Lung Ultrasound

Purpose & Preamble

This is not a standard operating procedure or a guideline it is a distillation of literature and available resources.

This document has the aim of aiding the potential scanning of lung during the COVID-19 pandemic. BMUS does not advocate now is the time to learn lung ultrasound if you are a complete beginner to chest ultrasound. Any training or undertaking of lung ultrasound should be with the support of Radiology Departments and/or Intensivists. Ultrasound Services should not feel pressured to deliver lung ultrasound services if they do not have adequately trained staff. Safety and competency – as always- is paramount.

This is a live document and will remain a live document due to increasing emerging information as the pandemic continues to unfold. It is a guidance document and not absolute.

It is advised that the video clip references given in this document are utilised for to allow better demonstration of the subject matter.

This document is not an extensive chest ultrasound document, nor by reading this does it denote competence in the examination. It is an aid to focus study in lung ultrasound during the Covid-19 pandemic.

Background

The high contagiousness of COVID-19 and the risk of transporting unstable patients with hypoxemia and hemodynamic failure may, in some cases, make chest CT a limited option for the patient with suspected or established COVID-19. Lung ultrasonography has been noted to have results that are similar to chest CT and superior to standard chest radiography for evaluation of pneumonia/pneumonitis and/or adult respiratory distress syndrome (ARDS) with the added advantage of ease of use at point of care, repeatability, absence of radiation exposure.[1] The table below is taken from the WHO interim guidance produced March 2020.[2]

Acute respiratory distress syndrome (ARDS) *(17-19)*	**Onset:** within 1 week of a known clinical insult or new or worsening respiratory symptoms. **Chest imaging** (radiograph, CT scan, or lung ultrasound): bilateral opacities, not fully explained by volume overload, lobar or lung collapse, or nodules. **Origin of pulmonary infiltrates**: respiratory failure not fully explained by cardiac failure or fluid overload. Need objective assessment (e.g. echocardiography) to exclude hydrostatic cause of infiltrates/oedema if no risk factor present. **Oxygenation impairment in adults** *(17, 19)*: • Mild ARDS: 200 mmHg < PaO_2/FiO_2[a] ≤ 300 mmHg (with PEEP or CPAP ≥ 5 cmH_2O, or non-ventilated) • Moderate ARDS: 100 mmHg < PaO_2/FiO_2 ≤ 200 mmHg (with PEEP ≥ 5 cmH_2O, or non-ventilated) • Severe ARDS: PaO_2/FiO_2 ≤ 100 mmHg (with PEEP ≥ 5 cmH_2O, or non-ventilated) • When PaO_2 is not available, SpO_2/FiO_2 ≤ 315 suggests ARDS (including in non-ventilated patients). **Oxygenation impairment in children:** note OI = Oxygenation Index and OSI = Oxygenation Index using SpO_2. Use PaO_2-based metric when available. If PaO_2 not available, wean FiO_2 to maintain SpO_2 ≤ 97% to calculate OSI or SpO_2/FiO_2 ratio: • Bilevel (NIV or CPAP) ≥ 5 cmH_2O via full face mask: PaO_2/FiO_2 ≤ 300 mmHg or SpO_2/FiO_2 ≤ 264 • Mild ARDS (invasively ventilated): 4 ≤ OI < 8 or 5 ≤ OSI < 7.5 • Moderate ARDS (invasively ventilated): 8 ≤ OI < 16 or 7.5 ≤ OSI < 12.3 Severe ARDS (invasively ventilated): OI ≥ 16 or OSI ≥ 12.3.

Anecdotal evidence from those who have working in units with multiple COVID-19 patients have indicated that imaging maybe more useful for problem solving i.e. looking for alternative diagnoses for chest symptoms such as pleural effusion.

Those who are experienced in Chest/Lung Ultrasound should be the team members who should be utilised. ANY Sonographer who feels that they absolutely cannot perform this type of examination with any degree of usefulness and produce an accurate report they should not be forced to do so and individuals should be professionally responsible to highlight this. This document has been created to allow a focus for study and professional development in the current crisis and a desire to aid medical colleagues where CT cannot be accesses or appropriate due to patient condition. It is not all encompassing for all chest ultrasound. Sonographers should also be reminded that medical management decisions will be made on issue of a lung ultrasound report and therefore consideration to a clear report is essential.

ALERT Imaging does NOT definitively diagnose COVID-19. It may define the extent of the disease or suggest and alternative/additional diagnosis.

Policy

Before commencement of the examination, the sonographer should enquire about;

- Suspected or Confirmed for COVID-19
- Be fully aware of the PPE required to perform the scan and how to decontaminate post procedure – including the machine.
- If on ITU be directed by the team in charge
- An ultrasound examination request should only be accepted where it will make a clear difference to the patient management pathway.
- The request for ultrasound examination should be vetted and performed when it is likely to affect patient management to avoid unnecessary exposure

To allow comparison to previous US scan it is important that as far as reasonably practicable, the examination should be standardised and images stored to a picture archiving computer system (PACS).

