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Lung Ultrasound in Acute Respiratory Care

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Lung Ultrasound in Acute Respiratory Care

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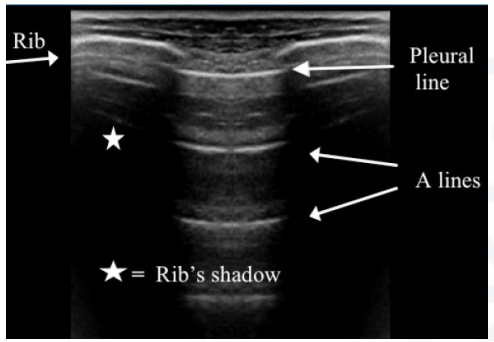
Aims / Learning objectives

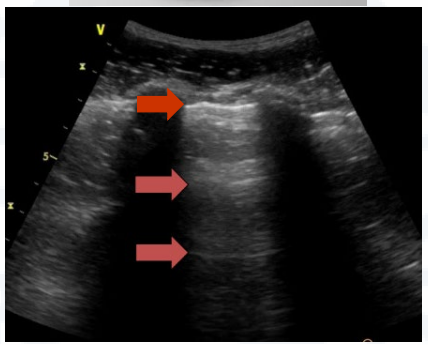
1. Know lung ultrasound equipment, e.g. machine, settings, probe
2. Know how to scan and (number of) views to use
3. Know the different lung ultrasound algorithms for diagnosing and monitoring
4. Know how to use lung ultrasound to predict weaning outcome

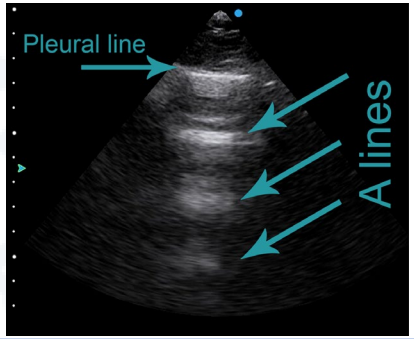
1. Equipment

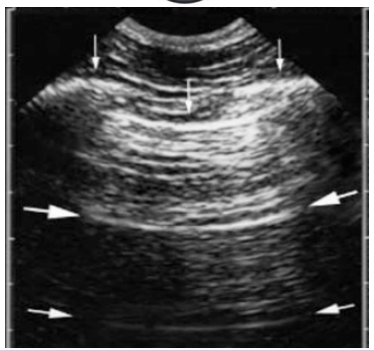

Lung ultrasound has been proven effective in detecting
pulmonary involvement and avoiding cross-contamination in
suspected COVID-19 patients.

1. Probes



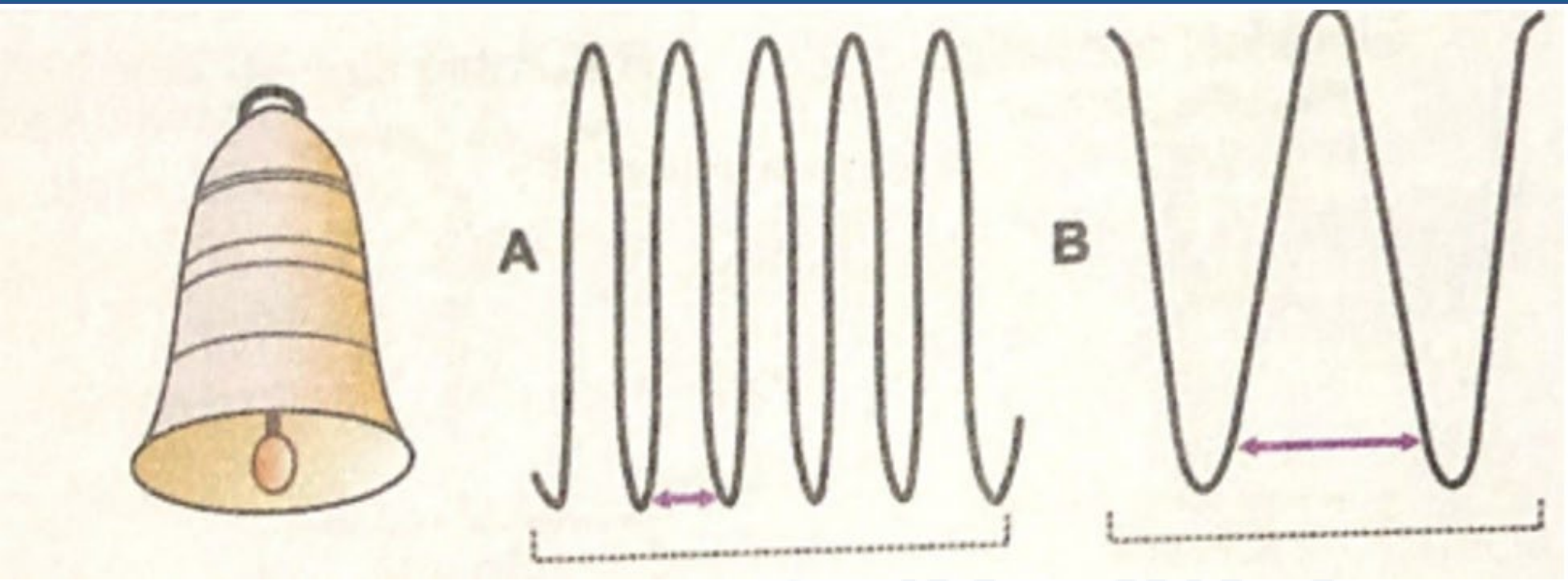






Type	Linear	Convex	Phased-array	Micro-convex
Frequency	high	low	low	wide range
Resolution	high	low	low	moderate
Penetration	low	good	good	good
Best for	Pleura artifacts	Consolidation/effusion	Consolidation/effusion	Consolidation/effusion

1. Probes



Relationship between frequency and wavelength:

A. High frequency, short wavelength

B. Low frequency, long wavelength

$$V = \frac{L}{t} \qquad V = \frac{\lambda}{T} \qquad V = \lambda * f$$

Velocity= Wavelength * Frequency

Frequency vs. Resolution

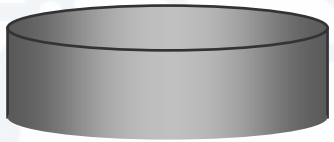
The frequency also affects the QUALITY of the ultrasound image

The **HIGHER** the frequency, the **BETTER** the resolution

The **LOWER** the frequency, the **LESS** the resolution

A 18 MHz transducer has very good resolution, but cannot penetrate very deep into the body

A 3 MHz transducer can penetrate deep into the body, but the resolution is not as good as the 12 MHz



Low Frequency
3 MHz

High Frequency
12 MHz

Frequency vs. Resolution

As a general rule, the depth of penetration of US in tissue is limited to 200 wavelengths. Thus, a high-frequency, short-wavelength 10 MHz transducer may penetrate only 3 cm into tissue, whereas a low-frequency 1 MHz transducer may penetrate 30 cm.

Pole

Which probe do you prefer when scanning for B-lines?

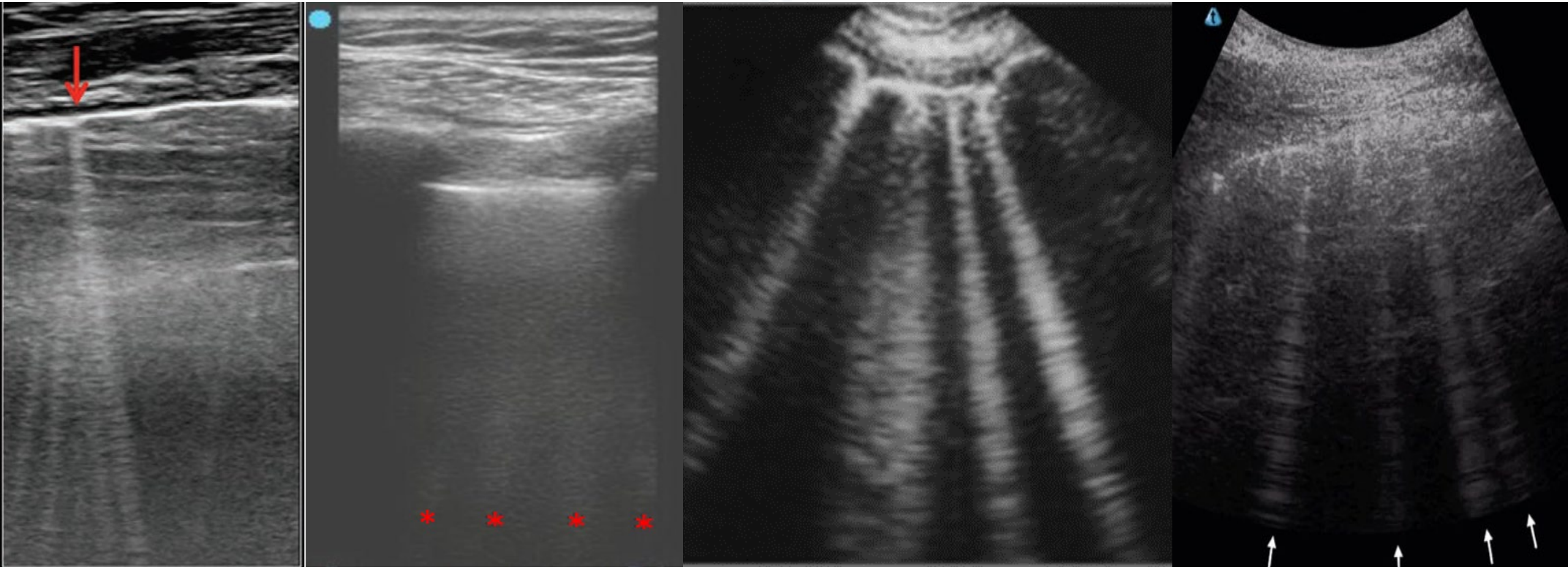
a) Linear

b) Convex

c) Phased-array

d) Micro-convex

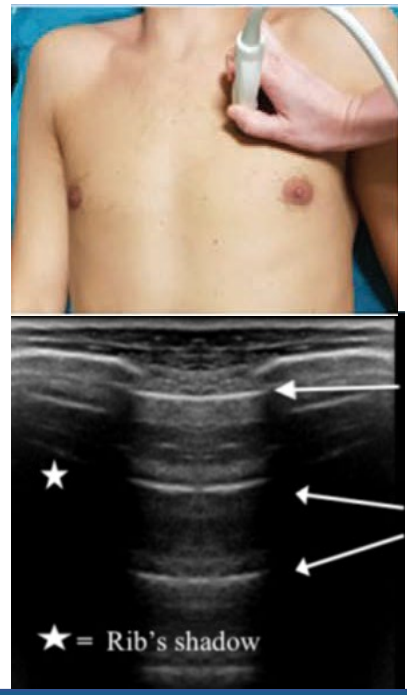
Lung ultrasound and B-lines: B careful!



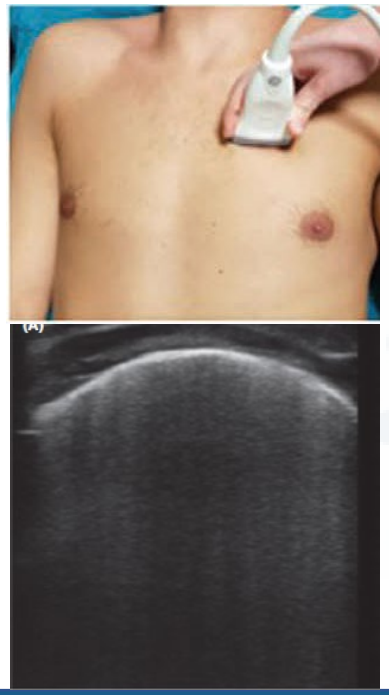
2. Scanning direction and views

Scanning direction

Longitudinal

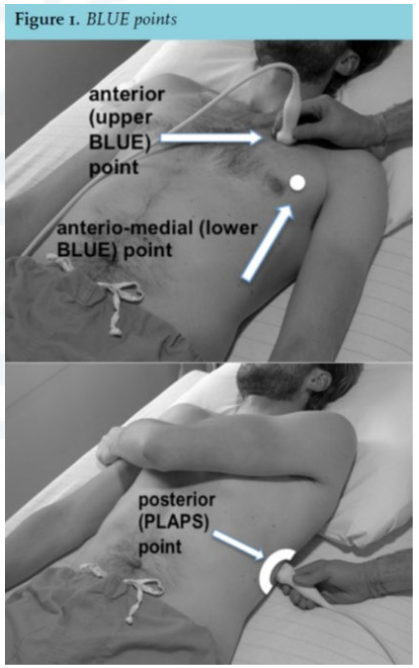


Transversal

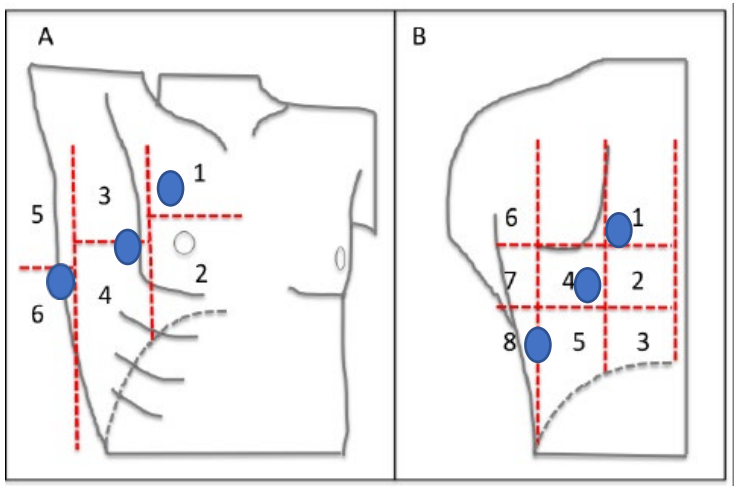


Views

Diagnosing



Monitoring



Anesthesiology June 2021, Vol. 134, 949–965.

