Netherlands Journal of Critical Care
Submitted May 2020; Accepted May 2020

REVIEW

POCUS series: point-of-care lung ultrasound in patients with COVID-19

A.X. Elzo Kraemer[1], S.L. Staal[1], J.E. López Matta[1,2], M.E. Haaksma[2,3], M.L. Heldeweg[2,3], J.M. Smit[2,3], P.R. Tuinman[2,3], D.J. van Westerloo[1,2], C.V. Elzo Kraemer[1,2]

The first two authors contributed equally to this work

[1]Department of Intensive Care, Leiden University Medical Center, Leiden, the Netherlands,
[2]Amsterdam Leiden Intensive care Focused Echography (ALIFE)
[3]Department of Intensive Care, Amsterdam UMC, Vrije Universiteit Amsterdam, Amsterdam, the Netherlands

Correspondence
D. van Westerloo - djvanwesterloo@lumc.nl

Keywords - lung ultrasound, POCUS, COVID-19

Abstract
This article is part of the point-of-care ultrasound (POCUS) series. During the Coronavirus Disease 2019 (COVID-19) pandemic, we have been managing large numbers of infected patients whilst maintaining high-quality healthcare. In this article we aim to provide a short and practical description on how point-of-care lung ultrasound can be of use to facilitate diagnosis and treatment in critically ill patients diagnosed with COVID-19.

Introduction
This article is part of the point-of-care ultrasound (POCUS) series in which we aim to provide high ultrasound techniques to aid in diagnosis, decision-making and assessment of therapy in the daily clinical practice of intensive care units (ICUs). During the Coronavirus Disease 2019 (COVID-19) pandemic that started late 2019, hospitals and other medical practices were confronted with a serious challenge: managing large numbers of infected patients whilst maintaining high-quality healthcare. In this issue, our aim is to provide a short and practical description on how lung ultrasound can be of use in critically ill patients diagnosed with COVID-19.

COVID-19 pneumonia is caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). The clinical picture of COVID-19 is often respiratory in nature and commonly involves the bilateral peripheral lung fields in the early stage of the disease and may go on to a more generalised ARDS-like pattern as the infection progresses.[1,2] Unfortunately, traditional lung imaging techniques such as computed tomography (CT) or chest radiography require transportation of highly infectious patients to the radiology department or the introduction of bulky machines into the ICU. Neither of these modalities is favourable as they increase the risk of infection and require time, availability and exposure of additional healthcare professionals. In contrast, lung ultrasound can be performed during clinical rounds by the same clinician who is evaluating the patient and will only take a few minutes. Moreover, lung ultrasound has shown to be a reliable tool for superficial lung alterations with a fairly similar diagnostic accuracy to a CT scan.[3-5] In addition, ultrasound machines are often already present on ICUs and can nowadays be as small as a handheld device, hence diminishing the time it takes to decontaminate the machine after the examination of each patient. We therefore suggest using lung ultrasound in the ICU as a way of quickly monitoring changes and aeration of superficial lung tissue of patients diagnosed with COVID-19.

Technique
Lung ultrasound can best be performed using a low-frequency convex probe, which allows for the visualisation of both the pleural line and the subpleural space. A high-frequency linear probe is less suitable to visualise the deeper subpleural space, although it can be used to better visualise the pleural line and lung sliding. Ideally the machine is used with a lung preset or an abdominal preset when using the convex probe without any filters. The use of filters or other imaging modalities could alter the appearance of B lines, an important finding in COVID-19.[6] The focus of the image should be positioned at the level of the pleural line with a penetration depth of 8-10 cm. It is best to scan for a full respiratory cycle. When performing lung ultrasound, a systematic protocol of examination is important. To achieve this, a specific scanning scheme must be used in which the left and right hemithorax are divided into different

zones. The best scanning approach in COVID-19 patients has yet to be elucidated, therefore, we use an empirical approach. There are multiple, well acknowledged, scanning schemes that could be considered for use, for instance the BLUE protocol developed by Lichtenstein.[7-9] However, since the Blue protocol only involves three regions on each hemithorax we believe that a scanning scheme in which 12 regions are involved better reflects the overall lung involvement. This is of particular importance because COVID-19 presents with a patchy pattern, as we discuss below. In this scheme the left and right hemithorax are divided into three zones and in these zones two scans are performed in the lower and upper half. A more detailed description of this scanning scheme can be found in the referenced literature.[9] The 12-zone scanning scheme enables us to calculate both the global aeration Lung Ultrasound Score (LUS) and the Lung Reaeration Score.[10,11] This makes it possible to quantify as well as monitor the loss of aeration and the amount of re-aeration of lung tissue after treatment. Furthermore, this could contribute to better communication between operators in different care settings.