Patient Consent.

The sonographer is required to obtain valid consent for lung ultrasound scanning. If procedures are performed on ITU, the sonographer should be familiar with procedures when performing scan in the 'best interests' of patients when verbal consent cannot be given.

Prior to the Examination

It is important that all precautions are taken when scanning COVID-19 patients (confirmed and suspected). It is suggested that all removable items from the ultrasound cart are taken away prior to the examination commencing. The machine should be protected with regard to prevention of contamination as far as is practicable to enable use. Probe covers which drape along the wire and sterile drapes may be utilised.

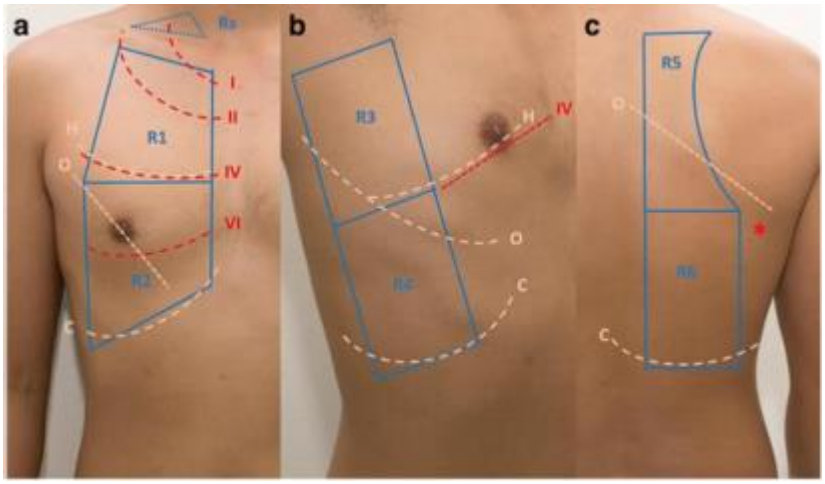
Examination.

Source documents : https://www.youtube.com/watch?v=nx6eHINDveM&feature=emb_title)

https://www.youtube.com/watch?v=8pw9Sxll68A&feature=youtu.be

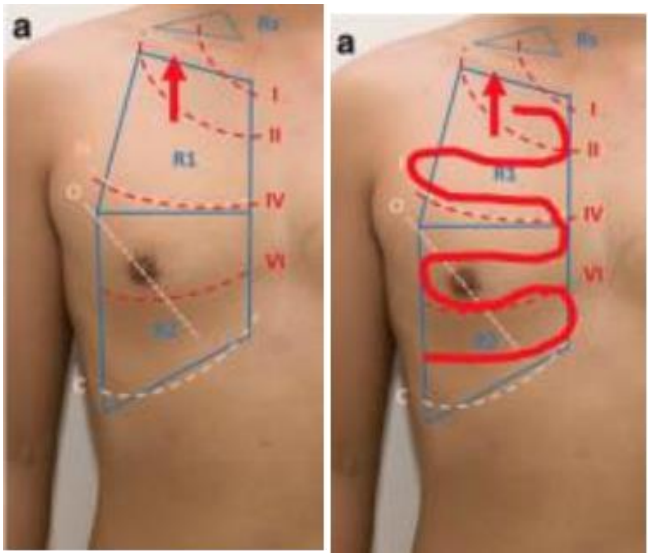
https://www.ics.ac.uk/ICS/FUSIC/ICS/FUSIC/FUSIC_Accreditation.aspx?hkey=c88fa5cd-5c3f-4c22-b007-53e01a523ce8

Standard Technique: where patient condition allows, acknowledging posterior chest will often be the most difficult if at all to obtain.



The standard zones for scanning:

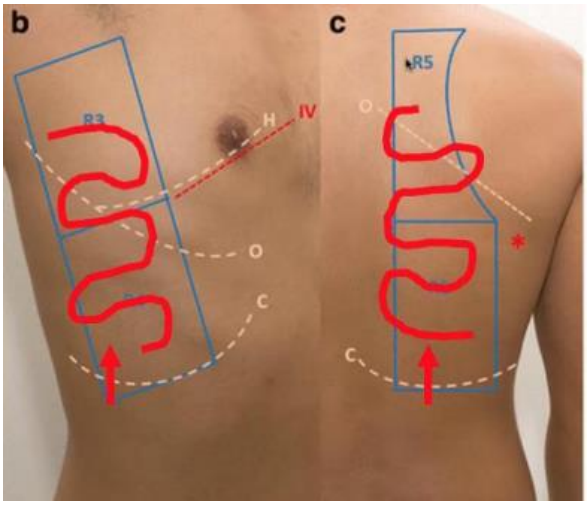
a) Anterior chest
b) Lateral chest
c) Posterior chest



This is the ‘mow the lawn’.