Neth J Med 2015 Mar;73(3):100-7; Am J Respir Crit Care Med 2019 Mar 15;199(6):701-714

2. Scanning direction and views

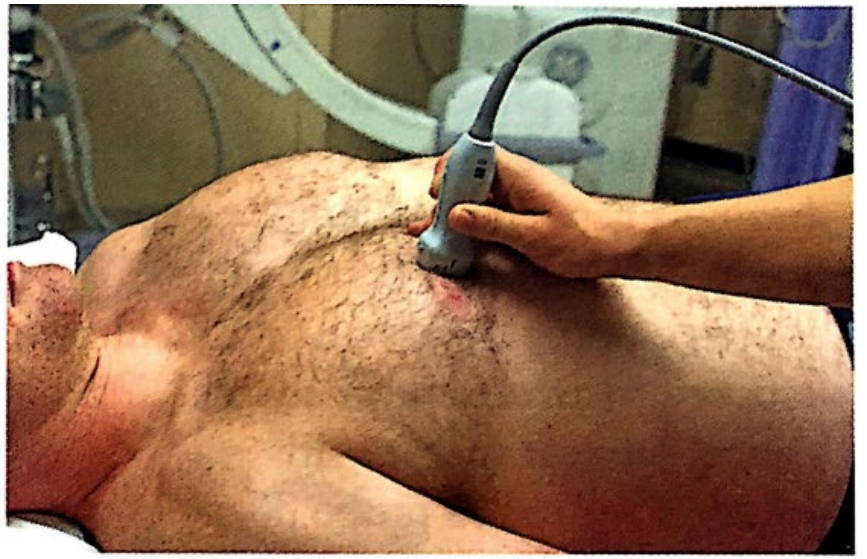


Figure 87.3. To evaluate for A lines, B lines, and lung slide, place the transducer on the anterior chest perpendicular to the chest wall and slide between the rib spaces with the indicator at 12 o'clock. To evaluate for pleural effusions, atelectasis/consolidation, and subdiaphragmatic structures, place the transducer in the mid-axillary line with the indicator at 12 o'clock. Slide the transducer superiorly and inferiorly until the diaphragm is identified. To completely evaluate this area, may need to move the transducer more posteriorly while angling upward toward the horizon.

Lung ultrasonographic characteristic

1-The thorax is an area where air and water are intimately mingled.

2-The lung is the largest organ in the human body.

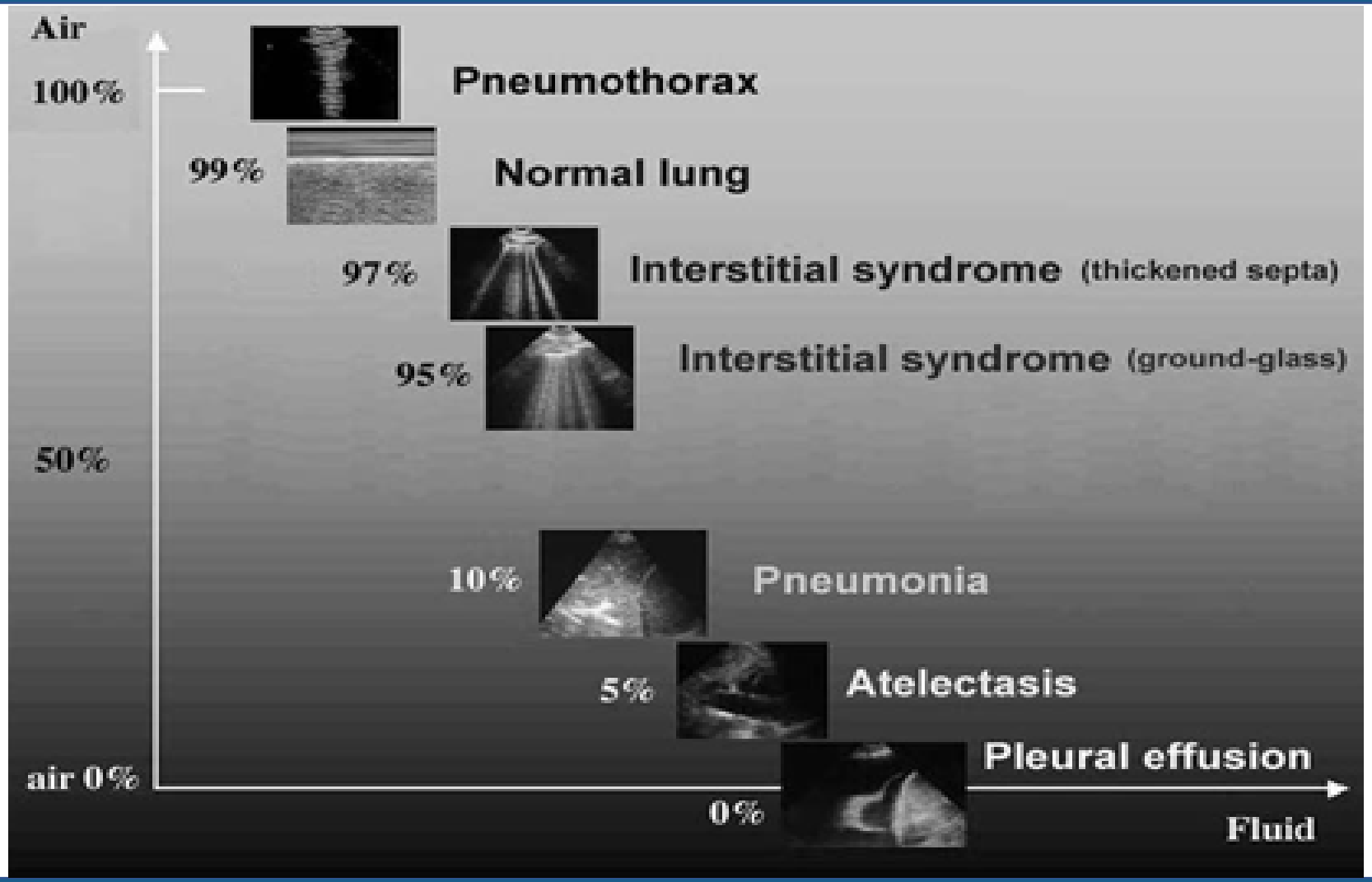
3-All signs arise from the pleural line

4-Lung signs are mainly based on the analysis of the artifacts.

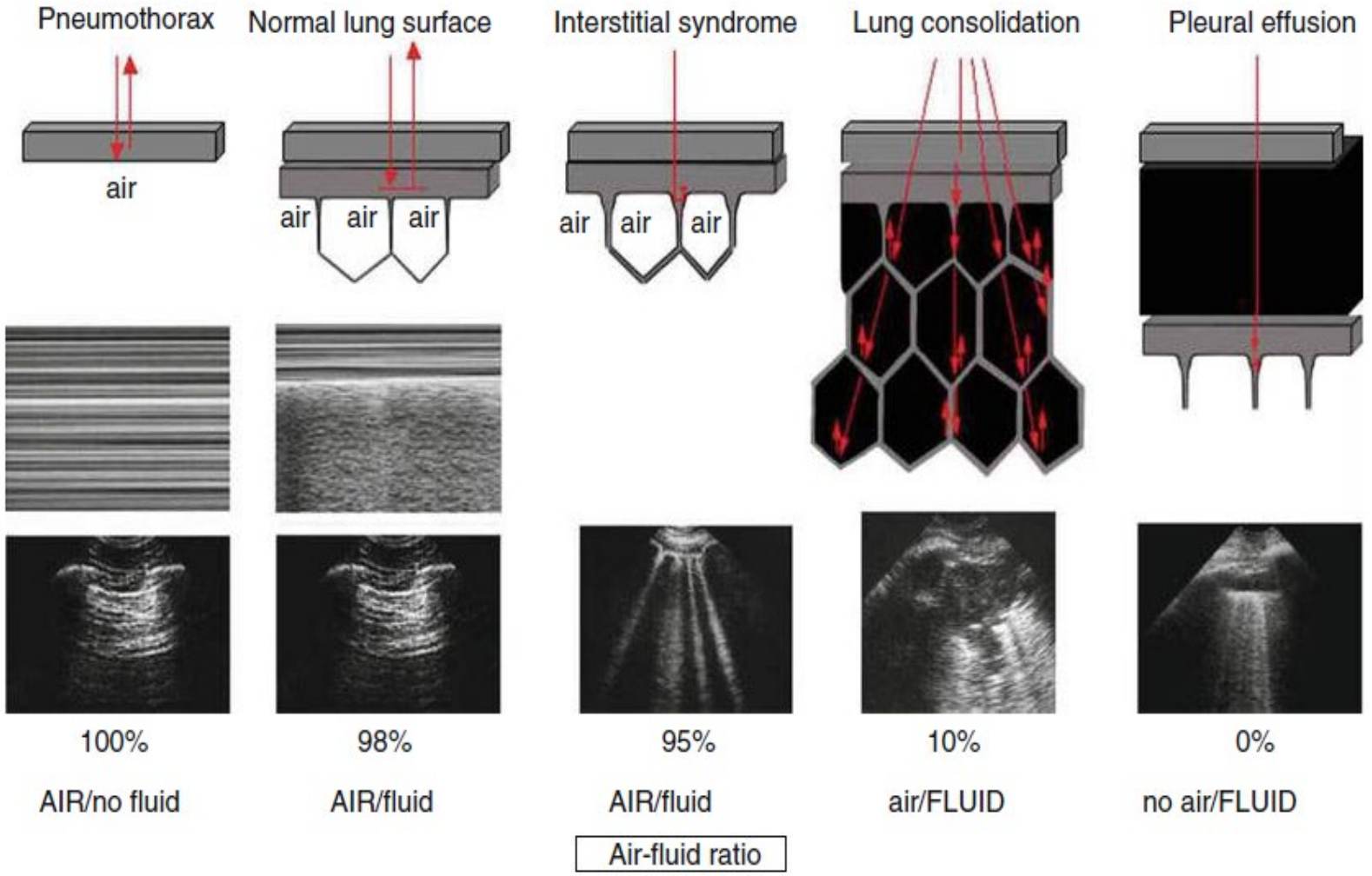
5- The lung is a vital organ. Most signs are dynamic.

6-Nearly all acute disorders of the thorax come in contact with the surface. This explains the potential of lung ultrasound, which is paradoxical only at first view.

Lung ultrasonographic characteristic



Lung ultrasonographic characteristic



The ten basic signs for the lung part of the BLUE-protocol

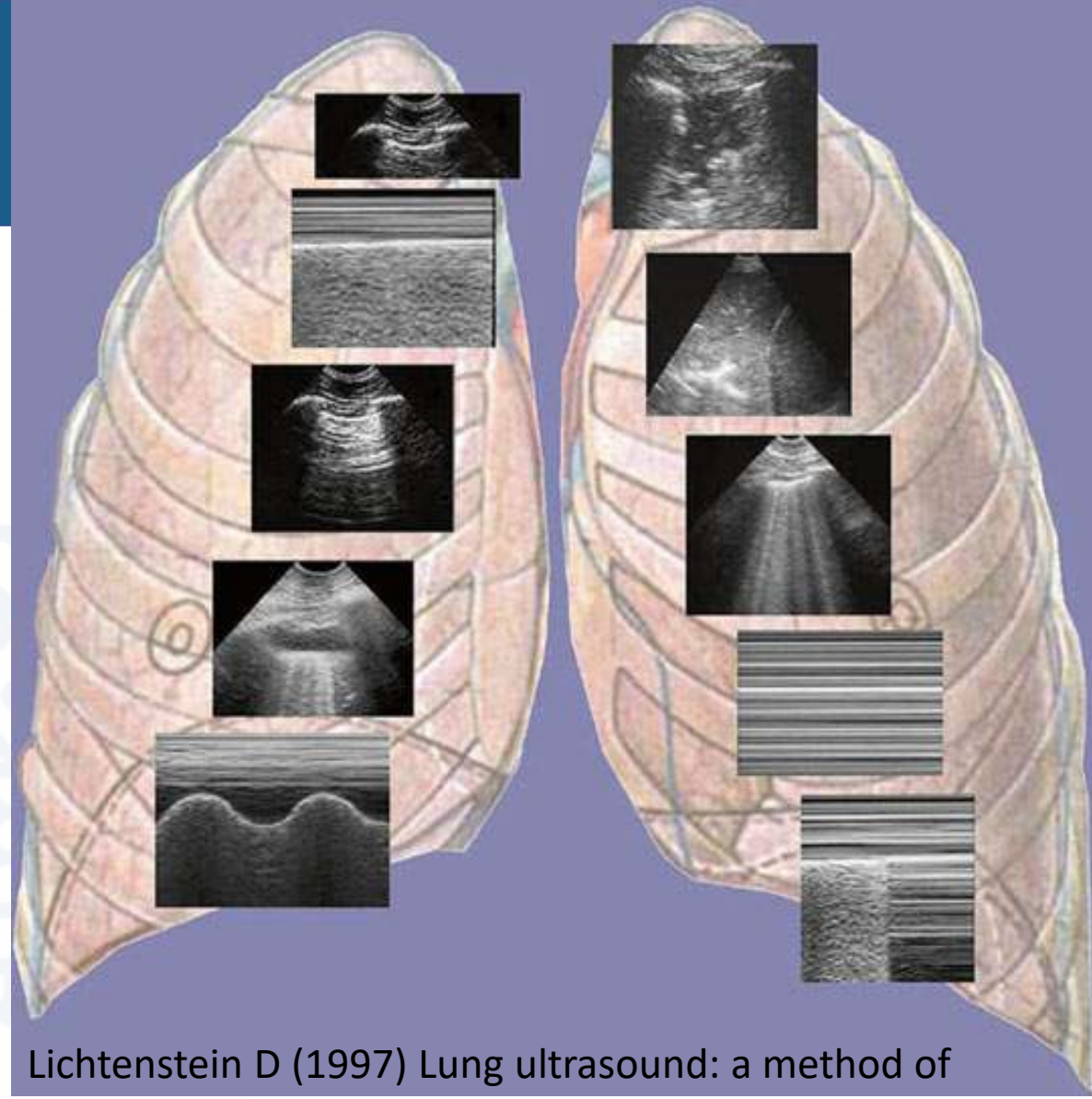
The basis pattern the bat sign

The second and third are signs of normality
A-lines , lung sliding

Pleural effusion
quad sign,sinusoid sign

Lung consolidation
shred sign, tissue like sign , dynamic sonographic air bronchogram
Interstitial syndrome
Lung rocket

Pneumothorax
Stratosphere sign and lung point , lung pulse



Lichtenstein D (1997) Lung ultrasound: a method of the future in intensive care? (Editorial). Rev Pneumol Clin 53:63–68

