Article published online: 2023-01-06

Lung Ultrasound: A Complementary Imaging Tool for Chest X-Ray in the Evaluation of Dyspnea

Aparna Murali[1] Anjali Prakash[1] Rashmi Dixit[1] Monica Juneja[2] Naresh Kumar[3] Prerna Padaliya[1]

[1] Department of Radiodiagnosis, Maulana Azad Medical College & Lok Nayak Hospital, New Delhi, India
[2] Department of Pediatrics, Maulana Azad Medical College & Lok Nayak Hospital, New Delhi, India
[3] Department of Pulmonary Medicine, Maulana Azad Medical College & Lok Nayak Hospital, New Delhi, India

Address for correspondence Aparna Murali, MD, Department of Radiodiagnosis, Maulana Azad Medical College & Lok Nayak Hospital, New Delhi, India (e-mail: aparnamurali31@gmail.com).

Indian J Radiol Imaging 2023;33:162–172.

Abstract

The present study was designed to evaluate the spectrum of imaging findings seen on chest ultrasonography in patients presenting with dyspnea and verify the concordance between chest X-ray and chest ultrasound.

Methods Fifty-three patients presenting with dyspnea were included in this study. Patients with known/suspected cardiac disease were excluded from the study. All patients underwent chest X-ray and chest ultrasound, reported by two different investigators. The concordance was analyzed using Cohen's kappa value with a '*p*-value' less than 0.05 considered statistically significant.

Results Among the fifty-three patients with dyspnea, five diagnostic pathologies were evaluated. Concordance between lung ultrasound and chest X-ray for diagnosis of pneumonia, pneumothorax, acute exacerbation of COPD/severe asthma, and diffuse alveolar interstitial syndrome was found to be high with Cohen's kappa value > 0.8 ($p < 0.01$). Ultrasound was able to correctly diagnose more cases of pneumothorax and pulmonary edema compared with chest X-ray with sensitivity and negative predictive value of 100%. Chest X-ray was found to be superior in correctly diagnosing COPD. The difference was, however, not statistically significant. Similarly, no statistically significant difference could be inferred between the diagnostic value of ultrasound and Chest X-ray in the diagnosis of pneumonia or pleural effusion.

Conclusions A high concordance was noted between ultrasound and chest X-ray for diagnosis of all pathologies studied ($p < 0.01$), the highest noted in pneumonia/pleural effusion and diffuse interstitial syndrome ($\kappa = 0.9$). Hence, ultrasound may be considered a complimentary imaging modality for Chest-X-ray in the evaluation of dyspnea.

Keywords
- A-lines
- B-lines
- dyspnea
- lung ultrasound

Introduction

Dyspnea is one of the most common presenting symptoms encountered in hospital admissions, with chest X-ray being the first-line radiological investigation ordered for its assessment. However, this modality has its limitations in the form of exposure to ionizing radiation and decreased sensitivity for certain findings in supine position. Although CT scan is

article published online
January 6, 2023

DOI https://doi.org/10.1055/s-0042-1759850.
ISSN 0971-3026.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

the gold standard and offers the definitive diagnosis in cases of clinical dilemma, high cost and unavailability in resource-poor settings apart from exposure to ionizing radiation hinder its feasibility in all cases.

Traditionally, the role of chest ultrasound was limited to the diagnosis of pleural effusion and guiding interventions such as thoracocentesis. Its major drawback was poor penetration of the ultrasound beam due to the overlying thoracic cage and air content within the lung which led to artifacts.

Lichtenstein, a medical intensivist, utilized these artifacts to propose the BLUE–protocol[1] (bedside lung ultrasound examination), which provides a standardized technique for performing and interpreting lung ultrasound in critically ill patients.

In recent years, lung ultrasound has gained popularity, particularly in the emergency and critical care units where it is used as PoCUS (point-of-care-ultrasound) and has become an indispensable tool to the intensivist.

Methodology

Ours was a cross-sectional study, conducted over a duration of 1 year in the Department of Radiodiagnosis, Maulana Azad Medical College and associated Lok Nayak Hospital and GIPMER, New Delhi. The study population comprised 53 patients of either sex, presenting with a complaint of dyspnea. All patients with a clinical history suggestive of acute coronary syndrome as a cause of dyspnea, patients on invasive ventilatory support, or with suspected/known metabolic causes of dyspnea were excluded from the study.

Ethical clearance was obtained from the Institutional Ethics Committee. Written informed consent/assent was documented from each patient.

Relevant history, clinical examination, and laboratory findings were recorded. All patients underwent chest-X-ray and chest ultrasound. Each modality was interpretated by two different investigators, blinded to each other. The ultrasound examinations were performed and interpreted by the first author, who had been trained by a senior resident with nearly 6 years of experience in ultrasound. The images were reviewed by a consultant with more than 15 years of experience in ultrasound.

Ultrasound was performed on an ACUSON S2000 ultrasound system (Siemens Healthineers) using 4C1-curved array ultrasound transducer (1–4 MHz). 9L4-linear array ultrasound transducer (4–9 MHz) was used in appropriate cases. Philips HD-11 ultrasound system (Philips Healthcare) with C5–2 curved array ultrasound transducer (2–5MHz) and/or L12–5 linear array ultrasound transducer (5–12 MHz) were used in a few patients of pneumothorax and pulmonary edema presenting to the emergency. We followed the 14 zone-focused thoracic ultrasound protocol by Laursen et al (►Fig. 1).

