CT AND US ARDS DIAGNOSIS

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فوق تخصص مراقبتهای ویژه

استاد تمام

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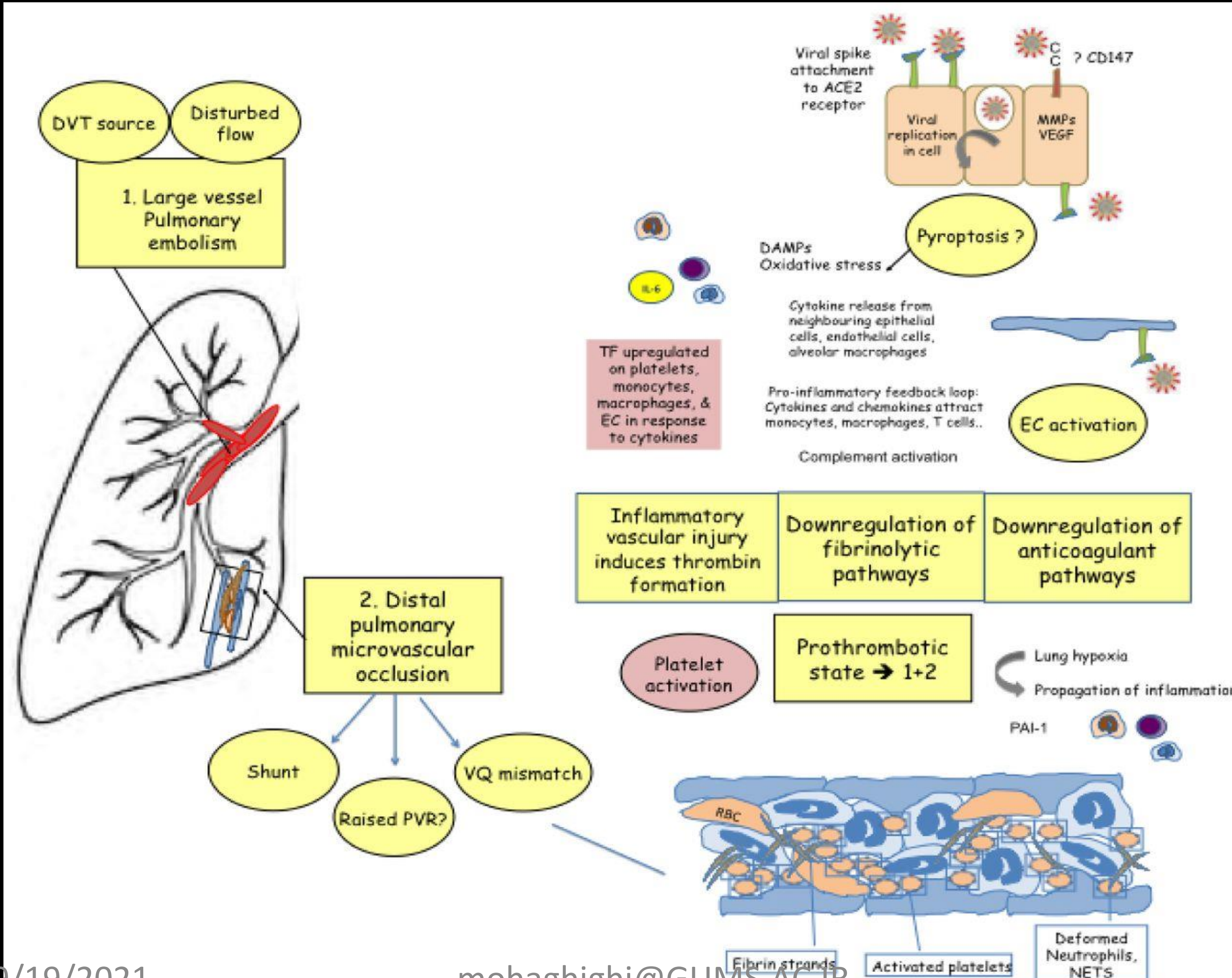
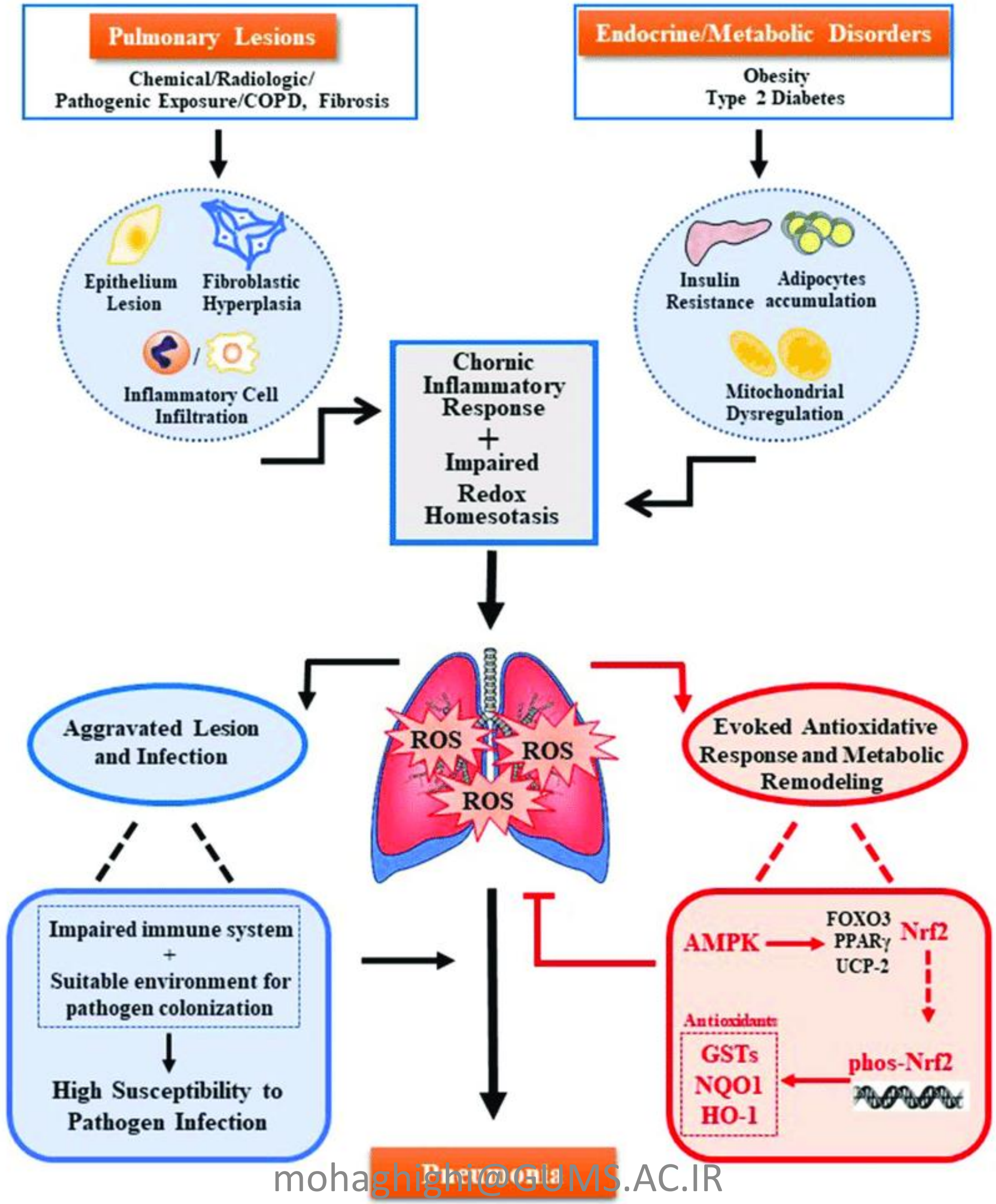

