

Point-of-care ultrasound for COVID-19 pneumonia patients in the ICU

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Abstract

Background

Point-of-care ultrasound (POCUS) has a major role in the management of patients with acute hypoxic respiratory and circulatory failure and guides hemodynamic management. There is scarce literature on POCUS assessment characteristics in COVID-19 pneumonia with hypoxic respiratory failure.

Methods

The study is an observational, prospective, single-center study conducted in the intensive care unit of Adan General Hospital from May 1st, 2020, to June 25, 2020. The study included adults suspected to have COVID-19 transferred to the intensive care unit (ICU) with fever or suspected respiratory infection. Patients were transferred to the ICU directly from the ED or general medical wards after reverse transcriptase-polymerase chain reaction (RT-PCR) testing. A certified intensivist in critical care ultrasound who was blinded to the RT-PCR results, if available at the time of examination, performed the lung ultrasound and echocardiology within 12 hours of the patient's admission to the ICU. We calculated the E/e' , E/A ratio, left ventricular ejection fraction EF, IVC diameter, RV size and systolic function. We performed ultrasound in 12 chest areas.

Results

Of 92 patients with suspected COVID-19 pneumonia, 77 (84%) cases were confirmed. The median age of the patients was 53 (82-36) years, and 71 (77%) were men.

In the group of patients with confirmed COVID-19 pneumonia, echocardiographic findings showed normal E/e' , deceleration time (DT), and transmittal E/A ratio in comparison to the non-COVID19 patients (P .001 for both). The IVC diameter was <2 cm with $> 50\%$ collapsibility in 62 (81%) patients with COVID-19 pneumonia; a diameter of > 2 cm and $< 50\%$ collapsibility in all patients, with a P value of 0.001, was detected among those with non-COVID-19 pneumonia. There were 3 cases of myocarditis with poor EF (5.5%), severe RV dysfunction was seen in 9 cases (11.6%), and 3 cases showed RV thrombus.

Chest US revealed four signs suggestive of COVID-19 pneumonia in 77 patients (98.6%) (sensitivity 96.9%, CI 85%-99.5%) when compared with RT-PCR results.

Conclusion

POCUS plays an important role in bedside diagnosis, hemodynamic assessment and management of patients with acute hypoxic respiratory and circulatory failure in patients with COVID-19 pneumonia.

Introduction

Although the lung is the primary organ involved in COVID-19 infection, cardiac involvement is frequently reported in patients with acute hypoxic respiratory failure (1). Thus, rapid, bedside assessment of the heart and lung in point-of-care ultrasound (POCUS) provides a clinician

with a more accurate initial diagnosis for patients presenting with acute hypoxic respiratory failure in the context of the COVID-19 pneumonia pandemic.

The cardiac component of ultrasonic examination is technically challenging because the cardiac structures need to be imaged from multiple different scan planes, indirectly obtaining left ventricular filling pressure using Doppler. Echocardiography views are obtained along with noncardiac views such as the chest (lung, pleura) and inferior vena cava (IVC). In infection with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), POCUS may help confirm the diagnosis of COVID-19 pneumonia and triage dyspnoeic and hypoxic patients and determine the need for subsequent management.

Many modified versions of POCUS employ echocardiography in COVID-19 patients (2,3), but we preferred to add LV filling pressures and IVC, as it can inform our approach for fluid responsiveness. A modified version of the ASE POCUS protocol may be of value in suspected or confirmed COVID-19 infection (4).

Methods

Setting and study population

This is an observational, prospective, single-center study that was conducted in the intensive care unit of Adan General Hospital from May 1st, 2020, to June 25, 2020. The study protocol was approved by the Ethical Committee of the Ministry of Health in Kuwait; informed consent was obtained from every patient or from his or her next of kin.

Patients were included if they were age > 18, suspected to have COVID-19 and had been transferred to the ICU with fever or suspected respiratory infection plus one of the following: respiratory rate > 30 breaths/min; severe respiratory distress; SpO₂ < 93% on room air (5). Patients were admitted to the ICU directly from the ED after reverse transcriptase-polymerase chain reaction (RT-PCR) testing was performed at the central virology laboratory in Kuwait. Clinical data were entered on a separate standardized data collection form at the time of patient enrollment by the treating critical care physician. Clinical data included the patient's age and sex, presenting symptoms, medical history, oxygen saturation from pulse oximetry and chest radiograph. An intensivist certified in critical care ultrasound who was blinded to the RT-PCR results, if available at the time of examination, performed the lung ultrasound within 12 hours of the patient's admission to the ICU.

