can be made to re-construct rooms to be negative pressure.

Special consideration of lab testing and diagnostic studies

COVID-19 testing in CICU. At our institution, testing for SARS-CoV-2 was performed using a reverse-transcriptase-polymerase-chain-reaction. At the beginning of the pandemic, initial testing for COVID-19 was via the New York Department of Health and results would take up to 24 hours. However, in house testing was rapidly developed. In our laboratory, results were reported for SARS-CoV-2 in less than 12 hours. If a patient's COVID status was unknown at the time of admission to the CICU but COVID-19 was expected, they were designated as a Person Under Investigation and all protocols and precautions relative to COVID-19 were followed until their status was determined. To be declared COVID-19 negative patients required 2 negative COVID tests. For intubated patients, a tracheal aspirate would additionally be required.

Timing of lab testing and diagnostic studies. As typical of critically ill patients, patients in an intensive care setting with COVID-19 will require frequent testing as part of their clinical assessment and management. To minimize unnecessary utilization of personal protective equipment (PPE) and reduce exposure risks, when possible the clinical team should standardize times when diagnostic studies, procedures or lab testing will be performed. Input from the entire clinical team, including staff physicians, nurses, CICU technicians, support staff, and respiratory therapists, is essential in formulating optimal times for testing to minimize entry and exit from the patient's room. There is also a risk associated with the transport of laboratory specimens through the hospital. At our institution, as part of daily clinical rounds, timing of scheduled lab draws for the day were discussed with plans to coincide with scheduled medication administration.

Diagnostic imaging. In the setting of a pandemic, consideration of the benefit of a diagnostic study must be balanced against the risks of obtaining it. These risks include exposure of staff, utilization of PPE, and potential "down-time" of any procedural or diagnostic suite required for adequate decontamination. Such constraints require clinicians to think critically about the expected value of otherwise routinely obtained tests, including echocardiograms, a pulmonary artery catheter, routine electrocardiograms or chest x-rays, and cross-sectional imaging among others. When appropriate, a limited or focused study may be sufficient to answer the clinical question. For example, a limited transthoracic echo and/or point-of-care ultrasound, with required views discussed in advance with an echocardiographer, may be sufficient to answer the clinical question in a critically ill patient and may significantly reduce unnecessary exposure of healthcare personnel to COVID-19.^{21,22} For patients in the prone position, transthoracic echocardiograms protocols for the prone or "swimmer" position should be considered in order to

increase the quality of the images obtained and improve the likelihood that the findings may effectively guide clinical management.²³

Special consideration of medication administration

Timing and administration of medications. Similar to lab testing, medication administration is likely to occur frequently throughout the day. The optimal timing of medications should be discussed with the bedside nurse and clinical pharmacist to consolidate medication delivery and potentially to align timing with other therapies such as turning and/or suctioning. The use of extension tubing can further allow nurses to deliver and titrate medications without entering the patient room. This strategy is particularly useful for medications requiring frequent titration including vasoactive agents or sedatives. It is important to note that this would be ineffective for rapid, large volume resuscitation which some patients may require. Extension tubing was used in our CICU rooms including negative pressure rooms. This allowed for medication titration to occur while also maintaining spatial distance.

Alternatives to common CICU medications. During a pandemic, national supply chains may be interrupted. Re-evaluation of common CICU medications and their alternatives should be created in conjunction with pharmacists. For example, in the case of sedation for mechanical ventilation, agents such as ketamine or long acting oral agents such as chlordiazepoxide may be used as substitutes for those more commonly used in a CICU. Developing such strategies in advance and in conjunction with clinical pharmacists is ideal.

Monitoring of patients with COVID-19

Telemetry and QTc monitoring. Many agents used in the CICU for treatment of COVID-19 as well as other concomitant illness have known toxicities including QT interval prolongation.²⁴ Obtaining a baseline 12-lead ECG is important in determining baseline QTc duration with follow up ECGs after medication initiation to monitor both the QTc duration and for any arrhythmias. However, to minimize repeated staff exposure to possible COVID-19 and to avoid the need for frequent ECGs, telemetry may be useful to monitor the QTc. This can be both from reading of manual printouts of the telemetry as well as a real-time display of the QTc on the telemetry screen. Although this value may only represent an average of a 3-lead tracing and not a full 12-lead ECG, it can provide valuable diagnostic information to determine whether QT prolonging agents can be continued, or if a 12-lead ECG may be warranted.

