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# Bedside Focused Cardiac Ultrasound in COVID-19 from the Wuhan Epicenter: The Role of Cardiac Point-of-Care Ultrasound, Limited Transthoracic Echocardiography, and Critical Care Echocardiography

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**Background:** Three cases of the application of focused cardiac ultrasound in patients with coronavirus disease 2019 are presented.

**Methods:** Cardiac point-of-care ultrasound, limited transthoracic echocardiography, and critical care echocardiography were applied in cases of heart failure, pulmonary embolism, and myocarditis with thrombus respectively.

**Results:** The impact on patient management and the global context of each presentation are discussed. **Conclusions:** Focused cardiac point-of-care ultrasound played an important, front-line role in the bedside management of patients during the COVID-19 pandemic in Wuhan, China. (J Am Soc Echocardiogr 2020;33:676-82.)

**Keywords:** Focused cardiac ultrasound, Point-of-care ultrasound, Critical care echocardiography, Limited transthoracic echocardiography, COVID-19 infection

The Wuhan Union Hospital is a large hospital system of three campuses in Wuhan, Hubei, China. The Union Hospital West Area was designated as the receiving site for febrile patients during the coronavirus disease 2019 (COVID-19) epidemic. Between January 23, 2020, and March 11, 2020, the Wuhan Hospital system accumulated 3,608 patients with presumed diagnoses of COVID-19. Seventy-eight ultrasound department staff members directly participated in the diagnostic care of these patients. Cardiac point-of-care ultrasound (POCUS), limited transthoracic echocardiography (TTE), and critical care echocardiography (CCE) all played key roles in the evaluation of cardiovascular complications associated with infection. Three select cases illustrate each of these applications of focused cardiac ultrasound in various settings and severity of disease. In each case, cardiac ultrasound was applied in context of the American Society of

Echocardiography protocol for POCUS,<sup>1</sup> American Society of Echocardiography recommendations for TTE,<sup>2</sup> or American Society of Echocardiography CCE and POCUS training recommendations.<sup>3</sup>

## CASE 1: DILATED CARDIOMYOPATHY

### Indication: Focused Cardiac Ultrasound at the Point of Care for Heart Failure Management

A 73-year-old man presented with 12 days of fever. Following hospital admission on February 6, 2020, he was diagnosed with novel coronavirus pneumonia (by ribonucleic acid testing). The patient did not have records of a medical history available, but he reported a history of heart failure. There was no history of coronary artery disease, diabetes, hypertension, cerebral infarction, acute coronary syndrome, tumor, kidney disease, or liver disease. There was no history of angiotensin-converting enzyme inhibitor or angiotensin receptor blocker therapy. Physical examination revealed blood pressure of 128/74 mm Hg, a heart rate of 72 beats/min, a temperature of 38°C, and normal oxygen saturation (97%). Upon lung auscultation, decreased breath sounds and crackles were noted.

### Initial Evaluation

Urgent pulmonary computed tomography (CT) revealed bilateral ground-glass attenuation suggestive of viral pneumonia. Laboratory findings revealed elevation of inflammatory indices (C-reactive protein 170 mg/L [normal range, 0.5–5 mg/L], erythrocyte

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Abbreviations
<b>BNP</b> = B-type natriuretic peptide
<b>CCE</b> = Critical care echocardiography
<b>COVID-19</b> = Coronavirus disease 2019
<b>CT</b> = Computed tomography
<b>PASP</b> = Pulmonary artery systolic pressure
<b>POCUS</b> = Point-of-care ultrasound
<b>TTE</b> = Transthoracic echocardiography

sedimentation rate 56 mm/h). The patient's B-type natriuretic peptide (BNP) level was significantly elevated at 1,077 pg/mL (normal range, <100 pg/L).

### Hospital Course

The patient continued to be febrile and to experience dyspnea but did not require ventilation. Given the findings on CT, elevated BNP, and symptoms, cardiac ultrasound was conducted on February 14, 2020, to rapidly assess left ventricular function, in a bedside, targeted assessment to help guide further

Doppler. Aortic regurgitation was thought to be severe by visual assessment but not fully quantified given the limits of the "quick-look" cardiac ultrasound scan (Figure 1, Supplemental Videos 1-4 available at [www.onlinejase.com](http://www.onlinejase.com)). Valvular function was only grossly assessed. Further time scanning was minimized on the basis of the findings.