Move the probe relatively slowly to allow you to observe as the patient breathes. Pause intercostally.

Transducer should be held perpendicular to the thoracic cage as illustrated below



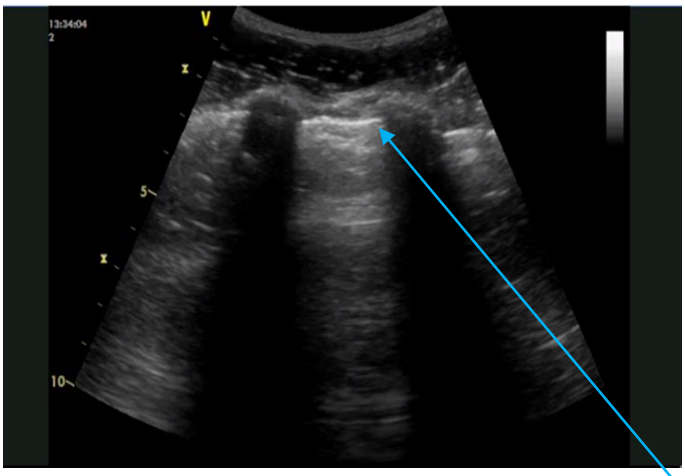
Technical Factors to be considered:

- turn off harmonics, compound imaging
- set focus to pleural line
- Depth at 12 cm (3.5MHz). Abdominal Curvy Transducer
- low dynamic range[3]

Findings of pathology are most likely in the lower posterior zones.

Alternative Resource - https://www.youtube.com/watch?v=8pw9Sxll68A&feature=youtu.be

Normal Lung



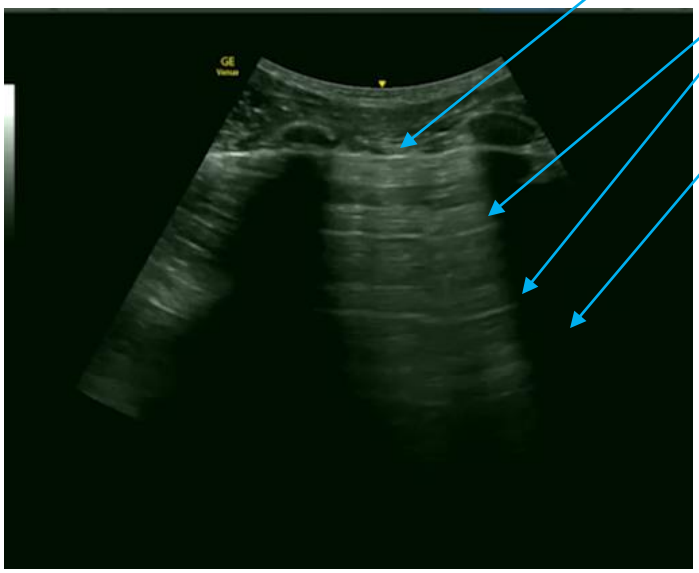
Taken from
https://academic.oup.com/bjaed/article/16/2/39/2897763

Normal lung:

Thin pleural line, sliding (on dynamic live scanning)

'Alines'