Longitudinal scans of the anterior and lateral chest wall were performed with the patient in the supine or semi-recumbent position. This was followed by an examination of the posterior chest wall with patient in the sitting position,

CASE PROFORMA

1. **PATIENT DETAILS**

NAME: **AGE/SEX:** **CR NUMBER:**

UNIT:

PRESENTING COMPLAINTS:

EXAMINATION FINDINGS:

ABG FINDINGS: **PFT/ECHO FINDINGS:**

ECG FINDINGS:

2. **CHEST ULTRASOUND FINDINGS**

FINDING	ZONE (R1-R7)	ZONE (L1-L7)
1.BAT-WING SIGN		
2.PLEURAL LINE:		
REGULAR/IRREGULAR		
3.LUNG SLIDING		
4.M-MODE:		
SEA-SHORE SIGN/ SINUSOIDAL SIGN / STRATOSPHERE SIGN		
5.A-LINES		
6.B-LINES:		
i. LUNG ROCKET PATTERN		
ii. DIFFUSE INTERSTITIAL SYNDROME		
iii. SEPTAL ROCKET PATTERN		
iv. GROUND GLASS ROCKET PATTERN		
7.PLEURAL EFFUSION:		
i. LUNG LINE		
ii. QUAD SIGN		
iii. SEPTATIONS		
iv. INTERNAL ECHOES		
v. SHRED SIGN		
vi. SUB-B LINES		
8. CONSOLIDATION:		
i. FRACTAL SIGN		
ii. C-LINE		
iii. LUNG SIGN		
iv. AIR-BRONCHOGRAMS		

3. LUNG ULTRASOUND PROFILE:

4. DIAGNOSIS ON ULTRASOUND:

5. CHEST X- RAY FINDINGS:

6. DIAGNOSIS ON CHEST-RAY:

7. FINAL DIAGNOSIS:

8. CHEST X-RAY AND ULTRASOUND FINDINGS ARE:

CONCORDANT/DISCORDANT

Fig. 1 Case proforma adopted.

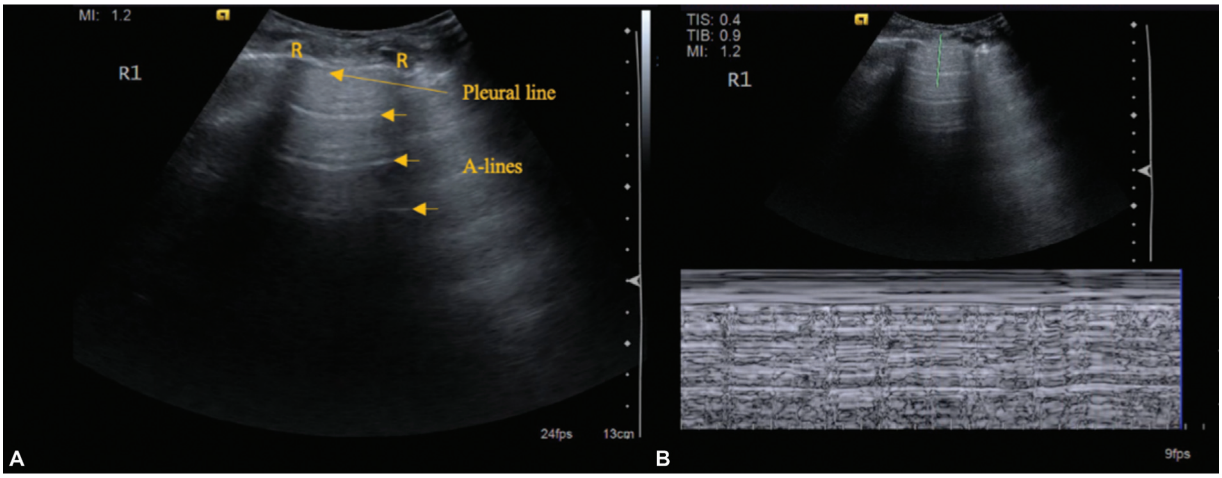

Fig. 2 (A) Longitudinal ultrasound scan of the anterior chest wall depicting the 'Bat sign': Two ribs (R) with posterior acoustic shadowing (wings of the bat), and the hyperechoic pleural line (body of the bat). A-lines can be seen parallel to the pleural line. (B) M-mode at the same location demonstrating the 'SEASHORE SIGN'- The motionless chest above the pleural line results in the horizontal 'waves,' and the lung sliding below the pleural line generates the 'sand,' seen as a granular pattern.

depending on the clinical status of the patient. The lung-chest wall interface showing the pleural line and various artifacts were imaged in all cases on gray scale ultrasound and the findings were analyzed for the following features.

- Rib shadows and underlying pleural line for the "Bat-wing" appearance, and A-lines (►**Fig. 2A**).
- Lung sliding on B and M modes (►**Fig. 2B**).
- B-Lines: location, laterality, pattern based on number of B-lines (►**Fig. 3**).
- Collections: lung line, quad sign, septations, internal echoes, shred sign, sub-B-lines (►**Fig. 4**).
- Consolidation: fractal sign, C-line, lung sign, sonographic air–bronchograms.

A diagnosis was made based on the ultrasound findings for the cause of dyspnea, and appropriate lung profile as devised by the BLUE Protocol was assigned. Chest ultrasound findings were correlated with chest X-ray findings, and concordance was checked. Due to ethical considerations, CT scans could not be used as a reference standard. Final diagnosis at the time of discharge was considered the gold standard for patients with no previous CT scans. However, in patients who had undergone a CT scan, findings were recorded in cases of discordance.

Statistical Analysis

The obtained data were entered in the MS-Excel and analyzed using the SPSS version 25.0. Qualitative data were

