Multiorgan Point-of-Care Ultrasound in a Patient With Coronavirus Disease 2019 Pneumonia Complicated by Subarachnoid Hemorrhage and Pulmonary Embolism

Alaa Haider, MD, Christoph Schmitt, MD, and Clemens-Alexander Greim, MD, PhD

Morbidity and mortality associated with the pandemic severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) disease (coronavirus disease 2019 [COVID-19]) are not only due to acute respiratory distress syndrome but also related to multiorgan involvement and dysfunction. In this report, we present a critically ill patient with severe COVID-19 pneumonia, during which he required extracorporeal membrane oxygenation and suffered from multiple complications. Bedside sonography became an important tool to manage the patient by adapting artificial ventilation parameters and played a key role in the diagnosis of thrombotic events and the monitoring of subarachnoid hemorrhage that unexpectedly complicated the case. (A&A Practice. 2020;14:e01357.)

Glossary

2D = 2-dimensional; ARDS = acute respiratory distress syndrome; COVID-19 = coronavirus disease 2019; CT = computed tomography; CTPA = CT pulmonary angiogram; DVT = deep vein thrombosis; ECMO = extracorporeal membrane oxygenation; ELSO = Extracorporeal Life Support Organization; EQUATOR = Enhancing the QUAlity and Transparency Of health Research; FiO₂ = fraction of inspired oxygen; ICU = intensive care unit; IVS = interventricular septum; LV = left ventricle; PE = pulmonary embolism; PEEP = positive end-expiratory pressure; POCUS = point-of-care ultrasound; PTT = partial thromboplastin time; RASS = Richmond agitation-sedation scale; RV = right ventricle; SAH = subarachnoid hemorrhage; SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2; SpO₂ = peripheral oxygen saturation; TCCS = transcranial color-coded duplex sonography; TTE = transthoracic echocardiography; VV = venenous

Morbidity and mortality associated with the pandemic severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) disease (coronavirus disease 2019 [COVID-19]) are not only due to acute hypoxic respiratory failure from acute respiratory distress syndrome (ARDS) but also related to multiorgan involvement and dysfunction.

We present a critically ill patient with COVID-19 pneumonia requiring mechanical ventilation and extracorporeal membrane oxygenation (ECMO). He suffered from deep vein thrombosis (DVT) followed by pulmonary embolism (PE). He also developed a subarachnoid hemorrhage (SAH) rarely reported as a possible complication in the course of COVID-19.

Point-of-care ultrasound (POCUS) played a key role in managing our patient. Ultrasound imaging not only minimized the potential harm of frequent transport of a highly infectious and cardiovascular unstable patient for diagnostic purpose but also uncovered complications and gave insights to the need for extensive multiorgan monitoring of critically ill COVID-19 patients. Written consent has been obtained from the patient. This manuscript adheres to the applicable Enhancing the QUAlity and Transparency Of health Research (EQUATOR) guideline.

Case Description

A 56-year-old White man with a history of arterial hypertension and a positive SARS-CoV-2 nasopharyngeal swab sample was admitted to our intensive care unit (ICU) due to worsening symptoms of dyspnea and hypoxic respiratory failure.

Physical examination on admission revealed a body temperature of 39.5 °C, no significant neurological abnormalities, a respiratory rate of 40 breaths per minute, peripheral oxygen saturation (SpO₂) of 88% with an oxygen mask flow rate of 15 L·min⁻¹, sinus tachycardia of 117 beats per minute, and blood pressure of 150/95 mm Hg. Laboratory findings showed marked lymphopenia, elevated C-reactive protein levels (22 mg/dL), a D-dimer of 1.2 µg/mL, normal procalcitonin levels, and a PaO₂/FiO₂ ratio of <100 mm Hg.

Respiratory Failure

Following endotracheal intubation, mechanical ventilation was started, and the patient was transferred to the radiology department for computed tomography (CT). Chest CT revealed ground-glass opacities and focal peripheral consolidations typical of COVID-19 pneumonia.
On ICU day 4, the Pao$_2$/Fio$_2$ ratio had dropped to 55 mm Hg despite compliance adjusted ventilatory support and kinetic therapy, including daily prone positioning and neuromuscular blockade. A bedside lung ultrasound examination showed increased diffuse bilateral confluent B-lines with pleural thickening and multiple small subpleural consolidations. Transthoracic echocardiography (TTE) revealed normal cardiac size and function.

In accordance with the Extracorporeal Life Support Organization (ELSO) COVID-19 guidelines, venovenous ECMO was established, and the correct position of the ECMO cannula was verified under sonographic guidance (Figure 1A). The previously started prophylactic unfractionated heparin dose was increased to a therapeutic partial thromboplastin time (PTT) level for ECMO therapy.