Findings

Normal lung structures include the following: A lines, reverberation artefacts arising from the pleural line; less than three B lines that arise from the pleural line; and lung sliding, the movement from the visceral pleura in reference to the parietal pleura. For a more detailed description of these artefacts we refer to previous articles.[9,12] Changes in the lung parenchyma of COVID-19 patients begin in the more distal regions and progress to the proximal areas.(1).The regions that seem to be most frequently affected are the right, middle and lower lobes followed by the left upper lobe.[2] The disease presents as a patchy pattern with spared areas. The course of the disease is usually as follows[13]: in earlier stages of the disease the pleural line alters; it thickens and becomes irregular, and B lines arise *(figure 1A)*. The amount of B lines seems to increase as the disease worsens and they become more coalescent *(figure 1B)*. In addition to these coalescent B lines small consolidations form which are often referred to as subpleural consolidations (<2 cm) *(figure 1C)*. These consolidations stay limited to the periphery and are present right under the pleural line. Recently some investigators have suggested that these subpleural consolidations could also be a manifestation of thrombotic complications of COVID-19.[14,15] In a more critical stage, these consolidations have been seen to increase in number and size, sometimes giving rise to a tissue-l pattern. When large consolidations are present in posterolateral areas, other causes should be considered, such as bacterial infection or compression/obstructive atelectasis.[6] The presence of dynamic air bronchogram(s) pleads more for a bacterial pneumonia/ventilator-associated pneumonia and rules out obstructive atelectasis.[14] A static or absent air bronchogram could be a sign of atelectasis but is not specific enough for this diagnosis. Pleural effusion can also be found, but this has been reported to be rare in COVID-19 patients.[13] The sonographic signs in COVID-19, as described, are very similar to ARDS[16] and other viral pneumonias.[8,17-19] Findings in ARDS include: anterior subpleural consolidations, absence or reduction of lung sliding, 'spared areas' of normal parenchyma *(figure 1D)*, pleural line abnormalities (irregular, thickened) and inhomogeneous distribution of B lines.[8] A characteristic artefact, which seems to be unique in COVID-19 patients, has been observed.[16,20] Volpicelli et al. called this artefact a 'light beam' and describe it as follows: 'a shining band-form artefact spreading down from a large portion of a regular pleural line, often appearing and disappearing with an on-off effect in the context of a normal A lines lung pattern visible on the background'. We have also observed this phenomenon frequently in our COVID patients.

Limitations

Monitoring patients using lung ultrasound is associated with several limitations. First, most patients hospitalised on the ICU are intubated, sedated and frequently paralysed. Therefore, visualising dorsal lung fields in patients in a supine position, or ventral lung fields in patients in a prone position can sometimes be quite challenging. This is especially true since obesity seems to be highly frequent among patients infected with COVID-19 who were admitted to the ICU.[21] Secondly, due to the heterogeneous and sometimes patchy distribution of the lung lesions, we suspect there will be a degree of inter-observer variability when performing lung ultrasound.[22] However, by scanning 12 lung fields in total, we aim to increase the likelihood of generating a representative picture of the lungs. Finally, lung ultrasound is based on the seven principles described by Lichtenstein and dictates that all signs arise from the pleural line.[23] Therefore, a lung ultrasound can only visualise pathology that extends to, or is located in, the peripheral parts of the lungs. Central lesions cannot be visualised by lung ultrasound, underlining the importance that the presence or absence of pathological signs on lung ultrasound needs to be put in its clinical context.

Conclusion

Patients with COVID-19 predominantly show a subpleural distribution, making them ideal candidates for monitoring using lung ultrasound. POCUS of the lungs is an accurate and non-invasive tool to measure disease severity and can be used to improve diagnosis, (evaluation of) treatment and decrease the necessity for patient transportation/CT scans.

Disclosures

All authors declare no conflict of interest. No funding or financial support was received.

