

Review Article



Things You Should Know in the Performing Echocardiographic Examination in Patients with COVID-19

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Conflict of Interest

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ABSTRACT

Novel coronavirus disease 2019 (COVID-19) is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and it has become a pandemic problem. Cardiovascular diseases are common in COVID-19 patients, especially in severe forms of infection, and these are associated with higher mortality. SARS-CoV-2 infection can cause cardiovascular disease and worsen preexisting disease by direct invasion, hypoxia associated with pneumonia, and immunologic mechanisms. Because prompt detection and proper treatment can be critical to COVID-19 patients, echocardiographic examinations are essential diagnostic tools in the diagnosis and determination of treatment options. However, because there is an increased risk of infection during echocardiographic examinations, healthcare providers should pay attention to mitigate the risk of infection during the diagnosis and management of COVID-19 patients.

Keywords: Echocardiography; COVID-19; Cardiovascular disease

INTRODUCTION

Novel coronavirus disease 2019 (COVID-19) is a pandemic issue and the number of COVID-19 patients reached 30 million globally in September 2020.^{1,2)} Because cardiovascular disease is a prevalent disease and a leading cause of death, there may be a substantial number of patients with cardiovascular disease and COVID-19. Moreover, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the etiology of COVID-19, can cause not only viral pneumonia but also major damage to the cardiovascular system.

Cardiovascular diseases are common in COVID-19 patients. These cardiovascular diseases can be seen as worsening of previous diseases by SARS-CoV-2 infection and/or newly developed diseases caused by the viral infection itself. In a USA study with 5,700 patients, 56.6% had hypertension, 41.7% obesity, 33.8% diabetes, 11.1% coronary artery disease, and 6.9% chronic heart failure.³⁾ SARS-CoV-2 can increase patient vulnerability to the cardiovascular morbidities exacerbated by COVID-19 infection. Underlying cardiovascular disease was associated with a 5-fold higher mortality risk in China.²⁾ The virus can damage cardiovascular tissue via direct invasion into cardiomyocytes and blood vessels. Also, the viral

infection can activate immunologic processes that can cause cardiovascular diseases.⁴⁾⁵⁾ Thus, COVID-19 patients frequently have various forms of cardiovascular disease.

Echocardiography is the most commonly used imaging modality in the detection of many cardiovascular problems. It can play an important role in the detection of cardiovascular disease and the determination of treatment strategies. However, performing echocardiography can expose healthcare providers to the risk of infection. Thus, we should pay attention to mitigate the possibility of infection by use of personal protection equipment. Also, sonographers should be aware of the cardiovascular effects of SARS-CoV-2 infection.

In this review article, I want to mention several things that we should know about the echocardiographic examination of COVID-19 patients.

WHO CAN RECEIVE AN ECHOCARDIOGRAPHIC EXAMINATION?

Echocardiographic examination should be considered in COVID-19 patients who present with cardiovascular symptoms and signs. These include chest pain, dyspnea, cardiogenic shock, change in electrocardiography, and elevation of cardiac biomarkers.

Chest pain is a frequent symptom in patients with COVID-19. If it is poorly localized and associated with exercise, the possibility of coronary artery disease increases, especially in patients with electrocardiographic changes suggestive of myocardial ischemia. Because the presence of viral pneumonia can cause pleuritic chest pain and make the differential diagnosis more difficult, the echocardiographic examination can give clues for accurate diagnosis. During echocardiographic examinations, echocardiographers should pay attention to find regional wall motion abnormalities (in coronary artery diseases), pericardial effusion (pericarditis) and right ventricular dysfunction with the presence of pressure overload (pulmonary embolism).

Dyspnea is one of the frequent symptoms seen. Of 1,099 adult COVID-19 patients in China, 18.7% presented with dyspnea.⁶⁾ The proportion of dyspnea cases increases with increasing disease severity.⁷⁾ Because dyspnea is associated with high mortality especially in patients with advanced age and hypertension,⁸⁾ patients who have cardiovascular disease including acute cardiac injury and heart failure should be carefully evaluated. Echocardiographic examinations should assess left and right ventricular function (in heart failure), regional wall motion abnormalities (in coronary artery disease), and right ventricular dysfunction with pulmonary artery pressure (in pulmonary embolism).