Rib shadows

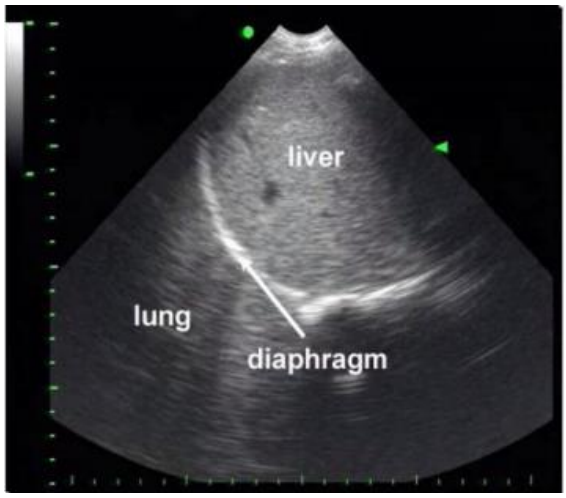


Taken from
https://www.youtube.com/watch?v=8pw9Sxll68A&feature=youtu.be

The bat wing sign

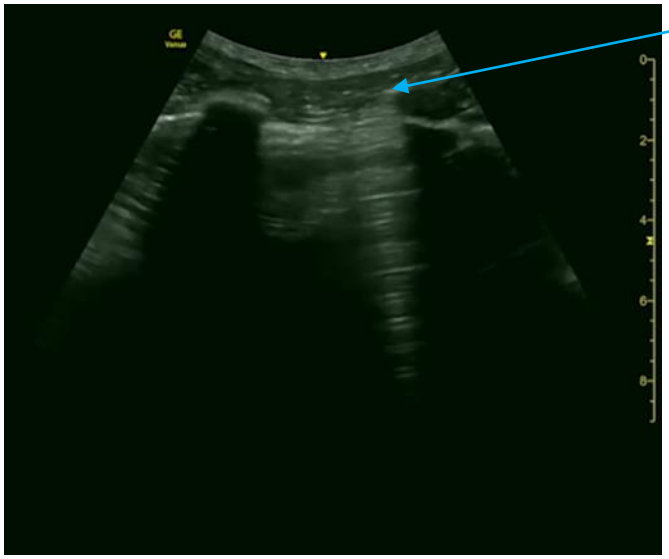
Seeing the bat wing sign (rib-pleural line-rib) can be used as a land mark of correct scanning plane. The artefacts that are produced by a normal pleural lines are described as 'A'Lines (Horizontal lines below the pleura*).[4,5] A-lines result from reverberation between the transducer and plural interface. They are equidistant and decrease in intensity

Taken from: Lichtenstein DA. Lung ultrasound in the critically ill. Ann Intensive Care. 2014;4(1):1. Published 2014 Jan 9. doi:10.1186/2110-5820-4-1
Husain LF, Hagopian L, Wayman D, Baker WE, Carmody KA. Sonographic diagnosis of pneumothorax. J Emerg Trauma Shock. 2012;5(1):76–81. doi:10.4103/0974-2700.93116



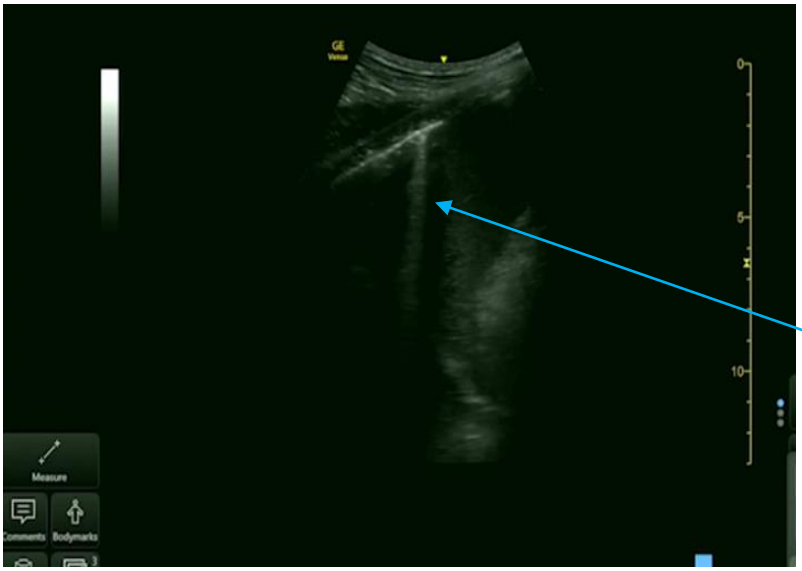
Normal Lung right lower segment. In a normal patient, mirror image artefact of the liver is seen above the right hemidiaphragm

Taken from
https://www.youtube.com/watch?v=8pw9Sxll68A&feature=youtu.be



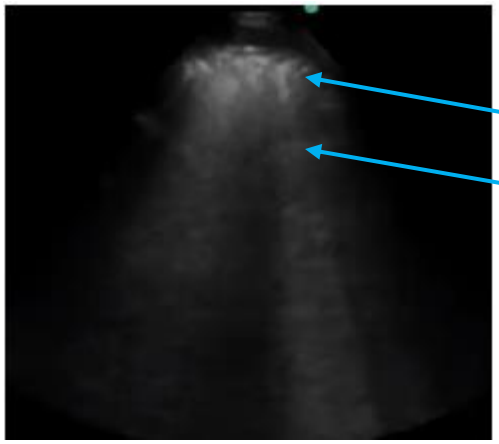
B-Lines intercostal space

B-lines are comet tail artefacts which extend from the pleural line to the depth of the image and extend backwards and forwards evenly on normal respiration.



