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Review article

Point of care and intensive care lung ultrasound: A reference guide for practitioners during COVID-19

S. Moore [a,*], E. Gardiner [b]

[a] NHS Greater Glasgow and Clyde, UK
[b] Glasgow Caledonian University, UK

A R T I C L E I N F O

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A B S T R A C T

Objectives: Current events with the recent COVID-19 outbreak are necessitating steep learning curves for the NHS workforce. Ultrasound, although not used in the diagnosis of COVID-19 may be utilised by practitioners at the point of care (POC) or on the intensive care units (ITUs) where rapid assessment of the lung condition may be required. The aim of this article was to review current literature surrounding the use of lung ultrasound in relation to COVID-19 and provide Sonographers with a quick and digestible reference guide for lung pathologies.
Key findings: Ultrasound is being used in Italy and China to help review lung condition during the COVID-19 outbreak however not strictly as a diagnostic tool as Computed Tomography (CT) of the chest and chest radiographs are currently gold standard. Ultrasound is highly sensitive in the detection of multiple lung pathologies which can be demonstrated in conjunction with COVID-19 however to date there are no specific, nor pathognomonic findings which relate to COVID-19 on ultrasound.
Conclusion: Lung ultrasound is highly sensitive and can quickly and accurately review lung condition creating potential to assess for changes or resolution over time, especially in the ITU and POC setting. However it should not be used as a diagnostic tool for COVID-19 due to low specificity in relation to the virus.
Implications for practice: The adoption of lung ultrasound to monitor lung condition during the COVID-19 outbreak may reduce the need for serial exposure to ionising radiation on the wards and in turn reduce the number of radiographers required to attend infected wards and bays, protecting both patients and the workforce.

Data collection

The data collection for this review article was undertaken using Pubmed, science direct and Researchgate with the key words; Lung ultrasound, COVID-19, POCUS, point of care ultrasound and intensive care ultrasound.

COVID-19

It is essential to note that imaging does not equate a diagnosis. While lung ultrasound is very sensitive[1] there are no specific or pathognomonic findings for COVID-19.[2] Clinical assessment and correlation with real-time reverse transcriptase polymerase chain reaction testing for COVID-19 is essential.[3] In both China and Italy Computed Tomography chest examinations and digital chest radiographs are the modality of choice to assist in the diagnosis.[2,3]

Lung ultrasound during COVID-19 outbreak

To date current literature from China and Italy doses not advocate lung ultrasound for the diagnosis COVID-19[2,3] however it is known that lung ultrasound may assist in monitoring lung conditions.[1,4–6]

The authors hypothesise that the use of ultrasound at the point of care or on intensive care may reduce the patient's serial exposure to ionising radiation. Sonographers, Radiologists and adequately trained intensivists would be able to undertake lung ultrasound at the bedside or in the imaging department, hopefully reducing the

* Corresponding author.
E-mail addresses: s.moore11nhs@gmail.com (S. Moore), Elaine.Gardiner@gcu.ac.uk (E. Gardiner).
@SonoStephen (S. Moore), @elaineclare (E. Gardiner)

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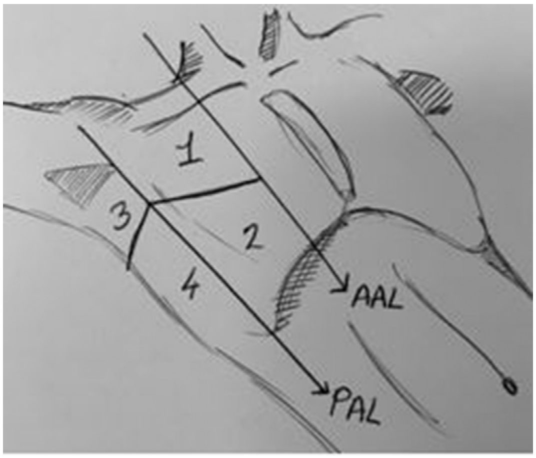

Figure 1. Windows used in lung ultrasound Anterior axillary line (AAL) Posterior axillary line (PAL).

number of radiographers required to attend infected wards and bays, protecting both patients and the workforce.