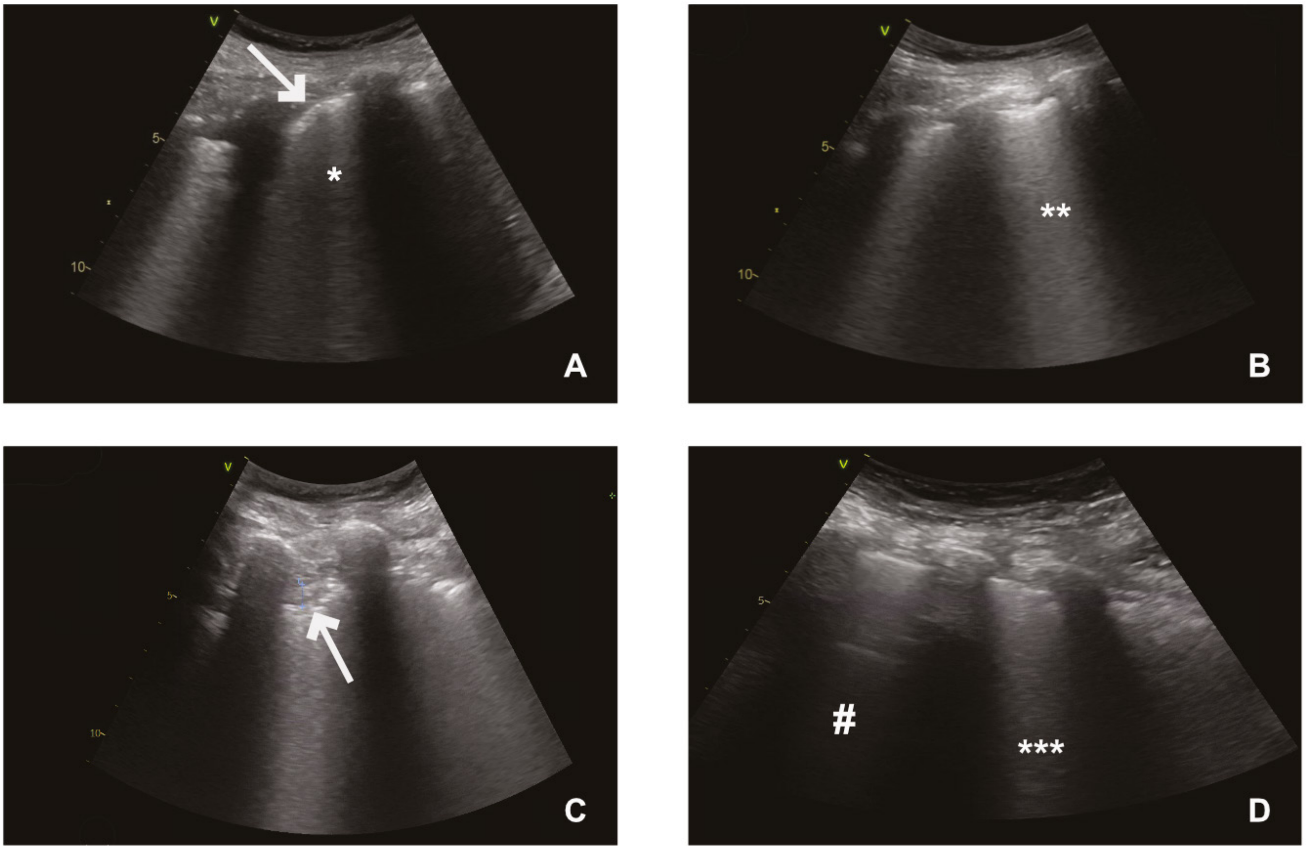

Figure 1. Lung ultrasound findings in COVID.
Panel A: thickened pleura, * represents B line.
Panel B: ** represents convalescence of B line also known as 'white lung',
Panel C: arrow marks subpleural consolidation and
Panel D: spared lung (#) and white lung (***)