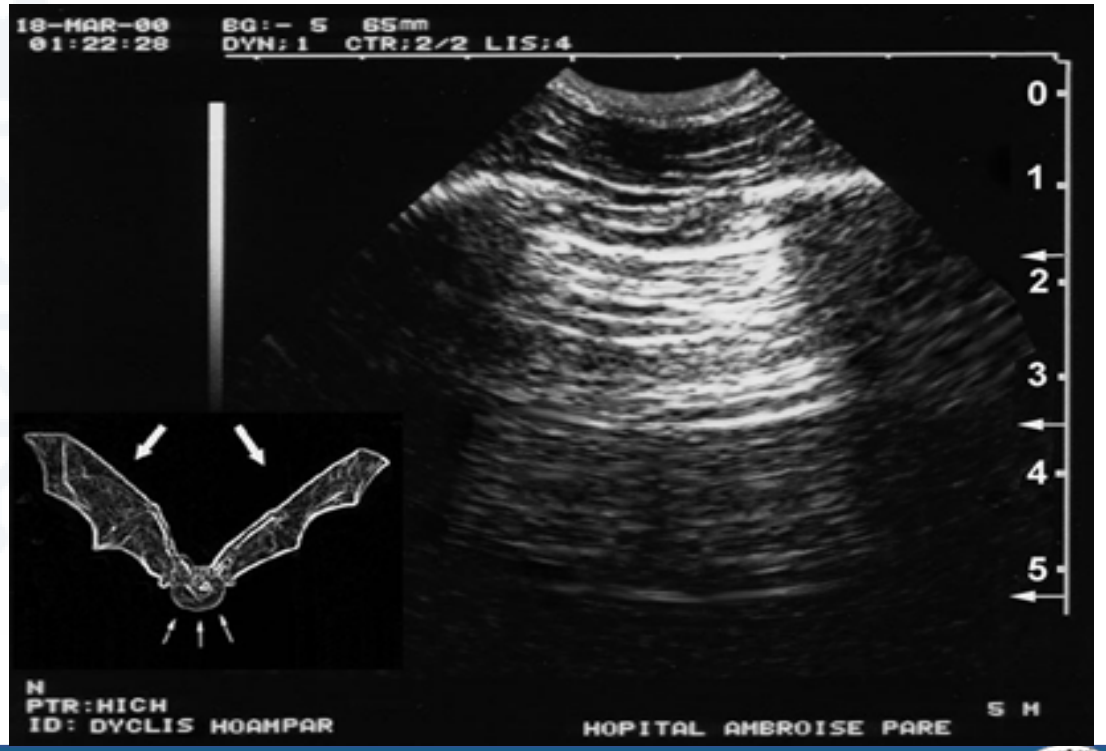
Bat wing

5 MHz microconvex probe is perfect for this part of lung investigation

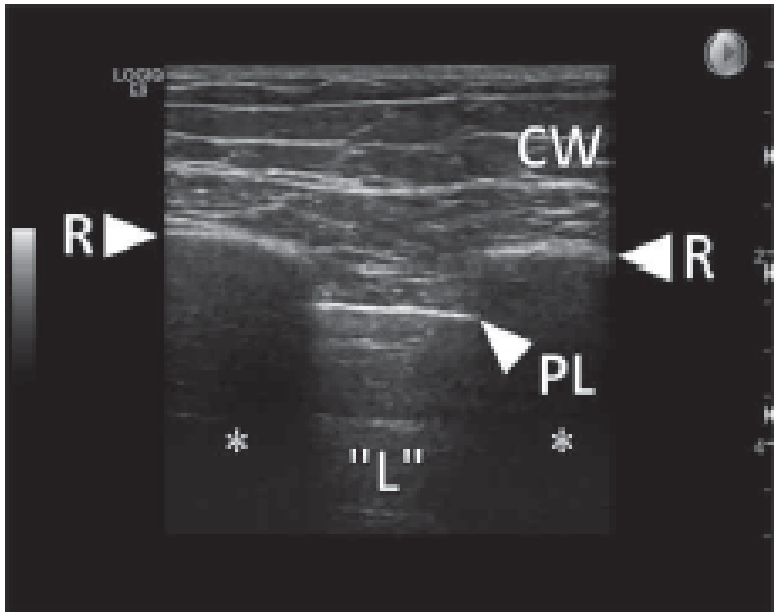
The thorax is built by the ribs and lungs

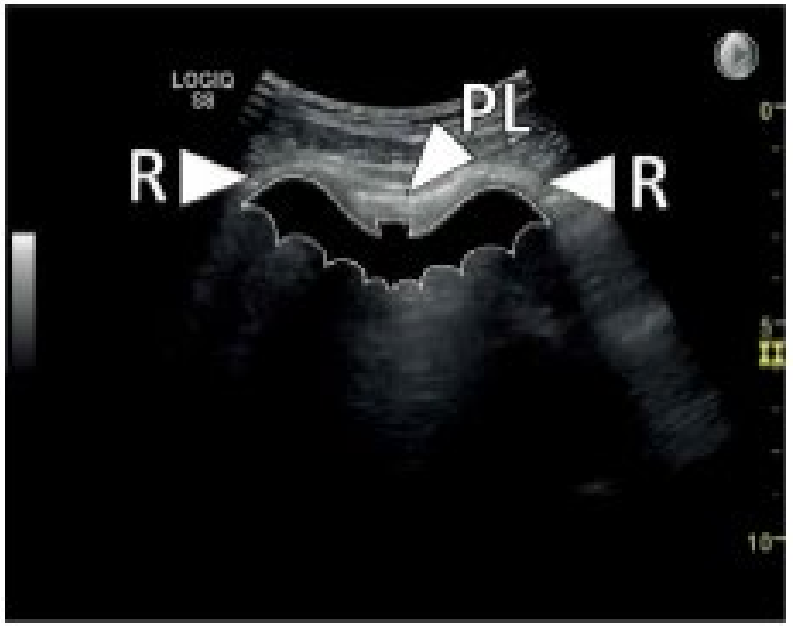
The rib is recognized easily: arciform hyperechoic structure and then acoustic shadow.

Between the top of 2 ribs, one can draw a “rib line.”



Bat wing sign



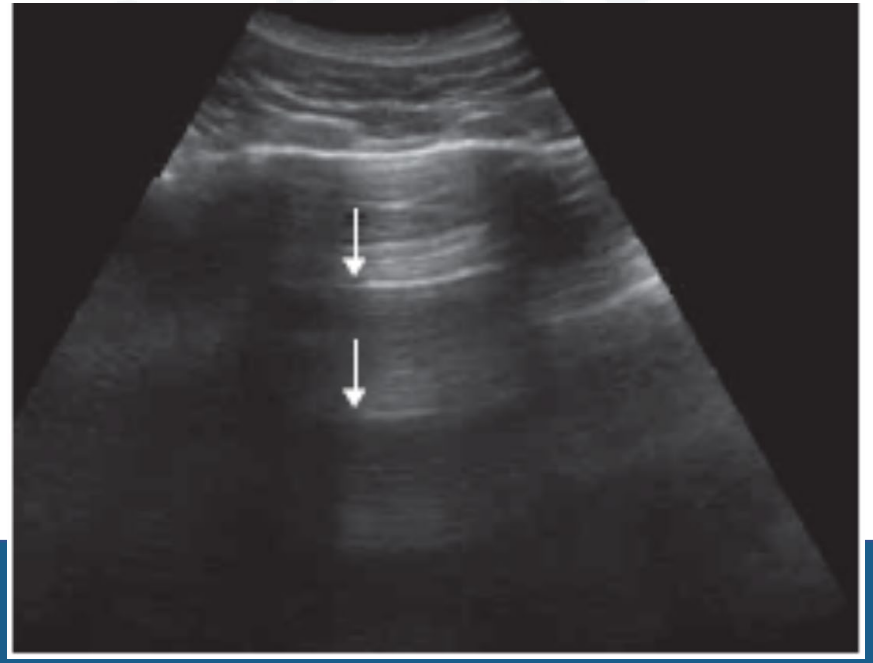


The Artifact Which Defines the Normal Lung Surface:
The A-line

1-Is the repetition of the pleural line, a roughly horizontal hyperechoic fi ne line parallel to the pleural line

2-The distance between the pleural line and the A-line is equal to the skin-pleural line distance.

3-They can be called A1-lines, A2-lines, etc., according to the number of observed lines, with little clinical relevance. Of same relevance, horizontal artifacts are sometimes seen between two A-lines and called “sub-A-lines” and even “subsub- A-lines



A Line

Characteristics

- A lines are a reverberation artifact, with serial repetitions of the pleural line.
- A lines are horizontal lines and are each separated by an equal distance (this is a reverberation artifact of the original distance from the probe to the pleural line).
- A lines are the normal expected pattern and represent aerated lung.

Differential Dx

- Normal lung, COPD/asthma, pneumothorax (A lines with absent lung slide), pulmonary embolism (without a pulmonary infarct).

Lung Sliding IN B-MODE
Seashore sign –sandy sea in M-MODE

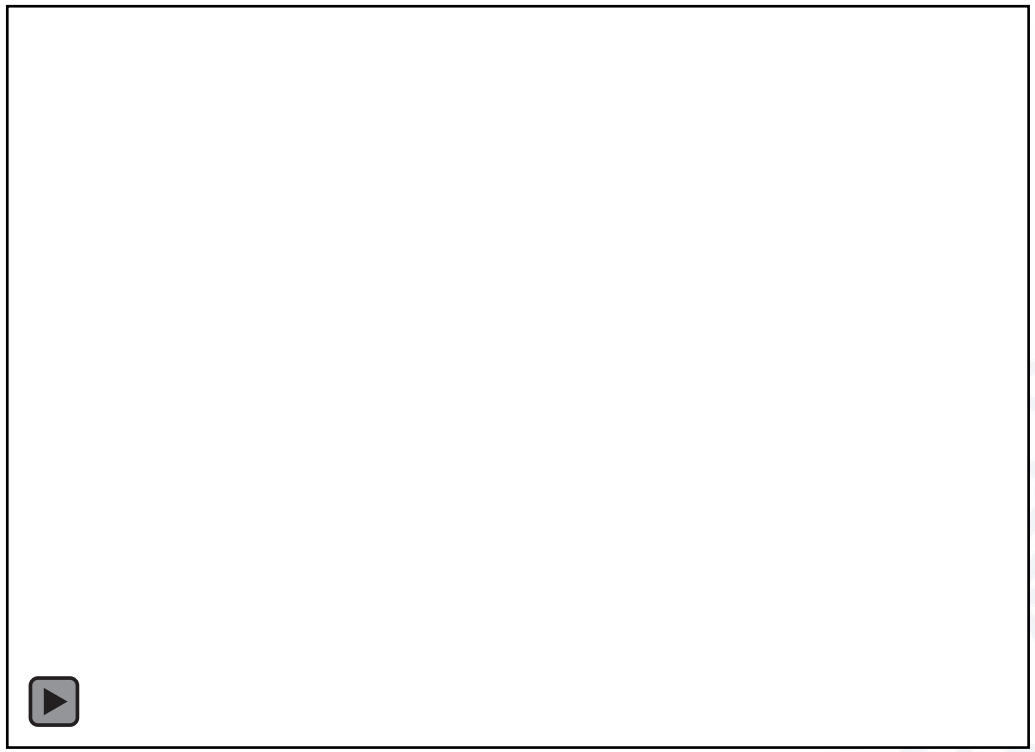
The pleural line is built by two layers: the parietal pleura, always motionless, and the visceral pleura, only when the lung is at the chest wall, moving or not.

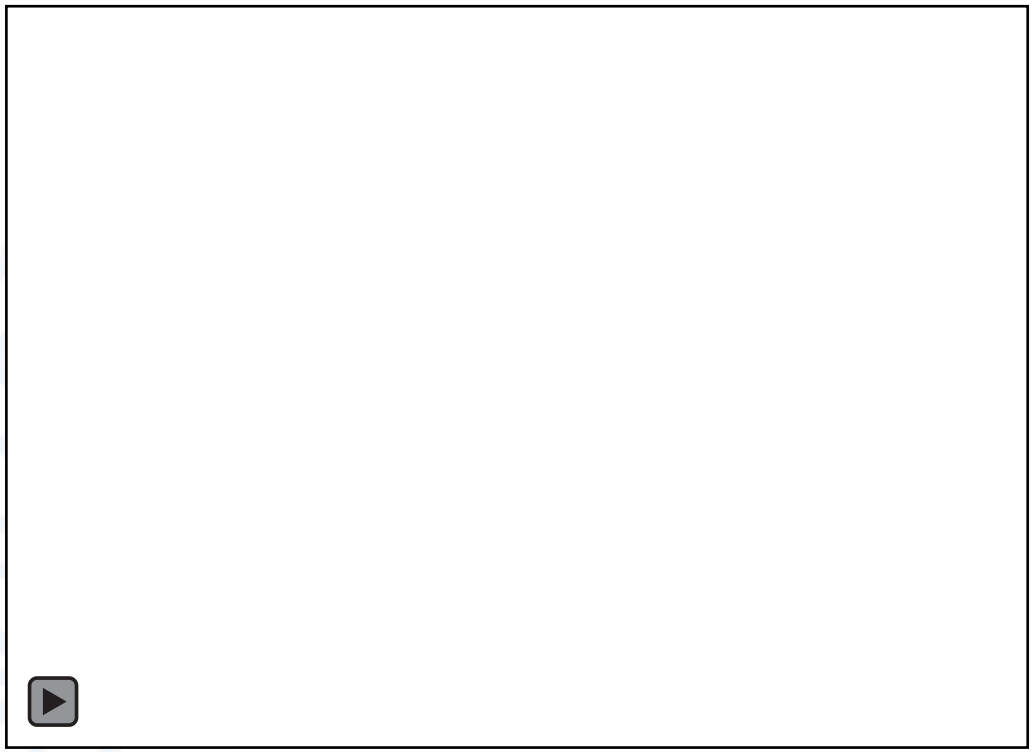
The sliding of the visceral pleura against the parietal pleura creates this sparkling at the pleural line.

Lung sliding indicates that, first, the lung is at the chest wall and, second, this lung works.

