# Pick Up Your Probes

## A Call for Clinically Oriented Point-of-Care Ultrasound Research in COVID-19

*Alan T. Chiem, MD, MPH* and *Jacqueline Shibata, MD, MS*
*Department of Emergency Medicine, Olive View–UCLA Medical Center, Sylmar, California, USA*

*George Lim, MD*
*Ronald Reagan UCLA Medical Center, California, Los Angeles, USA*

*Yiju Teresa Liu, MD, RDMS*
*Harbor–UCLA Medical Center, West Carson, California, USA*

In this commentary, we will discuss the advantages of point-of-care ultrasound (POCUS) in the evaluation of patients with coronavirus disease 2019 (COVID-19), as well as propose a framework of POCUS research topics germane to the clinical management of patients with COVID-19.

As of June 1, 2020, the COVID-19 pandemic has infected more than 6 million people worldwide and nearly 2 million Americans. In cities such as New York City and New Orleans, the pandemic has overwhelmed health care resources, including human resources, and equipment such as ventilators and personal protective equipment.[1] To conserve resources and reduce the risk of coronavirus transmission, guidelines such as those from the American College of Emergency Physicians recommend judicious testing in the evaluation and management of patients with suspected or confirmed COVID-19.[2] In addition, the American College of Radiology has recommended that routine chest radiography and computed tomography (CT) be limited to those patients with COVID-19 for whom imaging findings are likely to change management.[3]

These concerns for the need to reduce health care–associated transmission as well as to conserve resources highlight several advantages of POCUS. First, POCUS systems are highly portable in cart-based or handheld configurations compared to traditional imaging, allowing practitioners timely and convenient access to dynamic, cross-sectional imaging. This portability is particularly relevant for patients whose clinical status is too tenuous for transport to radiology as well as in resource-scarce health care settings. The relatively small size allows for rapid disinfection of POCUS machines compared to CT rooms, which may take longer than an hour to disinfect.[4] Second, as we will discuss, substantial literature establishes the high accuracy of POCUS to diagnose COVID-related pulmonary and cardiac complications with sensitivities and specificities comparable to CT. This is particularly convenient, as many medical specialties on the frontline of the COVID-19

*Manuscript accepted for publication June 7, 2020.*

*All of the authors of this article have reported no disclosures.*

*Address correspondence to Alan T. Chiem, MD, MPH, Department of Emergency Medicine, Olive View–UCLA Medical Center, 14445 Olive View Dr, North Annex, Sylmar, CA 91342, USA.*

*E-mail: achiem@mednet.ucla.edu*

**Abbreviations**
*ARDS, acute respiratory distress syndrome; COVID-19, coronavirus disease 2019; CT, computed tomography; FAST, focused assessment with sonography for trauma; ICU, intensive care unit; POCUS, point-of-care ultrasound; US, ultrasound*

doi:10.1002/jum.15394

 

pandemic, such as emergency medicine and critical care, already have established POCUS training, experience, and expertise. Both specialties offer subspecialty training, board certification in advanced POCUS, or both.[5]

Before we discuss imperative research questions for POCUS in COVID-19, we should emphasize a few points regarding existing COVID-19 POCUS research. First, there is a critique that there is no evidence to support POCUS in COVID-19 management. This is due to the fact that there have been no large-scale studies as of yet. This critique, if applied to other interventions, would have halted studies of any clinical trials, including the multiple studies on hydroxychloroquine.[6] Second, whereas there is a strong literature base in lung and cardiac ultrasound (US), most of these studies are diagnostic accuracy studies usually comparing POCUS to chest radiography. ***Studies that involve patients with COVID-19 need to progress beyond diagnostic accuracy and, rather, involve clinical integration and appropriate outcomes***. To achieve this, two major questions need to be raised when planning a POCUS study involving patients with COVID-19:

First, is the POCUS integration appropriate to show value beyond standard care, and are measured outcomes achievable? For example, Chen et al[7] showed that serially performed POCUS examinations on daily intensive care unit (ICU) rounds reduced the duration of mechanical ventilation and ICU days. This is a reasonable use of POCUS, since fluid balance and administration are daily questions posed on ICU rounds. Information from lung and inferior vena cava US can add value to clinical and laboratory parameters in guiding fluid management. This is in contrast to similar ICU-based studies that show no change in outcomes, such as the study by Mosier et al[8] or the Sonography in Hypotension and Cardiac Arrest in the Emergency Department trial,[9] which had POCUS protocols that were grossly inadequate for the outcomes measured. In the study by Mosier et al,[8] a POCUS examination was performed once, not serially, either before a heterogeneously defined set of interventions or after. Similarly, in the Sonography in Hypotension and Cardiac Arrest in the Emergency Department trial, most of the patients had severe sepsis or septic shock, yet patients were randomized to a single POCUS study versus the standard of care.[9] A plausible interpretation of the evidence is that, to show a benefit in critically ill patients, serial POCUS examinations need to be used to assess for the effect of an intervention (ie, fluid bolus).

