Critical Care Ultrasound: A Necessary and Mandatory Tool for Novel Coronavirus Pneumonia

Junyu Ma, MD, a, Xiaoqing Wu, MD, a, Lina Zhang, MD, b, Jun Duan, MD, a,*, Xiaoting Wang, MD, c,*; Chinese Critical Care Ultrasound Study Group (CCUSG)

a Surgical Intensive Care Unit, China-Japan Friendship Hospital, Beijing, China; b Department of Critical Care Medicine, Xiangya Hospital, Central South University, Changsha, Hunan, China; c Department of Critical Care Medicine, Peking Union Medical College Hospital, Tsinghua University, Beijing, China

Received April 19, 2020; revision received April 21, 2020; accepted April 22, 2020

Abstract: Ultrasound has developed as an invaluable tool in diagnosis and proper management in the critical care settings. There are four aspects of applying critical care ultrasonography, including substitutional ultrasound, predicational ultrasound, point-of-care ultrasound, and whole body ultrasound. All four aspects have been widely applied in Wuhan based on the special ultrasound lump test predicational critical patients (ULTPCP) protocol. We aim to introduce our own experience of utilizing critical care ultrasound to significantly improve outcomes, shorten the operation time, and reduce occupational exposure.

Key words: Intensive care; Point-of-care ultrasound; COVID-19 Pneumonia

Advanced Ultrasound in Diagnosis and Therapy 2020;02:119-122 DOI: 10.37015/AUDT.2020.200040

Up to 18 April 2020, more than two million confirmed cases of the novel coronavirus (SARS-CoV-2) infection have been diagnosed worldwide, posing severe public health risk. Critical care ultrasound plays an important role in the management of critically ill coronavirus disease 2019 (COVID-19) patients. The application of critical care ultrasound includes four aspects: substitutional ultrasound, predicational ultrasound, point-of-care ultrasound, and whole body ultrasound.

Substitutional Ultrasound

The diagnosis of COVID-19 is based on nucleic acid detection. However, sampling operations, specimens, source, and sampling timing can affect the accuracy of reverse transcription polymerase chain reaction (RT-PCR) testing. It has been reported that positive chest computerized tomography (CT) findings may occur before a positive RT-PCR result [1]. Experts then recommended early chest CT for screening suspected patients. However, the complexity of the disinfection process of CT may delay diagnosis and increase nosocomial spread of the virus. In the meanwhile, some developing countries and regions do not have enough equipment or funds to provide timely scanning for a large number of patients. When performed by trained physicians, lung ultrasound can be used as an alternative to chest CT due its portability, non-invasiveness, and repeatability. Therefore, we suggest utilizing lung ultrasound as a rapid assessment tool with the 12-zone method [3] for suspected COVID-19 patients. Undoubtedly, training intensive care doctors to conduct point-of-care ultrasound is critical and necessary, and it is critical during the outbreak of this COVID-19 pandemic (Fig. 1).
COVID-19 pulmonary lesions usually begin in the distal regions of the lung and progress proximally. Based on our current experience, the irregularly thickened pleural line and focal B-lines are the main abnormalities in the early stage of novel coronavirus pneumonia (NCP). More prominent B lines in multiple lobes and the appearance of shred sign, which stand for subpleural consolidation, would emerge as the disease progresses [2].

According to the treatment protocol we have adopted, positive lung ultrasound was defined as focal or confluent B lines and shred sign in more than one pulmonary zone. Of note, the RT-PCR testing is still vital because ultrasound cannot differentiate SARS-COV-2 from another viral infection of the same coronavirus family. Advanced ultrasound equipment such as robot-assisted teleultrasound is under development, and may be useful for remote ultrasonography.

**Predicational Ultrasound**

In the isolation ICU, because intensive care physicians need to wear a complete set of personal protective equipment before evaluation of patients in shock or performing endotracheal intubation, it takes a longer time than usual. At present, the judgment of deterioration is mainly based on the dynamic clinical data (i.e. respiratory rate, oxygen saturation), which are often lagging behind. Thus, we hope to use more quick and reliable indicators to monitor critically ill patients and to make sure endotracheal intubation, mechanical ventilation, and sedation are performed at the right time before the onset of severe hypoxia.

Based on our own experience, there are no clear indications to predict respiratory failure and when advanced respiratory supportive equipment will be needed via ultrasound findings and B line score. A high B-line score means there are bilateral diffuse B-lines (B7, B3 and confluent B-line) and shred sign. Thus, even if respiratory failure aggravates, B-line score and ultrasound signs cannot tell the difference. Large consolidation is not common, and it sometimes can be seen in late phase of the disease or secondary to bacterial infection.

In order to increase the accuracy of ultrasound, three indicators could be used in severe cases to detect any further deterioration. It is called ultrasound lump test predicational critical patients (ULTPCP) protocol, and the whole examination can be finished within 150s by well-trained physicians (Table 1). If the answer is “PRESENT” in any of these items, the severity of the patient should be questioned.