Viral spike attachment to ACE2 receptor
? CD147
Viral replication in cell
MMPs VEGF
Pyroptosis ?
DAMPs Oxidative stress
IL-6
DVT source
Disturbed flow
1. Large vessel Pulmonary embolism
Cytokine release from neighbouring epithelial cells, endothelial cells, alveolar macrophages
TF upregulated on platelets, monocytes, macrophages, & EC in response to cytokines
Pro-inflammatory feedback loop: Cytokines and chemokines attract monocytes, macrophages, T cells..
Complement activation
EC activation
Inflammatory vascular injury induces thrombin formation
Downregulation of fibrinolytic pathways
Downregulation of anticoagulant pathways
2. Distal pulmonary microvascular occlusion
Platelet activation
Prothrombotic state → 1+2
Lung hypoxia
Propagation of inflammation
PAI-1
Shunt
Raised PVR?
VQ mismatch
RBC
Fibrin strands
Activated platelets
Deformed Neutrophils, NETS



Pulmonary Lesions
Chemical/Radiologic/ Pathogenic Exposure/COPD, Fibrosis
Endocrine/Metabolic Disorders
Obesity
Type 2 Diabetes
Epithelium Lesion
Fibroblastic Hyperplasia
Inflammatory Cell Infiltration
Insulin Resistance
Adipocytes accumulation
Mitochondrial Dysregulation
Chornic Inflammatory Response + Impaired Redox Homesotasis
ROS
ROS
ROS
Aggravated Lesion and Infection
Evoked Antioxidative Response and Metabolic Remodeling
Impaired immune system + Suitable environment for pathogen colonization
High Susceptibility to Pathogen Infection
AMPK
FOXO3
PPARγ
UCP-2
Nrf2
Antioxidants
GSTs
NQO1
HO-1
phos-Nrf2

Table 2 The typical features on CT imaging of COVID-19

Parameter	Characteristic manifestations on CT imaging
Density	Ground glass opacity and consolidation, possible interlobular septal thickening
Shape	Patchy, sub-segmental, or segmental
Distribution	Mid and lower lungs along the bronchovascular bundles with bilateral involvement
Location	Peripheral and subpleural areas of the lung parenchyma
Concomitant signs (variable)	Air bronchogram, a small amount of pleural effusion, no obvious lymphadenopathy

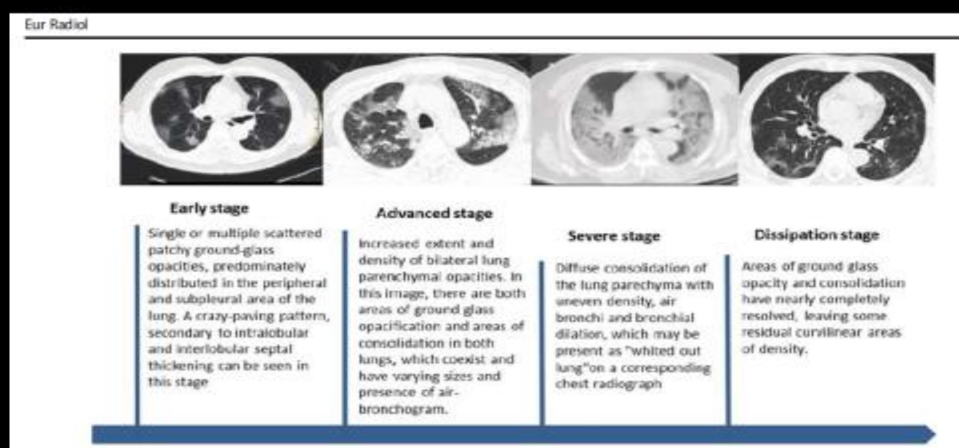


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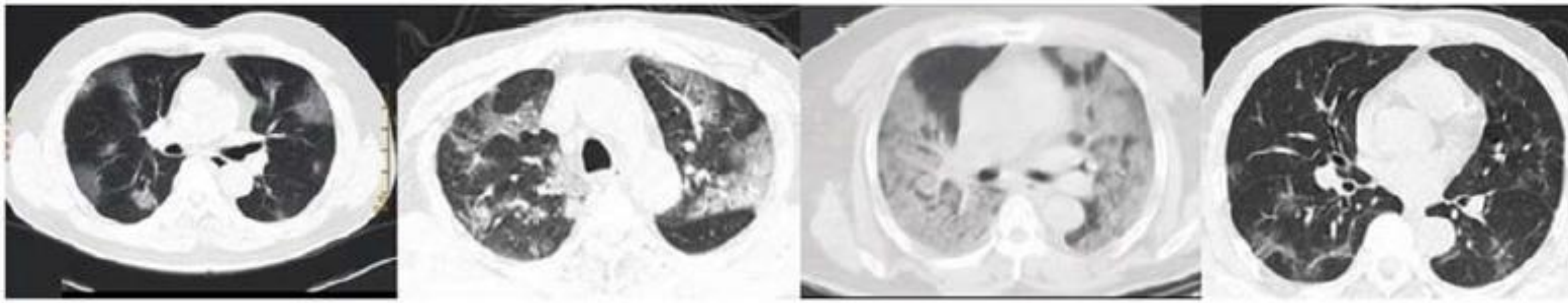
Table 2: CT imaging features of patients with COVID-19.

