Review Article

Point of Care Ultrasound in Coronavirus Disease 2019 Pandemic: One Modality Helping Multiple Specialties

Sangam Yadav, Abhishek Singh*, Kalung Manisha, Puneet Khanna

Department of Anesthesiology, Pain Medicine and Critical Care, All India Institute of Medical Sciences, New Delhi, India

Abstract

After the detection of novel coronavirus (2019) as the cause of a cluster of pneumonia in Wuhan, China, at the end of 2019, more than 10 million confirmed cases of coronavirus disease 2019 (COVID-19) have been reported around the globe. In the COVID-19 intensive care unit (ICU), the use of stethoscope is minimal for obvious reasons. Shifting of COVID-19 patients out of ICU setup increases the risk of transmission of infection to health-care workers as well as jeopardizes the safety of patients. Hence, diagnostic imaging has emerged as a fundamental component of the current management of COVID-19. Lung ultrasound (LUS) imaging has become a safe bedside imaging alternative that does not expose the patient to radiation and minimizes the risk of contamination. Ultrasound (USG) can be used to scan almost all vital organs (heart, kidney, vascular, brain, etc.) and also help in rapid decision-making regarding the management of COVID-19 patients. In this note, we review the current state of the art of LUS in evaluating pulmonary changes induced by COVID-19. The goal is to identify characteristic sonographic findings most suited for the diagnosis of COVID-19 pneumonia infections as well as to assess the impact of infection on other organs and utilizing the same in the management of COVID patients without compromising on the safety of patient or health-care provider.

Keywords: Coronavirus disease 2019, infection control, point of care ultrasound

INTRODUCTION

Amid the grim situation caused by an unprecedented outbreak of highly infectious coronavirus disease 2019 (COVID-19) pandemic, point of care ultrasound (POCUS) can be considered as the key screening tool for rapid assessment and confirmation of clinical findings in emergency and intensive care unit (ICU) admitted patients. Ultrasonography (USG) has the potential to replace stethoscope[1] and reduce the risk of radiation exposure. USG offers the advantage of simplicity, rapidity, practicality, portability, repeatability, low cost, ease of use, and absence of radiation. It has become an essential tool for clinicians to evaluate the cardiopulmonary status, guide invasive procedures, and manage emergencies.[2,3] Recommendation from various medical bodies such as the British Society of Echocardiography, European Association of Cardiovascular Imaging, and American College of Radiology are regularly being updated regarding cardiovascular and respiratory system imaging during the pandemic,[4,5] but there is limited reference to the role of POCUS for assessment of pulmonary and cardiovascular condition in patients suffering from COVID-19. POCUS can provide real-time detailed clinical information and images while following a robust infection prevention protocol. We will review some of the major areas of application of POCUS in the COVID-19 pandemic in our article.

LUNG

Lung ultrasound (LUS) is widely used by critical care physicians for diagnosing and evaluating multiple lung pathologies such as pulmonary edema, pneumothorax, interstitial lung disease, acute respiratory distress syndrome, and pneumonia.[6] We have recently seen extensive use of LUS while managing COVID-19-associated pneumonia in China and Italy.[7,8] Detection of COVID-19 by computed tomography (CT) chest has a sensitivity of 88%.[9] LUS has a high sensitivity for detecting ground-glass opacities, pleural

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Address for correspondence: Dr. Abhishek Singh,
Department of Anesthesiology, Pain Medicine and Critical Care, All India
Institute of Medical Sciences, New Delhi, India.
E-mail: bikunrs77@gmail.com

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thickening, and subpleural consolidation[10] and can be used as an aid to CT scan for diagnosing COVID-19.[8] LUS allows bedside evaluation of the chest giving crucial information about the lung condition which helps the clinicians in taking a rapid clinical decision.[1]

As per the BLUE protocol, bilaterally three zones, namely, upper blue, lower blue, and posterior-lateral alveolar and/or pleural syndrome (PLAPS) point are scanned. Commonly, the lesions such as subpleural thickening [Figure 1a] and consolidation are located in PLAPS region.

