The role of Chest Ultrasound in Follow up of COVID-19 Patients

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Abstract

Background: *The purpose of this review paper is to discuss the diagnostic and therapeutic value of lung ultrasonography in the context of coronavirus Disease 2019 (COVID-19). Ultrasound of the lungs is a straightforward diagnostic technique that helps find patients with symptoms that could be COVID-19 early on, which in turn helps with admission decisions and treatment planning. Not only may it be done in a variety of hospital wards, emergency rooms, primary care offices, and critical care units, but it can also be done in outpatient settings with the help of portable devices. In addition to clinical and laboratory evaluation, the article explains the usual findings on a COVID-19 lung ultrasonography, which include an interstitial pattern, pleural abnormalities, and consolidations. We outline the benefits and drawbacks of using lung ultrasonography in COVID-19, as well as the necessary equipment and training for this procedure. By searching the literature for the terms "COVID-19," "lung ultrasound," and "imaging," we were able to deduce the various regions' uses of this imaging technique. Children and pregnant women can benefit greatly from lung ultrasonography since it is a noninvasive, quick, and repeatable treatment that can be done at the point of care with minimal sterilization. since it uses non-ionizing radiation, it is possible to do multiple scans on the same patient. However, in the present pandemic environment, the patient and ultrasound operator cannot be physically close, which highlights the necessity for specific procedures to avoid and control infections. A big obstacle to the use of lung ultrasonography is the availability of competent personnel who are properly trained to do the procedure. In low- and middle-income countries, in particular, local practitioners can be better equipped to employ lung ultrasonography for COVID-19 management through training, advocacy, and increased awareness.*

Keywords: *Chest Ultrasound, COVID-19*

Introduction

The new coronavirus disease 2019 (COVID-19) pandemic has killed over 6.5 million people and infected over 600 million as of mid-September 2022. There has to be a quick, point-of-care diagnosis in every resource environment since an early COVID-19 diagnosis would enable early isolation and management.

As part of the diagnostic process that also involves laboratory and clinical examination, chest imaging is advised for symptomatic patients who are suspected of having COVID-19. The World Health Organization (WHO) established a sizable international expert committee to help with the creation of COVID-19 chest imaging guidelines at the outset of the pandemic in response to requests from member states [1]. While developing these guidelines, it became clear that chest radiography and chest computed tomography (CT) have a longer history of usage, better established methods, and more conclusive results in the therapy of COVID-19 than lung ultrasound. After the guidelines were published, the World Health Organization (WHO)

assembled a panel of experts from different countries to discuss the use of lung ultrasonography during the COVID-19 pandemic. The panel was carefully selected to ensure geographic balance and representation from resource-setting organizations. [1].

The examination of acute or critically ill patients with a variety of respiratory diseases has seen a dramatic surge in the usage of lung ultrasonography in the past few decades. Lung ultrasonography has recently gained favor as a straightforward method that can aid in the early diagnosis of COVID-19-related symptoms, bolster the admission decision, and guide treatment planning. This function has been demonstrated in a range of clinical contexts, such as general practitioners' offices, walk-in clinics, hospital wards, and intensive care units (ICUs) [2, 3]. Health officials may be able to better allocate resources if they investigated the feasibility of doing lung ultrasounds using portable equipment in outpatient settings (such as assisted living facilities, retirement apartments, and home care).

In COVID-19, lung ultrasonography is one of several imaging modalities that are being utilized. The ionizing radiation exposure and the increased risk of virus propagation resulting from the patient's transfer to the imaging department must be considered when using chest CT for diagnostic reasons, despite the fact that it has demonstrated a high sensitivity and specificity in detecting COVID-19 [1, 4-7]. Although chest radiography is less resource intensive than chest CT, it may be done at the point of care using mobile equipment, has similar specificity, but poorer sensitivity. Nevertheless, it does expose patients and workers to ionizing radiation, although at lower doses compared to chest CT.

Lung ultrasound is a valuable tool for diagnosing and managing COVID-19 in patients. This review paper covers the typical findings of a lung ultrasound, how it is used in different regions and countries, the necessary equipment, capacity building initiatives, and training requirements, as well as the benefits and drawbacks of this diagnostic tool.

