Review Article

Review of lung ultrasound findings in coronavirus disease 2019 (COVID-19): Effectiveness, applications and approach to lung ultrasound during times of a pandemic

ABSTRACT

As of 22 April 2020, there are 6 countries with >100,000 cases, 21 countries with 1000 to 10,000 confirmed cases and 53 countries with between 1000 and 10,000 confirmed cases of COVID-19. Six articles (5 research articles and 1 review article) with a total of 159 cases delineating the equipment, protocol, techniques, indications and follow-up management of COVID-19 were identified in a PUBMED search evaluating the role of lung Ultrasound. In the current review article, 55%-60% of the patients with COVID-19 were male; the median age has been reported between 34 and 59 years. Lung Ultrasound features of COVID-19 are related to the stage of the disease, the severity of lung injury, and comorbidities. This review article provides a summary of lung Ultrasound findings in COVID-19 and clinical guidance for the use and interpretation of lung ultrasound for patients with moderate, severe and critical COVID-19-related pulmonary syndrome.

Key words: COVID 19; lung ultrasound; POCUS

Background

In the late December 2019, a lower respiratory tract febrile illness was reported in a cluster of patients from Wuhan City, Hubei Province, China and a novel strain of coronavirus was isolated from the bronchoalveolar lavage of infected patients.[1] World Health Organization on 9 January 2020 named the pulmonary syndrome as Coronavirus Disease 2019 (COVID-19).[2] At the time of writing this letter on 22 April 2020, the number of confirmed cases stands at 2,574,994 with 178,658 reported deaths, according to an online virus tracker created by *The Lancet*, and hosted by Johns Hopkins University.[3] As of 22 April 2020, there are 6 countries with >100,000 cases, 21 countries with 1000 to 10,000 confirmed cases and 53 countries with between 1000 and 10,000 confirmed cases.[3] COVID-19 is a droplet infection primarily transmitted person-to-person by coughing or sneezing or close contact with infected individuals' upper respiratory tract secretions. A study that examined the first 425 infected cases in Wuhan estimated that the R0 (basic reproduction number) of novel coronavirus to be 2.2, that is each infected individual – on average – causes 2.2 new cases of the disease.[4] The study also calculated the incubation period in the group to be 5.2 days on average.[4]

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Reddy Ravikanth

Department of Radiology, Holy Family Hospital, Thodupuzha, Kerala, India

Address for correspondence: Dr. Reddy Ravikanth, Department of Radiology, St. John's Hospital, Kattappana – 685 515, Kerala, India.
E-mail: ravikanthreddy06@gmail.com

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In a pandemic like COVID-19, Ultrasound has established its role as the primary initial imaging modality by providing and optimizing patient care in dedicated hospital wards and quarantine centers using Point-of-Care lung Ultrasound (POCUS). Portability of Ultrasound machines with increasing image resolution has expanded the use of emergent imaging in such settings. Due to the high diagnostic accuracy, Ultrasound has been recommended as an imaging modality of choice in view of fewer infection control implications. Lung Ultrasound has been integrated into COVID-19 care pathway for patients admitted with respiratory failure. This review provides a summary of lung Ultrasound findings in COVID-19 and clinical guidance for the use and interpretation of lung ultrasound for patients with moderate, severe and critical COVID-19-related pulmonary syndrome.

Methods

The literature review was conducted in accordance with PRISMA checklist and guidelines for reporting of systematic reviews.

Search strategies

A MEDLINE search for pertinent literature was conducted from 1 January 2020 to 22 April 2020 using studies with the following MeSH search term: Ultrasound findings in COVID-19. This was combined with the sub-terms 'imaging in COVID-19,' and 'point-of-care lung Ultrasound in COVID-19,' in a single search. Studies delineating the equipment, protocol, techniques, indications and follow-up management of COVID-19 were considered.

Search criteria

The main sources of literature reviewed were case studies, case letters and research articles published from 1 January 2020 to 22 April 2020. Papers specifically delineating the equipment, protocol, techniques, indications and follow-up of COVID-19 management were considered were included as defined above. For scarcity of COVID-19, research articles related to Ultrasound, case reports, case letters, case series with less than ten subjects were also included. All animal or lab research studies were deemed irrelevant to the study topic of interest and were excluded.

Statistical analysis

Findings were tabulated using Microsoft Excel 2010 Microsoft Corp., Redmond, WA, USA, and statistical analyses were conducted using SPSS Statistical Package (version 20.0), IBM SPSS Statistics for Windows, V.20.0, IBM Corp., Armonk, NY, USA. The categorical data were expressed as rates, ratios, and percentages. The continuous data were expressed as mean ± standard deviation.