For physical examinations and assessment, we implemented a multiorgan POCUS protocol into our daily routine (Table). We used a mobile system for cardiac, lung, and vascular ultrasound (SPARQ, Philips, the Netherlands), which underwent meticulous pre- and postexamination disinfection according to the manufacturer recommendations. The POCUS examinations were performed by 2 highly-skilled ICU physicians certified in critical care ultrasound and focused TTE, and national and local guidance on personal protection equipment was followed.

During the period of ECMO therapy, the indications for prone positioning and positive end-expiratory pressure (PEEP) settings were based on the 12-point lung POCUS supported detection of dorsal consolidation and atelectasis. With this regime, the patient could be weaned from ECMO therapy on ICU day 18.

**DVT AND PE**

On ICU day 20, a routine 2-point vein compression ultrasound detected a thrombus formation in the contralateral femoral vein to the former ECMO access site (Figure 1B). Subcutaneous weight-adjusted prophylactic anticoagulation, which had been performed by fondaparinux, was increased to a therapeutic dose of 7.5 mg once daily.

On ICU day 22, the patient suffered from an unexplained worsening of the Pao$_2$/Fio$_2$ ratio with apparent respiratory acidosis and an elevated troponin value. Focused TTE showed hyperdynamic cardiac ventricles on low dose vasopressors with new findings suggestive of right ventricular pressure overload expressed in a flattening of the interventricular septum (a D-shaped left ventricle) and right ventricular systolic pressure of <60 mm Hg (Figure 1C). In accordance with these findings, the patient underwent thorax CT and CT pulmonary angiogram (CTPA) scans. Both demonstrated left lower lobe PE and a number of lung consolidations primarily on the right lung, correlating with our documented lung ultrasound examinations (Figure 2A, B). Fondaparinux-specific anti-Xa assay–guided therapeutic anticoagulation was maintained and, by the absence of right ventricular dilation on echocardiography, thrombolytic therapy was abandoned.

**SUBARACHNOID HEMORRHAGE**

Two days later, after maintaining hemodynamic and respiratory stability, the patient was on continuous positive airway pressure ventilation but failed a sedation interruption trial with an unexplained persistent Richmond agitation-sedation scale (RASS) score of −3.

With the patient at considerably high risk for bleeding and the possible need for surgical intervention, cranial CT and angiography scans were performed and showed small diffuse bilateral frontoparietal and intraventricular hemorrhage (Figure 3A, B). Also, a 5-mm pericallosal artery aneurysm was suspected but seemed unruptured and not causative for SAH. Neurosurgical consultation was recommended against invasive intracranial monitoring or emergent surgical intervention due to the high bleeding risk.

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**Figure 1.** Cardiovascular POCUS. A, 2D ultrasound image showing the location of the VV ECMO cannula in the inferior vena cava (arrow). B, Compression ultrasound examination was positive for a thrombus (arrows) in the right femoral vein on ICU day 20. C, Focused 2D transthoracic echocardiography parasternal short-axis view illustrating flattening of the interventricular septum (arrow) and D-shaped left ventricle. 2D indicates 2-dimensional; ICU, intensive care unit; IVS, interventricular septum; LV, left ventricle; POCUS, point-of-care ultrasound; RV, right ventricle; VV ECMO, venovenous extracorporeal membrane oxygenation.
under full anticoagulation. It was planned to re-evaluate the suspected aneurysm later after recovery from COVID.

On the basis of these findings, we agreed with our neurosurgical team on continuing the ventilatory weaning under low-dose sedation to a target RASS score of −1 with stepwise sedation reduction to avoid hypertensive episodes. We also implemented transcranial color-coded duplex sonography (TCCS) monitoring to our routine POCUS protocol. On ICU day 27, TCCS detected a moderate bilateral vasospasm event in both middle cerebral arteries with a mean flow velocity between 150 and 180 cm·s⁻¹ and a Lindegaard ratio of 3–5 that was normalized in 24-hour follow-up TCCS measurements under enteral nimodipine, euvolemia-targeted fluid therapy, and low-dose vasopressors to a target systolic blood pressure of 140 mm Hg (Figure 3C).

After 2 days of normal TCCS measurements, sedation reduction to a target RASS score of 0 to −1 was reached, and complete weaning from mechanical ventilation was achieved a few days later. The patient was discharged from ICU to the peripheral ward on day 43 with stable hemodynamic and pulmonary function with no neurological deficits.

Approximately 38 multiorgan POCUS examinations were performed during the patient’s ICU stay.