### Management

Heart failure treatment was initiated with  $\beta$ -blockers and diuretics. Over the course of the next 4 days, the patient's symptoms diminished, and his BNP level decreased markedly.

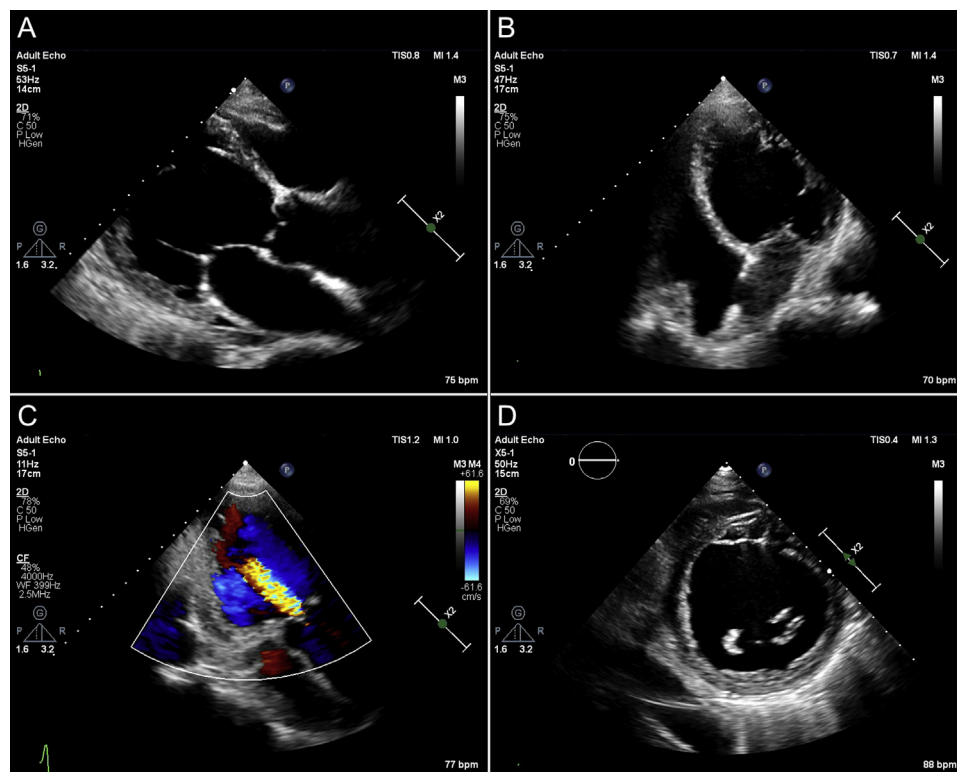
### Teaching Point 1: Application and Setting

Cardiac ultrasound at the point of care demonstrated the value of a rapid, bedside, binary assessment of the left ventricle, especially in a setting in which the cause of dyspnea is difficult to discern from the underlying respiratory condition. In some settings, such as in North America, such a bedside, quick-look scan would be described as cardiac POCUS. Cardiac POCUS to provide binary information can be achieved with limited training, often conducted with highly portable (handheld or mobile) devices, and can be performed by noncardiologists. In this case, full chamber and valvular function was not quantified using POCUS and was not required immediately, thereby limiting operator and/or sonographer exposure while affecting management. Comprehensive transthoracic echocardiographic

management and testing.

### Focused Cardiac Ultrasound

Bedside cardiac ultrasound revealed a severely enlarged and globular left ventricle with severe global impairment of systolic function. Left ventricular ejection fraction was estimated at 20%. Right ventricular size and function were normal. The aortic valve appeared structurally normal, but significant aortic regurgitation was noted on color



**Figure 1** (A) Parasternal long-axis view of the heart revealing a dilated left ventricle. (B) Apical four-chamber view of the heart revealing a dilated left ventricle with reduced function. Right ventricular function appeared normal. (C) Three-chamber view of the heart suggesting at least moderate aortic regurgitation. (D) Parasternal short-axis view of the heart near the base of the left ventricle confirming severe impairment of systolic function. See Supplemental Videos 1 to 4.