Advantages of ultrasound

Ultrasound can quickly assess lung condition[1,4,5] without the use of ionising radiation. The use of ultrasound may be best applied in the monitoring of lung conditions and quickly assessing for changes or resolution over time in the POC and ITU setting by either sonographers or intensivist practitioners with adequate training.

The advantage of lung ultrasound is that it is quick, non-invasive and portable and therefore able to be used at the bed side or ITU setting. There is no ionising radiation associated with ultrasound, it is readily available and the probe can easily be covered with sterile probe covers.

It is important to note that lung ultrasound findings can be suggestive of a wide range of conditions including: Pulmonary oedema, Pleural effusions, Interstitial lung disease, Consolidation, Pneumothorax and Empyema.[1,4]

These pathologies can occur in a wide range of conditions including: Chronic Cardiac Failure (CCF), Chest infections, Trauma, Chronic Obstructive Pulmonary Disease (COPD), Diabetes, Asthma, Asbestosis and many more. None of these features however are specific or pathognomonic to COVID-19[2]

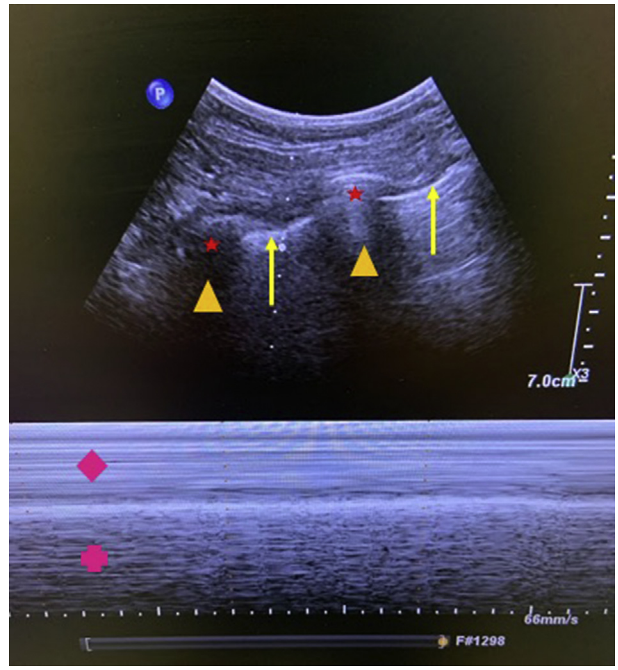

Figure 3. Normal Seashore sign on M-mode (Red star = Rib, Orange Triangle = Rib shadow, Pink Diamond = Static Intercostal Muscles on M-mode, Yellow Arrow = Pleural Line, Pink Cross = Normal Sliding Pleura on M-mode). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Windows and technique

Lung ultrasound is best practiced with an eight zone technique where views are obtained in each section outlined in Fig. 1. Longitudinal views and cross sectional view in each quadrant should be obtained bilaterally.[4,5] Best practice is to use a linear probe for superficial structures such as the pleura and a curve linear probe for deeper structures such as the diaphragm or pleural effusions.[4,5]

Normal Ultrasound appearances demonstrate the dermis, subcutaneous and pectoral layers most superficially with the ribs seen deeper with posterior shadowing and the intercostal musculature seen between the ribs. Just below the intercostal musculature we see the plural line, which in a normal chest should be seen sliding on gentle respiration. A-lines will be appreciated deeper to the pleural lines as an artificial reflection equally spaced and descending towards the bottom of the screen (Fig. 2).