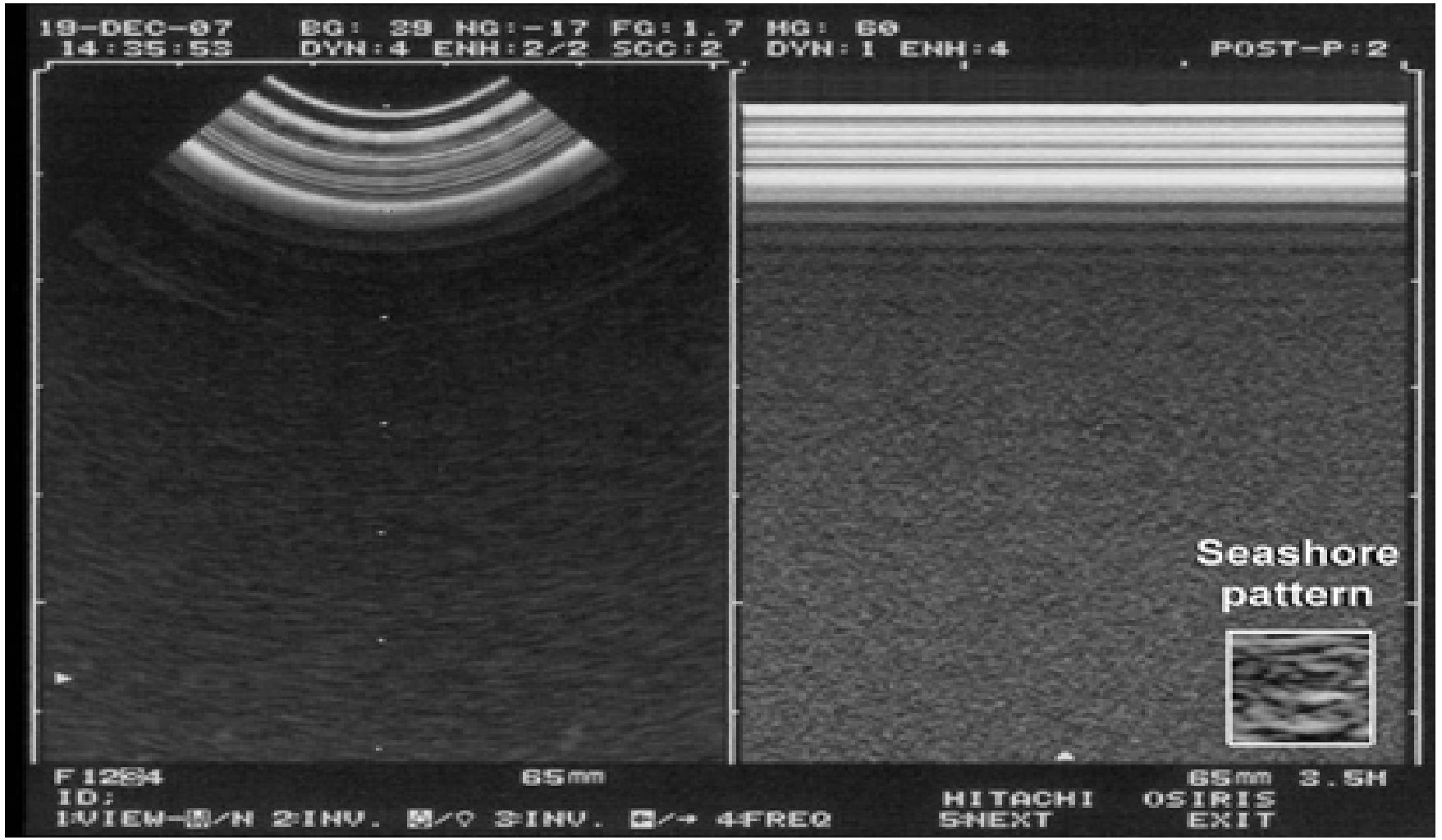
The present of lung sliding rull out PTX

Lung Sliding IN B-MODE
Seashore sign – sandy sea in M-MODE

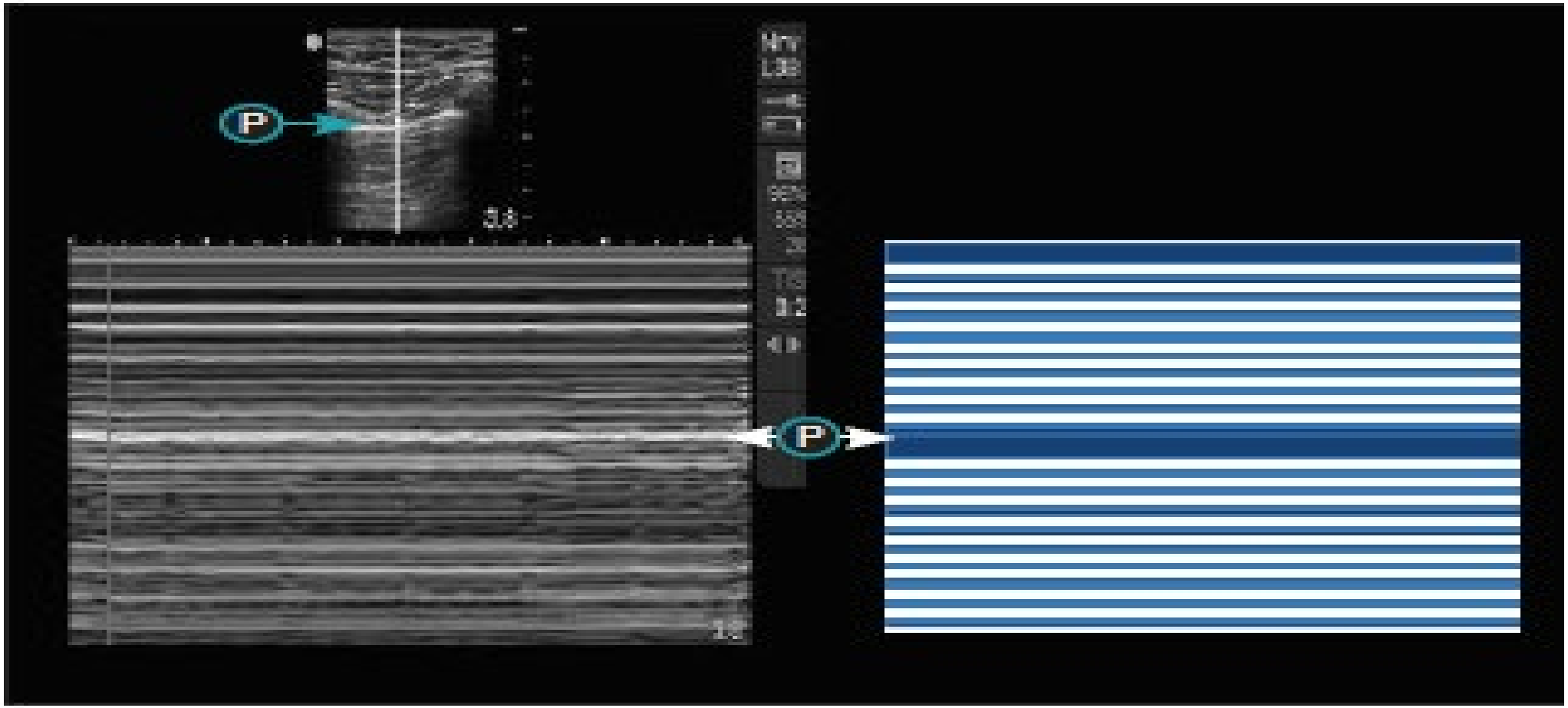




Lung Sliding IN B-MODE
Seashore sign –sandy sea in M-MODE



barcode sign



Lung Slide

Characteristics

- Horizontal hyperechoic line approximately 0.5 cm deep to the origin of rib shadows.
- Dynamic finding, variably described as shimmering, sparkling, glimmering, twinkling appearance.
- Represents the movement of the visceral on the parietal pleura. Is often more apparent at the lung base than at the apex of the lung.

- **Presence of lung slide rules out pneumothorax at the point of interrogation.**
- **Lung pulse is not the same as lung slide, but refers to pulsation of the pleural line interface with each cardiac pulsation, and is also able to rule out a pneumothorax when seen.**

- Utilizing M mode, normal lung slide results in a finding described as the “sandy beach sign.” This provides evidence of movement of the underlying lung, underneath the pleural line (the sand on a beach) as opposed to the relatively stationary superficial soft tissue structures (seen as "waves" on M mode imaging). If a pneumothorax is present, the M mode finding is referred to as the stratosphere sign or barcode sign and consists of multiple horizontal lines on the screen without the haziness generated by lung motion (Fig. 87.4).

- **Lung POINT: sign referring to the point or edge of a pneumothorax. Sliding lung is seen coming in and out of the ultrasound image as the patient breaths, and is juxtaposed to an area with absent lung slide. This finding is very specific for pneumothorax but not very sensitive, as it is not always seen and depends on pneumothorax location related to probe position.**

Differential Diagnosis for Loss of Lung Slide

- Pneumothorax
- Severe pneumonia or ARDS with significant loss of lung compliance
- Prolonged apnea
- Prior history of pleurodesis

- Examination on the left side with right mainstem intubation
- Ventilatory modes without significant tidal volumes (high frequency oscillation)
- Bullous lung disease
- Adhesions
- Pulmonary contusions

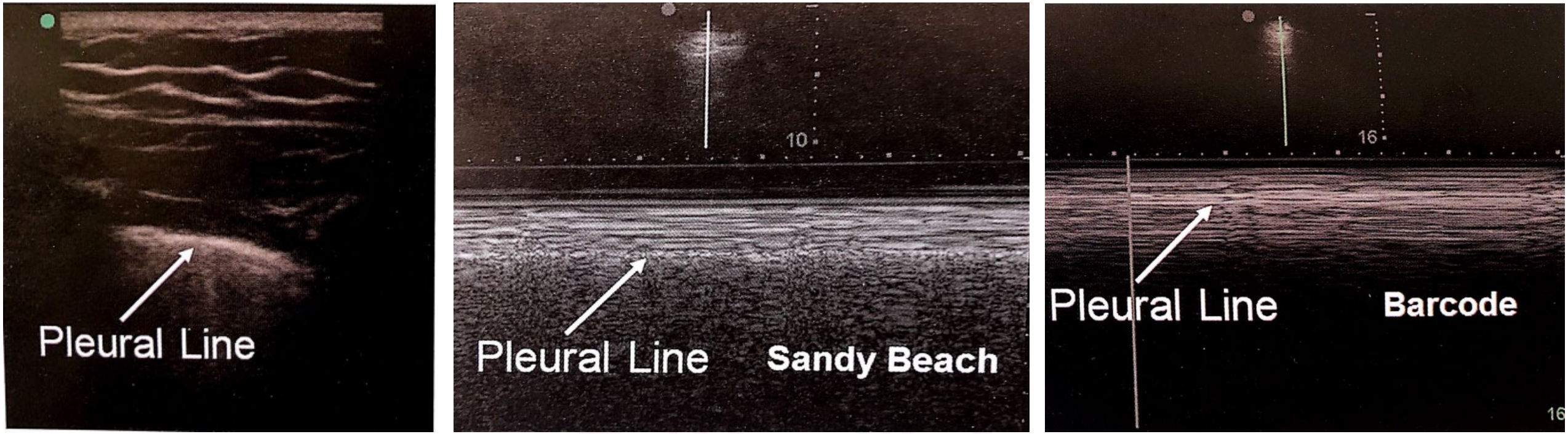


Figure 87.4.Lung slide represents the movement between the visceral and parietal pleura and is displayed as a bright, shimmering line between rib shadows (left). Movement beneath the pleural line can be assessed using M-mode. If the lung is in contact and moving below the pleural line, a grainy or sandy pattern is seen (middle). If there is no movement or the lung is not in direct contact with the parietal pleura, then a linear pattern is represented (right). These patterns are referred to as the sandy beach and stratosphere/barcode signs respectively.

B Lines :Interstitial Alveolar Syndrome

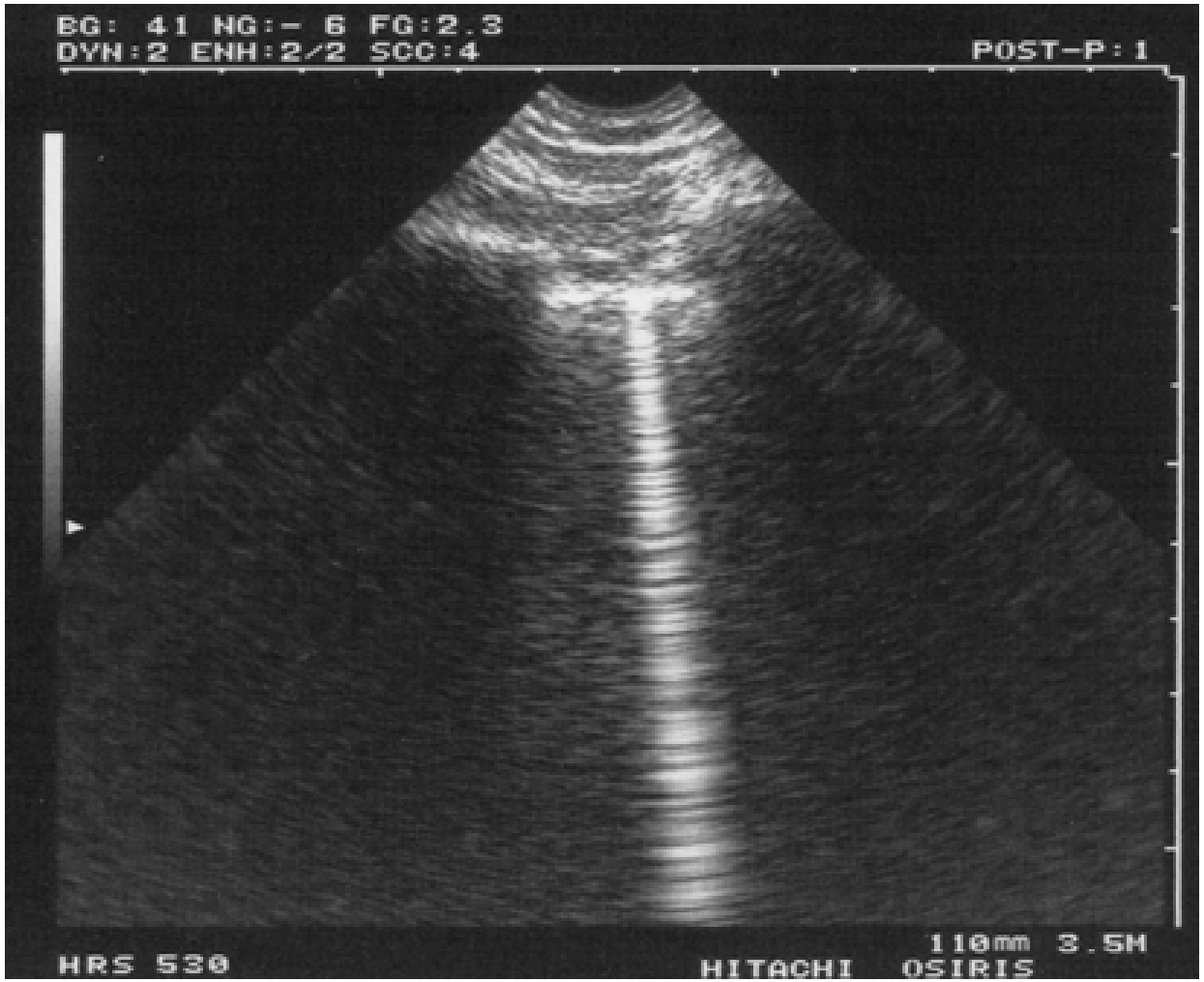
The B-line is an artifact having seven characteristic features Three are constant and four almost constant.