B-line lower left lung adjacent to spleen

Abnormal Findings Which Can be Associated with COVID-19



Abnormal Lung:

Thickened irregular pleura

Scattered ‘B-Lines’ *

No rib shadows

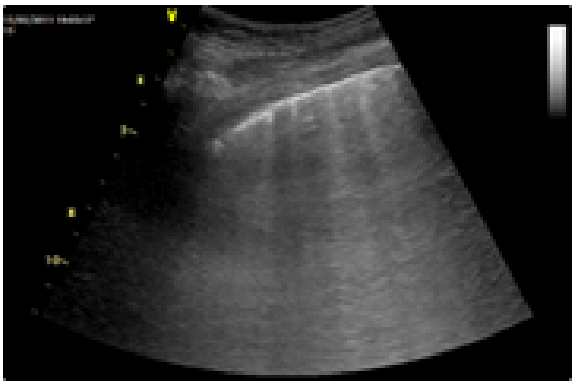
* B-lines appearances increases with interstitial oedema as the air / fluid interface causes reverberation.

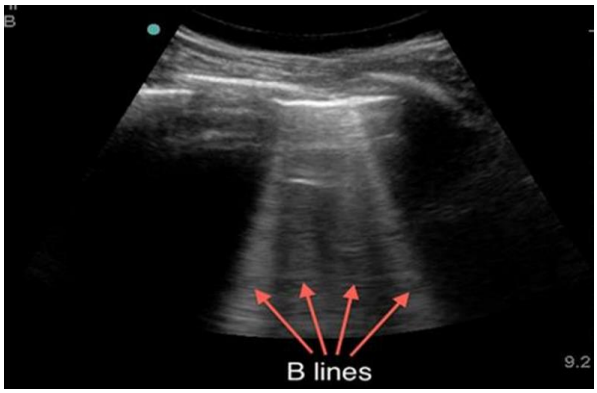
Similar to the comet tail artefacts generated by bowel, B-lines extend deep into the patient and move with lung sliding (if present). Much easier to identify in a dynamic image.

Focal scattered B-lines are seen during the early stages of COVID-19.

(However, a few B-lines (<3/field of view) can be a normal finding in the elderly, particularly around the base of the lungs. Serial scans may be useful.

As seen below, multiple B-lines in a diffuse, non-homogeneous pattern indicate lung interstitial syndrome. This is seen in COVID-19 patients as the disease progresses.





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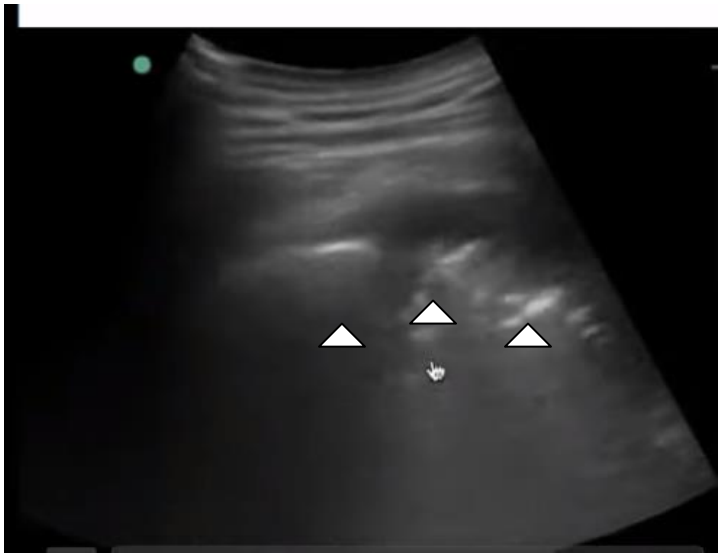
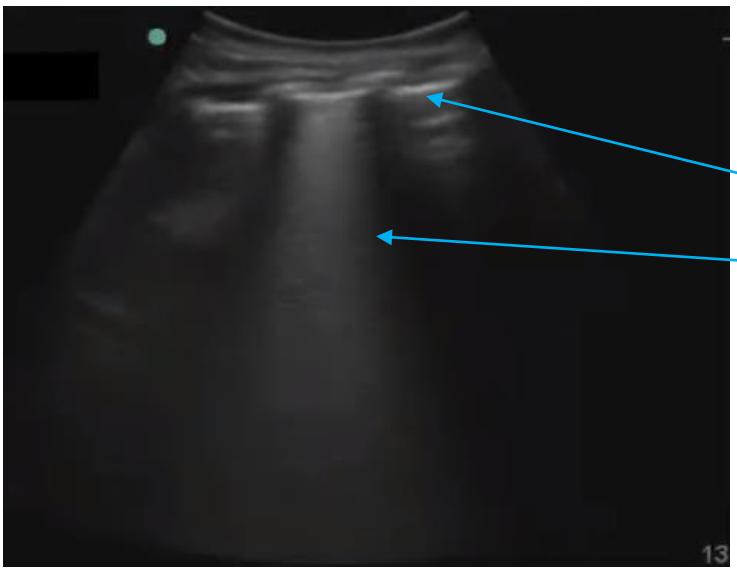
B-lines may obliterate A-lines. Re-appearance of A-lines seen in recovery patients.

