The following information resources have been selected by the National Health Library and Knowledge Service Evidence Virtual Team in response to your question. The resources are listed in our estimated order of relevance to practicing healthcare professionals confronted with this scenario in an Irish context. In respect of the evolving global situation and rapidly changing evidence base, it is advised to use hyperlinked sources in this document to ensure that the information you are disseminating to the public or applying in clinical practice is the most current, valid and accurate. For further information on the methodology used in the compilation of this document—including a complete list of sources consulted—please see our National Health Library and Knowledge Service Summary of Evidence Protocol.

YOUR QUESTION

What is the utility of lung sonography in COVID-19 pneumonia?

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IN A NUTSHELL

The potential utility of lung ultrasound (LUS) in COVID-19 patients is the subject of extensive investigation and debate. There is emerging evidence that LUS may be a useful aid in the triage and monitoring of COVID-19 pneumonia as it has high sensitivity for detecting pleural thickening, subpleural consolidation, and ground-glass opacity. It has the advantages of portability, point-of-care evaluation, reduced healthcare worker exposure, and repeatability during follow-up. The lack of ionising radiation is of particular relevance when imaging pregnant women and children[11]. It also has limitations—eg it cannot discern the chronicity of a lesion—and other imaging modalities may be required. In an Irish context, the following should also be taken into consideration so as not to exaggerate the potential utility of LUS:

1. While early reports suggest that LUS may be useful, the role of lung ultrasound in the evaluation of COVID-19 has not been established.

2. Lung ultrasound is heavily operator dependant and there is currently a shortage of relevant expertise in Ireland.
3. Lung ultrasound cannot detect ground-glass opacification in the lungs which is one of the signs of COVID-19 on standard imaging modalities. The mainstay of imaging evaluation in COVID-19 is chest radiography, supplemented by CT in certain clinical circumstances. Lung findings on CXR and CT are better described, are more objective, and are more likely to provide useful information to referring clinicians who are managing patients with this COVID-19. Further studies are needed to determine the added value of lung ultrasound in the management of COVID-19.
4. Lung ultrasound involves close contact between the patient and the sonographer for periods often exceeding 15 minutes, which increases the risk of transmission of infection to staff.

These comments are subject to change in the light of new evidence which may emerge in this rapidly evolving area. Distinction should be drawn between lung ultrasound and pleural ultrasound: NCPR recognises that there is a definite established role for the latter in the evaluation of pleural effusions.

2020 guidance from the Canadian Society of Thoracic Radiology/Canadian Association of Radiologists[1] suggests that LUS should not be used to diagnose or exclude COVID-19 pneumonia: "Although there is a growing identification of LUS patterns in COVID-19 pneumonia, the overlap with other causes of respiratory distress is unknown. Small outcome studies have been performed in patients with other causes of acute respiratory distress but are insufficient to support the use of LUS to contribute to or supersede established prognostic tools."

Other guidance, such as that from the Italian Network for Safety in Healthcare[4] and the Polish Association of Epidemiologists and Infectiologists[7], recommends the use of LUS for suspected COVID-19 pneumonia under certain circumstances: the Italian guidance recommends that chest ultrasound may be used if competencies are available and if strict disinfection protocols are followed after each examination[4]. The National Institutes of Health in the United States[9] comment that: "The optimal pulmonary imaging technique for people with COVID-19 is yet to be defined. Initial evaluation may include chest x-ray, ultrasound or, if indicated, CT.

Evaluation of patients with severe illness or pneumonia should include pulmonary imaging [CXR, US or if, indicated, CT] and ECG, if indicated."

A number of studies [13-15] note the utility of LUS in paediatrics; however, patient numbers in these reports are low. One commentator cautions against its use: "[given that] few children have COVID-19 and, particularly in winter, the prevalence of illnesses is high [with co-infection with COVID-19 in 40%], the pre-test probability of COVID-19 in children is low. That, together with the normal lung ultrasound on the patient we present here, convince us that ultrasound, though useful in many other scenarios, is a poor screening tool for COVID-19 in children"[16].

LUS remains an emerging area of interest in the context of COVID-19. Many authors highlight the need for larger prospective studies to evaluate the diagnostic and prognostic values, relevant findings, and discriminating features of LUS in the diagnosis and management of COVID-19. A number of pertinent trials have been registered and related studies continue to be released in pre-print format[58-59].

IRISH AND INTERNATIONAL GUIDANCE

Dennie C et al (2020) Canadian Society of Thoracic Radiology/Canadian Association of Radiologists Consensus Statement Regarding Chest Imaging in Suspected and Confirmed COVID-19 [1]

This consensus statement features a dedicated section entitled SHOULD LUNG ULTRASOUND BE USED TO DIAGNOSE OR EXCLUDE COVID-19 PNEUMONIA? The authors state: "Lung ultrasound should not be used to diagnose or exclude COVID-19 pneumonia. Although there is a growing identification of LUS patterns in COVID-19 pneumonia, the overlap with other causes of respiratory distress is unknown. Small outcome studies have been performed in patients with other causes of acute respiratory distress but are insufficient to support the use of LUS to contribute to or supersede established prognostic tools such as the Sequential Organ Failure Assessment score. Any use of LUS in patients with COVID-19 should be done within the context of a controlled research study, ideally with operators blinded to other clinical markers of severity. Risks of viral exposure to operators are unknown, but some authors suggest the examination should only be performed by those already caring for the patient in another capacity."