**(1) Diaphragm ultrasound**

Patients breathe deeply and rapidly to compensate for hypoxia when respiratory function deteriorates. Diaphragm movement can reflect the patient's respiratory drive to some extent. Excursion amplitude (EA) of diaphragm from end-expiration to end-inspiration is measured. Considering time, we suggest visual estimating of the EA. When the respiratory rate increases even faster and blood oxygen saturation has not yet deteriorated, the diaphragm EA should be reviewed. Higher EA suggests that the patient's respiratory function is on the edge of decompensation. For patients with severe NCP, EA>20mm indicates strong respiratory drive, which need to be closely monitored as critical cases. Immediate endotracheal intubation should be performed as necessary.

**(2) Echocardiography**

Echocardiography is used to screen for heart abnormalities for critically ill COVID-19 patients. Visual estimation of the echocardiogram takes less than 1 minute for each patient. We focus on whether the left ventricular (LV) contraction is normal and right ventricular (RV) is enlarge, and we look for signs of circulatory deterioration before it happens. By parasternal LV long axis, LV systolic dysfunction may present as overall hyperdynamic, segmental dyskinesia, and diffuse myocardial inhibition [4]. Among them, segmental dyskinesia may due to coronary heart disease (coronary related segmental distribution) or takotsubo cardiomyopathy (coronary artery unrelated) [5], and diffuse myocardial inhibition usually results from sepsis or drugs induced myocardial damages. The size of RV is judged on apical four chamber section by comparing with the size of the LV. Enlarged RV is defined as the size of RV is equal or bigger than the size of LV. Patients with reduced LV systolic function and en-larged RV should be monitored closely. Supportive and goal-directed treatments should be started as early as heart.
rate becomes to rise and blood pressure becomes to drop.

(3) Limited (two-point) compression ultrasonography

Limited (two-point) compression ultrasonography is preferred for the diagnosis of deep vein thrombosis (DVT) in COVID-19 patients. Almost all critically ill NCP patients have an elevated D-dimer level, and the autopsy results often indicates the presence of pulmonary vessels thrombosis. We focus only on popliteal and femoral veins because a thorough vascular exam can be really time-consuming. The ULTPCP protocol has been used for a rapid diagnosis and management of COVID-19 patients, and almost all physicians can master this protocol and pass the scenario simulation after 2 hours of training and 2 hours of practice (Table 1).

Table 1 Ultrasound lump test predicational critical patients’ protocol (ULTPCP protocol)

| Name: | ID: |
|-------|-----|
| Setting: | |
| Operator | |
| LUNGS | |
| Screening for diaphragm excursion amplitude (15” ×2) | EA>20mm | EA≤20mm |
| HEART | |
| Screening for LV dyskinesia (PLAX, 15”) | PRESENT | ABSENT |
| Screening for LV dyskinesia (PSAX, 15”) | PRESENT | ABSENT |
| Screening for enlarged RV (A4C, 15”) | PRESENT | ABSENT |
| DEEP VEINS | |
| Screening for femoral venous thrombosis (15” ×2) | PRESENT | ABSENT |
| Screening for popliteal venous thrombosis (15” ×2) | PRESENT | ABSENT |

Point-of-Care Ultrasound

Point-of-care ultrasound is defined as a goal-directed, bedside ultrasound examination performed by a healthcare provider to answer specific diagnostic questions [6]. The best example of point-of-care ultrasound is screening the cause of respiratory failure when simple lung lesions cannot explain the clinical manifestations. Cardiac factors causing respiratory failure also need to be ruled out via critical consultation ultrasound examination (CCUE) protocol, which include the detailed information about LV, RV, lung, inferior vena cava (IVC), cardiopulmonary interaction, fluid responsiveness, etc. Therefore, for COVID-19 patients who have newly develop respiratory failure or worsened hypoxemia, besides lung lesions, airway, thoracic cavity, chest wall compliance and pulmonary blood vessels, fluid volume, tissue perfusion, and cardiogenic factors should all be carefully evaluated. In addition, if COVID-19 patients develop shock in the later phase, the focus assessed transthoracic echocardiography (FATE) protocol can be used to quickly assess the cause of circulatory failure to guide clinical treatment. When critical patients suddenly have cardiac arrest, focused echocardiographic evaluation in life support (FEEL) protocol [7] can help to evaluate cardiac motion and anatomy, identify false and true PEA, determine the cause of false PEA (severe systolic disorder, severe hypovolemia, severe acute right heart failure, and pericardial tamponade), and make timely and accurate judgment for spontaneous circulation recovery (Fig. 2).