**HIGHLIGHTS**

- POCUS provided assessment of the left ventricle in a case of cardiomyopathy.
- Limited TTE suggested pulmonary embolism in context of deep vein thrombosis.
- Critical Care Echo demonstrated acute myocardial injury and thrombus.

evaluation of the degree of aortic regurgitation, if clinically warranted, could be attained at a later date, or in a targeted manner if the clinical status changes.

**Teaching Point 2: Patient Impact**

Cardiac ultrasound played an important role in guiding heart failure management. The decision to conduct cardiac ultrasound was based on the finding of symptoms and an elevated BNP level, known to be generally associated with an unfavorable course in heart failure and pneumonia. However, not all patients with elevated BNP may require evaluation or treatment for heart failure. In this case, the patient continued to be symptomatic, and cardiac POCUS affected management by suggesting the need for heart failure therapies. It is likely that aortic regurgitation and dilated cardiomyopathy were underlying conditions, but etiology could not be confirmed by this technique. Because of the severe shortage of medical resources during the pandemic, only one cardiac ultrasound examination was conducted during the hospital stay to answer a targeted clinical question. Thus, the etiology of aortic regurgitation was not fully determined but deferred for examination using comprehensive TTE at a later time following resolution of the pandemic.

**Teaching Point 3: Global Context**

It is not yet well established whether COVID-19 is correlated with dilated cardiomyopathy, and further study is required confirm this association. COVID-19, like many other acute illnesses, may play a role in unmasking or exacerbating underlying chronic cardiovascular conditions. Thus it has been suggested that excessive cytokine release syndromes might be occurring with the infection and this syndrome contributing to cardiac injury and cardiovascular events.<sup>4,5</sup>

**CASE 2: ACUTE PULMONARY EMBOLISM****Indication: Limited TTE for Assessment of the Right Ventricle**

A 69-year-old man presented to the hospital following 10 days of fever and 2 days of chest pain. The patient had been bedbound for >3 days. There was no history of hypertension, coronary artery disease, diabetes, hypertension, cerebral infarction, acute coronary syndrome, tumor, kidney disease, or liver disease. Upon admission on February 2, 2020, the patient was found to be positive for the novel coronavirus by nucleic acid testing and was diagnosed with viral pneumonia. Physical examination revealed blood pressure of 115/74 mm Hg, an elevated heart rate of 133 beats/min, a temperature of 37°C, and decreased oxygen saturation (85%) requiring invasive ventilation. Cardiac examination was noncontributory, although mild lower leg edema was noted.

**Initial Evaluation**

The patient's Geneva score was 3, and his Wells score was 2, suggesting high risk for deep vein thrombosis and pulmonary embolism. Laboratory tests revealed an elevated white blood cell count of  $10.5 \times 10^9/L$ , an elevated D-dimer level of 6.82  $\mu g/L$ , and a BNP level of 632 pg/mL (normal range, <100 pg/L). The patient required noninvasive ventilation. Given the presence of chest discomfort, tachycardia, D-dimer elevation, and leg edema, cardiac and lower leg ultrasound was recommended to assess for possible pulmonary embolism. The patient underwent bedside, limited TTE on February 17, 2020.

**Focused Cardiac Ultrasound**

Limited TTE showed that the right ventricle was severely enlarged, with severe impairment of function. The right atrium was mildly enlarged. There was moderate tricuspid regurgitation. Severe pulmonary hypertension was present, and pulmonary artery systolic pressure (PASP) was estimated at 74 mm Hg, assuming an elevated right atrial pressure (the inferior vena cava was >21 mm and collapsed <50%). Normal left ventricular size and systolic function were quantified (Figure 2, Supplemental Videos 5-7 available at [www.onlinejase.com](http://www.onlinejase.com)).