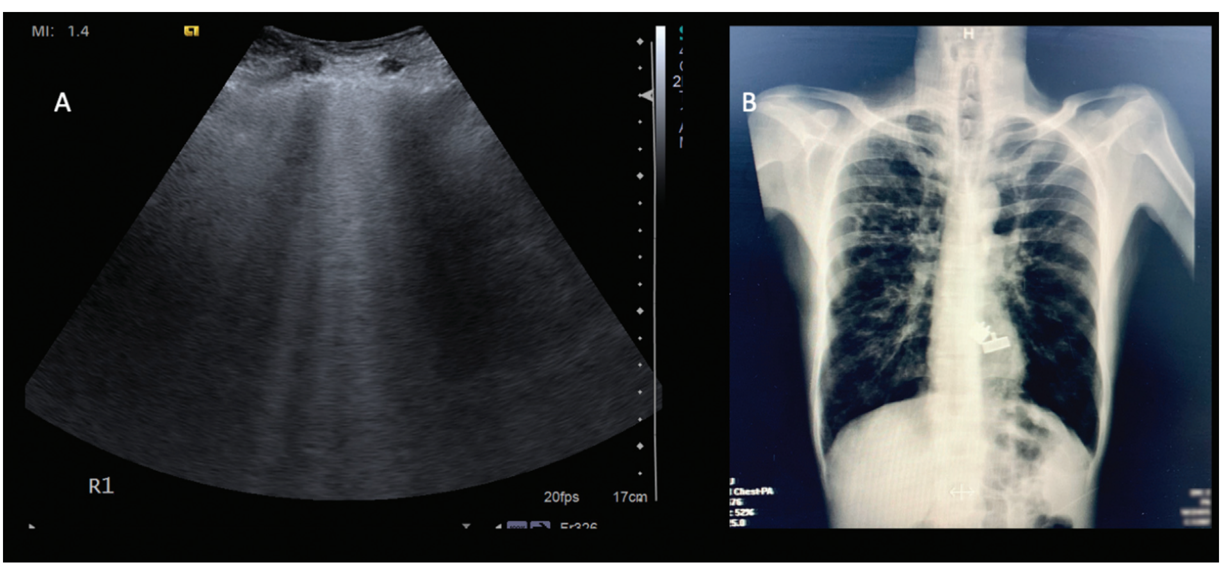

Fig. 3 (A): Longitudinal gray-scale ultrasound scan of the right anterior chest along the midclavicular line, in the second intercostal space, in an elderly male patient presenting with dyspnea and cough revealed unilateral lung rocket pattern. Although the patient was afebrile, the pattern of unilateral lung rockets prompted a diagnosis of consolidation. However, chest X-ray (B) revealed fibronodular opacities in right upper zone. Bilateral lung fields were hyperinflated as well. The final clinical diagnosis at the time of discharge was acute exacerbation of COPD in a patient with old Koch's.

Fig. 4 (A) 'QUAD' SIGN, a sonographic sign of pleural effusion, visualized as a rough quadrilateral framing the effusion (star) bounded by pleural line superiorly(arrowhead), the lung line inferiorly and the two ribs (R) with their posterior acoustic shadow on either side. (B) 'Sub-B lines' (arrow heads) seen arising from the lung line/visceral pleural line, deep to the pleural effusion indicating the underlying lung to be aerated. (C) 'Tissue like' echotexture of the underlying lung beneath the visceral pleural line showing multiple sonographic bronchograms and a shredded deep border known as 'SHRED SIGN/FRACTAL SIGN' representing pleural effusion with underlying lung consolidation.

expressed in percentage and statistical difference between the proportions were tested by chi-square test or Fischer's exact test. Sensitivity, specificity, positive predictive value, and negative predictive value of chest X-ray and chest ultrasound were calculated for different pathologies. The concordance between chest ultrasound and chest X-ray findings was analyzed using Cohen's kappa value with '*p*' value less than 0.05 considered statistically significant.

Results

The study consisted of 53 patients presenting with dyspnea, with ages of the patients ranging from 6 months to 65 years. The maximum number of patients (22.6%) were in the age group of 11 to 20 years.

A total of five pathologies were evaluated-

Lung consolidation (with/without pleural effusion) constituted the largest group of pathologies (►**Table 1**). We studied four patterns of consolidation,[1] the most common being non-translobar consolidation seen in 82.7% of cases, identified by "Fractal sign/shred sign." Translobar consolidation was identified by the "Lung sign." Seven patients with "Unilateral lung rockets" were also diagnosed with pneumonia.

Pleural effusion (►**Table 2**) was found in patients with pneumonia, pulmonary edema and hydropneumothorax in the study. Visualization of the "Lung line"[2] identified the presence of pleural effusion. Internal septations and internal echoes were used to help characterize the collection as an empyema. The status of the underlying lung was defined as consolidated/non-aerated on the basis of presence of the "Fractal sign"(►**Fig. 4C**) and "Sub-B lines" (►**Fig. 4B**).

Pneumothorax/hydropneumothorax Nine patients in our study showed "absent lung sliding" with "A-line" sign (A profile) and were diagnosed with pneumothorax. The "Lung Point"[3] sign was seen in 77.7% of cases and showed a high specificity of 97.8%. Additionally, this sign helped in determining the size of the pneumothorax, with the findings being correlated on chest X-ray.

Our study included five patients of acute exacerbation of COPD/severe asthma diagnosed on ultrasound on the basis of "A-no V-no PLAPS profile," defined by the presence of A-lines and maintained lung sliding after ruling out PLAPS (posterolateral alveolar/pleural syndrome) and DVT (deep venous thrombosis). Hence, all five cases diagnosed as COPD/asthma showed lung sliding with seashore sign on the M-mode. Although B-lines were present in two patients, they were less than three in number and thus considered insignificant.

Table 1 Chest ultrasound features in patients with consolidation ($n = 29$)

Imaging findings	Diagnostic categories showing consolidation			
	Consolidation with pleural effusion ($n = 17$)	Consolidation only ($n = 9$)	Hydropneumothorax/ Pneumothorax ($n = 3$)	Total
'Fractal sign'	14	7	3	24
'Lung sign'	4	2	1	7
C-line	1	3	0	4
Air bronchogram	17	6	3	26
Effusion	17	0	3	20
Unilateral lung rocket	4	3	0	7
Irregular/thickened pleural line	2	6	1	9

Table 2 Chest ultrasound features in patients with Pleural effusion ($n = 29$)

Imaging finding	Diagnostic categories showing pleural effusion				
	Pleural effusion only ($n = 5$)	Consolidation with associated pleural effusion ($n = 17$)	Pulmonary edema ($n = 4$)	Hydro-pneumothorax ($n = 3$)	Total
Lung line	5	17	4	3	29
Sinusoidal sign	4	16	4	3	27
Quad sign	5	15	2	3	25
Septations	2	5	0	0	7
Internal echoes	2	11	0	0	13
Shred/Fractal sign	0	16	0	3	19
Sub B-Lines	5	11	2	0	18

Our study included eight cases of diffuse interstitial syndrome. Five cases presented with acute dyspnea with the absence of irregular pleural line or subpleural consolidations and were diagnosed as pulmonary edema, corresponding to the B profile of the BLUE-protocol. On the contrary, the three cases that presented with chronic dyspnea showed an irregular pleural line with subpleural consolidation and were diagnosed as interstitial lung disease (ILD).

Out of 53 cases included in our study, 47 cases showed concordant diagnosis (►**Tables 3** and **4**) on ultrasound and chest X-ray (88.6%). Our study revealed a high concordance between ultrasound and chest X-ray ($p < 0.01$) for diagnosis of all the pathologies studied (►**Table 5**).