Rubin GD et al (2020) The Role of Chest Imaging in Patient Management During the COVID-19 Pandemic: A Multinational Consensus Statement From the Fleischner Society [2]

"This statement focuses exclusively on the use of chest radiography and CT of the thorax. Although US has been suggested as a potential triage and diagnostic tool for COVID-19 given the predilection for the disease in subpleural regions, there is limited experience at this time as well as infection control issues."

British Medical Ultrasound Society (2020) COVID-19 Lung Ultrasound Guidance [3]

"Although CXR and Computed Tomography (CT) remain the mainstay in diagnosing the pulmonary manifestations of COVID -19 infection, it is expected that pressure on these modalities is likely to escalate. Point of Care Ultrasound Scanning (POCUS) may be of assistance, particularly in clinical triage. There is current literature stating that there are comparable results to

CT in some aspects of lung assessment in COVID patients." BMUS provide a practical 17-page document which it refers to as "an aid to focus study in lung ultrasound during the COVID-19 pandemic."

Italian Network for Safety in Healthcare (2020) Patient Safety Recommendations for COVID-19 Epidemic Outbreak. Version 2.0 [4]
"Chest X-rays have limited sensitivity in early stages of COVID-19 pneumonia. CT scan is more sensitive, but raises logistical problems. If ultrasounds competencies are available, use chest US, but disinfect US probes after contact with every COVID-19 suspected patient."

Neri E et al (2020) Use of CT and artificial intelligence in suspected or COVID-19 positive patients: statement of the Italian Society of Medical and Interventional Radiology [5]
The Italian SIRM recommends CXR as a first-line imaging tool, CT as an additional tool that shows typical features of COVID-19 pneumonia, and ultrasound of the lungs as a monitoring tool.

Pérez Pallarés J et al (2020) SEPAR-AEER Consensus Recommendations on the Usefulness of the Thoracic Ultrasound in the Management of the Patient with Suspected or Confirmed Infection with COVID-19 [6]
"In this [Spanish] consensus document we propose the use of thoracic ultrasound for early diagnosis and for the daily evaluation of the progression of lung lesions by a single explorer without the need to use the chest CT. In this consensus, it is proposed to carry out a systematic ultrasound examination of the thorax dividing it by quadrants and therefore identifying the ultrasound signs that are related to the type of parenchymal or pleural affectation that the patient has: A lines, B lines, parenchymal condensation, pleural line and pleural effusion. These findings will facilitate the decision making regarding the patient management, both when deciding the place of admission of the patient and the type of treatment to be prescribed."

Flisiak R et al (2020) Management of SARS-CoV-2 infection: recommendations of the Polish Association of Epidemiologists and Infectiologists as of March 31, 2020 [7]
With regard to imaging the authors recommend:
"Imaging
- Lung X-ray is the basis for the identification of lung lesions and can be performed with portable devices.

- Computed tomography [without contrast] has a high sensitivity for detecting interstitial lesions, valuable together with the assessment of the acid-base balance in predicting deterioration.
- Pulmonary ultrasound can be an easy method for early detection of pneumonia directly at the admission office."

World Health Organization (2020) Clinical management of severe acute respiratory infection (SARI) when COVID-19 disease is suspected. Interim guidance 13 March 2020 [8]

Table 2. Acute Respiratory Distress Syndrome (ARDS)
"If ARDS is suspected the suggested chest imaging is radiograph, CT scan, or lung ultrasound: bilateral opacities, not fully explained by volume overload, lobar or lung collapse, or nodules."
No specific chest imaging recommendations are made if pneumonia is suspected.

National Institutes of Health (US) COVID-19 Treatment Guidelines (2020) Management of Persons with COVID-19 [9]

"The optimal pulmonary imaging technique for people with COVID-19 is yet to be defined. Initial evaluation may include chest x-ray, ultrasound or, if indicated, CT. Evaluation of patients with severe illness or pneumonia should include pulmonary imaging [CXR, US or if, indicated, CT] and ECG, if indicated."

British Society of Thoracic Imaging (BSTI) (2020) COVID-19 Lung Ultrasound Guidance [10]

Dr Tom Semple, Consultant Cardiothoracic Radiologist at the Royal Brompton Hospital, has created a video outlining guidance on lung ultrasound for COVID-19 patients in critical care areas. The video is available HERE.

POINT-OF-CARE TOOLS

What does BMJ Best Practice say?

BMJ Best Practice (2020) COVID-19 [11]

Lung ultrasound is listed within the Emerging Tests section of the Investigations component of this topic: "There is emerging evidence that lung ultrasound may be a useful aid in the diagnosis of COVID-19 as it has

high sensitivity for detecting pleural thickening, subpleural consolidation and ground-glass opacity. It has the advantages of portability, bedside evaluation, reduced healthcare worker exposure, and repeatability during follow-up. However, it also has limitations—eg it is unable to discern chronicity of a lesion—and other imaging modalities may be required. Ultrasound also appears to be a useful imaging modality in pregnant women and children."

What does UpToDate say?

UpToDate (2020) Coronavirus disease 2019 (COVID-19): Critical care and airway management issues [12]

"Imaging: Typical imaging findings do not appear to be different in mild or severe cases of COVID-19: eg ground-glass opacification with or without consolidative abnormalities, consistent with viral pneumonia, minimal or no pleural effusions. While imaging with chest computed tomography (CT) was commonly performed in Chinese cohorts, we prefer to avoid its use, unless necessary; if chest CT is used as a diagnostic tool, its use must be balanced with the risk to other patients and healthcare workers during the process of patient transport and time spent in the CT room. Characteristic findings on bedside lung ultrasound include thickening of the pleural line and B lines supporting alveolar consolidation. Pleural effusions are unusual."