**Management**

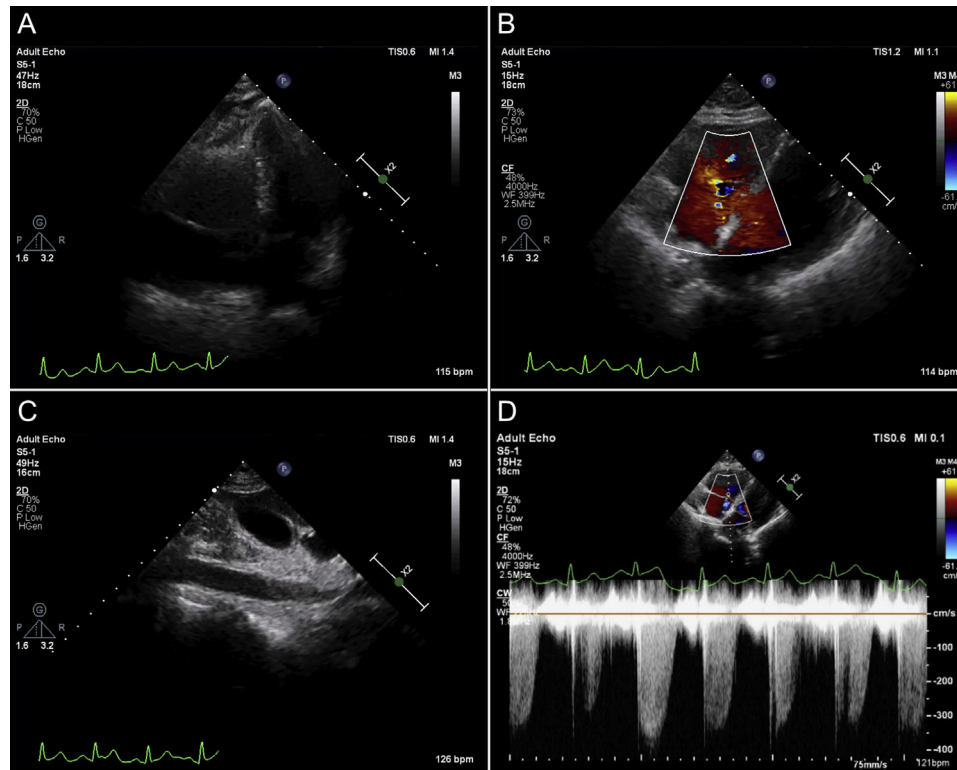
Ultrasound of the right lower extremity was conducted, revealing a hypoechoic region in the posterior tibial vein confirmed as a filling defect by color Doppler. In combination with the limited results of TTE, the patient was diagnosed with an acute pulmonary embolism in the context of a deep vein thrombosis and urgently managed as per the standard heparinization protocol, but the patient continued to deteriorate and succumbed to his illness.

**Teaching Point 1: Application and Setting**

In this case, limited TTE, in an intensive care unit setting, allowed visualization of the right ventricle, which is traditionally difficult to image. A highly skilled operator was able to visualize the right ventricle through modified views and obtain the highest tricuspid regurgitant jet velocity, required for estimation of PASP. Depending on the setting, such a skilled acquisition may be obtained by an echocardiographer (as occurs in China) or by a sonographer, typical for a North American setting. Along with performing maneuvers (sniff) to document inferior vena cava distensibility, such careful quantification may not be part of the repertoire of most non-cardiology-trained POCUS operators. TTE provides high-quality imaging, archiving, and quality control, along with expert interpretation of the presence of severe pulmonary hypertension, required for documentation of this serious condition necessitating treatment (anticoagulation) that can have risks.

**Teaching Point 2: Patient Impact**

This patient with viral pneumonia experienced acute pulmonary embolism in the context of deep vein thrombosis. Limited TTE differentiated between a right- and a left-sided heart lesion, leading to hemodynamic deterioration and the observed symptoms. Anticoagulation therapy was initiated on the basis of the results of this test alone, so high confidence in the presumed diagnosis was required. It is important to note that TTE is not typically the accepted approach for diagnosis of pulmonary embolism but provides indirect evidence. However, when confining patients to a COVID-19 isolation ward, the logistics of performing CT were felt to be challenging and too low yield given the disadvantages of patient transport, including personnel needed for transport, associated use of



**Figure 2** (A) Apical four-chamber view indicated enlargement of the right ventricle with impaired function. Right atrial enlargement was present. (B) Modified view of the right ventricle confirmed impaired function and detected moderate tricuspid regurgitation. (C) Subcostal view of the inferior vena cava demonstrated a dilated vessel that collapsed <50% suggesting increased right atrial pressure. (D) Continuous-wave Doppler of the tricuspid valve revealed elevated regurgitant velocity consistent with increased PASP. See Supplemental Videos 5 to 7.

personal protective equipment (PPE), and postprocedural cleaning required (several hours of cleaning the computed tomographic scanner after scanning a patient with COVID-19). Finally, we note that PASP was severely elevated, raising the possibility that beyond the diagnosis of acute pulmonary embolism, the differential diagnosis included the possibility of underlying pulmonary hypertension or recurrent pulmonary embolic disease.

