[2023 신입 호흡기 임상강사 워크숍]

Lung Ultrasound in ICU

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Ultrasound imaging

Advantages	Disadvantage
• No radiation • Rapid, Portability • Can assess moving structures (heart) • Non-invasive (patient comfort during test)	• Dependent on operator training • Difficulty in evaluating deep tissues (retroperitoneal vessels) • Sound waves cannot penetrate bone and metal • Gas collections interfere with visualization

→ Unlike other parts of the body, normal healthy lung is not actually visualized on the screen. Instead, the lung tissue is seen as **artifacts**.

Point of care US in ICU

- Ultrasound examination that is performed at the bedside, interpreted directly by the clinician
- **A** (airway) – **B** (breathing) – **C** (circulation)

	Shock/Hypotension	Dyspnea
Airway	**Airway ultrasound** Confirmation of endotracheal intubation Identification of the cricoid membrane for cricothyrotomy	
Breathing	**Lung ultrasound** Pneumothorax Hemothorax, Pleural effusion, Empyema (sepsis), Drainage Pulmonary edema	

	Shock/Hypotension	Dyspnea
Circulation	**Focused cardiac ultrasound** Pericardial effusion/Cardiac tamponade, Drainage Left ventricular systolic function (hypokinesia, hyperkinesia) Right ventricular dilatation/Systolic dysfunction IVC diameter and collapsibility	
	Abdominal ultrasound Hemoperitoneum Abdominal aortic aneurysm Hydronephrosis (sepsis) Acute cholecystitis (sepsis)	
	Leg-vein compression ultrasound Deep venous thrombosis (pulmonary embolism)	
	Ultrasound-guided vascular access Intravenous line placement, REBOA, ECMO	

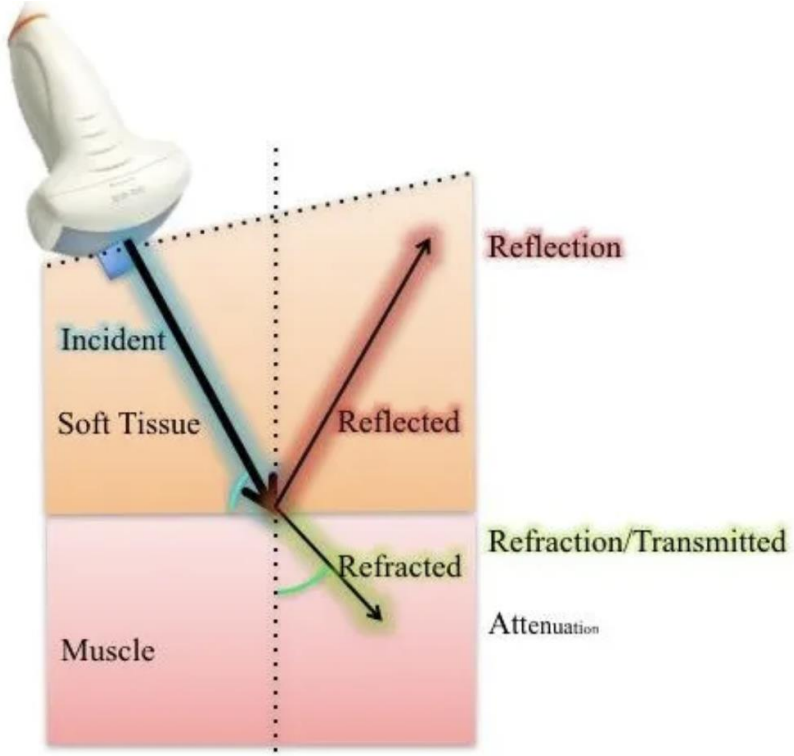
J Korean Med Sci 2020;35(7):e54 /.*Acute Medicine & Surgery* 2020;7(1):e481

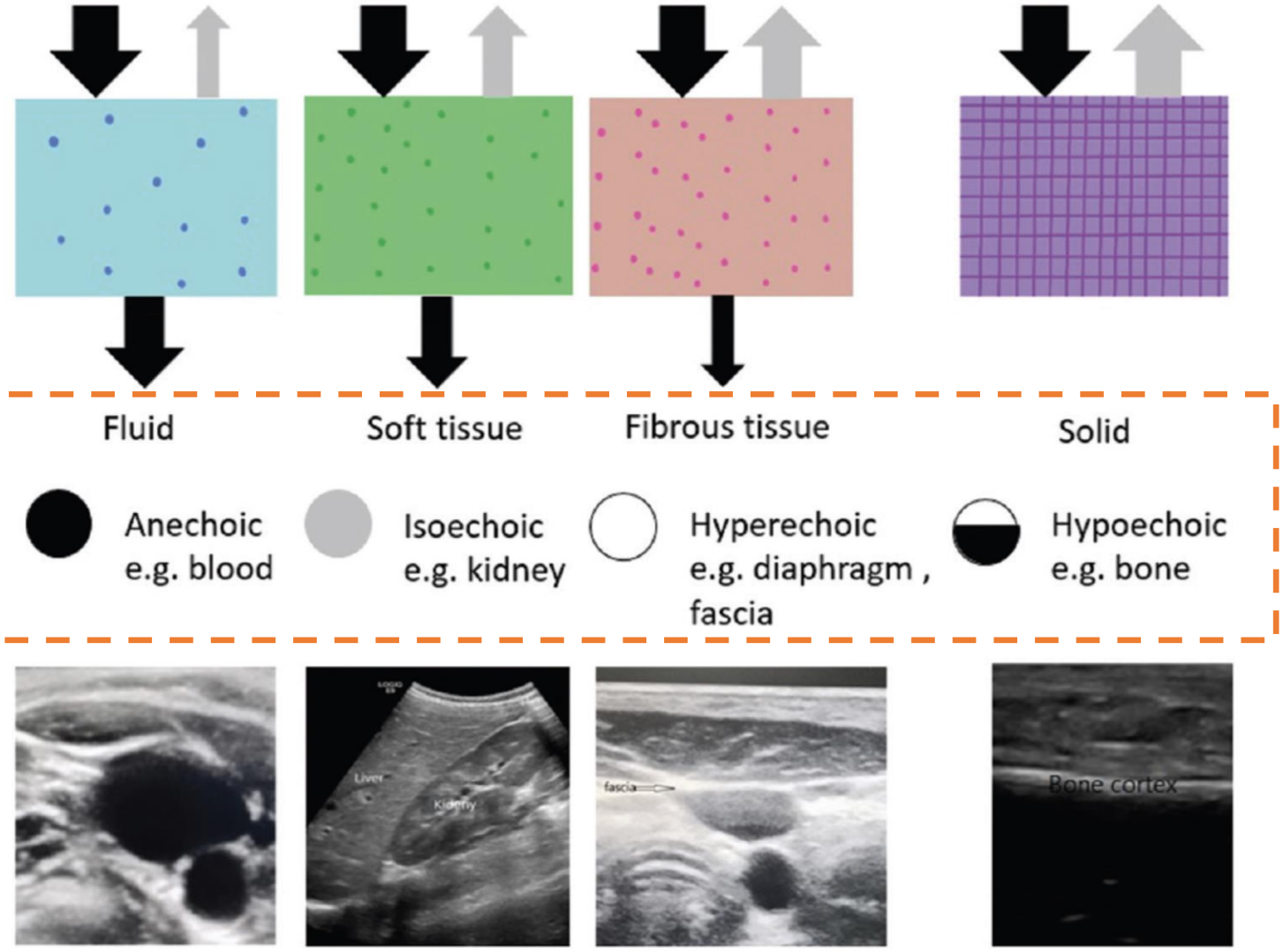
CONTENTS

- Basic principles
- Interpretation of Thoracic US
  - Normal lung findings
  - Injured lung findings
- Respiratory muscle US
- Technique and protocols
  - BLUE protocol (2008)
  - PoCUS in Weaning failure (2020)

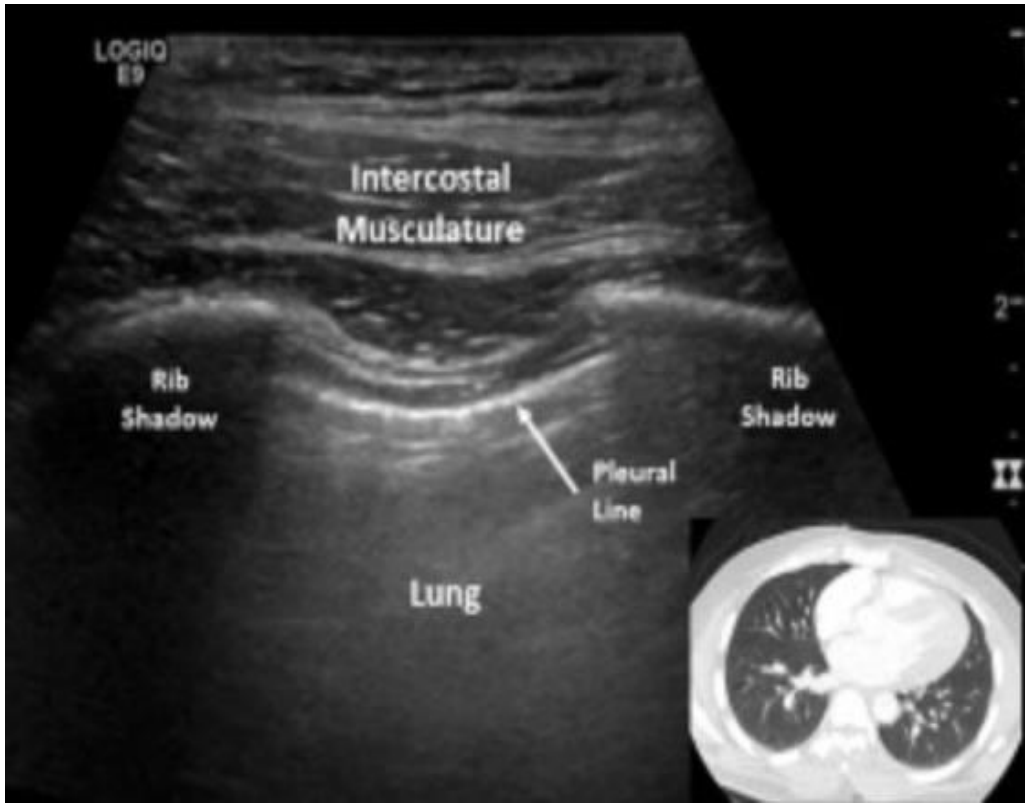
Basic principles

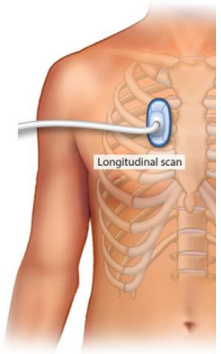
- Echogenicity

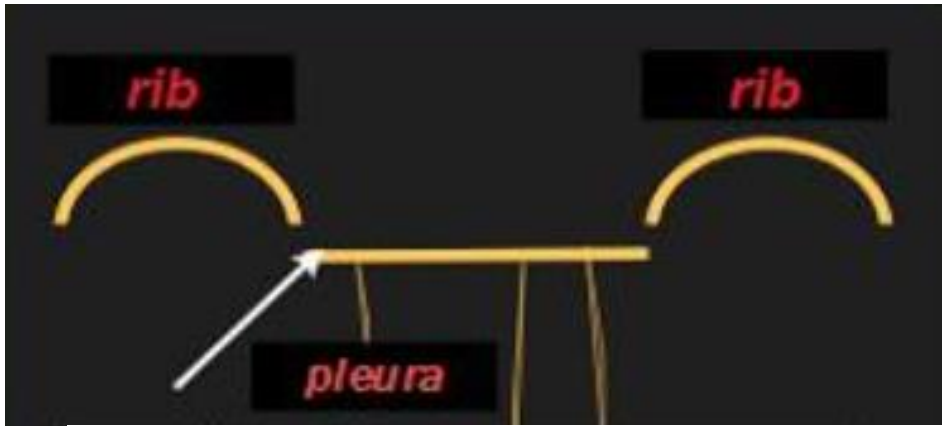


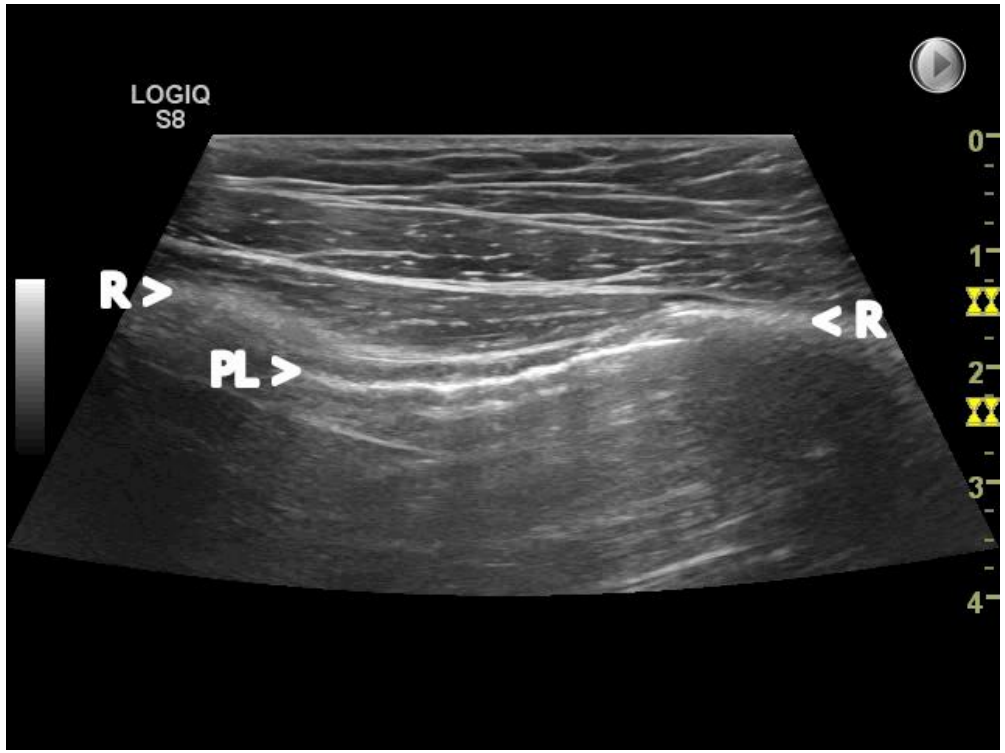


Basic principles





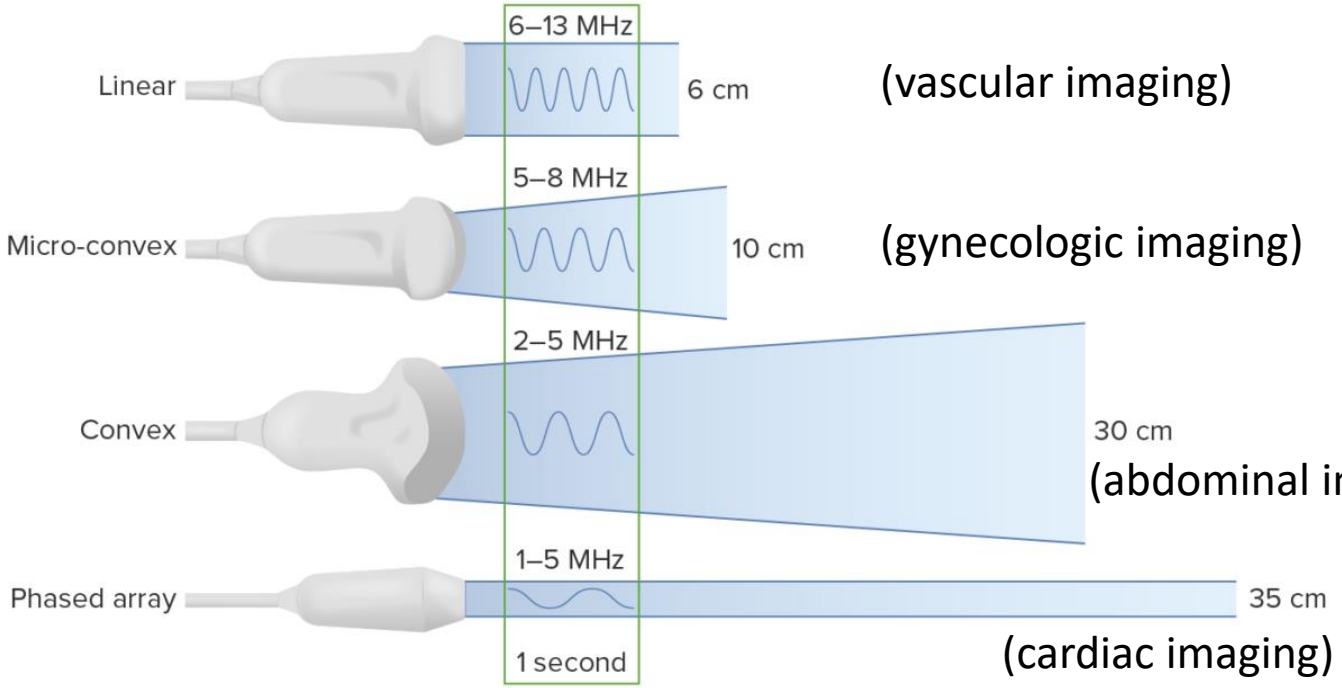




- Rib shadow (bat sign)

Transducer (probe)

- Acts as an emitter and receptor of sound waves
- Types:



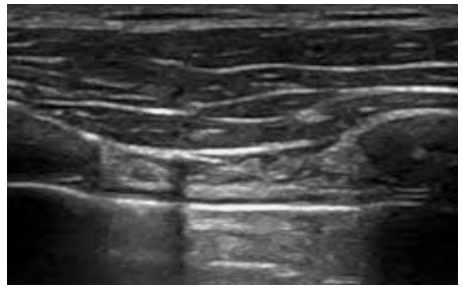
(vascular imaging)

(gynecologic imaging)

(abdominal imaging)

(cardiac imaging)

Low penetration
High resolution

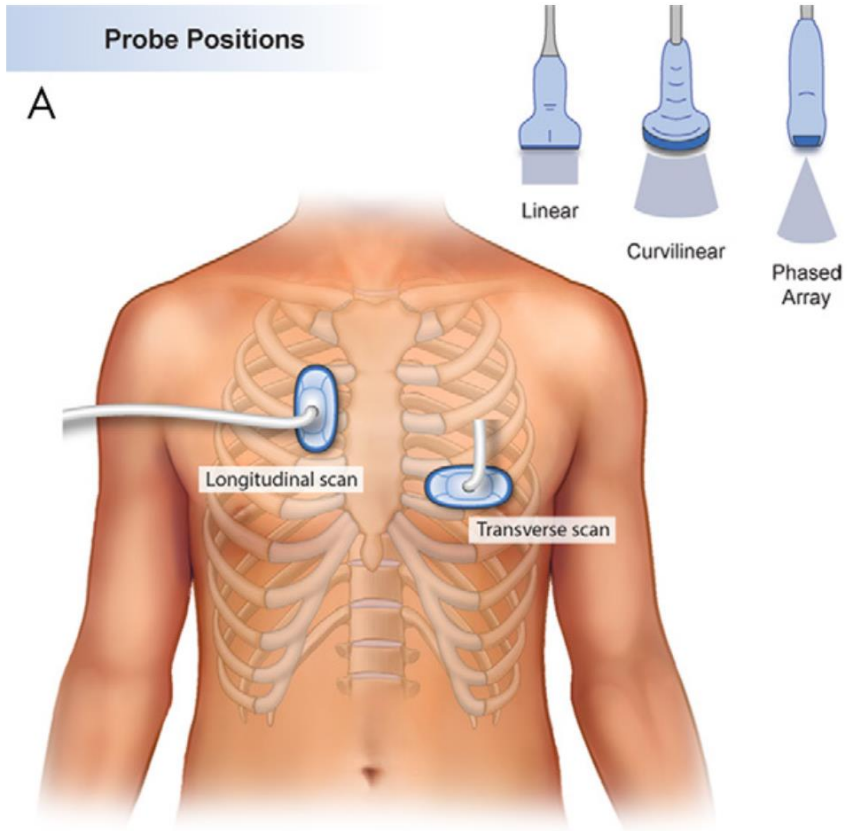


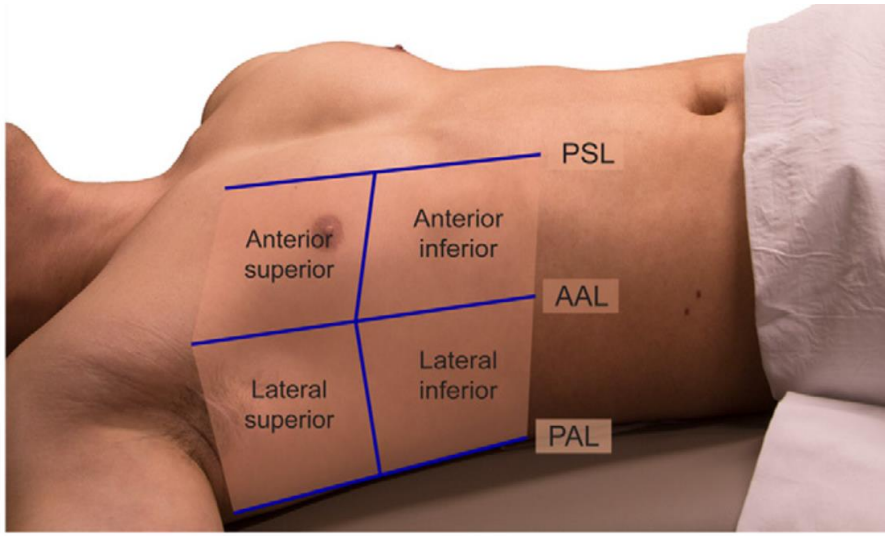
High penetration
Low resolution

(thoracic imaging)

