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Ultrasound probe scratches the pleural surface: revealing the shades of COVID-19 (SARS-CoV-2) pneumonia

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SUMMARY

We present a case of a patient diagnosed with COVID-19 pneumonia and illustrate the changes observed using thoracic ultrasound alongside disease evolution. The case renders how COVID-19 pneumonia can sonographically correlate with chest radiograph findings and links with the oxygen requirement during different clinical stages of illness. We compare these images as the patient escalates through mild disease on low flow oxygen therapy, moderate disease on high flow oxygen therapy and severe disease requiring mechanical ventilation in the Intensive Care Unit. We then reveal further imaging showing recovery of the disease process. We recommend utilising thoracic ultrasound as it provides clinical effectiveness, ensures patient, staff and equipment safety (in the much-needed personal protective equipment environment) without exposure to radiation. This case report invites clinicians and researchers to share their thoracic ultrasound experience during the COVID-19 pandemic with a wider audience. We hope our observations will increase awareness and give credibility to thoracic ultrasound in future aspects of disease management.

BACKGROUND

The COVID-19 (SARS-CoV-2) pandemic is a challenge of unprecedented proportions and remains a concern despite months of devastation. Its entire impact remains uncertain. This virus affects multiple organs of the body; however, lung involvement determines major morbidity and mortality. SARS-CoV-2 is enigmatic due to its unmeasurable virulence, unpredictable course and lack of definitive treatment. Patients may endure a turbulent clinical journey, face uncertainty and prolonged hospitalisation. Management depends on sound clinical suspicion, prompt diagnosis, dedicated patient-care areas, risk assessment and establishing ceilings of care. Such plans heavily rely on the availability of prompt swab results which may not be feasible. Hence, an efficient clinical correlation of suspicious cases with radiological findings is paramount.¹

COVID-19 pneumonia can exist with initially indiscernible radiographic findings which may later evolve. Chest X-ray and CT scans are the most frequently used imaging modalities as the turbulent nature of COVID-19 pneumonia can lead to rapid radiological changes. Various renowned radiology societies have formulated guidelines and protocols ensuring the best possible imaging to diagnose,

monitor and evaluate COVID-19 pneumonia. When a patient with COVID-19 pneumonia deteriorates, updated imaging is required immediately. The ultimate choice depends on available resources, infection control protocols, personal protective equipment (PPE), logistics and local protocols. Thoracic ultrasound is a cutting-edge modality with advantages of being readily available, ambulatory, economical, reliable and user-friendly.² It can be accessed safely within the intensive care setting and provides dynamic, real-time imaging which can be readily reproduced.³

CASE PRESENTATION

A 58-year-old man was admitted to hospital via the emergency department in April 2020 with exertional dyspnoea and cough for 24 hours. He described myalgia and intermittent fevers for a week. His medical history comprised gastro-oesophageal reflux disease and haemorrhoids. He lived at home, never smoked and led an active lifestyle. On arrival to the emergency department, his oxygen saturations were noted to be 85% on room air, his respiratory rate 19 breaths/min, pulse 97 beats/min, blood pressure 120/71 mmHg and temperature 37.8°C. On examination, bilateral chest crackles were auscultated and initial arterial blood gas showed a PaO₂ of 5.9 kPa. Supplementary oxygen of 3 L/min improved his saturations to 95%. White cell count of 2.1×10⁹/L, lymphocytes 1.0×10⁹/L and serum C-reactive protein 61 mg/L were noted on his blood work. Initial thoracic ultrasound displayed patchy pleural thickening and roughening. Increased number of B-lines and relative preserved A-lines were seen (figure 1A–D). Chest X-ray (figure 1E) showed bilateral, predominantly left-sided basal air space shadowing. Nasopharyngeal swabs confirmed COVID-19 (SARS-CoV-2) pneumonia. The patient was admitted into a dedicated COVID-19 cohort ward. Antibiotics were prescribed for a potential community acquired bacterial pneumonia.