The consolidation pattern with the air-bronchogram pattern in COVID-19 is characteristically peripherally distributed which can be easily picked with USG [Figure 1b].[11] The interlobar thickening pattern characterized by presence of B-lines is easily located using USG helping us getting a clear picture of the progression. The subpleural consolidations in COVID-19 have reduced Doppler signal indicating absent or reduced blood flow and a poor prognosis, which is contrary to findings in common inflammation where the flow is significantly increased.[12] This reduced blood flow worsens the V/Q mismatch and increases dead space ventilation. The B-line pattern which denotes the parenchymal or interlobar edema is the characteristic finding in COVID-19, which has a patchy and irregularly distribution, which is noncharacteristic of pulmonary edema.[12] The spared area in between denotes the thickened subpleural interlobular septa. Discontinuous or continuous B-lines (waterfall sign) under the pleural line or diffused B-line (white lung sign) are observed.[12] The pleural effusion pattern is not commonly associated with COVID-19 pattern, but its presence is associated with a severe stage of the disease [Figure 1c].[13] Early stages of the disease have focal B-lines and pleural thickening, which in the later stages is replaced by confluent

Figure 1: (a) Subpleural thickening seen with curvilinear probe in posterior-lateral alveolar and/or pleural syndrome view. (b) Air bronchogram seen with curvilinear probe in posterior-lateral alveolar and/or pleural syndrome view. Arrows denoting air bronchogram. (c) White arrow indicate pleural effusion seen with curvilinear probe in posterior-lateral alveolar and/or pleural syndrome view

B-lines, pleural line thickening, and lobar consolidation. Another significant finding is the rate of progression of the disease. In patients in whom the USG findings were the result of several days of the disease, it is potentially less evolutive than similar patterns observed at a very early stage.[11] During recovery, the A-line patterns are restored. These finding should be correlated to the blood investigations such as procalcitonin to rule in COVID-19 infection.

However, USG has its limitations. They are not able to detect centrally situated consolidation due to bacterial superinfection. They are not able to recognize the chronicity of the lesion, resulting in the inability to diagnose COVID-19 in patients with preexisting lung pathology. They are not able to detect wheeze or crepitation, which can be easily identified by stethoscope. Since the chances of infection transmission are high by the use of the stethoscope in an intubated patient, increasing airway pressure can be used as a guide for diagnosing bronchospasm in intubated patients, but the same is difficult in the nonintubated patient.

CARDIAC

Cardiovascular comorbidity has the highest death rate in COVID-19 patients which is approximately 10.5%, as per the American Society of Echocardiography. A systemic infection such as COVID increases demand on the heart as well as the poor lung condition as highlighted, impacts the cardiac function.[14] The drugs used in treatment such as hydroxychloroquine and azithromycin have the potential of QT_C prolongation and precipitating arrhythmia as well. There are other multiple mechanisms of cardiac injury in COVID 19 such as cytokine surge, viral myocarditis, and acute plaque rupture, leading to the acute coronary syndrome.[15] Point of care cardiac ultrasound (USG) is one of the valuable tools for the bedside assessment of ventricular function, especially in a situation where the cause of dyspnea is difficult to differentiate from underlying respiratory illness. Cardiac POCUS can provide a significant information with limited training and can be performed by noncardiologist. POCUS has the advantage of prompt real-time image availability, which helps in immediate bedside interpretation and patient management. Focused echocardiography should include the assessment of the left ventricle (ejection fraction, contractility), right ventricle (tricuspid annular plane systolic excursion, tricuspid regurgitation), valves, and pericardium (thickening/effusion). The standard 4-chamber view allows for the assessment of gross contractility along with the comparison of ventricular dimension to exclude pulmonary embolism [Figure 2]. The stroke volume can be assessed using the parasternal long-axis view to determine the left ventricular outflow tract (LVOT) area and getting velocity-time integral across the LVOT in a four-chamber view. Parasternal short-axis view helps to determine the volume status as well as the regional wall motion abnormality along with the territory of coronary circulation involved. The viral myocarditis can lead to/precipitate myocardial infraction/cardiac failure/cardiogenic
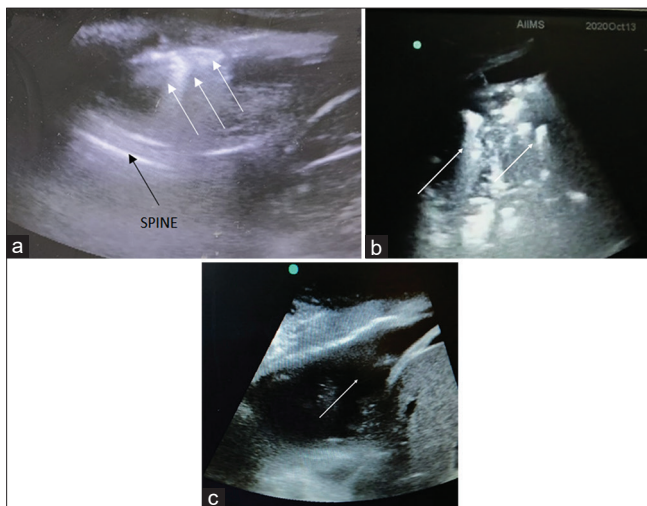
shock. POCUS echocardiography can help identify the etiology of shock and help in early initiation of treatment with inotropic agents.