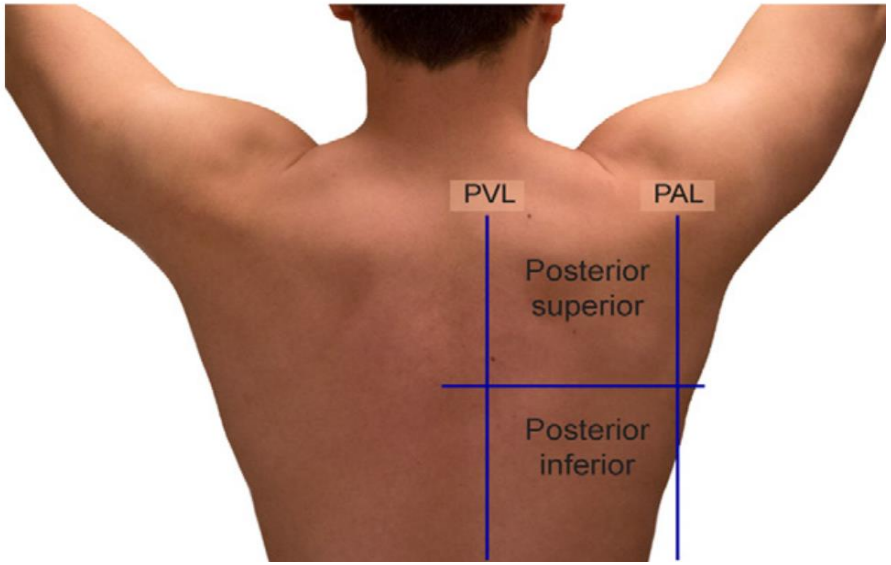
* Low *vs.* High frequency probe / Higher frequencies → detailed image

Probe positions





Anterior
: air (pneumothorax)



Lateral / Posterior
: consolidations and effusions

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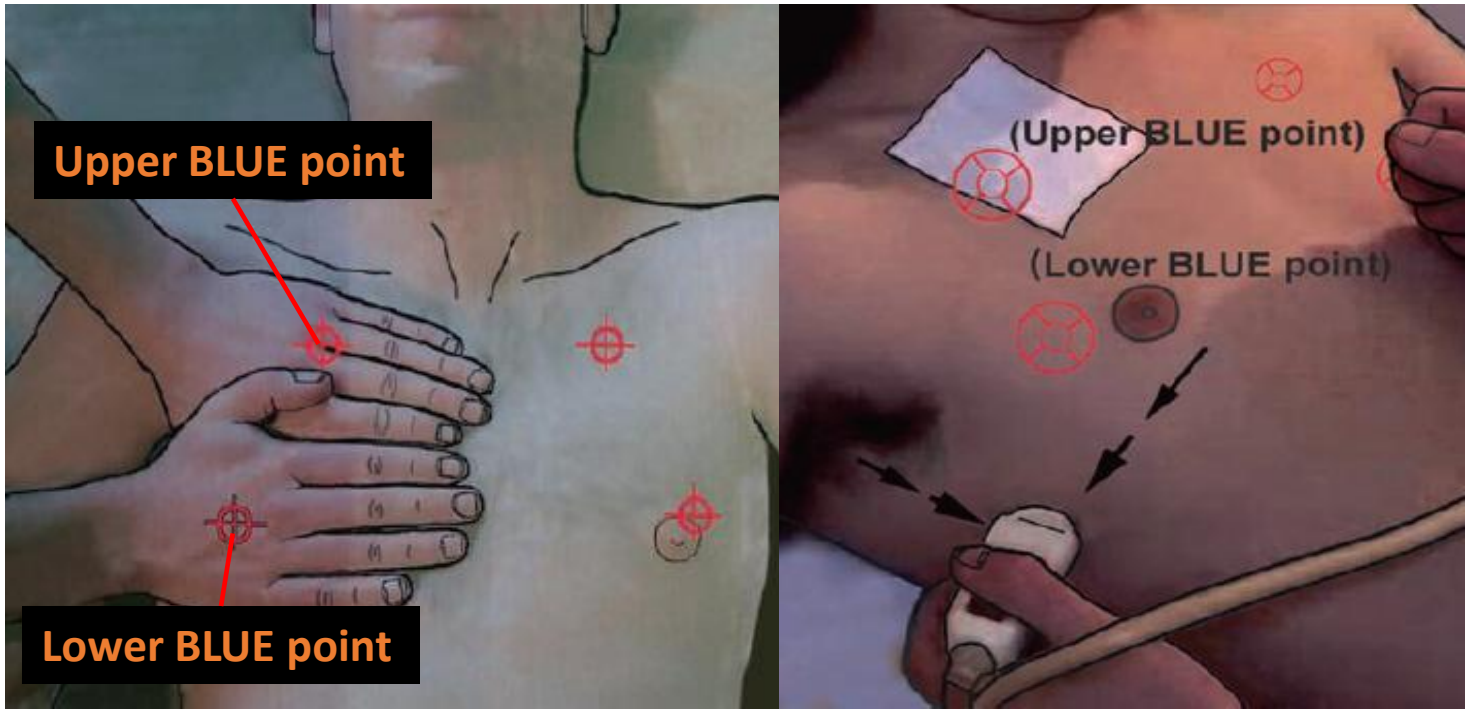
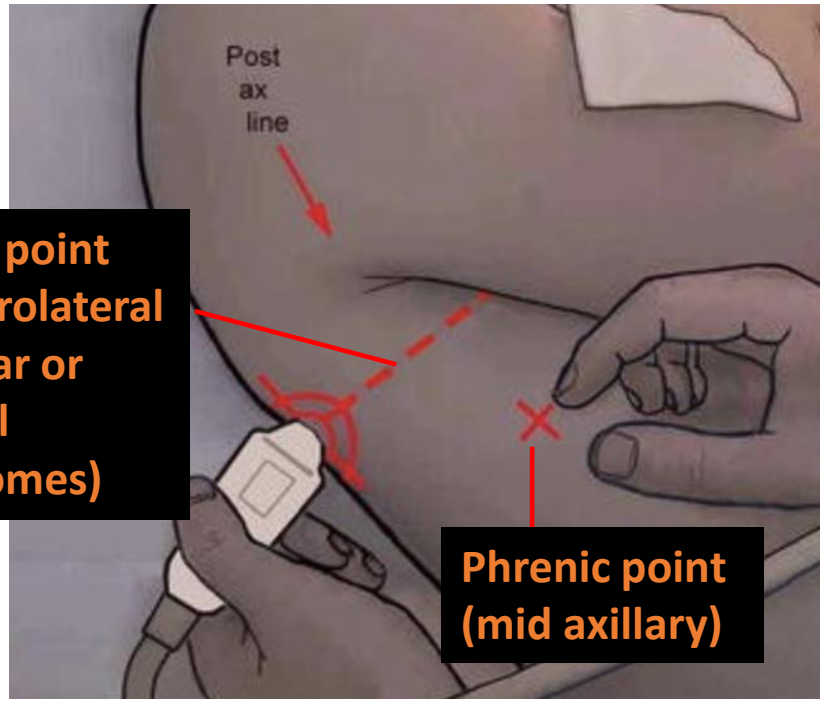
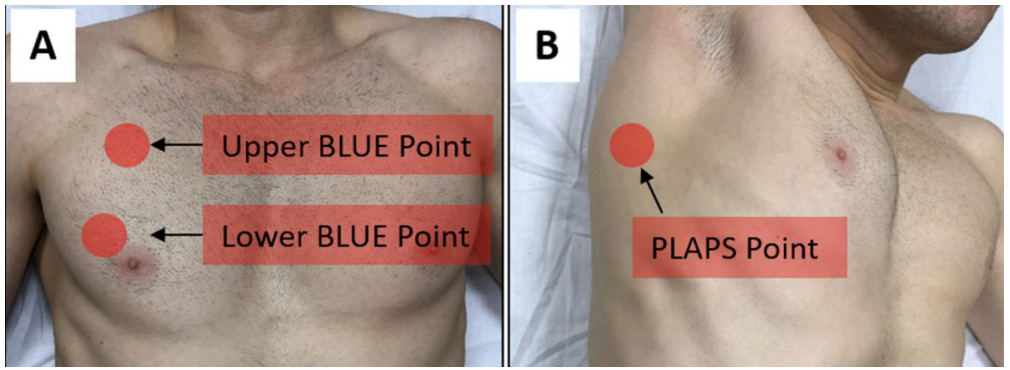
Probe positions: BLUE protocol

- BLUE (Bedside Lung US in Emergency)

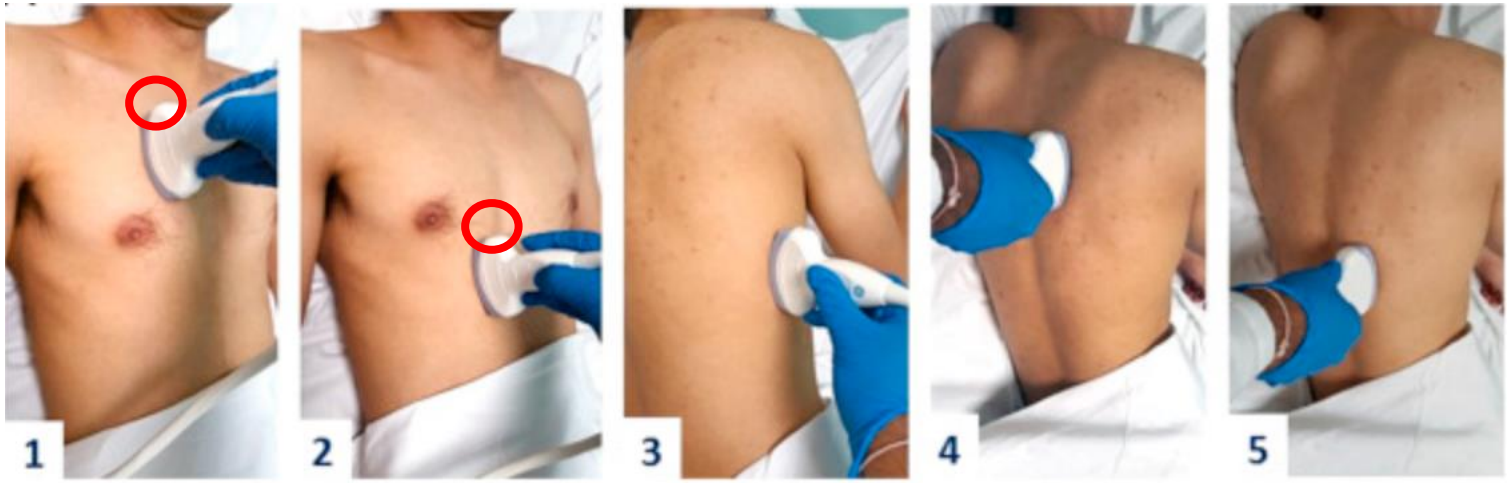




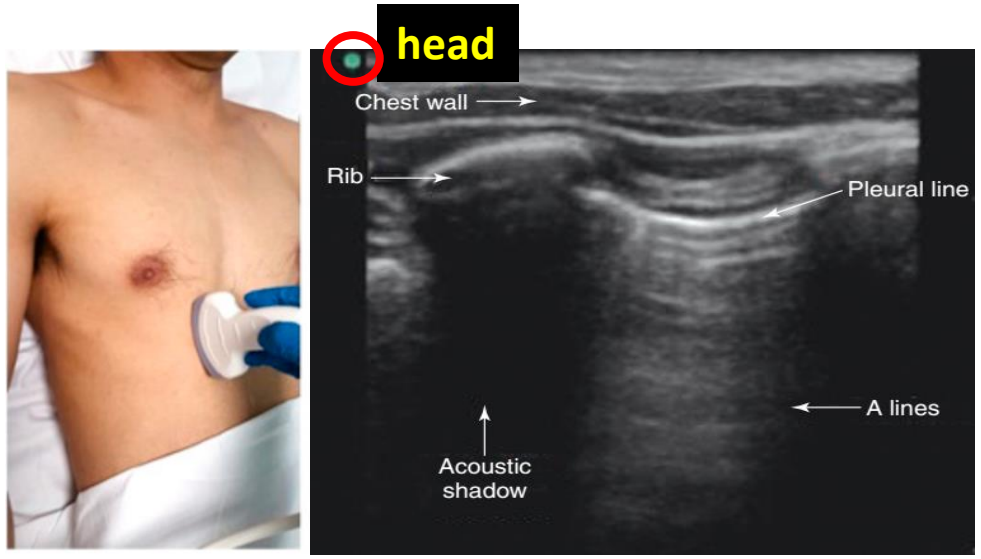


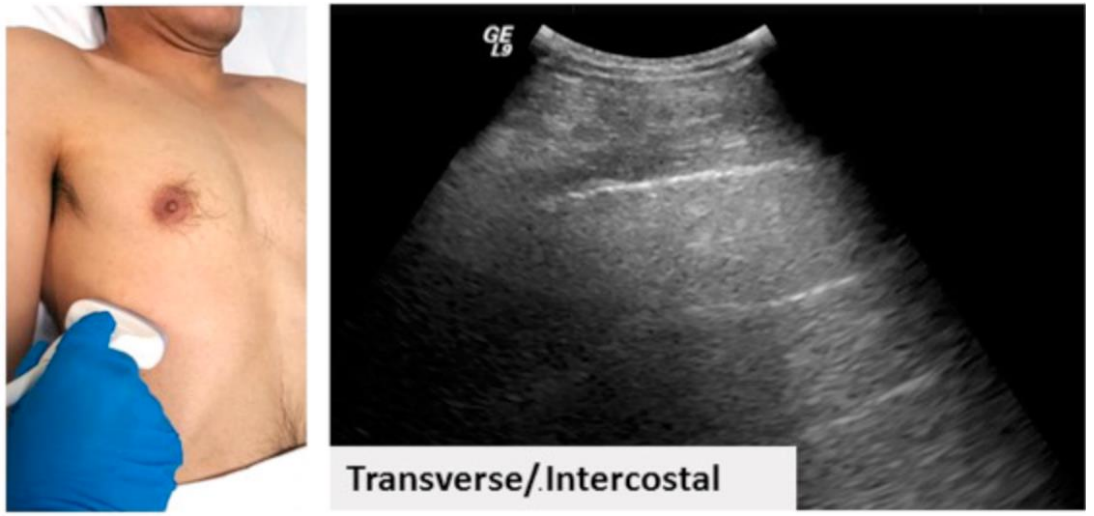
Chest 2008;134:117-125

Probe positions



- Indicator cephalad
- Perpendicular to chest wall → “Rib shadows” confirm position and guide to pleura

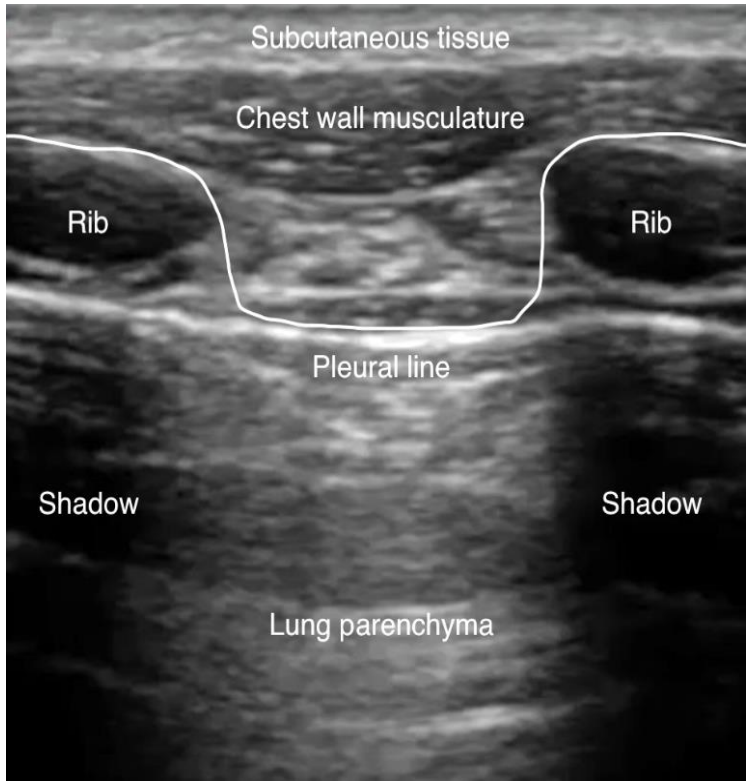


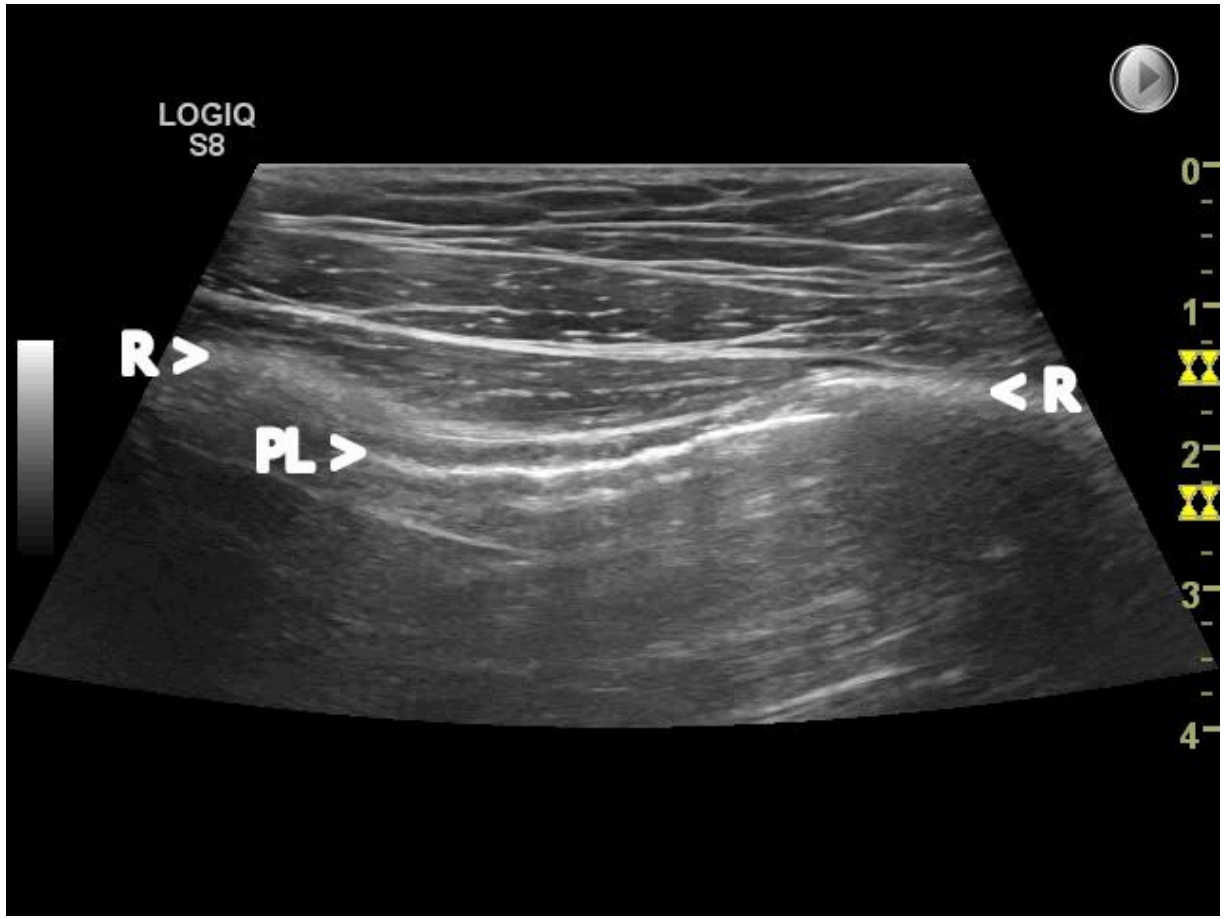


Current Problems in Diagnostic Radiology 2017;46(4):305-316

Normal lung findings: Lung sliding (1)

- Horizontal sliding movements of the visceral pleura with respiration along the parietal pleura