The second question is whether the outcome is appropriate for the POCUS intervention being studied. In the above-mentioned trials, mortality was selected. Although a powerful outcome, this is usually inappropriate when assessing an imaging or monitoring modality. These patients are critically ill and unlikely to benefit solely from imaging but, rather, the selection of appropriate management based on the imaging findings. Outcomes should be proximally related to the POCUS examination, such as whether a fluid-responsive state on the POCUS examination leads to fluid administration. For example, Shokoohi et al[10] found that in patients presenting with undifferentiated hypotension, POCUS reduced physician diagnostic uncertainty in 30% of patients and increased the proportion of a definitive diagnosis from less than 1% to 12%, leading to a change of therapy in 24% of patients. The mortality outcomes that follow depend less on the POCUS examination and more on associated interventions, patient comorbidities, the severity of disease, and a multitude of other factors. Although subtle and intuitive, it is important to underscore that any monitoring system including POCUS by itself cannot yield improvement in patient-centered outcomes, but rather, it is the clinical interventions providers perform based on the monitoring system that yield benefit.

In addition, providers must be ready to take actions appropriate to POCUS findings before outcomes can be studied. The Kirkpatrick model of evaluation may be applied to assess POCUS clinical integration, with the lowest tiers focusing on learning and ensuring that all clinicians participating in the study are appropriately trained.[11] Higher tiers focus on the impact of POCUS on clinician behavior, followed by an impact on clinical outcomes. Many POCUS studies essentially leapfrog these initial tiers to assess clinical outcomes before ensuring that the necessary building blocks are in place. For example, Holmes et al[12] showed that POCUS had no effect on CT use or mortality in stable pediatric patients presenting with blunt trauma. The proximal outcome of clinical suspicion of intra-abdominal injury after negative focused assessment with sonography for trauma (FAST) results was reduced to 1% or less in 173 patients. However, 28% in this subgroup still received a CT scan, none of which revealed any injury. If these patients with 1% or less clinical suspicion of intra-abdominal injury after a FAST exam had their CT scans deferred, the CT use rate would have been 14% lower than in the non-FAST arm. This would have been a statistically and clinically significant difference, given the reduction in radiation to the pediatric study population. Although further discussion on the factors associated with CT scanning of a low-risk group as well as the inadequate sensitivity of FAST in ruling out intra-abdominal injury is beyond the scope of this commentary, future POCUS studies should target proximal outcomes along with potential barriers to a behavioral change. Once POCUS studies show a clear and consistent behavioral change, the focus may then be shifted to clinical outcomes such as the mechanical ventilation duration and length of stay.

With this framework in mind, we have identified the following key topics for imminent POCUS research during the COVID-19 pandemic:

## Prognostication of Patients With COVID-19 Discharged From the Emergency Department

Current guidelines at many emergency departments recommend discharge of patients without tachypnea, increased work of breathing, and hypoxia. Portable chest radiography is often performed with typical findings of peripheral, multifocal, hazy, or reticulonodular densities.[13] Despite these findings, many of these patients will recover at home, with anecdotal reports that some worsen. Point-of-care US may better characterize these findings by the presence of subpleural consolidations or effusions, the degree of B-lines seen, as well as the presence of alveolar consolidation.[14] Point-of-care US may also describe findings associated with a higher likelihood of clinical decompensation that would necessitate closer follow-up or even admission. In addition, research may evaluate the relative diagnostic accuracy and technical ease of several protocols, including the bedside lung ultrasound evaluation,[15] the 8 lung zones of Volpicelli et al,[16] and the 14-point protocol of Soldati et al.[14]

## Prognostication of Admitted Patients

Roughly 80% of patients admitted with COVID-19 do not require intensive care and are discharged when they clinically improve.[17] However, care of these patients is typically reactive, as laboratory and radiographic abnormalities are obtained usually at the time of decompensation, with limited utility before development of frank clinical signs. There is no convenient prognostication tool that clinicians can use to predict the common pulmonary and cardiac complications described below. Based on prior work, serial POCUS adapted for COVID-19 may be able to identify these complications earlier than traditional assessments.