Over the next 48 hours, his oxygen requirements increased. High flow nasal oxygen (HFNO) therapy delivering 60% oxygen at 60 L/min was commenced. Enhanced pleural notching, raggedness and swelling was evident on repeat ultrasound. The B-lines augmented in frequency, density, intensity and diversity. The C-lines emerged with sub-pleural micro-consolidations (figure 2A–F). Chest X-ray at this time exhibited new dense patchy changes in the middle/lower zones (figure 2G).



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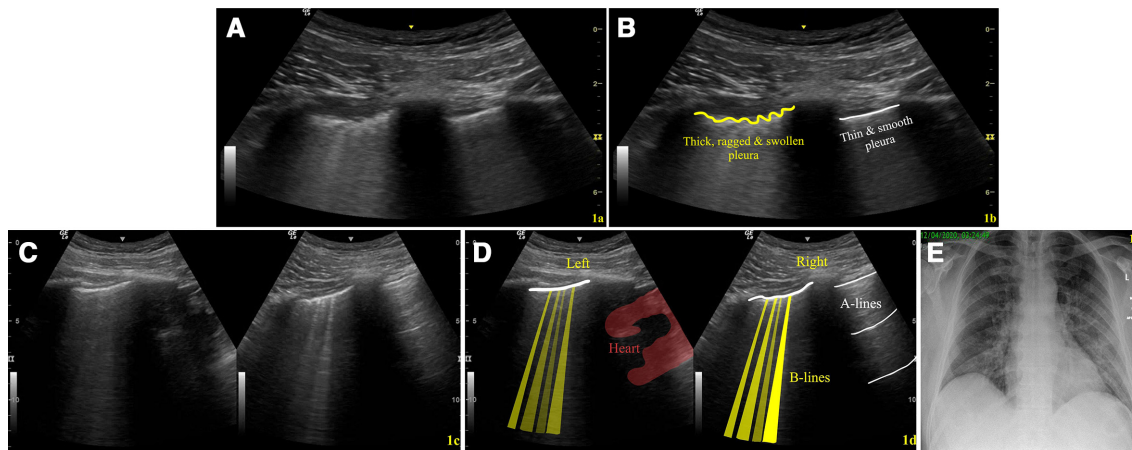


Figure 1 (A) Thoracic ultrasound showing pleural involvement on the left, sparing on the right. (B) Thoracic ultrasound showing pleural involvement on the left, sparing on the right (with graphical overlay). (C) Thoracic ultrasound showing bilateral geographical pleural lesions, B-lines and A-lines. (D) Thoracic ultrasound showing bilateral geographical pleural lesions, B-lines and A-lines (with graphical overlay). (E) Chest X-ray showing predominantly left-sided patchy changes.

On the fourth day, he remained hypoxic despite maximum HFNO settings and developed tachypnoea. He was intubated and transferred to the Intensive Care Unit (ICU) for mechanical ventilation. Thoracic ultrasound unveiled predominantly condensed B-lines and a multitude of C-lines. The heterogeneous peripheral consolidations were visible with air bronchograms. Fluid bronchograms and overt pleural fluid were absent despite significant oedema. The visceral pleura separated haphazardly (shredded) from parietal pleura and crescendo oedema made it scrambled and unrecognisable (figure 3A–F). His chest X-ray manifested progressive bilateral reticular opacities particularly in the lingula and right middle zone (figure 3G).

OUTCOME AND FOLLOW-UP

The patient remained in ICU for 27 days where his ventilation was weaned as oxygen requirements improved. He was successfully extubated to HFNO and subsequently to nasal cannula on the 30th day of admission. Thoracic ultrasound showed a restoration of dominant A-lines and smoothing of pleural surface, with fewer B-lines and resolving consolidations (figure 4A–D). His chest X-ray at extubation revealed a decrease in the intensity of peripheral reticular shadowing described previously (figure 4E). The patient remained on the respiratory ward before

safe discharge home. On clinical review 6 weeks post discharge he remains well. He mentions ongoing shortness of breath on exertion which is gradually improving as he continues his community rehabilitation.