References

1. Pan F, Ye T, Sun P, et al. Time Course of Lung Changes On Chest CT During Recovery From 2019 Novel Coronavirus (COVID-19) Pneumonia. Radiology. 2020:200370.
2. Yoon SH, Lee KH, Kim JY, et al. Chest Radiographic and CT Findings of the 2019 Novel Coronavirus Disease (COVID-19): Analysis of Nine Patients Treated in Korea. Korean J Radiol. 2020;21:494-500.
3. Chiumello D, Umbrello M, Sferrazza Papa GF, et al. Global and Regional Diagnostic Accuracy of Lung Ultrasound Compared to CT in Patients With Acute Respiratory Distress Syndrome. Crit Care Med. 2019;47:1599-606.
4. Duclos G, Lopez A, Leone M, Zieleskiewicz L. 'No dose' lung ultrasound correlation with 'low dose' CT scan for early diagnosis of SARS-CoV-2 pneumonia. Intensive Care Med. 2020; May 4;1-2. doi: 10.1007/s00134-020-06058-7. [Online ahead of print].
5. Winkler MH, Touw HR, van de Ven PM, Twisk J, Tuinman PR. Diagnostic Accuracy of Chest Radiograph, and When Concomitantly Studied Lung Ultrasound, in Critically Ill Patients With Respiratory Symptoms: A Systematic Review and Meta-Analysis. Crit Care Med. 2018;46:e707-e14.
6. Dietrich CF, Mathis G, Blaivas M, et al. Lung B-line artefacts and their use. J Thorac Dis. 2016;8:1356-65.
7. Lichtenstein DA, Meziere GA. Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol. Chest. 2008;134:117-25.
8. Volpicelli G, Elbarbary M, Blaivas M, Lichtenstein DA, Mathis G, Kirkpatrick AW, et al. International evidence-based recommendations for point-of-care lung ultrasound. Intensive Care Med. 2012;38:577-91.
9. Slegers CAD, Blans MJ, Bosch FH. Instructions for the use of critical care ultrasound in Dutch daily practice: the Rijnstate ICU manual, ready for broad acceptance? Neth J Crit Care. 2014:4-18.
10. Rouby JJ, Arbelot C, Gao Y, et al. Training for Lung Ultrasound Score Measurement in Critically Ill Patients. Am J Respir Crit Care Med. 2018;198:398-401.
11. Bello G, Blanco P. Lung Ultrasonography for Assessing Lung Aeration in Acute Respiratory Distress Syndrome: A Narrative Review. J Ultrasound Med. 2019;38:27-37.
12. Touw HR, Tuinman PR, Gelissen HP, Lust E, Elbers PW. Lung ultrasound: routine practice for the next generation of internists. Neth J Med. 2015;73:100-7.
13. Smith MJ, Hayward SA, Innes SM, Miller ASC. Point-of-care lung ultrasound in patients with COVID-19 - a narrative review. Anaesthesia. 2020; Apr 10. doi: 10.1111/anae.15082. [Online ahead of print].
14. Zotzmann V, Lang CN, Bamberg F, Bode C, Staudacher DL. Are subpleural consolidations indicators for segmental pulmonary embolism in COVID-19? Intensive Care Med. 2020; Apr 23;1-2. doi: 10.1007/s00134-020-06044-z. [Online ahead of print].
15. Tee A, Wong A, Yusuff T, Rao D, Sidhu P. Contrast-enhanced Ultrasound (CEUS) of the Lung Reveals Multiple Areas of Microthrombi in a COVID-19 Patient. Intensive Care Med. 2020; May 18;1-3. doi: 10.1007/s00134-020-06085-4.[Online ahead of print].
16. Volpicelli G, Gargani L. Sonographic signs and patterns of COVID-19 pneumonia. Ultrasound J. 2020;12:22.
17. Tsai NW, Ngai CW, Mok KL, Tsung JW. Lung ultrasound imaging in avian influenza A (H7N9) respiratory failure. Crit Ultrasound J. 2014;6:6.
18. Testa A, Soldati G, Copetti R, Giannuzzi R, Portale G, Gentiloni-Silveri N. Early recognition of the 2009 pandemic influenza A (H1N1) pneumonia by chest ultrasound. Crit Care. 2012;16:R30.
19. Volpicelli G, Frascisco MF. Sonographic detection of radio-occult interstitial lung involvement in measles pneumonitis. Am J Emerg Med. 2009;27:128 e1- e3.
20. Huang Y, Wang S, Liu Y, et al. A Preliminary Study on the Ultrasonic Manifestations of Peripulmonary Lesions of Non-Critical Novel Coronavirus Pneumonia (COVID-19). Infect Dis Pulm. 2020. doi : 10.21203/rs.2.24369/v1. [Online ahead of print].
21. Simonnet A, Chetboun M, Poissy J, et al. High prevalence of obesity in severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) requiring invasive mechanical ventilation. Obesity (Silver Spring). 2020; Apr 9. doi: 10.1002/oby.22831. [Online ahead of print].
22. Guan CS, Lv ZB, Yan S, et al. Imaging Features of Coronavirus disease 2019 (COVID-19): Evaluation on Thin-Section CT. Acad Radiol. 2020;27:609-13.
23. Lichtenstein DA. Lung ultrasound in the critically ill. Ann Intensive Care. 2014;4:1.