## Development and Management of Acute Respiratory Distress Syndrome

Several studies have shown that lung US has greater than 90% sensitivity and specificity for acute respiratory distress syndrome (ARDS), which roughly 50% of patients admitted with COVID-19 develop.[18–20] Serial POCUS may help identify which patients are worsening before overt clinical decompensation by an increase in involved lung zones, B-lines, or alveolar consolidation. Once these patients are identified, they may be upgraded to a higher level of care for close monitoring and timely required interventions. In addition, if a concerning trend is shown on a POCUS examination, this may affect decisions as to the timing of intubation as well as implementation of lung-protective strategies.[21]

With COVID-associated ARDS, there is growing concern for severe atelectasis, particularly in the basilar and posterior lung segments. Therefore, many providers believe that COVID-19 hypoxemia is especially responsive to positive end-expiratory pressure and prone positioning. However, increasing levels of positive end-expiratory pressure and prone positioning are not without risk and should be performed with more evidence than simply hypoxemia. With POCUS, derecruited lung zones are seen as alveolar consolidation with US signs of hepatization of the lung and air or fluid bronchograms.[22] Research may define the areas involved, so that selective measures may be instituted that preferentially recruit those affected lung zones.[23] In addition, dynamic US assessments such as diaphragmatic excursion may help better characterize the work of breathing and readiness for extubation.[24] A POCUS-guided alveolar recruitment strategy may be compared to current prone positioning, as delineated by the Prone Positioning in Severe Acute Respiratory Distress trial.[25]

## Development of Cardiac Injury

Cardiac complications are common in critically ill patients with COVID-19, occurring in roughly 20% of this cohort.[26] These complications include viral myocarditis, myocardial infarction, pericardial effusions, and right ventricular dysfunction either as a result of pulmonary embolism or worsening pulmonary vasoconstriction due to hypoxia. However, similar to the current reactive practice of ARDS detection and management, these cardiac complications are usually diagnosed and treated after clinical deterioration. The serial use of POCUS has the potential to detect these cardiac complications earlier, which would allow for preemptive interventions to prevent complications such as cardiorenal syndrome, shock liver, and right ventricular failure. For example, a decline in left ventricular systolic dysfunction detected by serial POCUS may alert clinical teams to involve a cardiology consultation earlier, as well as to initiate inotropic support, before the development of hypotension, end-organ failure, or increases in shock indices. There is robust POCUS literature to support assessments of left ventricular systolic dysfunction,[27,28] right ventricular dysfunction,[29] as well as the presence of pericardial effusion and associated tamponade.[30] On the basis of this literature base, the American Society of Echocardiography recently released a statement in support of POCUS use in the management of patients with COVID-19.[31]

In addition, there are recent reports of the development of a hypercoagulable state and associated venous thromboembolism in up to 30% of severely ill patients with COVID-19.[32] Patients with COVID-19 who develop pulmonary embolism in the context of ARDS and consequent pathophysiologic right-to-left shunts often have a very poor prognosis. Therefore, outcomes such as mortality will likely not differ with the use of POCUS. However, surveillance POCUS to identify the development of a right ventricular pressure or volume overload and the presence of deep venous thrombosis will expedite this diagnosis. Furthermore, POCUS will allow clinicians to further risk stratify a patient who is too tenuous for transport to radiology in the diagnosis of pulmonary embolism and allow for empiric management with anticoagulation or thrombolysis. The use of POCUS can also lead to alternative diagnoses that render pulmonary embolism unlikely, allowing for a substantial reduction in CT use and leading to decreased COVID-19 exposure to radiology staff as well as decreases in the CT turnaround time for other patients.[33]

## L and H Subtypes of COVID-19

Although lung findings in patients with COVID-19 are nonspecific and seen in other disease processes, Gattinoni et al[34] recently hypothesized the presence of two distinct phenotypes in COVID-19 pneumonia: one characterized by a low-elastance/high-compliance state (type L) and the other characterized by a high-elastance/low-compliance state (type H). Hypoxemia in type L is primarily due to loss or impaired hypoxic pulmonary vasoconstriction, whereas in type H, lung characteristics are typical of severe ARDS, in which there is a high degree of pulmonary edema and alveolar consolidation. Lung POCUS may help differentiate these phenotypes with a higher degree of B-lines and alveolar consolidation seen in type H than type L. In addition, since normal pulmonary artery pressures are typically seen in type L, the inferior vena cava will show normal respirophasic changes as opposed to the dilated and plethoric inferior vena cava in type H. In more challenging cases, spectral Doppler US may be used to assess for elevated pulmonary artery pressures and relatively normal left atrial pressures to characterize type H.