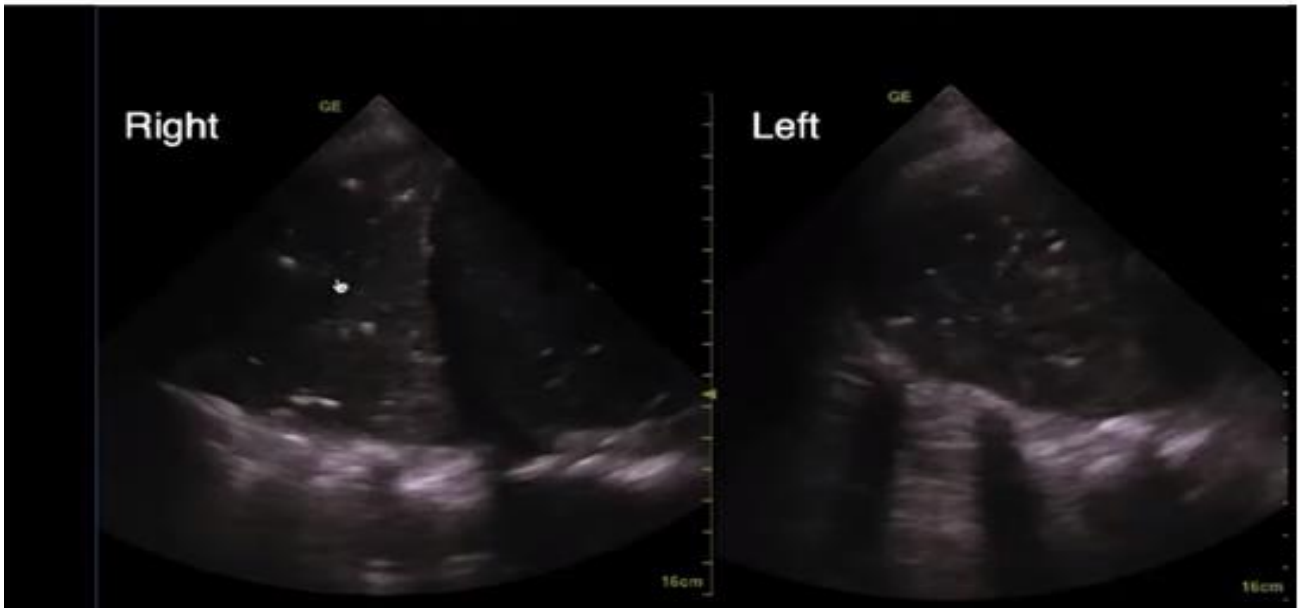


Sub pleural consolidation
Increased density in B Lines

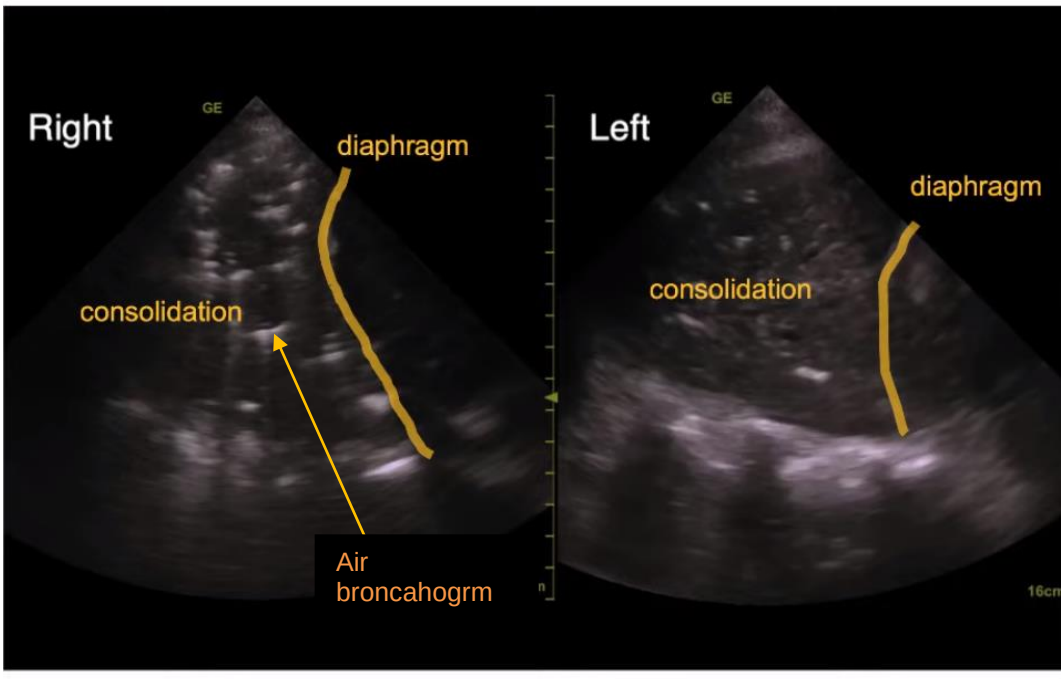


Irregular pleural line

Patchy B Lines



More severe disease resulting in a large area of consolidation



It may be possible to see the spine continuing into the chest sue to the consolidation. It is usually obscured due to air in the normal lungs