**DISCUSSION**

Current data suggest that ≤5% of COVID-19 patients become critically ill and require intensive care therapy.² These cases can be complicated by ARDS, cardiac insufficiency, and multiorgan failure.³

Our patient severely suffered from ARDS requiring ECMO, and the course was complicated by DVT, PE, and SAH. The highly contagious nature of COVID-19 and the commonly occurring cardiovascular and pulmonary instability necessitated specific patient management in ICU. Limited personnel and logistic resources had to be considered, including the shortage of personal protective equipment and the infection risk during transportation for advanced diagnostics (eg, CT scans).

Bedside POCUS imaging is a safe and reliable noninvasive tool in ICU. It is a guide to invasive procedures and serves as a diagnostic modality that can complement physical examination in the hands of a competent, well-trained ICU physician.⁴ However, POCUS has its limitations and should be used as a tool to supplement clinical decisions rather than to replace gold standard diagnostics if available.

Lung ultrasound evidently has good sensitivity and specificity in the diagnosis of patients with respiratory failure.⁵ In our case, it provided us with valuable clinical

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### Table. Multiorgan POCUS in COVID-19 Protocol

| Organ                      | Assessment                      | Findings                                      | Management and considerations          |
|----------------------------|---------------------------------|-----------------------------------------------|----------------------------------------|
| Daily POCUS protocol       |                                 |                                               |                                        |
| Lung                       | 12 point examination            | B-lines >3–5⁺                                 | PEEP                                   |
|                            |                                 | Consolidation/atelectasis                     | Kinetic therapy                        |
|                            |                                 | Pleural effusion⁺                             | (prone position)                       |
|                            |                                 | Progression/regression                        | Pleural fluid drainage                  |
|                            |                                 | Left and right ventricular size and function  | Further diagnostics or therapy         |
|                            |                                 | Valvular pathology                            | when suspected:                         |
|                            |                                 | Pericardial effusion                          | Pulmonary embolism                      |
|                            |                                 | Fluid status                                  | Cardiomyopathy                         |
|                            |                                 |                                               | Heart failure                           |
|                            |                                 |                                               | Acute coronary syndrome                 |
|                            |                                 |                                               | Tamponade                               |
| Cardiac                    | Apical 4-chamber view            | Suspected intracranial hemorrhage or ischemia | Anticoagulation                        |
|                            | Parasternal long axis            |                               | Further diagnostics?                    |
|                            | Parasternal short axis           |                               |                                        |
|                            | Inferior vena cava               |                               |                                        |
|                            |                                 |                                               |                                        |
| Vascular                   | Leg veins                        | Two-point compression (femoral and popliteal veins) |                                      |
| Daily by neurological      | Transcranial 2D and color-coded |                                               |                                        |
| abnormalities              | duplex sonography                |                                               |                                        |
| Cranial                    |                                 |                                               |                                        |
|                            |                                 |                                               |                                        |
|                            |                                 |                                               |                                        |

Abbreviations: 2D, 2-dimensional; COVID-19, coronavirus disease 2019; PEEP, positive end-expiratory pressure; POCUS, point-of-care ultrasound.

⁺Exclude cardiac causes using echocardiography when present.
information on a daily basis about the extent of the lung injury and the dynamic pattern of its progress. We followed a 12-point lung examination protocol to detect atelectasis, B-lines, and overdistension of the ventilated lung areas. Above all, the indication for prone positioning was based on the sonographic detection of dorsal consolidations and atelectasis. In approximately 60%, these decisions resulted in a significant uniform increase in lung aeration, reflected by an increase in the Pao₂/Fio₂ ratio. This also markedly reduced the indications for follow up chest X-rays and lung CT scans during the patient’s entire ICU stay.

POCUS also was valuable in guiding intravenous cannulation and confirming the correct location of the ECMO cannula. It enabled us to early detect DVT, which supported the suspicions of PE when unexplained worsening of his Pao₂/Fio₂ ratio occurred. Further sonographic imaging with TTE revealed right ventricular overload and justified the need for an angiographic CT scan, which confirmed the diagnosis.

PE may occur in ≤31% of critically-ill COVID-19 patients. POCUS increases the accuracy and sensitivity of diagnosing PE and should be regarded as a first-line imaging tool, when CT is not immediately available.