Shock is a relatively frequently encountered problem, and its incidence is about 67% in COVID-19 patients requiring intensive care.⁹⁾ Patients with shock have increased mortality. There are 4 types of shock including cardiogenic, obstructive, hypovolemic, and distributive, and these can be seen in COVID-19 patients.¹⁰⁾ In patients with shock, echocardiographic examination can differentiate the cause of shock. Echocardiographers should assess left ventricular size, systolic and diastolic function, right ventricular size and function, presence of significant valvular heart disease, regional wall motion abnormalities, flow acceleration of the left ventricular outflow tract with color Doppler, amount of pericardial effusion, and the size of the inferior vena cava and its collapsibility. **Table 1** lists common echocardiographic findings that can be found in shock patients.

Table 1. Common echocardiographic findings can be found in shock patients

Type of shock	Disease category	LV size	LV systolic function	RWMA	VHD	RV size	RV systolic function	PE	IVC size	Memo
Cardiogenic	Myocardial infarction	N or ↑	N or ↓	++	Variable	N or ↑	N or ↓	–	Variable	RWMA not consistent with coronary territory
	Myocarditis	N	N or ↓	–	Variable	N or ↑	N or ↓	– or +	Variable	
	SCMP	N or ↑	↓	+	Variable	N or ↑	N or ↓	–	Variable	
Obstructive	Tamponade	N or ↓	N or ↑	–	Variable	N or ↓	N or ↑	++	↑↑	Impaired diastolic function; respiratory variation of MV and TV inflow
	Pulmonary embolism	N or ↓	N	–	Variable	N or ↑	↓	–	↑↑	Clots sometimes seen; short PA acceleration time; dilated PA
Hypovolemic	Dehydration, vomiting, hemorrhage	↓	N or ↑	–	Variable	N or ↓	N or ↑	–	↓	Kissing LV
Distributive	Sepsis, cytokine storm, anaphylaxis, neurogenic	Variable	Variable	–	Variable	Variable	Variable	–	Variable	

IVC: inferior vena cava, LV: left ventricle, MV: mitral valve, N: normal, PA: pulmonary artery, PE: pericardial effusion, RWMA: regional wall motion abnormality, RV: right ventricle, SCMP: stress-induced cardiomyopathy, TV: tricuspid valve, VHD: valvular heart disease.

Electrocardiographic changes can be one of the indications for undertaking investigations into possible cardiovascular diseases. One study reported ventricular tachycardia/ventricular fibrillation was seen in 11 of 187 patients (about 5.9%) and was associated with myocardial injury.¹¹⁾ The presence of atrial fibrillation might be associated with hypoxemia and systemic inflammation. Because changes in the ST-segment or newly appeared T wave changes can be associated with myocardial injury,¹²⁾ cardiac biomarkers and echocardiographic examination should be performed to diagnose the type of cardiac injury.

Injury to cardiomyocytes can lead to an increase in cardiac troponins, and hemodynamic stress to cardiac chambers can increase the concentration of B-type natriuretic peptide (BNP) and N-terminal B type natriuretic peptide (NT proBNP). The concentrations of cardiac troponins and BNP/NT proBNP can be used in the differentiation of cardiac problems.

Concentrations of cardiac troponins can increase as a result of pre-existing cardiac diseases and/or acute cardiac injury associated with COVID-19. In previous studies, about 7%–28% of patients had elevated concentrations of cardiac troponins, especially in patients admitted to the intensive care unit and in patients who later died.⁹⁾¹¹⁾¹³⁾¹⁴⁾ Generally, it is not recommended to do a work-up or treatment for myocardial injury in patients with mild elevations of cardiac troponins < 2–3 times the upper normal limit. However, diagnostic work-up should be performed in patients with strongly suggested angina chest pain and/or electrocardiographic changes suggesting myocardial damage even though they have a mild elevation of cardiac troponins. Patients with marked elevations in cardiac troponins > 5 times the upper normal limit, should require work-up for myocarditis, stress-induced cardiomyopathy, or type I myocardial infarction triggered by SARS-CoV-2 infection.¹⁴⁾¹⁵⁾¹⁷⁾¹⁸⁾ Echocardiographic examination should be considered in patients without typical symptoms or electrocardiographic changes in myocardial damage.