Results

Six articles (5 research articles and 1 review article) with a total of 159 cases were identified in a PUBMED search with the aforementioned parameters evaluating the role of lung Ultrasound. In the current review article, 55%-60% of the patients with COVID-19 were male; the median age has been reported between 34 and 59 years. The spectrum of the chest Ultrasound manifestations of COVID-19 pneumonia upon admission included B-lines (98%) and subpleural consolidations (83%). Characteristic Ultrasound manifestations in non-critical COVID-19 cases were visible in the posterior and inferior segments of the lung (67%). In progressive disease, irregular, thickened pleural lines with scattered discontinuities (73%) and alveolar consolidations (63%) were noted on the chest Ultrasound. Pleural effusions were uncommon (8%) and are typically small. Lung abnormalities are typically found in multiple lung zones (89%).

Discussion

The findings of the lung Ultrasound features of COVID-19 pneumonia are related to the stage of disease, the severity of lung injury, and the presence of comorbidities. However, lung Ultrasound cannot detect lesions that are deep within the lung aerated lung blocks transmission of Ultrasound and is a recognized limitation. On the lung Ultrasound, the predominant pattern is of varying degrees of interstitial syndrome and alveolar consolidation, the degree of which is correlated with the severity of the lung injury.[5]

Indications of lung ultrasound in COVID-19

Soldati *et al*.[6] suggested the potential diagnostic accuracy of the lung Ultrasound in the following situations:

- Triage (pneumonia/non-pneumonia) of symptomatic patients in emergency department settings
- Diagnostic suspicion and awareness in the emergency department settings during a potential pandemic
- Prognostic stratification and monitoring of the patients with pneumonia in emergency department settings
- Monitoring treatment of intensive care unit patients with regard to ventilation and weaning
- Monitoring the therapeutic response
- Reducing the number of health care professionals exposed in times of a pandemic considering the contagiousness of the disease.

Ultrasound equipment in the times of a pandemic

Soldati *et al*.,[7] recommended wireless probe and tablets are the most appropriate Ultrasound equipment to reduce contamination and promote sterilization because they can be easily wrapped in single-use plastic covers. The study suggested maximum sterilization procedures to be followed

for cases, probes, and keyboard covers and to use portable machines if wireless equipment is unavailable, which then must be dedicated to the patients with COVID-19.

Lung Ultrasound scan acquisition protocol for COVID-19

Soldati *et al*.[7] suggested Ultrasound scan acquisition protocol for COVID-19 as given below:

- Scanning of 14 areas – three posterior, two lateral, and two anterior segments for 10 seconds each
- Use convex or linear transducers and use a single-focal point modality (no multi focusing), and set the focal point on the pleural line
- Lung scans were suggested to be intercostal (not orthogonal to the ribs) to cover the widest surface possible with a single scan
- Evaluation of bilateral multiple areas to study the extent of the lung surface affected. The protocol also suggested that 16 areas in total should be evaluated: anterior midclavicular (apical, medial, and basal), right and left; posterior paraspinal (apical, medial, and basal), right and left; and lateral axillary (apical and basal), medial right and left
- Keeping the mechanical index (MI) low, starting from 0.7 and reducing further, if possible
- Avoiding saturation phenomenon as much as possible, control gain, and diminish MI, if needed
- Avoiding the use of cosmetic filters and specific imaging modalities, including harmonic imaging, contrast, Doppler, and compounding
- Achieving the highest frame rate possible
- Saving data in DICOM format.

Severity of COVID-19 scoring on lung ultrasound

- To help classify COVID-19 cases, Soldati *et al*.,[7] suggested scoring the disease burden on a 0-to-3 scale. At the end of each procedure, the sonographer should note the quadrant with the highest score
- Score 3 indicates the most severe findings, such as dense and extended white lung with or without larger consolidations
- Score 2 would include a broken pleura line with small-to-large consolidated areas before the breaking line. Some appearances of white lung could also be visualized
- Score 1 presents an indented pleura line with vertical areas of white below the indention
- For Score 0, the pleura line is continuous and regular with horizontal artifacts (A-line).