INTERNATIONAL LITERATURE

ARTICLES RELATING TO CHILDREN

Denina M et al (2020) [Observational Study, Pre-Publication Release]Lung Ultrasound in Children With COVID-19 [13]

Investigators have shown that in adults with COVID-19 pneumonia, bedside US correlates with CT findings. This Italian study represents a preliminary report of lung ultrasound characteristics in children affected by COVID-19. While the number of patients analyzed is small [n=8], the high concordance between radiologic and LUS findings suggests that ultrasound may be a reasonable method to detect lung abnormalities in children with COVID-19. Although further studies are needed to better understand and characterize LUS findings in this novel disease in children, we propose LUS routinely

protocol examinations as a useful tool in the diagnostic and clinical management of mild/severe COVID-19 in children.

Musolino AM et al (2020) Lung Ultrasound in Children with COVID-19: Preliminary Findings [14]

This report describes LUS features of 10 consecutively admitted children with COVID-19 in two tertiary-level pediatric hospitals in Rome. LUS revealed signs of lung involvement during COVID-19 infection. In particular, vertical artifacts (70%), pleural irregularities (60%), areas of white lung (10%) and subpleural consolidations (10%) were the main findings in patients with COVID-19. No cases of pleural effusions were found. According to our experience, the routine use of LUS in the evaluation of children with suspected or confirmed COVID-19, when performed by clinicians with documented experience in LUS, was useful in diagnosing and monitoring pediatric COVID-19 pneumonia, reducing unnecessary radiation/sedation in children and exposure of health care workers to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).

Musolino and Supino (2020) [Letter] The Role of Lung Ultrasound in Diagnosis and Follow-Up of Children With Coronavirus Disease 2019 [15]

The authors provide their opinion that LUS is helpful in diagnosis and in follow-up management of the COVID-19 children. They suggest that LUS is useful to complement the clinical evaluation and to monitor the evolution of lung disease until its resolution. They provide an overview of how the LUS is performed.

Scheier E et al (2020) [Letter] Lung ultrasound cannot be used to screen for COVID-19 in children [16]

This letter outlining the case of an 8-year-old child who was given a point of care ultrasound with a linear probe to screen for pneumonia. All areas of the chest, upper back and axillae were interrogated from apices to the diaphragm. The child had A-lines throughout without pleural irregularities or effusion and was discharged home to continue symptomatic care.
The authors conclude: "[given that] few children have COVID-19 and, particularly in winter, the prevalence of illnesses is high [with co-infection with COVID-19 in 40%], the pretest probability of COVID-19 in children is low. That, together with the normal lung ultrasound on the patient we present

here, convince us that ultrasound, though useful in many other scenarios, is a poor screening tool for COVID-19 in children."

ARTICLES RELATING TO PREGNANT WOMEN

Buonsenso D et al (2020) [Case Series] Clinical role of lung ultrasound for the diagnosis and monitoring of COVID-19 pneumonia in pregnant women [17]
This Italian case series reports on four cases of pregnant women affected by COVID-19 infection who have been monitored with lung ultrasound examination. All patients showed ultrasound features indicative of COVID-19 pneumonia at admission: irregular pleural lines and vertical artifacts [B-lines] were observed in all four cases, whereas patchy areas of white lung in two cases. LUS was more sensitive than chest X-ray in detecting COVID-19. Three patients had resolution of lung pathology at ultrasound after 96 hours of admission. Two pregnancies are ongoing, whereas two patients had cesarean delivery with no fetal complications. PCR testing of both cord blood and newborn swabs were negative in both cases.

Kalafat E et al (2020) [Case Report] Lung ultrasound and computed tomographic findings in pregnant woman with COVID-19 [18]
The authors report a case of positive lung ultrasound findings consistent with COVID-19 in a woman with an initially negative RT-PCR result. The lung ultrasound-imaging findings were present between the negative and subsequent positive RT-PCR tests and correlated with CT findings. The point-of-care lung-ultrasound examination was easy to perform and, as such, could play an important role in the triage of women with suspected COVID-19. The neonatal swabs, cord blood and placental swab RT-PCR tests were negative for SARS-CoV-2, a finding consistent with the published literature suggesting no vertical transmission of this virus in pregnant women.

Inchingolo et al (2020) [Clinical Opinion] The Diagnosis of Pneumonia in a Pregnant Woman with COVID-19 Using Maternal Lung Ultrasound [19]
The authors report their experience of lung ultrasound examination in the diagnosis of SARS-CoV-2 pneumonia in a pregnant woman, stating: "Point-of-care lung ultrasound examination could play a key role in the assessment of pregnant women with suspicion of 2019-nCoV infection. In particular, in this case, lung ultrasound findings were crucial to indicate anti-viral treatment in presence of substantially normal chest X-ray. It's worth

underlying that we decided to perform X-ray because of different contribution, in terms of imaging findings, provided by X-ray compared to lung ultrasound. In particular, X-ray allows us a panoramic view giving information also regarding thoracic — not only pulmonary zones not detectable at ultrasound examination. On the other hand, ultrasound examination has a better sensitivity for pneumonia referring to focal alterations of peripheral airspace geometry of the lung."

REVIEW ARTICLES RELATING TO ADULT PATIENTS

Smith MJ et al (2020) Point-of-care lung ultrasound in patients with COVID-19 - a narrative review [20]

This narrative review provides a summary of evidence and clinical guidance for the use and interpretation of lung ultrasound for patients with moderate, severe and critical COVID-19 associated lung injury. Mechanisms by which the potential lung ultrasound workforce can be deployed are explored, including a pragmatic approach to training, governance, imaging, interpretation of images and implementation of lung ultrasound into routine clinical practice."

