

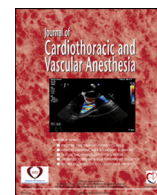


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Special Article

Electrophysiology Practice During COVID-19 Pandemic: A New York Tertiary Hospital Experience

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As hospitals became overwhelmed during the Covid-19 pandemic in March-May in New York, Cardiology and Electrophysiology (EP) departments rapidly developed protocols for case selection as well modifying the practice of managing the cases. Recommendations by the AHA/HRS as well as American Society of Anesthesiology (ASA) were considered in the multidisciplinary collaborative approach to patient care and personnel safety and the anesthesiology team had an integral role in developing protocols for workflow, care, recovery and transport during these challenging times.

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THE SEVERE acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which originated in Wuhan, China, in the last quarter of 2019, is now a global pandemic, affecting all aspects of life. The United States has been affected significantly by this global crisis, accounting for more than one third of the world's cases and being the country with the highest numbers of cases globally. This has strained the healthcare system and society, especially in New York State and New York City, which have been the hardest hit areas thus far.¹⁻³

The disease conferred by SARS-CoV-2, coronavirus disease 2019 (COVID-19), is believed to be predominantly respiratory in origin, with pneumonia and acute respiratory distress syndrome being responsible for most critical care unit patient admissions. The virus causes pulmonary illness by attaching to the angiotensin-converting enzyme-2 receptor on respiratory epithelium and entering cells through this mechanism. Cardiac myocytes and other cells contain

angiotensin-converting enzyme-2 receptors, and therefore there are other targets of SARS-CoV-2 and other end-organs at risk. Indeed, it is now appreciated that a significant number of cardiac abnormalities and arrhythmias are associated with COVID-19 disease.^{1,2,4}

Herein, the authors' experience with their institution's electrophysiology (EP) service during the fight against COVID-19 at North Shore University Hospital, a "hot-spot" hospital just outside the city limits of New York City, is discussed. Their tertiary care center has a complex EP laboratory and an advanced heart failure and transplantation program.

COVID-19–Related Arrhythmias

In a report from Wuhan describing 138 COVID-19 patients, 16 of 36 patients admitted to the intensive care unit (ICU) had arrhythmias (44.4%).⁵ A report of 115 patients admitted to the University of Alabama at Birmingham ICU noted that 19 of the 115 (16.5%) COVID-19 patients developed an atrial tachycardia that had not been present on admission. These included 12 cases of atrial fibrillation, six cases of atrial flutter, and one case of atrial tachycardia.⁶ Atrial tachycardia is the most

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common COVID-19–related arrhythmia, but other arrhythmias, such as ventricular tachycardia, torsades de pointes, and conduction abnormalities, also have been encountered.^{4,7,8} Many patients have associated myocardial dysfunction, myocarditis,⁶ septic shock, and systemic inflammation⁷ and have demonstrated cardiac arrest rhythms, including pulseless electrical activity and ventricular fibrillation. In addition to direct myocardial viral involvement, there are other mechanistic explanations for the large incidence of arrhythmias in this population. The prothrombotic state induced by severe SARS-CoV-2 infection can cause coronary ischemia, left ventricular dysfunction, cardiogenic shock, and pulmonary emboli, with resultant right ventricular dysfunction, all of which can manifest arrhythmias.^{9,10} The direct effects of hypoxia and electrolyte disturbances and the effects of QT-prolonging medications can predispose to the development of arrhythmias.^{9,10} In addition, the medications specifically used for treatment of COVID-19, such as hydroxychloroquine, chloroquine, and azithromycin, are known to prolong the QT interval and may lead to fatal ventricular arrhythmias.¹¹

EP Procedures During the Pandemic

As the outbreak of COVID-19 overwhelmed the practice of medicine, hospitals and healthcare systems formed task forces to address the management of procedures and allocation of resources, equipment, and staffing. In general, the important role of the electrophysiologist in cardiac health is primary because 40% of cardiology encounters are arrhythmia-related. A similar incidence of electrophysiologic disease has been reported during the COVID-19 pandemic.

Teamwork is essential because the electrophysiologist might be called to address the arrhythmias in coordination with primary care, ICU, cardiology, and anesthesia teams for any patient who needs urgent, emergency, or semi-urgent EP procedures. In the authors' institution, the task force that was formed to guide procedures in the EP/catheterization laboratory worked in conjunction with hospital administration, the anesthesia department, and engineering and transportation departments, as well as providers, to determine the steps and workflow required to ensure appropriate isolation of COVID-19–positive patients or persons under investigation.