Lung ultrasound findings in COVID-19

Lomoro *et al*.[8] performed the lung ultrasound in 22 patients at admission and observed various B lines patterns (focal, multifocal, and confluent) due to interlobular septa thickening or hazy opacities in all cases (100%), ultrasound showed various B lines patterns (focal, multifocal, and confluent) due to interlobular septa thickening or hazy opacities. Subpleural consolidation was observed in six patients (27.3%) and a thickened pleural line was observed in three patients (13.6%).

Poggiali *et al*.[9] evaluated the role of lung Ultrasound in 12 patients who presented to the emergency department with COVID-19 pneumonia. The study found a diffuse B-pattern with spared areas in all the patients (100%). Only three patients had posterior subpleural consolidations. Chest CT findings in all 12 patients and strongly correlated with Ultrasound findings. The study confirmed organizing pneumonia in four patients that was earlier detected with lung ultrasound.

Huang *et al*.[10] in a study of 20 patients (40 lungs and 240 lung areas) assessed the Ultrasound manifestations of subpleural lesions of non-critical COVID-19. The study suggested that irregular discontinuous pleural lines were noted in 36/240 patients (15%), subpleural consolidation in 53/240 (22%), air bronchogram sign in 37/240 patients (15.4%), visible B lines in 91/240 patients (38%), localized pleural thickening in 19/240 patients (8%), localized pleural effusion in 24/240 patients (10%) and poor blood flow in segmental consolidations in 50/53 patients (94.3%). The study suggested Lung Ultrasound to provide reference for the diagnosis of COVID-19 and efficacy evaluation.

Ianniello *et al*.[11] in a retrospective review of a cohort including 84 children suggested that pneumonic findings in COVID-19 showed multiple B-lines, findings were consistent with interstitial involvement. The study suggested lung Ultrasound to be the first-line technique to identify small pneumonic consolidations, especially for "CXR-occult" findings.

Sofia *et al*.[12] in their pictorial review suggested Ultrasound to be a relevant method for monitoring the patients with COVID-19. The review suggested acute interstitial disease represented by vertical hyperechoic artifacts (B-lines) that depart from the pleural line as the main ultrasound finding in COVID-19 pneumonia. The review suggested >3 B-lines on a lung scan to be pathological with the number of B lines correlating with the disease severity. The review suggested that in the early stage of COVID-19, lung changes tend to be more localized, and mainly detected in the subpleural regions of one or both lungs. However, in more advanced and critical cases, Ultrasound findings resemble other pneumonia features, such as diffuse consolidations in both the lungs, white out the lungs and occasional pleural effusions.

Peng *et al*.[13] performed lung Ultrasound on 20 patients with COVID-19 using a 12-zone method. The study observed patterns across a continuum from mild alveolar interstitial pattern, to severe bilateral interstitial pattern, to lung consolidation and suggested the characteristic findings on lung Ultrasound as below:

- Irregularity and thickening of the pleural line
- Multifocal, and confluent B lines
- Multifocal translobar and non-translobar patterns of consolidations with occasional mobile air bronchograms
- The appearance of A lines during recovery phase
- The rarity of pleural effusions.

Role of Ultrasound in COVID-19

Ultrasound due to its inexpensive nature with no radiation and ability for repeatability for repeated re-evaluation has a very crucial role to play in the setting of a pandemic like COVID-19. Ultrasound findings in COVID-19 mostly depend on the stage and severity of the disease. However, Ultrasound cannot detect lesions deeper in the lung. On the lung Ultrasound, the patients with COVID-19 typically demonstrate both translobar and non-translobar consolidations of various sizes indicating disease progression, irregular thickening of pleural lines seen in moderate disease, scattered or confluent B-lines (waterfall sign) with irregular vertical artifacts is an early sign.[14] Pleural effusions are relatively rare.

The value of point-of-care ultrasound (POCUS)

With the growing outbreak of the novel coronavirus disease (COVID-19) worldwide, healthcare providers are facing unprecedented challenges and working conditions. The role of Point-of-Care Ultrasound due to its bedside imaging capability becomes all the more important in the current scenario of a pandemic. Point-of-Care has a role in the identification of affected lung segments and B-lines. In atypical pneumonia, especially COVID-19 may demonstrate confluence of B-lines (waterfall sign). Point-of-care ultrasound can also be valuable in the evaluation of shock to help monitor IVC collapsibility, fluid management, and the lung B-lines.[15] Point-of-care ultrasound has a crucial role in performing therapeutic intervention in a patient who may need a pleural tap to improve their respiratory status. Ultrasound is also sensitive in diagnosing pneumothorax in an intubated patient requiring PEEP and has in the course of their therapy acquired pneumothorax and also in guiding therapeutic interventions for the same. Point-of-care ultrasound examinations show better results than chest radiographs and are easily repeatable for re-evaluation.