VASCULAR

COVID-19 causes endothelial injury. As the patients are immobile, the chances of thromboembolic events are very high in patients with moderate-to-severe symptoms. Such patients are prone to TIA, strokes, myocardial infarction, pulmonary embolism, acute kidney injury, etc. USG can be used to check the patency of the lower limb veins to rule out deep vein thrombosis (DVT).[16] The superficial femoral, common femoral, saphenous vein, and popliteal veins are assessed daily to rule out DVT. Checking for compressibility of vein [Figure 3a and b], flow by color Doppler and augmentation of flow with compression in the veins can help assess the patency of the limb veins. Since the patient-modified WELL'S score cannot be effectively applied in ICU patients who are mostly not in a state to give a history USG can help confirm, diagnose, and guide theraphy.

USG works as our new set of eyes in poor vision condition which arises while working in personal protective equipment (PPE). They can be used during central venous cannulations, with increased first-pass success and reduced complications [Figure 4]. It can also be used for confirmation of Ryle's tube position after placement [Figure 5].

FLUID THERAPY

Strict fluid regulation is important for improving patient outcomes as both over or under hydration can prove catastrophic for COVD-19 patients suffering from multiple organ dysfunction. By measuring daily weight in the ICU or calculating fluid balance can help us to guide fluid and diuretic therapy. However, due to increased vascular permeability caused inflammatory mediators in COVID-19 results in extravasation of body fluids in interstitial space which

manifest as intravascular hypovolemia but increased total body water. Use of high positive end-expiratory pressure, vasoplegic state due to sepsis, and existing cardiac dysfunction results make blood pressure and central venous pressure, a poor indicator of the hemodynamic status of the patient.[17] USG can help in the assessment of fluid responsiveness by determining the inferior vena cava collapsibility/distensibility index, which will help us guide fluid therapy and optimize hemodynamics.

IVC collapsibility index (IVCI) (spontaneous breathing)

$$= \frac{IVC_{maximum} - IVC_{minimum}}{IVC_{mean}} \times 100$$

IVC distensibility index (IVDI) (mechanical ventilation)

$$= \frac{IVC_{maximum} - IVC_{minimum}}{IVC_{mean}} \times 100$$

IVCI >12% is associated with fluid responsiveness in spontaneous breathing patient and IVDI >18% in mechanically ventilated ones.

AIRWAY

Airway management is a crucial part of managing critically ill COVID-19 patients. Point of care airway USG will help in predicting difficult airway, help in confirming the correct placement of the endotracheal tube, assist in the USG-guided tracheostomy, and to assess patient's readiness before extubation.
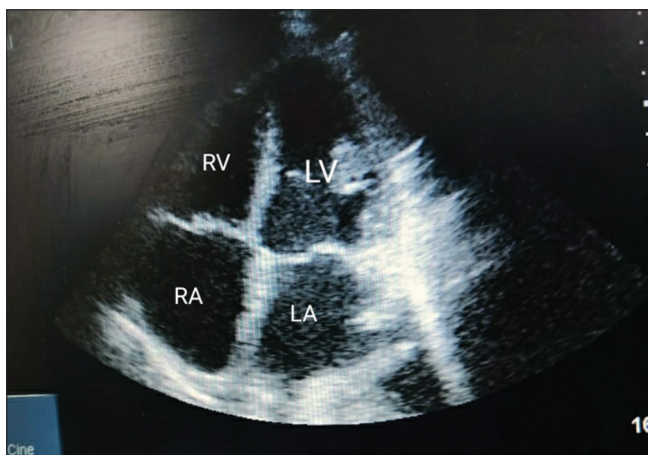