Summary

COVID-19 is a bilateral pneumonitis

Signs include

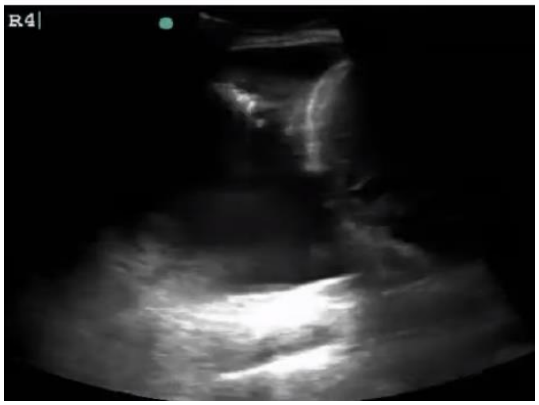
- Pleural thickening
- Focal, patchy B-lines
- Subpleural lesions
- Most often found in the lower posterior zone of the lung

Table 1 CT and ultrasonographic features of COVID-19 pneumonia

Lung CT	Lung ultrasound
Thickened pleura	Thickened pleural line
Ground glass shadow and effusion	B lines (multifocal, discrete, or confluent)
Pulmonary infiltrating shadow	Confluent B lines
Subpleural consolidation	Small (centomeric) consolidations)
Translobar consolidation	Both non-translobar and translobar consolidation
Pleural effusion is rare.	Pleural effusion is rare
More than two lobes affected	Multilobar distribution of abnormalities
Negative or atypical in lung CT images in the super-early stage, then diffuse scattered or ground glass shadow with the progress of the disease, further lung consolidation	Focal B lines is the main feature in the early stage and in mild infection; alveolar interstitial syndrome is the main feature in the progressive stage and in critically ill patients; A lines can be found in the convalescence; pleural line thickening with uneven B lines can be seen in patients with pulmonary fibrosis

Intensive Care Med. Mar 2020.[6]

Alternative Diagnoses



Important Note: Large pleural effusions have shown to be rare in COVID-19 patients

Empyema

There is emerging evidence to suggest that some patients, particularly in a younger age group demographic, are presenting with abdominal pelvic pain as the only symptom. It may possible with this group of patients to note whilst scanning the upper abdomen, the normal lung or otherwise.

Reporting

ALERT Imaging does NOT definitively diagnose COVID-19. It may define the extent of the disease or suggest and alternative/additional diagnosis.

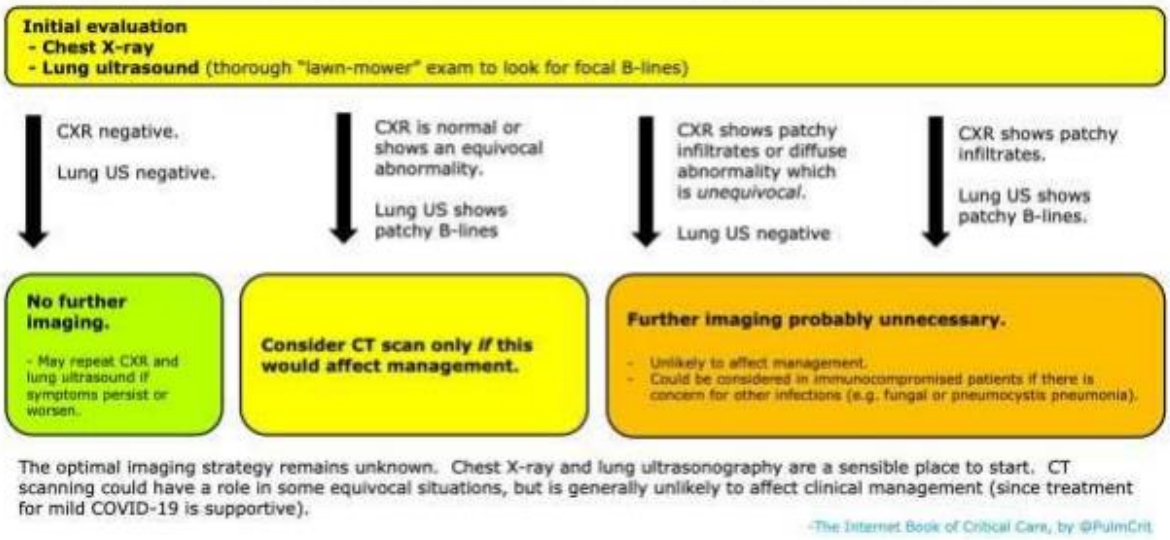
Report findings in a clear way. Bullet point reports may be useful.