Conclusion

Lung Ultrasound features of COVID-19 are related to the stage of the disease, the severity of lung injury, and comorbidities. Characteristic ultrasound findings include small multifocal and non-translobar consolidations, irregular and thickened pleural lines, multifocal and confluent B lines. For the first time in the era of modern medicine, all of humankind is facing the same threat considering the contagiousness of the coronavirus and the need to reduce nosocomial outbreaks. This also give us ample opportunity to change our research approach that involves a better understanding of disease manifestations and to further explore and promote the applications of lung Ultrasound for the safe management of patients and health personnel alike in the setting of pandemics like the present COVID-19 outbreak and threats we might encounter soon. Research findings need to be shared among countries to provide the best health care to humankind during these uncertain times of a pandemic.

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Conflicts of interest

There are no conflicts of interest.

References

1. Li Q, Guan X, Wu P, Wang X, Zhou L, Tong Y, *et al*. Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. N Engl J Med 2020;382:1199-207.
2. WHO 2020, "We now have a name for the #2019nCoV disease: COVID-19. I'll spell it: C-O-V-I-D hyphen one nine – COVID-19", Tweet, 11 February, viewed 2020 Feb 11. Available from: https://twitter.com/WHO/status/1227248333871173632.
3. Wuhan Coronavirus (2019-nCoV). Global Cases (by Johns Hopkins CSSE).Case Dashboard. [Last accessed on 2020 Apr 22].
4. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, *et al*. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China.Lancet 2020;395:497-506.
5. Buonsenso D, Pata D, Chiaretti A. COVID-19 outbreak: Less stethoscope, more ultrasound. Lancet Respir Med 2020;8:e27.
6. Soldati G, Smargiassi A, Inchingolo R, Buonsenso D, Perrone T, Briganti DF, *et al*. Is there a role for lung ultrasound during the COVID-19 pandemic? J Ultrasound Med 2020;39:1459-62.
7. Soldati G, Smargiassi A, Inchingolo R, Buonsenso D, Perrone T, Briganti DF, *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;39:1413-9.
8. Lomoro P, Verde F, Zerboni F, Simonetti I, Borghi C, Fachinetti C, *et al*. COVID-19 pneumonia manifestations at the admission on chest ultrasound, radiographs, and CT: Single-center study and comprehensive radiologic literature review. Eur J Radiol Open 2020;7:100231.
9. Poggiali E, Dacrema A, Bastoni D, Tinelli V, Demichele E, Mateo Ramos P, *et al*. Can lung US help critical care clinicians in the early diagnosis of novel coronavirus (COVID-19) pneumonia? Radiology 2020;295:E6.
10. Huang Y, Wang S, Liu Y, Zhang Y, Zheng C, Zheng Y, *et al*. A preliminary study on the ultrasonic manifestations of peripulmonary lesions of non-critical novel coronavirus pneumonia (COVID-19). 2020. doi: 10.2139/ssrn.3544750.
11. Ianniello S, Piccolo CL, Buquicchio GL, Trinci M, Miele V. First-line diagnosis of paediatric pneumonia in emergency: Lung ultrasound (LUS)

in addition to chest-X-ray (CXR) and its role in follow-up. Br J Radiol 2016;89:20150998.doi: 10.1259/bjr.20150998.
12. Sofia S, BoccatondaA, MontanariM, Spampinato M, D'ardes D, Cocco G, *et al.* Thoracic ultrasound and SARS-COVID-19: A pictorial essay. J Ultrasound 2020;23:217-21.
13. Peng QY, Wang XT, Zhang LN; Chinese Critical Care Ultrasound Study Group (CCUSG). Findings of lung ultrasonography of novel corona virus pneumonia during the 2019–2020 epidemic. Intensive Care Med 2020;46:849-50.
14. Vetrugno L, Bove T, Orso D, Barbariol F, Bassi F, Boero E, *et al*. Our Italian experience using lung ultrasound for identification, grading and serial follow-up of severity of lung involvement for management of patients with COVID-19. Echocardiography 2020;37:625-7.
15. Buonsenso D, Piano A, Raffaelli F, Bonadia N, de Gaetano Donati K, Franceschi F. Point-of-care lung ultrasound findings in novel coronavirus disease-19 pnemoniae: A case report and potential applications during COVID-19 outbreak. Eur Rev Med Pharmacol Sci 2020;24:2776-80.