Wan DY et al (2020) [Review] Current practice and potential strategy in diagnosing COVID-19 [21]

This review article features a section on lung ultrasound specifically stating: "Apart from CT, lung ultrasound (US) was also recommended recently. It was once reported to be superior to standard CT for evaluation of pneumonia or respiratory distress syndrome. Peng et al performed lung US on 20 patients and summarized five main clinical findings, including thickening of the irregular pleural line. A strong connection between ultrasonography findings and the disease stages was also reported. This indicates its great use in dynamically monitoring COVID-19 progression. The Chinese Critical Ultrasound Study Group published Critical-Ultrasound-Based Recommendations on Severe COVID-19 recently, in which lung US findings and relevant managements were described in detail." [The Chinese Critical Ultrasound Group here can be found below. See reference 40.]

Lomoro P et al (2020) COVID-19 pneumonia manifestations at the admission on chest ultrasound, radiographs, and CT: single-center study and comprehensive radiologic literature review [22]

The authors sought to investigate the imaging features of emerging COVID-19 pneumonia on chest ultrasound (US), radiographs (CXR) and computed tomography (CT) examinations performed at admission and to provide a comprehensive radiological literature review on on-going radiological data from recent publications. 58 patients [36 men, 22 women; age range, 18–98 years] were included in the study. Among these, chest US, CXR and CT were performed respectively in 22, 32 and 42 patients. Lung US findings were consistent with diffuse B lines (100%) and subpleural consolidations (27.3%).

Vetrugno L et al (2020) [Review] 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 [23]

Lung ultrasound (LU) has rapidly become a tool for assessment of patients stricken by the novel coronavirus 2019 (COVID-19). Over the past two and a half months [January to March 2020] we have used this modality for identification of lung involvement along with pulmonary severity in patients with suspected or documented COVID-19 infection. Use of LU has helped us in clinical decision making and reduced the use of both chest x-rays and computed tomography (CT).

Dong D et al (2020) [Review] The role of imaging in the detection and management of COVID-19: a review [24]

Specifically in respect of lung ultrasound, the authors suggest: "As a non-invasive, radiation-free and portable imaging method, lung ultrasound (LUS) allows for the initial bedside screening of low-risk patients, diagnosis of suspected cases in the emergency room setting, prognostic stratification, and monitoring of the changes in pneumonia. Peng et al reported that lung ultrasonography can provide results comparable with chest CT for evaluation of COVID-19 pneumonia. For severe or critical patients, especially those admitted to the ICU and requiring ventilation, LUS is necessary for patient management and monitoring the effectiveness of treatments. More importantly, the use of LUS can reduce the exposure risk between infected patients and health care workers, and discriminate between lower- and higher-risk patients. Bunosenso et al reported a confirmed case that LUS showed an irregular pleural line with small subpleural consolidations, areas of white lung and thick, confluent and irregular vertical artifacts (B-lines).

For pregnant women with suspected COVID-19, chest CT examination should be avoided as much as possible due to the high radiation dose risk to the fetus. As an alternative, Moro et al recommended that obstetricians and gynecologists to perform lung examination using LUS."

OBSERVATIONAL STUDIES, ORIGINAL STUDIES AND CASE REPORTS/SERIES RELATING TO ADULTS

Soldati G et al (2020) Proposal for international standardization of the use of lung ultrasound for COVID-19 patients; a simple, quantitative, reproducible method [25]

Italian clinicians formed a LUS COVID-19 team and developed a proposed standardized approach to optimize the use of lung ultrasound in patients with COVID- 19, focussing on equipment, procedure, classification (and scoring system for severity), and data sharing.

Soldati G et al (2020) [Case Series] Contrast-Enhanced Ultrasound in Patients With COVID-19: Pneumonia, Acute Respiratory Distress Syndrome, or Something Else? [26]

The authors report 3 cases of COVID-19 pneumonia in which contrast-enhanced ultrasound was suggestive of consolidations with perfusion defects, at least in part caused by ischemic or necrotic changes and not only by inflammatory or atelectasis events.

Yasukawa K and Minami T (2020) [Retrospective Observational Study] Point-of-Care Lung Ultrasound Findings in Patients with Novel Coronavirus Disease (COVID-19) Pneumonia [27]

This study from the United States evaluated ultrasound findings from 10 admitted patients. The authors suggest that: "Point-of-care lung ultrasound has multiple advantages, including lack of radiation exposure and repeatability. Also, lung ultrasound has been shown to be more sensitive than a chest radiograph in detecting alveolar-interstitial syndrome. The utilization of lung ultrasound may also reduce exposure of healthcare workers to severe acute respiratory syndrome-coronavirus-2 and may mitigate the shortage of personal protective equipment."

Zieleskiewicz L et al (2020) [Case Series] Ultrasound findings in patients with COVID-19 pneumonia in early and late stages: Two case-reports[28]
These French case reports compared CT scan and ultrasound imaging on two cases of confirmed COVID-19 patients at early and late stages of the disease. The authors suggest that: "These two suggestive cases underline the potential of LUS for COVID-19 pneumonia assessment at different stages of the disease. Even if all LUS signs are not specific, presence of these various pattern in a clinical context is very suggestive of viral pneumonia. Thus LUS, when the clinical context is evocative, may help physicians to identify COVID-19 patients. After a proper validation of LUS against chest CT scan, one can believe that LUS could serve as a diagnostic and a triage tool detecting at risk patients, thus allowing a better allocation of ICU resources as previously described in another context." They also suggest that LUS should also be associated with multi-organ point-of-care ultrasound.