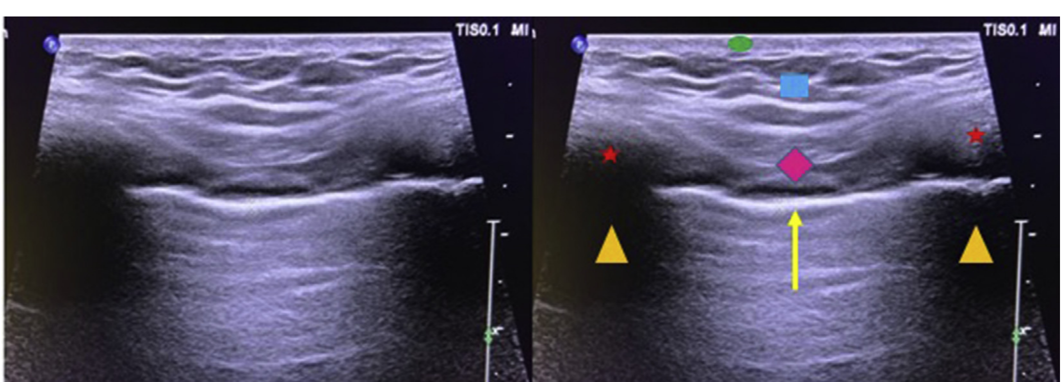

Figure 2. Normal ultrasound appearances (Red star = Rib, Orange Triangle = Rib shadow, Pink Diamond = Intercostal Muscles, Yellow Arrow = Pleural Line, Blue Rectangle = Subcutaneous Fat, Green Oval = Dermal layers). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

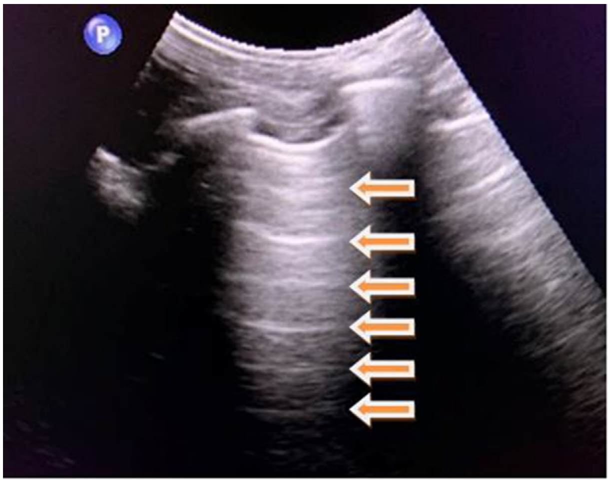

Figure 4. Normal A-lines seen as parallel lines (Orange arrows) in the intercostal space which descend to the bottom of the screen. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

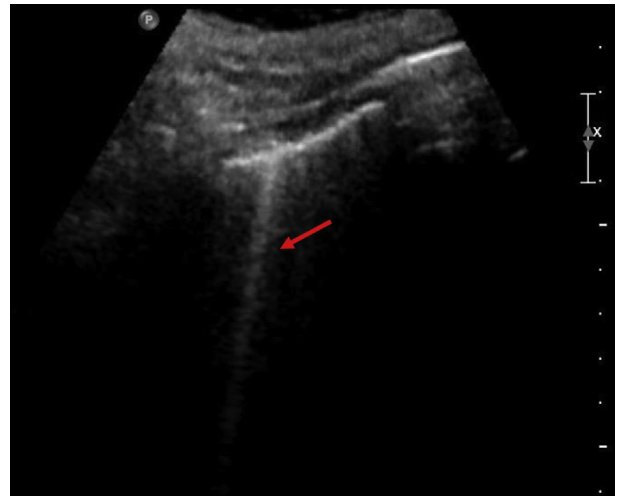

Figure 6. Normal B-lines seen in the intercostal space (Red Arrow = Single normal B-line). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Normal ultrasound appearances and signs

The pleural sliding sign/seashore sign

Visually look for dynamic sliding of the pleura in real time. You should see gentle movement with respiration passing between the ribs just deep to the intercostal musculature. Progress to use M-mode in the intercostal space to look for the seashore sign[6] (Fig. 3). This appearance is created by normal sliding pleura[4,6] and represents the seashore where a sandy beach (the sliding pleura) reaches the waves of the sea (the superficial layers of the chest wall).