The present study was undertaken to evaluate the imaging features of patients presenting with dyspnea on ultrasound. The principles of the BLUE-protocol[2] were applied to assist in arriving at a diagnosis.

Table 3 Concordance of USG pathology with chest X-ray findings ($n = 53$)

	No.	%
Concordance present	47	88.6
Concordance absent	6	11.3

Table 4 Concordance of individual diagnoses on USG with chest X-ray findings ($n = 53$)

Pathology	Concordance	Discordance
Pneumonia/pleural effusion	28	2
Pneumothorax/ hydropneumothorax	7	2
Interstitial lung disease (ILD)	3	0
Pulmonary edema	4	1
Acute exacerbation of COPD/asthma	5	0
Pulmonary infarct	0	1

Lung Consolidation

In the BLUE-protocol[2], "pneumonia" refers to anterior consolidation. PLAPS refers to consolidation and/or pleural effusion in posterolateral lung zones.

We utilized the following patterns of consolidation[3,4] to diagnose pneumonia

1. "Non-translobar consolidation"–Visualized as an area of tissue-like appearance or echotexture with a shredded deep border, also known as "Fractal sign/shred sign."
2. "Translobar consolidation" –characterized by absence of the "Fractal sign" with the entire consolidated lobe showing a "tissue-like" echotexture, also known as "hepatization"/"Lung sign."
3. "C-line" –represents a small subpleural consolidation and has an irregular, dotted and curvilinear appearance.
4. "Unilateral lung rocket" pattern–Three B-lines between two ribs refers to a pattern called, "Lung rocket." When unilateral, this pattern can be helpful in diagnosing pneumonia. The associated finding of irregular pleural line may also be noted.

Table 5 Concordance of individual diagnoses on USG and chest X-ray with Cohen's kappa value ($n = 53$)

Pathology	Positive diagnosis		Kappa
	USG	Chest X-ray	
Pneumonia/pleural effusion	30	28	0.9
Pneumonia only	8	6	0.83
Pneumothorax/ hydropneumothorax	9	7	0.85
Diffuse interstitial syndrome	8	7	0.92
Acute exacerbation of COPD/Asthma	5	7	0.81
Pulmonary infarct	1	0	–

Note: $p < 0.01$ for all.

Table 6 Discordant cases on ultrasound and chest-X-ray ($n = 6$)

S.no	Ultrasound		Chest X-ray: findings and diagnosis	Final diagnosis
	Findings	Diagnosis		
1)	Lung sliding absent with A-line sign (A' profile) and Lung Point sign in left anterior zones	Pneumothorax	COPD changes with large bulla in left upper and mid zone	COPD
2)	Lung sliding absent with A-line sign (A' profile) and Lung Point sign on right side	Pneumothorax	Normal	Pneumothorax (CT – pneumothorax in right pleural cavity along costal, mediastinal and diaphragmatic pleura)
3)	Multiple B-lines seen diffusely in more than one scanning zone bilaterally	Pulmonary edema	Normal	Pulmonary edema (CT – ground glass opacities in bilateral upper lobes with fissural thickening)
4)	Wedge shaped hypoechoic areas with few air-bronchograms and absence of signal on color doppler seen, correlative history of upper limb DVT +	Pulmonary infarct	Consolidation, likely due to active infective etiology	Pulmonary infarct (CT- peripheral subpleural wedge shaped areas of consolidation with few showing air bronchograms in a known case of chronic pulmonary thromboembolism)
5)	Unilateral lung rocket pattern on right side (A/B profile)	Pneumonia	COPD changes with sequelae to old Tuberculous infection	COPD changes in a case of old treated Koch's
6)	Unilateral lung rocket pattern on left side (A/B profile)	Pneumonia	Sequelae to old Tuberculous infection	Old treated Koch's with URTI

5. Sonographic air bronchograms are useful for characterization of lung consolidation,[5] some of them showing a branching pattern and moving with respiration, described as "dynamic" air bronchograms.[6] This helps to differentiate pneumonia from resorptive atelectasis.

Concordance between lung ultrasound and chest X-ray for the diagnosis of pneumonia was found to be high with Cohen's kappa value (►**Table 5**) of 0.83 ($p < 0.01$). Zanobetti et al[7] reported a concordance of 0.70 ($p < 0.0001$) between lung ultrasound and chest X-ray for diagnosis of pneumonia.

In our study, two cases were diagnosed on ultrasound as pneumonia (A/B profile) due to presence of unilateral lung rockets (►**Fig. 3**, ►**Table 6**). However, chest X-ray findings with retrospective analysis of clinical details revealed a history of previously treated tuberculosis.). Both these cases revealed fibrotic and fibronodular opacities on chest X-ray in the zones corresponding to the B lines on USG.

Our study included one case of pulmonary infarct (►**Fig. 5**) in a 34-year-old male patient with history of chronic intravenous drug abuse. Chest X-ray was reported as consolidation, likely due to active infective etiology due to lack of adequate clinical details provided on the requisition form. However, when we performed chest ultrasound, careful history taking prompted a search for pulmonary infarction. Our findings were consistent with Mathis et al[8] with the infarcted region appearing as a subpleural, hypoechoic wedge-shaped area with no doppler signal. Previously performed upper limb venous doppler had also revealed thrombus in right brachial and axillary vein.

The present study showed that lung ultrasound (►**Table 7**) had a sensitivity of 100%, specificity of 94.8%, positive predictive value of 87.5%, and negative predictive value of 100% for diagnosis of pneumonia. This was concordant with Lichtenstein et al[3] who reported a sensitivity of 90% and a specificity of 98%, and Pagano et al[9] who reported a sensitivity of 98.5%, specificity of 64.9%, positive predictive value of 83.8%, and a negative predictive value of 96.0%.

Chest X-ray was found to have a sensitivity, specificity, positive predictive value, and negative predictive value of 100% (►**Table 8**). The difference could be attributed to the small sample size and the fact that dyspnea was considered as the mandatory inclusion criteria for patient selection in our study and febrile patients with no respiratory distress were excluded. Hence, there were no radiographically occult cases.