To care for patients with EP disturbances during the crisis, the Heart Rhythm Society (HRS) COVID-19 Rapid Response Task Force, in conjunction with the American College of Cardiology (ACC) Electrophysiology Council, and American Heart Association (AHA) Council on Clinical Cardiology released a joint statement to provide guidance for the management of patients with COVID-19–related arrhythmias.¹² The statement addressed the management of invasive and noninvasive procedures, with attention paid to the importance of triage and the potential exposure risk to patients, healthcare providers, and industry representatives.^{12,13}

The HRS/ACC/AHA statement described the triage of procedures into three categories. Urgent or emergency procedures should not be postponed, semi-urgent procedures are prioritized based on clinical characteristics and health system

resources, and non-urgent or elective procedures should be postponed. The HRS/ACC/AHA recommendation to postpone or cancel non-urgent procedures was based on federal and state executive orders and the strain on hospital systems that were diverting all resources to care for COVID-19 patients (Table 1).^{12,13}

For persons under investigation for COVID-19–related illness, HRS/ACC recommended waiting for the viral infection test result so that equipment and resources could be conserved judiciously. The HRS/ACC guidance document also placed increased emphasis on the use of telemedicine, digital health, and remote device monitoring because these underutilized programs can prove to be highly effective methods of monitoring.

Anesthetic Considerations for EP Procedures During COVID-19 Pandemic

Anesthesiologists are well-suited to be an integral part of the management of care for patients undergoing EP procedures during the COVID-19 crisis. Anesthesiologists provide specific consultation, provide appropriate anesthetic management, and coordinate the efforts of the involved teams in order to ensure the safest approach. Consideration is given to the prioritization of procedures, work environment, anesthetic technique, airway management, and anesthesia equipment cleaning and maintenance.¹⁴

Because of the highly contagious nature of SARS-CoV-2, transmission by asymptomatic carriers, and a significant false negative rate in diagnostic testing, it might be challenging to accurately identify and isolate all COVID-19 patients. Thus, the American Society of Anesthesiologists (ASA) recommends an escalation of standard practice during airway management for all patients, using rapid-sequence induction and minimization of positive-pressure ventilation as routine to minimize the potential for aerosolization of droplets. Fiberoptic intubations should be avoided unless absolutely necessary.^{14–18}

Management of Cardiac Implantable Electronic Devices

The HRS COVID-19 Rapid Response Task Force published guidance for healthcare providers for the management of patients with cardiac implantable electronic devices (CIEDs),

Table 1
HRS/ACC/AHA Recommendations

Triage	Urgent/emergency	Should not be postponed
	Semi-urgent	Prioritized on clinical characteristics and resources
PUI	Non-urgent/elective	Should be cancelled/postponed
		Wait for the viral test result to conserve/ manage resources
Visits/monitoring		Telemedicine, digital health, remote-device monitoring

Abbreviations: ACC, American College of Cardiology; AHA, American Heart Association; HRS, Heart Rhythm Society; PUI, Person Under Investigation
Adapted from the Heart Rhythm Society.¹²

with an emphasis on limiting exposure to both patients and clinicians.^{19,20}

All outpatient monitoring should be done remotely when possible. For inpatient or emergency room management, preliminary discussion should be performed via phone or telehealth consultation. Interrogation of the device should be performed only if will affect patient care. Routine device interrogation should be avoided, and “in-hospital” remote monitoring technology should be used if necessary. The HRS task force discourages routine checks for CIED evaluation and preoperative CIED interrogation if a patient is not pacemaker-dependent. Routine evaluation for magnetic resonance imaging for patients with loop recorders also is discouraged.

In the perioperative period, rather than interrogation, magnet placement is encouraged for suspending antitachycardia therapies in patients with defibrillators and in pacemaker-dependent patients when electromagnetic interference is expected. Dedicated remote interrogation devices with cellular and internet connections strongly are encouraged.^{19,20}

Device interrogation only would be prioritized for the following logistic scenarios: suspected device malfunction (inappropriate pacing or shocking), suspected elective replacement interval, preoperative evaluation if no interrogation within six months, and urgent/emergency magnetic resonance imaging evaluation. Direct interrogation also may be prioritized for the clinical conditions of syncope, untreated tachycardia, and stroke etiology.^{19,20} All interrogation equipment should be cleaned with disinfecting wipes after each use (Table 2).