BNP/NT proBNP is a quantitative cardiac biomarker that indicates hemodynamic stress, and it can be a useful marker of heart failure. The concentrations of BNP/NT proBNP can be associated with pre-existing cardiovascular disease and/or acute stress associated with COVID-19.¹⁴⁾¹⁹⁾²⁰⁾ Increased NT proBNP (> 88.64 pg/mL) was associated with high mortality in COVID-19 patients.²¹⁾ However, a routine check of BNP and cardiac troponins are not recommended in current practice guidance.

ECHOCARDIOGRAPHIC EXAMINATIONS IN COVID-19 PATIENTS

The echocardiographic examination can give diagnostic information and treatment guidelines for general clinical practice. It should be performed in patients with high suspicion of cardiovascular disease, evidence of increased concentration of cardiac biomarkers, and electrocardiographic changes. However, echocardiographic examination in patients with COVID-19 requires the protection of healthcare providers from infection as well as the prevention of infection that can be spread through the echocardiographic machine. Thus, we should avoid performing transthoracic echocardiographic examinations in patients in whom the echocardiographic finding does not change the management strategy. Point-of-care ultrasound (POCUS) can assess the heart, chest, and vessels and it can give useful information. POCUS may determine the need for other subsequent diagnostic tests including formal echocardiography, computerized tomography, or coronary angiography.²²⁾ Because transesophageal echocardiography has increased risks for the spread of SARS CoV-2 due to aerosolization of large viral loads, it should be performed only in the case where other alternative imaging modalities are not available.

In order to reduce infection, decontamination of echocardiographic machines is essential after echocardiographic examination. However, it is difficult to decontaminate a full echocardiographic platform and takes a lot of time and effort. Thus, handheld echocardiographic devices can be alternatives to conventional echocardiographic machines for the management of COVID-19 patients. In one study that compared conventional echocardiographic machines and handheld devices, limited echocardiographic examinations were successfully used to screen for cardiovascular conditions in COVID-19 patients.²³⁾ The authors reported that handheld echocardiographic examinations are sufficient to give information required for the management of COVID patients while reducing examination time (79% less time) and sonographer exposure.

WEARING PERSONAL PROTECTIVE EQUIPMENT IS CRUCIAL TO MITIGATE THE POSSIBILITY OF INFECTION

Because the infectivity of SARS-CoV-2 is high, healthcare workers are exposed to an increased possibility of infection. In one study performed in the Netherlands, 86 subjects (0.9%) had positive tests for SARS-CoV-2 among 9,705 healthcare workers at 2 teaching hospitals.²⁴⁾ Only 3 of them had direct exposure to a patient positive for COVID-19. Another study showed 110 subjects (1.1%) tested positive for the virus among a total of 9,684 healthcare workers.²⁵⁾ Wu et al.²⁾ reported that 1,716 (3.8%) of 44,672 healthcare providers in China tested positive for the virus. Thus, healthcare providers should pay attention to prevent infection during the echocardiographic examination.

The degree of protection should vary depending on the risk of infectivity. During the echocardiographic examination in COVID-19 patients, echocardiographers should put on a disposable surgical cap and a medical protective mask (FFP2, FFP3, or N95). Personnel should put on inner disposable gloves, goggles or a facial field, protective gown, and outer disposable gloves. Echocardiographers should focus on gathering only the images needed to answer clinical questions to reduce the examination time. Wearing personal protective equipment is very hot and uncomfortable for healthcare providers. Also, goggles or facial

shields can be blurred by breathing within the protective mask. Therefore, if possible, it is recommended to reduce the examination time by only acquiring absolutely necessary images.

After the echocardiographic examination, echocardiographers should pay attention to prevent the spreading of infection during the removal of personal protective equipment. First, echocardiographers should replace outer gloves with new ones. Then, personnel should remove the protective gown along with outer gloves, take off goggles, mask, and cap, and remove inner disposable gloves. Hands should be well sanitized at every stage.

SEVERAL CARDIOVASCULAR MANIFESTATIONS CAN BE IDENTIFIED DURING ECHOCARDIOGRAPHIC EXAMINATION IN PATIENTS WITH COVID-19

In one prospective international study of echocardiography that included 1,216 patients from 69 countries, 667 (55%) patients had abnormal echocardiographic findings including 479 (39%) with left ventricular abnormality, and 397 (33%) with right ventricular abnormality. There were 36 (3%) with new myocardial infarction, 35 (3%) with myocarditis, and 19 (2%) with stress-induced cardiomyopathy.²⁶⁾ Abnormal echocardiographic findings were associated with an immediate change in management compared with normal echocardiographic findings (45% vs. 20%, $p < 0.001$).