Example Reports:

1) There is a unilateral large pleural effusion evident. Very rarely associated with COVID-19 patients

2) There is evidence of bilateral irregular pleural thickening, scattered b-lines and an absence of rib shadowing. These are ultrasound features which can be associated with COVID-19/ARDS/Pneumonitis

Possible schema for imaging in patients with respiratory symptoms and suspected COVID-19



The optimal imaging strategy remains unknown. Chest X-ray and lung ultrasonography are a sensible place to start. CT scanning could have a role in some equivocal situations, but is generally unlikely to affect clinical management (since treatment for mild COVID-19 is supportive).

-The Internet Book of Critical Care, by @PulmCrit

Further Reading & References

This document should not be used in isolation and therefore further reading is strongly advised.

You may need to familiarise yourself with the glossary of terminology in this document to understand the pathophysiology further with regard to pneumonitis etc.

The teaching tool which is the source documents of this guidance is :

https://www.youtube.com/watch?v=nx6eHINDveM&feature=emb_title

https://www.youtube.com/watch?v=8pw9Sxll68A&feature=youtu.be

https://www.ics.ac.uk/ICS/FUSIC/ICS/FUSIC/FUSIC_Accreditation.aspx?hkey=c88fa5cd-5c3f-4c22-b007-53e01a523ce8 – this document contains datasets to aid reporting and further standards on decontamination

Other online training resources include.

http://www.thepocusatlas.com/pulmonary

http://www.thepocusatlas.com/covid19

1. Quian-Yi P et al. Findings of lung ultrasonography of novel corona virus pneumonia during the 2019–2020 epidemic. Intensive Care Medicine. 2020. https://doi.org/10.1007/s00134-020-05996-6

2. WHO Interim Guidance. Clinical management of severe acute respiratory infection (SARI) when COVID-19 disease is suspected. March 2020.

3. Gargani L, Volpicelli G. How I do it: lung ultrasound. Cardiovasc Ultrasound. 2014;12:25. Published 2014 Jul 4. doi:10.1186/1476-7120-12-25. https://www.slideshare.net/ICNUploads/introduction-to-lung-ultrasound-35740844

4. Lichtenstein DA. Lung ultrasound in the critically ill. Ann Intensive Care. 2014;4(1):1. Published 2014 Jan 9. doi:10.1186/2110-5820-4-1

5. Husain LF, Hagopian L, Wayman D, Baker WE, Carmody KA. Sonographic diagnosis of pneumothorax. J Emerg Trauma Shock. 2012;5(1):76–81. doi:10.4103/0974-2700.93116

6. Arabi Y et al. COVID-19: a novel coronavirus and a novel challenge for critical care. Intensive Care Medicine 2020.

7. Millar A. Practical approach to lung ultrasound. BJA Education, Volume 16, Issue 2, February 2016, Pages 39–45. https://doi.org/10.1093/bjaceaccp/mkv012

8. Falcetta et al. The role of lung ultrasound in the diagnosis of interstitial lung disease. Shanghai Chest, 2 (5). 2018.

9. Huang, Y. et al A preliminary study in the Ultrasound Manifestations of Peripulmonary Lesion of Non-Critical Novel Coronavirus Pneumonia (COVID-19). SSTN. 2020

10. Mayo, P.H., Copetti, R., Feller-Kopman, D. *et al.* Thoracic ultrasonography: a narrative review. *Intensive Care Med* **45,** 1200–1211 (2019). https://doi.org/10.1007/s00134-019-05725-8

11. COVID-19 outbreak: less stethoscope, more ultrasoundhttps://doi.org/10.1016/S2213-2600(20)30120-X

Cross-Reference

Departmental COVID-19 decontamination procedures

Departmental COVID-19 PPE for suspected and confirmed cases

Departmental COVID-19 Donning and Doffing procedures for ITU/aerosol generated environment

Contributors and Acknowledgements:

Adrian Wong. Consultant Intensive Care Medicine and Anaesthesia. Kings College Hospital, London

Catherine Kirkpatrick. Consultant Sonographer United Lincolnshire Hospitals NHS Trust

Andrew Longmead. Advanced Practitioner Sonographer. Royal Chesterfield Hospital.

Heather Venables. Senior Lecturer ,Acting Assistant Discipline Lead (Diagnostic Imaging), University of Derby

Pamela Parker. Consultant Sonographer. Hull University Teaching Hospitals NHS Trust