Personnel

Both the Centers for Disease Control and Prevention and the Occupational Safety and Health Administration have published guidelines for personal protective equipment (PPE) and its use.^{21,22}

The ASA has offered specific guidance for provider protection during anesthetic management, including endotracheal intubation and equipment recommendations.¹⁵⁻¹⁷ The HRS recommendations include suggested modifications of the management of CIEDs in order to minimize personnel exposure.^{19,20}

Institution Experience

In the authors’ tertiary cardiovascular center, from March 16 to May 16, there were 115 cases operated, procedures in Electrophysiology Suite, excluding five implantable loop recorders. These included 60 device implantations and generator replacements, 21 catheter ablations, 10 device lead extractions, and 24 cardioversions. Among the catheter ablations, eight were for ventricular tachycardia and 13 were for either atrial fibrillation, atrial flutter, or supraventricular tachycardia (Table 3).

During the same interval in 2019 there were 426 cases procedures in EP Suite and 106 loop recorders were implanted.

The triage of procedures was implemented by the authors’ institution as soon the ACC/AHA and HRS guidelines were

Table 2
HRS Task Force Management of CIEDs of Inpatients/Emergency Department

Preliminary discussion/consultation over the phone	
Discourages	
<ul style="list-style-type: none"> • Routine CIED interrogation • Preoperative interrogation for non-pacer–dependent patients • Routine evaluation for MRI planning for patient with ILR 	
Encourages	
<ul style="list-style-type: none"> • Magnet placement for suspension of antitachyarrhythmias • Therapy and asynchronous pacing in pacer-dependent patients • Dedicated interrogation devices • Remote interrogation devices 	
Prioritize device interrogation	
<ul style="list-style-type: none"> • Suspected device malfunction (inappropriate pacing or shocking) • Suspected ERI • Preoperative interrogation if no evaluation within 6 mo • Urgent/emergency MRI evaluation • Syncope, untreated tachycardia, stroke etiology 	
Equipment cleaning	
<ul style="list-style-type: none"> • Disinfecting wipes after each use 	

Abbreviations: CIED, cardiac implantable electronic devices; ED,; ERI, elective replacement interval; HRS, Heart Rhythm Society; ILR, implantable loop recorder; MRI, magnetic resonance imaging.

published. The determination of urgent, semi-urgent or semi-elective, and elective was made by the EP team in collaboration with the primary or ICU team for inpatients or the primary care physician for outpatients. Most procedures were urgent and semi-urgent (eg, device implantations or replacements for diagnoses such as syncope, high-degree atrioventricular block, or replacement interval indications). Urgent and semi-urgent lead extractions were performed for infection or malfunction, and cardioversions and catheter ablations were scheduled for symptomatic arrhythmias refractory to medical treatment.

Only two patients were known to be COVID-19-positive at the time of their procedure, and 71 patients had negative results. The remaining 42 patients presented early during the pandemic when there was a relative paucity of COVID-19 testing available and unreliable rapid testing. The urgency of the procedure dictated whether a procedure was performed before a COVID-19 test result could be returned. The authors’ hospital developed protocols for testing and procedural management

Table 3
NSUH Experience

Sex	Female	41
	Male	74
Status	Inpatient	46
	Outpatient	69
COVID-19 status	Positive	2
	Negative	71
	N/A	42
Procedures	Device implantation/generator change	60
	Catheter ablation	21
	Atrial fibrillation/flutter	13
	VT	8
	Cardioversions	24
	Lead extractions	10

Abbreviations: COVID-19, coronavirus disease 2019; NSUH, Northshore University Hospital; VT, ventricular tachycardia.

and dictated that all patients who did not have a COVID-19 test result would be treated as if they were positive.

There were six fatalities, for a death rate of 5%, which was much higher than the institution's usual mortality rate in the EP service. Two of the fatalities were COVID-19-positive. One patient, who had a leadless pacemaker, died of sepsis. The second patient, who had a dual-chamber pacemaker, died of cardiogenic shock as a result of extensive coronary thrombosis, which was believed to be COVID-19 related. The other four fatalities occurred after discharge, and the causes of death are unclear, but the patients were COVID-19 negative.