Thomas A et al (2020) [Case Report] Lung ultrasound findings in a 64-year-old woman with COVID-19 [29]
The authors propose that lung ultrasonography may be useful in the workup of patients with suspected COVID-19 even though differentiating between different causes of viral pneumonia is not possible.

Tung-Chen Y (2020) [Case Report] Lung ultrasound in the monitoring of COVID-19 infection [30]
The purpose of this case report is to describe the natural course of the disease in mild infection in a 35-year-old man managed at home. The authors suggest that LUS is an excellent tool in the characterisation of COVID-19 infection and is more available than CT or X-ray; and emphasise the utility and the opportunity that LUS presents in some clinical scenarios, and how it may serve as a monitoring and therapy guide.

Farrow R et al (2020) [Case Report] Early Multi-organ Point-of-Care Ultrasound Evaluation of Respiratory Distress During SARS-CoV-2 Outbreak: Case Report [31]
This American syudy outlines the case of a COVID-19 patient who presented to the emergency department twice within a 24-hour period with rapidly progressing illness. A multi-organ point-of-care ultrasound evaluation was used on the return visit and assisted clinical decision-making. The authors suggest that "a multi-organ POCUS exam allows for quick assessment of

acute dyspnea in the emergency department. As the lung involvement of COVID-19 is primarily a peripheral process it is readily identifiable via lung ultrasound. We believe that when applied efficiently and safely a POCUS exam can reduce clinical uncertainty and potentially limit the use of other imaging modalities when treating patients with COVID-19."

Duclos G et al (2020) [Case Report] "No dose" lung ultrasound correlation with "low dose" CT scan for early diagnosis of SARS-CoV-2 pneumonia [32]
This case report provides a comparison of lung ultrasonography with chest CT scan in a 54-year-old male with SARS-CoV-2 pneumonia. The contemporaneous scans permit direct comparison of the lung ultrasonography findings with the chest CT. They demonstrate similar findings in terms of location of the areas of pulmonary involvement and the pattern of parenchymal disease. The authors suggest that: "Lung ultrasonography may be considered a useful alternative to low-dose chest CT for diagnosis and management of COVID-19 given its ease of use, repeatability, reproducibility, absence of radiation and immediate bedside application that obviates the need to transport the critically ill patient to the CT scanner."

Buonsenso D et al (2020) [Case Report] Point-of-Care Lung Ultrasound Findings in Novel Coronavirus Disease-19 Pnemoniae[33]
This Italian case report provides a lung ultrasound description of nCoV-19 pneumonia in a relatively young man with respiratory distress and confirmed etiological diagnosis. Lung ultrasound clearly documented signs suggestive for interstitial-alveolar damage showing bilateral, diffuse pleural line abnormalities, subpleural consolidations, white lung areas and thick, irregular vertical artifacts.
The authors suggest that the use of pocket devices in particular has several applications—including scope to perform lung ultrasounds in an outpatient setting by GPs; and allowing a better pre-triage to determine those patients that should be sent to hospital.

Alkhafaji M et al (2020) [Case Report] Visual Case Discussion A Case of Lung Ultrasound Findings in a 73-year-old male with COVID-19 [34]
This case report describes the use of bedside lung ultrasound in a 73-year-old male in a hospital in the US. The authors describe the ultrasound findings and discuss the merits of ultrasound use.

Ji L et al (2020) [Case Report] Serial bedside lung ultrasonography in a critically ill COVID-19 patient [35]

The authors of this Chinese case report describe serial bedside LUS findings in a critically ill COVID-19 patient and suggest that it provides the following learning points for clinicians: "During COVID-19 pandemic, chest CT has played a crucial role in the rapid diagnosis of this disease. While the increasing risk of contagiousness and moving unstable patients make chest CT a limited choice for critically ill patients with COVID-19 pneumonia, more recently, lung ultrasonography (LUS) has been identified as a sensitive and semi-quantitative tool in the assessment of pneumonia, especially in the intensive care unit."

LETTERS AND COMMENTARIES RELATING TO ADULTS

Volpicelli G and Gargani L. (2020) [Short Communication] Sonographic signs and patterns of COVID-19 pneumonia [36]

This Italian paper provides a detailed overview of the sonographic signs of interest in COVID-19 using lung ultrasound: "Pneumonia in COVID-19 has peculiar features and can be studied by lung ultrasound in the early approach to suspected patients. The sonographic signs are non-specific when considered alone, but observation of some aspects of vertical artifacts can enhance the diagnostic power of the ultrasound examination. Also, the combination of sonographic signs in patterns and their correlation with blood exams in different phenotypes of the disease may allow for a reliable characterization and be of help in triaging and admitting patients."

Dudea SM (2020) [Editorial] Ultrasonography and SARS-CoV 2 infection: a review of what we know and do not yet know [37]

This paper provides an overview of lung ultrasound under the following headings:

- Positive diagnosis: the US changes reported in SARS CoV2 lung infection
- Triage
- Assessment of the severity of lung damage
- Evolution of the disease

- Cardiac evaluation
- POCUS
- The disadvantages of US examination
- Unknown and work in progress [role of Doppler and CEUS]

Xing C et al (2020) [Letter] Lung ultrasound findings in patients with COVID-19 pneumonia[38]

In this study, the authors characterize the lung ultrasound findings COVID-19 pneumonia in 20 patients, and study the relationship between the ultrasound findings and clinical severity and the time-course of disease progress. Bedside lung ultrasound was performed to detect B-lines, lung consolidation and pleural line abnormalities at 5 areas in each lung. Vascular ultrasound was also performed to detect potential deep vein thrombosis.
The authors conclude that: "Collectively, lung ultrasound could serve as a valuable tool for the detection and follow-up of lung lesions in COVID-19 pneumonia and also provide supplemental imaging information for current recommended radiological examination, with the advantages of radiation-free, flexibility and cost effective."