Constant features:

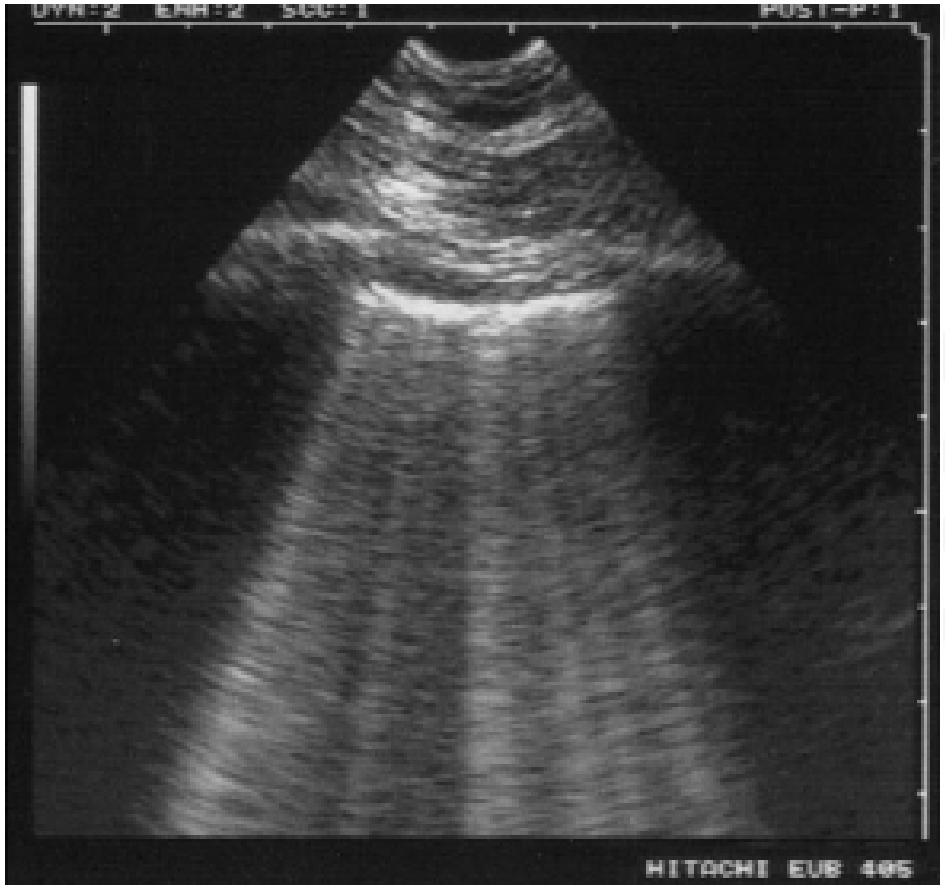
1. This is a comet-tail artifact, always.
2. It arises from the pleural line, always.
3. It moves with lung sliding, always.

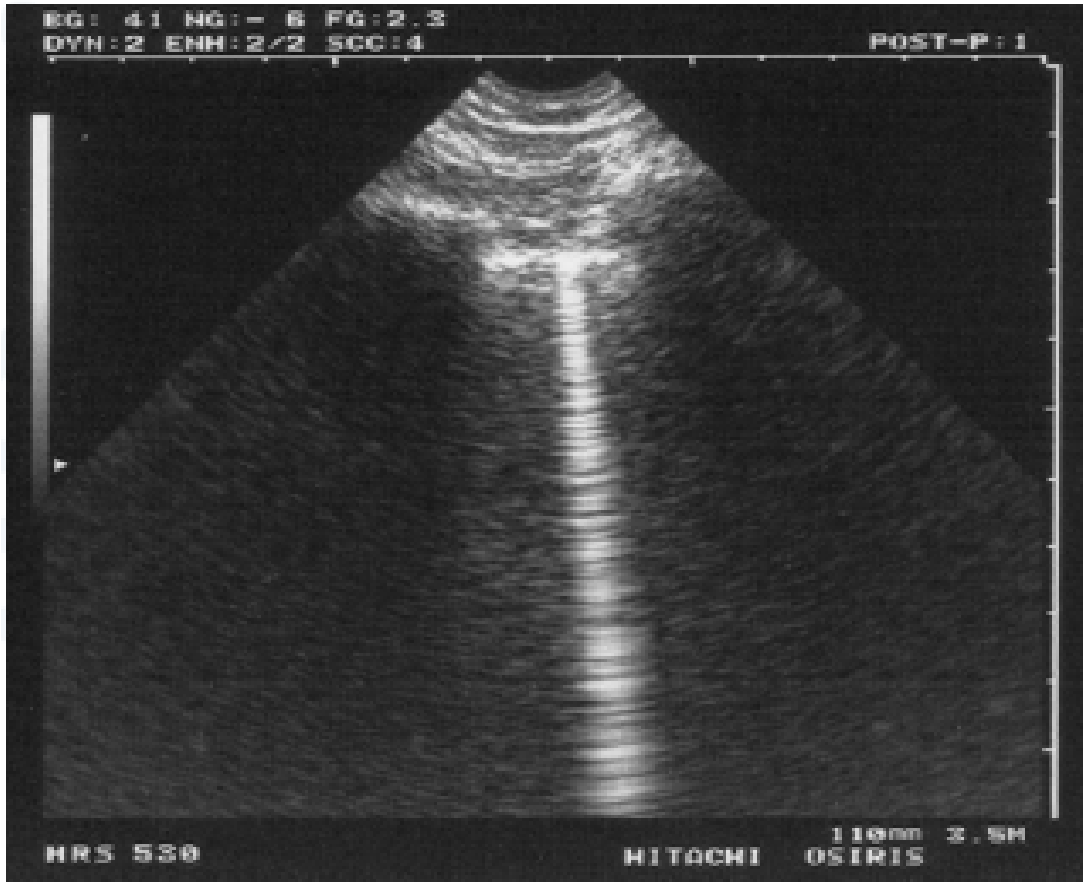
Almost constant features (93–97 %)

4. Almost always, it is well defined, laser-like.
5. Almost always, it is long, spreading out without fading to the edge of the screen.
6. Almost always, it obliterates the A-lines.
7. Almost always, it is hyperechoic.



B Lines :Interstitial Alveolar Syndrome





B Lines :Interstitial Alveolar Syndrome

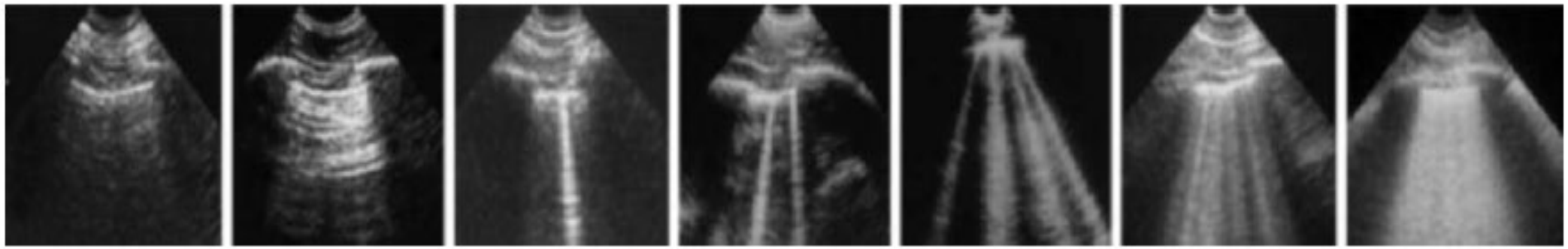
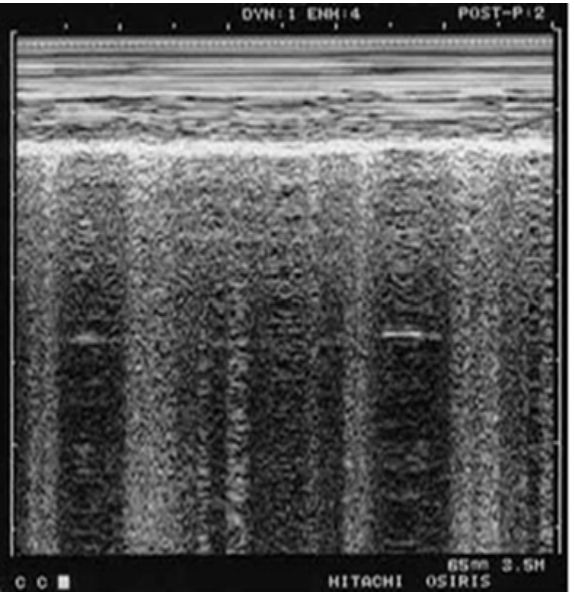


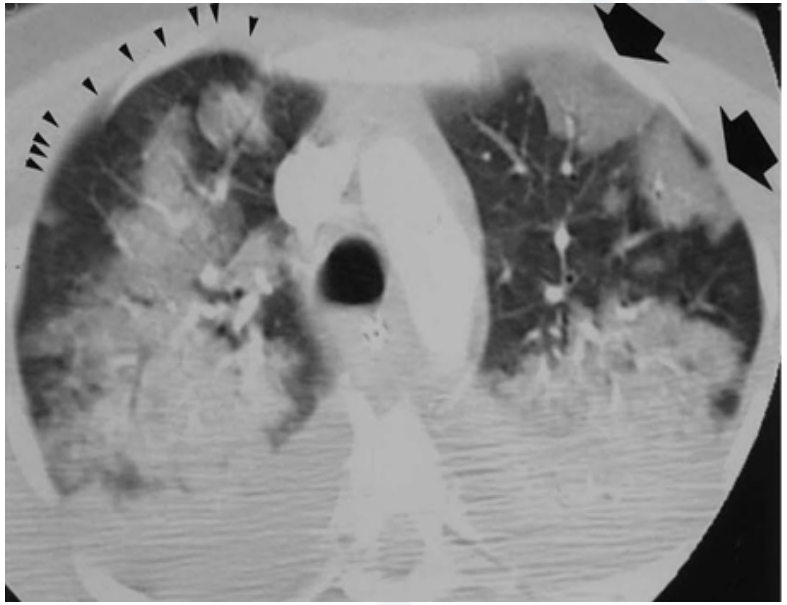
Fig. 12.2 From no B-line to countless B-lines, a continuum. This figure shows, from *left* to *right*, an O-line then an A-line, then a b-line then a bb-line. Then follow three types of lung rockets: septal rockets, ground-glass rockets, then the Birolleau variant (countless B-lines)

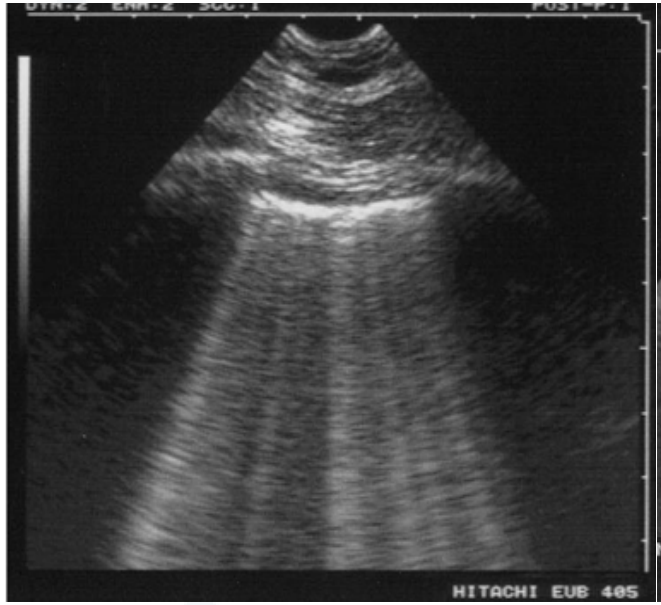
Physiopathologic Meaning of the B-Lines

3 mm: intralobular septa thickening GGO
7mm : interlobular septa thickening Kerely B lines

The presence of B Line rull out PTX







The Birolleau Variant
Countless B Lines

Physiopathologic Meaning of the B-Lines

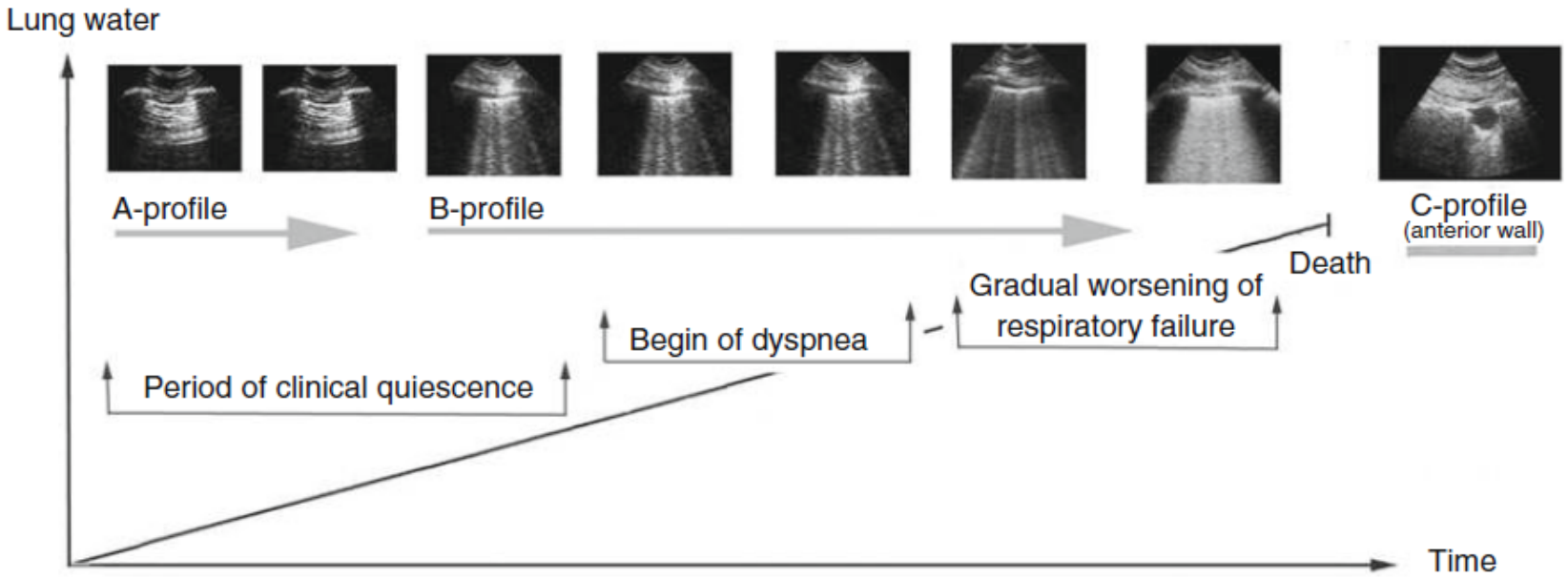


Fig. 24.1 Ultrasound dynamic of pulmonary edema. This figure shows the relative independency between clinical status and ultrasound changes. With worsening of the disease, the lung ultrasound artifacts make sudden changes whereas the clinical worsening makes regular changes. In this figure, the first clinical signs appear once a B-profile is present. In other words, ultrasound allows to anticipate the clinical signs of edema. Mostly, this figure shows that patients with the same ultrasound profile (the B-profile) can have a wide range of clinical presentations, from quiescence to acute respiratory failure. This diagram also highlights the hypothesis that the C-profile is unlikely in hemodynamic pulmonary edema and should occur only at a very late stage (if occurring)

