Whole-Body Point-of-Care Ultrasound: A Critical Tool for COVID-19 Care

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Abstract

SARS-CoV-2, the virus that causes COVID-19, can attack the body from head to foot and potentially cause injuries to the brain, heart, lungs, kidneys, vascular system—and even "Covid toes." In the fight against a global pandemic that has infected millions and killed hundreds of thousands of patients globally, point-of-care ultrasound (POCUS) offers a safe, cost-effective and clinically influential tool, supported by an ever-expanding body of evidence. Benefits of POCUS include the rapid diagnosis of the wide range of COVID-19 manifestations and also the safe and successful guidance of potentially lifesaving procedures. After helping to make critical diagnoses, POCUS can then help track the effects of treatment and changes in the patient's condition, while helping to minimize frontline providers' exposure to this highly contagious viral illness. Diagnostic POCUS applications include evaluations of the brain, lungs, heart, vascular system, abdominal organs and assessment of the extremities for blood clots. Procedural applications include safe and efficient guidance of vascular access, endotracheal tube placement, regional anesthesia and other procedures. This paper outlines the latest scientific evidence to support a "multi-organ" and "whole-body" approach using essential POCUS diagnostic and procedural applications to optimize care of the severely ill COVID-19 patient.

Background/Introduction

In the early 1990s, frontline physicians in emergency medicine and critical care were among the first to recognize the value of ultrasound at the bedside as a timesaving, cost-saving and lifesaving tool for diagnosing and treating critically ill or injured patients.[1,2,3,4] In 1993, Lichtenstein and Axler described a whole-body approach to point-of-care ultrasound (POCUS) that had a direct impact on the diagnosis and therapeutic plan for their ICU patients.[5] Since then, comparative studies have found that multi-organ POCUS can expedite accurate diagnosis of emergency department patients with respiratory symptoms or undifferentiated hypotension (shock), as compared with standard care.[6,7] Whole-body ultrasound has also been shown to decrease the need for other diagnostic testing and thus reduces costs.[8]

In the context of COVID-19, many frontline providers now use POCUS on a daily basis in their practice. Applications of this tool have rapidly evolved and expanded as our knowledge of this frightening and complex disease has grown. One of the newest discoveries, published in April 2020, is that COVID-19 has three stages that occur at different points in time and affect different organ systems beyond the lungs.[9] Patients with Stage 1 (early infection, characterized by viral infiltration and lymphocytopenia) and Stage II (a pulmonary phase with respiratory difficulties and abnormal chest imaging findings) present with respiratory manifestations, while those with Stage III (hyperinflammation/cytokine storm) are at high risk for such dire complications as acute respiratory distress syndrome (ARDS), severe blood clotting, cardiac failure and shock.

The population at highest risk of advancing to Stage III complications are elderly patients or those with comorbidities. However, even young patients without comorbidities can progress to Stage III, sometimes with frightening rapidity. On May 20, 2020, the Centers for Disease Control and Prevention (CDC) issued updated clinical guidance for the management of patients with confirmed COVID-19, cautioning, "Clinicians should be aware of the potential for some patients to rapidly deteriorate one week after illness onset. Among all hospitalized patients, a range of 26% to 32% were admitted to the ICU."[10] Compounding the challenges of diagnosing and managing these critically ill patients is the highly contagious nature of the new coronavirus, which is spread via respiratory droplets.

With this recent evidence of multi-organ complications, the use of POCUS is rapidly expanding to help diagnose and manage many more organ systems than the lung. Furthermore, the benefits of POCUS are becoming more apparent as we decrease unnecessary utilization of modalities that may increase exposure to more health care providers such as chest x-rays and CT scans.

Safely Expediting Rapid, Efficient and Cost-Effective Diagnosis

Current, evidence-based applications of multi-organ ultrasound for the COVID-19 patient include the following assessments, as clinically warranted **(Figure 1, Table 2)**:

- **Lung** Over the last decade, clinical and physical studies have demonstrated the ability of lung ultrasound (LUS) to identify ARDS, interstitial lung disease, pulmonary edema, subpleural consolidations and pneumothorax (a potential complication in ventilated patients).[11,12] Multiple investigators suggest that lung ultrasound (LUS) can play a key role in the management of patients with COVID-19-related lung damage across care pathways.[13] As compared to such monitoring modalities as auscultation, chest x-ray and CT scans, LUS has a high diagnostic accuracy and fewer infection control issues.[14,15] LUS has demonstrated utility to rapidly assess the severity of SARS-CoV-2-associated viral pneumonia/ARDS, track the evolution of the disease, monitor response to prone positioning, assist in the management of extracorporeal membrane therapy and guide decision-making about weaning patients from ventilation.[16] Use of LUS can also reduce utilization of chest x-rays and CT,[17] and may be helpful in triaging patients in the prehospital setting to an appropriate level of care.[18] Other advantages include low costs and practical applications in limited-resource settings, including triage-tent facilities and field hospitals.[19] Several investigators have described the characteristic sonographic signs of COVID-19-associated lung involvement, including an abnormal, thickened pleural line and the presence of B lines.[20,21]