Khalili N et al (2020) [Letter] Lung Ultrasound in COVID-19 Pneumonia: Prospects and Limitations [39]

The authors discuss the advantages and disadvantages afforded by lung ultrasound. Although lung ultrasound has several advantages including the absence of radiation, lower contamination risk, lower cost, and repeatability, one of its limitations is the relatively lower sensitivity in comparison to chest CT scan. Another disadvantage of this imaging modality is that ultrasound cannot usually detect lesions that are deep and intrapulmonary. They assert that lung ultrasonography is not appropriate for the initial diagnosis of COVID-19.
Regarding the detection of COVID-19 pneumonia they assert: "Infiltrations detected by lung ultrasound can be suggestive of pulmonary edema, infarct or lobar pneumonia; nevertheless, a confirmed diagnosis of either of these findings requires a complementary imaging modality such as chest CT. Thus, we believe that the previously published studies might have exaggerated the usefulness and value of lung ultrasonography in the management of COVID-19."
The authors conclude by suggesting that ultrasonography may be helpful in COVID-19 management; however, its use in COVID-19 diagnosis and

screening is limited. Chest CT scan remains the imaging modality of choice for diagnosing COVID-19.

Peng QY et al (2020) [Letter] Chinese Critical Care Ultrasound Study Group (CCUSG). Findings of lung ultrasonography of novel corona virus pneumonia during the 2019-2020 epidemic [40]

A report from China on lung ultrasonography conducted with 20 patients with COVID-19 using a 12-zone method. The authors state that:
"The findings of lung ultrasonography features of SARS-CoV-2 pneumonia/ARDS are related to the stage of disease, the severity of lung injury, and comorbidities. 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. A recognized limitation of lung ultrasonography is that it cannot detect lesions that are deep within the lung, as the aerated lung blocks transmission of ultrasonography—ie the abnormality must extend to the pleural surface to be visible on ultrasonography examination. Chest CT is required to detect pneumonia that does not extend to the pleural surface. Based on our experience, we consider that lung ultrasonography has major utility for management of COVID-19 with respiratory involvement due to its safety, repeatability, absence of radiation, low cost and point of care use; chest CT may be reserved for cases where lung ultrasonography is not sufficient to answer the clinical question. We find there is utility of lung ultrasonography for rapid assessment of the severity of SARS-CoV-2 pneumonia/ARDS at presentation, to track the evolution of disease, to monitor lung recruitment maneuvers, to guide response to prone position, the management of extracorporeal membrane therapy, and for making decisions related to weaning the patient form ventilatory support."

Piliego C et al (2020) [Letter] The ultrasound guided triage: a new tool for prehospital management of COVID-19 pandemic [41]

This paper from Italy outlines the potential advantages and disadvantages of the use of lung ultrasound in COVID-19 patients. It suggests that ultrasound could form a valuable triage tool particularly in field hospitals to enable early diagnosis outside hospital and provides a proposal for a US-guided triage algorithm. The authors conclude by suggesting that: "Although the US triage has not yet been validated by prospective studies, it is a concept that needs prompt definition and investigation to improve our ability

to decide which patients need hospitalization immediately when resources are limited and need to be conserved."

Pierce CW (2020) [Comment] Clarifying the role of lung ultrasonography in COVID-19 respiratory disease [42]

This article is a response to an article by Thomas et al[29]. The authors critique the assertions made by that article and suggest: "In general, lung ultrasonography in critical illness provides information that is probably best regarded as complementary to radiography of the chest. The unique benefit of lung ultrasonography in the current context includes bedside feasibility, in particular when advanced chest imaging is unavailable or contraindicated for infection control".

Kirkpatrick AW and McKee JL (2020) [Comment] Lung ultrasonography in a woman with COVID-19: This examination could be remote [43]

This article is a response to an article by Thomas et al[29]. Kirkpartick and McKee endorse the use of lung ultrasound and suggest the potential of remote telementored ultrasonography (RTMUS) which could be conducted by non-physicians who are guided remotely.

Antúnez-Montes OY and Buonsenso D (2020) [Pre-Proof Article] Routine use of Point-of-Care lung ultrasound during the COVID-19 pandemic [44]

This Italian paper strongly encourages clinicians not to rely solely on auscultation in patients with dyspnea and to reduce their use of X-rays and imaging modalities during the COVID-19 pandemic.

Lepri G et al (2020) [Short Communication] The emerging role of lung ultrasound in COVID-19 pneumonia [45]

This Italian paper outlines: lung ultrasound role in the evaluation of the lung; the role of CT in COVID-19 pneumonia; and the role of LUS in COVID-19 pneumonia. The authors conclude that: "recent data have suggested that LUS may be important in the follow-up of COVID-19 pneumonia patients through the scoring of sonography findings which appear to correlate with CT scan alterations according to the different phases and severity of lung involvement."