The alveoli are quickly damaged in cases of COVID-19 pneumonia, and the damage is usually bilateral and mostly located on the periphery [4, 8]. Most commonly seen in COVID-19 pneumonia on ultrasonography of the lungs are consolidations, interstitial patterns, and pleural abnormalities; these findings tend to be bilateral, patchy, and have clearly defined sparing zones [9–11]. Lung ultrasonography appears to be an ideal diagnostic tool for COVID-19 because pulmonary alterations frequently exhibit subpleural localization and abnormalities along the pleural line are detected by this modality. Figure 1 shows the typical findings of a lung ultrasonography in patients with COVID-19 pneumonia. [12].

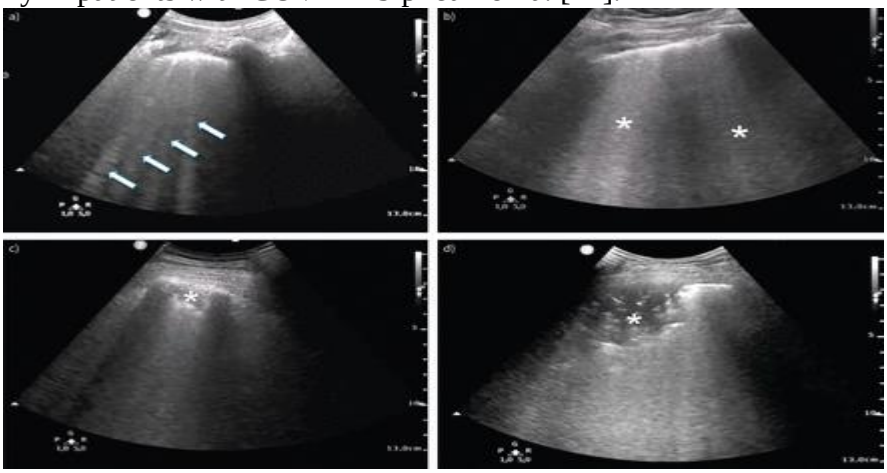


Figure 1: Typical lung ultrasound findings in patients with coronavirus disease 2019 (COVID-

19) pneumonia. a) Interstitial involvement with separated B-lines (arrows) and irregular pleural line; b) confluent B-lines (asterisks); c, d) consolidations (asterisks); d) air bronchograms.

Interstitial involvement

The hallmark of interstitial syndrome on ultrasound is the presence of vertical hyperechoic artifacts, or "B-lines," that travel in unison with the patient's respiration and often begin at the pleural line and eventually reach the screen's edge [13]. In addition to a decreased aerated/non-aerated space ratio and interstitial involvement from oedema or increased collagen/fibrotic deposition, B-lines are not exclusive to COVID-19 and can be seen in a wide variety of pulmonary diseases. The distribution of B-lines, in conjunction with clinical presentation, can be used to distinguish COVID-19 pneumonia from other diseases. The most common observation in this case is bilateral, typically asymmetrical B-lines that do not have a cranial-caudal distribution gradient [10]. An abnormal pleura and interstitial lung ultrasonography pattern was observed in 92% of COVID-19 patients brought to the emergency department, with 86% of those patients exhibiting bilateral abnormalities [11].

There is minimal interstitial involvement when there are few dispersed B-lines, but the clinical picture is worse when there are more converging B-lines. Convergent hyperechoic aberrations and the indistinguishability of B-lines in severe interstitial illness are the causes of the "white lung" appearance [14, 15].

With COVID-19, a specific artefact known as "light beam" has been documented. A big, bright band-shaped B-line, emerging from a segment of the normal pleural line within the framework of the usual A-line pattern, often emerges and vanishes as the patient breathes in and out. Possible correspondence between this artefact and ground-glass opacities detected on CT in the early stages of active illness [16].

Alterations of the pleural line

Lung ultrasonography often finds changes to the pleural line in COVID-19 patients [10, 11]. As seen in acute respiratory distress syndrome (ARDS) and interstitial lung disease/pulmonary fibrosis, the pleural line might seem thicker, uneven, or fractured in affected areas. In conjunction with pleural changes, one can notice a decrease or complete absence of the typical pleural sliding. Alterations to the pleural lines and small, subcentimetric consolidations inside the pleura are both possible.