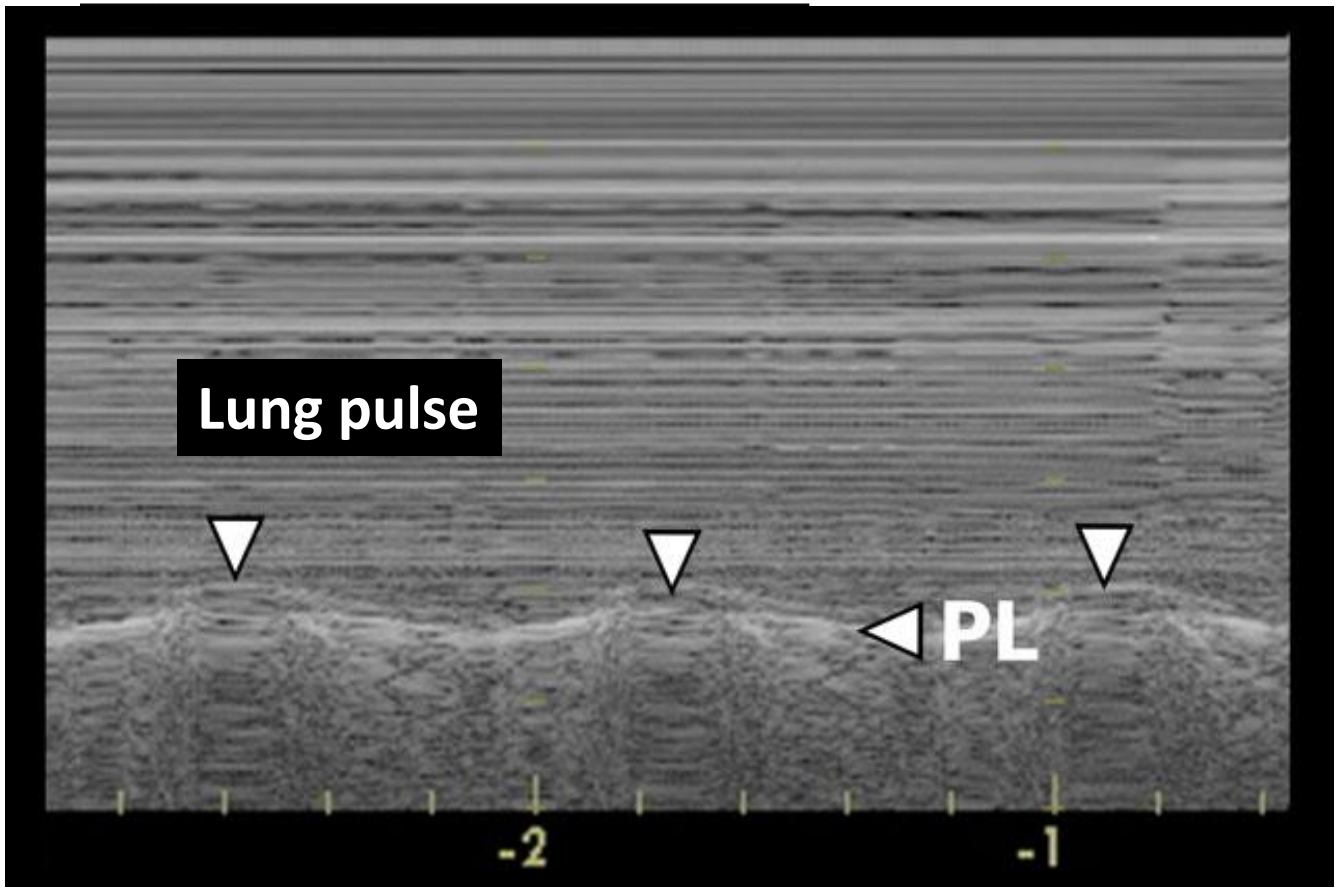




→ **Sliding = both the pleural (visceral and parietal) are in contact !!**

Normal lung findings: Lung sliding (2)

- **Seashore sign** (M-mode)
  - superficial to the pleura
    : horizontal lines
  - deep to the pleura
    : the lung motion
    → **“sandy” pattern**



Radiology: Cardiothoracic Imaging 2021;3(2):e200564

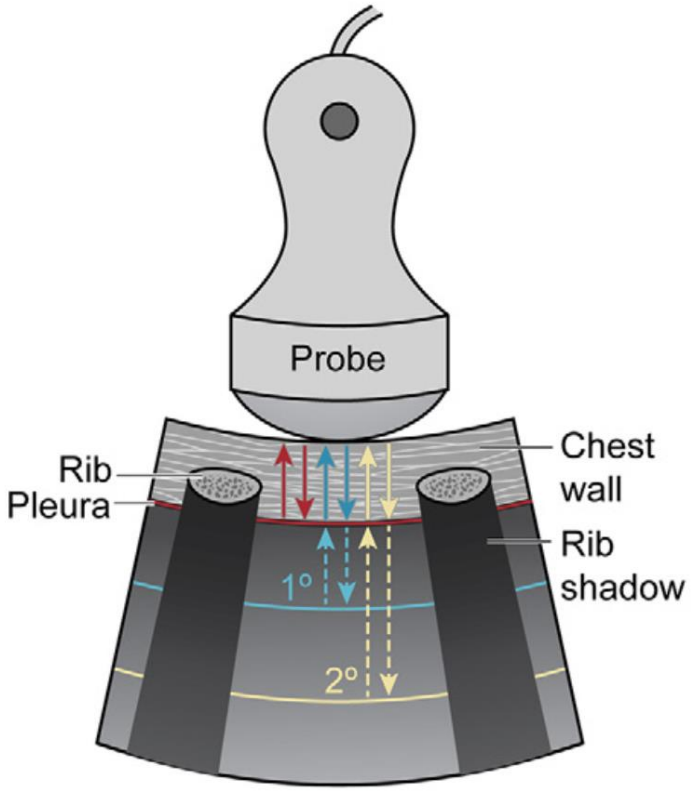
Normal lung findings: A-lines

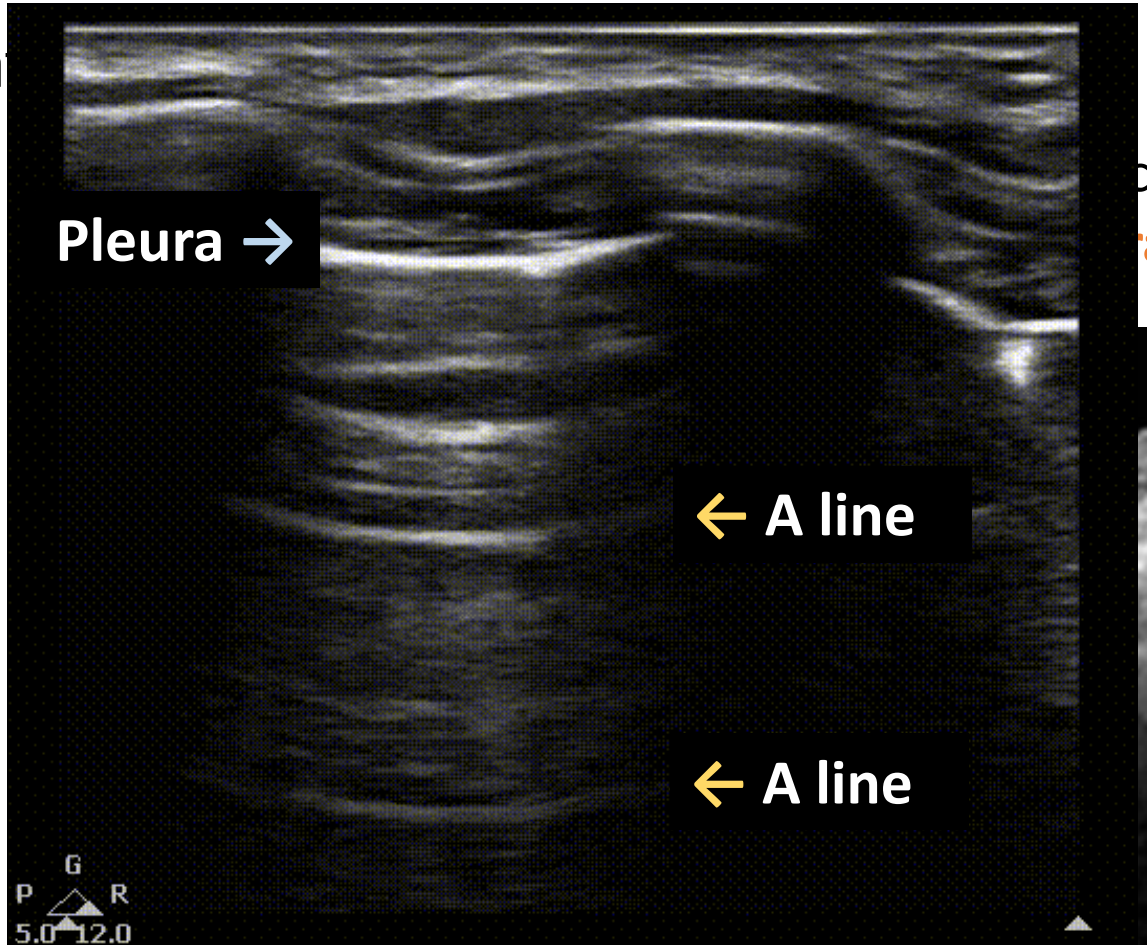
- Reverberation artifact

  : Hyperechoic horizon

ce from skin to pleura

rated lung !!





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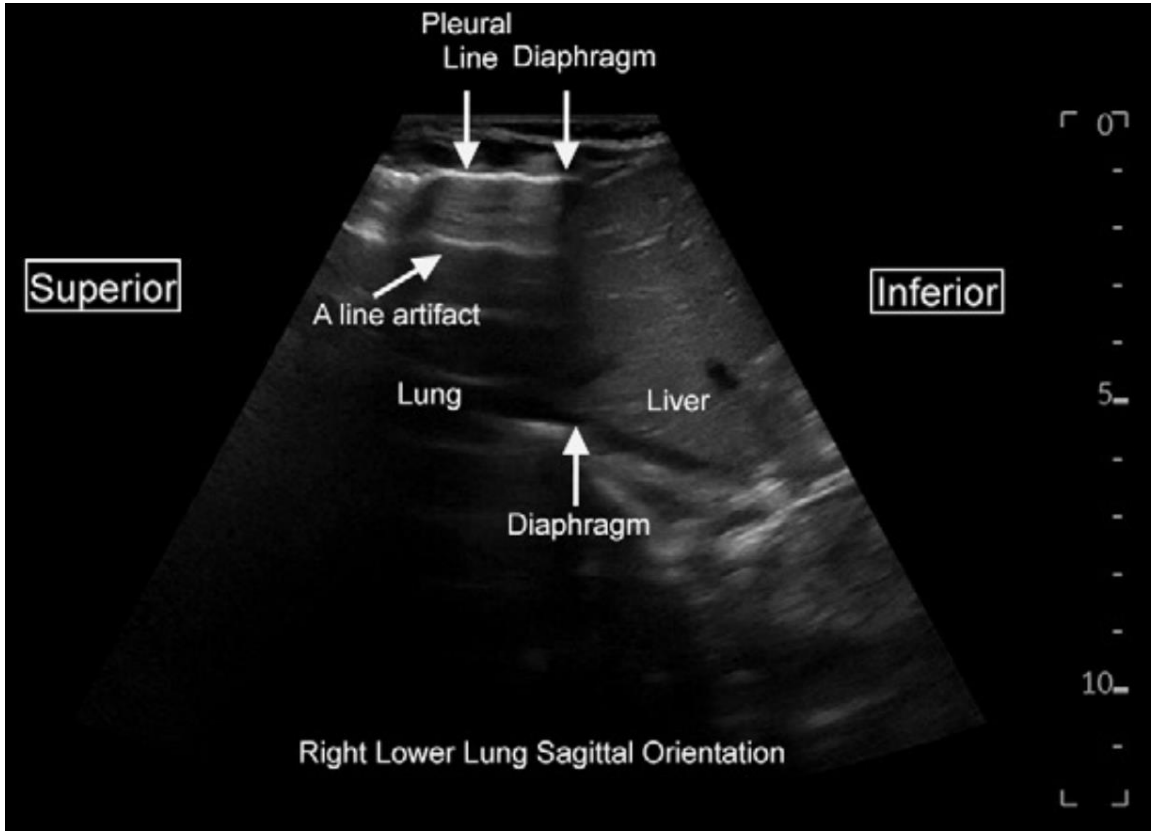
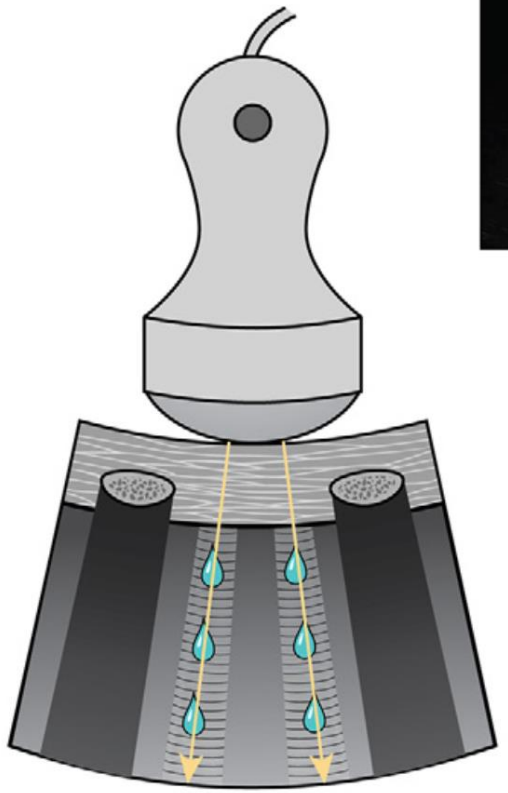
Normal lung findings: Curtain sign

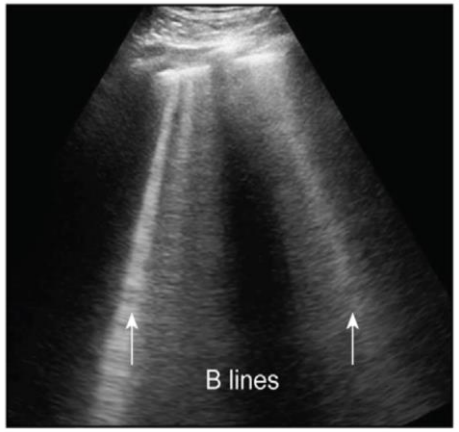
- the inferior aspect of the lung field,
  - the costophrenic recesses
  - the peripheral lung bases

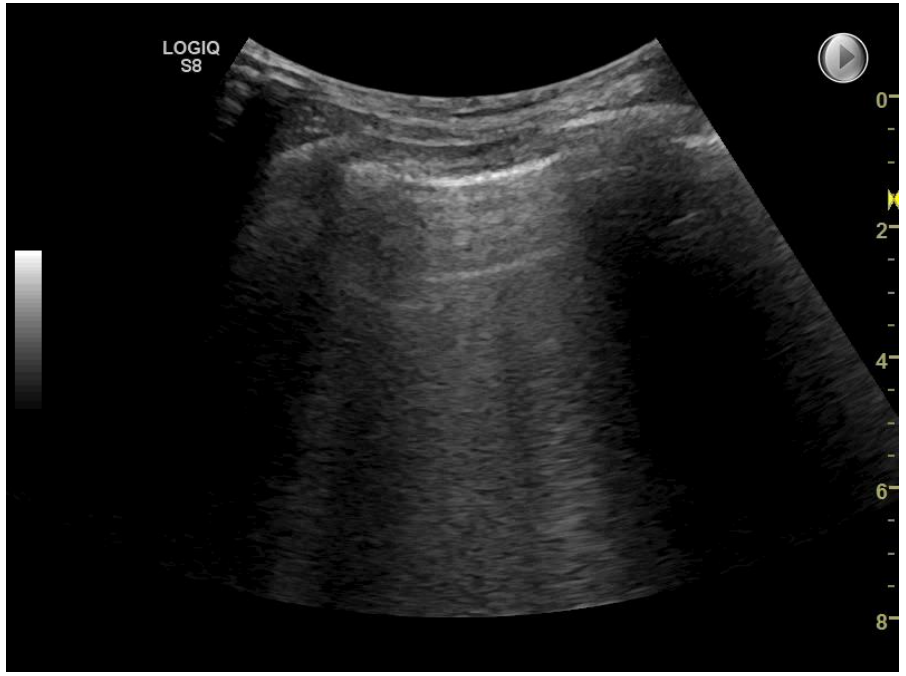


Journal of Medical Ultrasound 2017;25(2):101-104
Radiology: Cardiothoracic Imaging 2021;3(2):e200564

Abnormal lung findings: B-lines (1)







- Arise from pleura
- Hyper-echoic vertical line
- Erases, or obliterates the A-lines
- Move with respiration

- **More than three B-lines** is indicative of increased density
  → **"B sign", "B pattern"**

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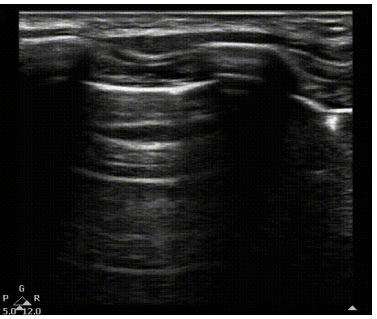
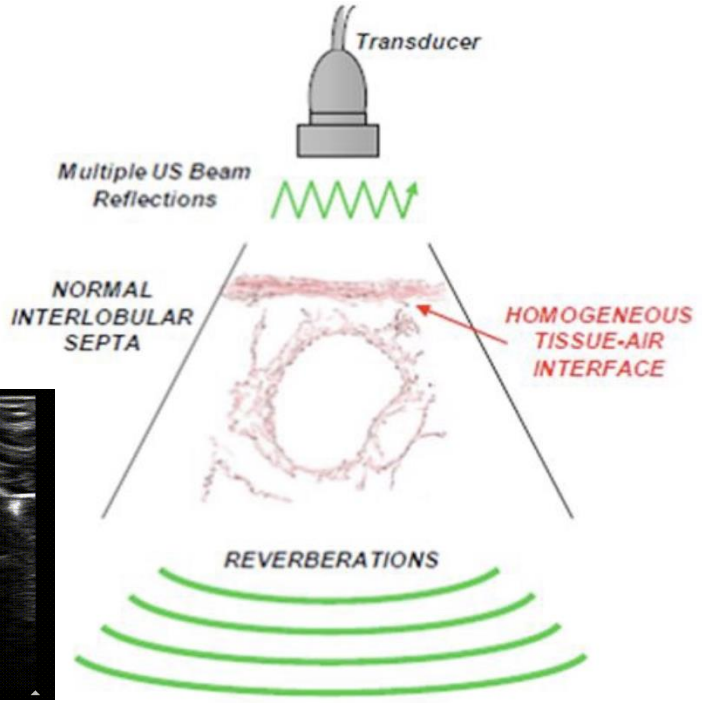
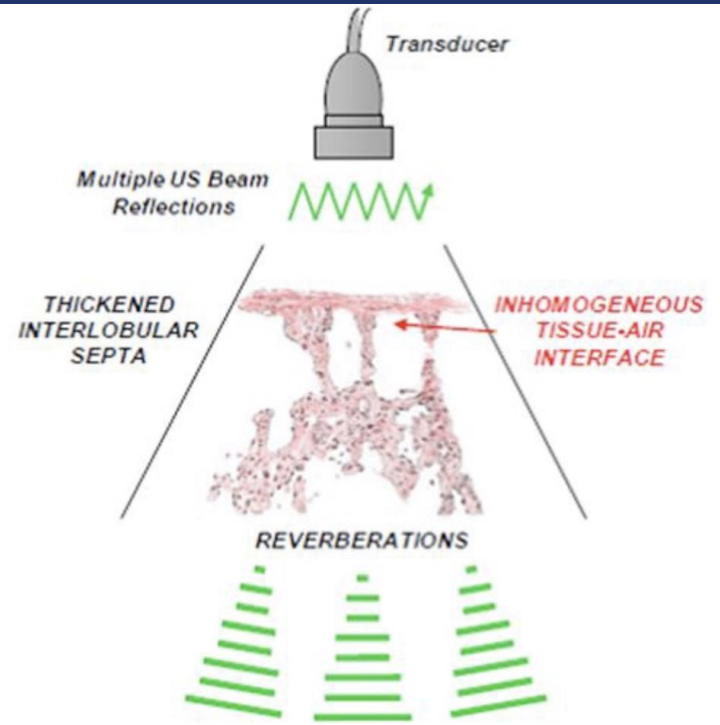
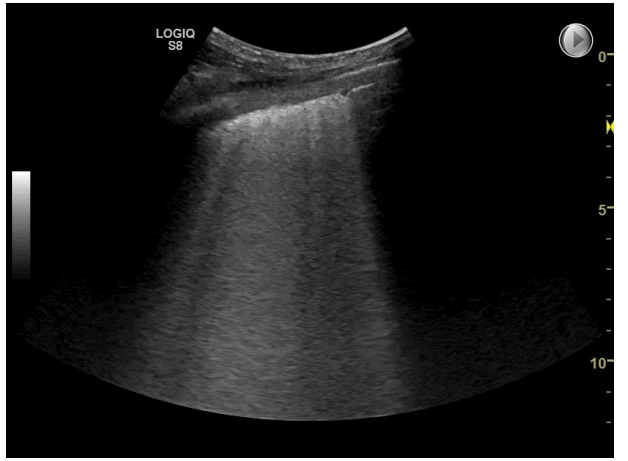
Abnormal lung findings: B-lines (2)