Physiopathologic Meaning of the B-Lines

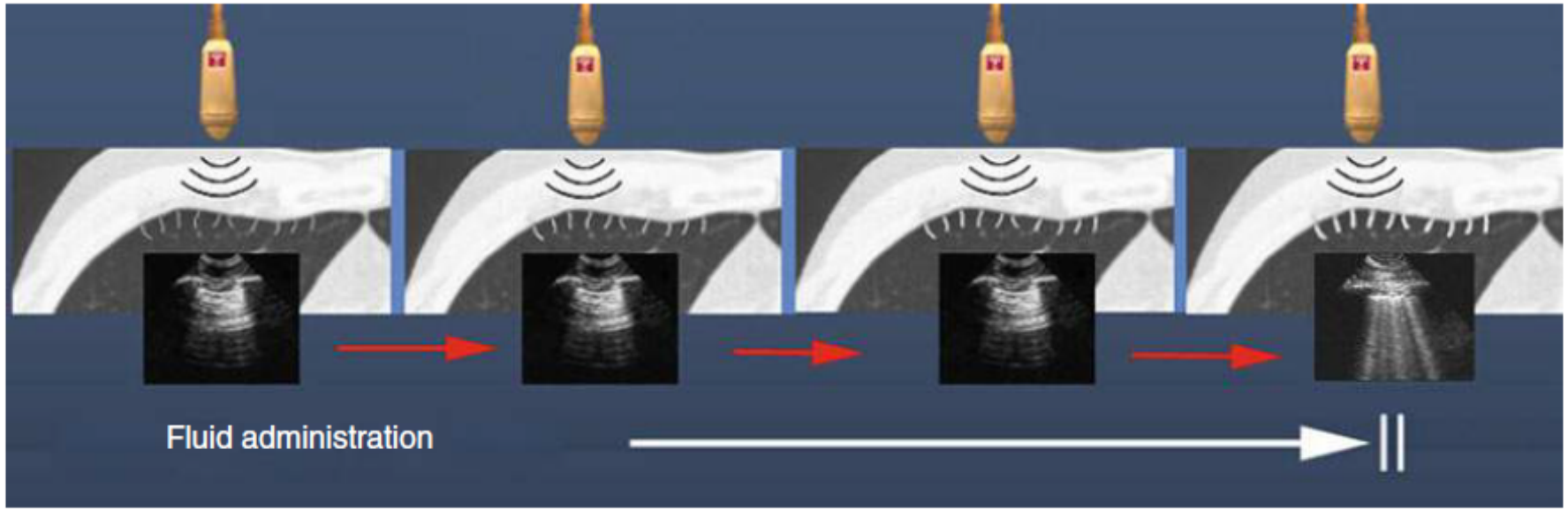
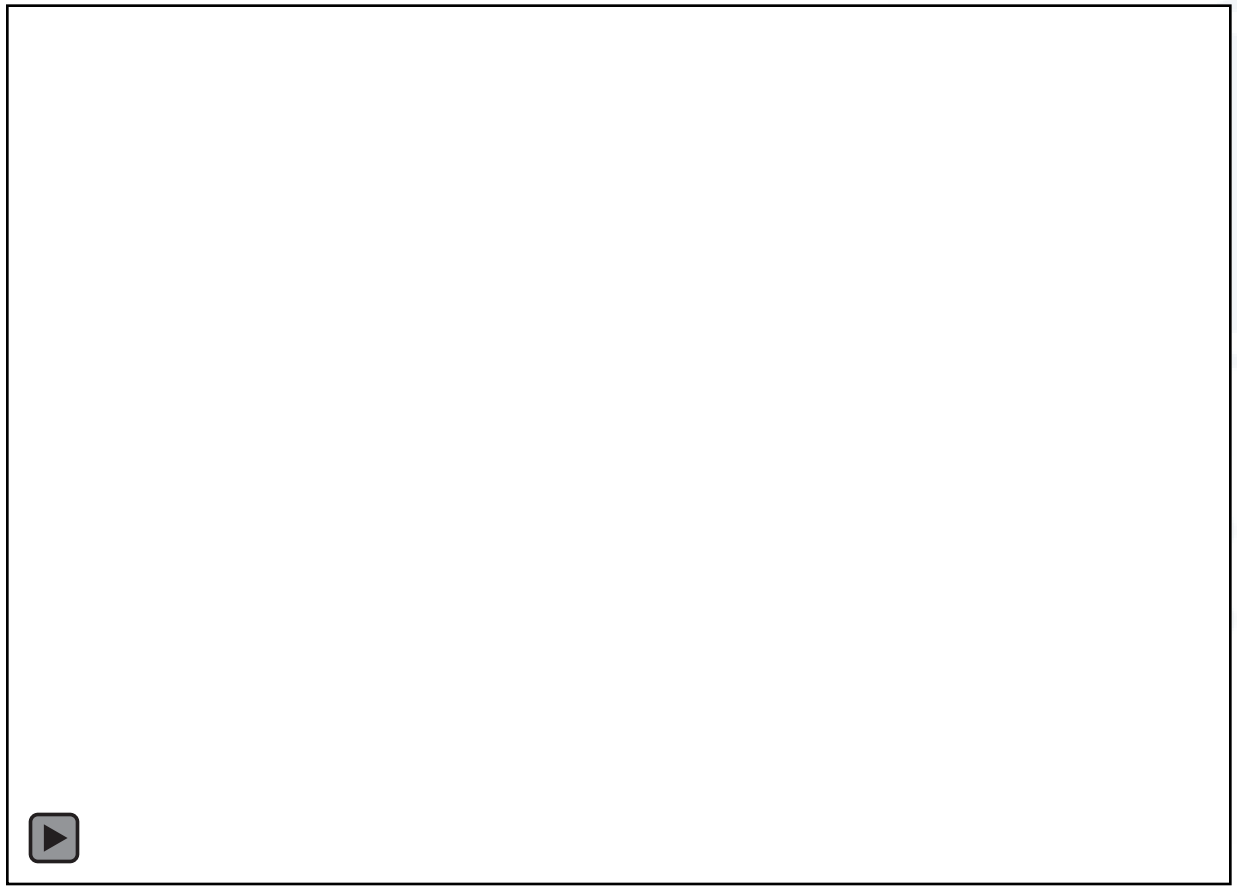
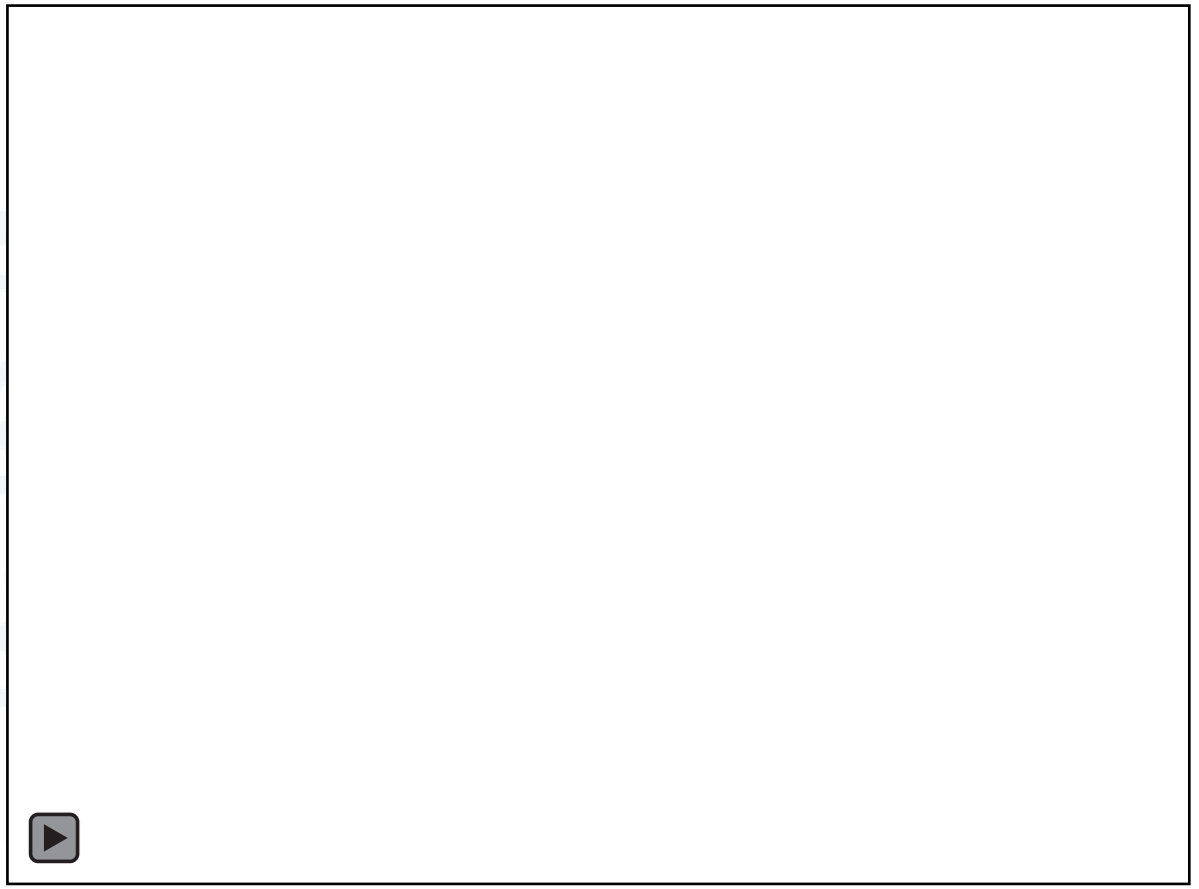


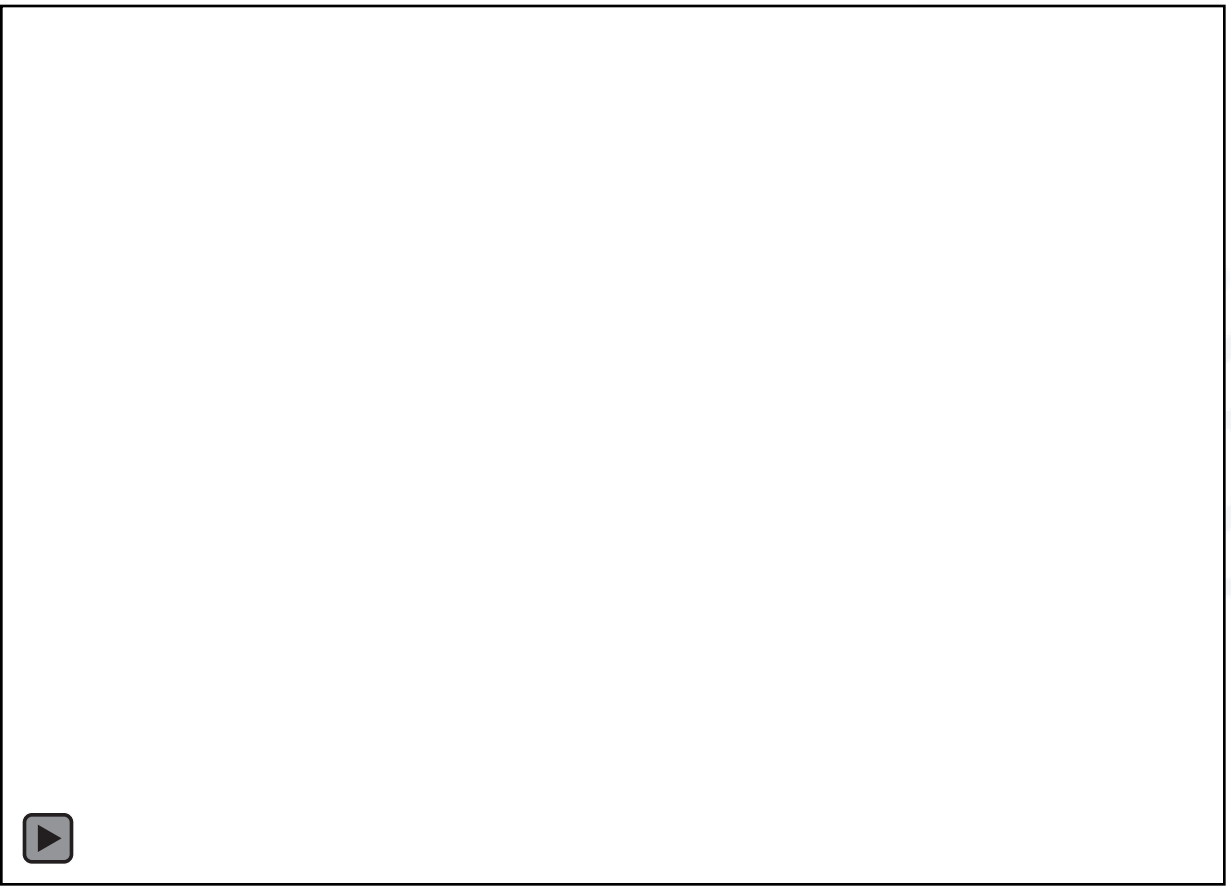
Fig. 30.2 The concept of the swelling septa. Fluid therapy under sonographic control. On the left image (lung CT), subpleural interlobular septa are drawn. Fine, they yield A-lines. Under fluid therapy, on the second and third steps, one can see the septa regularly thickening, without ultrasound change. At the last, right step, from a very level of septal edema, the lung artifacts suddenly become B-lines (here, lung rockets). At this level, we witness a fluid overload at the early, silent step. We see also, of high importance, that whereas the septa gradually enlarge, the artifacts suddenly go up from state A to state B, at a precise threshold. Here, at the fourth step, the PAOP has just reached the value of 18 mmHg: Enough fluid was given. The two vertical lines symbolize the practical action of the FALLS-protocol: discontinuing fluid therapy. This is a dichotomous rule: only A-lines or B-lines have been described, with no intermediate step