Consolidations

When the pleural line is disrupted and the air content in the lung tissue goes below 10% of normal aeration, solid lesions form. Patients with COVID-19 pneumonia typically have numerous consolidations, which tend to form in the lower posterior regions more commonly. Air bronchograms may or may not be seen [17, 18]. Lobar hepatisation, which is more common in cases of bacterial pneumonia, is rare.

Additional findings

Elastography and contrast-enhanced ultrasonography (CEUS) are two cutting-edge uses of ultrasound that have the ability to improve the diagnostic yield of ultrasound in the lungs.

To identify changes in capillary perfusion, contrast-enhanced ultrasonography (CEUS) makes use of sulfur-hexafluoride microbubbles. In COVID-19 patients, CEUS may reveal low-perfusion regions and numerous infarction locations in the periphery [19, 20].

By studying how waves travel through different types of tissues, ultrasound elastography may quantify how pliable a material is [21]. Using ultrasonic elastography, researchers in an animal model were able to demonstrate a decrease in lung surface wave speed associated with interstitial lung oedema [22].

A clearer picture of how these cutting-edge tools fit into the clinical assessment of COVID-19 pneumonia requires additional data collection.

Differential diagnosis and complications

Patients infected with COVID-19 may present with a variety of symptoms and consequences. Laboratory results, the disease's prevalence during the pandemic phases, and the patient's past medical history (including comorbidities like cardiovascular disease, lung interstitial disease, or fibrosis) must be considered and understood in conjunction with the results of the lung ultrasound in order to appropriately account for these situations [23].

Respiratory viral infections

Lung ultrasonography results are comparable in different viral pneumonias, making differential diagnosis with other viral lung infections challenging. These findings include patches of white lung, pleuropulmonary line abnormalities, solitary or confluent B lines, and small subpleural consolidations (<0.5 cm) [24, 25].

Asthma caused by bacteria

In this case, bacterial pneumonia is likely due to the existence of an isolated big lobar consolidation together with air bronchograms. Compared to traditional radiology tests, lung ultrasound during the 2009 H1N1 pandemic was able to differentiate between bacterial and viral pneumonia or coexistence of the two infections with an agreement between observers of 0.82 [26]. The reliability of lung ultrasonography for pneumonia diagnosis has been the subject of a great deal of research. Lung ultrasonography has a sensitivity and specificity of above 90% for diagnosing pneumonia, according to two meta-analyses [27, 28].

Myocardial infarction and embolism of the lungs

Excessive inflammation, diffuse intravascular coagulation, hypoxia, and immobilization are the main causes of venous and arterial thromboembolism in COVID-19 [29]. Patients with COVID-19 have an increased risk of pulmonary embolism, with reported rates ranging from 1.6% to 36% in non-ICU wards [30, 31] and from 14% to 25% in ICUs [29, 30]. Even when a patient's lungs appear normal on ultrasound, pulmonary embolism may be present if they are experiencing severe dyspnea or other symptoms of respiratory failure [32, 33]. Lung ultrasonography presents unique challenges when diagnosing pulmonary embolism in COVID-19 patients: Multiple COVID-19 inflammatory abnormalities might be difficult to differentiate from triangular or rounded pleural-based lesions, which are typically signs of pulmonary embolism [34]. Pulmonary infarcts and COVID-19 inflammatory lesions can be differentiated with the use of CEUS [35]. Patients suspected of having pulmonary thromboembolism should always be investigated for CT pulmonary angiography as the imaging exam of choice[36, 37] due to the seriousness of the condition and the possibility of a targeted therapy.

Cardiac arrest

Rarely seen in COVID-19 pneumonia, diffuse and symmetrical B-lines distributed according to gravity are more typical of cardiogenic pulmonary edema. Compared to chest radiography and natriuretic peptides, lung ultrasonography combined with clinical evaluation greatly improved the accuracy of distinguishing acute decompensated heart failure from noncardiac causes of acute dyspnea [38]. Additionally, lung ultrasonography may aid in the diagnosis of heart failure when utilized in conjunction with a more comprehensive bedside ultrasound examination that also includes the heart, deep veins of the extremities, and inferior vena cava [39].