- **Heart** One of the newest discoveries, published in May 2020 by Mount Sinai cardiologists, is that findings from bedside echocardiology may prognosticate a COVID-19 patient's risk for unfavorable outcomes or mortality.[22] Specifically, the study demonstrated that right ventricular dilation in hospitalized patients appeared to be an indicator of high-risk cases that may require a higher level of care. Two other recent publications have revealed that about 20% to 30% of hospitalized patients with confirmed cases of COVID-19 suffer myocardial injury.[23,24] In one of these studies, Shi and colleagues linked this injury to increased risk for ARDS, acute kidney injury and other complications. In the other, Guo et al. found that cardiac injury and heart failure contributed to about 40% of deaths in a cohort of hospitalized patients, either individually or in tandem with respiratory failure. In patients with COVID-19-associated thromboembolic disease, heart attacks have also been reported. Bedside echocardiography offers a highly accurate and repeatable tool to interrogate the heart.[25] Cardiac POCUS applications include the assessment of right and left ventricular function, ejection fraction, pericardial effusion and regional wall motion abnormalities.[26,27] Evidence-based guidelines have been published for point-of-care cardiac ultrasound by critical care physicians.[28]

- **Thromboembolic disease** Awareness among frontline clinicians is rapidly increasing about the high risk for thromboembolic disease in patients with severe COVID-19 infections. In a cohort of ICU patients, 25% developed CT- and/or ultrasound-confirmed arterial or venous thromboembolism (VTE), with pulmonary embolism (PE) and DVT ranking among the more common manifestations.[29] Several other recent studies have reported similar findings, suggesting that frontline physicians should have a high index of suspicion for this disorder, especially in ICU patients. Multi-organ POCUS typically includes screening for DVT, which can easily be visualized with ultrasound. The key findings are direct clot visualization or detection of a noncompressible vein. A massive PE can present with right heart strain secondary to a large clot in the lungs that can be visualized with bedside echocardiography. In a study of ED patients, a limited compression ultrasound study using two compression points yielded a sensitivity and specificity comparable to that of full examination for the detection of lower extremity DVT.[30]

- **Brain** COVID-19 may increase patients' risk for ischemic (clot-induced) stroke, according to an extensive literature review by experts from 18 countries.[31] The use of transcranial Doppler ultrasound (TCD) to identify ischemic strokes from acute intracranial artery blockage has been established, with an overall 94% specificity and 79% sensitivity, as compared with computerized tomographic angiography.[32] Hemorrhagic (brain bleeding) stroke has also been described in COVID patients.[33] POCUS provides rapid assessment of intracranial pressure (ICP) though measurements of optic nerve sheath diameter (ONSD) to monitor the severity of hemorrhagic strokes. A recent meta-analysis has confirmed the accuracy of ONSD as a noninvasive surrogate marker of increased ICP.[34,35]

▪ **Abdominal** Although COVID-19 has been predominately associated with respiratory manifestations, gastrointestinal symptoms, hepatic injury and acute kidney injury (AKI) have also been described. The mechanism of injury is not fully understood, but may be a sequela of viral hepatitis, hyperinflammation, gut microbiome alterations or medication toxicity. A recent systematic review revealed that 58% to 78% of patients with severe COVID-19 infections develop varying degrees of liver injury. The investigators also report that similar complications have also been seen during outbreaks of two other coronaviruses: SARS and MERS.[36] POCUS can be used to interrogate the liver for signs of hepatitis or liver failure and to evaluate the intraperitoneal space for free fluid that might be ascites. A study of 5,449 patients hospitalized with COVID-19 found that nearly 37% of them developed AKI. AKI was most commonly seen in mechanically ventilated patients, with 52% of this group developing AKI within 24 hours of intubation. Doppler-based renal resistive index measurement is a rapid, noninvasive tool that may allow early detection of AKI in ICU patients. A 2015 meta-analysis has confirmed a high level of diagnostic performance, with a pooled sensitivity of 0.83 and specificity of 0.84.[37]