A-lines

A-lines are a form of reverberation artifact caused by reflections of the pleura. These are seen as parallel lines to the sliding pleura which are equally spaced and descend towards the bottom of the screen (Fig. 4).[4,6] A-lines can help to indicate normal aerated lung[4,6,7] however may also be present in a pneumothorax, so careful interrogation of the pleural line for both visual sliding and employing the use of M-mode to look for the seashore sign is essential to help exclude a pneumothorax.

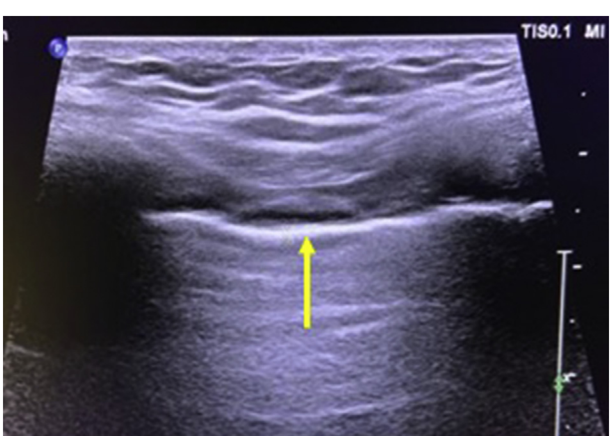

Figure 5. Normal Pleural line = <0.2–0.3 mm (Yellow Arrow = Pleural Line). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Figure 7. >3 B-lines in the intercostal space is suggestive of pulmonary oedema (Red Arrows = Multiple closely associated thick B-lines). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

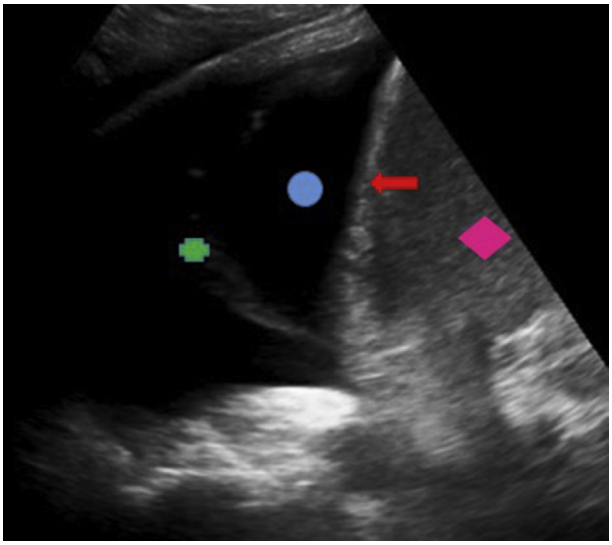

Figure 8. Simple pleural effusion (Blue Circle = Fluid in the pleural space/pleural effusion, Pink Diamond = Liver, Red Arrow = Diaphragm, Green Cross = Lung Tissue). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Pleural line

The pleural line is a thin, echogenic line seen just deep to the intercostal musculature between the ribs. A normal pleural line measures <0.2–0.3 mm (Fig. 5).[8]

B-lines

B-lines are another form of reverberation artifact in which bright comet tail like lines are seen extending from the pleural line to the bottom of the screen obliterating A-lines (Fig. 6).[6] B-lines move in synchronization of respiration[6] and normal lung can demonstrate up to three B-lines per lung window/intercostal space.[6]

Pathological features on ultrasound

Pulmonary oedema

Ultrasound has a sensitivity and specificity of 94.1% and 92.4% respectively with regard to identifying pulmonary oedema.[4]

Figure 9. Thickened and irregular pleura suggestive of interstitial lung disease (Yellow Arrows = Thickened irregular pleura). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

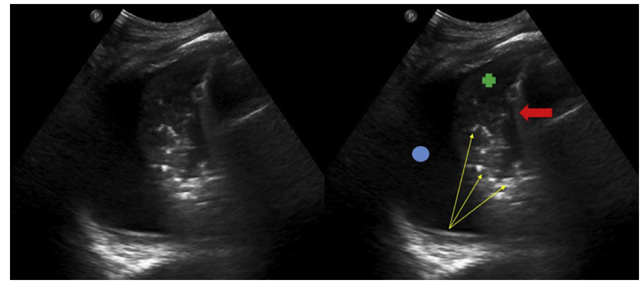

Figure 10. Pleural effusion (Blue Circle) with underlying lung consolidation and shredding appearance from an air-bronchogram. (Yellow Arrows = air-bronchogram/shredded appearance, Green Cross – Lung parenchyma, Red Arrow = Diaphragm). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