Lumbar puncture

Pleural effusion is a rare complication of COVID-19 and is typically caused by some underlying

health issue [11, 18]. In comparison to chest radiography, ultrasound has far higher diagnostic accuracy when it comes to detecting, quantifying, and monitoring pleural effusion [40, 41]. Thoracentesis and pleural drainage are two examples of image-guided operations that can benefit from lung ultrasonography.

Chest infection

Pneumothorax that develops on its own is unusual in COVID-19 patients who are not in critical care [42]. It has a significant mortality rate and is more common in patients with early severe COVID-19 [43]. The exact cause is unclear, however it is likely associated with patients' ability to do harm to their own lungs. When a patient has a pneumothorax, an ultrasonography of the chest will show certain characteristics. These include the absence of B-lines, a lack of lung sliding, and the identification of a lung point. This point is the junction between the margin of the pneumothorax and the normal visceral/parietal pleura coupling; it is a size-determining tool that is specific to pneumothorax [44]. When compared to chest radiography, lung ultrasound performs much better in detecting pneumothorax [45]. More so than chest radiography, which has a sensitivity of 39% to 52% and a specificity of >98%, lung ultrasonography is useful for monitoring pneumothorax, particularly in severely sick patients, with reported sensitivity ranging from 78% to 90% [45-48].

Underlying emphysema

Patients with severe illness [49], pneumothorax or pneumomediastinum [50], typically as a result of invasive mechanical ventilation and barotrauma, may develop subcutaneous emphysema, but it is uncommon in COVID-19 patients. Many reverberation artifacts are evident during lung ultrasound scans because of subcutaneous gas bubbles, which makes it difficult to see deeper structures like the ribs and the lung.

Using lung ultrasonography for triage purposes

For patients with suspected or confirmed COVID-19, chest imaging should be done in addition to clinical and laboratory examination. This will help with decisions like whether to admit them to the hospital or discharge them home, and whether to admit them to the main ward or the intensive care unit [1].

Pulmonary ultrasonography results in outpatients with probable COVID-19 pneumonia are associated with illness severity and the necessity of hospitalization referral [51]. When it comes to diagnosing COVID-19 pneumonia in emergency departments, lung ultrasonography has a sensitivity of over 90% and a specificity of 20-65% [11, 52]. Thus, it appears that a negative lung ultrasound in patients with symptoms is a valid result, and further invasive, expensive, and time-consuming testing is unnecessary. Also, adult emergency department patients exhibiting signs of lower respiratory tract infection can be accurately classified as either needing ward admission or safe outpatient management using early lung ultrasonography [53]. In a similar vein, early ED lung ultrasonography has successfully distinguished between patients who have survived and those who have not. In addition, there was a correlation between the level of lung aeration loss and the clinical result [54].

The prevalence of pleural thickening, subpleural consolidations, and total lung ultrasound score increased with worsening disease in a prospective investigation of 120 adult patients with COVID-19. The results of the ultrasound were predictive of clinical deterioration and were associated with mortality [55]. Refractory hypoxaemia was associated with an increased total lung ultrasound score, pleural effusions, consolidations of the lungs, and areas with multiple coalescent B-lines in intensive care unit patients [56]. In hospitalized patients, the onset of respiratory failure was predicted by the lung ultrasonography severity score [18]. According to a

recent systematic review, there is a correlation between pleural abnormalities, the presence of three or more B-lines on lung ultrasound, and an increased risk of unfavourable outcomes such as death, need for mechanical ventilation, or admission to the intensive care unit [57]. These findings are in line with this review.

Research demonstrating the usefulness of lung ultrasound—which shields pregnant patients from ionizing radiation—in a study involving COVID-19 pregnant women established the utility of this imaging modality. This study discovered that the quantification using lung ultrasound score has a strong correlation with the patient's symptoms and the illness development, allowing for the prediction of when clinical symptoms would get worse or better [58].

Diagnostic accuracy of lung ultrasound and comparison with other chest imaging modalities

Ultrasound of the lungs has not been shown to be an effective diagnostic tool for COVID-19 pneumonia. It has been shown in multiple trials that point-of-care lung ultrasonography is an incredibly sensitive diagnostic, especially when used in high prevalence areas [11, 59-61]. The integration of probability patterns of lung ultrasound with clinical findings allows to rule in or rule out COVID-19 pneumonia at the bedside, according to an international multicenter study with over 1400 patients [23]. Lung ultrasound has shown a high degree of sensitivity in the diagnosis of interstitial syndrome, which is consistent with earlier findings [14, 15]. But there's a problem with the lack of specificity.