### Teaching Point 3: Global Context

At this time, a prothrombotic risk associated with COVID-19 has been suggested but remains to be established. Preliminary analysis of our cohort during this pandemic has shown that in COVID-19, patients with deep vein thrombosis were sicker, were bedbound for longer, and had a significantly longer prothrombin time compared with patients who did not have deep vein thrombosis (unpublished data). It remains critical to understand and further investigate the direct association between COVID-19 and deep vein thrombosis.

### CASE 3: ACUTE MYOCARDIAL INJURY

#### Indication: CCE for Diagnosis of Extent of Myocardial Injury and Anticoagulation Management

A 45-year-old woman presented to the hospital following 7 days of fever and 1 day of chest pain. She had been bedbound for 3 days. The patient did not have records of a medical history available, but she reported a history of hypertension. COVID-19 nucleic acid test results were positive, and the patient was

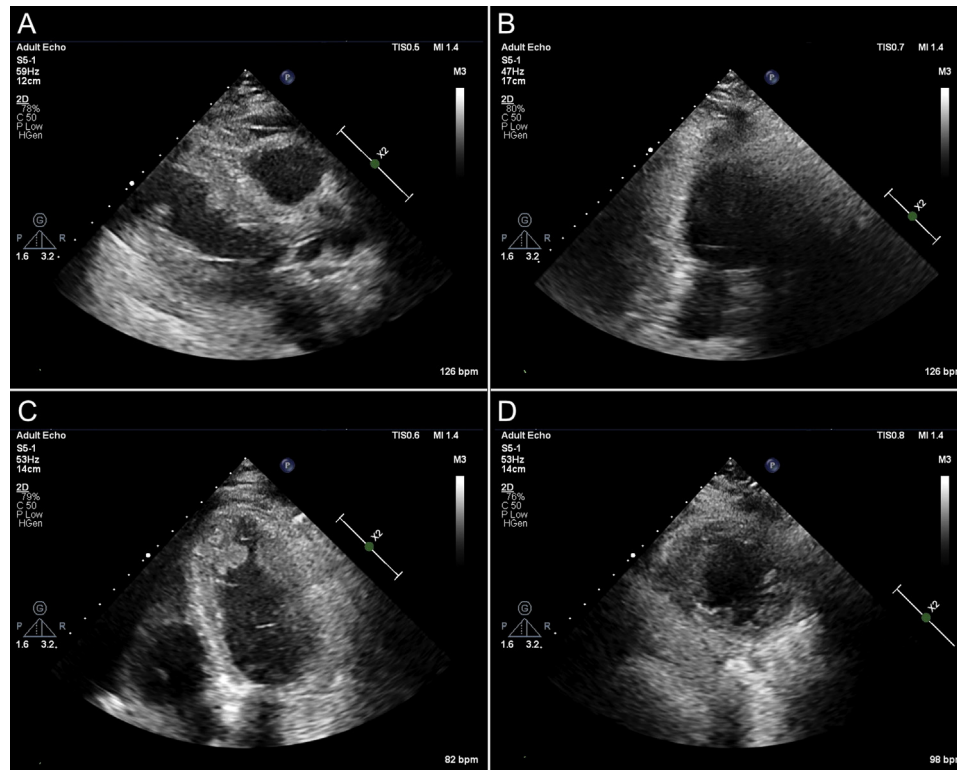
admitted for viral pneumonia. Physical examination revealed blood pressure of 111/73 mm Hg, a heart rate of 118 beats/min, a temperature of 38.5°C, and initially normal oxygen saturation (99%), and the patient did not require invasive ventilation. Lung auscultation revealed coarse breath sounds, and cardiac auscultation was otherwise unremarkable.