Figure 2: Cardiac four-chamber view with cardiac probe in subcoastal view. RA: Right atrium, RV: Right ventricle, LA: Left atrium, LV: Left ventricle
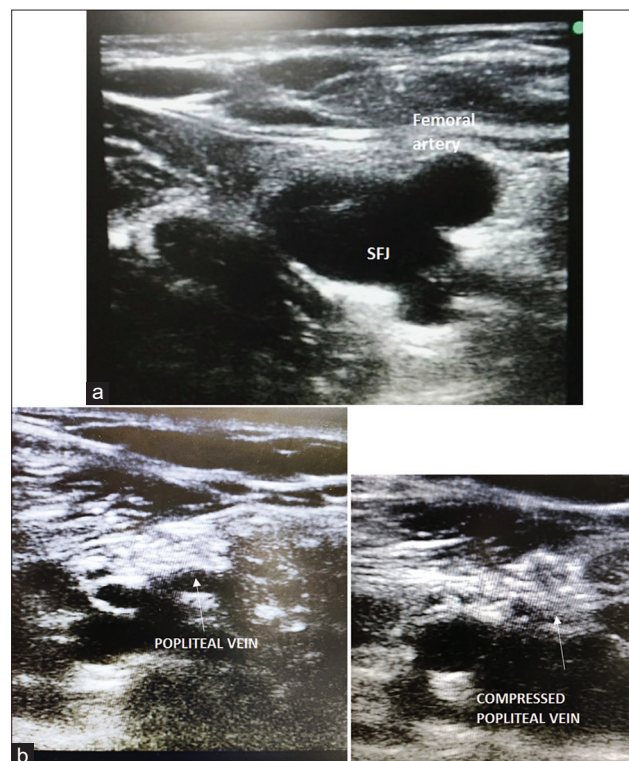

Figure 3: (a) Patent Sapheno femoral junction seen with linear probe placed transversely beneath the groin. (b) Compressible popliteal vein seen with linear probe placed transversely in the popliteal fossa

Airway evaluation by ultrasound

It is important to evaluate the airway before going for intubation. However, in critically ill COVID-19 patients, the conventional method of airway evaluation such as mouth opening, thyromental distance, Mallampati classification, interincisor gap, and the mandibular protrusion is difficult to execute as some patients may not follow our commands, while in some situation, it is not safe. Predictors of difficult airway such as neck circumference, soft-tissue thickness on the anterior part of the trachea, width of the tongue, and lateral pharyngeal wall can be measured by bedside USG to diagnose and predict difficult airway.[18] Working in PPE precludes the use of a stethoscope, and anesthesiologist must rely on airway USG and end-tidal carbon dioxide for confirmation of endotracheal placement.[19]

ULTRASOUND-GUIDED TRACHEOTOMY

Tracheostomy plays a crucial role in the management of critically ill COVID-19 patients as these patients may require prolonged ventilation until their lung recovers from illness. USG helps in locating the trachea and associated airway anatomy, thus improving the success rate and reducing the duration of the procedure, both of which is important in critically ill COVID-19 patients suffering from severe hypoxia [Figure 6].[20]

Ultrasound-guided weaning and extubation

Prolonged endotracheal intubation and ventilation in patients with COVID-19 are associated with complications such as tracheal mucosal damage, granuloma formation, and edema. Early extubation can be harmful and results in high reintubation rates and mortality. During weaning from mechanical ventilation, USG can be used for the assessment of the status of the lung, diaphragm, and chest wall, which will help in guiding the process of spontaneous breathing trial.[21] LUS can be used for predicting the extubation risk and patients with the LUS score are >17 should remain intubated as they have a high probability of developing complications after extubation.[22,23]