▪ **Hemodynamic/Shock Assessment** Increasingly, frontline physicians are seeing seriously or critically ill COVID-19 patients who meet diagnostic criteria for sepsis and septic shock, but the SARS-CoV-2 virus appears to be the sole cause in the vast majority of them. For example, a recent study found that blood and respiratory tract cultures were negative for bacteria and funguses in 76% of such patients in a COVID-19 cohort.[38] Li et al. hypothesize that these patients—who develop typical clinical signs of shock—have a disorder that they call “viral sepsis.”[39] Because septic shock is one of the most common causes of death in critically ill COVID-19 patients, close monitoring of hemodynamics is essential. Adding to the complexity of managing these patients, they often have comorbidities, especially cardiac comorbidities. Therefore, assessing cardiac function before administering fluid is crucial for avoiding overload. POCUS offers several modalities to evaluate ventricular filling pressures, cardiac output and fluid responsiveness, which are frequent concerns in ICU patients. Assessment of the collapsibility of inferior vena cava and left ventricular end-diastolic area can provide accurate measurements of reduced filling pressure and the need for fluids. Ultrasound can also be used to evaluate respiratory variation on Doppler flow across left ventricular outflow tract or peripheral arteries to further determine the hemodynamic status of a patient.[41]

Improving the Speed, Safety and Success of Potentially Lifesaving Procedures

A rapidly expanding body of evidence supports the following procedural applications of POCUS for the COVID-19 patient **(Figure 2, Table 2)**:

▪ **Airway Ultrasound** Many COVID-19 patients will require advanced airway procedures, such as endotracheal intubation, to help their rapidly declining respiratory status. Unrecognized malposition of the endotracheal tube (ETT) can have devastating consequences in the critically ill patient. Current guidelines recommend that proper ETT placement be confirmed as rapidly as possible, with minimal disruption to other resuscitation efforts. Evidence from anesthesia, emergency departments and the prehospital setting has consistently revealed that real-time tracheal POCUS enables fast, safe and effective postintubation confirmation through direct visualization of the tube and bilateral lung sliding. Moreover, the technique is easy for clinicians to learn. In 2019, Arya et al. conducted one of the first studies of the accuracy of ETT confirmation in ICU patients. They found that POCUS was 100% successful at identifying proper tracheal placement, while the positive and negative values of POCUS to identify accidental esophageal intubation were 100% and

97%, respectively.[42] Ultrasound guidance can also improve the safety, speed and success of another lifesaving airway procedure: surgical cricothyrotomy, which can have complication rates of up to 40% when landmark-based techniques are used.[43]

▪ **Vascular Access and Other Needle-Based Procedures** Annually, 200 million peripheral intravenous (PIV) catheters are placed in U.S. hospitals for volume resuscitation and delivery of nutrients, lifesaving medications and blood products.[44] However, obtaining PIV access is difficult in about 35% of patients who present to the ED, particularly if traditional "landmark" or palpitation methods are used, according to a recent meta-analysis. In a 2016 policy statement, the American College of Emergency Physicians (ACEP) recommended POCUS to facilitate placement of PIV and central venous catheters (CVCs), citing such benefits as "improved patient safety, decreased procedural attempts and decreased time to perform many procedures in patients [for] whom the technique would otherwise be difficult." This group may include many COVID-19 patients, either because they are dehydrated or have comorbidities that make PIV access problematic. Widespread adoption of ultrasound guidance would also help clinicians to achieve a "one-stick standard" for vascular access, ACEP noted. Endorsed in guidelines from numerous medical societies, ultrasound-guided CVC is now the standard of care.[47] Rates as low as zero for CVC complications, including pneumothorax and hemothorax,[48] have been reported with ultrasound guidance, which has also been shown to reduce central-line-associated bloodstream infections by 35%.[49] Ultrasound may also significantly reduce serious adverse events and the cost of care in patients undergoing other commonly performed needle procedures to drain fluid from the heart, lungs and abdomen: pericardiocentesis, thoracentesis and paracentesis.[50,51,52]

▪ **Regional Anesthesia** New practice recommendations from two anesthesiology societies advocate the use of regional anesthesia instead of general anesthesia for patients with COVID-19.[53] The goal is to reduce the need for aerosol-generating medical procedures, such as intubation and extubation, that may unnecessarily expose more healthcare workers.