Lung ultrasound

We performed lung ultrasonography for every patient admitted to the ICU with COVID-19 suspicion using a 12-zone method (6). There were six zones for each hemithorax: two anterior, two axillary, and two posterior zones on each side. The anterior chest wall was defined as extending from the parasternal line

to the anterior axillary line. This zone was divided into upper and lower regions at the third intercostal space. The lateral area from the anterior to the posterior axillary line was divided into upper and lower halves. The posterior zone was identified from the posterior axillary line to the paravertebral line. The ultrasound images were saved to a hard drive and reviewed by a senior intensivist trained in critical care ultrasound. The ultrasound imaging was performed using a portable ultrasound machine (GE Vivid iq, Horten, Norway) equipped with a 3.5-MHz broadband curvilinear transducer. The probe was placed in an oblique position on the intercostal space, and the pleural line was centered in the middle of the image by adjusting the depth settings. The oblique position of the probe on the intercostal space allows visualization of a large portion of the pleural line without interruption by rib shadows.

Measurements

Pleural sliding and A-lines (repetitive lines parallel to the pleural line) on ultrasound are seen in normal healthy lungs (5). Interstitial syndrome is indicated by the presence of multiple B lines (more than three lines in one region). The four signs of COVID-19 pneumonia on lung ultrasound evaluation are as follows (6) (see Fig. 1, 2):

1. Bilateral B-lines in both separate and coalescent forms, sometimes patchy, frequently giving the appearance of a shining white lung. The B lines maintain their brightness until the end of the screen. They arise either directly from limited sliding pleura or from a small subpleural consolidation.
2. Bilateral diffuse irregularities of the pleural line.
3. Absence of significant pleural effusion.
4. Presence of multiple subpleural consolidations of various sizes.

Each lung zone was assigned a score to predict overall lung aeration (6). Score 0: predominant A-lines or < 3 separated B-lines. Score 1: at least three B-lines or coalescent B-lines occupying <_50% of the screen without a clearly irregular pleural line. Score 1p: at least three B-lines or coalescent B-lines occupying <_50% of the screen with a clearly irregular pleural line. Score 2: coalescent B-lines occupying > 50% of the screen without a clearly irregular pleural line. Score 2p: coalescent B-lines occupying > 50% of the screen with a clearly irregular pleural line. Score 3: large consolidations (at least > 1 cm).

Echocardiography

Elevated left ventricular filling pressure (LVFP) is indirectly evaluated by echocardiography, reflecting the myocardial relaxation and stiffness diseases of LV [8, 9]. Tissue Doppler imaging of early mitral annular velocity (e') is a good indicator of LV myocardial relaxation. After measuring the transmitral peak early filling velocity, E is the ratio of E/e' and is used as an indirect measure of LVFP. E/e' lateral > 12, E/e' mean > 13, or E/e' septal > 15 indicates elevated LVFP, whereas $E/e' < 8$ (any location) indicates normal LVFP [5].

In both systole and diastole, the E and e' velocities are measured from the apical four-chamber view by placing a 5-mm sample volume over the lateral or medial part of the mitral annulus to cover the longitudinal excursion of the mitral annulus. The velocity scale is set to approximately 20 cm/sec above

and below the zero-velocity baseline; we reduced to the minimum the angulation between the plane of cardiac motion and the ultrasound beam. The recommendation for spectral recordings is a sweep speed of 50 to 100 mm/sec at end expiration [8].

The average from 3 consecutive cycles was measured for all reported echocardiographic measurements. The LV volume and LV ejection fraction were assessed as recommended by the ASE (7). Mitral inflow was analyzed for peak E (early diastolic) and peak A (late diastolic) velocities, E/A ratio, and deceleration time of E velocity.

Data analysis: Statistical analyses were performed using Statistical Package for the Social Sciences (IBM SPSS 19). Patients with acute hypoxic respiratory failure admitted with suspicion of COVID-19 were divided into two groups: patients with confirmed COVID-19 pneumonia and patients with non-COVID-19 disease. Student's *t*-test was used to assess differences between the groups in the case of a normal distribution. Fisher's exact test was used for categorical data. Statistical significance was assumed at $P < 0.05$.