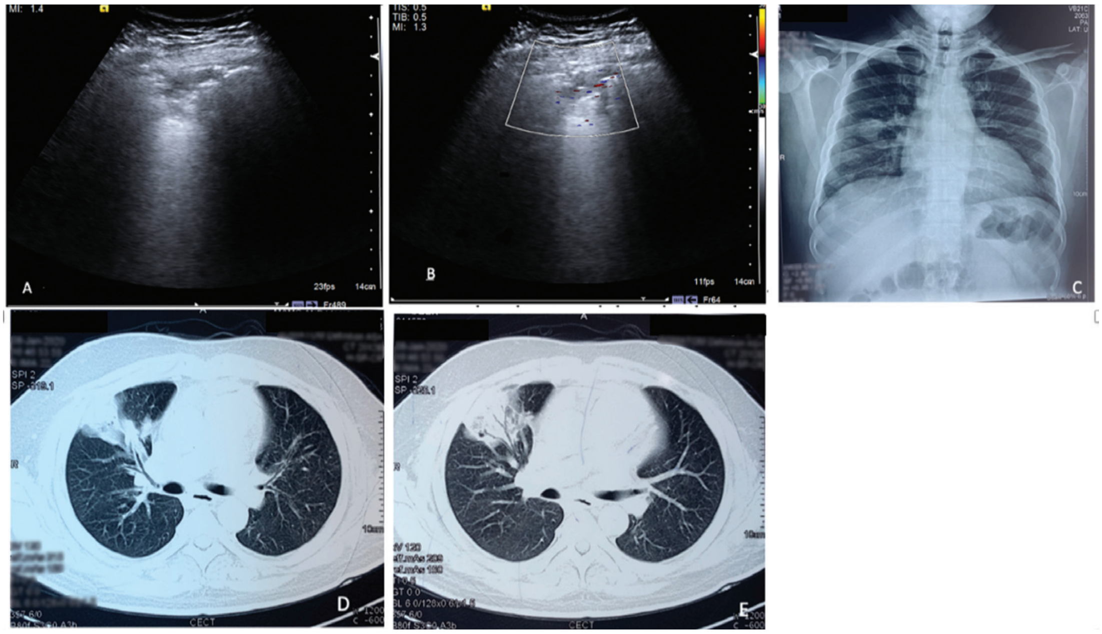

Fig. 5 (A and B): Longitudinal gray scale ultrasound scans in a 34-year-old chronic intravenous drug abuser revealed a wedge shaped area of 'tissue like' echotexture with shredded deeper margin in (A) anterior and (B) anterolateral chest wall. Color doppler showed reduced vascularity in the lesion. (C) Chest X-ray in the patient was reported as consolidation. The patient had history of chronic deep venous thrombosis in right axillary and brachial vein with subsequent pulmonary embolism in previous CT scans and was treated for the same before presenting to us. (D and E) CECT chest revealed subpleural wedge shaped areas of consolidation showing air bronchograms in right lung parenchyma, corresponding to the lung zones showing the consolidation on ultrasound. A diagnosis of pulmonary infarct was thus made.

Table 7 Comparison of Ultrasound and Chest-X Ray in ability to correctly diagnose the studied pathology

Pathology	Correctly diagnosed on USG	Correctly diagnosed on CXR	*p*-Value
Pneumothorax ($n = 8$)	8	7	0.99
Pulmonary edema ($n = 5$)	5	4	0.99
Pleural effusion/pneumonia ($n = 28$)	28	28	–
ILD($n = 3$)	3	3	–
Acute exacerbation of COPD/asthma ($n = 7$)	5	7	0.46
Pulmonary infarct ($n = 1$)	1	0	–
Old Koch's with URTI ($n = 1$)	0	1	–
Overall ($n = 53$)	50	50	–

Table 8 Diagnostic value of chest X-ray in different pathologies

Pathology	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
Pleural effusion with/without consolidation	100% (84.56–100)	100% (88.78–100)	100%	100%
Pneumonia	100% (76.84–100)	100% (90.97–100)	100%	100%
Pneumothorax/hydropneumothorax	87.5% (47.35–99.68)	100% (92.13–100)	100%	97.83% (87.80–99.65)
Diffuse interstitial syndrome	87.5% (47.3–99.6)	100.0% (92.1–100.0)	100.0%	97.8% (87.8–99.6)
Acute exacerbation of COPD/Asthma	100% (59.0–100)	100.0% (92.2–100)	100.0%	100%

Pleural Effusion

In the BLUE-protocol,[1] the following imaging findings have been described for diagnosis of pleural effusion –

1. "Lung line" –refers to the visceral pleural line, outlining the effusion. It is oriented almost parallel to the parietal pleura (pleural line), and is seen in all effusions.
2. "Quad sign" –refers to the appearance of the effusion when framed by the visceral line inferiorly, pleural line superiorly, and rib shadows on either side.
3. "Sinusoid sign" –refers to the tracing obtained on the M-mode, generated due to respiratory excursions of the lung.

In our study, the sensitivity and specificity for diagnosis of pleural effusion on ultrasound was 100% (►Table 7). This was in agreement with Lichtenstein et al[1,4] who reported a sensitivity of 93% and specificity of 97%.

Pneumothorax

In the BLUE-protocol pneumothorax is diagnosed by A' profile. This is constituted by-

1. " Absent Lung sliding"–Lung sliding is seen as a to-and-fro twinkling movement of the pleural line. Absent lung sliding is seen in case of pneumothorax, which may be confirmed by demonstrating the "Barcode" or "Stratosphere sign" on the M-mode. In the present study, absent lung sliding had a specificity of 77.7% when used as a sole criterion to diagnose pneumothorax.
2. "A-line sign" –This refers to the presence of anterior A-lines with absent B-lines.[10,11] This sign has a reported sensitivity and a negative predictive value of 100%, and a specificity of 60%.[4] The diagnostic accuracy is further improved on combining A-line sign and absent lung sliding.[4] This was concordant with our study, with the specificity rising to 97.8% on combining absent lung sliding with the "A-line sign"[4] at the site of abolished lung sliding.
3. "Lung point" sign[12]–This is the next sign which is sought for in a patient with suspected pneumothorax. In our study, a high specificity (97.8%) of the 'Lung point" sign was noted with a low sensitivity of 75%. This is in accordance with Lichtenstein et al,[4] who reported a 100% specificity with a relatively low sensitivity of 66% for this sign, stating that it is often absent in cases of large pneumothorax with total lung collapse.