Invasive hemodynamics, cardiac output monitoring, and mechanical circulatory support in COVID-19-related acute cardiogenic shock. Optimizing hemodynamics in the critically ill patient is a routine yet complex challenge within the CICU. The COVID-19 pandemic

presents similarly complex patients, many of whom have not only respiratory failure but also shock and multi-organ system dysfunction. While distributive or septic shock appear to be most common, cardiogenic or mixed cardiogenic/septic shock may occur, especially in those with pre-existing baseline cardiac disease.^{12,25} Fluid management and titration of vasoactive medications can be particularly challenging in these patients, especially those with concomitant ARDS.^{26,27} Clinicians have to balance the diagnostic information gained from an invasive procedure such as placement of a pulmonary artery catheter for hemodynamic monitoring with the risks of such a procedure to both patient and staff. If pulmonary artery placement is required, we recommend that highly experienced operators perform the procedure at the bedside when feasible. In lieu of a pulmonary artery catheter, central venous pressure monitoring with a central venous catheter may be useful in assessing hemodynamics including central venous oxygen saturation and determining how to optimize fluid resuscitation and intravascular volume.²⁸

Further, point of care ultrasonography may take on increased importance in this context for the rapid assessment of the size of the inferior vena cava as a marker of volume status. Additionally, the use of continuous cardiac output monitors may be considered. The approach to acute mechanical circulatory support will need to adapt to unique challenges resulting from COVID-19 disease. The complexity of severe COVID-19 disease with concomitant cardiac failure emphasizes the need for a multidisciplinary team to help guide clinical decisions and management. A multidisciplinary “advanced heart team” consisting of cardiac intensivists, advanced heart failure specialists, acute mechanical circulatory support team and cardiothoracic surgeons is recommended to manage these complex patients in order to decide which mechanical circulatory support device provides optimal hemodynamic support while minimizing the need for patient transportation and personnel exposure to COVID-19.²⁹⁻³¹

Cardiac arrest

There are specific challenges to consider when treating cardiac arrest in a CICU patient with suspected or confirmed COVID-19.³² The survival and neurologic recovery among patients with COVID-19 who undergo cardiopulmonary resuscitation (CPR) has only been reported among patients in Wuhan, China. In that study, among 136 patients with an in-hospital cardiac arrest, only 4 (2.9%) of patients were alive at 30 days.³³ Interim guidance on the management of a cardiac arrest in this population has been recently released by the American Heart Association.³⁴ Specific areas addressed by these guidelines focus on reducing exposures to health care workers. Strategies include limiting members entering the room, prioritizing ventilation strategies associated with decreased aerosolization, and carefully considering the appropriateness of initiation and

continuation of cardiopulmonary resuscitation (CPR). Strategies employed at our institution to achieve these goals include:

- 1) Defining team member roles: Team roles are defined proactively at the beginning of clinical shifts. Limiting PPE and room entry only to those who must be at the bedside is an important consideration in order to both preserve equipment as well as maintain safety for all staff.
- 2) Preparing supplies: Maintaining adequate supplies is paramount for clinician safety as compressions and ventilation can be highly aerosolizing. However donning PPE properly can introduce delays to life saving interventions. Code carts can be modified to include PPE to be utilized only during cardiac arrests. This approach ensures that PPE is available at time of cardiac arrest, reduces waste, and minimizes time spent before resuscitation. When possible, defibrillator pads should be placed on patients on admission to the CICU. For patients who have an arrest which may be anticipated, placing a backboard or firm surface beneath the patient early in their care, or having a step stool in position in the room, reduces time to adequate CPR.
- 3) Prone CPR: Proning may be used in the CICU for management of refractory hypoxemic respiratory failure in patients with confirmed or suspected COVID-19. For patients who cannot be placed in the supine position before or during a cardiac arrest, guidelines from the American Heart Association suggest prone CPR may be reasonable.³⁵ We have previously described one approach to prone CPR which includes positioning a sternal counter-pressure device attached to a standard CPR board beneath the patient.³⁶ With a firm surface in place, chest compressions can be delivered at the T7-10 vertebral bodies.
- 4) Advanced Code Planning and Communication: Code teams may change multiple times during a 24-hour shift. With frequently changing teams and changes to institutional and national policies, careful attention must be paid to ensure that new policies are effectively and broadly implemented. To address this, daily code huddles including the code team leaders and cardiac intensivists may be performed to identify code roles, review policy changes, and to discuss prior code experiences for collective learning.