Acute myocardial infarction

ST-segment elevation myocardial infarction (STEMI) can be diagnosed by the presence of ST-segment elevation and symptoms compatible with myocardial infarction. Non-STEMI (NSTEMI) can be diagnosed in patients with elevated cardiac troponins without ST-segment elevation in the electrocardiographic examinations. Echocardiographic examinations are beneficial for the diagnosis of acute myocardial infarction, and they can find regional wall motion abnormalities consistent with coronary territories suggested by the electrocardiographic findings and complications associated with myocardial infarction including decreased left ventricular systolic function, mitral regurgitation, ventricular septal rupture, and pseudoaneurysm.²⁷⁾

Reperfusion treatment should be performed in patients with symptom onset < 12 hours and persistent ST-segment elevation in at least 2 contiguous electrocardiographic leads with reciprocal changes in the electrically opposite leads.²⁸⁾ In patients with NSTEMI, treatment should be performed according to the patients' risk. For patients at high risk, medical stabilization and an early invasive strategy should be used. Primary percutaneous coronary intervention (PCI) in patients with STEMI should be performed to ensure the safety of the interventional cardiologist team.²⁹⁾ Primary PCI can be delayed up to 60 minutes in cases where the implementation of protective measures is insufficient. The healthcare providers should wear a protective gown, goggles or face shield, and 2 gloves during the PCI. After the procedure, healthcare providers should remove protective gear properly to prevent the spread of SARS-CoV-2 infection.

Chronic heart failure

Left and right ventricular abnormalities are frequent problems in COVID-19 patients.²⁶⁾ In one study of 21 patients admitted to an intensive care unit for severe SARS-CoV-2 infection,

7 patients (33.3%) had dilated cardiomyopathy.¹⁸⁾ Patients with chronic heart failure have a higher risk of SARS-CoV-2 infection due to the presence of several cardiovascular risk factors and older age. Viral infection and subsequent bacterial infection are major precipitating factors for acute decompensated heart failure in patients with pre-existing heart failure.

The echocardiographic examination can show a dilated left ventricle with reduced ejection fraction in patients with heart failure and reduced ejection fraction. Some of them can show right ventricular dilatation and dysfunction. Functional mitral regurgitation and tricuspid regurgitation can be observed in some patients. Patients with heart failure with preserved ejection fraction can have normal or near-normal left ventricular systolic function. However, they have a dilated left atrium with altered mitral inflow velocities. BNP/NT proBNP level and changes in these values can be useful for the diagnosis of heart failure. Also, clinicians should find previous echocardiographic data and compare current findings with those if there is available data. Because patients with acute heart failure aggravated by infection have a high mortality rate,³⁰⁾³¹⁾ these patients should be treated carefully. Clinicians should maintain optimal medical therapies including angiotensin-converting enzyme inhibitors or angiotensin receptor blockers since there is insufficient evidence to discontinue these medications if beneficial to patients.³¹⁾

Acute heart failure

Acute heart failure may complicate the clinical features of COVID-19, especially in severe patients. Possible mechanisms that cause acute heart failure include acute myocardial ischemia, infarction or direct infection, acute respiratory distress syndrome due to severe pneumonia, acute kidney injury, stress-induced cardiomyopathy, tachyarrhythmias, and hypoxia. The presence of acute heart failure should be suspected in patients with new-onset symptoms, changes in the electrocardiogram, acute cardiomegaly and/or bilateral pleural effusion, and elevated BNP/NT proBNP levels.

Acute myocardial injury can be found in about 8% of COVID-19 patients, and the incidence is about 13 fold higher in severe patients cared for in intensive care units compared with severe patients cared for in non-intensive care units.³²⁾ The evidence of acute myocardial injury is present in 22%–31% of patients with severe SARS-CoV-2 infection.⁷⁾¹⁷⁾³³⁾ Echocardiography can aid the differential diagnosis of these patients by giving information on left ventricular function and wall motion abnormalities. Other imaging modalities including computerized tomography and magnetic resonance imaging can give additional information. Kim et al.³⁴⁾ showed this utility in a patient with increased cardiac troponins and BNP levels who was confirmed with acute viral myocarditis. Computerized tomography can give information on coronary artery disease as well as the thickness of the myocardium and perfusion status. Magnetic resonance imaging can give additional information about the myocardium and inflammation (**Figure 1**).