Fortunately, the EP laboratory is located within the catheterization suite, which enabled the creation of a procedure room that would serve COVID-19 patients for both EP and coronary catheterization procedures. The assigned procedure room was confirmed to have negative-pressure ventilation, and high-efficiency particulate air filters were present on the anesthesia machine. The room was emptied of any redundant or unnecessary equipment, and a clean, isolated storage area in the adjacent monitoring room was delineated with zippered plastic curtains. Nearby in the suite, a specific soiled utility and a decontamination room were assigned. Another procedure room was repurposed and converted to a preoperative holding and recovery area for both the EP and catheterization laboratory, because these usual units had to be transformed into COVID-19 ICUs during the surge. Written protocols for care were developed in accordance with the HRS guidelines, and elevators and routes of transport were assigned for COVID-19 patients. The anesthesiology department generated videos detailing the proper procedure for donning and doffing of PPE while always ensuring that there was adequate supply to maintain the safety of staff (Table 4).

Clinically, the daily huddle addressed each case individually to review indications and the protocol to be followed. Outpatients who were scheduled for semi-urgent or urgent procedures were screened for COVID-19 viral antigen before being admitted to the hospital.

For the COVID-19–positive inpatients, consent for anesthesia services was obtained telephonically, and a full report on the patient was communicated before transport was activated. At the procedure room, all personnel entering the room donned PPE before entering the room and doffed inside the room immediately before exiting. At the conclusion of the procedure, the patient either recovered in the procedure room with a post-anesthesia care unit nurse or was transported directly to a COVID-19 ICU. After recovery in the procedure room, the patient was transferred to a COVID-19–specific floor.

The anesthetic technique used for each case was discussed with the proceduralist and the patient, taking into consideration the patient's symptoms, the common anesthetic technique that would have been used before the pandemic, and the risk of aerosolization associated with that particular airway management.

For device implantations in COVID-negative or undetermined patients, sedation using midazolam with fentanyl or a propofol infusion was used. For patients requiring general anesthesia with endotracheal intubation, a rapid-sequence

Table 4
Institution Protocols/Changes

Creation of a COVID-19 procedure room with negative pressure ventilation
HEPA filters on anesthesia machines
Removed redundant/unnecessary equipment
Monitoring room: clean, isolated by zippered plastic curtains
Designated soiled utility/decontamination room
Repurposing of a procedure room as recovery room
Recovering COVID-19 patients in the procedure room
Established specific routes and elevators for COVID-19 patients
PPE donning and doffing instructional videos

Abbreviations: COVID-19, coronavirus disease 2019; HEPA, high-efficiency particulate air; PPE, personal protective equipment.

induction with the use of video laryngoscope was used in alignment with the ASA recommendations. Whenever possible, deep extubation was used to minimize aerosolization.

For the two known COVID-19–positive patients, monitored anesthesia care was used, with very light sedation (1 mg midazolam and 50 µg fentanyl), with an oxygen mask instead of nasal cannula, in order to cover both the mouth and nose. A surgical mask was placed on top of the oxygen delivery mask.

For perioperative management of patients with CIEDs, the HRS recommendations were followed and device interrogation related to perioperative management was performed remotely, as is routinely done for outpatient interrogation. In-person interrogation was performed rarely and only for emergency situations, such as preoperative interrogation, in which case, a designated device was used and was disinfected after each use.

In the epicenter of this major pandemic, the institution had redeployed staff to cover the ICUs and emergency room. As such, some of the nursing and technology staff were reassigned to the COVID-19 units, and some of the electrophysiologists were deployed as back-up consultants. Given the fact that only urgent and semi-urgent procedures were performed, the EP laboratory had a reduced schedule volume and functioned very efficiently despite a skeleton staff. Communication preoperatively and at the morning huddle was critical to implementing a plan that was appropriate for the patient, the personnel, and the procedure and recovery periods.

Conclusions

The current pandemic has challenged the delivery of routine and emergency care worldwide and has forced changes to ensure the safety of patients and healthcare personnel.

EP laboratories in the hot spot areas, with a significant number of COVID-19–positive patients, have had to adapt. The authors did this by limiting cases to urgent and semi-urgent according to HRS guidelines, modifying the procedure areas and recovery areas to accommodate COVID-19–positive patients, altering cleaning and disinfecting areas, and adopting a more proactive approach through telemedicine in order to limit personnel and equipment exposure.

Anesthesiologists are a critical part of the EP team, often functioning as a central communication resource for care and clinical processes. This is especially applicable to the care of

patients during the COVID-19 pandemic. In addition to navigating the anesthesia and airway challenges, the coordination of care according to the recent HRS recommendations and establishing workplace safety protocols are prime roles for the anesthesiology consultant.

Conflict of Interest

None.