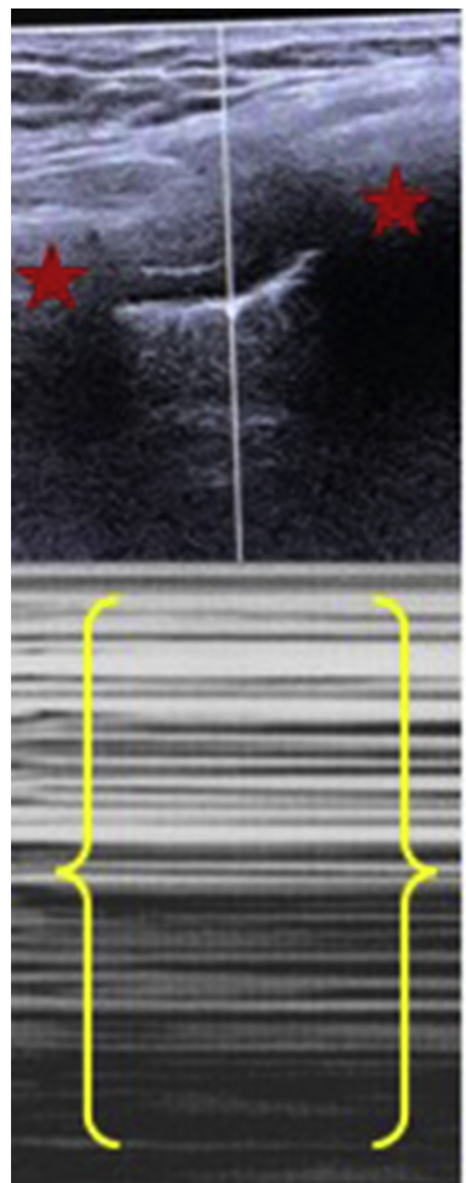

Figure 11. Barcode sign on M-mode. These appearances are suggestive of a pneumothorax (Red Stars = Ribs, Yellow Callipers = Barcode sign). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Ultrasound features are of >3 B-lines per intercostals space[4] which indicates an increase in fluids within the lung parenchyma.[4] Causes for this are multifactorial and include chronic cardiac disease, fibrosis and pneumonia and well as many other respiratory conditions (Fig. 7).

Simple pleural effusions

Ultrasound has a sensitivity and specificity of 90%[4] and 93%[9] respectively with regard to identifying simple pleural effusions. Pleural effusions are seen as an anechoic region of free fluid seen above the diaphragm[9] and between the parietal and visceral layer of the thoracic pleura (Fig. 8).[4] Pleural effusions are commonly seen in the gravity dependent portion of the thorax.[9] Often the underlying lung parenchyma can be demonstrated. The vertebral bodies of the thoracic spine can often be seen above the diaphragm when there is a pleural effusion; this sign is sometimes called a V-line.[4]

Interstitial lung disease (with connective tissue disease)

Ultrasound has a sensitivity and specificity of 85.9% and 83.9% respectively with regard to identifying interstitial lung disease.[10] Common findings are >3 B-lines seen per window[10] and a thickened, irregular pleural line >0.3 mm.[11] While interstitial lung disease is an umbrella term which can be suggestive of many pathologies, pleural irregularities are suggestive of fibrosis/parenchymal scarring[11] (Fig. 9).