CT findings	Number of studies	Number of patients (
Patterns of the lesion		
Ground-glass opacity with consolidation	60	768 (18%)
Ground-glass opacity	60	2482 (65%)
Consolidation	60	1259 (22%)
Crazy paving pattern	24	575 (12%)
Reversed halo sign	24	146 (1%)
Other signs in the lesion		
Interlobular septal thickening	23	691 (27%)
Air bronchogram sign	23	531 (18%)
Distribution		
Bilateral	48	3952 (80%)
Unilateral	48	641 (20%)
Right lung	8	48 (62%)
Left lung	8	29 (38%)
Number of lobes involved		
One lobe	13	278 (14%)
Two lobes	13	299 (11%)
Three lobes	13	250 (13%)
Four lobes	13	212 (15%)
Five lobes	14	384 (34%)
More than one lobe	14	1145 (76%)
Lobe of lesion distribution		
Left upper lobe	14	731 (74%)
Left lower lobe	20	504 (46%)
Right upper lobe	19	455 (40%)
Right middle lobe	15	326 (38%)
Right lower lobe	17	784 (74%)
Other findings		
Pleural effusion	60	94 (1.6%)
Lymphadenopathy	60	21 (0.7%)
Pulmonary nodules	22	262 (9%)

Table 3 Frequency of chest CT findings in COVID-19

CT signs	Frequency	Stage
Ground glass opacity	++++	E/A/S
Consolidation without ground glass opacity	++	S
Ground glass opacity and crazy paving	++	E/A/S
Ground glass opacity with consolidation	+++	E/A/S
Patchy ground glass opacity	+++	E
Bilateral distribution	++++	E/A/S/D
Peripheral distribution	+++	E
Air bronchogram	++	E/A/S
Pleural effusion	+	S
Strip-like opacity	+	D

The appearance frequency of each CT characteristic is described in order from low to high as (+~++++); *E*, *A*, *S*, and *D* stand for stage early, advanced, severe, and dissipation



Early stage

Single or multiple scattered patchy ground-glass opacities, predominately distributed in the peripheral and subpleural area of the lung. A crazy-paving pattern, secondary to intralobular and interlobular septal thickening can be seen in this stage

Advanced stage

Increased extent and density of bilateral lung parenchymal opacities. In this image, there are both areas of ground glass opacification and areas of consolidation in both lungs, which coexist and have varying sizes and presence of air-bronchogram.

Severe stage

Diffuse consolidation of the lung parechyma with uneven density, air bronchi and bronchial dilation, which may be present as "whited out lung"on a corresponding chest radiograph

Dissipation stage

Areas of ground glass opacity and consolidation have nearly completely resolved, leaving some residual curvilinear areas of density.

COVID-19 autopsies

Carsana et al [MedRxiv pre-print doi 10.1101/2020.04.19.20054262v1]	Northern Italy n=38 Age ~69, ICU duration ~7 d Transthoracic biopsies	Diffuse alveolar damage (DAD) in all, mostly early / exudative (few fibrinous) Platelet-fibrin thrombi in small arterial vessels (<1mm) 86% (n=33/38), mostly focal or plurifocal
Dolhnikoff et al JTH doi 10.1111/jth.14844	Brazil n=10 Minimally invasive autopsies	8/10 had fibrin thrombi in small pulmonary arterioles, no pulmonary infarction
Barton et al . Am J Clin Pathol doi: 10.1093/ajcp/aqaa062.	Oklahoma, USA n=2 Autopsies	n=1 DAD n=1 bronchopneumonia, complications of myotonic dystrophy and cirrhosis
Fox et al [MedRxiv pre-print doi 10.1101/2020.04.06.20050575v1]	Louisiana, USA n=4 Autopsies	Edematous lungs with DAD Some microthrombi in pulmonary arterioles Pulmonary arteries free of thromboemboli