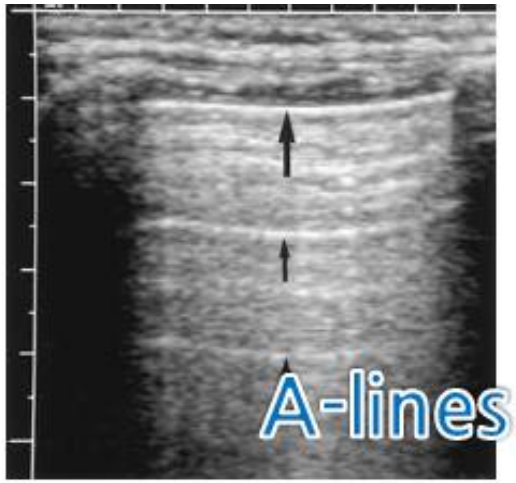


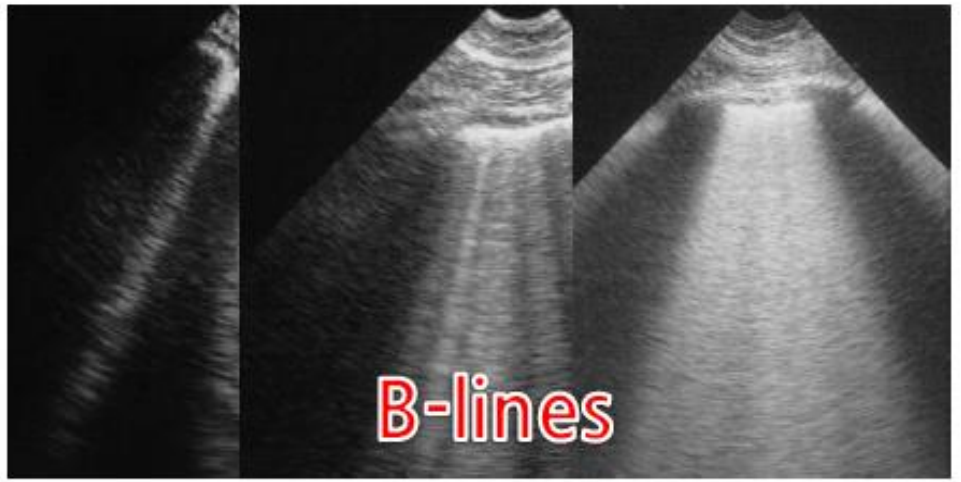






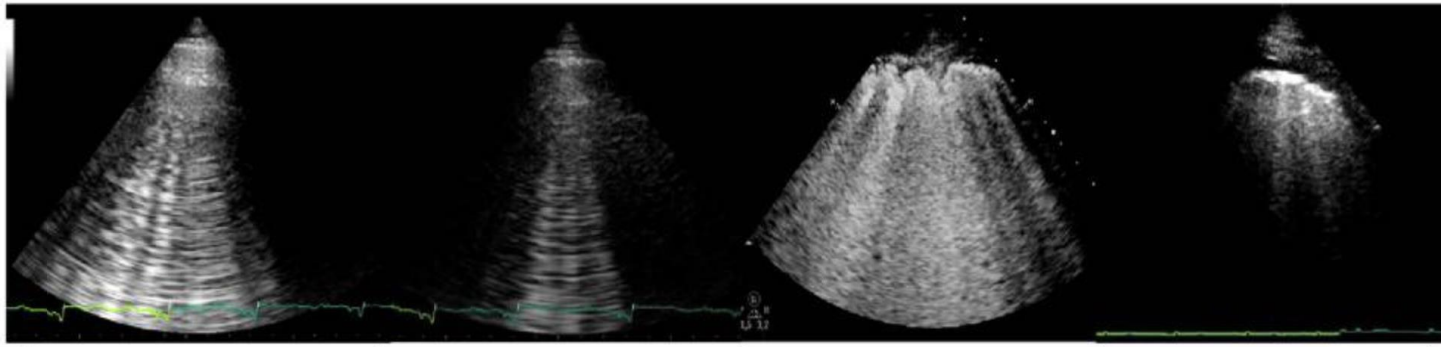
Healthy (well-aerated)





Pulmonary edema (fluid-filled)
Pneumonia (consolidated)

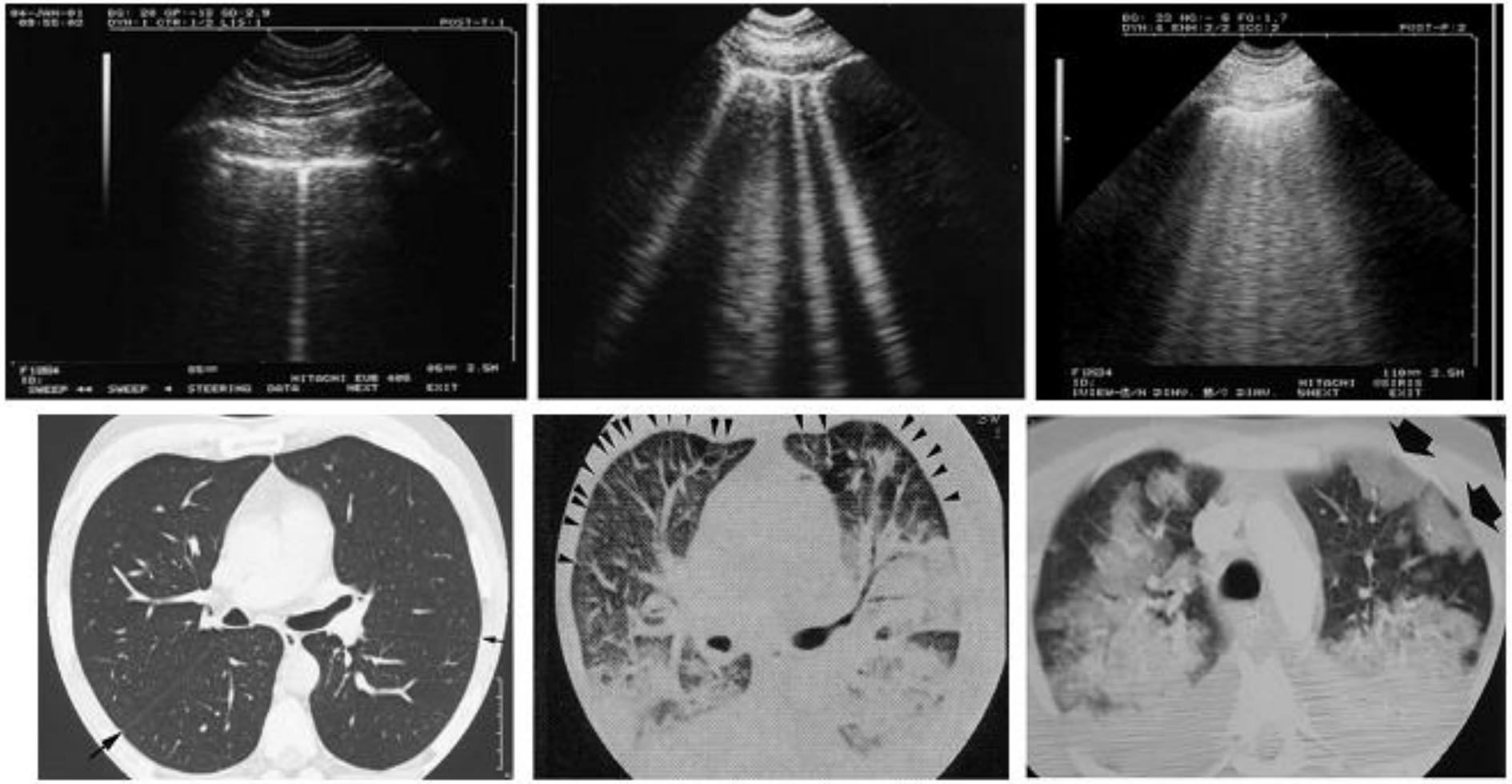
Interstitial syndrome (B pattern)



	Acute cardiogenic pulmonary edema	Chronic heart failure	ALI/ARDS	Pulmonary fibrosis
Clinical setting	acute	chronic	acute	chronic
B-lines number	++++	+/++/+++	++++	+/++/+++
B-lines distribution	multiple, diffuse, bilateral (white lung)	multiple, diffuse, bilateral, following decubitant regions (black and white lung)	non-homogeneous distribution, presence of spared areas	more frequently posterior at lung basis
Other LUS signs	pleural effusion	pleural effusion	pleural effusion, pleural alterations, parenchymal consolidations of various size	pleural thickening
Echocardiogram	abnormal	abnormal	likely normal	likely normal

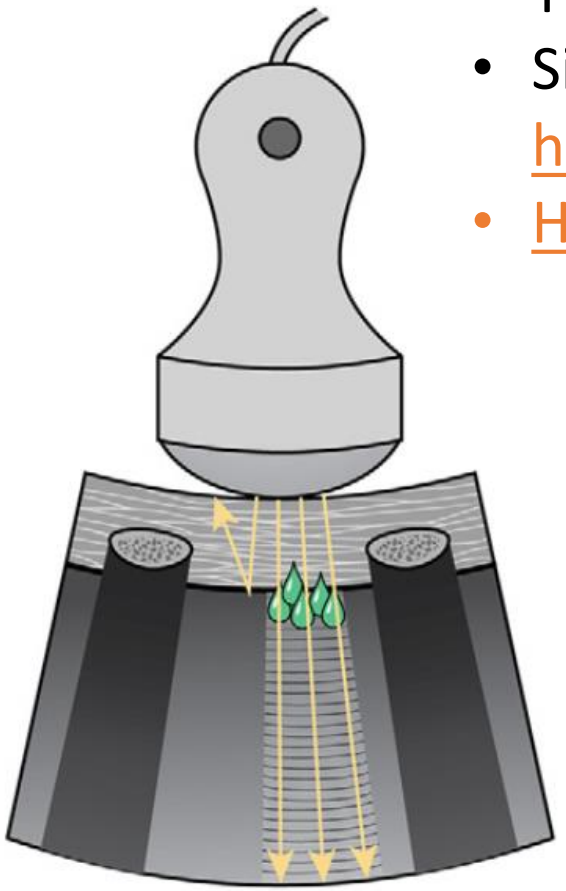
Cardiovascular Ultrasound 2011;9:6

Abnormal lung findings

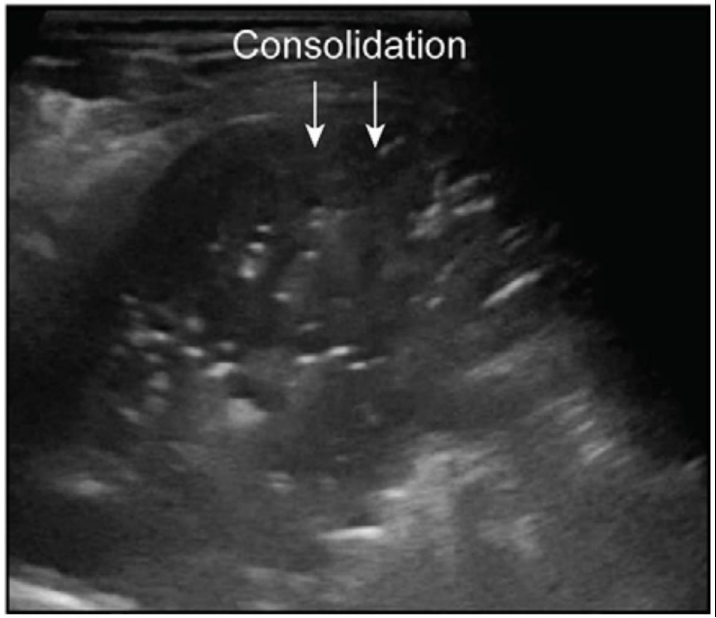


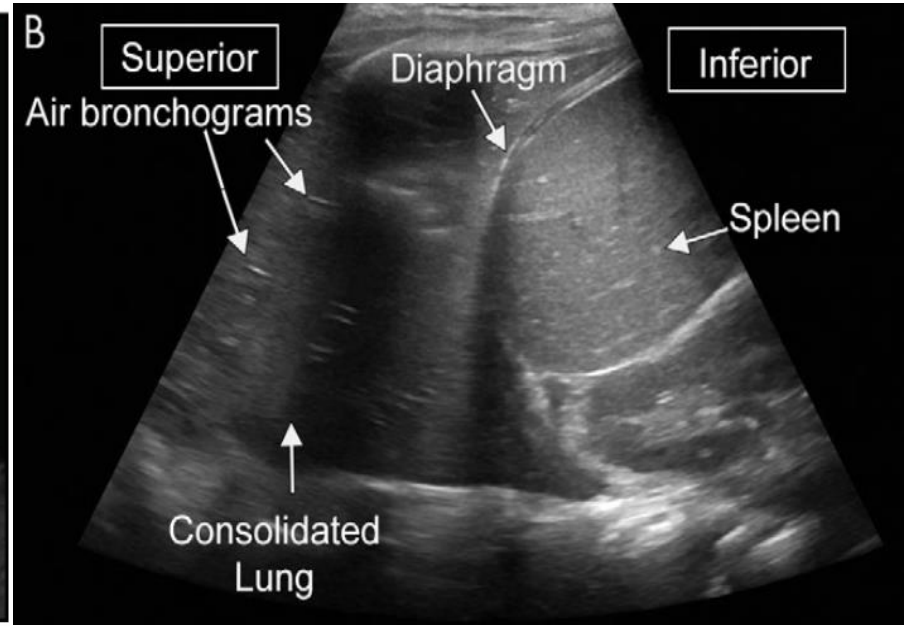
Journal of Medical Ultrasound 2017;25(2):101-104

Abnormal lung findings : Consolidation (1)



- Tissue-like pattern, not artifact!
- Similar to the liver, representing so-called hepatization of the pulmonary parenchyma
- Hyper-echoic foci = air bronchograms





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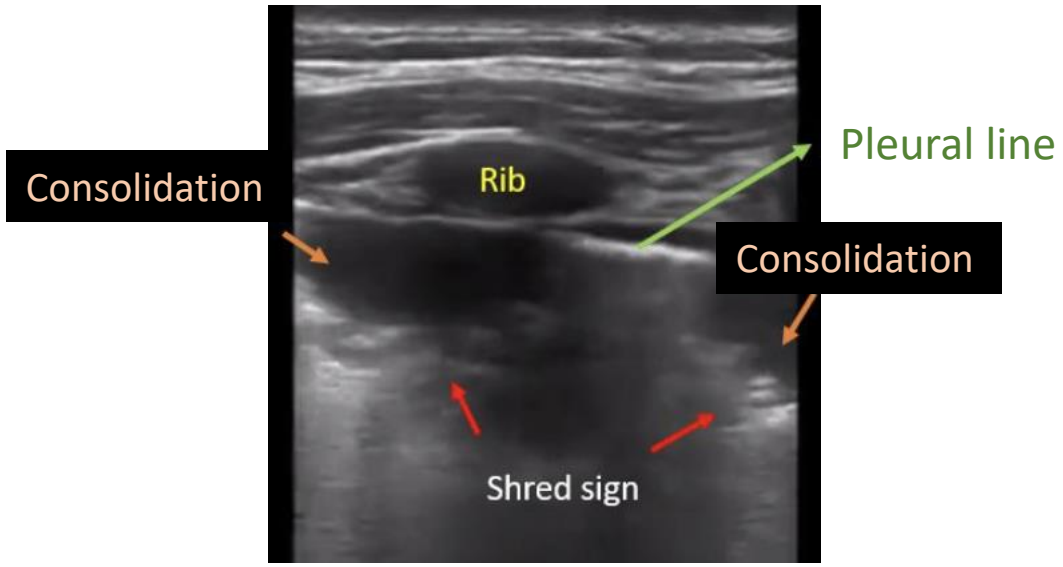
Abnormal lung findings: Consolidation (2)

- Shred sign
  - Typical alveolar consolidation,
  - Tissular pattern arising from the pl
    shredded border



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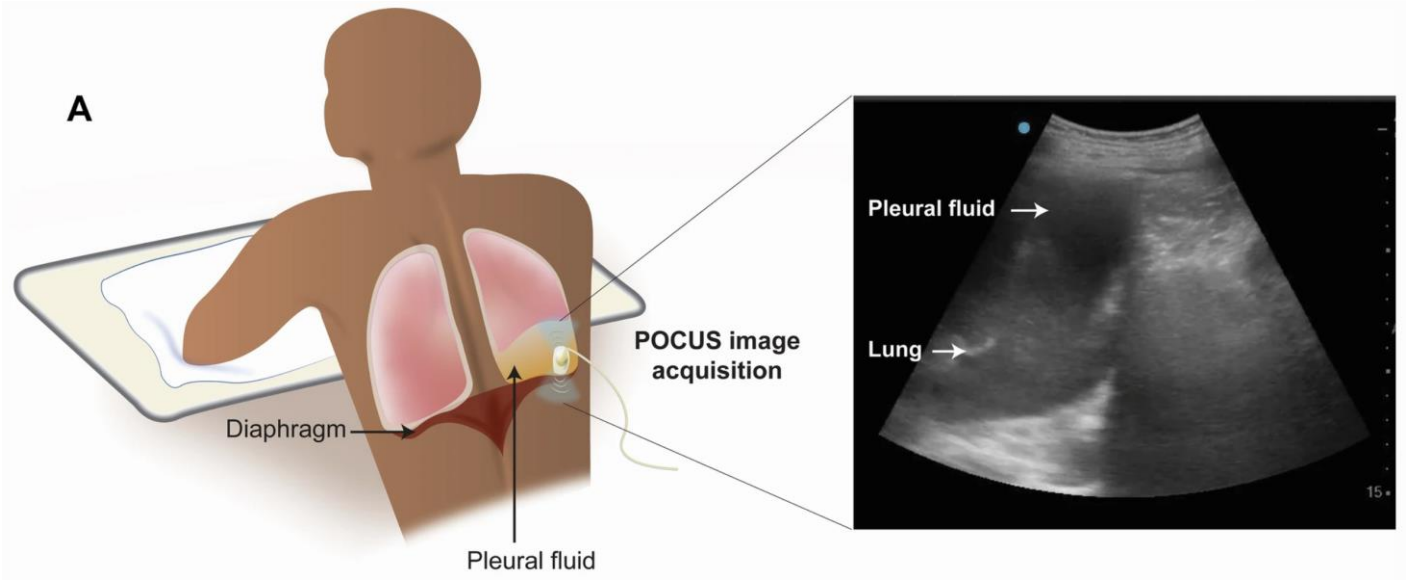
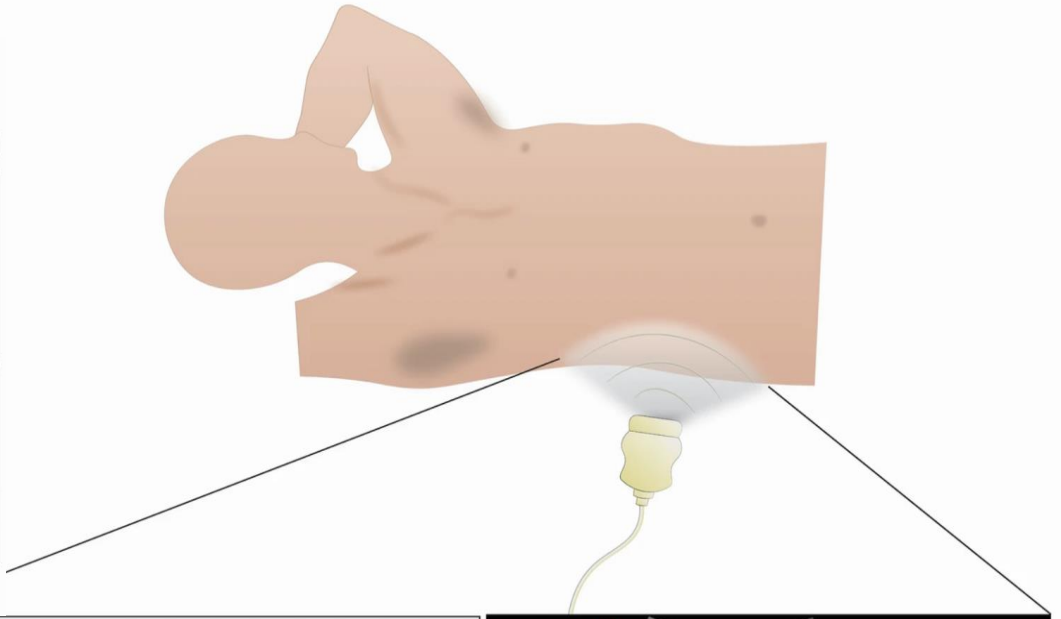
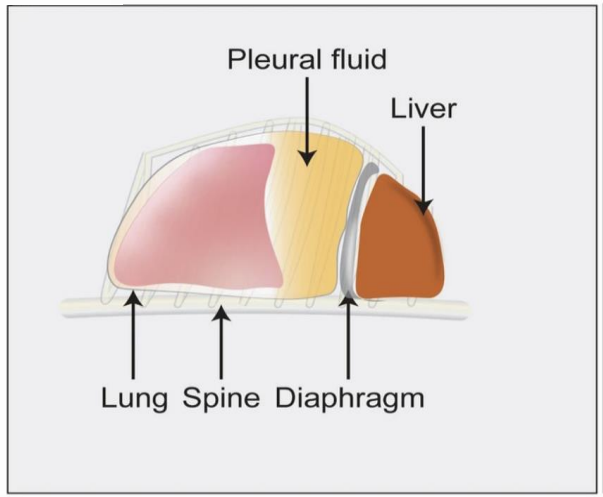
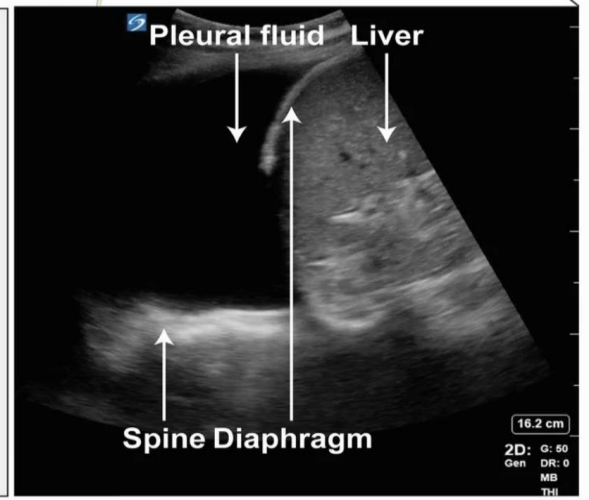
Abnormal lung findings: Pleural effusion