A joint statement from the American Society of Regional Anesthesia and Pain Medicine and the European Society of Regional Anesthesia and Pain Therapy reports that the odds of transmission to a provider during tracheal intubation are 6.6 times higher, compared to those who are not exposed to tracheal intubation. Moreover, regional anesthesia is beneficial for patients because it reduces the risk of postoperative complications. Many comparative studies, systematic reviews and meta-analyses have demonstrated that ultrasound-guided regional anesthesia (UGRA) produces longer block durations, faster onset times, improved block success and a reduced need for opioids.[54,55,56,57]

Conclusion

POCUS has been described as "the Swiss Army knife of medicine" because it offers a remarkably versatile tool to improve the safety and quality of COVID-19 care in patients. By facilitating the rapid and highly accurate diagnosis of a range of disease manifestations—and guiding potentially lifesaving procedures—the whole-body approach to ultrasound helps ensure that patients who fall ill with the new coronavirus receive optimal care at every stage of their medical journey. Along with helping medical providers save lives, POCUS also helps protect frontline providers from falling ill with the highly contagious disease they are fighting. In May 2020, Cleveland Clinic investigators concluded, "In patients with COVID-19 infection, [POCUS] is an excellent tool for comprehensive assessment, given that ultrasound is already widely used in patient care, handheld ultrasound devices are easy to clean, and the nature of the virus is critical and dynamic."[58]

Covid-19 Complications

Figure 1: Diagnostic Applications of Point-of-Care Ultrasound

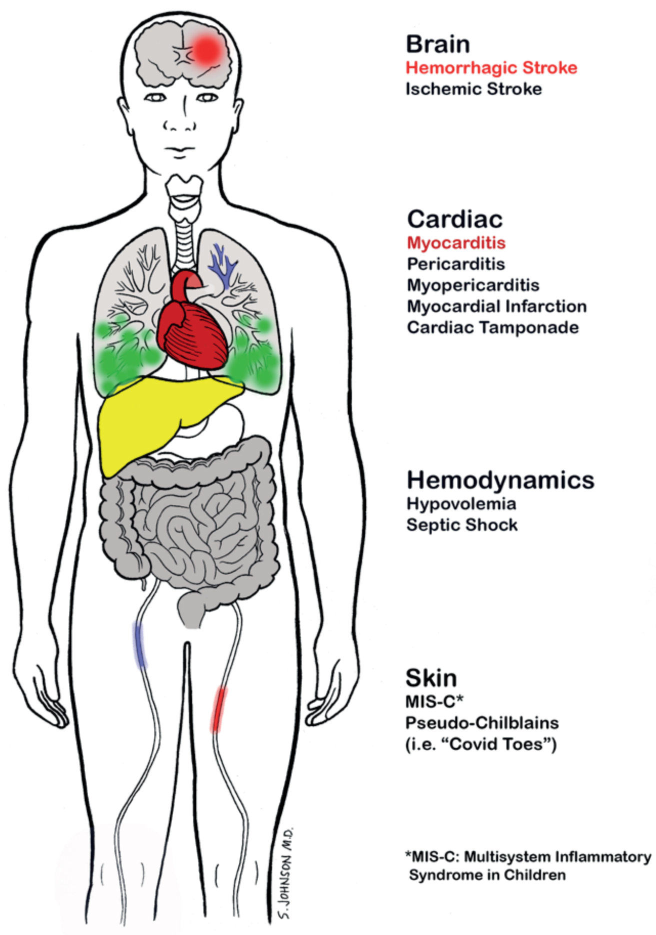

Table 1: Diagnostic Applications of Point-of-Care Ultrasound

Organ System Evaluation	COVID-19 Complications	Ultrasound Application
Brain	Ischemic Stroke Hemorrhagic Stroke	Transcranial Doppler Intracranial pressure assessment using optic nerve sheath diameter
Lung	COVID Viral pneumonia Acute Respiratory Distress Syndrome Pneumothorax Pleural Effusion	Identification of pulmonary edema (B-lines Subpleural consolidations Pleural effusions Lung sliding
Cardiac	Myocarditis Pericarditis Myopericarditis Myocardial infarction Cardiac tamponade	Cardiac ejection fraction Pericardial effusion Regional wall motion abnormalities Right/left ventricular function
Abdomen	Hepatitis Kidney injury	Assessment for hepatomegaly Renal Resistive Index Evaluate free fluid in the intraperitoneal space
Blood vessels	Thromboembolic Disease Deep vein Thrombosis Pulmonary embolism	Direct clot visualization of upper and lower Extremities Compressibility of veins Right heart strain
Hemodynamics	Hypovolemia Septic shock	Diagnose type of shock Evaluate intravascular volume status and fluid responsiveness Inferior vena cava collapsibility Respiratory variation on Doppler flow across left ventricular outflow tract/ peripheral arteries