In COVID-19, there has been a dearth of research comparing the diagnostic efficacy of lung ultrasound with other imaging modalities. The diagnostic accuracy of chest CT, chest radiography, and lung ultrasound in symptomatic patients suspected of having COVID-19 was assessed in 37 studies that were systematically reviewed in April 2021. The results showed that, respectively, these tests had a pooled sensitivity of 89%, 72%, and 78%, and a specificity of 81%, 71%, and 76% [1]. The diagnostic accuracy of lung ultrasound was found to be comparable with chest CT in a multicenter prospective study. The sensitivity and specificity for lung ultrasound were 71.0%, 91.9%, and 0.81 compared to 88.4% and 82.0% for CT, respectively. This suggests that lung ultrasound can help rule out clinically relevant cases of COVID-19 pneumonia in emergency departments and diagnose COVID-19 more easily in areas with a high prevalence of the virus [59]. Lung ultrasonography also proved useful in ruling out COVID-19 symptoms in the lungs, particularly in individuals without a prior history of heart or lung disease (sensitivity and negative predictive value of 100%) [60]. Nevertheless, computed tomography (CT) performed better than lung ultrasound for COVID-19 diagnosis at hospital admission (sensitivity 90-95% and specificity 43-69% vs. 94-93% and 7-31% for lung ultrasound, respectively) [61]. To confirm these findings, additional COVID-19 prevalence investigations are needed.

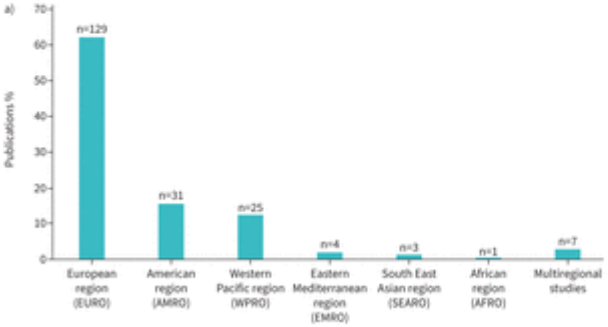
It is possible that, under the hands of trained professionals, lung ultrasonography is the best imaging method for children [62]. It is important to consider the potential risks of radiation exposure to children when deciding whether or not to utilize chest radiography or chest CT for the diagnosis of COVID-19 [1]. Findings from lung ultrasounds in children are comparable to those in adults [63], with a higher frequency in moderate to severe cases [64]. Ultrasound of the lungs and computed tomography scans of the chest can reveal anomalies indicative of COVID-19 in certain infants whose chest radiographs come back normal [65, 66].

The use of lung ultrasound in COVID-19 in different regions/countries

A recent online survey by the International Society of Radiology revealed that COVID-19 imaging practices vary globally. The most commonly used imaging modalities were CT and conventional chest radiography, while intensivists and those doing bedside imaging in the

intensive care unit often utilized lung ultrasound, typically with small mobile units for point-of-care ultrasound [67]. When the initial wave of the COVID-19 epidemic hit, anaesthesiologists and intensivists in Italy were already heavily using lung ultrasonography, and their usage only grew from there [68].

As of the article's creation, there was no comprehensive review of current trends in the worldwide usage of lung ultrasonography for COVID-19 therapy. Hence, we used the search terms "COVID-19," "lung ultrasound," and "imaging" to scour the PubMed and Google Scholar databases for any information we could glean about the application of this imaging technique in various parts of the world. Review articles were not considered, however case reports and series were. The requirements for the literature review were met by 200 publications published between May 2020 and November 2021.You may find information about the countries of origin and a summary of the regional distribution of these publications in Figure 2.



b)

Country	National articles (+ multinational articles)
Australia	4
Belgium	2 (+2)
Brazil	6
Canada	7 (+3)
China	19
Denmark	4
France	6 (+2)
Germany	11
Greece	1
India	1
Iran	1
Ireland	0 (+2)
Israel	3
Italy	55 (+7)
Kuwait	1
Mexico	3 (+1)
The Netherlands	0 (+2)
Pakistan	1
Peru	1
Poland	2
Russia	1
Saudi Arabia	1
Singapore	1
South Africa	1
South Korea	1
Spain	15 (+2)
Switzerland	2
Turkey	7
UK	13 (+5)
USA	14 (+5)

FIGURE 2

Geographical distribution of publications on use of lung ultrasound in coronavirus disease 2019 (COVID-19) based on the results of the literature review. a) Distribution of the publications according to the six World Health Organization regional offices for a total of 200 publications on use of lung ultrasound in COVID-19, including 187 national articles and 13 multinational papers. Data presented as “EURO” comprise papers published by one single country in Europe as well as six articles jointly published by more than one European country.