DISCUSSION

The normal lungs are encased in the pleural lining, which is sonographically visible as a bright shimmering line due to the lung sliding during inspiration and expiration. Under this pleural line, lungs remain obscure due to strong the pleural reflection of ultrasound waves which creates a ‘snow and fog’ appearance. The ultrasound waves generate artefacts in the form of A and B lines. In pneumonia, inflammation generates a fluid medium and the pleural surface produces exaggerated artefacts of various lines (A, B and C lines). In bacterial pneumonia, lungs are boggy (fluid filled) and induce fluid and air bronchograms, which are Doppler sensitive. As pneumonia worsens, the pneumonic fluid immerses lung and the ‘fluid colour’ sign becomes positive.⁴ However, in COVID-19 the radiological features are phenotypically diverse; distribution is geographical and patchy and lungs are not fluid immersive. Thoracic ultrasound is highly sensitive to visualise and delineate the multiple spectra of COVID-19 pneumonia.⁵

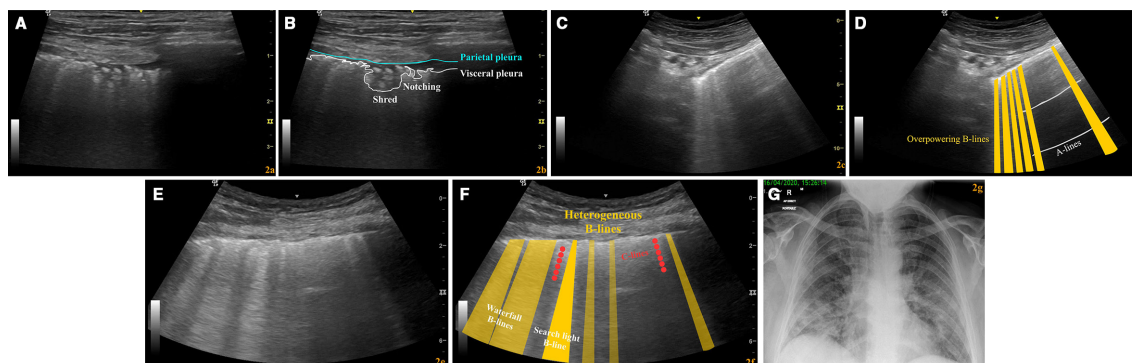


Figure 2 (A) Thoracic ultrasound showing extensive pleural notching and pleural shred. (B) Thoracic ultrasound showing extensive pleural notching and pleural shred (with graphical overlay). (C) Thoracic ultrasound showing coarse, diverse B-lines overpowering A-lines. (D) Thoracic ultrasound showing coarse, diverse B-lines overpowering A-lines (with graphical overlay). (E) Thoracic ultrasound showing coarse (search light sign), coalescent (waterfall sign) B-lines and few C-lines. (F) Thoracic ultrasound showing coarse (search light sign), coalescent (waterfall sign) B-lines and few C-lines (with graphical overlay). (G) Chest X-ray showing bilateral, basal and enhanced patchy lesions.