Schultz MJ et al (2020) [Editorial] Challenges and Opportunities for Lung Ultrasound in Novel Coronavirus Disease (COVID-19) [46]

This editorial from Thailand provides an overview of the Yasukawa and Taro paper and highlights the potential advantages of lung ultrasound: "This easy-to-perform bedside tool could prove to be important in diagnosis, prognostication, and follow-up of patients, and might also enable identification of recruitable lung lesions to guide invasive ventilation".

Soldati G et al (2020) [Letter] Is There a Role for Lung Ultrasound During the COVID-19 Pandemic? [47]

This Italian paper asserts: "Given that LUS can identify changes in the physical state of superficial lung tissue which correlate with histopathologic findings and can be identified on CT but remain hidden in a large percentage of chest radiographs, the role of LUS can be relevant in the context of the COVID- 19 epidemic."
The authors suggest that lung ultrasound could be used in the following situations:

- Triage [pneumonia or non- pneumonia] of symptomatic patients at home as well as in the prehospital phase.
- Diagnostic suspicion and awareness in the emergency department setting.
- Prognostic stratification and monitoring of patients with pneumonia on the basis of the extension of specific patterns and their evolution toward the consolidation phase in the emergency department setting.
- Treatment of intensive care unit patients with regard to ventilation and weaning.
- Monitoring the effect of therapeutic measures, antiviral or other.
- Reducing the number of healthcare professionals exposed during patient stratification. A single clinician would be necessary to perform an objective medical examination and imaging investigation directly at the patient's bed."

Manivel V et al (2020) CLUE: COVID-19 Lung Ultrasound in Emergency Department [48]

This Australian paper comprises: an overview of the current evidence on lung ultrasound in COVID-19; technical aspects of LUS in COVID-19; sonographic features in COVID-19; and an overview of the CLUE protocol: the COVID-19 Lung Ultrasound in Emergency protocol. The authors conclude: "CLUE protocol which incorporates lung ultrasound scoring system and

supplemental oxygen requirement at the time of examination, when performed by a trained emergency clinician, can help risk-stratify suspected COVID-19 patients. This protocol will aid the clinician to make rapid and appropriate bedside clinical decisions, potentially decrease reliance on chest X-rays or CT chest and aid disposition planning from the emergency department."

Fox S and Dugar S (2020) Point-of-care ultrasound and COVID-19 [49]

This paper from the USA suggests that because the utility of each application varies by setting, individual institutions should consider how they can best use ultrasound within their specific environments. It addresses the typical ultrasound findings of COVID-19 and indicates that: "these lung ultrasound findings are not specific to COVID-19 and are seen in other pneumonias (viral and bacterial) and inflammatory pneumonitis. Severe cases of COVID-19 are similar in appearance to acute respiratory distress syndrome from other etiologies. The findings differ from cardiogenic pulmonary edema, which is frequently characterized by bilateral lower-lobe-predominant B lines with smooth pleura. Alternatively, lack of lung ultrasound findings consistent with COVID-19 infection in acute respiratory failure may suggest an alternative etiology." The authors also discuss: the potential applications of lung ultrasound; other applications of point-of-care ultrasound; disinfection protocol and the DLETE Protocol.

Flower DL et al (2020) The Use of Point of Care Lung Ultrasound and Echocardiography in the Management of COVID-19 [50]

This paper from the UK suggests that the use of lung US and echocardiography should be included in the clinical assessment and management of patients suffering from COVID-19.

Fiala MJ (2020) [Correspondence] Ultrasound in COVID-19: a timeline of ultrasound findings in relation to CT [51]

The author reviews existing studies and suggest that the characteristic ultrasound findings [bilateral and multilobar B-lines, subpleural consolidates, irregular pleural line and decreased flow] have been shown to be highly consistent with CT findings and can be expected to develop over a similar timeline. The author provides a table which outlines symptom onset in days and the corresponding common findings in both CT and ultrasound. The author suggests that ultrasound may be useful to clinicians, particularly in emergency/triage settings.

Poggiali E et al (2020) [Letter] Can Lung US Help Critical Care Clinicians in the Early Diagnosis of Novel Coronavirus (COVID-19) Pneumonia? [52]
This short letter from Italian clinicians outlines their experience of using US in patients who presented to their emergency department with COVID-19 pneumonia. They describe ultrasound findings in the patients and recommend the use of bedside US for the early diagnosis of COVID-19 pneumonia in all the patients who present to the emergency department with flu-resembling symptoms.

Cheung JC and Lam KN (2020) [Comment] POCUS in COVID-19: pearls and pitfalls [53]
The authors describe practical considerations around the potential use of point-of-care ultrasound (POCUS) in COVID-19 patients such as machine selection, scanning protocol, documentation and limitations.

Additional letters which were published as responses to other COVID-19 articles are:

Soldati G et al (2020) [Letter] On Lung Ultrasound Patterns Specificity in the Management of COVID-19 Patients [54]

Vetrugno L et al (2020) [Letter] Lung Ultrasound and the COVID-19 "Pattern": Not All That Glitters Today Is Gold Tomorrow [55]

Ji L et al (2020) [Letter] Response to letter to the editor: "Lung Ultrasound early detection and monitoring in COVID-19 pneumonia: fact and fiction" [56]

Sperandeo M and Trovato GM (2020) [Letter] Lung Ultrasound early detection and monitoring in COVID-19 pneumonia: fact and fiction [57]

PRE-PRINTS NOT YET PEER-REVIEWED

Yale Tung Chen et al (2020) [Pre-Print Not Yet Peer Reviewed] Correlation between chest computed tomography and lung ultrasonography in patients with coronavirus disease 2019 (COVID-19) [58]
This Spanish prospective study was carried out in the emergency department of confirmed or clinically highly suspicious COVID-19 patients