The present study revealed a high concordance between ultrasound and chest X-ray for diagnosis of pneumothorax with Cohen's kappa value (►Table 5) of 0.89 ($p < 0.01$). This was in agreement with Zanobetti et al[13] who reported a concordance of 0.85.

Two cases were discordant on chest-X-ray (►Table 6) with one of the discordant cases identified as having a large bulla in the left upper zone in a patient of COPD (►Fig. 6). This was also described by Aziz et al[14] who published a case report on presence of "Lung point' sign in a case of COPD with large bullae. The other case (►Fig. 7) was found to have pneumothorax on CT, with chest X-ray being reported normal.

The overall sensitivity, specificity, positive predictive value, and negative predictive value of ultrasound for diagnosis of pneumothorax was found to be 100%, 97.7%, 88.8%, and 100%, respectively, on utilizing the various signs as described (►Table 9). However, sensitivity was only 87.5% on chest X-ray with a negative predictive value of 97.83% (►Table 8). The difference was not statistically significant (►Table 7).

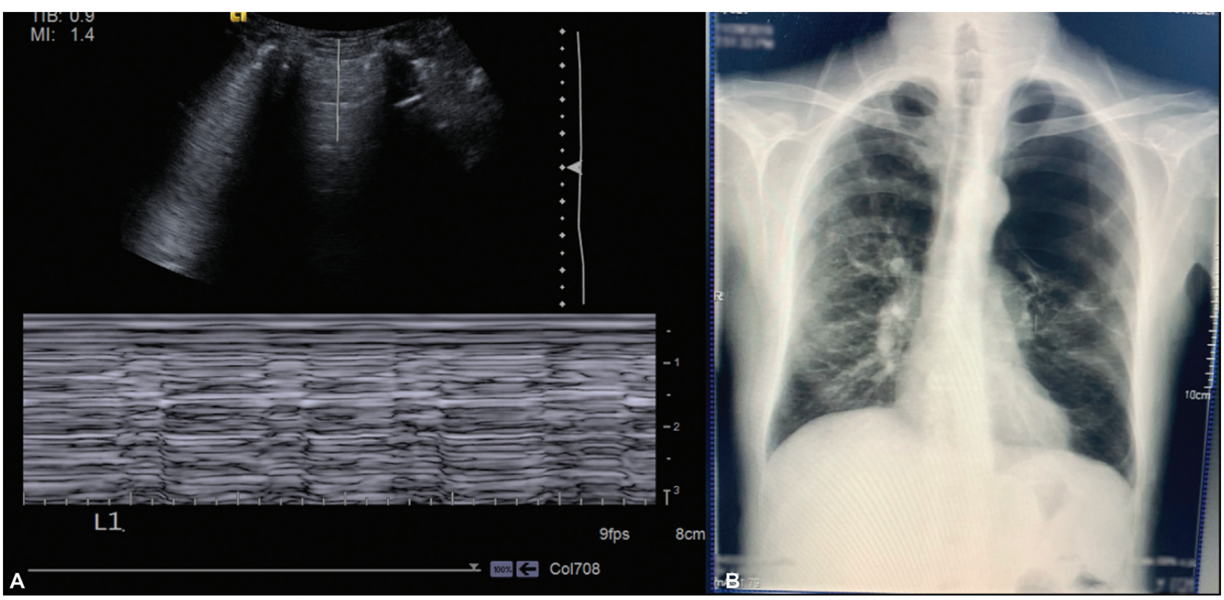

Fig. 6 (A): Longitudinal gray-scale ultrasound scan of the left anterior chest along the midclavicular line, in the left second intercostal space, in a 60-year-old afebrile male patient presenting with dyspnea and cough revealed A-lines with absent lung sliding. Pneumothorax was suspected on the basis of ultrasound findings. However, Chest X-ray revealed (B) a large bulla in the left upper and mid zones. The final clinical diagnosis of the patient at the time of discharge was acute exacerbation of COPD.