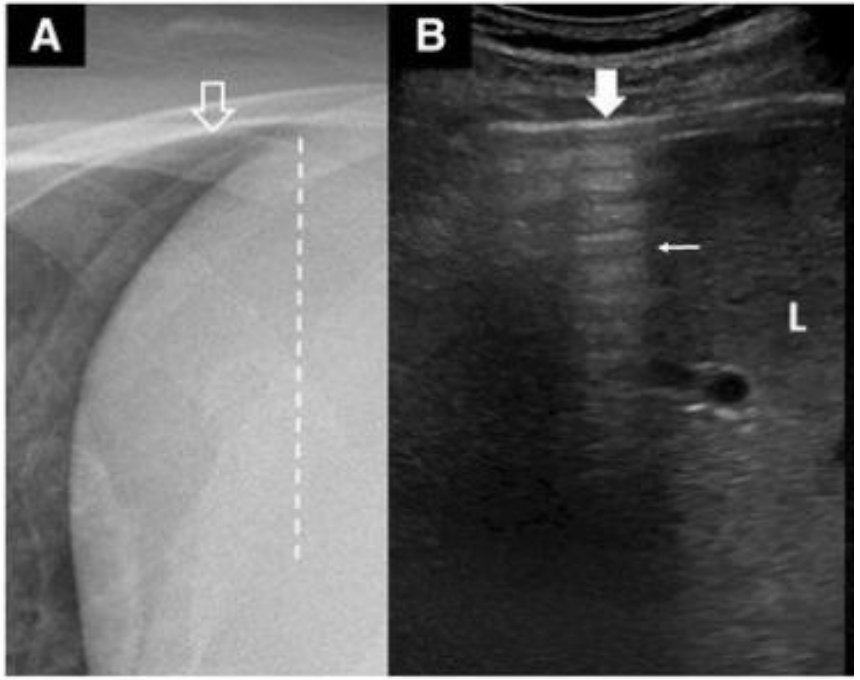
- Sitting at the mid-scapular line
- Supine at the posterior axillary line
- Longitudinal approach
- Liver (Rt) / Spleen (Lt)

→ **V(ml) = 16~20 x pleural separation (mm)**

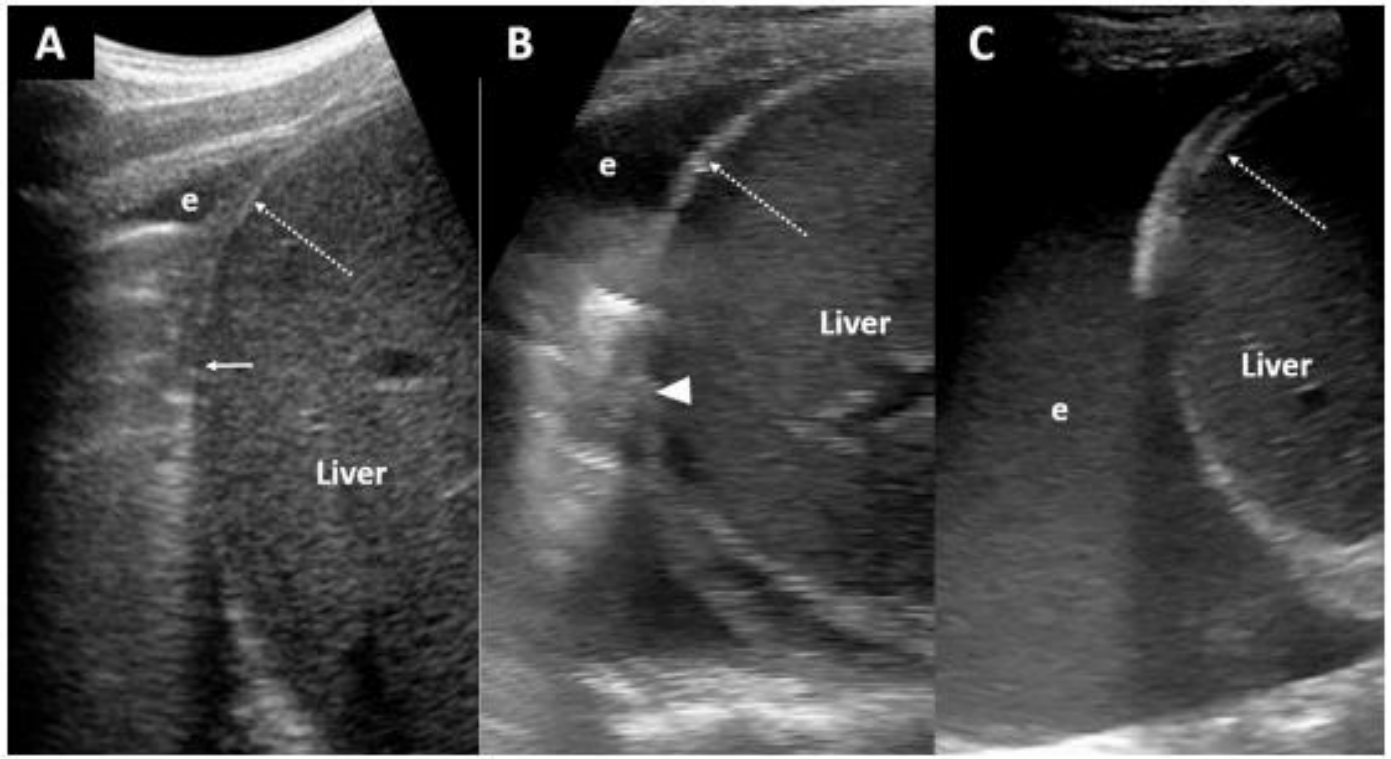
Ultrasound J 2021;13:40

Abnormal lung findings

- Abnormal curtain sign



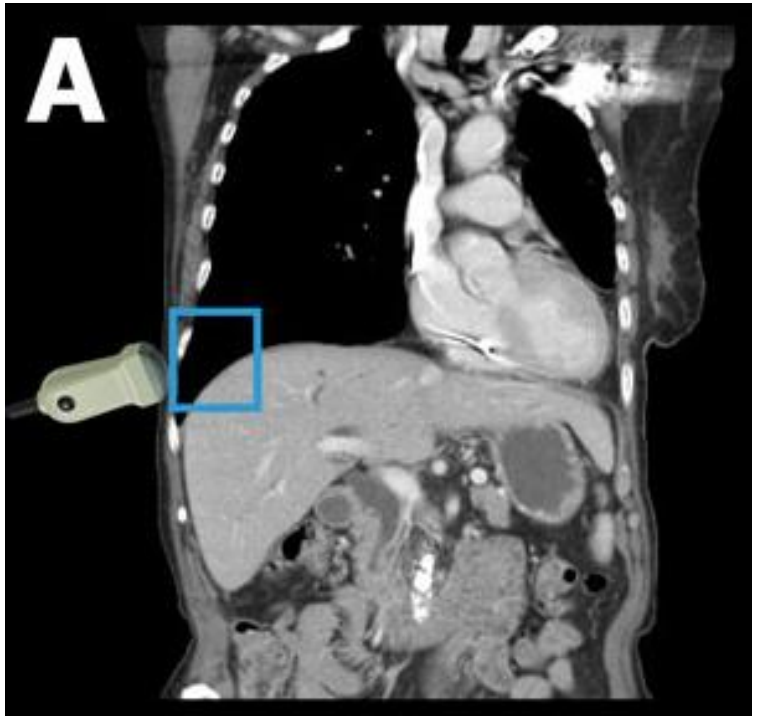
Normal

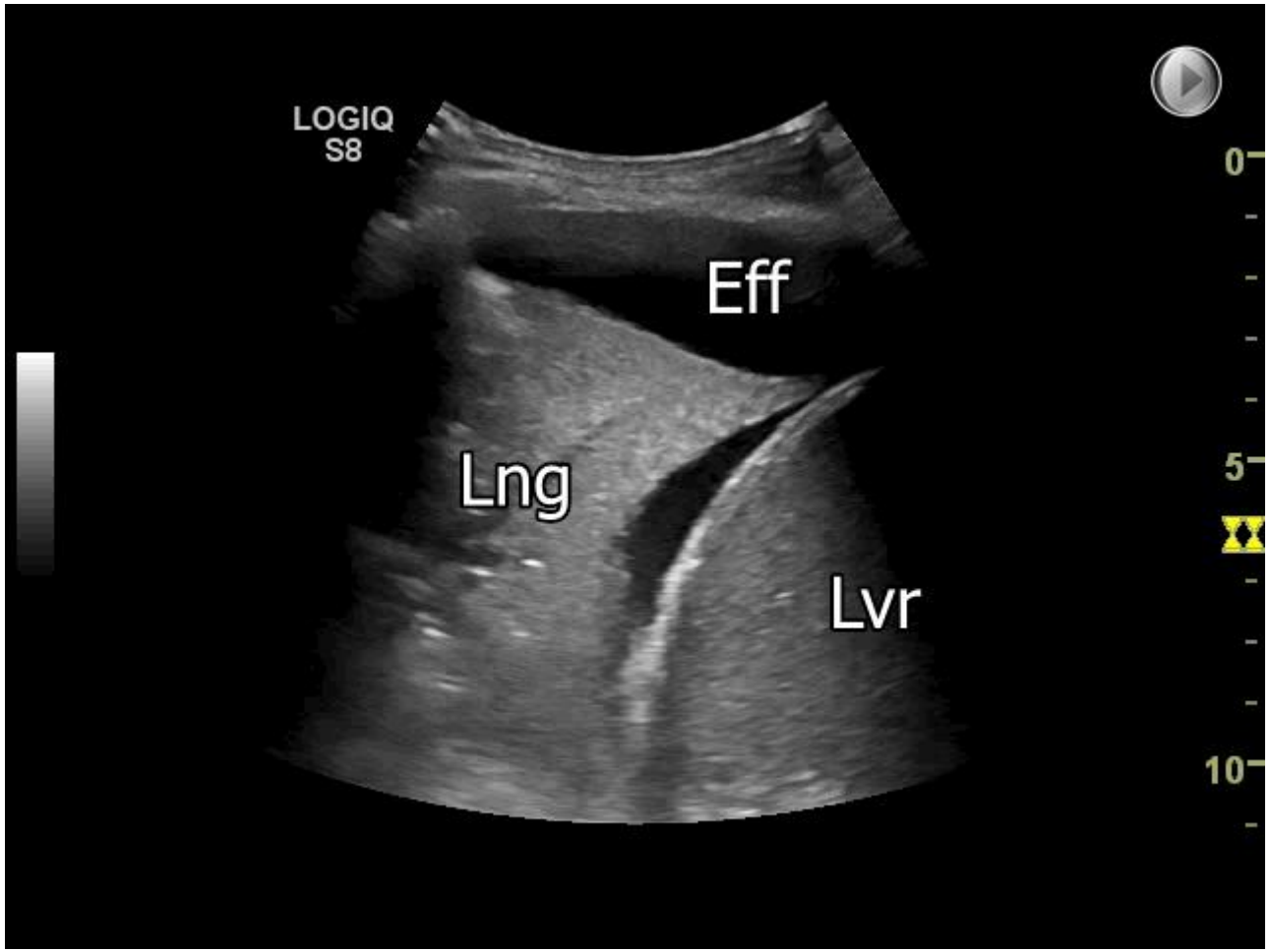


Journal of Medical Ultrasound 2017;25(2):101-104

Abnormal lung findings

- Pleural effusion

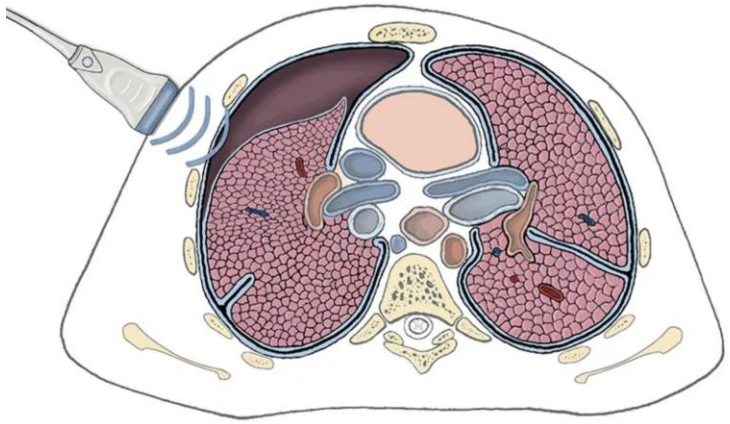


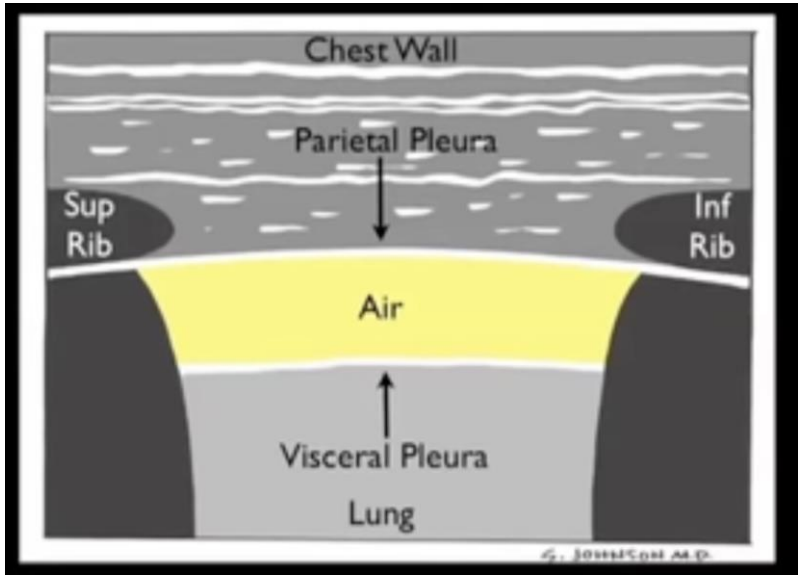


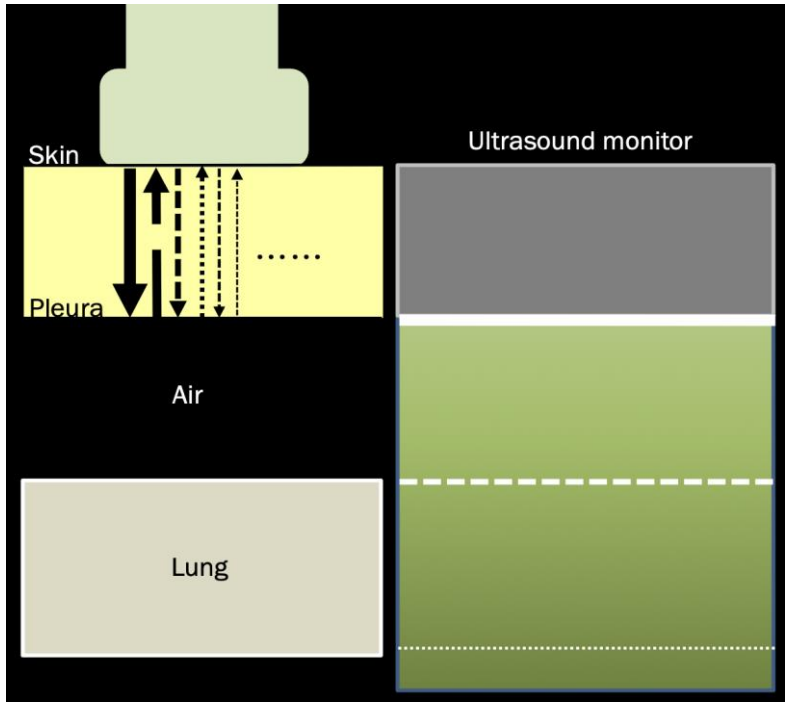
Journal of Medical Ultrasound 2017;25(2):101-104

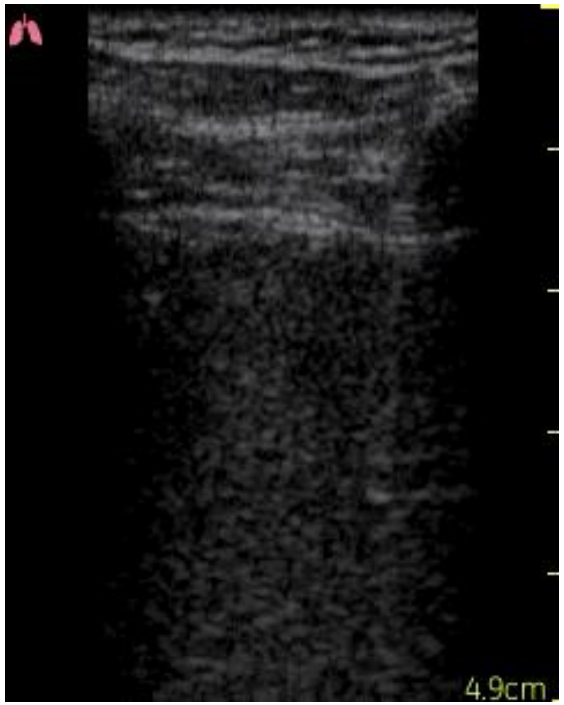
Abnormal lung findings: Pneumothorax (1)

- Air-filled space = A-line
- No attached pleura
  - Absence of lung sliding
  - Absence of B-line



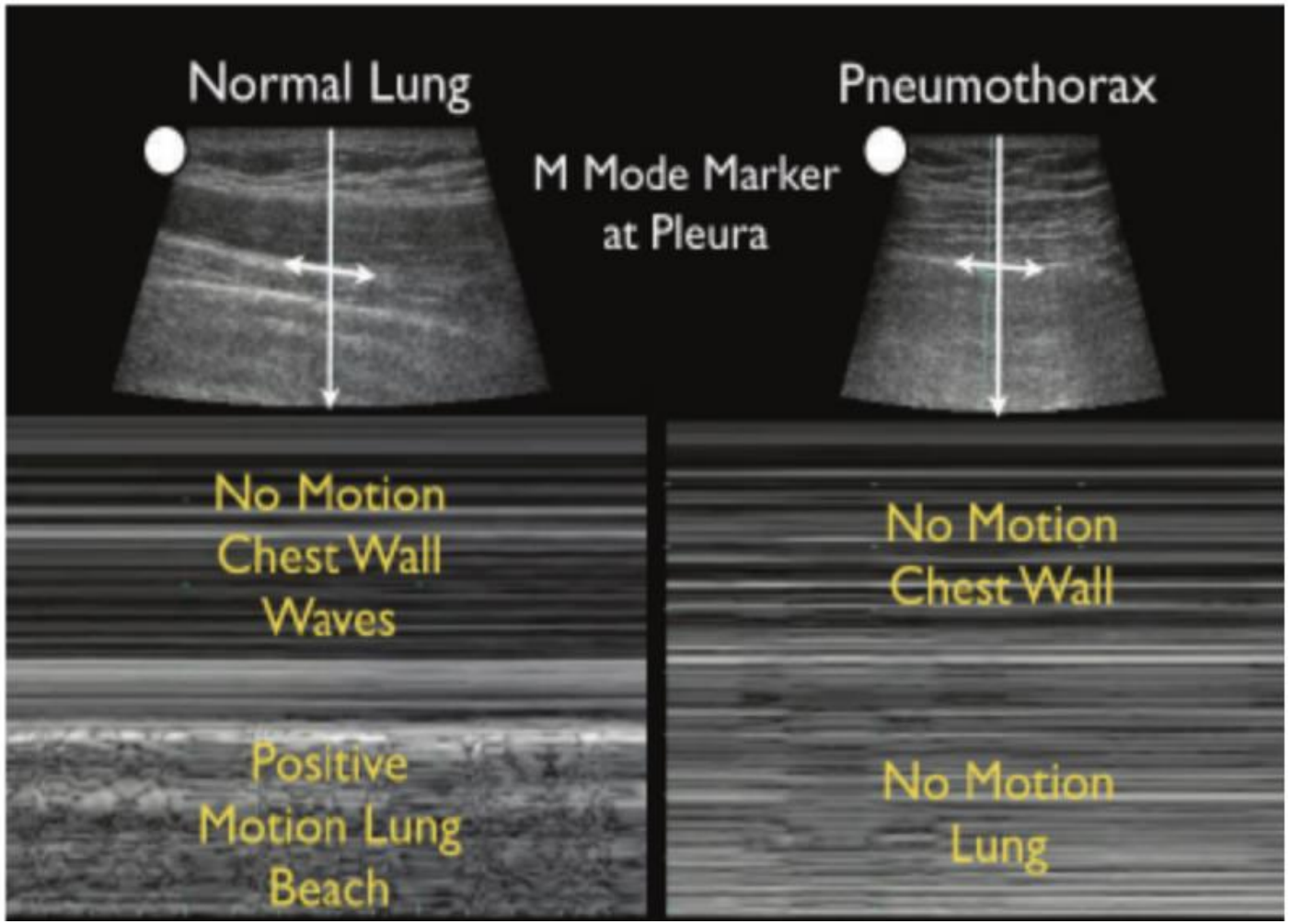




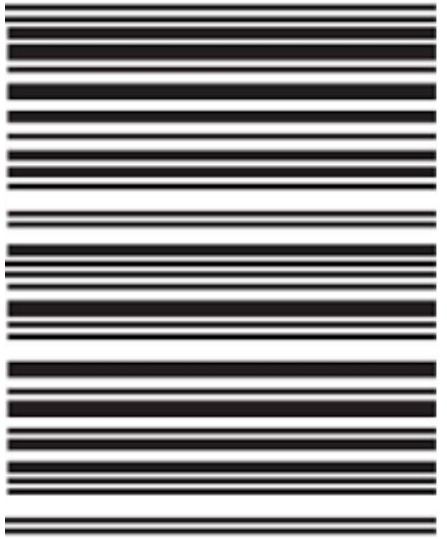


Abnormal lung findings: Pneumothorax (M-mode)