Consolidation

Ultrasound has a sensitivity and specificity of 89% and 94%[4] respectively with regard to identifying consolidation, however consolidated lung must be in contact with the pleura to be visualised.[4] Focal areas of hepatisation occur when there is increased fluid content in the lung parenchyma, allowing the propagation of sound through the lung tissue until it hits a bronchus containing air where reflection occurs, creating a shredded appearance within the lung tissue.[4] These shredded areas represent a visible air-bronchogram[4] and mimics pneumobilia above the diaphragm. The term hepatisation is used as the appearances of the lung tissue are similar to that of the liver, especially when pneumobilia is present (Fig. 10). Other features include >3B-lines obliterating A-lines and possible pleural effusions on the affected side[4] (Fig. 10).

Pneumothorax

Ultrasound has a sensitivity that ranges between 75 and 100% and a specificity of 95.6% respectively.[4] Beware that A-lines may still be present in a pneumothorax[4] however there will be no demonstrable B-lines as well as no visible sliding pleura observed, on further interrogation with M-mode applied in the intercostal space the Barcode sign will be present (Fig. 11). The Barcode sign is demonstrated on M-mode scanning and is where a loss of normal sliding pleura produces a parallel linear pattern even with gentle respiration.[4]

Complex pleural effusions

Ultrasound has a sensitivity of 92% and a specificity of 93% respectively for pleural effusions.[12] Causes of complex pleural effusions are multifactorial however the most common causes are chest infections leading to pyogenic collections, or trauma leading to a hemothorax. There are two kinds of complex pleural effusion.

Complex non-septated

These complex pleural effusions contain low level echoes and debris.[9,12] Depending on clinical history these may be a hemothorax in the context of trauma or may be empyema in the presence of clinical sepsis.

Complex septated

These complex pleural effusions are seen to be containing low level echoes and septations (12,13). Given the clinical history these may be organising hemorrhagic content in the context of trauma or empyema if clinically septic.

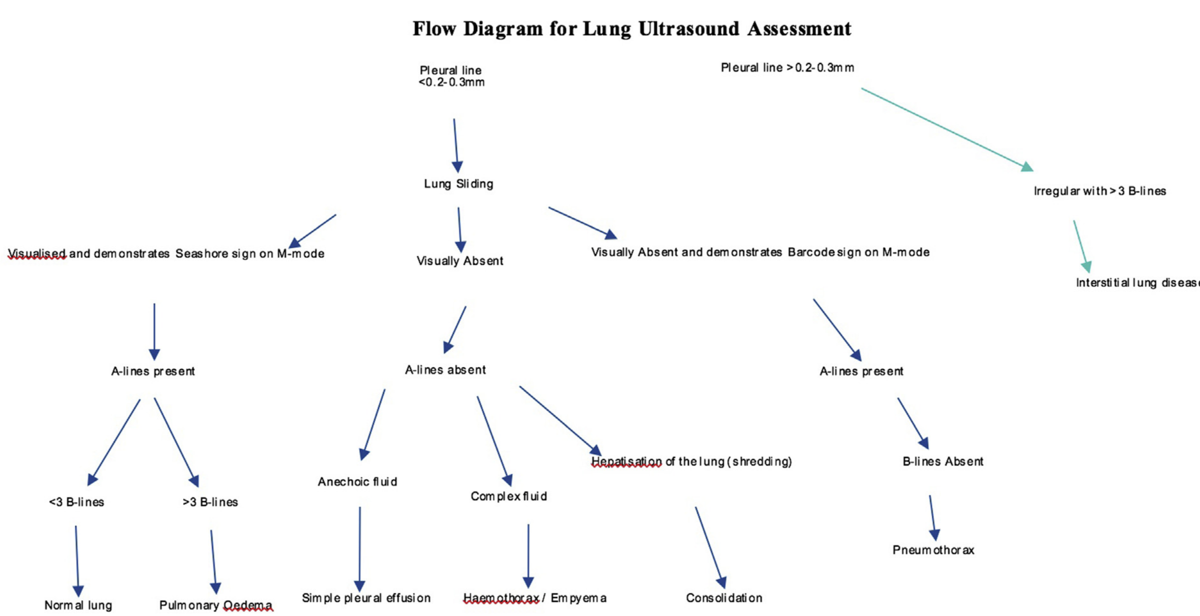

Figure 12. Flow diagram of Lung Ultrasound Assessment.