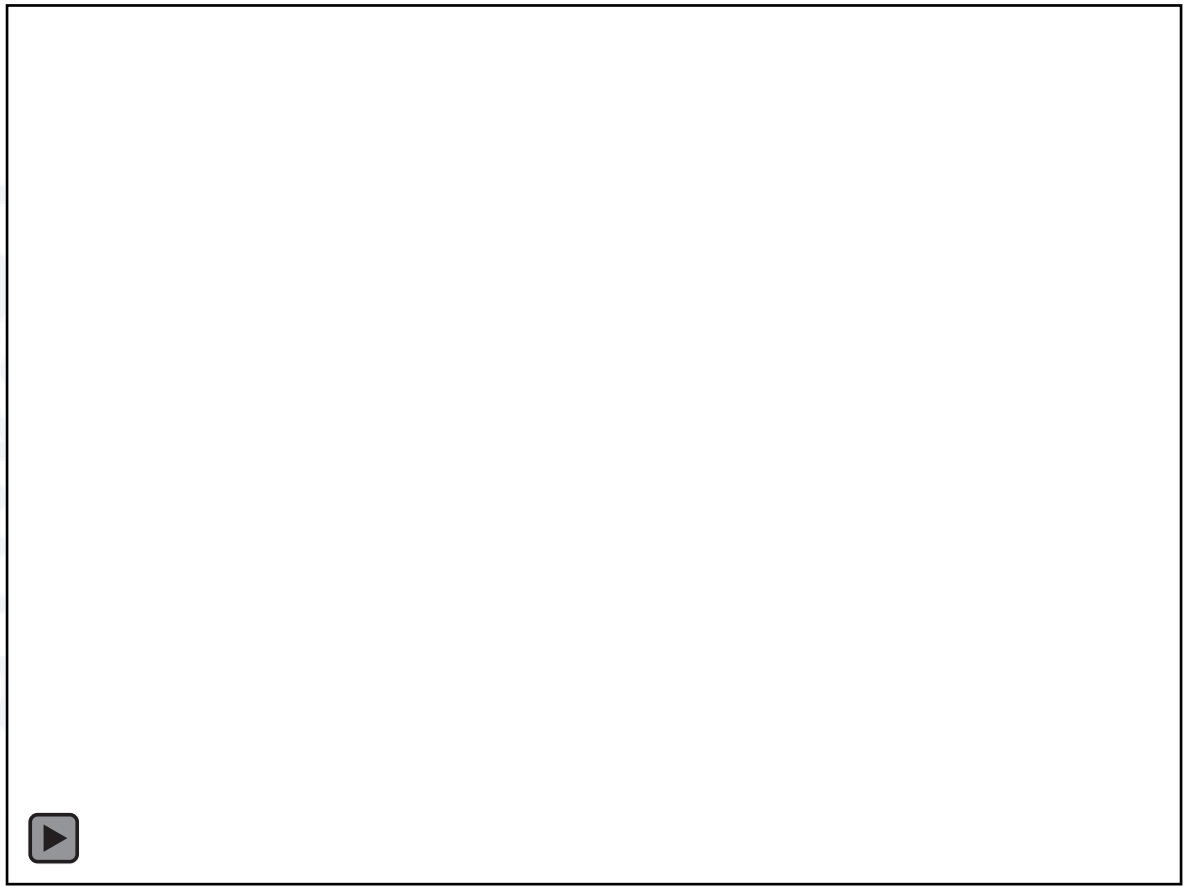
Lung sliding –B lines -Minimal effusion diaphragmatic movement is visible





Lung sliding –Multiple B lines
Both signs rull out PTX





- Represents thickened subpleural interlobular septae surrounded by air-filled alveoli.
- The more B lines and the closer they are together, generally signifies a more severe involvement of the interlobular septae and progressive alveolar involvement.

Differential Diagnosis

- ARDS, cardiogenic pulmonary edema both interstitial and alveolar, pneumonia, lung contusion, interstitial lung disease.
- Multiple anterior and symmetric B lines: Generally signifies cardiogenic pulmonary edema.
- Asymmetric B lines interspersed with normal areas of A lines: noncardiogenic edema/ARDS, pneumonia(Fig.87.5).

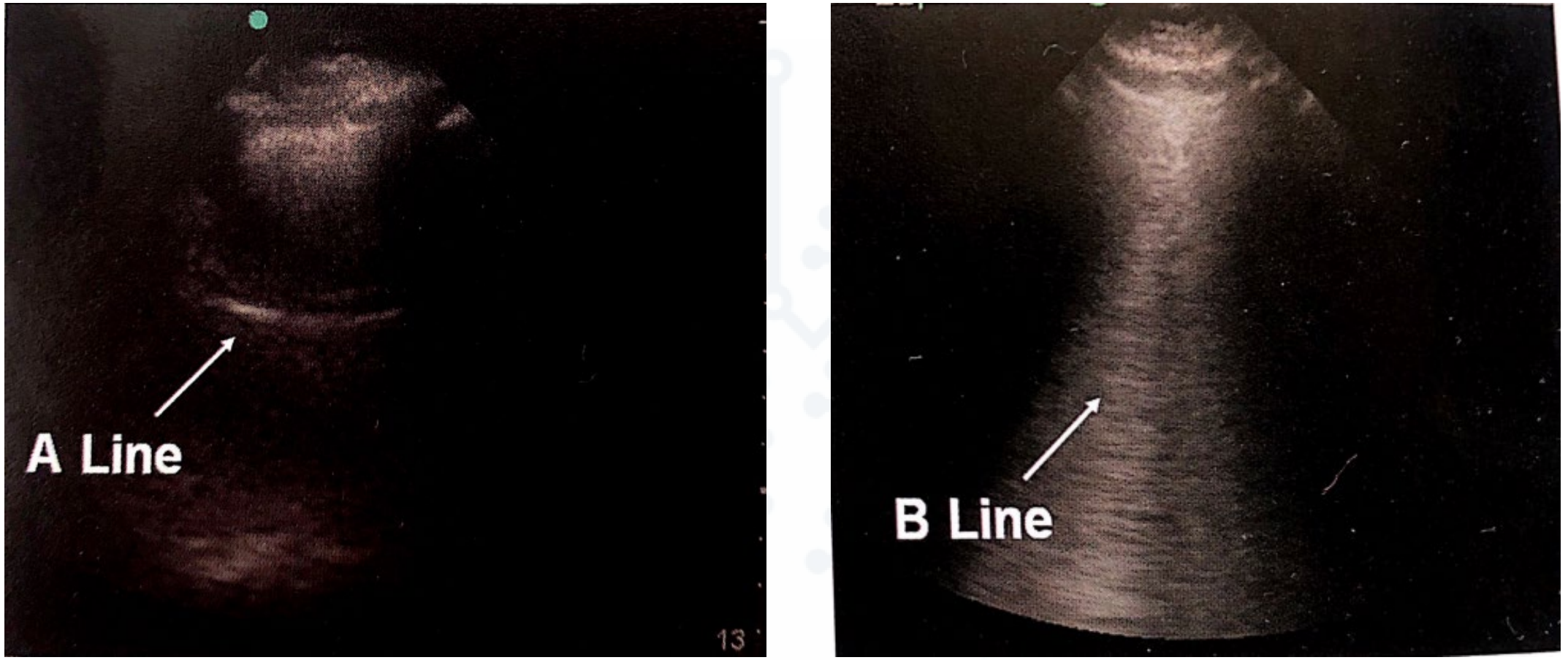


Figure 87.5. A lines, created by reflections of the pleural line, are equidistant horizontal lines (left).B lines are dominant, bright vertical lines that move with the pleura, extend to the bottom of the screen, and represent thickened, fluid-filled interlobular septae (right).

- Air bronchograms may be seen in the consolidated lung.

- They appear as a hyperechoic artifact which moves with respiration and represents the movement of air within bronchi of the consolidated lung, suggesting pre-served patency of the proximal airway.

- Dynamic air bronchograms can differentiate pneumonia (present) from simple atelectasis (absent).

Differential Dx

- Atelectasis, pneumonia, ARDS, tumor or mass, lung contusion.

Pleural Effusion

Characteristics

- Pleural fluid is anechoic (black) on ultrasound.
- Most effusions are free flowing and so the patient should be positioned to optimize the view.
- Ultrasound can detect very small pleural effusions, before they are seen on a CXR.
- There should be at least 1 cm of pleural fluid before an attempt at thoracentesis is performed.
- Ultrasound of pleural fluid reveals it to be dynamic, meaning there is movement with respiration.

- It is always important to define the boundaries of the pleural fluid:

- The boundaries of the pleural space consist of the chest wall, the diaphragm, and the lung.

- This is a routine but extremely important component of pleural ultrasound, to avoid misidentifying the diaphragm and confusing it with the perirenal fascia.

- Misidentification of the diaphragm can result in major injury if a thoracentesis is attempted with resultant subdiaphragmatic injury to the liver or spleen.

- **Fluid characteristics:**

- **Simple fluid is anechoic.**

- **Exudates may not be anechoic and may have what appears to be swirling debris within the fluid (plankton sign)**

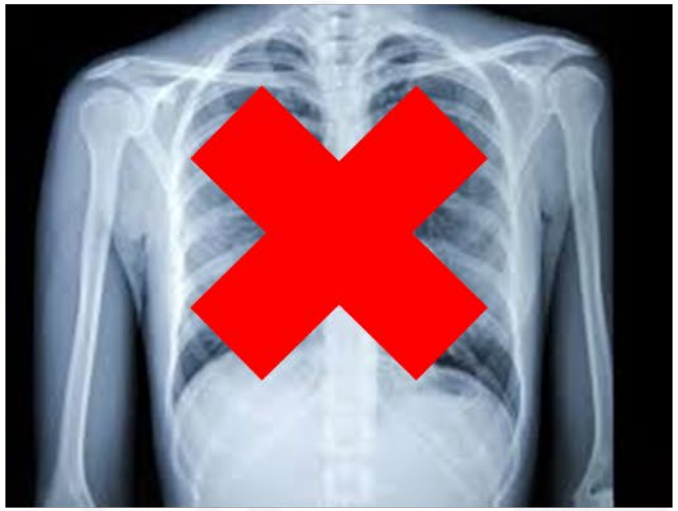
- **Complex effusions may have multiple fibrous strands and septations within the effusion which are often not seen with CT.**

  - **This may signify loculation of the fluid and could be due to a parapneumonic effusion, empyema , or a resolving hemothorax (Fig.87.6).**

3. Diagnosing the cause of ARF

Sens 37%
Spec 89%

SCIENTIFIC REPORTS | (2020) 10:7347



Sens 49%
Spec 92%

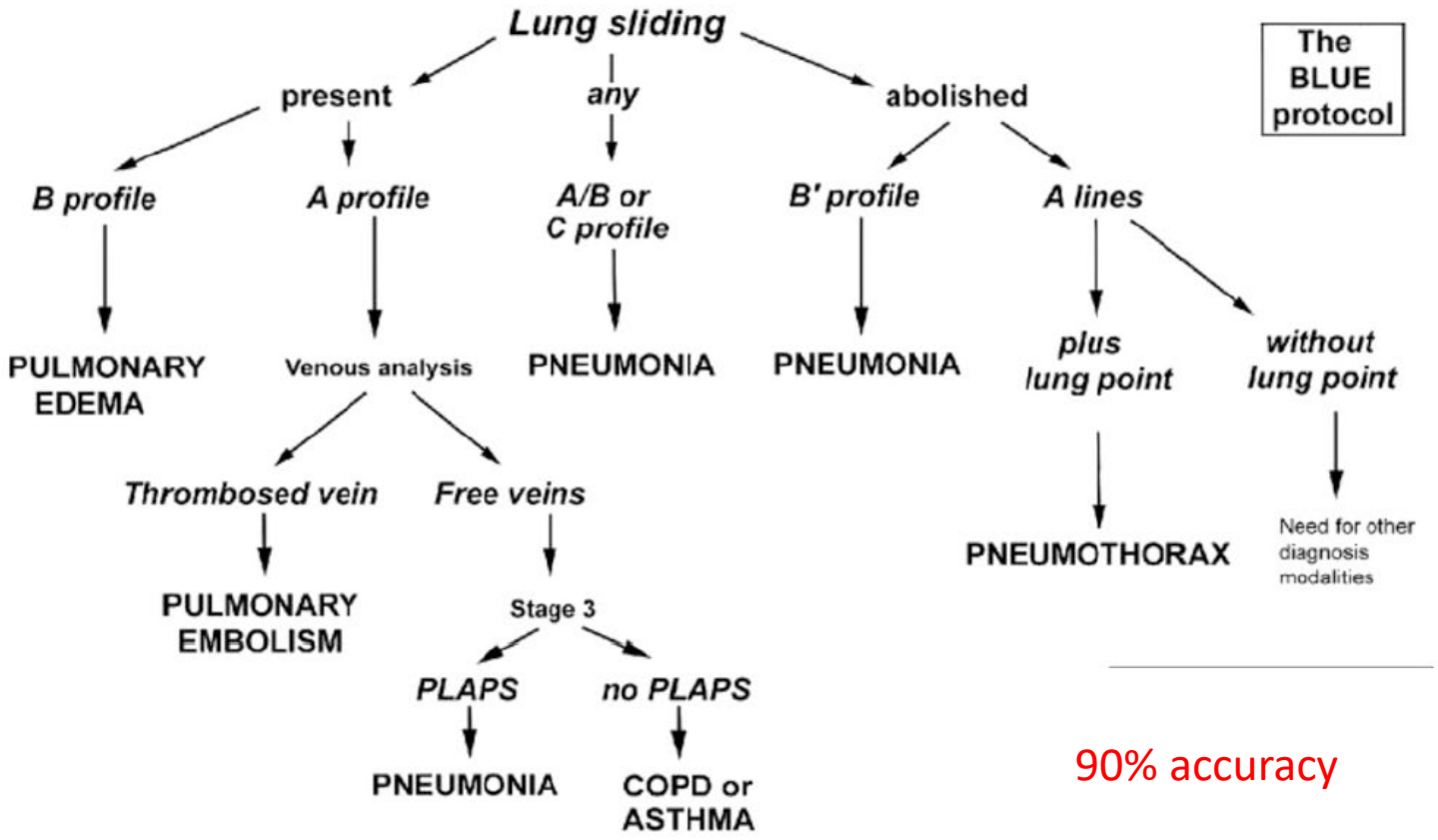
Crit Care Med 2018; 46:e707–e714

Sens 95%
Spec 94%

Crit Care Med 2018; 46:e707–e714

3. Diagnosing the cause of ARF

Ultrasound 'ingredients':
Lung sliding
A, A/B, B, C profile
Lung point
Veins
PLAPS



90% accuracy

FIGURE 7. A decision tree utilizing lung ultrasonography to guide diagnosis of severe dyspnea.