Because it does not necessitate any special setup, ultrasound is both a cheap and widely available imaging technique. It can be powered by batteries or regular electrical outlets. In addition to being sturdy, portable, and requiring little in the way of upkeep, machines are also highly mobile. Emergency and critical care settings can benefit from point-of-care ultrasonography for COVID-19 management [68], and it can also be used outside of hospitals [69]. Particularly in low- and middle-income countries (LMICs), there may be a dearth of competent personnel properly trained to do lung ultrasound and a general lack of knowledge about the numerous benefits of ultrasound technology. Local medical professionals can be better equipped to scale up the use of lung ultrasonography for COVID-19 management by training, advocacy, and raising awareness. Lung ultrasound could become more commonplace as a result of telemedicine's ability to make remote knowledge available for clinical and educational uses. In situations with limited resources, diagnostic ultrasound systems powered by artificial intelligence have the potential to reduce variability, achieve standardized picture acquisitions, enhance diagnostic accuracy, and pave the way for future clinical applications of lung ultrasound.

Equipment, capacity building and training needs

Technology needs and issues related with ultrasound equipment

Specified ultrasonic probes or equipment are not necessary for a lung ultrasonography. For transthoracic ultrasound, any commercially available portable ultrasound machine that can produce standard B-mode images will do [14, 70]. The evaluation of interstitial lung disorders can be done with a pocket-sized device that is just as effective as standard equipment [71, 72] and can drastically cut down on the time it takes to do a bedside examination [73, 74]. The evaluation of the heart, lung vascularization, and vasculature is greatly enhanced by ultrasound machines that are equipped with color Doppler, pulsed-wave Doppler, and cardiac functionality [75]. For bedside monitoring of diseases such pleural reactive inflammatory effusion or peripheral thrombus embolism in severe cases of COVID-19 infection, high-end systems including CEUS, shear-wave elastography, and image fusion could be of benefit [19, 76]. Turning off or limiting the use of advanced ultrasound modes, such as tissue harmonic imaging, compound imaging, various pre- and post-processing techniques, filters, and interpolation algorithms, can improve the visualization of B-line artefacts [77, 78].

Considerations such as patient anatomy, size, age, and the goal of the test play a crucial role in transducer selection, which in turn affects the results of a lung ultrasound [77]. We recommend transducers with a variety of forms and frequencies, such as micro-convex and low-frequency convex probes, high-resolution linear probes, and sector (phased-array) cardiac probes [70, 77]. When it comes to imaging superficial structures and abnormalities, such as pleural irregularities, pneumothorax, subpleural consolidations, and small amounts of pleural effusion, specifically in the anterior fields, or when evaluating muscles of the chest wall, such as the diaphragm or intercostals, high-frequency and high-definition linear transducers are the way to go. Their low penetration capacity and high superficial definition make them ideal for these tasks. Deep structures, including consolidations and pleural effusions, can be seen with low-frequency phased-array and convex transducers. Thick parietal wall portions, particularly in the lateral and posterior fields, can also be visualized [77-79]. The pleural surface may be seen more clearly and the probe can penetrate deeper with micro-convex (small surface) technology [14]. When comparing low-frequency and high-frequency probes, more B-lines are visible with the former [77, 78].

Essentials of lung ultrasound education

Having competent personnel who are well-versed in the ins and outs of lung ultrasonography is of the utmost importance in light of the current COVID-19 outbreak. Anaesthesiologists and intensivists in Italy were surveyed following the first wave of the COVID-19 pandemic. The results showed that while residency programs were gradually adding lung ultrasonography training, 76.7% of the participants had not gotten certified in the field [68].