In patients with COVID-19 who died and were included in these studies, the pathology appears largely consistent with ARDS given DAD (note ~50% of cases of ARDS have DAD on autopsy, more common in severe disease). Many cases do have microthrombi in pulmonary arterioles, which has also been found in cases of ARDS. There's obvious selection bias in terms of who is selected for autopsies/biopsies and only captures the severe end of the spectrum

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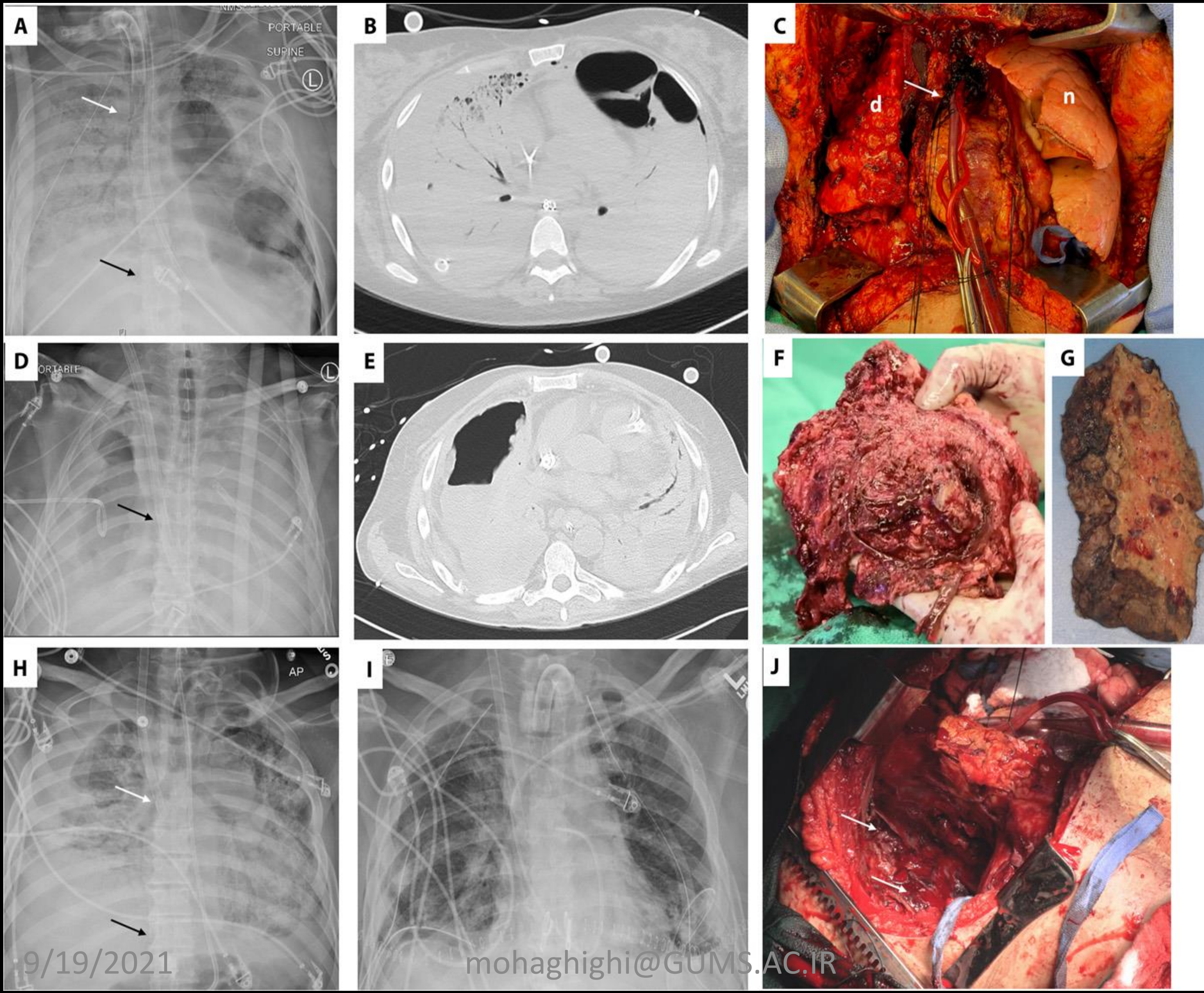
A
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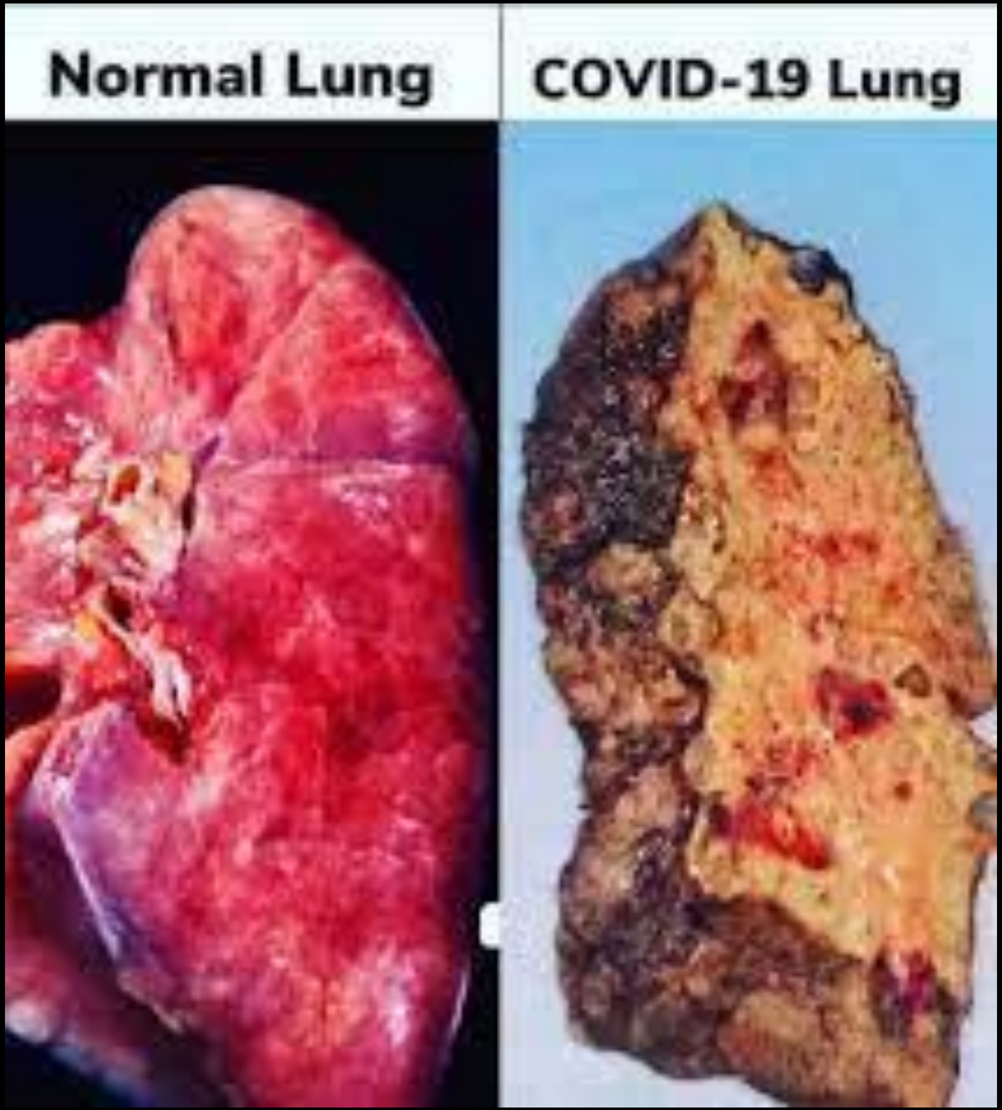
Normal Lung
COVID-19 Lung

patients.