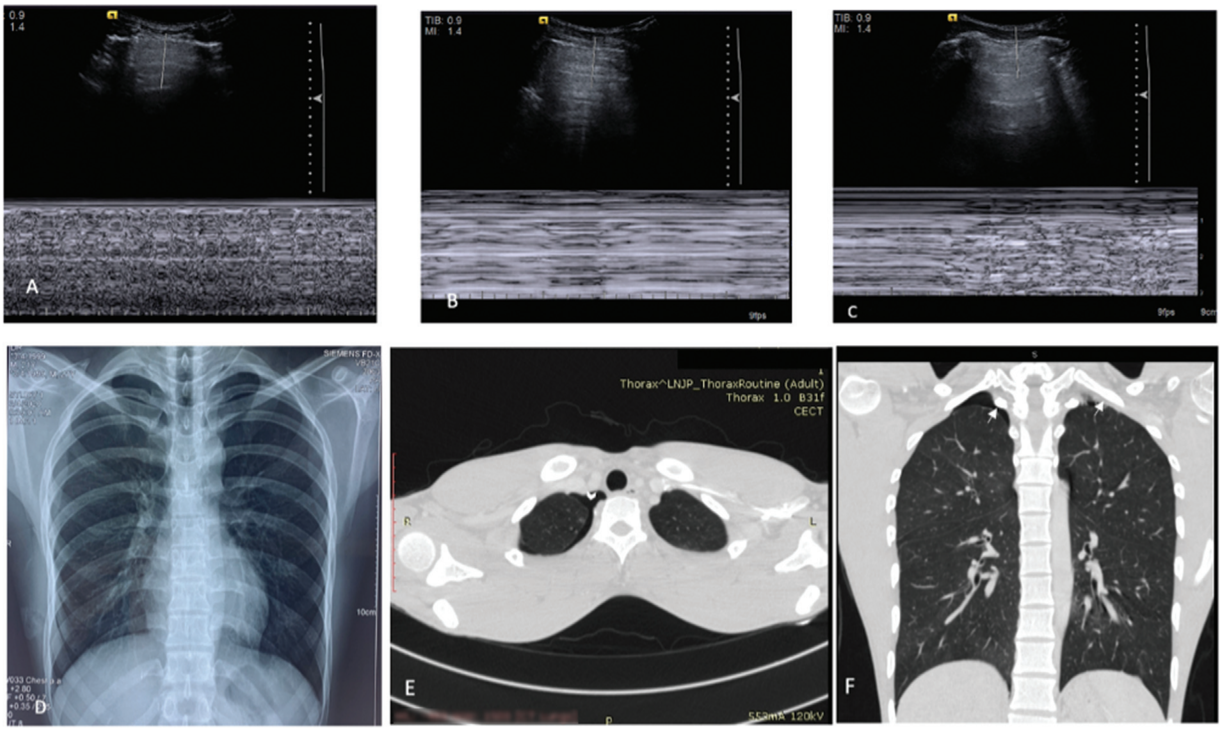

Fig. 7 (A-C): Longitudinal ultrasound scans performed in a 21-year-old, tall lean male patient who presented with acute dyspnea and chest pain revealed (A) A-lines, no B-lines with maintained lung sliding seen as Sea-shore sign on M-mode tracing in the anterior chest. (B) Absence of lung sliding with Stratosphere sign was localized at right lateral upper chest wall in mid-axillary line. (C) The lung point was demonstrated medially between the anterior axillary line and mid clavicular line, representing a small pneumothorax. (D) Chest X-ray in the same patient was reported as normal with no evidence of pneumothorax (D) CECT Chest subsequently revealed a small pneumothorax tracking along apical segment of right upper lobe (arrow head) in axial scans. (E) Subcentimetric cysts (F) were also noted in apical segments of bilateral upper lobes in the coronal scan, confirming the diagnosis of spontaneous pneumothorax as made on ultrasound which was radiographically occult.

Acute Exacerbation of COPD/Severe Asthma

Acute exacerbation of COPD/severe asthma is diagnosed on lung ultrasound on the basis of the "A-no V-no PLAPS" profile.[1]

1. "A-profile," defined by anterior lung sliding and A-lines was first sought for (►**Fig. 2**). In the present study, all seven cases that were diagnosed with COPD on ultrasound had an absence of bilaterally disseminated B-lines, a pattern which has been reported to allow bedside distinction between pulmonary edema and COPD.[11]
2. "no V": After scanning the anterior lung zones and obtaining an "A-profile," bilateral lower limbs were examined for presence of DVT which was absent in all the cases. This is because a DVT, if present, would indicate a diagnosis of pulmonary embolism.[2]
3. "no PLAPS": Finally, the lateral and posterior lung zones were also examined for presence of fluid, lung rockets, and consolidation to rule out PLAPS.

Table 9 Diagnostic value of chest USG in different pathologies

Pathology	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
Pleural effusion with/without consolidation	100% (84.56–100)	100% (88.78–100)	100%	100%
Pneumonia	100% (76.84–100)	94.87% (82.68–99.37)	87.50% (64.47–96.43)	100%
Pneumothorax/hydropneumothorax	100.0% (63.06–100)	97.78% (88.23–99.94)	88.89% (53.53–98.23)	100%
Diffuse interstitial syndrome	100.0% (63.0–100.0)	100.0% (92.3–100.0)	100.0%	100.0%
Acute exacerbation of COPD/Asthma	71.4% (29.0–96.3)	100.0% (92.2–100.0)	100.0%	95.8% (87.7–98.6)

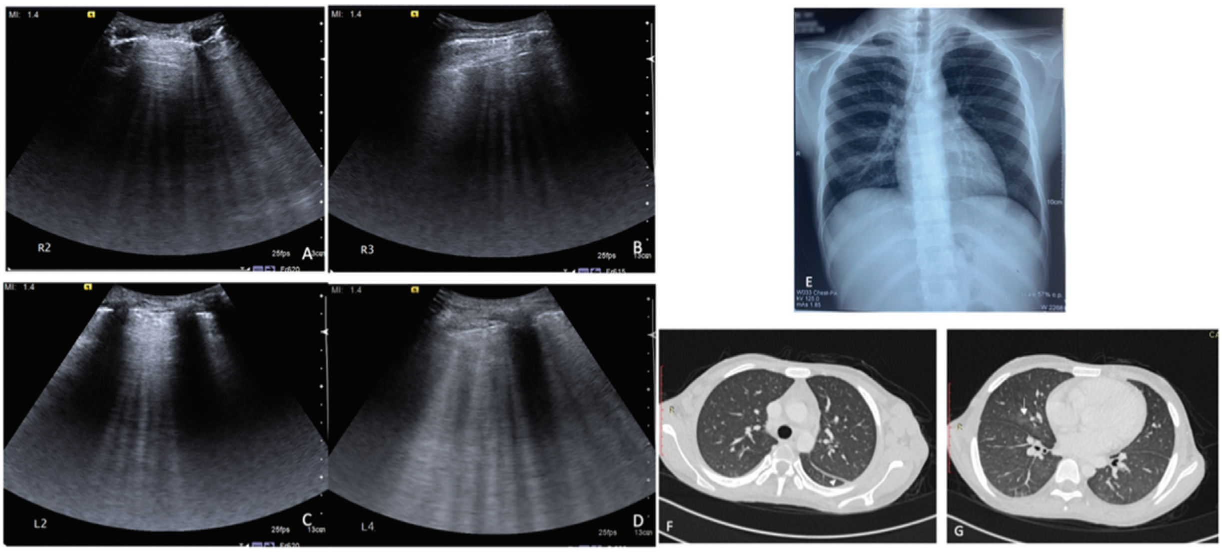

Fig. 8 (A-G): Sagittal gray-scale ultrasound scans in a 15-year-old afebrile male presenting with dyspnea and cough revealed diffuse interstitial syndrome with multiple diffuse B-lines in >1 lung zones bilaterally in the form of 'Ground glass rockets'. (E) Chest X-ray in the same patient was however reported as normal. (F and G) CECT chest confirmed the findings of ultrasound with the presence of fissural thickening (arrow head) and ground glass opacities (arrow).

Two cases of COPD were however not detected on ultrasound (►**Table 6**) and were diagnosed as pneumothorax (►**Fig. 6**) and pneumonia (►**Fig. 3**) as discussed above.