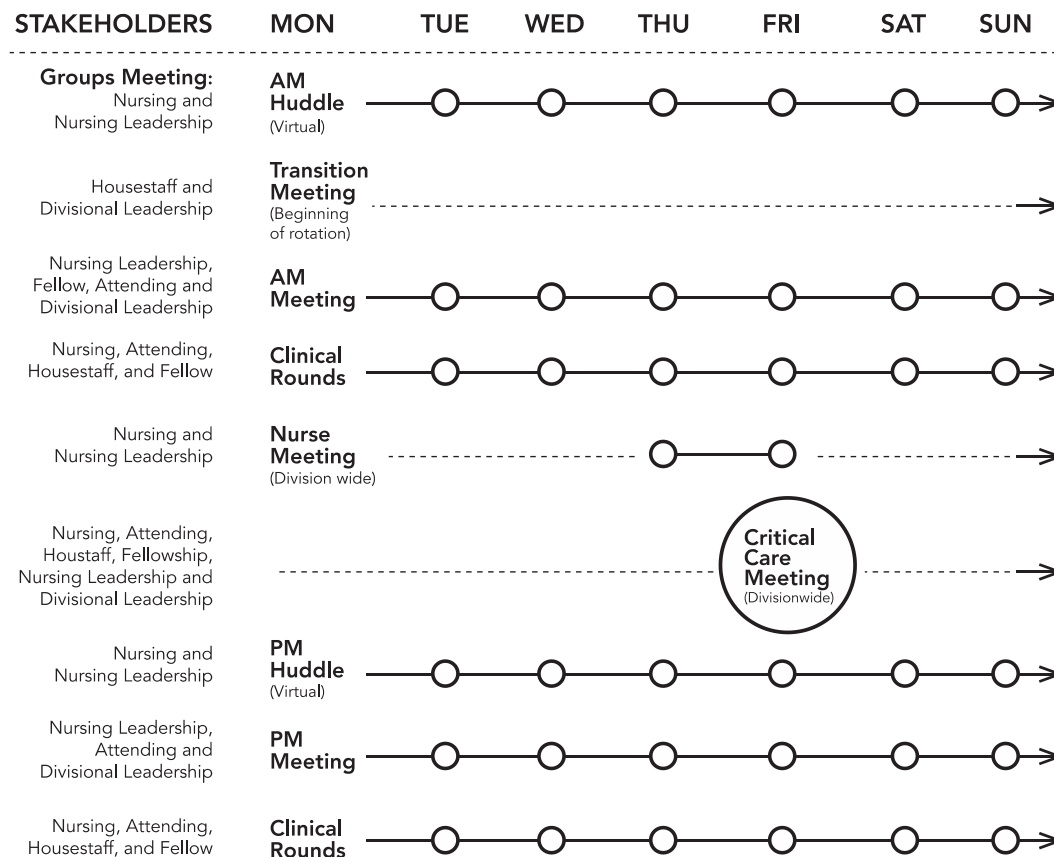
Staffing and personnel changes

Team huddles and feedback

In the CICU it is essential to have effective communication between the staff on clinical service and hospital leadership. Much of the existing communication infra-

structure at CUIMC was leveraged in order to adapt to needs specific to the COVID-19 pandemic (Figure 1). For house staff teams, prior to the beginning of each new rotation, the house staff met with leadership from the Division to address expectations and updated CICU protocols during the COVID-19 pandemic. There are also multiple nursing specific meetings to discuss acute changes occurring in the CICU, anticipate challenges, and provide an opportunity for staff feedback. These include a CICU nurses "AM huddle" before each change of shift and nursing divisional meetings three times a week. Nursing leadership (charge nurse and Patient Care Director of the cardiac intensive care unit) additionally communicates with the cardiology division leadership (Director and Associate Director of the CICU) at least daily. Before clinical work rounds, there is an AM meeting which includes the charge nurse, cardiac intensivists, and cardiology fellow to discuss significant anticipated clinical changes (intubations, extubations, procedures, proning, initiation of dialysis or mechanical circulatory support) among CICU patients in order for advanced planning of resources, including identifying additional nursing and/or staff needs. This time is also used to discuss any changes in protocols, discuss opportunities for innovation, identify areas requiring further staff education, and raise and/or address any safety concerns of the staff. Cardiac intensivists and fellows have direct communication with the CICU director at least daily. Once a week, there is a division-wide "Critical Care Meeting" led by the CICU director and open to all CICU members but mandatorily including all cardiac intensivists (on or off service) as well as representatives from nursing, advanced practice providers, pharmacy, social work, and cardiology fellows rotating on the CICU using a web-based platform. This meeting provides an open forum to discuss ongoing concerns raised by the staff, follow-up regarding the efficacy of strategies and interventions, the state of the Division, and provide staff forewarning on institutional potential policy changes which may be applicable to the CICU. Finally, to share our experience with those in other units throughout NewYork-Presbyterian, the existing Critical Care Working Group which includes CICU leadership would meet 2-3x per week during the peak phase of the pandemic. This group specifically helped to develop guidelines on CPR, intubations, medical therapies, ventilation, tracheostomy, proning policies, and chest tube management among others. Additionally, at our institution, there is daily formal communication between CICU leadership and other subspecialty intensive care unit leadership teams in order to share lessons learned, rapidly disseminate new information and operational protocols, thereby strengthening multidisciplinary collaboration across intensive care units throughout the hospital.