Results

Of 92 patients suspected to have COVID-19 pneumonia, 77 (84%) cases were confirmed. The median age of the patients was 53 (82 – 36) years, and 71 (77%) were men. The clinical characteristics of the patients in relation to COVID-19 pneumonia confirmation are shown in Table 1.

Table 1
Clinical characteristics of the patients

	Confirmed COVID-19 77 cases (84.4%)	Non-COVID-19 15 cases (15.5%)	Total 92 cases (%)	P value
Median age (IQR, years)	53 (82 - 36)	68 (25-80)		
Male	64 (83%)	7 (46%)	71 (77%)	0.005
Medical history				
IHD	9 (11%)	10 (66%)	19 (20%)	< 0.0001
CABC	2(2.6)	8(53%)	10 (10%)	0.001
Hypertension	20 (25%)	12 (80%)	32 (34%)	0.002
Diabetes mellitus	25 (32%)	14 (100%)	39 (42%)	< 0.0001
COPD	3 (3%)	3 (20%)	2 (2%)	0.02
Chronic renal impairment	25 (32%)	10 (66%)	10 (66%)	0.015
Cancer	0	1(6%)	1 (1%)	0.091
Status on admission to ICU				
Acute MI	2 (2.6)	10 (10%)	12 (13)	0.001
Acute PE	9(11.6)	0		0.186
Duration of symptoms (median in days)	5 (2-10)	2 (3-4)		
Hypoxemia	All	All	77 (100%)	0.02
PO ₂ /FiO ₂ (mean)	145	226		0.026
HFNC	35 (71%)	2(33%)	50 (64%)	0.002
IV	21 (27%)	4 (26%)	25(27%)	
Facemask	17(22%)	2 (13%)	19 (20%)	
SOFA score (mean)	7.7	6		0.39
Echocardiogram findings (mean)				
E/A	1.1	1.8		0.001

IHD: ischemic heart disease; HFNC: high-flow nasal cannula; IV: invasive ventilation; COPD: chronic obstructive pulmonary disease; SPC: subpleural consolidation

	Confirmed COVID-19 77 cases (84.4%)	Non-COVID-19 15 cases (15.5%)	Total 92 cases (%)	P value
DT	252	151		< 0.0001
E/E'	9.7	19		< 0.0001
LVEF	66	55		0.01
IVC < 2 cm	62 (80)	0		< 0.0001
IVC > 2 cm	15(19.4)	100		< 0.0001
US chest finding				
Aeration score	27	21		0.018
SPC	13	1		< 0.0001
IHD: ischemic heart disease; HFNC: high-flow nasal cannula; IV: invasive ventilation; COPD: chronic obstructive pulmonary disease; SPC: subpleural consolidation				

In the group of patients with confirmed COVID-19 pneumonia (Table 2), echocardiographic findings showed normal E/e', DT, and E/A in comparison to non-COVID19 patients (P 0.001 for both). The IVC diameter was < 2 cm with > 50% collapsibility in 62 (81%) patients with COVID-19 pneumonia, whereas patients with non-COVID-19 pneumonia had a diameter of > 2 cm and < 50% collapsibility, with a P value of 0.001. There were 3 cases of myocarditis with poor EF (5.5%), severe RV dysfunction was seen in 9 cases (11.6%), and 3 cases showed RV thrombus. Acute myocardial infarction was observed in 2 cases of COVID-19 pneumonia (2.5%) and acute CVA in 6 (6.5%). Pulmonary hypertension with normal RV systolic function was found in 11 patients (14%). We observed mild pericardial effusion with no constriction in 4 COVID-19 and nil in non-COVID-19 cases.

Chest US revealed four signs suggestive of COVID-19 pneumonia in 77 patients (98.6%) (sensitivity 96.9%, CI 85%-99.5%) when compared with RT-PCR results. The aeration score was significantly higher for COVID-19 pneumonia (P 0.018), as was the total number of subpleural consolidation in the 12 zones of the chest (P > 0.0001).