In our study, ultrasound showed a sensitivity of 71.4%, specificity of 100%, positive predictive value of 100%, and negative predictive value of 95.8% in the diagnosis of COPD/asthma (►**Table 9**). This is in concordance with Zanobetti et al,[7] who reported a sensitivity, specificity, positive predictive value, and negative predictive value of 86.8%, 96.1%, 89.7%, and 94.9% for diagnosis of COPD/asthma by ultrasound. In contrast, chest X-ray showed a 100% sensitivity, specificity, positive predictive value, and negative predictive value (►**Table 8**). The difference was, however, not statistically significant (►**Table 7**).

Diffuse Interstitial Syndrome

Diffuse interstitial syndrome[1,4] is diagnosed on ultrasound by demonstrating multiple (three or more) B-lines[15] in more than one scanning zone on the anterolateral chest, bilaterally. The following patterns were identified

1. "Lung rocket" pattern (three B-lines) was present in all eight patients diagnosed with diffuse interstitial syndrome.
2. "Septal rocket" pattern (four B-lines) representing interlobular septal thickening was also noted in all.
3. "Ground glass rocket" pattern (>five B-lines) representing ground glass areas on CT was seen in seven cases.

CECT/HRCT chest was subsequently also performed in three patients, as requisitioned by the treating clinician. Correlation with ultrasound revealed the findings to correspond with each other, further supporting the diagnosis.

Diffuse interstitial syndrome is seen in pulmonary edema and interstitial lung disease.[16,17] A "regular pleural line" can help differentiate pulmonary edema from interstitial lung disease.[4] We were able to appreciate a regular pleural line in all five cases of pulmonary edema. On the contrary, irregular, thickened or fragmented appearance of pleural line was noted in all three cases of interstitial lung disease.

There was only one discordant case (►**Fig. 8**), reported normal on chest X-ray.

Sensitivity, specificity. Positive and negative predictive value of ultrasound (►**Table 9**) were found to be 100%, likely due to small sample size. Chest X-ray (►**Table 8**) was found to have a sensitivity and negative predictive value of 87.5% and 97.8%, however the difference was not statistically significant (►**Table 7**).

Limitations of Our Study

The main limitation of our study was the exclusion of critically ill patients and patients on mechanical ventilation. A correlative CT report was also not available for every case due to ethical considerations. Difficulty in interpreting ultrasound findings was also encountered in patients with sequalae of tubercular infection and obese patients. All chest X-rays had been performed in posteroanterior (PA view) in erect position, unlike the studies in critically ill patients, which mandate a bedside supine chest X-ray. Hence, we were unable to obtain a statistically significant difference in diagnostic value of ultrasound and chest X-ray. However, we were able to verify a high concordance between ultrasound and chest X-ray with $p < 0.01$. The duration of examination was found to be under 5 minutes, suggesting the importance of a bed-side ultrasound for feasible and quick diagnosis.

Conclusion

Ultrasound is a useful imaging modality in the evaluation of dyspnea. With its noninvasive nature, easy availability, and lack of ionizing radiation, ultrasound is capable of diagnosing common respiratory pathologies causing dyspnea including pneumonia, pneumothorax, pulmonary edema and acute exacerbation of COPD/severe asthma, apart from its traditional use in detecting pleural effusion. It also shows a high concordance with Chest X-ray, the current first-line imaging investigation for evaluation of dyspnea in diagnosis of these pathologies and can hence be considered a complimentary imaging modality for the same

Conflict of Interest
None declared.

References

1. Lichtenstein DA. BLUE-protocol and FALLS-protocol: two applications of lung ultrasound in the critically ill. Chest 2015;147(06):1659–1670
2. Laursen C, Rahman N, Volpicelli G. Thoracic ultrasound. European Respiratory Society; 2018
3. Lichtenstein DA, Lascols N, Mezière G, Gepner A. Ultrasound diagnosis of alveolar consolidation in the critically ill. Intensive Care Med 2004;30(02):276–281
4. Lichtenstein D. Lung Ultrasound in the Critically Ill: The BLUE Protocol. Switzerland: Springer Nature; 2016
5. Weinberg B, Diakoumakis EE, Kass EG, Seife B, Zvi ZB. The air bronchogram: sonographic demonstration. Am J Roentgenol 1986;147(03):593–595
6. Lichtenstein D, Mezière G, Seitz J. The dynamic air bronchogram. A lung ultrasound sign of alveolar consolidation ruling out atelectasis. Chest 2009;135(06):1421–1425
7. Zanobetti M, Poggioni C, Pini R. Can chest ultrasonography replace standard chest radiography for evaluation of acute dyspnea in the ED? Chest 2011;139(05):1140–1147
8. Mathis G, Dirschmid K. Pulmonary infarction: sonographic appearance with pathologic correlation. Eur J Radiol 1993;17(03):170–174
9. Pagano A, Numis FG, Visone G, et al. Lung ultrasound for diagnosis of pneumonia in emergency department. Intern Emerg Med 2015;10(07):851–854
10. Lichtenstein D, Mezière G, Biderman P, Gepner A. The comet-tail artifact: an ultrasound sign ruling out pneumothorax. Intensive Care Med 1999;25(04):383–388
11. Lichtenstein D, Mezière G. A lung ultrasound sign allowing bedside distinction between pulmonary edema and COPD: the comet-tail artifact. Intensive Care Med 1998;24(12):1331–1334
12. Lichtenstein D, Mezière G, Biderman P, Gepner A. The “lung point”: an ultrasound sign specific to pneumothorax. Intensive Care Med 2000;26(10):1434–1440
13. Zanobetti M, Scorpiniti M, Gigli C, et al. Point-of care ultrasonography for evaluation of acute dyspnea in the ED. Chest 2017;151(06):1295–1301
14. Aziz SG, Patel BB, Ie SR, Rubio ER. The lung point sign, not pathognomonic of a Pneumothorax. Ultrasound Q 2016;32(03):277–279
15. Reissig A, Kroegel C. Transthoracic sonography of diffuse parenchymal lung disease: the role of comet tail artifacts. J Ultrasound Med 2003;22(02):173–180
16. Reissig A, Copetti R. Lung ultrasound in community-acquired pneumonia and in interstitial lung diseases. Respiration 2014;87(03):179–189
17. Buda N, Piskunowicz M, Porzezińska M, Kosiak W, Zdrojewski Z. Lung ultrasonography in the evaluation of interstitial lung disease in systemic connective tissue diseases: criteria and severity of pulmonary fibrosis - analysis of 52 patients. Ultraschall Med 2016;37(04):379–385