Covid-19 Ultrasound Procedures

Figure 2: Procedural Applications of Point-of-Care Ultrasound

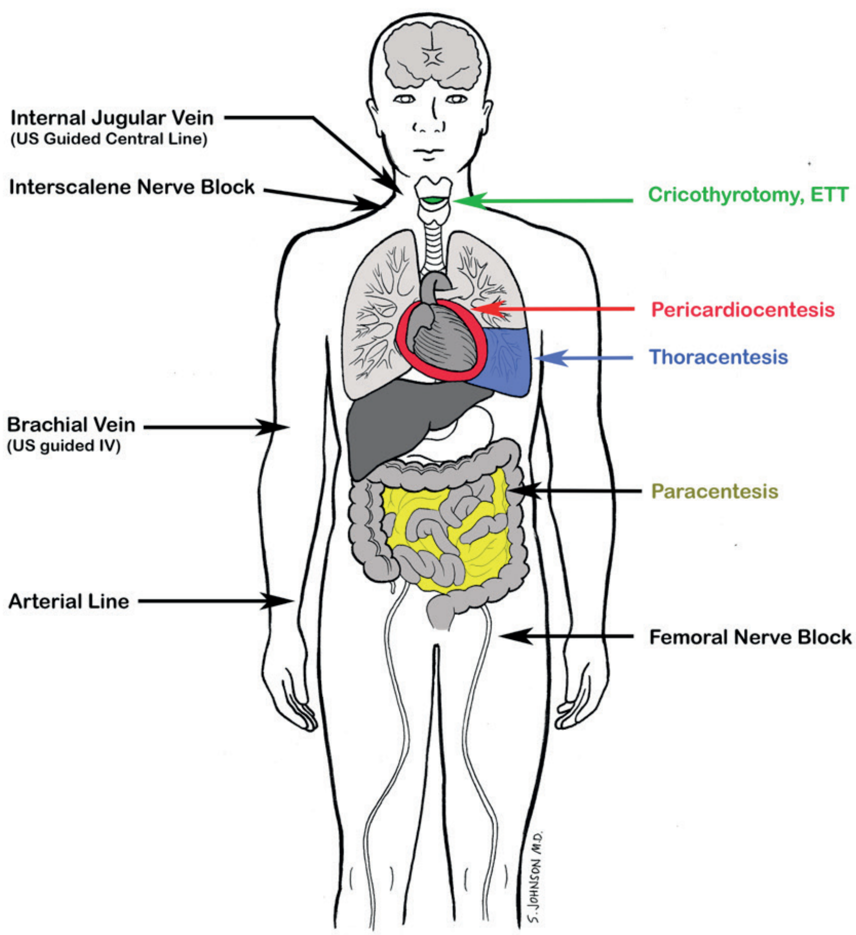

Table 2: Procedural Applications of Point-of-Care Ultrasound

Procedure	Potential Complications	Ultrasound Benefits
Peripheral IV placement	Difficulty with peripheral access, leading to delays in care	Safe and efficient US-guided PIV, higher first-pass success rate, reduced need for CVCs
Central Venous Catheterization	Iatrogenic pneumothorax, hematomas, carotid artery puncture, central-line associated blood vessel complications	Safer and faster CVC placement, confirmation of accurate placement, lower rate of complications compared to landmark techniques, reduced infection risk
Arterial line placement	Difficulty with arterial access	Safe and efficient line placement with a high rate of first-pass success
Endotracheal Tube Placement	Intubation Confirmation	Visualization of ETT and bilateral lung sliding to confirm
Surgical Procedures	General anesthesia requires intubation and aerosolization of Coronavirus	Surgical procedures can be done with ultrasound-guided regional anesthesia and decrease aerosolization exposure risk to health care staff
Pericardiocentesis	Direct needle damage to the heart	Direct visualization of needle and guide wire to safely place catheter in pericardial space
Thoracentesis	Pneumothorax, increased length of stay and higher costs	Lower risk of lung puncture as compared to landmark techniques
Paracentesis	Bleeding complications	Reduced risk for bleeding complications, compared to landmark techniques
Cricothyrotomy	Difficulty identifying landmarks, incorrect placement of incision	Assists with accurate identification of landmarks and placement during this high-risk emergent airway procedure

Author bio

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