Discussion

POCUS is of great importance as a bedside tool for immediately identifying types of acute respiratory failure and shock with guided hemodynamic management. Many protocols have been adopted and validated (10, 11). Some protocols have adopted only LUS for fluid management and diagnosis of respiratory failure (12). In patients with COVID-19 pneumonia, LUS is utilized mainly for diagnostic

purposes and is difficult to apply for fluid assessment because of lung pathology. The most common types of shock in COVID-19 pneumonia patients are septic shock, cardiogenic shock and massive pulmonary embolism with right ventricular dysfunction (2). Hypovolemia and hypovolemic shock should always be considered and can be assessed with echocardiography. (decrease of cardiac output, hyperdynamic left ventricle," IVC collapse and high respiratory variability, LV filling pressures).

The frontline intensivist may grossly evaluate the level of LV filling pressure based on the qualitative interpretation of the mitral Doppler pattern (DT, E/A, E/E'), which helps in differentiation between hydrostatic pulmonary edema and acute respiratory distress syndrome (ARDS) (12). Accurate prediction of a predefined level of invasive pulmonary artery occlusion pressure (PAOP) by Doppler indices is of clinical value in ventilated and nonventilated patients presenting with acute respiratory failure (14). Accordingly, combined Doppler indices appear to be of additional value for estimating LV filling pressure, principally in critically ill patients with underlying cardiac diseases known to alter diastolic properties and predict reload fluid responsiveness (15). Our patients were characterized by normal filling pressures, in contrast to patients with non-COVID-19 pneumonia. In patients with COVID 19, pneumonia presenting with hypotension and normal filling pressures can allow fluid administration and follow-up of the response.

The size variations of the IVC (collapsibility and distensibility) with respiration can serve as a predictor of a patient's volume status. Greater than 50% collapse of the IVC correlates with intravascular volume depletion (16). Most of our patients had IVC > 50% change in diameter with respiration, except for patients with LV and RV dysfunction, which might indicate volume depletion at presentation. IVC variability combined with transmitral Doppler can assess the volume status of patients with circulatory instability and acute hypoxic respiratory failure.

The different forms of cardiac involvement observed in our prospective study are consistent with the cardiovascular disease observed in patients with other severe viral respiratory infections (17). Right ventricular dysfunction was observed in 11.6% of COVID-19 patients. Confirmed acute pulmonary embolism and right ventricular acute dilatation were observed in 9, and thrombus was seen in the right ventricle in 3 with acute deterioration, hypoxic respiratory and circulatory failure. These are likely to reflect severe respiratory disease in COVID-19 pneumonia and clinical and subclinical pulmonary thromboembolism due to coagulation dysfunction (18).

Left ventricular dysfunction was present (in one-third of patients) in the form of myocarditis and cardiogenic shock, pericarditis and acute myocardial infarctions. These results are in agreement with recent published data from ESC, though the pathology of LV dysfunction in COVID-19 needs more clarification (19).

The sonographic appearance of the lungs in COVID-19 patients depends upon the time course of the illness. We chose to assess patients with early signs after admission because the method is important for early diagnosis, and the results are expected to be unique to COVID-19 pneumonia before ARDS develops or secondary infection develops after admission to the ICU. Volipicilli et al. reported irregularity of the

pleural line, bilateral patchy distribution of multiform clusters of B lines, and multiple small peripheral consolidations (20). The aeration score was higher in COVID-19 pneumonia, and SPC counting was almost zero in non-COVID-19 pneumonia patients, suggesting it as a characteristic of sonographic findings for COVID-19 pneumonia.

The limitation of our prospective study is the small number of patients and unequal population between the groups in a single-center study.

Conclusion

The majority of patients with COVID-19 pneumonia have normal to low LV filling pressures based on echocardiography. POCUS plays an important role in bedside diagnosis, hemodynamic assessment, and management of patients with acute hypoxic respiratory and circulatory failure in patients with COVID-19 pneumonia. LUS may play an important role in the diagnosis of COVID-19 pneumonia.

Declarations

Disclaimers

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Contribution

Zouheir I Bitar wrote the article, M hsamsah, O Bamasood, O Madraani and Huda Alfoudri shared in the discussion and revision of the manuscript

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Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

Ethics approval and consent to participate

The study protocol was approved by the Ethical Committee of the Ministry of Health in Kuwait; informed consent was obtained from every patient or from his or her next of kin.

Consent for publication

Not applicable.

Availability of data

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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