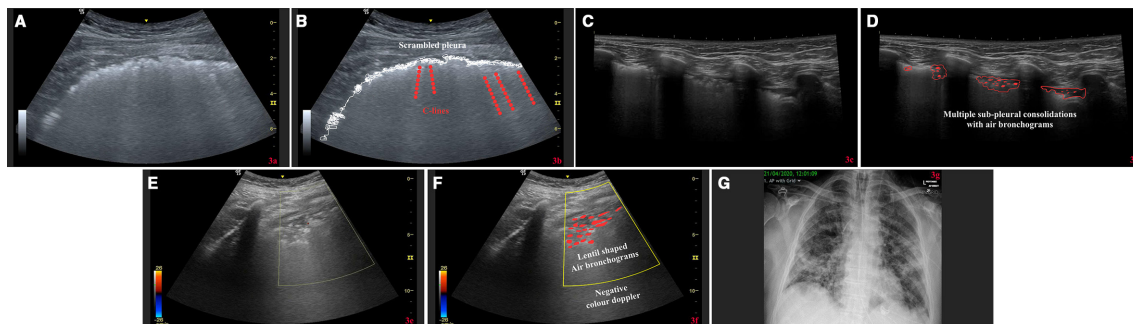


Figure 3 (A) Thoracic ultrasound showing loss of pleural integrity (scrambled pleura) and C-lines. (B) Thoracic ultrasound showing loss of pleural integrity (scrambled pleura) and C-lines (with graphical overlay). (C) Thoracic ultrasound showing multiple consolidations and air bronchograms. (D) Thoracic ultrasound showing multiple consolidations and air bronchograms (with graphical overlay). (E) Thoracic ultrasound showing air bronchograms and negative doppler activity (negative fluid colour sign). (F) Thoracic ultrasound showing air bronchograms and negative doppler activity (negative fluid colour sign) (with graphical overlay). (G) Chest X-ray showing bilateral, peripheral consolidations.

A series of thoracic ultrasounds performed during the clinical course of this patient captured the various patterns of COVID-19 pneumonia.

Early/mild COVID-19 pneumonia

On admission, early thoracic ultrasound (figure 1A–D) visualises sparing of some pleural surfaces (skipped pleura) which are thin and smooth, but some patchy areas of irregular, thick and swollen pleura are seen emitting B-lines (hyperechoic vertical lines extending the full length of the ultrasound image). A-lines (normal horizontal lines) persist, but the number of B-lines (normally less than three per intercostal space) begins to surpass them. The preservation of A-lines denotes that lung involvement is mild, and aeration is not fully compromised. This is reflected by the non-specific changes on the chest X-ray (figure 1E) and low flow oxygen requirement.

Progressing/moderate COVID-19 pneumonia

Within 48 hours, the patient's condition deteriorated and oxygen requirements progressed to HFNO. Thoracic ultrasound revealed bilateral, predominantly peripheral lung changes. Extensive pleural raggedness, notching and oedema were evident. The visceral and parietal pleural separation created shredded areas ('shred sign') (figure 2A,B). The numerous, dense,

course, intense and diverse B-lines emerged from the pleural surface overpowering the obliterated A-lines (figure 2C,D). The condensed B-line emissions created a panorama of waterfall ('waterfall sign') and eclipse of focal B-lines emerges as search lights ('search light sign') on the sliding pleural surface. Smaller vertical C-lines seemed to emerge (not reaching the full length of ultrasound image), indicative of early micro-consolidations (figure 2E,F). These changes demonstrated disease progression and compromised aeration requiring high flow oxygenation. This was also evident on chest X-ray which showed pronounced changes had emerged (figure 2G).

Critical/severe COVID-19 pneumonia

During this stage of COVID-19, the lung injury was extensive and oxygen demand was critical, requiring intubation and mechanical ventilation. Thoracic ultrasound findings portrayed the pleural surface as the epicentre of complete storm. Pleural integrity was lost at various areas of lung surface and the 'scrambled pleura sign' was seen due to severe oedema (figure 3A,B). Prominent C-lines and sub-pleural consolidations were visible containing air-bronchograms, but no fluid-bronchograms (figure 3C,D). Doppler activity in these consolidations was absent, hence the negative 'fluid colour sign' was noted (figure 3E,F). The chest X-ray (figure 3G) illustrated complete lung devastation.