Stress-induced cardiomyopathy is a clinical syndrome with transient left ventricular systolic dysfunction, and it can be associated with emotional stress and physical stress.³⁵⁾ There is a female incidence predominance that is especially higher in postmenopausal women. The predominant symptoms include chest pain (> 75%) and/or dyspnea (about 50%).³⁶⁾ Electrocardiographic abnormalities can be seen in about 95% of patients, usually ischemic ST-segment changes with T wave inversion.³⁷⁾ Cardiac biomarkers can be elevated in more than 90% of patients,³⁸⁾ and peak troponin levels are generally less than 10 ng/mL.³⁶⁾ The incidence of stress-induced cardiomyopathy was reported to be 2% of 1,216 patients from

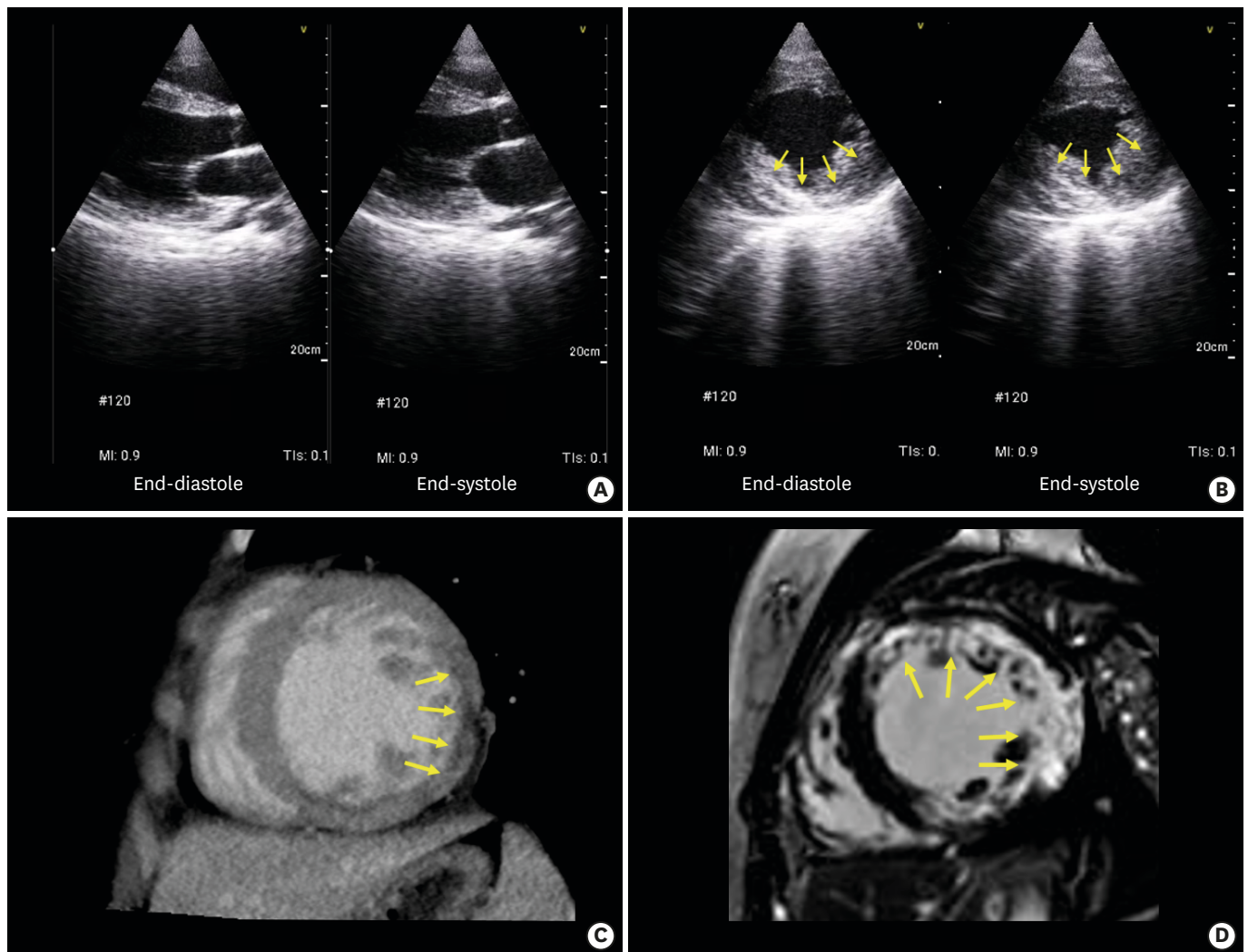


Figure 1. Point of care echocardiography in a patient with acute myocarditis in a 24-year-old woman with novel coronavirus disease 2019 (A, B). Parasternal long axis view showed decreased left ventricular systolic function with decreased wall motion abnormality at the posterior wall (A). Midventricular parasternal short-axis view demonstrated decreased wall motion of the posterior wall (B). Thin, hyperechoic myocardium was noted at the posterior wall of the left ventricle with a low-density area by cardiac computed tomography (arrows, C). Late gadolinium enhancement of the magnetic resonance image showed diffuse high signal intensity at the anterior, lateral, and posterior wall of the left ventricle (arrows, D). These images are provided by professor In-Cheol Kim from Keimyung University Dongsan Hospital, Keimyung University School of Medicine, Daegu, Republic of Korea.

69 countries.²⁶⁾ The echocardiographic examination is the preferred imaging test for the diagnosis of stress-induced cardiomyopathy. Typical type stress-induced cardiomyopathy shows apical ballooning with decreased left ventricular systolic function (**Figure 2**). The midventricular or basal segmental akinesis/dyskinesis is a variant of stress-cardiomyopathy.³⁵⁾ The diagnosis of stress-induced cardiomyopathy requires the absence of atherosclerotic coronary artery disease by coronary angiography. However, performing coronary angiography is difficult due to the risk of spreading infection in COVID-19 patients.

Acute right ventricular dysfunction

The possible etiologies of right ventricular dilatation and dysfunction include acute pulmonary embolism, right ventricular infarction, and flash pulmonary edema. The differentiation of right ventricular dysfunction from an acute pulmonary embolism and right ventricular infarction depends on the presence of regional wall motion abnormalities in