NERVOUS SYSTEM

USG has a very limited role in diagnosing cranial pathology. Coronavirus can gain assess to the central nervous system (CNS) through hematogenous spread or dissemination through cribriform plate and olfactory bulb. The inflammatory response and respiratory impairment contribute to the development of delirium, ischaemic stroke, seizure, etc. Several factors such as increasing partial pressure of arterial CO_2 due to respiratory failure and the use of high postive end-expiratory pressure leads to the development of higher intracranial pressure (ICP). Increased ICP in a patient with deteriorating GCS can be assessed noninvasively using the optic nerve sheath diameter [Figure 7]. The normal nerve sheath diameter is 5 mm, which is measured 3 mm behind the globe. An increase in diameter suggests a rise in ICP
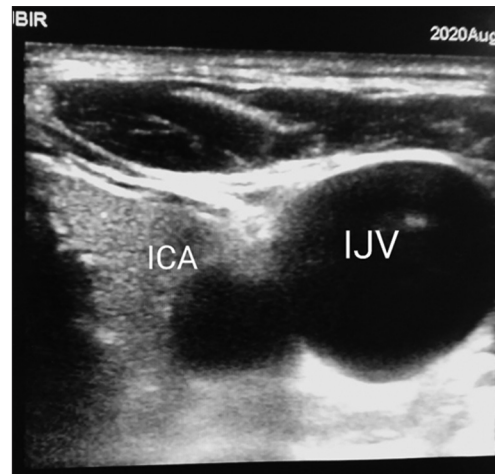

Figure 4: Ultrasound guided central venous cannulation with linear probe at the level of cricoid. ICA: Internal carotid artery, IJV: Internal jugular vein
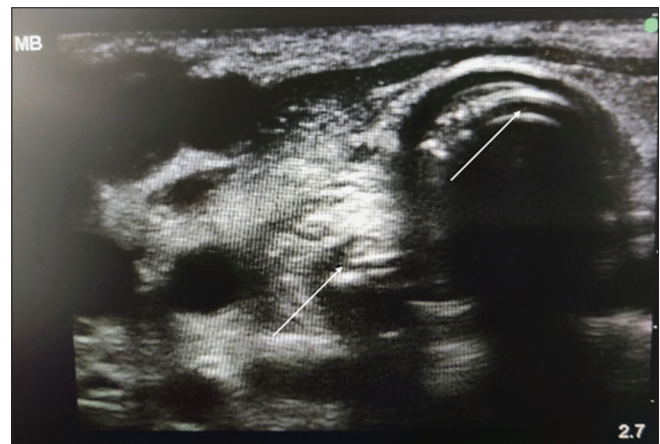

Figure 5: Double trachea sign with linear probe placed transversely on neck of patient
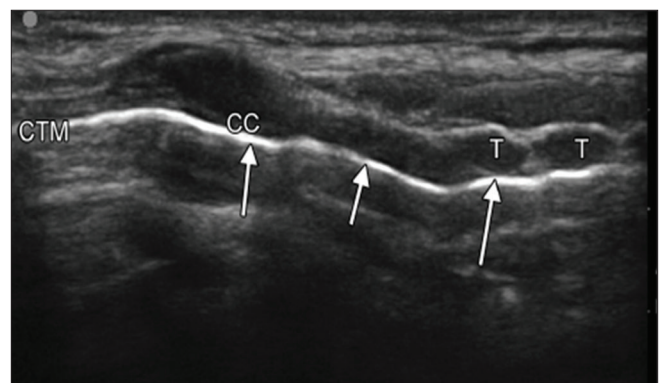

Figure 6: Airway anatomy seen with linear probe placed sagittal plane over the neck. CTM: Cricothyroid membrane, CC: cricoid cartilage, T: Trachea

and warrants a CT/magnetic resonance imaging depending on clinical suspicion. Increased ICP causes prolonged ICU stay and difficult recovery.[24] Cerebral vasospasm can also be diagnosed using the Lindegaard ratio[25] using transcranial Doppler. However, achieving a proper window is a major concern.
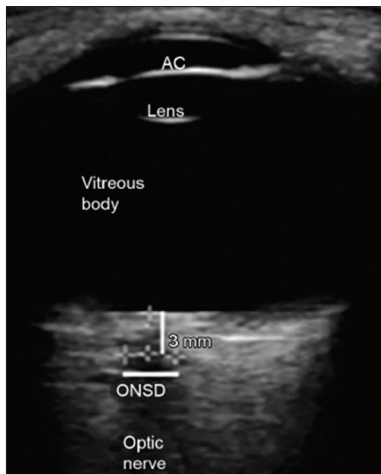
Figure 7: Optic nerve sheath diameter. AC: Anterior chamber, ONSD: Optic nerve sheath diameter