Figure 1



This model depicts the communication structure at Columbia University Irving Medical Center which was leveraged during the peak phase of the coronavirus disease-2019 pandemic to maintain open communication between house staff, fellows, attendings, nursing, nursing leadership (charge nurse and Patient Care Director of the cardiac intensive care unit), and cardiology division leadership (director and associate director of cardiac intensive care unit).

Team restructuring

To account for higher patient volume, medical teams may need to be restructured so as to allow for expanded team sizes. The goal of such expansion in the CICU is to adapt standard staffing and resources to increase patient capacity without impacting patient care. There are multiple ways to achieve this which will be specific to each institution. At our institution, we have attempted strategies involving splitting teams into smaller units and flattening the staffing pyramid so that only essential team members are physically on rounds. This also allows for social distancing within the unit. Specifically, at CUIMC, 10 of our 28 CICU beds had the capacity to have 2 patients in one room. These rooms were reconfigured to allow for 2 patients per room and increase the total CICU capacity to 38 beds. Care teams were divided to have 2 teams of 10 patients and 2 teams of 9 patients. In the final rounding model, each team consisted of 1 cardiac intensivist as the attending of record, 3 NPs or residents,

and 1 fellow for each team on weekdays and 1 fellow per 2 teams on weekends. Routine physical examinations are limited to one team member per day to minimize PPE use and potential exposure to COVID-19. Further examinations occurred as necessary throughout the day if it was anticipated to result in an acute change in management. To adapt to both the clinical and emotional demands of managing patients with COVID-19,³⁷ the typical service model was changed to 1 week on followed by 1 week off service. With this approach, the CICU is able to manage a greater volume of patients, and cardiac intensivists were not redeployed to other care areas. The CICU nurse-to-patient ratio is 1:2 (for patients not on mechanical support) with nurses trained in critical care. When the hospital was at peak capacity, an alternate care model helped to meet the increased volume by having a non-critical care nurse supporting a CICU nurse, with a CICU nurse-to-patient ratio of 1:3. Alternative staffing models utilized in other locations throughout the NewYork-

Presbyterian system have been previously described.¹⁹ Any intensivist who is not deployed is considered to be part of the deployable pool for the CICU if a provider was not able to work due to being quarantined or if he/she became ill.

Team dynamics and team leadership

Delivery of skilled patient care in a crisis and/or pandemic setting requires effective management of team dynamics. Crew resource management (CRM), a set of procedures to be used in environments in which human errors may have large consequences, has been used to ensure safety by reducing such errors. TeamSTEPPS (Team Strategies and Tools to Enhance Performance and Patient Safety),³⁸ a CRM program offered by the Agency for Healthcare Research and Quality (AHRQ), emphasizes an understanding of team structure and skills that include communication, leadership, situation monitoring and mutual support. Critical information should be communicated concisely through techniques that include SBAR (situation, background, assessment and recommendation), through call-out (informing all team members simultaneously during emergency situations) and closed-loop communication, and structured handoffs during transitions in care. Effective team leadership requires ensuring the team is organized, communicating clinical plans and team goals, giving and encouraging feedback, facilitating conflict resolution and encouraging teamwork. Leaders in a crisis such as that created by COVID-19 that may involve high mortality and risk to staff must assume heightened responsibility for assessing, supporting and potentially replacing team members who exhibit signs of emotional distress. At our institution, wellness support resources for all employees including peer support groups are readily available. In addition, weekly debriefing sessions with the cardiac intensivist, advanced care providers, and nurses are done in order to review challenging cases and to address well-being issues with staff. Situation monitoring also requires team members' awareness of patient status; ongoing assessment of their own and each other's needs, strength and limitations; monitoring the environment for safety and resource availability; and communication to promote a "shared mental model." Mutual support requires teamwork to provide assistance and support with tasks, assertive advocacy for patients, delivery of respectful but timely and goal-oriented feedback, and conflict resolution. Ideally, a CICU team will be familiar with CRM concepts before a crisis occurs. However, leaders of teams with insufficient training in CRM may still employ techniques like TeamSTEPPS while educating staff and clinicians about the need for process improvement.