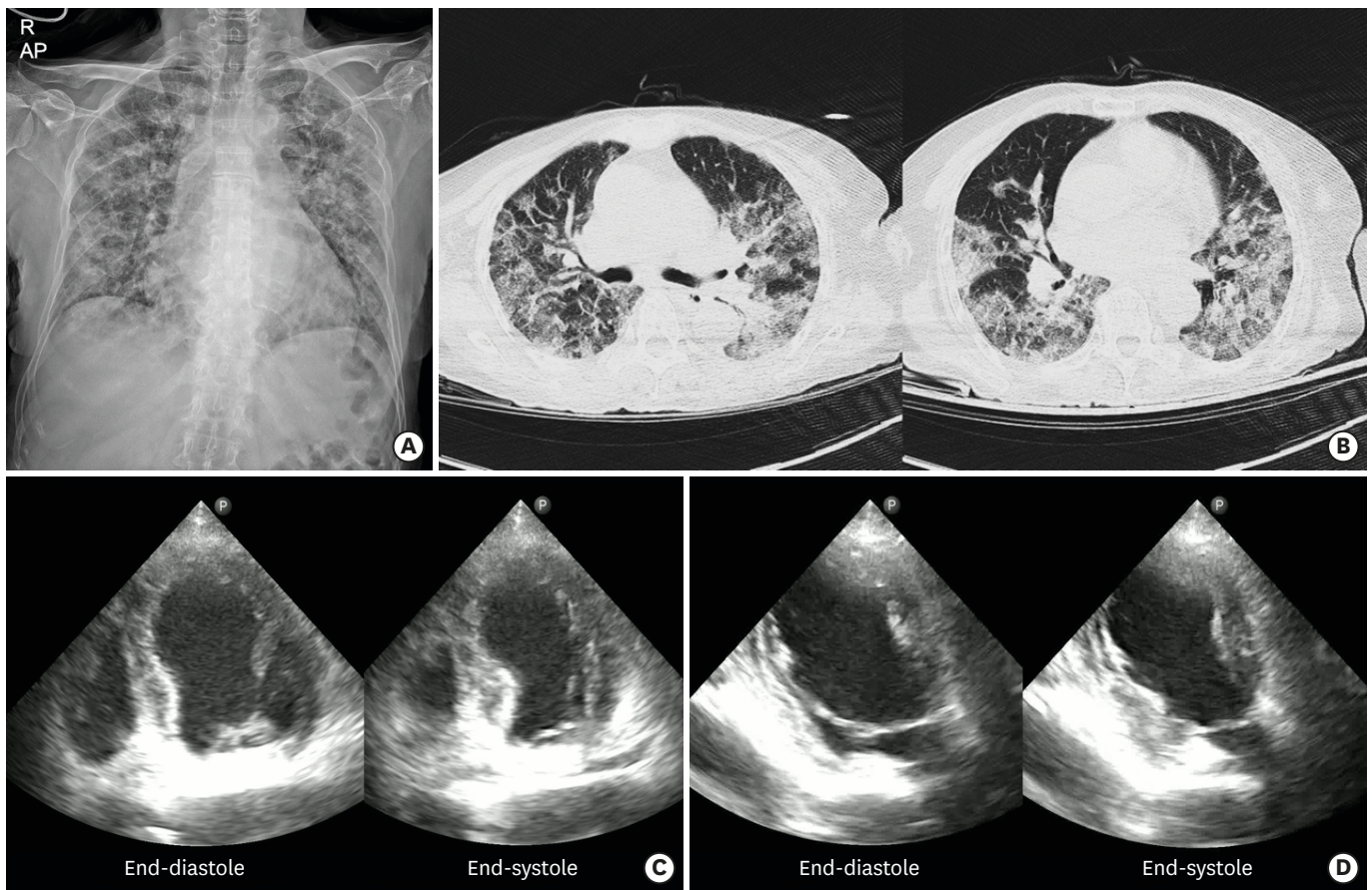


Figure 2. A typical case of stress-induced cardiomyopathy in a 73-year-old woman who required intensive care due to the novel coronavirus disease 2019. Chest X-ray shows diffuse ground-glass appearance suggesting viral pneumonia (A). Computerized tomographic scans demonstrate diffuse infiltration of bilateral lung fields (B). Apical 4- and 2-chamber views reveal apical ballooning with dyskinetic movement and severely decreased left ventricular systolic function (C, D).

the inferior wall on echocardiographic examination. Electrocardiographic findings can be used for this differentiation. The maximal velocity of tricuspid valve regurgitation can give information about the presence of pulmonary hypertension. However, the differentiation between pulmonary embolism and flash pulmonary edema requires additional imaging studies including contrast-enhanced computerized tomography or ventilation-perfusion single-photon emission computed tomography (SPECT), and the former can be diagnosed with thrombotic occlusion on the computerized tomographic scan and positive ventilation-perfusion defect on the ventilation-perfusion SPECT.

Pericardial effusion and cardiac tamponade

Various etiologies, including viral pericarditis, uremia, chest trauma, coagulopathy, and underlying malignancy, can result in pericardial effusion and subsequent cardiac tamponade.³⁹⁾⁴⁰⁾ Water-bag shaped cardiomegaly on the chest X-ray, and ST and T wave changes in the electrocardiogram can be seen. Echocardiographic examination can give information about the amount and hemodynamic status of this problem. Echocardiographic features suggesting cardiac tamponade include large pericardial effusion with swinging heart, the diastolic collapse of the right atrium and the right ventricle, respiratory variation in mitral E velocity > 25%, and inferior vena cava plethora without respiratory collapse. If echocardiographers find these signs, pericardiocentesis should be considered to relieve pericardial pressure.

CONCLUSION

SARS-CoV-2 infection has become a pandemic problem. Cardiovascular diseases are common in COVID-19 patients, especially in severe forms of infection. Because SARS-CoV-2 infection can cause cardiovascular disease and can worsen preexisting disease, prompt detection, and proper treatment can be critical to COVID-19 patient recovery. In the diagnosis and management of COVID-19 patients, healthcare providers should pay attention to mitigate the risk of infection.

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