Research Article

Echocardiographic Features in Patients with Critical COVID-19 Requiring Endotracheal Intubation

Vito Sollazzo[1†], Francesco Dibiase[1], Pietro Paolo La Torre[1], Wandisa Giordano[1], Dario Galante[2], Maria Lucia Pellegrino[2], Marisa Placentino[3]

ABSTRACT

Aim: COVID-19 has changed the way that we manage severe cardiorespiratory insufficiency caused by severe compromise of both the lungs and the cardiovascular system. The aim of this report is to share our experience of the use of echocardiography in patients with critical COVID-19 requiring endotracheal intubation.

Methods: We used transthoracic echocardiography for rapid evaluation of the hemodynamic status and for monitoring patient's responses to therapy and ventilator management. This enabled us to identify cardiac involvement that was unpredictable and complex.

Results: The main cardiac abnormalities found were hyperdynamic status, Tako-Tsubo syndrome, right ventricular dilatation and acute pulmonary hypertension, and myocardial injury.

Conclusion: The use of echocardiography in patients with COVID-19 is useful for diagnostic purposes. It is also useful for pulmonary management and is particularly useful for cardiac management.

Keywords: COVID-19; Echocardiography; Endotracheal intubation; Pulmonary hypertension

Abbreviation: CO: Cardiac Output; EF: Ejection Fraction; IS: Interventricular Septum; IVC: Inferior Vena Cava; LV: Left Ventricle; RV: Right Ventricle; SPBP: Systolic Pulmonary Blood Pressure

Introduction

On December 31, 2019, the World Health Organization (WHO) was alerted by the Public Health Commission of the province of Hubei, China, regarding some cases of severe pneumonia, of unknown etiology, characterized by symptoms such as fever, malaise, dry cough, dyspnoea and severe respiratory failure, which occurred in the urban area of Wuhan [1-3].

A new coronavirus strain, Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2), was identified as the cause of pneumonia, subsequently named coronavirus disease 2019 (COVID-19). Since then, the epidemic spread, initially to neighboring countries, such as Japan and South Korea, and then to other continents, with the first cases documented in Europe, in January and February 2020. On March 11, 2020, the WHO declared COVID-19 a pandemic.

As a result of the COVID-19 pandemic, the emergency unit and the Department of Intensive Cardiology Care at the hospital in Southern Italy suddenly faced a new emergency of managing patients with severe cardiorespiratory failure.

Chinese researchers had already issued a warning of serious involvement of the heart in patients with SARS-CoV-2 infection [4]. We witnessed a continuous flow of patients being admitted with heart problems, as well as lung problems, as the target organ of COVID-19.

The cardiac involvement had multiple mani-

[1]Cardiology Unit, Giuseppe Tatarella Hospital, ASL Foggia, Italy

[2]Anesthesia and Resuscitation Unit, Giuseppe Tatarella Hospital, ASL Foggia, Italy

[3]Cardiology Unit, T Masselli Mascia Hospital, ASL Foggia, Italy

[†]Author for correspondence: Vito Sollazzo, Cardiology Unit, Giuseppe Tatarella Hospital, ASL Foggia, Cerignola, 71042, Italy, E-mail: v.sollazzo@tiscali.it

festations, including acute coronary syndromes and myocardial infarction, the acute exacerbation of heart failure, myocarditis, and severe arrhythmias. Almost all the patients who required endotracheal intubation had evidence of cardiac involvement. As a result, we needed to perform a rapid assessment of patients, hemodynamic status in order to monitor their response to treatment. In our hospital, we introduced a serial echocardiographic evaluation with Point-Of-Care Ultrasound (POCUS) for patients with COVID-19 undergoing endotracheal intubation for severe respiratory failure with alkalosis, hypocapnia, severely reduced peripheral saturation and moderate-to-severe hypoxemia (<60 mmHg). This allowed our team to rapidly identify patients with cardiac involvement [5,6].

Methods

We used echocardiography to as a way to rapidly determine the hemodynamic status of intubated patients with COVID-19 using an echocardiographic examination protocol. We used 5 echocardiographic windows: the long parasternal axis; the short parasternal axis; 4 apical chambers; and 4 subxiphoid chambers and the subxiphoid Inferior Vena Cava (IVC).

In order to document patients, hemodynamic status, cardiac function, systemic perfusion, we measured the diameter of the IVC, the Ejection Fraction (EF) and the integral velocity time of the left ventricle, and the response of the hemodynamic status to the infusion of liquids, amines, and inotropes.

For hemodynamic management, we followed the 5 P-rule: central venous pressure; pulse rate; pump function; blood pressure to reach adequate organ perfusion as the final objective.

Results

The clinical characteristics of COVID-19 are related mainly to the severity of lung disease and cardiovascular complications. In the 30 patients with critical COVID-19 and endotracheal intubation, we have found the following cardiac abnormalities: 6 of them (20%) showed a hyperdynamic status; 4 patients (13%) a takotsubo syndrome; 12 patients (40%) a right ventricular dilatation and pulmonary hypertension and the last 8 patients (27%) a myocardial injury.