References

- Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet* 2020;395:497–506.
- Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease (COVID 19) outbreak in China: Summary of a report of 72314 cases from the Chinese Center for Disease Control and Prevention. *JAMA* 2020;323:1239–42.
- World Health Organization. Coronavirus disease 2019 (COVID 19) situation report-43. Available at: <https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200303-sitrep-43-covid-19.pdf>. Accessed March 3, 2020.
- Wang D, Hu B, Hu C, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. *JAMA* 2020;323:1061–9.
- Colon CM, Barrios JG, Chiles JW, et al. Atrial arrhythmias in COVID-19 patients. *JACC Clin Electrophysiol* 2020;6:1189–90.
- Wu CI, Postema PG, Arbelo E, et al. SARS-CoV-2, COVID-19 and inherited arrhythmias syndromes. *HeartRhythm* 2020;17:1456–62.
- Lazzerini PE, Boutjdir M, Capocchi PL. COVID-19, arrhythmic risk, and inflammation: Mind the gap!. *Circulation* 2020;142:7–9.
- Chang D, Saled M, Garcia-Bengo Y, et al. COVID-19 infection unmasking Brugada syndrome. *Heart Rhythm Case Rep* 2020;6:237–40.
- Klok FA, Kruip MJHA, van der Meer NJM, et al. Incidence of thrombotic complications in critically ill ICU patients with COVID-19. *Thromb Res* 2020;191:145–7.
- Chen J, et al. Findings of acute pulmonary embolism in COVID-19 patients. *Lancet* 2020;[E-pub ahead of print].
- Simpson TF, Kovacs RJ, Stecker EC. Ventricular arrhythmia risk due to hydroxychloroquine-azithromycin treatment for COVID-19. *Cardiol Magazine* 2020.
- Dhanunjaya RL, Chung MK, Gopinathannair R, et al. Guidance for cardiac electrophysiology during the coronavirus (COVID-19) pandemic from the Heart Rhythm Society COVID-19 Task Force; Electrophysiology section of the American College of Cardiology; and the Electrocardiography and Arrhythmias Committee of the Council on Clinical Cardiology, American Heart Association. *HeartRhythm* 2020;17:e233–41. <https://doi.org/10.1016/j.hrthm.2020.03.028>.
- Heart Rhythm Society. COVID-19 Task Force update: April 15, 2020; Available at: <https://www.hrsonline.org/COVID19-Challenges-Solutions/hrs-covid-19-task-force-update-april-15-2020>. Accessed April 20, 2020.
- Zhao S, Ling K, Yan H, et al. Anesthetic management of patients with COVID-19 infections during emergency procedures. *J Cardiovasc Anesth* 2020;34:1125–31.
- Ambulatory Surgery Center Association. COVID-19: American Society of Anesthesiologists recommendations for anesthesia management. Available at: <https://www.ascassociation.org/asca/resourcecenter/latestnewsresourcecenter/covid-19/covid-19-anesthesia-recommendations>. Accessed April, 20, 2020.
- American Society of Anesthesiologists. COVID-19. Available at: <https://www.asahq.org/in-the-spotlight/coronavirus-covid-19-information>. Accessed April, 21 2020.
- Orser B. Recommendations for endotracheal intubation of COVID-19 patients. *Anesth Analg* 2020;130:1109–10.
- Ierardi AM, Wood B, Gaudino C, et al. How to handle a COVID-19 patient in the angiographic suite [e-pub ahead of print]. *Cardiovasc Intervention Radiol* 2020. <https://doi.org/10.1007/s00270-020-02476-8>; Accessed.
- Crossley HG, Poole JE, Rozner MA, et al. The Heart Rhythm Society (HRS)/American Society of Anesthesiologists (ASA) Expert Consensus Statement on the perioperative management of patients with implantable defibrillators, pacemakers and arrhythmia monitors: facilities and patient management this document was developed as a joint project with the American Society of Anesthesiologists (ASA), and in collaboration with the American Heart Association (AHA), and the Society of Thoracic Surgeons (STS). *Heart Rhythm* 2011;8:1114–54.
- Heart Rhythm Society. COVID-19 Task Force update, March 27,2020 Available at: <https://www.hrsonline.org/hrs-covid-19-task-force-update-march-27-2020>. Accessed April 2, 2020.
- Optimizing the Supply of PPE: <https://www.cdc.gov/coronavirus/2019-ncov/hcp/ppe-strategy/general-optimization-strategies.html>. Accessed July 16, 2020.
- COVID-19 Control and Prevention: <https://www.osha.gov/SLTC/covid-19/controlprevention.html>. Accessed October 19, 2020.