### Initial Evaluation

Laboratory tests revealed a white blood cell count of  $11.7 \times 10^9/L$ , an elevated high-sensitivity troponin I level of 9,889.4 ng/L (normal range, <100 ng/L), and a BNP level of 632 pg/mL (normal range, <100 pg/L). Electrocardiography was noncontributory. The patient did not require invasive ventilation but was admitted to an intensive care setting. Cardiac ultrasound was indicated to evaluate the history of chest pain and significant elevation of troponin in the context of acute respiratory distress syndrome. A targeted ultrasound examination was conducted in the critical care unit on the basis of the patient's medical history, clinical condition, and laboratory findings.

### Focused Cardiac Ultrasound

Left ventricular size was normal. There were extensive wall motion abnormalities involving the basal to apical anterior walls. There was an apical aneurysm with a mural thrombus. Left ventricular ejection fraction was significantly reduced and visually estimated at 45%. There were no significant valvular abnormalities (Figure 3, Supplemental Videos 8-11 available at [www.onlinejase.com](http://www.onlinejase.com)).



**Figure 3** (A) Parasternal long-axis view demonstrating wall thickening and moderate impairment of systolic function. There was a basal anterior wall motion abnormality. (B) Partial apical four-chamber/two-chamber view demonstrating extension of wall motion abnormality into the apex with likely aneurysm (best visualized in [Supplemental Video 9](#)). (C) Apical four-chamber view demonstrating the presence of a large apical thrombus. (D) Parasternal short-axis view proximal to the apex demonstrating impairment of systolic function. See [Supplemental Videos 8 to 11](#).

### Management

Given the diagnosis of acute myocardial injury, an acute coronary syndrome protocol with heparinization was administered. Beta-blockade for myocardial protection was begun. CCE was repeated 14 days later. The segmental wall motion abnormality was still present, and the mural thrombus appeared to be larger. Anticoagulation therapy was continued. After resolution of pneumonia, the patient was discharged in stable condition.

### Teaching Point 1: Application and Setting

The application of CCE by skilled operators in the intensive care unit allows the treating physician to make a clinical determination of an often complex hemodynamic scenario. The presence of this skill allows serial assessment by operators who are already present in the unit, without having to expose sonographers or other operators not normally functioning in those units. In this case, CCE provided good visualization of wall motion abnormality, often one of the most challenging skills in echocardiography. Most important, the thrombus was clearly visualized in this setting at baseline and with serial study.

### Teaching Point 2: Patient Impact

In this case, echocardiography was conducted because of symptoms and an elevated troponin level. COVID-19 may be associated with segmental wall motion abnormalities and the consequent sequelae of aneurysm formation and thrombus. CCE played a role in the decision to initiate anticoagulation and provide myocardial protective

therapy. It is important to note that as of yet, there are no clear guidelines for the performance of cardiac ultrasound in the context of troponin elevation. Troponin elevation and chest pain appear common in severe cases of COVID-19, but this may not always necessitate cardiac ultrasound. Finally, in this particular case, it was difficult to discern whether there was a new wall motion abnormality or whether the thrombus was present previously. Thus, the chronicity of the findings is not clear, in part because of the lack of availability of previous medical charting and echocardiography. This represents an important challenge a COVID-19-designated hospital may face in a crisis situation when serving patients referred from a wide geographic region, especially if medical records from other facilities are not readily available.

### Teaching Point 3: Global Context

The mechanisms of myocardial injury in COVID-19 are not well understood but are thought to be due to direct myocardial tissue damage rather than coronary obstruction, similar to other acute and viral respiratory illnesses. In the case presented, left ventricular dysfunction was segmental. Thus, in addition to fulminant myocarditis, acute myocardial infarction triggered by the infection may have been a possible underlying mechanism, due to either plaque rupture or segmental injury from supply-demand mismatch. It has recently been proposed that stage III, or the extrapulmonary stage, of COVID-19 represents a host inflammatory response during which multiple-organ dysfunction may ensue.<sup>6</sup> Typically this stage may be characterized acute respiratory distress syndrome, shock, and cardiac failure. This stage is associated with elevation of inflammatory



**Figure 4** Patients with confirmed COVID-19 were managed in isolated units. Ultrasound equipment was dedicated to the units and consisted of a variety of applications from handheld mobile devices to full-service machines. All scans were conducted by trained individuals in full PPE.

markers, troponin, and BNP. Further investigation is required to delineate the mechanisms of disease at this stage.