Seashore sign

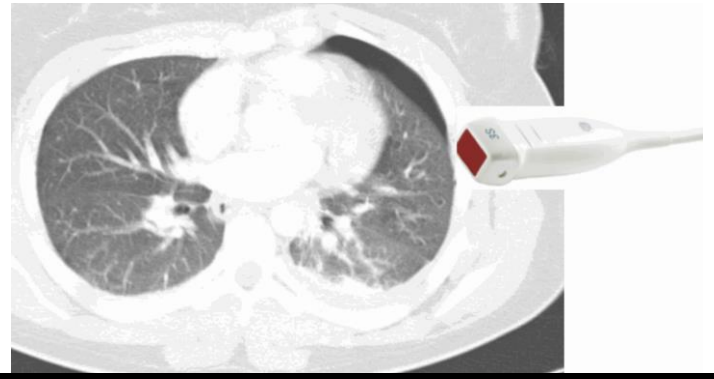


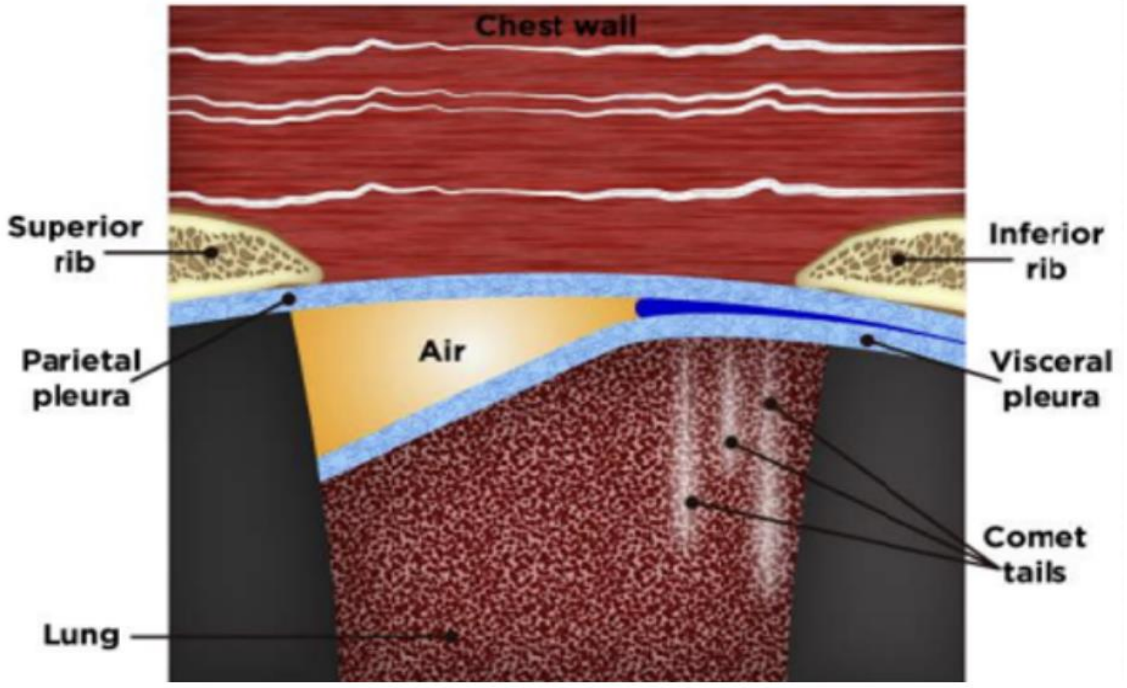
Barcode sign
or Stratosphere sign

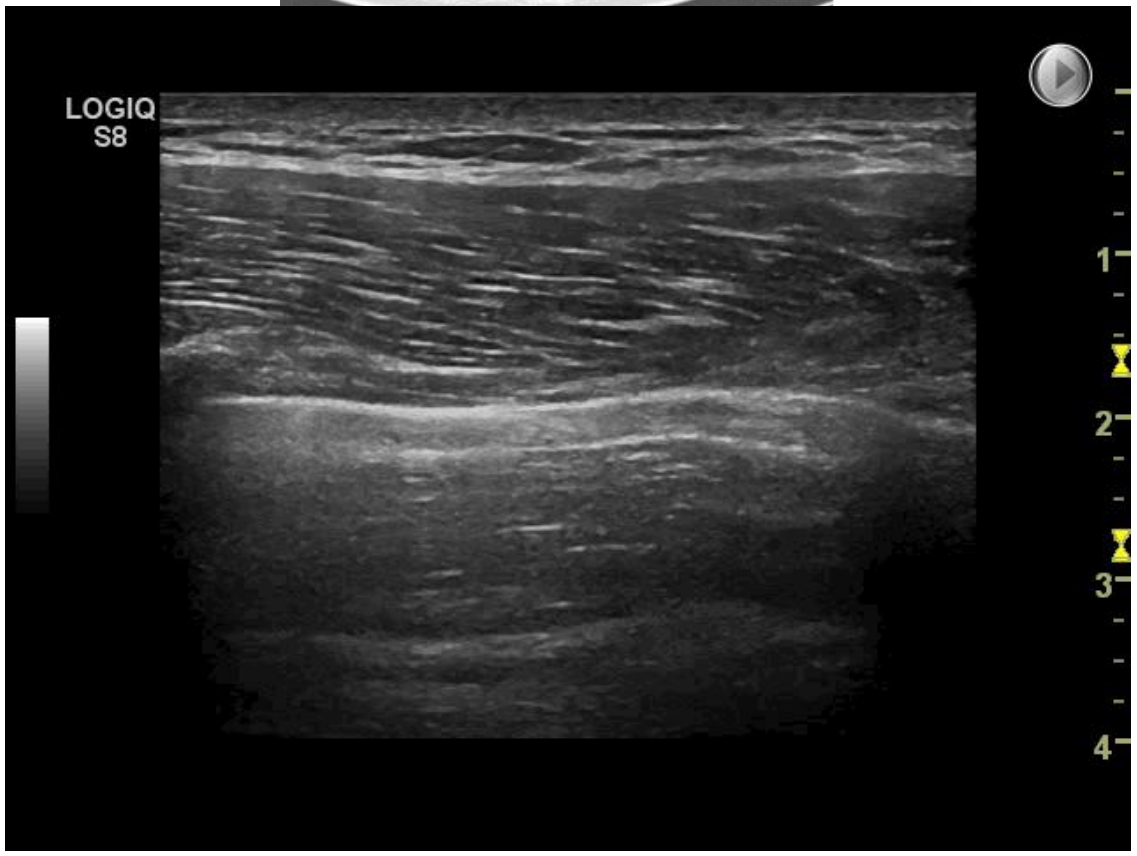


Abnormal lung findings: Pneumothorax (3)

- **Lung point**
  - Change of lung sliding pattern
  - Visceral pleural meet parietal pleura
  - 100% detection of PNX



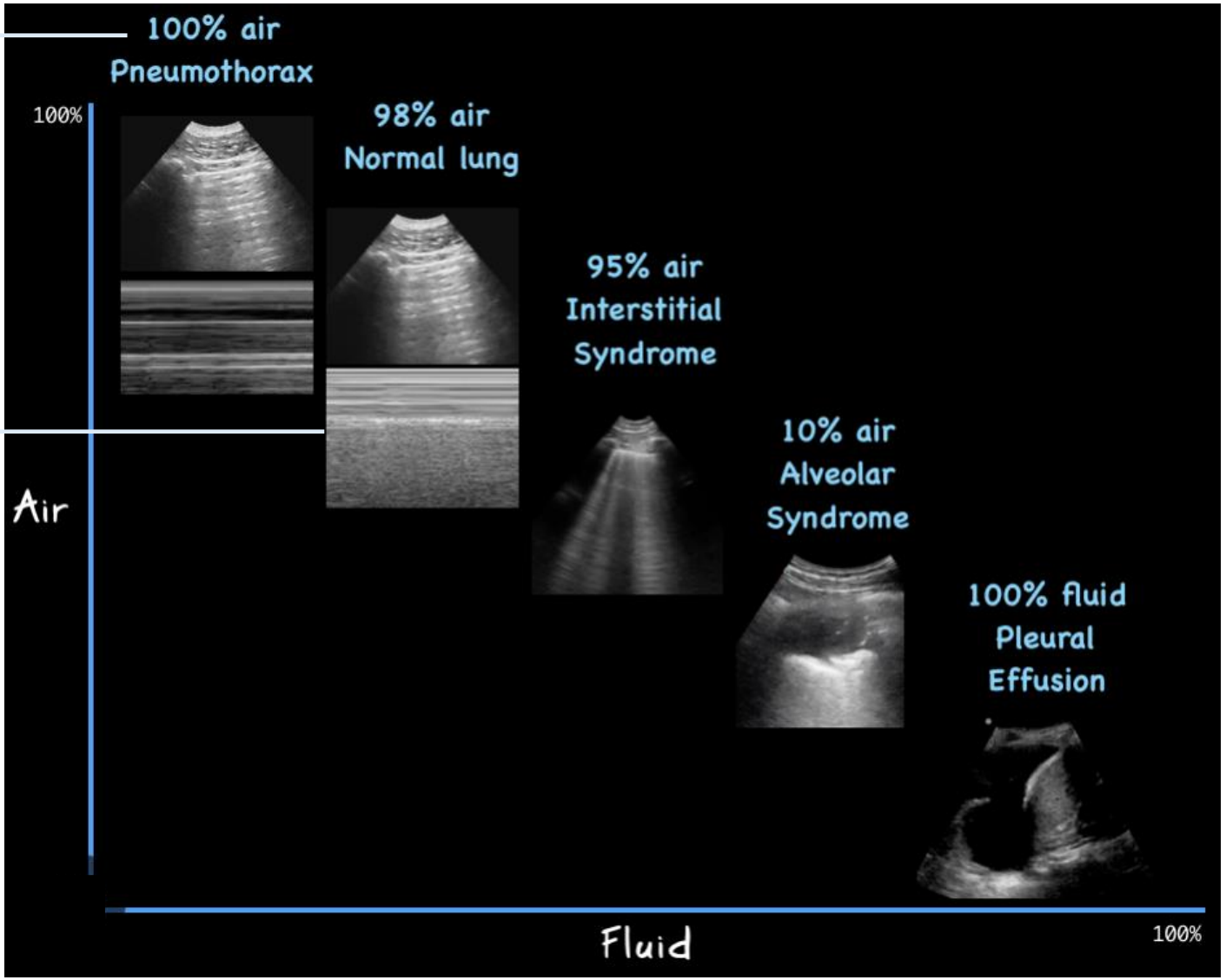




Continuum of aeration in LUS

[PNX]
- No lung sliding
  : barcode sign
- Lung point (hard to find)
- A-lines

[Normal lung]
- Lung sliding
  : seashore sign
- A-lines
- Curtain sign

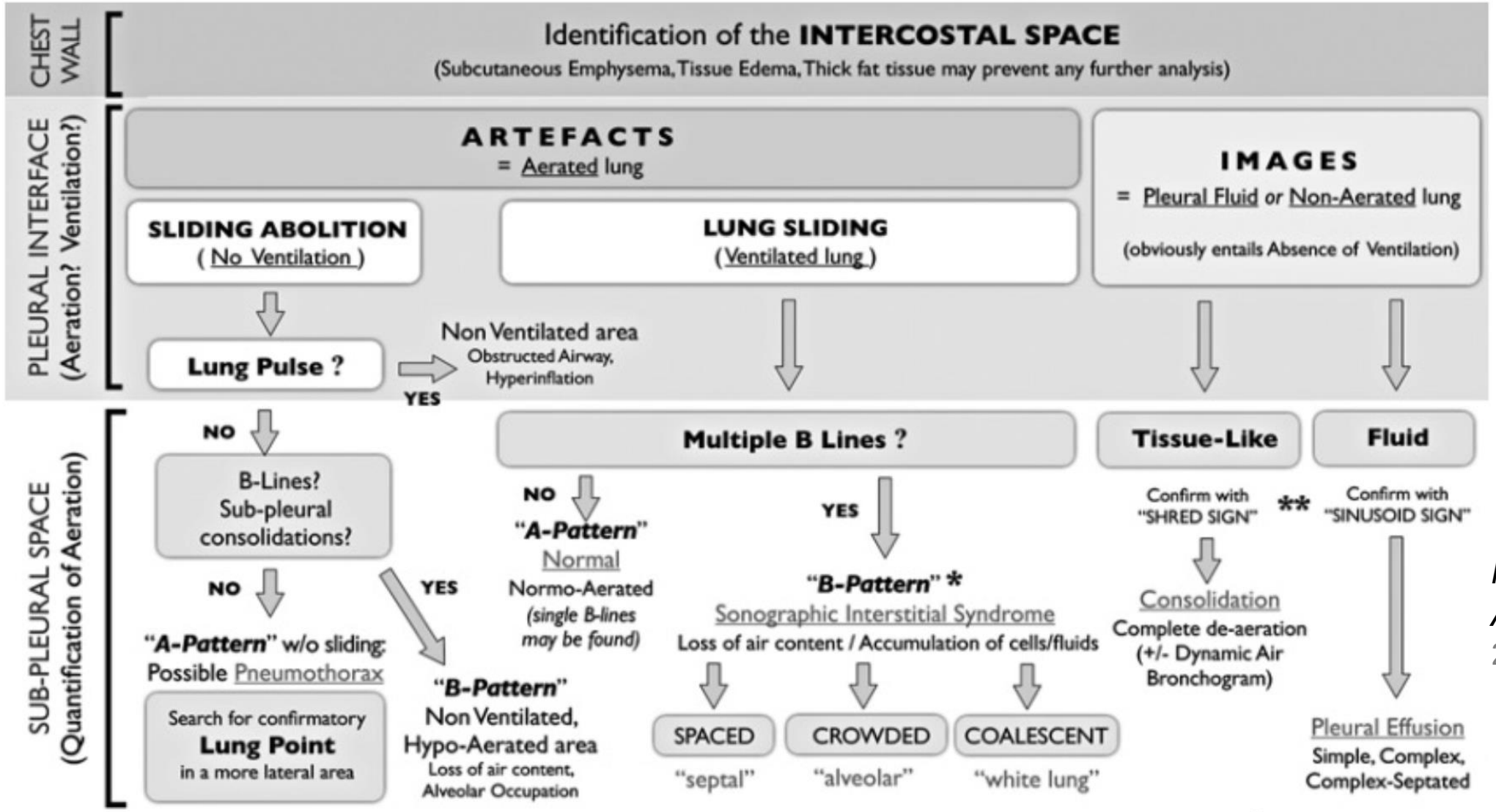


[Pneumonia]
- B-lines
- Hepatization of lung
- Shred sign
- Possible small pleural effusion

[Cardiogenic pulmonary edema]
- Widespread bilateral B-lines
- Normal lung sliding
- Possible bilateral pleural effusion

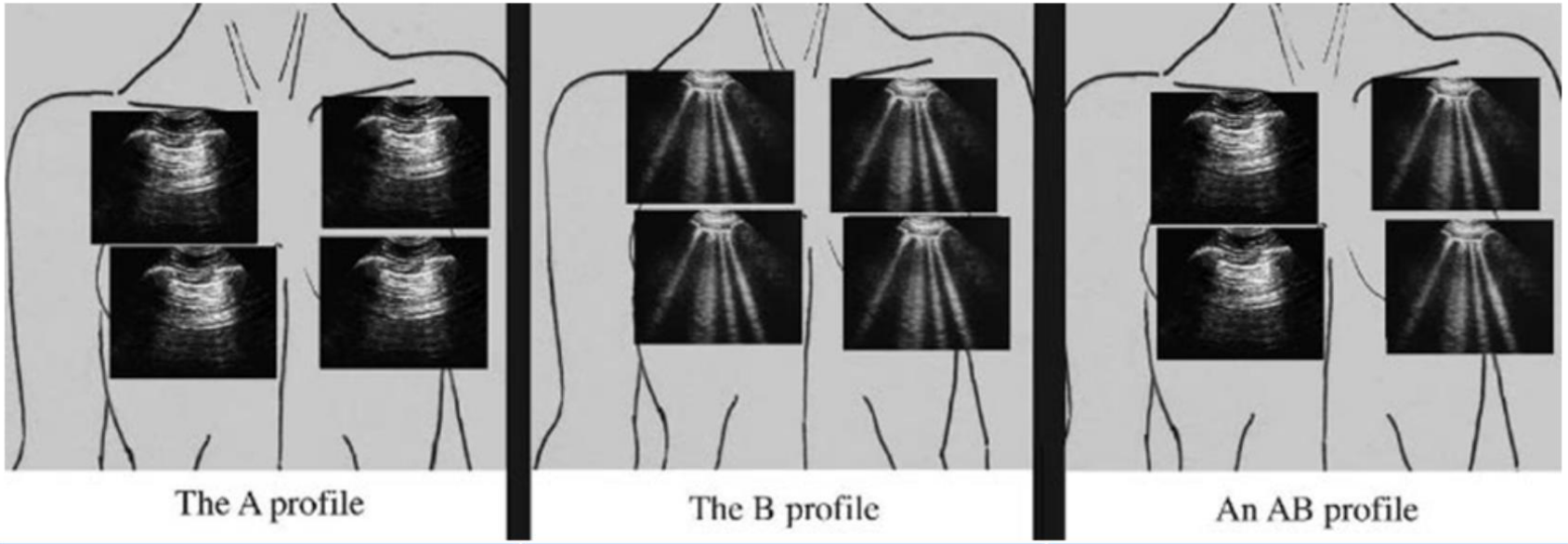
[ARDS]
- Bilateral or unilateral B-lines
- Normal lung sliding

Interpretation of LUS



Minerva Anestesiol 2012;78(11):1282-96

BLUE (Bedside Lung US in Emergency) protocol

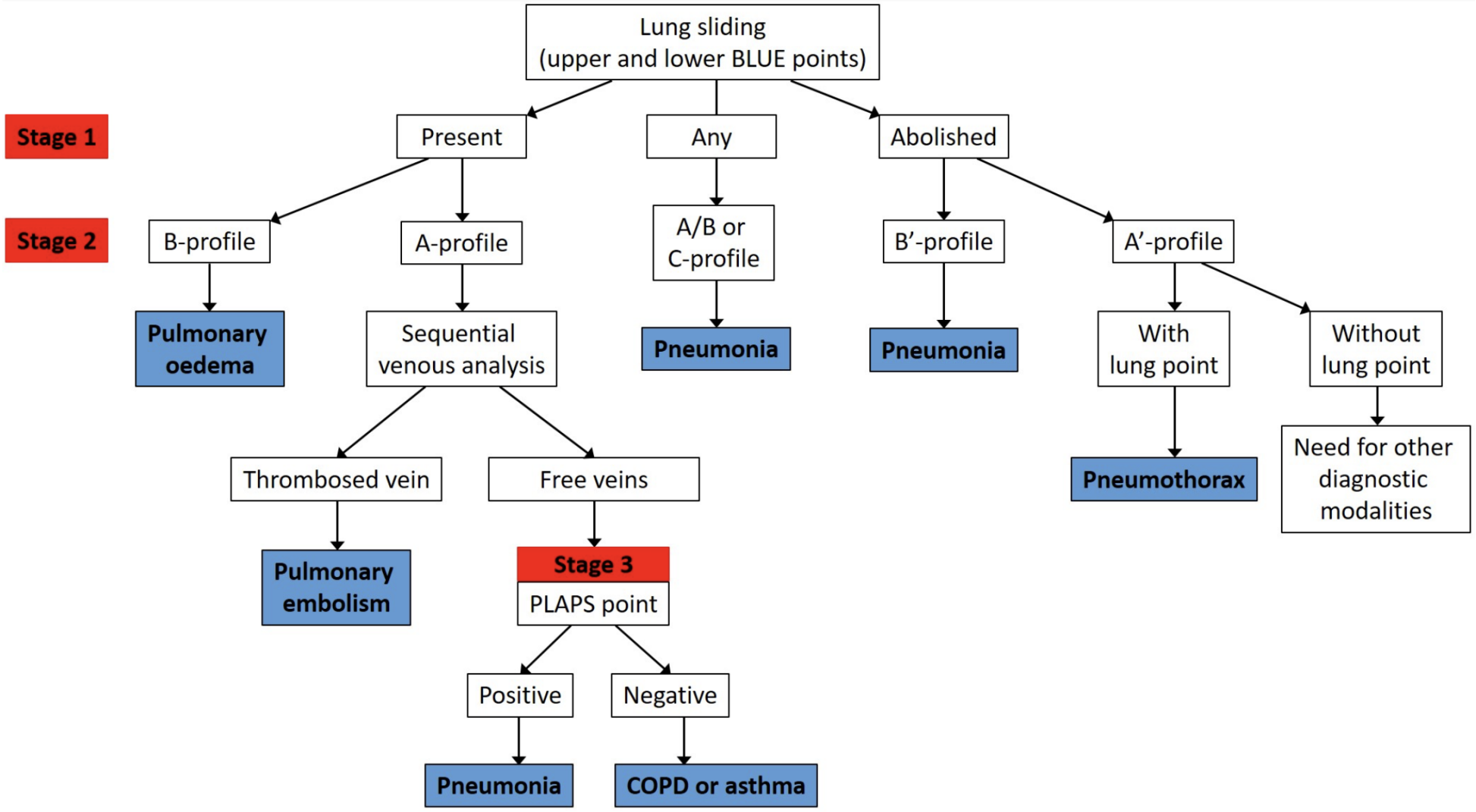


A Profile (A lines + sliding)	B Profile (+ sliding)	AB Profile (+ sliding)
+ COPD/asthma	+ pulmonary oedema	+ pneumonia
+ PE	- COPD/asthma	- Pulmonary oedema
+ Posterior pneumonia	- PE	- COPD/asthma
- Pulmonary oedema nearly ruled out	- pneumothorax	