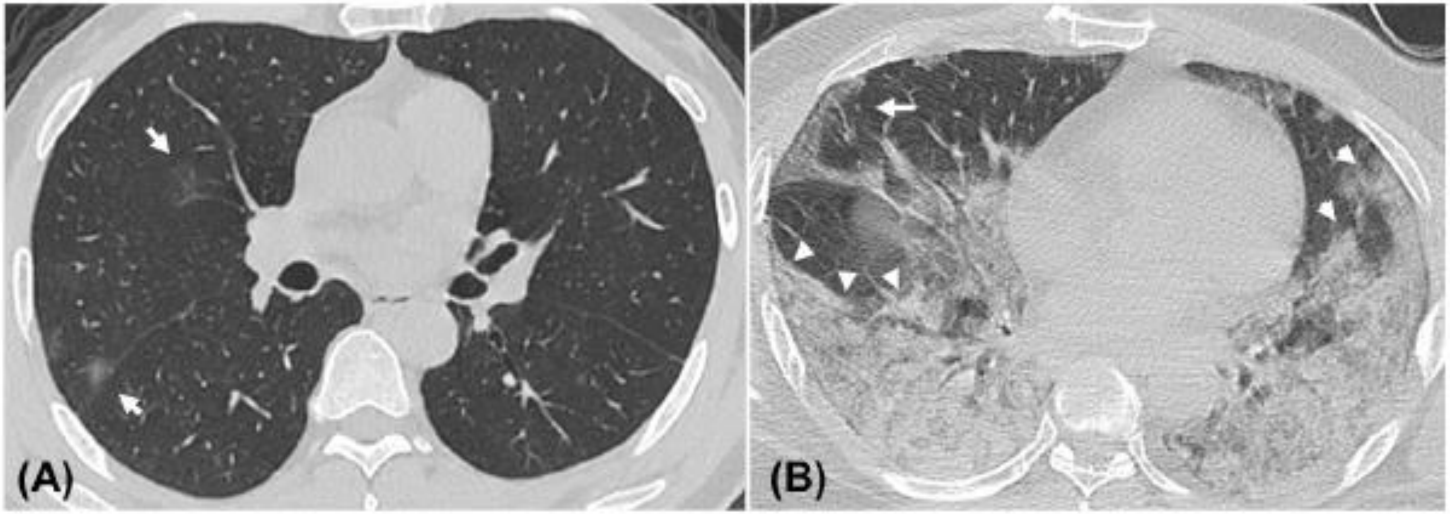

Figure 2

An axial CT image from a 49-year-old male (Panel A) in the COVID-19 group presents multiple ground-glass opacities with rounded morphology at both right upper lobe and left lower lobe (arrow) (severity score: 2). An axial CT image from a 50-year-old male (Panel B) shows severer change bilaterally with diffuse ground-glass opacities (arrow) and consolidation (arrowhead).