No universal agreement has been reached on the minimum education or experience required to do a lung ultrasonography [80]. Further study with verified theoretical and practical assessments for evaluation is advised by a systematic review that revealed few high-quality studies for lung ultrasound training [81]. After completing ≥10 guided scans, doctors who had no prior experience with ultrasonography were able to competently and autonomously conduct lung ultrasounds, with an accuracy rate of over 95% of the time [82]. Trainees without experience in this process could become competent after 25 guided lung ultrasonography examinations, according to another study [83]. Clinicians can gain good competency and accurate identification of lung patterns with only a brief formal training in lung ultrasonography [9, 10, 84–89].

Lung ultrasound scoring system standardization

Lung ultrasonography may seem easy at first glance due to the short learning curve and small number of ultrasonographic patterns; nonetheless, a systematic approach is required for examination to yield the most trustworthy results [13, 90]. Lung ultrasonography relies heavily on the operator, which is a well-known drawback [91, 92]. To reduce the possibility of mistakes in the diagnosis of lung disease, it has been proposed that ultrasonography abnormalities be defined and labelled clearly [13].

If we want most doctors to be able to spot lung ultrasound symptoms and keep inter-examiner variability to a minimum, we require a standardized ultrasonographic method [93]. Selecting the probe and imaging settings is the first step in the examination. The next step is to partition the chest surface so that all parts of the lungs are covered.

Artefacts from air, lung parenchyma, the chest wall, and the pleura make up the bulk of lung ultrasound findings [13, 94]. To avoid these artefacts, it is crucial to use a single-focal point modality, focus at the level of the pleural line, and set the depth to 6-7 cm from the pleural line. To keep the echoic image consistent over the entire screen, including the bottom edge, the gain should be adjusted. Make sure to avoid using any cosmetic filters or specialized modalities like harmonic imaging, contrast, or compounding, and aim for the greatest possible frame rate [95].

It has been proposed that patients with COVID-19 undergo a standardized approach to lung ultrasonography examinations [96]. The recommended examination sequence for patients who can sit for long periods of time includes 14 assessments total, with three posterior, two lateral, and two anterior assessments for each hemithorax. When a patient is unable to remain in a sitting position, a 12-zone acquisition protocol is typically used, which is less complicated. Before accurately identifying the pleura within the intercostal region, a longitudinal scan should be conducted, visualizing the so-called "bat sign" throughout. The usefulness of a score based on extension of artifacts per scan may be limited because the length of the visualised pleura varies greatly among individuals and even within the same patient across different intercostal gaps [97]. Therefore, when doing a lung ultrasound with the express purpose of quantifying lung aeration, a transversal scan is the way to go because it provides a much larger window and a more consistent pleural length.

Various lung ultrasonography grading systems have evolved from attempts to quantify aeration loss. The gold standard uses an ultrasonographic pattern to demarcate the four stages of aeration loss [98–101]. This regional lung ultrasound score is highly linked with quantitative computed tomography-assessed tissue density, and it has demonstrated good diagnostic accuracy in ARDS patients compared to chest CT [102, 103]. Lung ultrasonography typically employs a 12-zone technique, where each region of the lungs is evaluated for aeration loss and given a score between 0 and 3. The only areas that cannot be examined using lung ultrasonography are the dorsal segments of the upper lobes of the lungs, which are situated behind the scapula [104]. The worst ultrasound pattern seen in each area is used to allocate points. The total of all the regions is then used to determine a score for the lungs, which can be anywhere from 0 to 36; a lower number indicates less aeration. It is possible to track this score over time and use it to evaluate the efficacy of the treatments since it provides a comprehensive view of lung aeration. Standardized reporting of the examination and the acquisition of representative images (possibly saved as video clips) are also necessary for serial comparisons and monitoring.

Each scan can be assigned a percentage of the existence of pathological symptoms (0-30-50-70-100%), which helps to better quantify the extent of the disease. Pathological findings such as separated and coalescent B-lines, light beams, and consolidations define a diseased area. To obtain a percentage of the whole examination, add the percentages of diseased lung in each area and divide by the total number of scans. By using this method, the percentage of diseased lung

may be more accurately calculated and the extent of lesions can be monitored over time [105].