## Conclusions

With concerns about infection control as well as the limitations of current assessments, we will see that POCUS will become integral in the management of COVID-19, particularly for early identification and prognostication of cardiac and pulmonary complications.

In *The Fellowship of the Ring*, J. R. R. Tolkien[35] wrote: "'I wish it need not have happened in my time,' said Frodo. 'So do I,' said Gandalf, 'and so do all who live to see such times. But that is not for them to decide. All we have to decide is what to do with the time that is given us.'" In much the same way, COVID-19 presents POCUS practitioners and researchers a unique opportunity to advance the study and integration of clinical US that will ultimately change the practice of bedside medicine.

## References


1. Driggin E, Madhavan MV, Bikdeli B, et al. Cardiovascular considerations for patients, health care workers, and health systems during the COVID-19 pandemic. *J Am Coll Cardiol* 2020; 75: 2352–2371.
2. American College of Emergency Physicians. ACEP COVID-19 field guide. American College of Emergency Physicians website. https://www.acep.org/corona/covid-19-field-guide/diagnosis/testing/. Accessed May 21, 2020.
3. American College of Radiology. ACR recommendations for the use of chest radiography and computed tomography (CT) for suspected COVID-19 infection. American College of Radiology website. https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Recommendations-for-Chest-Radiography-and-CT-for-Suspected-COVID19-Infection. Accessed April 7, 2020.
4. Buonsenso D, Pata D, Chiaretti A. COVID-19 outbreak: less stethoscope, more ultrasound. *Lancet Respir Med* 2020; 8:e27.
5. Stowell JR, Kessler R, Lewiss RE, et al. Critical care ultrasound: a national survey across specialties. *J Clin Ultrasound* 2018; 46: 167–177.
6. Tang W, Cao Z, Han M, et al. Hydroxychloroquine in patients with mainly mild to moderate coronavirus disease 2019: open label, randomised controlled trial. *BMJ* 2020; 369:m1849.
7. Chen Z, Hong Y, Dai J, Xing L. Incorporation of point-of-care ultrasound into morning round is associated with improvement in clinical outcomes in critically ill patients with sepsis. *J Clin Anesth* 2018; 48:62–66.
8. Mosier JM, Stolz U, Milligan R, et al. Impact of point-of-care ultrasound in the emergency department on care processes and outcomes in critically ill nontraumatic patients. *Crit Care Explor* 2019; 1:e0019.
9. Atkinson PR, Milne J, Diegelmann L, et al. Does point-of-care ultrasonography improve clinical outcomes in emergency department patients with undifferentiated hypotension? An international randomized controlled trial from the SHoC-ED investigators. *Ann Emerg Med* 2018; 72:478–489.
10. Shokoohi H, Boniface KS, Pourmand A, et al. Bedside ultrasound reduces diagnostic uncertainty and guides resuscitation in patients with undifferentiated hypotension. *Crit Care Med* 2015; 43: 2562–2569.
11. Heydari MR, Taghva F, Amini M, Delavari S. Using Kirkpatrick's model to measure the effect of a new teaching and learning methods workshop for health care staff. *BMC Res Notes* 2019; 12:388.
12. Holmes JF, Kelley KM, Wootton-Gorges SL, et al. Effect of abdominal ultrasound on clinical care, outcomes, and resource use among children with blunt torso trauma: a randomized clinical trial. *JAMA* 2017; 317:2290–2296.
13. Jacobi A, Chung M, Bernheim A, Eber C. Portable chest X-ray in coronavirus disease-19 (COVID-19): a pictorial review. *Clin Imaging* 2020; 64:35–42.
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.
15. Lichtenstein DA. BLUE-protocol and FALLS-protocol: two applications of lung ultrasound in the critically ill. *Chest* 2015; 147: 1659–1670.
16. Volpicelli G, Cardinale L, Garofalo G, Veltri A. Usefulness of lung ultrasound in the bedside distinction between pulmonary edema and exacerbation of COPD. *Emerg Radiol* 2008; 15:145–151.
17. Cummings MJ, Baldwin MR, Abrams D, et al. Epidemiology, clinical course, and outcomes of critically ill adults with COVID-19 in New York City: a prospective cohort study. *Lancet* 2020; 395:1763–1770.
18. Lichtenstein D, Goldstein I, Mourgeon E, Cluzel P, Grenier P, Rouby JJ. Comparative diagnostic performances of auscultation, chest radiography, and lung ultrasonography in acute respiratory distress syndrome. *Anesthesiology* 2004; 100:9–15.
19. Stefanidis K, Dimopoulos S, Kolofousi C, et al. Sonographic lobe localization of alveolar-interstitial syndrome in the critically ill. *Crit Care Res Pract* 2012; 2012:179719.
20. Hasan AA, Makhlouf HA. B-lines: transthoracic chest ultrasound signs useful in assessment of interstitial lung diseases. *Ann Thorac Med* 2014; 9:99–103.
21. Kangelaris KN, Ware LB, Wang CY, et al. Timing of intubation and clinical outcomes in adults with acute respiratory distress syndrome. *Crit Care Med* 2016; 44:120–129.
22. Copetti R, Soldati G, Copetti P. Chest sonography: a useful tool to differentiate acute cardiogenic pulmonary edema from acute respiratory distress syndrome. *Cardiovasc Ultrasound* 2008; 6:16.
23. Bouhemad B, Brisson H, Le-Guen M, Arbelot C, Lu Q, Rouby JJ. Bedside ultrasound assessment of positive end-expiratory pressure-induced lung recruitment. *Am J Respir Crit Care Med* 2011; 183:341–347.