Hyperdynamic status is characterized by an increase in cardiac output and the EF, with or without a reduction of the peripheral vascular resistance. It generally occurs as the initial response to the disease and systemic inflammation.

Takotsubo syndrome is characterized by anomalies of segmental contractility with hyperkinesia of the base segments; apical ballooning of the left ventricle and a large reduction in the EF; functional mitral insufficiency; and cardiogenic shock [7,8].

Right ventricular dilatation and acute pulmonary hypertension occur secondary to internal factors, including alveolar damage, capillary and vascular thrombosis related to severe inflammatory and procoagulant status, hypocapnia as a result of inadequate ventilation and right ventricular afterload; and external factors such as an increase in the administration of vasoactive fluids and amines that lead to an increase in the right ventricular preload [9].

The myocardial injury occurs mainly in the terminal phase of the disease and is caused by prolonged severe hypoxia and incoercible inflammation with irreversible cardiac failure [10].

The correlation between clinical and echocardiographic characteristics in patients with COVID-19 undergoing endotracheal intubation and the probable underlying causes are shown in **Table 1**.

Discussion

Transthoracic echocardiography is of practical value in patients with COVID-19 who require intubation. It is useful for rapid assessment of cardio-circulatory status and the type of shock; monitoring of the right ventricular function; and monitoring of the left ventricular.

Shock can be classified into four types: redistributed shock; cardiogenic shock; hypovolaemic shock; and obstructive shock. Echocardiography in patients in critical condition is extremely useful for identifying the pathophysiological mechanism that underlies the shock and in order to guide the choice of treatment. In intubate patients with COVID-19 the most common types of shock are septic and cardiogenic. However, obstructive shock can occur due to factors such as pericardial effusion. Hypovolaemic shock is rare.

Table 1: Correlation between clinical and echocardiographic features of COVID-19 patients undergoing endotracheal intubation.

Clinical features and number of patients	Echocardiographic features	Causes
6 Patients with hyperdynamic status	Increase in CO and EF of LV with or without a decrease in peripheral vascular resistance	Cardiac stress in response to increased inflammation of the preload LV infusion of fluids, decreased LV afterload leading to a reduction in peripheral vascular resistance
4 Patients with Tako-Tsubo Syndrome	Hyperkinesia of the basal segments and apical ballooning of the LV, with functional mitral insufficiency	Increase in plasma catecholamines with microvascular dysfunction, inflammation, and spasm of epicardial vessels
12 Patients with right ventricular dilation and acute pulmonary hypertension	Dilation of the RV with D sign of the IS, tricuspid valve insufficiency, and increased SPBP	Increase in pulmonary vascular resistance caused by hypoxia, hypercapnia, inflammation and thrombosis, infusion of fluids, and inadequate ventilation
8 Patients with diffuse myocardial injury	Severe reduction of systolic and diastolic function of both ventricles	Severe hypoxia, prolonged anoxia, inflammation, and micro-vascular dysfunction. The low flow status is caused by widespread cardio-depression after cardiac arrest and reduction of peripheral resistance due to lactic acidosis

Patients with COVID-19 who require endotracheal intubation, often experience a rapid increase in vascular resistance due to hypoxia, pulmonary vascular spasm, hypercapnia and inflammation with a thrombotic component, and potentially fatal severe right ventricular dysfunction. However, inappropriate mechanical ventilation can lead to an increase in lung resistance with right ventricular dysfunction. The right ventricular function can easily be monitored with echocardiography which provides important information for the management of the respiratory and cardio-circulatory function.

COVID-19 pneumonia differs from SARS in which the damage, although severe, is confined to the lung. Intubated patients with COVID-19 generally have a multi-organ failure which can progress rapidly and is often fatal. In these patients, cardiac and pulmonary vascular involvement with the prevalent thrombotic component is often severe and may be caused by a cytokine storm. During hypoxia and respiratory distress, there may be a severe reduction of the global contractile function of the left ventricle due to the presence of anomalies of the local kinetics and widespread hyperkinesia. In the early phase, there is a hyperdynamic status, while patients with terminal diseases experience irreversible widespread cardio depression and cardiogenic shock with the low peripheral flow. Diffuse cardio depression can also occur as a result of prolonged hypoxia before and during the endotracheal intubation process, as well as subsequent to late or protracted cardiopulmonary resuscitation which inevitably leads to a marked reduction in peripheral vascular resistance caused by lactic acidosis.

In our case series, we have documented two cases of irreversible takotsubo syndrome in patients with no prior risk factors or known cardiovascular disease. This may have a sudden onset and be non-responsive to mechanical support systems such as intra-aortic counterpulsation and veno-arterial extracorporeal membrane oxygenation.

Conclusion

In our experience, transthoracic echocardiography should be an integral part of ultrasound in critical conditions. It is an extremely useful tool for assessing cardiovascular status, determining the type of shock, and guiding the ventilator management of patients with COVID-19 pneumonia. It is feasible, convenient, and useful in critically ill patients such as those undergoing endotracheal intubation, and those with severe cardiovascular impairment.

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