\+ : potential diagnosis
\- : diagnosis ruled out

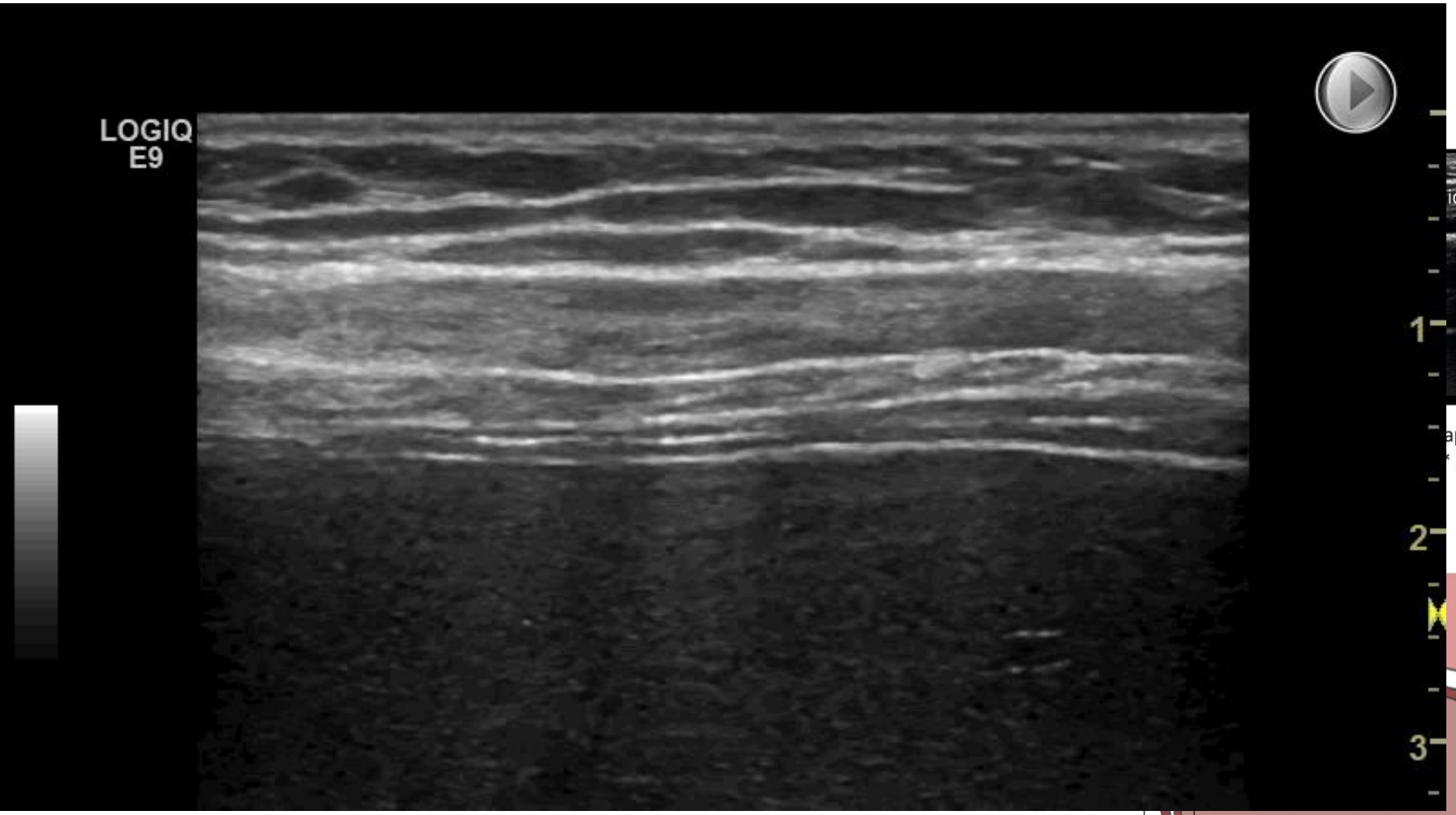
Chest 2008;134:117-125

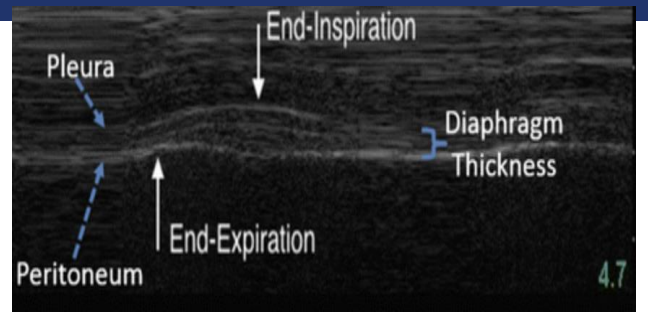
BLUE (Bedside Lung US in Emergency) protocol

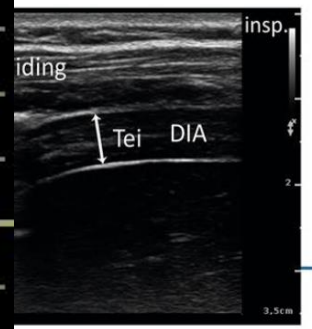


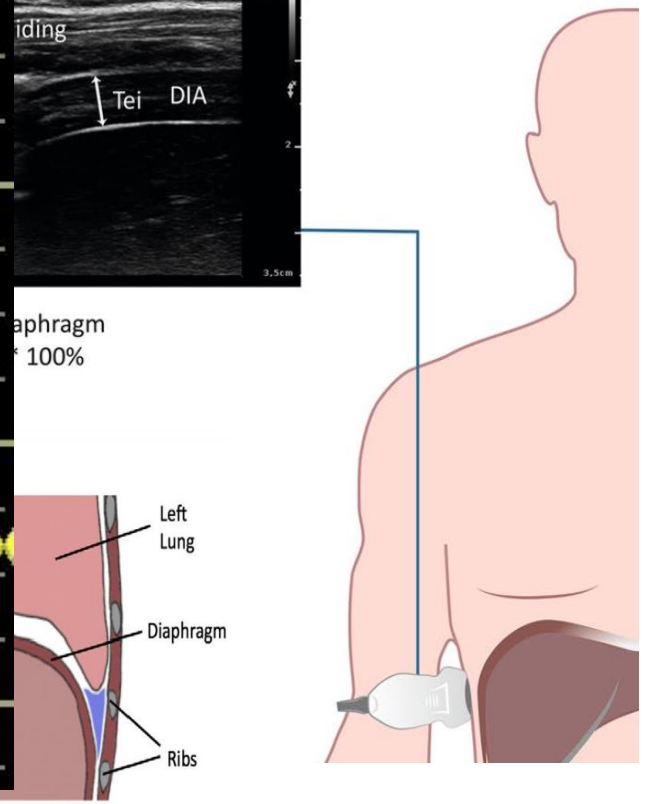
Chest 2008;134:117-125

Respiratory muscle US: Diaphragm (1)



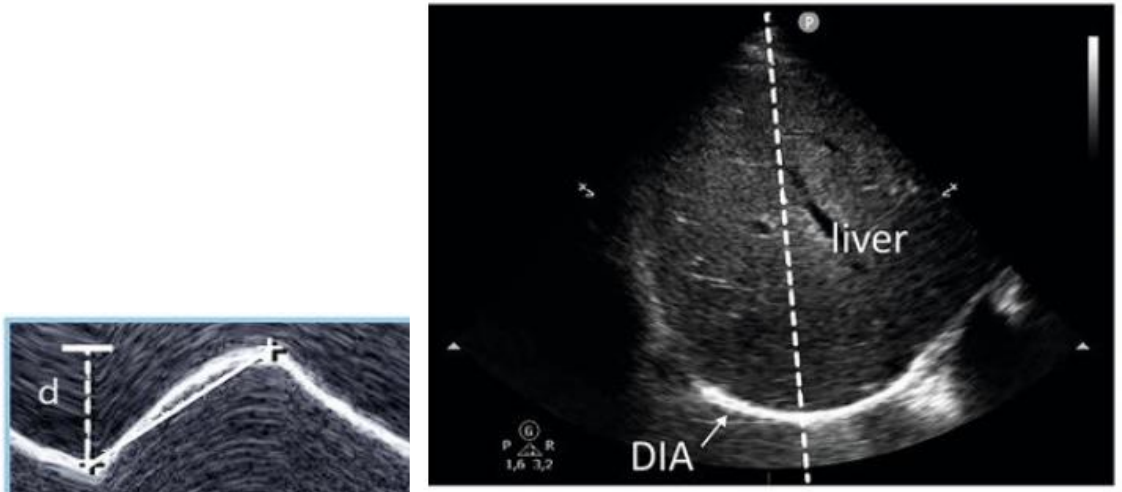


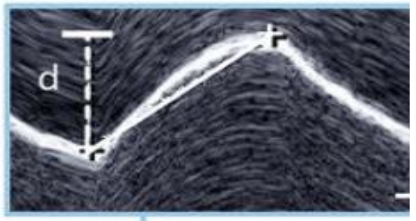


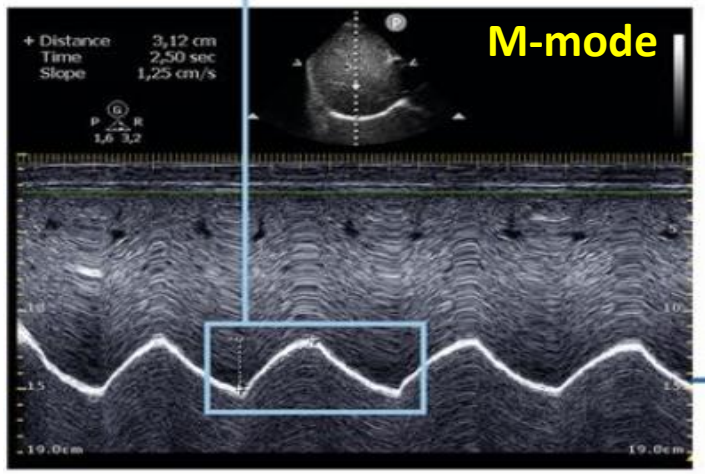


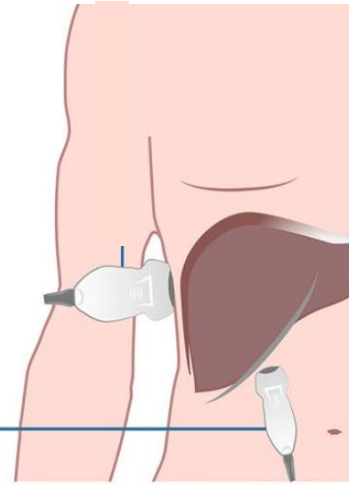
Intensive Care Med 2020;46:594-605

Respiratory muscle US: Diaphragm (2)









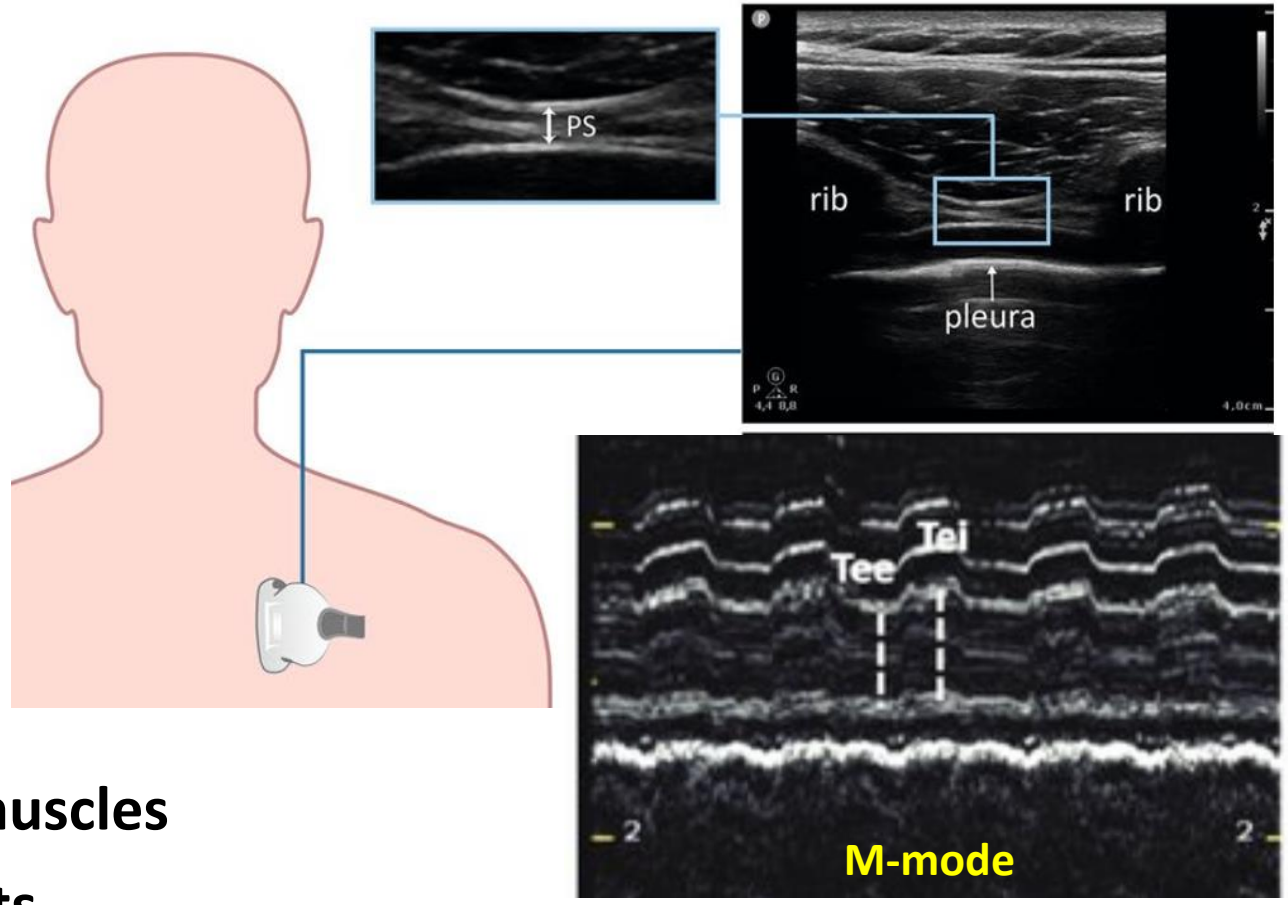
Intensive Care Med 2020;46:594-605

Respiratory muscle US: Intercostal muscle

- **Parasternal intercostal muscle**

- Intercostal approach
- Linear probe
- 2nd intercostal space
- 6~8cm lateral to the sternal edge

- **→ In healthy subjects,**
  thickening of parasternal intercostal muscles
  is observed only during maximal efforts



Intensive Care Med 2020;46:594-605

PoCUS in WEANING FAILURE

ABCDE-ultrasound approach

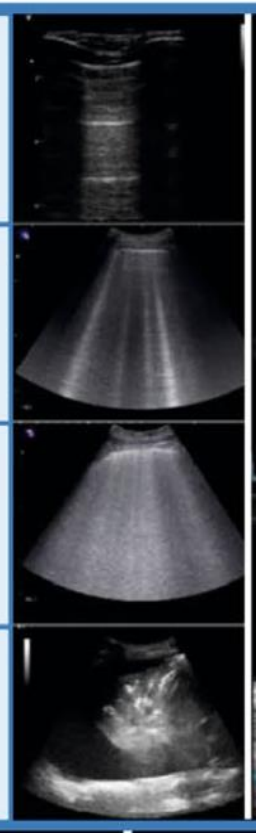
Aeration score & pleural effusion

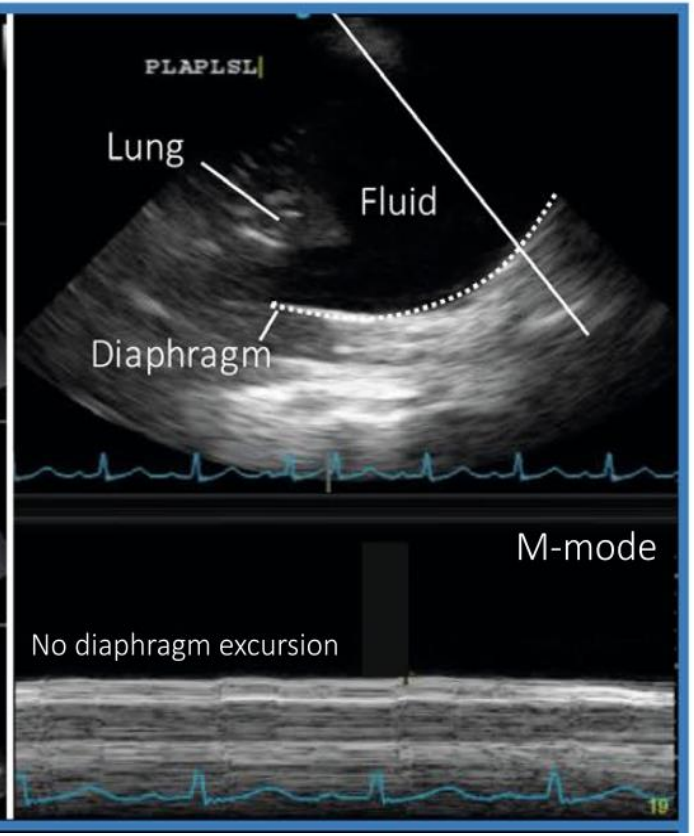
Assess lung aeration (LUS score) and the presence of pleural fluids

Aeration score:[2] *extubation failure associated with aeration score >17 and increase in B-lines during SBT ≥6; extubation success associated with aeration score <13*

Pleural effusion: mm x 20 mL = estimated drainage amount

0	Normal aeration	***Horizontal A-lines*** (or no more than two B-lines)
1	Moderate loss of aeration	***Multiple B-lines*** (either regularly spaced (7mm apart), or irregularly and even coalescent, but only visible in a limited area of the intercostal space
2	Severe loss of aeration	***Multiple coalescent B-lines*** in prevalent areas of the intercostal spaces and observed in one or several intercostal spaces
3	Complete loss of aeration	***Lung consolidation*** with or without air bronchograms

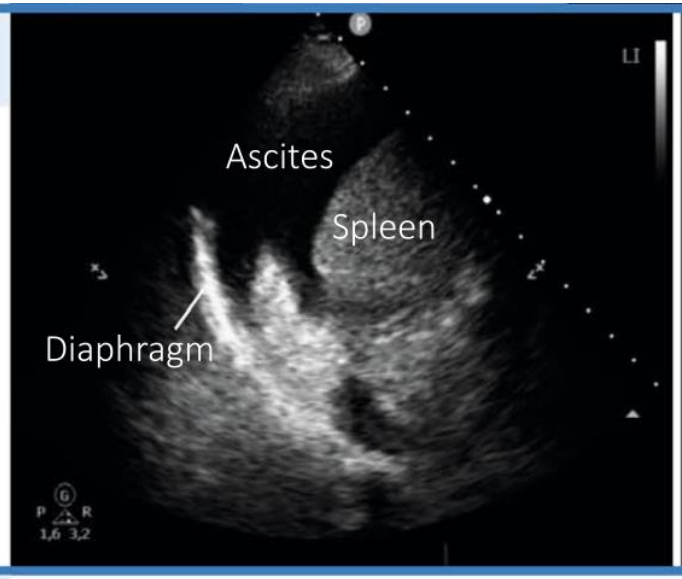


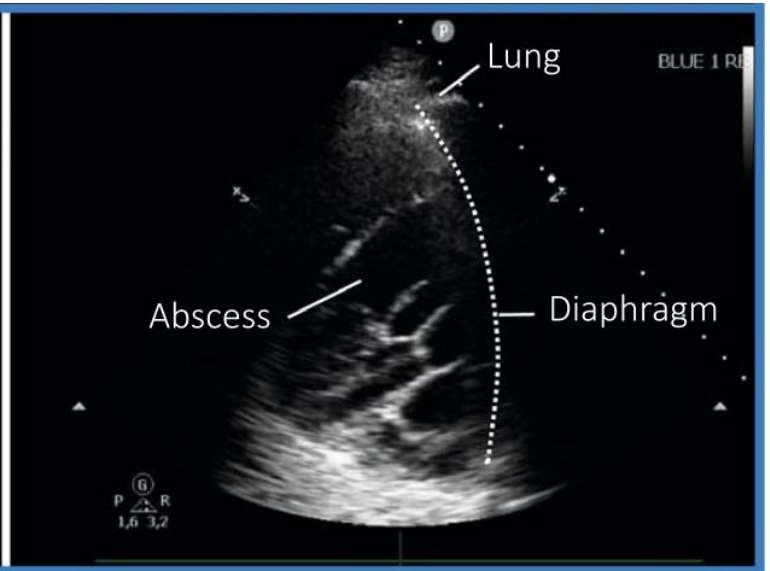


Intensive Care Med 2020;46:594-605

Below the diaphragm

Screen for ascites or abscesses;
high intra-abdominal pressures may alter respiratory mechanics