To our knowledge, cerebral hemorrhage in COVID-19 patients has been reported only in a few cases as causative for impaired consciousness. Given that there is a potential risk of neurological complications in COVID-19 patients due to hypoxic brain injury and acute cerebrovascular disease, persistence of impaired consciousness in our patient—though medical sedation had been discontinued for 8 hours—required enhanced alertness. Although sonographic imaging has the potential for detecting major intracranial bleeding and ischemic cerebrovascular disease, it was not conclusively for intracranial pathology in our case. However, when SAH was diagnosed by CT imaging, duplex sonography became a part of our POCUS routine and, in the following days, detected cerebral vasospasm as a complication of SAH. In our tertiary care hospital ICU, TCCS is an integral part of our POCUS training and is a daily practice to monitor for the development of vasospasm in all aneurysmal SAH patients.

Several societies have published statements and recommendations emphasizing the role of POCUS during the COVID-19 pandemic. In this case report, multiorgan POCUS combining 12-point lung protocol with TTE and vascular POCUS was a practical bedside modality for supervising vascular access, narrowing the differential diagnosis in acute respiratory and hemodynamic instability, and detecting vascular and cardiac pathology at an early stage. It also supported the decision for taking transport associated risks to the patient and hospital staff to perform nonbedside comprehensive CT diagnostics outside the COVID-19 isolation...
environment on ICU. Studies should address the important role of POCUS in critically ill COVID-19 patients.

DISCLOSURES
Name: Alaa Haider, MD.
Contribution: This author helped in the medical care of the patient, writing the first draft, and literature review.
Name: Christoph Schmitt, MD.
Contribution: This author helped in the management of the patient and writing the manuscript draft and obtained consent from the patient for publication.
Name: Clemens-Alexander Greim, MD, PhD.
Contribution: This author helped review, write, and edit the manuscript.
This manuscript was handled by: Kent H. Rehfeldt, MD.

REFERENCES
1. Shekar K, Badulak J, Peek G, et al. Extracorporeal life support organization coronavirus disease 2019 interim guidelines: a consensus document from an international group of interdisciplinary extracorporeal membrane oxygenation providers. ASAIO J. 2020;66:707–721.
2. Guan WJ, Ni ZY, Hu Y, et al. Clinical characteristics of coronavirus disease 2019 in China. N Engl J Med. 2020;382:1708–1720.
3. Yang X, Yu Y, Xu J, et al. Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study. Lancet Respir Med. 2020;8:475–481.
4. Lichtenstein DA, Mezière GA. Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol. Chest. 2008;134:117–125.
5. Peng QY, Wang XT, Zhang LN; Chinese Critical Care Ultrasound Study Group (CCLSG). Findings of lung ultrasonography of novel coronavirus pneumonia during the 2019-2020 epidemic. Intensive Care Med. 2020;46:849–850.
6. Banfi C, Pozzi M, Siegenthaler N, et al. Veno-venous extracorporeal membrane oxygenation: cannulation techniques. J Thorac Dis. 2016;8:3762–3773.
7. Klok FA, Kruip MJHA, van der Meer NJM, et al. Confirmation of the high cumulative incidence of thrombotic complications in critically ill ICU patients with COVID-19: an updated analysis. Thromb Res. 2020;191:148–150.
8. Konstantinides SV, Meyer G, Becattini C, et al. 2019 ESC Guidelines for the diagnosis and management of acute pulmonary embolism developed in collaboration with the European Respiratory Society (ERS): the task force for the diagnosis and management of acute pulmonary embolism of the European Society of Cardiology (ESC). Eur Respir J. 2019;54:1901647.
9. Muhammad S, Petidis A, Cornelius JF, Hänggi D. Letter to editor: severe brain haemorrhage and concomitant COVID-19 Infection: a neurovascular complication of COVID-19. Brain Behav Immun. 2020;87:150–151.
10. Mao L, Jin H, Wang M, et al. Neurologic manifestations of hospitalized patients with coronavirus disease 2019 in Wuhan, China JAMA Neurol. 2020;77:683–690.
11. Blanco P, Blaivas M. Applications of transcranial color-coded sonography in the emergency department. J Ultrasound Med. 2017;36:1251–1266.
12. Naqvi J, Yap KH, Ahmad G, Ghosh J. Transcranial Doppler ultrasound: a review of the physical principles and major applications in critical care. Int J Vasc Med. 2013;2013:629378.
13. Johri AM, Galen B, Kirkpatrick JN, Lanspa M, Mulvagh S, Thammam R. ASE statement on point-of-care ultrasound during the 2019 novel coronavirus pandemic. J Am Soc Echocardiogr. 2020;33:670–673.
14. Soldati G, Smargiassi A, Inchingolo R, et al. Proposal for international standardization of the use of lung ultrasound for patients with COVID-19: a simple, quantitative, reproducible method. J Ultrasound Med. 2020;39:1413–1419.