Figure 2 Both desktop (GE VENUE) and handheld (GE Vscan) ultrasound devices were used in critically ill COVID-19 patients.
Whole Body Ultrasound

Whole body ultrasound can be used to evaluate organ damage other than heart and lungs and also guide the central venous catheter (CVC) and peripherally inserted central venous catheter (PICC) placement, percutaneous dilational tracheostomy (PDT), gastrointestinal tract management, and ECMO management, etc. Specifically, when patients have neurological symptoms, whole body ultrasound could help evaluate the intracranial pressure by measuring the width of the optic nerve sheath, the displacement of the midline of the brain, and the blood flow of the brain to explore possible the causes; For kidney involvement, ultrasound can be used to assess kidney size, shape, volume, renal sinus, renal pelvis, renal blood flow semiquantitative assessment, and resistance index and pulse index, etc., to differentiate different causes of acute kidney injury (AKI). In addition, for some COVID-19 patients, gastrointestinal (GI) symptoms could be the first manifestation, and GI intolerance is also common during medical treatment. For these patients, the measurement the GI wall thickness, lumen, mobility, and gastric residual volume (GRV), etc. is needed to understand GI tract function, and to place the postpyloric nutrition pathway under the guidance of ultrasound [8]. For patients in need of extracorporeal membrane oxygenation (ECMO) treatment, critical care ultrasound can help guide the initiation of ECMO by identifying the intended vascular structure, detect some of the complications associated with ECMO, and determine the best time to discontinue ECMO [9]. Of note, when performing the interventional procedure, medical staff always wear secondary or even tertiary personal protective equipment, which make the interventional operation even more complex. For this reason, whether it is central venous catheterization, arterial catheterization, peripheral venipuncture, or venous blood collection, it is recommended to use ultrasound as a guide to significantly improve outcomes, shorten the operation time, and reduce occupational exposure.

Summary

The four aspects of critical care ultrasound for COVID-19 have been widely used in Wuhan, which has greatly reduced the time for diagnosis and patient triage. Any kind of ultrasound devices from small to big, cheap to expensive, and simple to complex could be used. With the help of critical care ultrasound, more convenience and confidence tend to be achieved. Of note, the special ULTPCP protocol is highly feasible and well worth promoting.

Acknowledgement

Funding was provided by discipline construction project of Peking Union Medical College (Grant no. 201920102304) and educational reform project of Peking Union Medical College (Grant no. 10023201902301).

We wish to thank Dr. Yang Hai from Thomas Jefferson University for editing our manuscript.

Conflict of Interest

Authors have no conflicts of interest related to this work to declare.

References

[1] Ai T, Yang Z, Hou H, Zhan C, Chen C, Lv W, et al. Correlation of chest CT and RT-PCR testing in coronavirus disease 2019 (COVID-19) in China: a report of 1014 cases. Radiology. 2020 Feb 26; 200642. DOI: 10.1148/radiol.2020200642.

[2] Peng QY, Wang XT, Zhang LN; Chinese Critical Care Ultrasound Study Group (CCUSG). Findings of lung ultrasonography of novel coronavirus pneumonia during the 2019-2020 epidemic. Intensive Care Med. 2020 Mar 12:1–2. DOI: 10.1007/s00134-020-05996-6.

[3] Soummer A, Perbet S, Brisson H, Arbelot C, Constantin JM, Lu Q, et al; Lung Ultrasound Study Group. Ultrasound assessment of lung aeration loss during a successful weaning trial predicts postextubation distress. Crit Care Med 2012; 40: 2064-72.

[4] Peng QY, Wang XT, Zhang LN; Chinese Critical Care Ultrasound Study Group (CCUSG). Using echocardiography to guide the treatment of novel coronavirus pneumonia. Crit Care 2020; 24: 143.

[5] Khalid N, Ahmad SA, Shlofmitz E, Chhabra L. Pathophysiology of takotsubo syndrome. 2020 Jan 16. StatPearls [Internet]. PMID: 30844187.

[6] Campbell SJ, Bechara R, Islam S. Point-of-care ultrasound in the intensive care unit. Clin Chest Med 2018; 39: 79-97.

[7] Breitkreutz R, Price S, Steiger HV, Seeger FH, Ilper H, Ackermann H, et al; Emergency Ultrasound Working Group of the Johann Wolfgang Goethe-University Hospital, Frankfurt am Main. Focused echocardiographic evaluation in life support and peri-resuscitation of emergency pa-tients: a prospective trial. Resuscitation 2010; 81: 1527-33.

[8] Abu-Zidan FM, Cevik AA. Diagnostic point-of-care ultrasound (POCUS) for gastrointestinal pathology: state of the art from basics to advanced. World J Emerg Surg 2018; 13: 47.

[9] Doufle G, Roscoe A, Bilija F, Fan E. Echocardiography for adult patients supported with extracorporeal membrane oxygenation. Crit Care 2015; 19: 326.