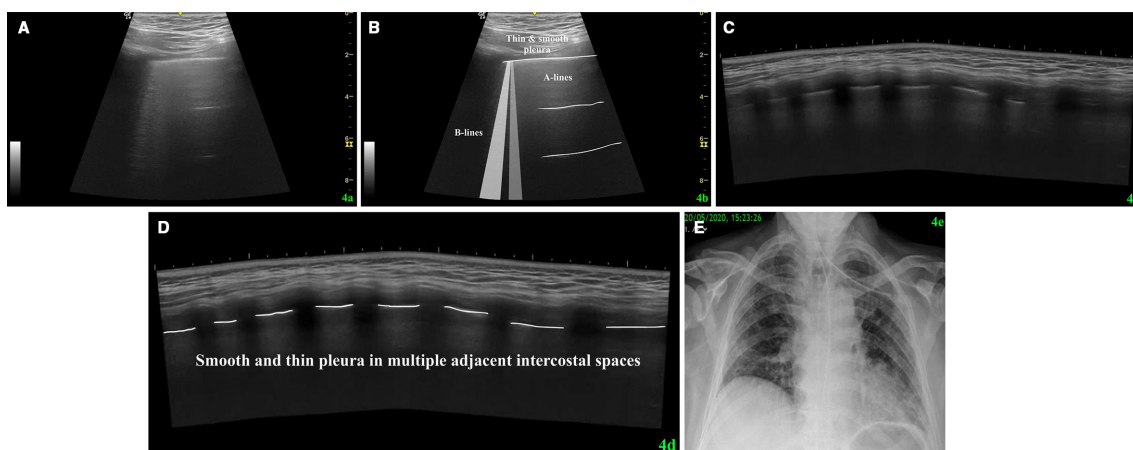


Figure 4 (A) Thoracic ultrasound showing smooth pleura alongside re-emergence of A-lines and occasional B-lines. (B) Thoracic ultrasound showing smooth pleura alongside re-emergence of A-lines and occasional B-lines (with graphical overlay). (C) Thoracic ultrasound showing panoramic view of smooth and thin pleural surface globally. (D) Thoracic ultrasound showing panoramic view of smooth and thin pleural surface globally (with graphical overlay). (E) Chest X-ray showing bilateral, resolving air-space shadowing.

Recovery of COVID-19 pneumonia

As the patients' clinical condition settled, thoracic ultrasound images showed thin, smooth pleura with mostly A-lines alongside occasional B-lines visible (figure 4A–D). Oxygen demand decreased, chest X-ray (figure 4E) demonstrated improvement and ultimately the patient was successfully discharged home with ongoing community care and follow-up.

This case is one of many chosen by our team to share our positive experience which led to adoption of ultrasound use during the influx of patients with COVID-19 pneumonia within our hospital. The case strongly suggests that supplementary oxygen, being the mainstay of treatment for COVID-19 pneumonia, is better prioritised and titrated based on changes in thoracic ultrasound findings and hence the decision making process can be aided. Although sonographic findings are merely artefacts which may not pinpoint the definite diagnosis⁶, in the clinical context of COVID-19 illness, these sonographic artefacts can direct a clinician towards aetiology and favour COVID-19 pneumonia from the wider spectra of diagnostic possibilities.⁷ Given the time constraints and possible increased risk of cross contamination to the operator, we would discourage performing daily thoracic ultrasound on every patient in ICU. This case demonstrates that thoracic ultrasound is warranted as the clinical status of the patient with COVID-19 pneumonia changes. Disease progression and analysis, radiological comparison, patient comfort and avoiding transfer to the radiology department for chest X-ray and CT imaging are the major factors advocating bedside thoracic ultrasound use in COVID-19 pneumonia. Thoracic ultrasound is an ever-evolving technology which requires training and

competencies; currently trainees within acute, intensive care and respiratory medicine are required to achieve level-1 ultrasound as per their relevant Royal Colleges. Many centres adhere to the Point-Of-Care UltraSound (POCUS) and Bedside Lung Ultrasound in Emergency (BLUE) protocols for ultrasound use for pneumonia and Acute Respiratory Distress Syndrome (ARDS).⁸ Although experience and skill are paramount, we encourage readers to consider adapting thoracic ultrasound use during this pandemic, incorporating their exiting knowledge to aid management of patients with COVID-19 pneumonia.

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Learning points

- ▶ This case illustrates how thoracic ultrasound decodes various phases of disease evolution and helps to recognise different levels of COVID-19 pneumonia severity.
- ▶ The usability, cost effectiveness, versatility and ergonomics denote ultrasound technology as a premier choice of chest imaging aiding in the management of COVID-19 pneumonia.
- ▶ Thoracic ultrasound can be considered a go-to radiological modality as it displays real-time dynamic findings alongside clinical changes such as tachypnoea.
- ▶ We hope our observations will increase awareness and give credibility to thoracic ultrasound in future aspects of disease monitoring, prognostication and management.

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