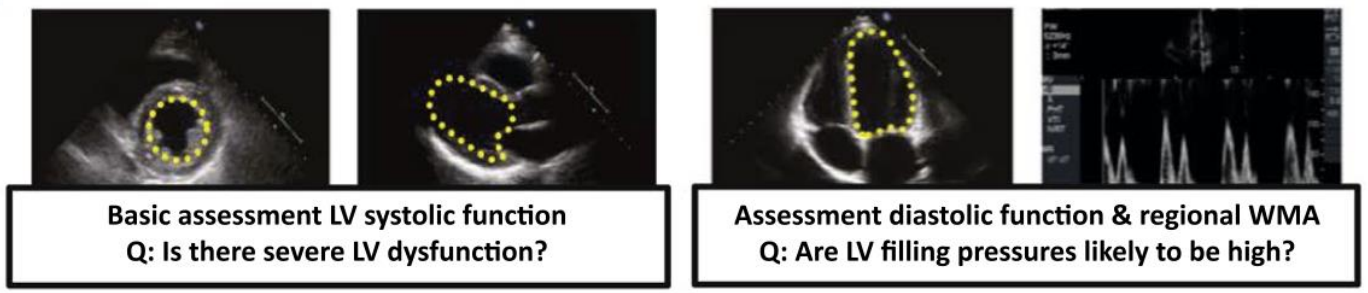




Cardiac

Assess cardiac function: LV systolic and diastolic function, preload dependency and obstructive cardiomyopathy

LV function:[2] *moderate to severe diastolic impairment: E'<8 cm/s, E/A 0.8-1.5 or >2; systolic dysfunction: LVEF <40%*



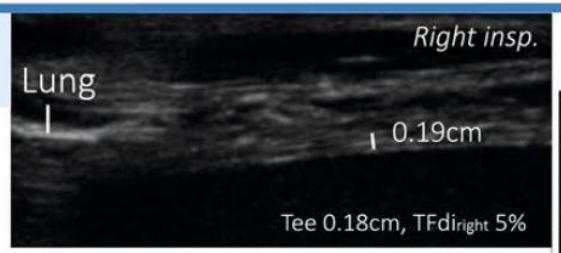
Modified from Vieillard-Baron et al, ICM 2019. Fig. 2 Different approaches for cardiovascular evaluation in basic and advanced critical care echocardiography (CCE)

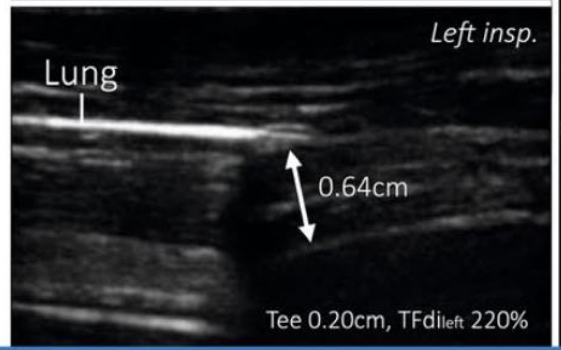
Intensive Care Med 2020;46:594-605

Diaphragm

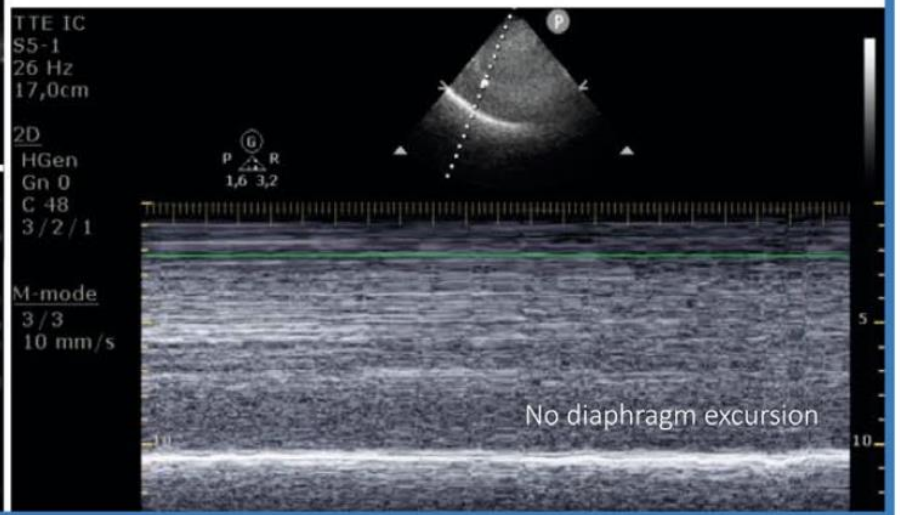
Measure thickness, TFdi and excursions during tidal breathing and maximal effort; assess symmetry

Extubation success: TFdi >30-36%, >10mm excursions (bilateral DD) and >25mm excursions (unilateral DD, unaffected side during max. effort)



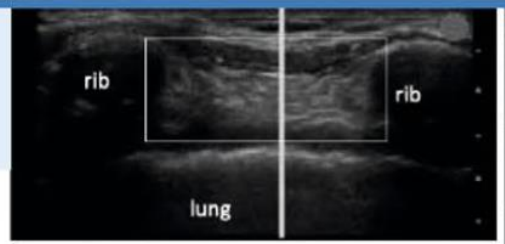


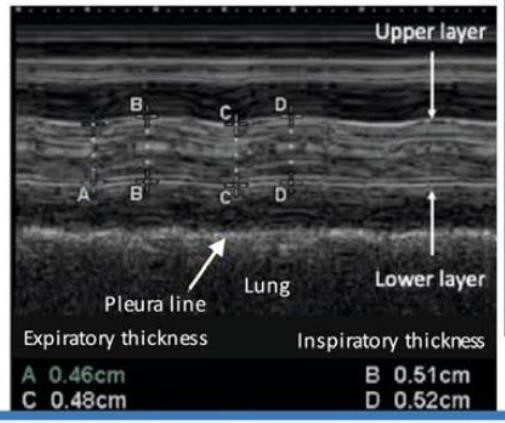
Example of right-sided DD with compensation left

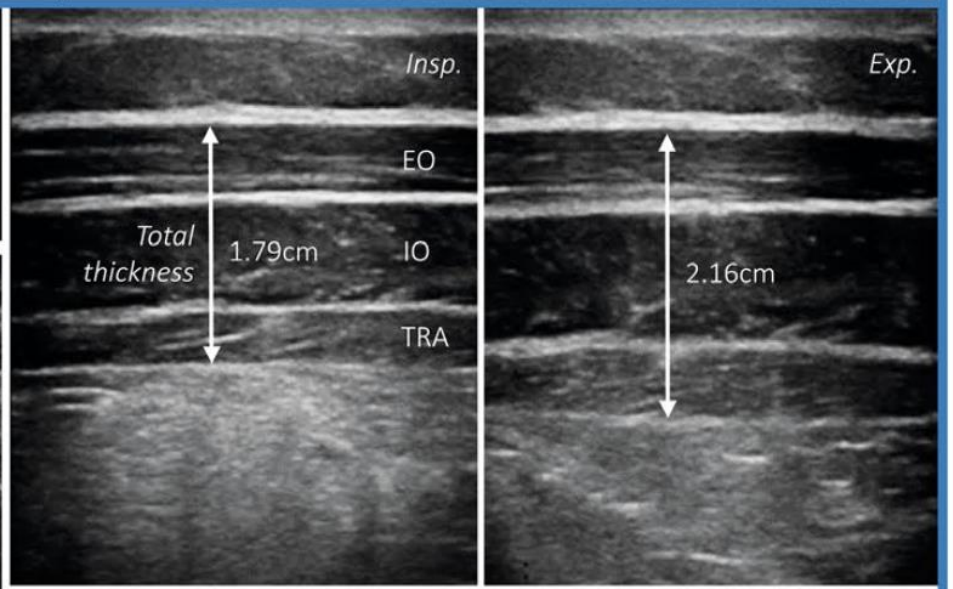


Extra-diaphragmatic respiratory muscles

Evaluate accessory respiratory muscles during SBT; active use indicates high work of breathing / low diaphragm capacity







Example active expiration: $TFabd_{total}$ 23%

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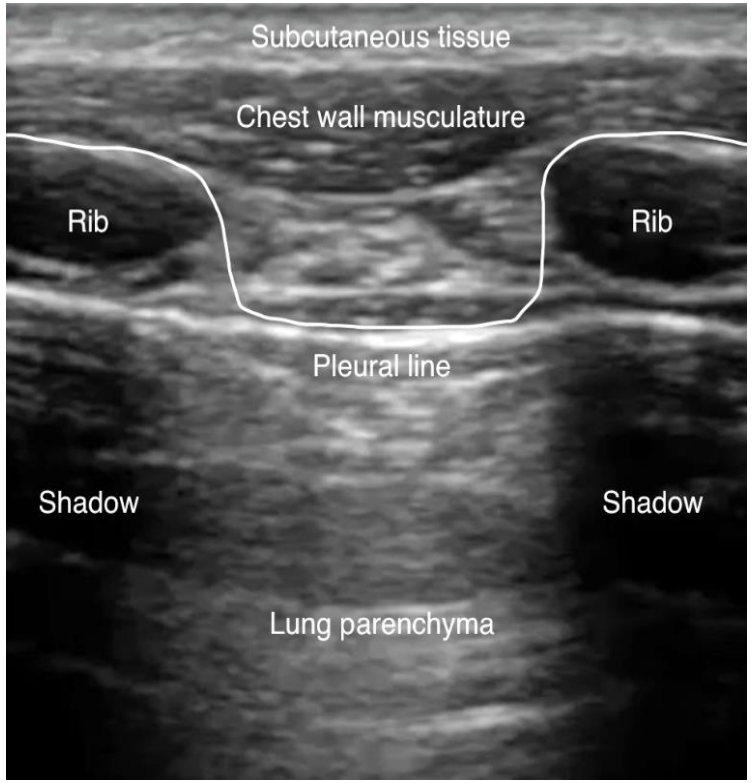
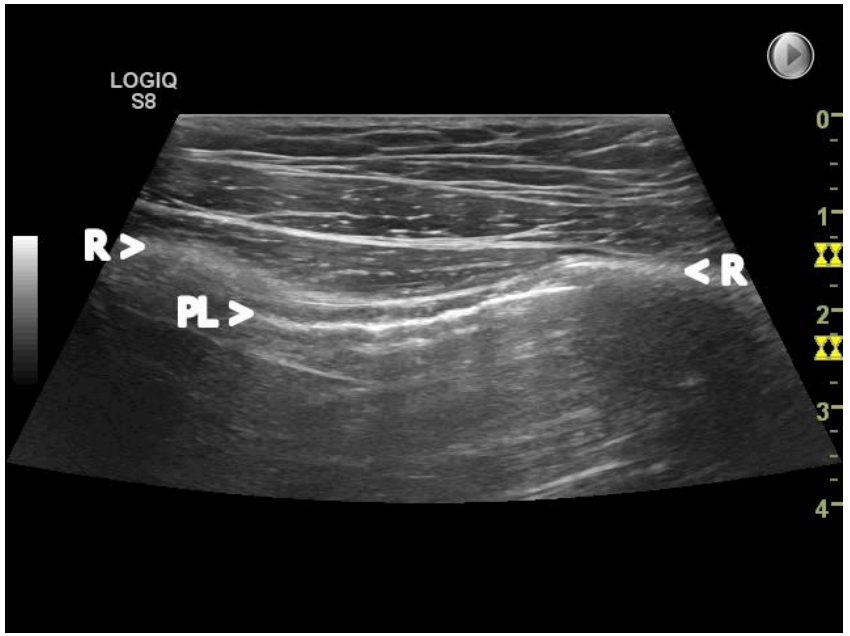
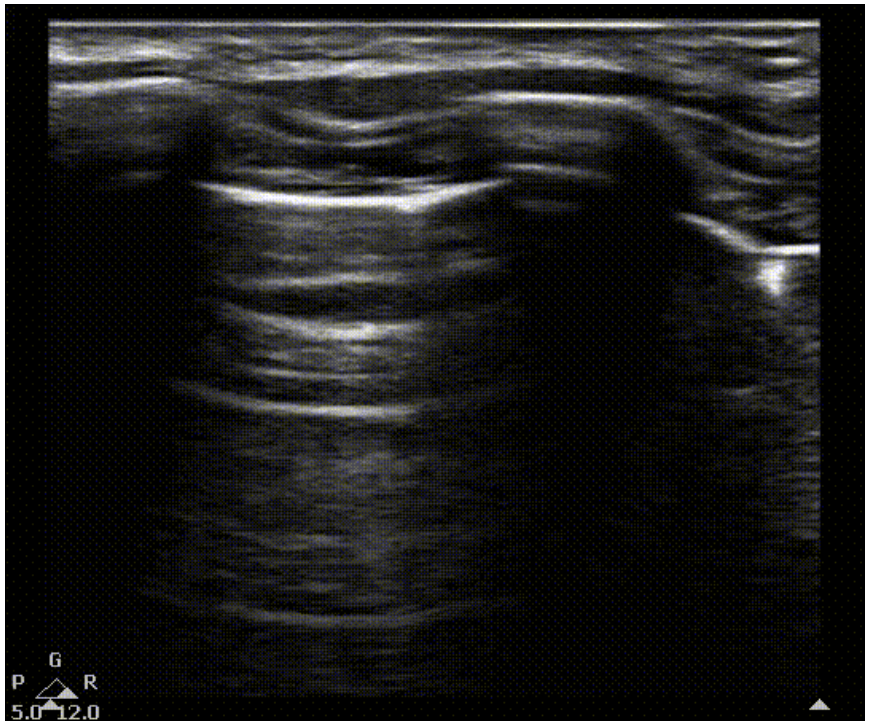
Summary

- Basic principles: the lung tissue is seen as **artifacts**
- **Interpretation of Thoracic US**

  - Normal lung findings: Lung sliding (seashore sign), A-lines, curtain sign



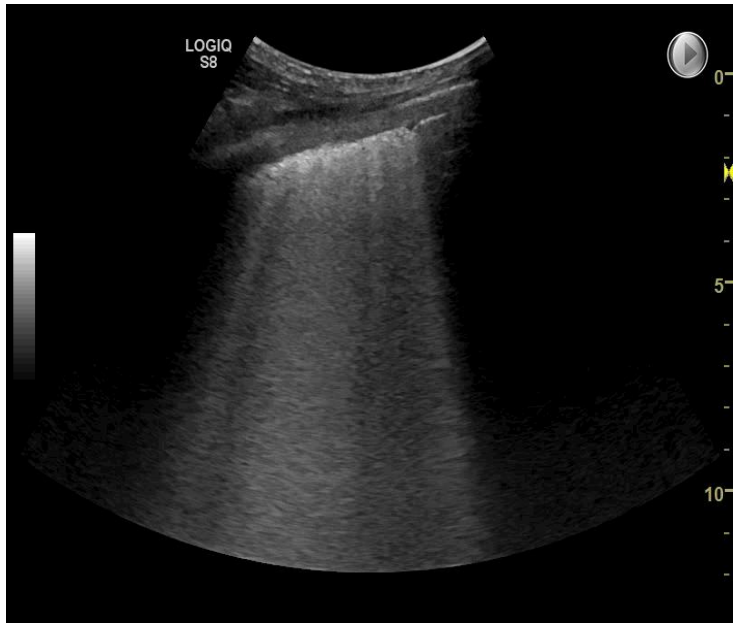


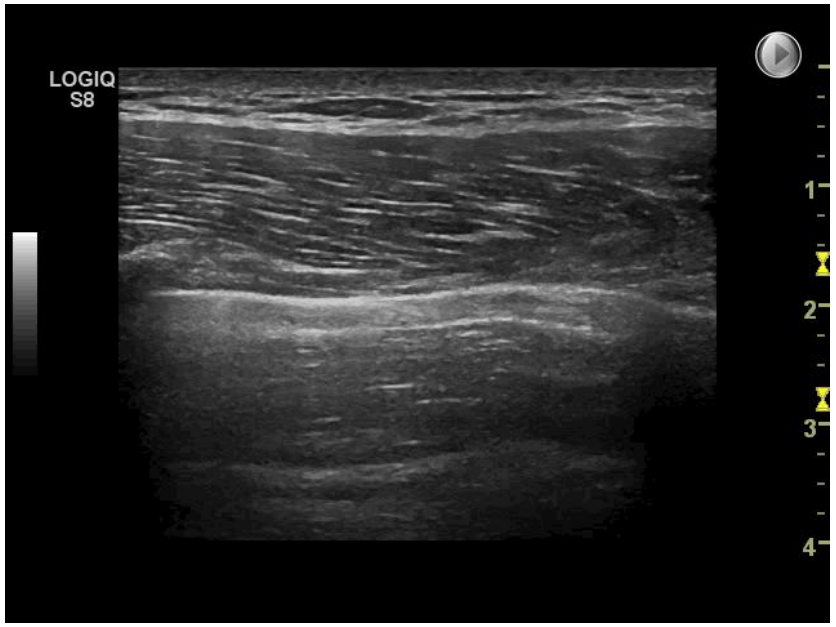


Summary

- **Interpretation of Thoracic US**

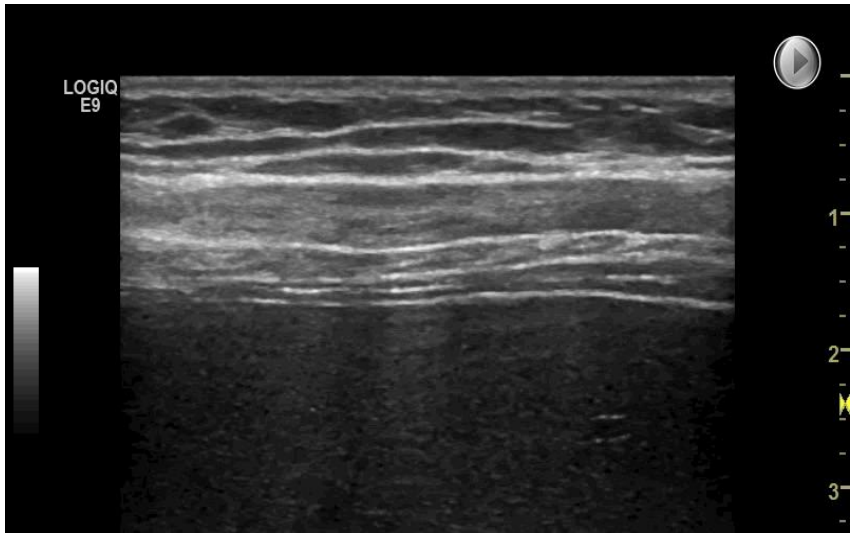
- Injured lung findings: B-lines, interstitial syndrome (B-patterns),
consolidation (tissue-like, shred sign),
pleural effusion, PNX (lung point, barcode sign)

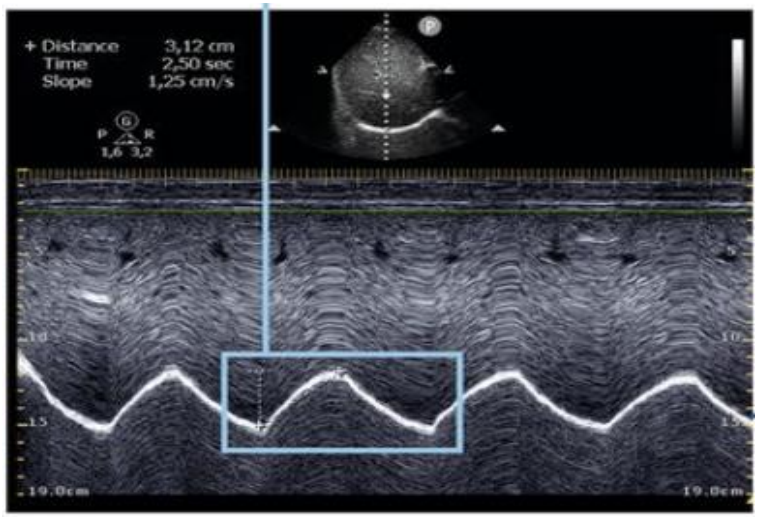




Summary

- **Respiratory muscle US:** Diaphragmatic thickening fraction (DTF), diaphragmatic excursion (ED)





- **Technique and protocols:** BLUE protocol (Upper/lower points, PLAPS point)
  PoCUS in WF (A-B-C-D-E)

- Thank you for your attention ☺