CHEST 2008; 134:117-125;

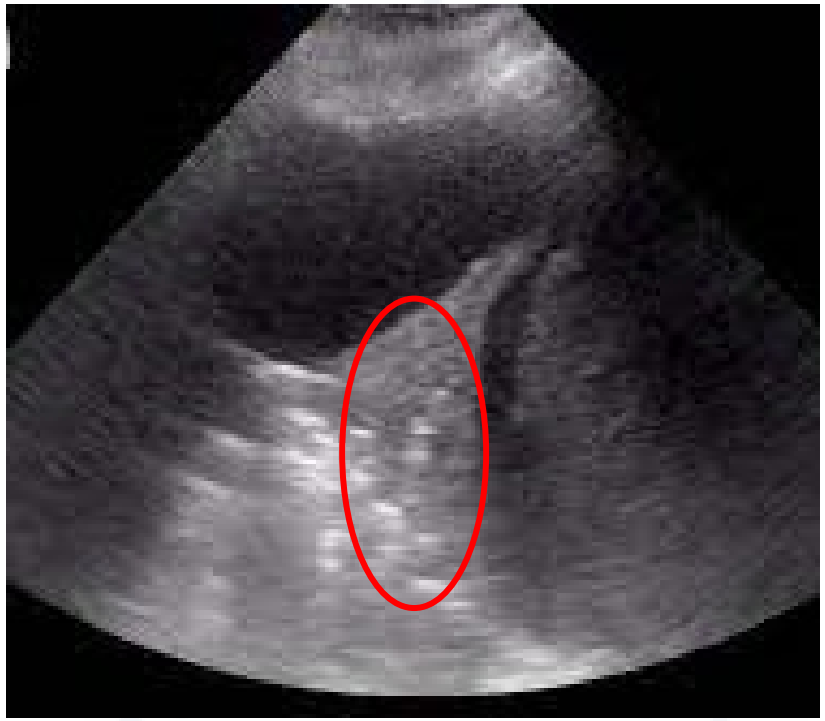
3. Advanced ‘ingredients’ for diagnosing cause of ARF

ARDS vs CPE

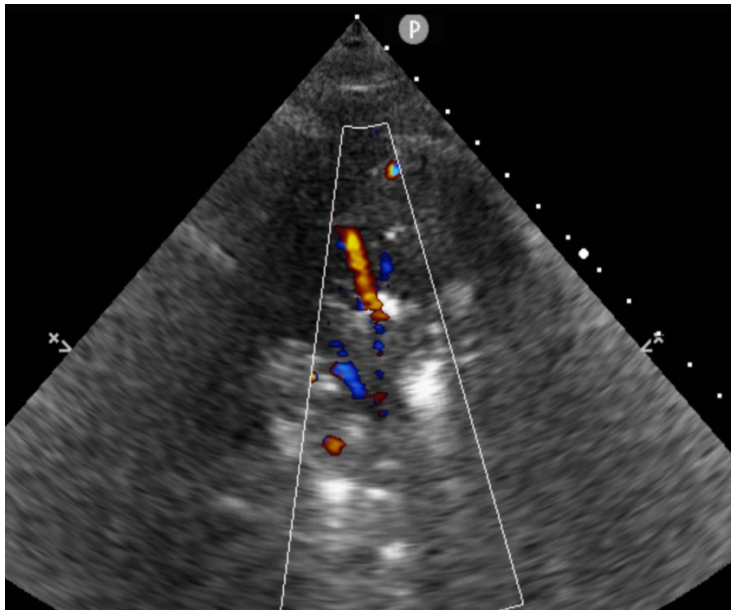
Pleural line abnormalities

Pneumonia vs Atelectasis

airbronchogram



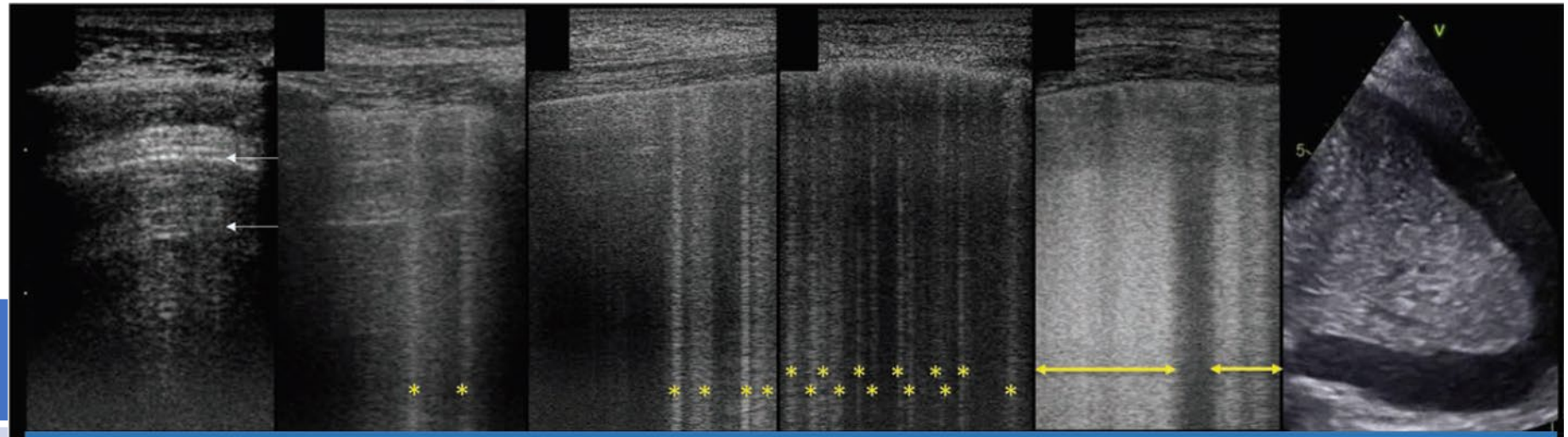
Doppler



Heldeweg et al. Submitted for publication; Haaksma et al Crit Care Med 2021

3. Monitoring lung aeration

Setting/Patients
Hemodialysis Heart failure ILD
ICU: VAP, recruitment, ARDS

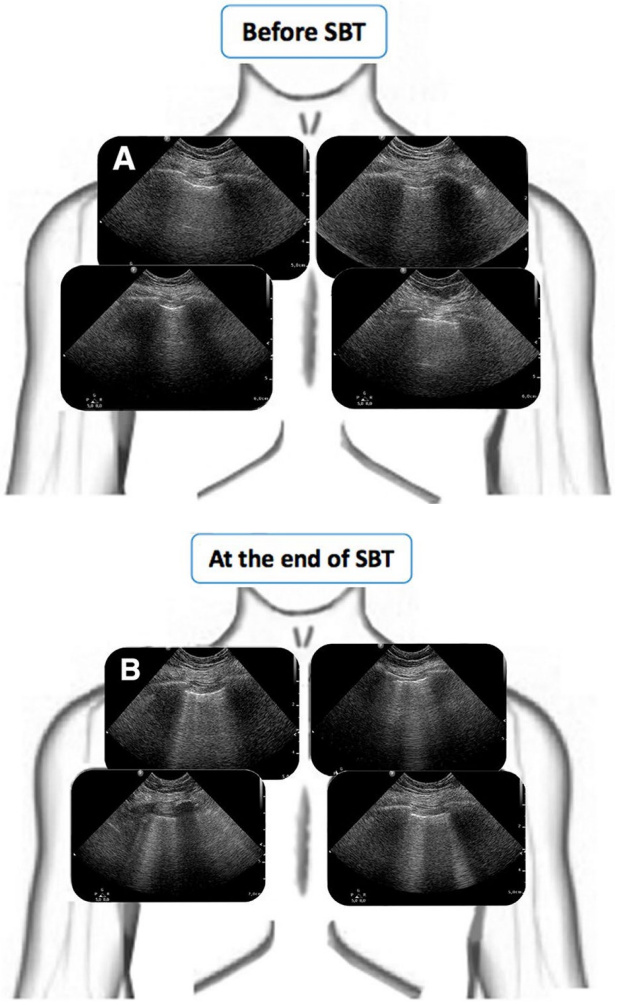


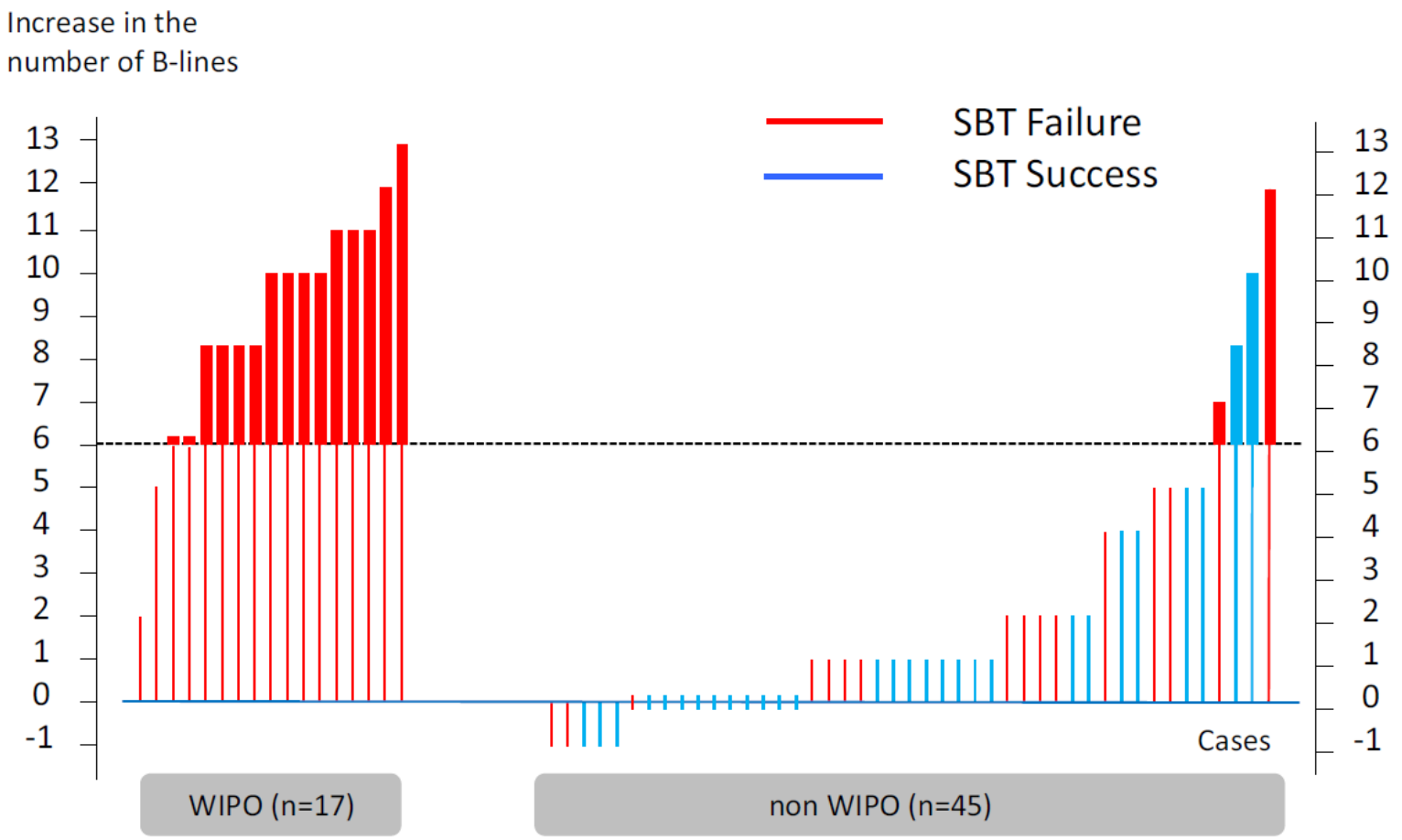
B-lines score					
0	2	4	7	9	-
Lung Ultrasound score					
0	0	1	2	2	3

Anesthesiology June 2021, Vol. 134, 949–965; Intensive Care Med 2020 Mar;46(3): 544-545

4. Predicting weaning success:

Weaning-induced pulmonary oedema (WIPO)





Intensive Care Med 2019 May; 45(5): 601-608

In summary

1. Use a simple machine; lung setting for artifacts; goal of scanning→ choice of probe
2. Start with longitudinal scanning
3. For diagnosing: 6-8 views and BLUE-protocol

   For monitoring:

   - (6-)28 view using B-lines score (normal ward/outpatient clinic)
   - (6-)12 views using Lung Ultrasound Aeration Score (ICU)
4. For weaning: 4 views and calculate Delta B-lines (≥6 associated with WIPO)

List of references

1. Mojoli et al. Am J Respir Crit Care Med 2019 Mar 15;(6):701-714
2. Heldeweg et al. Intensive Care Med 2021 Jun 26;1-3
3. Lichtenstein et al. CHEST 2008; 134:117-125
4. Winkler et al. Crit Care Med 2018; 46:e707-714
5. Mongodi et al. Anesthesiology 2021 Jun 1;134(6): 949-965
6. Haaksma et al. Intensive Care Med 2020 Mar;46(3): 544-545
7. Ferré et al. Intensive Care Med 2019 May;45(5):601-608

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Thank You

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