### **GENERAL DESCRIPTION OF ULTRASOUND SERVICES AT WUHAN HOSPITAL**

#### **COVID-19 Units**

All patients presenting or referred to our Western Hospital were severely ill patients with coronavirus pneumonia requiring management in a critical care or intensive setting. During the epidemic, all focused ultrasound scans were performed at the bedside in dedicated, isolated COVID-19 units, providing targeted information in real time.

#### **Scanning Procedures**

All personnel wore full PPE when entering the COVID-19 ward to conduct ultrasound (Figure 4). PPE was changed between patients and whenever leaving. Typically focused ultrasound scans were completed in <30 min but could extend up to 1 hour. Conducting scans in a fully protected state (wearing protective clothing, double gloving, masks, goggles, face shields) added time. Donning and off-

ing PPE, cleaning, and planning a targeted examination added time, even though these were focused studies. Some scans were abbreviated to provide only binary information, similar to POCUS. However some required more quantitative data as per limited TTE. Patients undergoing mechanical ventilation in our practice do not require being kept in the prone position for prolonged periods of time, so all scans were conducted in the supine position.

#### **Personnel and Equipment**

All scans were conducted by trained individuals who were either caring for the patients or who then provided their findings immediately to the treating physician directly in the COVID-19 isolation unit. Simultaneously, images were stored in the ultrasound machine. At the end of the day, following inspection and cleaning, images were copied to hard disk and saved in Digital Imaging and Communications in Medicine or JPG format for later viewing. A variety of handheld, portable, and full-service machines were used. All devices were dedicated to the COVID-19 unit and did not leave that unit. After each scan, device probes were cleaned with hydrogen peroxide disposable wipes. After each day of scanning, the entire device or machine was stored in a dedicated room for ultraviolet

disinfection and air disinfection. Once a machine entered the COVID-19 ward, it remained in that ward and was not shared with any other parts of the hospital.

## DISCUSSION

The goal of this case series is to illustrate the variety of applications for focused cardiac ultrasound during the COVID-19 pandemic. All cases demonstrate the targeted nature of the scans providing real-time, bedside information affecting subsequent management. In the first case, cardiac POCUS provided binary information with respect to the presence of left ventricular dysfunction. A valvular lesion was noted but not fully quantified given the limits of this application of cardiac ultrasound. Nor was this information immediately required for the management of the patient, thus reducing operator and sonographer exposure. In the second case, pulmonary embolism was suspected, and given the challenge of assessing the right ventricle, application of conventional limited TTE provided a high-quality diagnostic evaluation of this chamber and quantified an estimate of PASP. The third case, conducted in the setting of acute respiratory distress syndrome, warranted CCE, which revealed complex disease. Serial imaging was performed, triggered by a change in clinical status. In each case, cardiac ultrasound was performed when indicated and when findings were thought to affect the subsequent clinical management decision. Judicious use of cardiac ultrasound can minimize exposure risk for sonographers, operators, and patients. The use of cardiac ultrasound, when not appropriate, may not only increase the risk for contagion but use resources, such as PPE, cleaning supplies, and equipment required to manage critically ill patients. The American Society of Echocardiography has developed a statement on the protection of patients and echocardiography service providers during the 2019 novel coronavirus outbreak, with an additional supplement focused on CCE and POCUS.<sup>7</sup>

## CONCLUSION

Cardiac ultrasound plays an important role in guiding the management of the cardiovascular disorders that may accompany infection with the novel coronavirus, but the true extent of cardiac involvement in COVID-19 is not yet known. This case series illustrates the role of ultrasound when there was suspicion of cardiac disease applied in three distinct settings: POCUS, limited conventional TTE, and CCE. Although the work flow model in a Chinese setting is based on acquisition by echocardiographers, the indications and protocols can be translated to other settings in which a diverse array of practitioners

may apply ultrasound in an identical manner. In each case, given the serious risk and consequences of contagion with COVID-19 infection, cardiac ultrasound was conducted at an inflection point, in light of symptoms or objective abnormal parameters, and when findings directly affected subsequent management.

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## SUPPLEMENTARY DATA

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.echo.2020.04.004>.

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