Channeling additional skillsets

In addition to having a firm understanding of critical care cardiology, critical care clinicians must adapt to the

changing CICU environment by expanding their skillsets to include tele-education, supply/chain management, and telehealth. Given the increase in patient volume, an expansion of the usual team to include clinicians from other disciplines outside of cardiology is to be expected. As these new clinicians may need to provide care outside of their usual scope of practice, fast on-boarding and education of these clinicians who may not usually practice within a CICU setting will be necessary. At CUIMC centralization of multidisciplinary educational resources including training videos, webinars, and tele-education are performed and disseminated on a daily and/or weekly basis. The cardiac intensivist and staff also serve as a consultative resource throughout the hospital to other clinicians given the clinical expertise of the CICU in the management of critically ill patients with cardiovascular complications of COVID-19.¹³⁻¹⁵ Further, cardiac intensivists should participate in supply/chain management decisions in conjunction with administrators and leadership. Lastly, to decrease transmission risk, many hospitals now limit and/or restrict visitation of family members especially within critical care settings. Therefore, reliance on telehealth within the CICU setting is essential in order to provide comprehensive daily updates with respect to patient care progress that can replace the daily "bedside family meeting." This includes conducting tele-palliative care sessions with family members and healthcare proxies to discuss code status and goals of care. When faced with challenging ethical issues or conflicts,³⁹ an ethics consultation should be performed to guide the primary team's decision. At our institution, we have also emphasized utilizing our partnerships with palliative care and engaging in early goals of care discussions with patients and family. For patients who are not intubated and can participate in family meetings, providing a tablet or mobile phone at bedside for patients to be able to communicate directly with family members should be considered.

Health and safety of personnel

It is imperative to ensure reduction of infectious threat to team members. As further discussed below, when possible, COVID-19 positive patients should be placed in airborne infection isolation rooms (negative-pressure rooms).²⁰ Consistent with guidance from the Centers for Disease Control and Prevention, all staff must be educated in the proper donning and doffing of PPE.⁴⁰ Frequent handwashing, including before and after all patient contact, must be enforced. A unit "champion" may be designated to periodically assess staff adherence to infection prevention protocols and ensure that donning and doffing is performed properly. Only essential team members should be present in a patient's room during cardiac resuscitations or during aerosol-generating procedures and members must not be allowed

to enter the patient room before being appropriately covered with PPE.³⁴

Procedural safety

Existing practices in CICUs should be utilized in order to ensure patient and operator safety during procedures. Some considerations are particularly important during a pandemic such as COVID-19 when a high volume of procedures is anticipated, and the CICU may include new team members, redeployed from other care areas and/or specialties. Time outs and checklists should be used before and during performance of all procedures. As recommended by the Society for Critical Care Medicine, endotracheal intubation should only be attempted by the most experienced proceduralists available.⁴¹ Additionally, at our institution, multiple highly-skilled teams consisting of procedurally experienced clinical staff have been designated. These teams of expert proceduralists are utilized throughout the hospital, including within the CICU, such that invasive procedures can be safely and expeditiously performed, while also minimizing overall procedural time, need for excess PPE, and the number of individuals who must enter a patient's room.

Employee testing

All matters related to risk of potential exposure or infection of clinical staff were handled by employee health services. The clinical staff followed procedures for self-quarantine and return to work as mandated by the hospital and local governance. Testing for healthcare workers was first offered to those with symptoms related to COVID-19. At present, all healthcare workers can now be tested for COVID-19 including through the use of antibody testing.

Conclusions

The CICU is capable of providing care to the most critically ill patients throughout the hospital. This will continue to be the case during the COVID-19 pandemic where a hospital's critical care capacity will be filled and, in many cases, expanded. Cardiac intensivists should anticipate being the primary clinician for many COVID-19 positive patients. Further, the CICU intensivist must be mindful of the large team of clinicians who will similarly face complex and novel challenges with COVID-19 including nurses, advanced practice providers, pharmacists, respiratory therapists, physical therapists, and social workers, among others. In this environment being an effective physician will require excellent clinical management, team leadership, hospital communication, and continuous learning such that the CICU may safely and continuously adapt to the ongoing and dynamic challenges of the COVID-19 pandemic.

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