(n=51) who were subjected to a chest CT and concurrent LUS exam. An experienced ED physician performed the LUS exam blind to the clinical history and results of the CT scan, which were reviewed by two radiologists in consensus for signs compatible with COVID-19: bilateral ground-glass opacities in peripheral distribution. Compatible LUS exam was considered a bilateral pattern of B-lines, irregular pleural line and subpleural consolidations. The indication for CT was a negative or indeterminate RT-PCR test (49.0%) followed by suspicion of pulmonary embolism (41.2%). Radiological signs compatible with COVID-19 were present in thirty-seven patients (72.5%) on CT scan and forty patients (78.4%) on LUS exam. The presence of LUS findings was correlated with a positive CT scan suggestive of COVID-19 (OR: 13.3, 95%CI: 4.5-39.6, p<0.001) with a sensitivity of 100.0% and a specificity of 78.6%, positive predictive value of 92.5% and negative of 100.0%. There was no missed diagnosis of COVID-19 with LUS compared to CT in our cohort. The LUS Score had a good correlation with CT total severity score (ICC 0.803, 95% CI 0.60-0.90, p<0.001). CONCLUSION: LUS presents similar accuracy compared to chest CT to detect lung abnormalities in COVID-19 patients.

Haaksma M et al (2020) [Pre-Print Not Yet Peer Reviewed] Lung ultrasound findings in patients with novel SARS-CoV2 [59]

This Dutch paper aims to present an overview of lung ultrasound characteristics in critically ill patients with SARS-CoV-2 pneumonia in general and in relation to the duration of symptoms and clinical parameters. The authors conclude that: "SARS CoV2 results in significant ultrasound changes, with decreased lung sliding, thickening of the pleural line and a C-profile being the most observed. With time, a thickened and irregular pleural line, C-profile and pleural effusion become more common findings."

FOREIGN LANGUAGE ARTICLES

D'Andrea A et al (2020) L'imaging integrato nel percorso del paziente con COVID-19: dalla diagnosi, al monitoraggio clinico, alla prognosi [The role of multimodality imaging in COVID-19 patients: from diagnosis to clinical monitoring and prognosis] [60]

Osterwalder J. (2020) COVID-19 – mehr Lungen-PoCUS und sparsam mit Stethoskop, Thoraxröntgen und Lungen-CT umgehen [COVID-19 - More Lung Pocus and Sparing Use of Stethoscope, Chest X-Ray and Lung CT] [61]

Feng XY et al (2020) [Application of Pulmonary Ultrasound in the Diagnosis of COVID-19 Pneumonia in Neonates] [62]

Lovas A et al (2020) A képalkotó diagnosztika jelentősége a COVID–19-fertőzött betegek ellátásában [Importance of the imaging techniques in the management of COVID-19-infected patients] [63]

ONGOING STUDIES

Yujiao Yang et al (2020) Lung ultrasound for the diagnosis of COVID-19: a systematic review and meta-analysis of diagnostic test accuracy [64]
This protocol states that the systematic review will address the following questions:

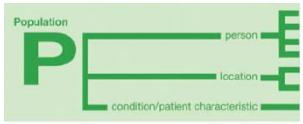
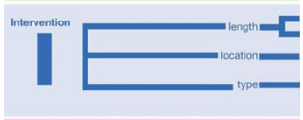
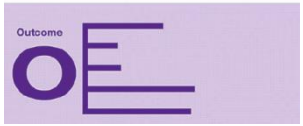
1. What are the diagnostic values of LUS in the identification of cases with COVID-19 infection?
2. What are the most commonly reported LUS findings of COVID-19-confirmed cases?
3. Do changes in LUS findings reflect the time of COVID-19 infection course?
4. Is there any difference of LUS findings between pneumonia due to COVID-19 and other etiologies?

ONGOING CLINICAL TRIALS

A significant number of ongoing trials relating to the use of lung ultrasound in COVID-19 patients are listed on the Cochrane COVID-19 Study Register and other trials registries.

Produced by the members of the National Health Library and Knowledge Service Evidence Team†. Current as at 04 June 2020.This evidence summary collates the best available evidence at the time of writing and **does not replace clinical judgement or guidance**. Emerging literature or subsequent developments in respect of COVID-19 may require amendment to the information or sources listed in the document. Although all reasonable care has been taken in the compilation of content, the National Health Library and Knowledge Service Evidence Team makes no representations or warranties expressed or implied as to the accuracy or suitability of the information or sources listed in the document. This evidence summary is the property of the National Health Library and Knowledge Service and subsequent re-use or distribution in whole or in part should include acknowledgement of the service.

The following PICO(T) was used as a basis for the evidence summary:

	COVID-19 PNEUMONIA
	LUNG SONOGRAPHY
	
	

The following search strategy was used:

KEYWORDS:
ROUTINELY USED COVID-19 SEARCH
(LUNG OR THORACIC OR CHEST OR PULMONARY OR THORAX) AND (SONOGRAPHY OR SONOGRAPHIC OR ULTRASOUND OR ULTRASONIC OR ULTRASONOGRAPHY)
PNEUMONIA
MESH HEADINGS:
(MH "Ultrasonography+")
(MH "PNEUMONIA, VIRAL") OR (MH "PNEUMONIA")
EMTREE HEADINGS:
ULTRASOUND/
EXP PNEUMONIA/

† Ms. Maura Flynn, Librarian, Midland Regional Hospital, Tullamore [Author]; Brendan Leen, Area Library Manager, HSE South [Editor]

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