Conclusion

Lung ultrasound is a highly sensitive and specific modality which can be used to monitor a variety of lung conditions (Fig. 12). The advantages of ultrasound make it an ideal modality for use in the POC and ITU setting for clinicians who need to quickly review the condition of critically ill patients. The use of lung ultrasound during the COVID-19 outbreak should not be used in the diagnosis of corona virus as CT and chest radiographs are the modality of choice, however its safe and appropriate use could help reduce patients serial exposure to ionising radiation, as well as reduce the number of radiographers who need to attend infected wards or bays to perform portable chest X-rays.

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Conflict of interest statement

None.

References

1. Poggiali E, Dacrema A, Bastoni D, Tinelli V, Demichele E, Ramos PM, et al. Can lung US help critical care clinicians in the early diagnosis of Novel Coronavirus (COVID-19) pneumonia? *Radiology* 2020. Available at: https://pubs.rsna.org/doi/pdf/10.1148/radiol.2020200847. [Accessed 21 March 2020].
2. Kong W, Agarwal P. Chest imaging appearances of COVID-19 infection. *Radiol Cardiothorac Imag* 2020;**2**(1):1–22. https://doi.org/10.1148/ryct.2020200028.
3. Kanne JP, Little BP, Chung JH, Elicker BM, Ketai LH. Essentials for Radiologists on COVID-19: an update – Radiology scientific expert panel. *Radiology* 2020;**1**(1):1–4. https://doi.org/10.1148/radiol.2020200527.
4. Wimalasena Y, Kocierz L, Strong D, Watterson J, Burns B. Lung ultrasound: a useful tool in the assessment of the dyspnoeic patient in the emergency department. Fact or fiction? *Br Med J* 2016;**35**(4):1–9. https://doi.org/10.1136/emermed-2016-205937.
5. Volpicelli G, Mussa A, Garofalo G, Cardinale L, Casoli G, Perotto F, et al. Bedside lung ultrasound in the assessment of alveolar-interstitial syndrome. *Am J Emerg Med* 2006;**24**(6):689–96. https://doi.org/10.1016/j.ajem.2006.02.013.
6. Saraogi A. Lung ultrasound: present and future. *Lung India* 2015;**32**(2):250–7. https://doi.org/10.4103/0970-2113.156245.
7. Doerschug KC, Schmidt GA. Intensive care ultrasound: III. Lung and pleural ultrasound for the intensivist. *Ann Am Thorac Soc* 2013;**10**(6):708–12. https://doi.org/10.1513/AnnalsATS.201308-288OT.
8. Dietrich CF, Mathis G, Cui XW, Ignee A, Hocke M, Hirche O, et al. Ultrasound of the pleurae and lungs. *Ultrasound Med Biol* 2015;**41**(2):351–65. https://doi.org/10.1016/j.ultrasmedbio.2014.10.002.
9. Prina E, Torres A, Roberto C. Ultrasound in the diagnosis & management of pleural effusions. *J Hosp Med* 2015;**10**(12):811–6. https://doi.org/10.1590/S1806-37132014000100001.
10. Xie HQ, Zhang WW, Sun DS, Chen XM, Yuan SF, Gong ZH, et al. A simplified lung ultrasound for the diagnosis of interstitial lung disease in connective tissue disease: a meta-analysis. *Arthritis Res Ther* 2019;**21**(93):1–9. https://doi.org/10.1186/s13075-019-1888-9.
11. Rotondo C, Chiala A, Nivuori M, Coladonato L, Giannini M, Righetti G, et al. SAT0216 chest ultrasound signs of interstitial lung disease in systemic sclerosis patients: a comparison between high resolution chest computed Tomography findings. *Ann Rheum Dis* 2013;**75**(2):747. https://doi.org/10.1136/annrheum-dis-2011-201072.
12. Brogi E, Gargani L, Bignami E, Barbariol F, Marra A, Forfori F, et al. Thoracic ultrasound for pleural effusion in the intensive care unit: a narrative review from diagnosis to treatment. *Crit Care* 2017;**21**(325):1–11. https://doi.org/10.1186/s13054-017-1897-5.