24. Vetrugno L, Guadagnin GM, Barbariol F, Langiano N, Zangrillo A, Bove T. Ultrasound imaging for diaphragm dysfunction: a narrative literature review. *J Cardiothorac Vasc Anesth* 2019; 33:2525–2536.
25. Guérin C, Reignier J, Richard JC, et al. Prone positioning in severe acute respiratory distress syndrome. *N Engl J Med* 2013; 368:2159–2168.
26. Madjid M, Safavi-Naeini P, Solomon SD, Vardeny O. Potential effects of coronaviruses on the cardiovascular system: a review [published online ahead of print March 27, 2020]. *JAMA Cardiol.* https://doi.org/10.1001/jamacardio.2020.1286.
27. Randazzo MR, Snoey ER, Levitt MA, Binder K. Accuracy of emergency physician assessment of left ventricular ejection fraction and central venous pressure using echocardiography. *Acad Emerg Med* 2003; 10:973–977.
28. Moore CL, Rose GA, Tayal VS, Sullivan DM, Arrowood JA, Kline JA. Determination of left ventricular function by emergency physician echocardiography of hypotensive patients [published correction appears in *Acad Emerg Med* 2002; 9:642]. *Acad Emerg Med* 2002; 9:186–193.
29. Weekes AJ, Thacker G, Troha D, et al. Diagnostic accuracy of right ventricular dysfunction markers in normotensive emergency department patients with acute pulmonary embolism. *Ann Emerg Med* 2016; 68:277–291.
30. Goodman A, Perera P, Mailhot T, Mandavia D. The role of bedside ultrasound in the diagnosis of pericardial effusion and cardiac tamponade. *J Emerg Trauma Shock* 2012; 5:72–75.
31. Johri AM, Galen B, Thamman R, et al. ASE statement on point-of-care ultrasound (POCUS) during the 2019 novel coronavirus pandemic. American Society of Echocardiography website. https://www.asecho.org/wp-content/uploads/2020/04/POCUS-COVID_FINAL2_web.pdf. Accessed May 28, 2020.
32. Maatman TK, Jalali F, Feizpour C, et al. Routine venous thromboembolism prophylaxis may be inadequate in the hypercoagulable state of severe coronavirus disease 2019 [published online ahead of print May 27, 2020]. *Crit Care Med.* https://doi.org/10.1097/CCM.0000000000004466.
33. Koenig S, Chandra S, Alaverdian A, Dibello C, Mayo PH, Narasimhan M. Ultrasound assessment of pulmonary embolism in patients receiving CT pulmonary angiography. *Chest* 2014; 145:818–823.
34. Gattinoni L, Chiumello D, Caironi P, et al. COVID-19 pneumonia: different respiratory treatments for different phenotypes? *Intensive Care Med* 2020; 46:1099–1102.
35. Tolkien JRR. *The Fellowship of the Ring.* New York, NY: Houghton Mifflin Co; 1994.