Infection prevention and control measures when performing lung ultrasound

Regarding infection prevention and control (IPC), there are unique difficulties in doing lung ultrasounds on patients who have confirmed or suspected COVID-19. Unlike chest radiography and CT, this treatment requires close physical contact with the patient throughout. When doing a lung ultrasound, the sonographer and patient may be as close as 30–50 cm apart, and the patient may be instructed to breathe deeply in and out while holding their breath. Depending on the patient and the specialist's expertise, a lung ultrasound evaluation for COVID-19 patients can take anywhere from five to ten minutes [106]. To avoid the transmission of COVID-19 and guarantee the safety of patients and healthcare workers, it is essential that IPC precautions be effectively implemented during lung ultrasonography procedures [107]. Competence in IPC, including PPE use, equipment cleaning protocols, and accessory and equipment administration and maintenance, should be a goal of training.

All individuals involved in the practice of ultrasound, including both practitioners and patients, should adhere to standard procedures for personal protection equipment and hand cleanliness [107, 108]. Cleaning and disinfecting probes used on essential aseptic fields or contaminated through contact with blood, mucosal membranes, or bodily fluids during usage must continue to be normal clinical practices for ultrasound practitioners [107-109]. Use a low- or intermediate-level instrument-grade disinfectant to wipe out any exposed parts of the ultrasound machine or probe. The usage of handheld touch screens and individual sachets of gel is also strongly advised [110].

In the context of the COVID-19 pandemic, lung ultrasound has many potential uses, such as determining which patients should be admitted to the hospital, which patients should be sent to the intensive care unit for more severe lung involvement, and which patients can have their COVID-19 pneumonia symptoms tracked. Patients with thoracic problems (such as pneumothorax, heart failure, pleural effusion, or progressive pulmonary involvement) who need to be transferred to a higher level of medical care can be identified and therapeutic management can be informed by point-of-care ultrasound. More sophisticated uses of ultrasound in the lung, like computed tomography (CEUS) and elastography, can reveal details about the perfusion of the periphery of the lung, the extent of infarction, and the amount of interstitial edema in the lungs.

Lab results, the disease's prevalence during the pandemic phases, the patient's medical history (including comorbidities like cardiovascular disease, lung interstitial disease, or fibrosis), and the results of a lung ultrasound are all necessary for evaluating and interpreting the results of a COVID-19 pneumonia diagnosis.

Performing a lung ultrasound at the bedside, without moving unstable patients, is a noninvasive, quick, and repeatable procedure that requires simple sterilisation. The patient is typically monitored clinically by a physician, who can then interpret the imaging features of the lung ultrasound in addition to other important clinical and laboratory findings. An important consideration for allocating resources wisely is the feasibility of doing lung ultrasonography in outpatient settings. Because it does not expose patients to ionizing radiation, lung ultrasonography is a safe imaging modality for diagnosing and monitoring COVID-19 in pregnant women and children. It can also be performed on the same patient multiple times.

Due to a lack of standardized training programs and the necessity for qualified personnel, lung ultrasonography has not been widely used. When deciding to launch a lung ultrasound service, it is important to take into account the patient's and operator's physical proximity, as well as the

necessity to take specific measures to prevent and control infections, particularly in light of the present pandemic situation. In the end, it's well-known that lung ultrasound can reliably diagnose respiratory failure and is at least as sensitive and specific as traditional chest radiography. However, compared to lung CT scans, inter-rater agreement is lower for ultrasound, and the sensitivity and specificity aren't as good.

Healthcare providers, especially those working in low- and middle-income countries (LMICs), can benefit from organized, standardized training in the various lung ultrasonography applications in the context of the COVID-19 pandemic. There needs to be a worldwide effort to address the growing concern of multi-organ symptoms following a COVID-19 acute infection. These symptoms can range from coughing and shortness of breath to exhaustion, headaches, palpitations, chest and joint pain, physical limitations, depression, and insomnia. For diagnostic evaluation of lung involvement in those individuals and for monitoring of short- and long-term pulmonary alterations, lung ultrasound—which is portable, inexpensive, and relatively easy of access—may be the appropriate imaging method. Artificial intelligence (AI) has the ability to enhance computer-assisted processing of lung ultrasound pictures, which could be particularly useful in areas with limited human resources. The potential use of lung ultrasonography in the treatment of COVID-19 may be illuminated by more studies that investigate those questions.

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