Current Evidence of Use of Point of Care Ultrasound in Coronavirus Disease 2019

Kariyanna *et al.* reported a case of 55 years of man with COVID-19 in whom the thrombus in transit was diagnosed with point of care USG. Although the CT angiography is the gold standard for diagnosing venous thromboembolism, Kariyanna *et al.* successfully demonstrated that POCUS can be used as an alternative for screening patients with COVID-19 who are at risk of developing venous thromboembolism.[26] Prisca *et al.* successfully used lung POCUS in a 9-year-old obese boy with COVID-19 to assess lung pathology. They emphasized that POCUS can be used as a potentially efficient tool for bedside assessment of patients with COVID-19.[27] Buonsenso *et al.* used LUS in pregnant women with COVID-19 to monitor the progress of disease and response to treatment.[28] Nick *et al.* did a study in the emergency department regarding using point-of-care LUS for triaging patients with COVID-19. They found out that lung POCUS showed outstanding sensitivity and negative predictive value but poor specificity, accuracy, and positive predictive value as compared to RT-PCR. They concluded that POCUS may provide early ER triage and can be used as safe screening tool for evaluating COVID-19 patients.[29] Bhoi *et al.* in their article have briefly summarized the application of POCUS in managing COVID-19 patients from the triage area in the emergency to the ICU.[30]

Recommendation for safe use of ultrasound during coronavirus disease 2019 pandemic

Preventing cross-infection among patients and health-care professionals is of prime importance during the pandemic. There is limited evidence regarding reducing cross-infection while using USG in the COVID-19 pandemic. The Centers for Disease Control and Prevention (CDC) in 2020 has outlined standard precaution for COVID-19. These are:
1. USG practitioners with health problems placing them at risk to COVID-19 are to be excluded from performing an USG

2. USG practitioners must have undergone infection control training and if required fit testing for respirators
3. Hand hygiene
4. Scanning should be performed with one hand (clean) and the other hand semi-clean, in contact with the keyboard. Gel application is to be done with the semi-clean hand dispensing clean gel. Postprocedure thorough cleaning if the gel bottle with low-level disinfectant (LLD) to be done.

Preparing and cleaning of ultrasound equipment

1. USG monitor and user interface should be cleaned using LLD with agents recommended by CDC and environmental protection agency
2. Equipment cover such as for USG scanner can be used to enhance the workflow as LLD of the equipment is time consuming. However, the presence of cover does not prevent the need for cleaning the equipment at regular intervals
3. Reduce the number of transducers connected to the USG machine
4. USG transducers and cables should be cleaned after each use.

Transducer cleaning and disinfection

Spaulding classification system of the reusable device includes noncritical, semi-critical, and critical (also referred to as low-risk, medium risk, and high risk, respectively).
1. Noncritical devices are USG transducers that come into contact with intact skin. It can be disinfected using LLD or intermediate-level disinfection
2. Semi-critical and critical devices are USG transducers which come in contact with blood, body fluids, nonintact skin, and mucous membrane. This must be cleaned with high-level disinfection (HLD) method. A single-use transducer cover is mandatory.

The normal practices of HLD are not changed in context to COVID-19; the only change is that all external probes must undergo cleaning first, as the remaining gel can act as barriers to disinfectant. This should be followed by LLD.

Specific recommendation regarding ultrasound gel

In the context of the COVID-19 pandemic, it is recommended that, for any external examination of COVID-19 patients, nonsterile, single-use gel packets be used whenever possible and discard any unused portions.

We will be suggesting some more recommendations for the proper use of USG-based on our clinical experience.
1. There should be designated USG for COVID area in the hospital
2. Handheld devices are preferred as they can be easily cleaned
3. Card-based USG devices should not contain unnecessary items such as gel bottles, baskets, or printers
4. Touch screen machines are preferable than keyboard-based machines

5. While performing aerosol-generating procedures in the operation room or ICU, all the nonessential components of the USG machine should be covered by clear plastic and sheaths should be used to cover cord and probe
6. After performing the scan, remove all drapes and covering gently to avoid aerosolization of the virus
7. Wipe the entire machine surface with ethanol wipes inside the procedure room before doffing
8. Give sufficient time for the surface to get dry
9. Machine to be moved out of the procedure room and again the entire surface to be cleaned by ethanol wipes.

CONCLUSION

POCUS can go a long way in managing and treating COVID-19 patients. It is a valuable tool to assess cardiopulmonary status, airway, response to treatment, and guide invasive procedures in COVID-19 patients. Proper application of POCUS during a pandemic will improve safety and outcome. Reduced exposure, low cost, portability, and easy disinfection are the points which makes it a lucrative option in such trying times.

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Conflicts of interest

There are no conflicts of interest.

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