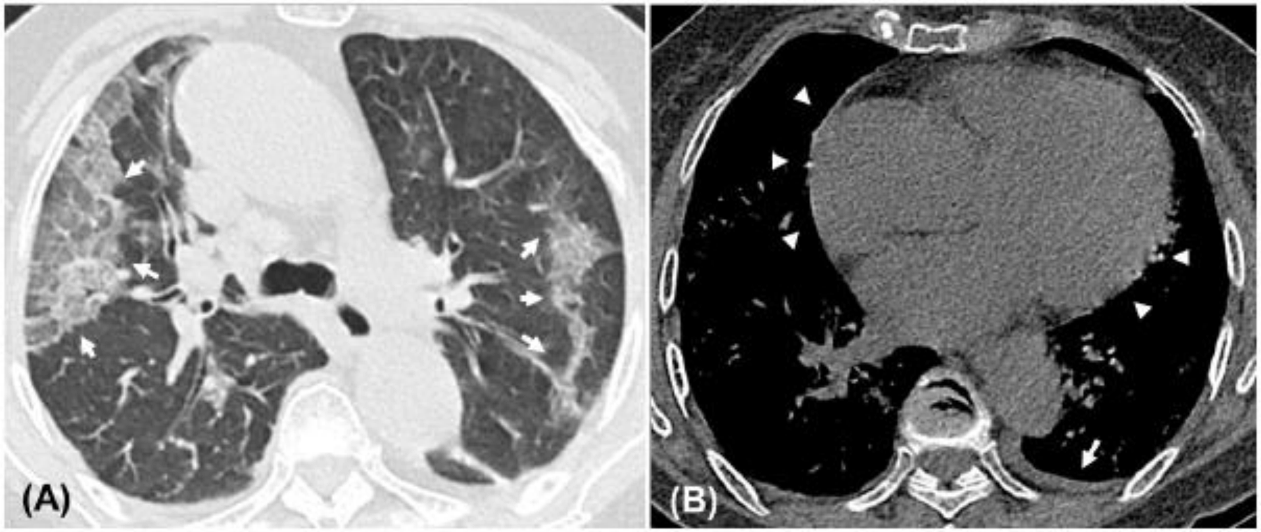

Figure 3

Case of an 80-year-old female. An axial CT image with lung widow (Panel A) shows patchy ground-glass opacities with inter- and intralobular septal thickening in the subpleural area at bilateral upper lobes(arrow). An axial image with soft-tissue window (Panel B) shows enlarged heart(arrowhead), as well as unilateral pleural effusion(arrow). This patient developed severe illness rapidly and died soon after being sent to intensive care unit.

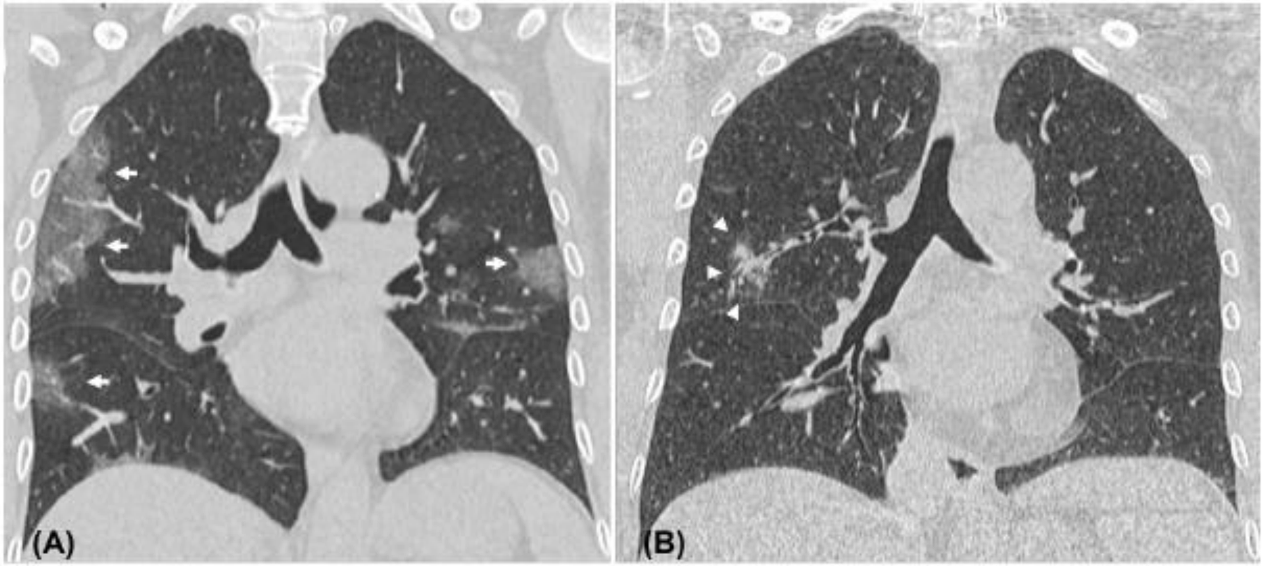

Figure 4

A coronary CT image from a 65-year-old female (Panel A) in the COVID-19 group presents patchy opacity at right upper lobe and rounded morphology like ground-glass opacity at left upper lobe. A coronary CT image from a 56-year-old female (Panel B) shows irregular-shaped mixed ground-glass and consolidation opacities (arrowhead).

Fig. 2 Chest radiograph (**a**) in a 61-year-old man shows bilateral patchy, somewhat nodular opacities in the mid to lower lungs [16]. Unenhanced computed tomography (CT) images (**b**) in a 33-year-old woman., Images show multiple ground glass opacities in the periphery of the bilateral lungs. The bilateral, peripheral patterns of opacities without subpleural sparing are common and characteristic CT findings of the 2019 novel coronavirus pneumonia [22]. Chest CT image of a 71-year-old male (**c**) shows consolidation in the peripheral right upper lobe and a patchy area of ground glass opacity with some associated consolidation intra- and interlobular septal thickening within the left upper lobe [25]

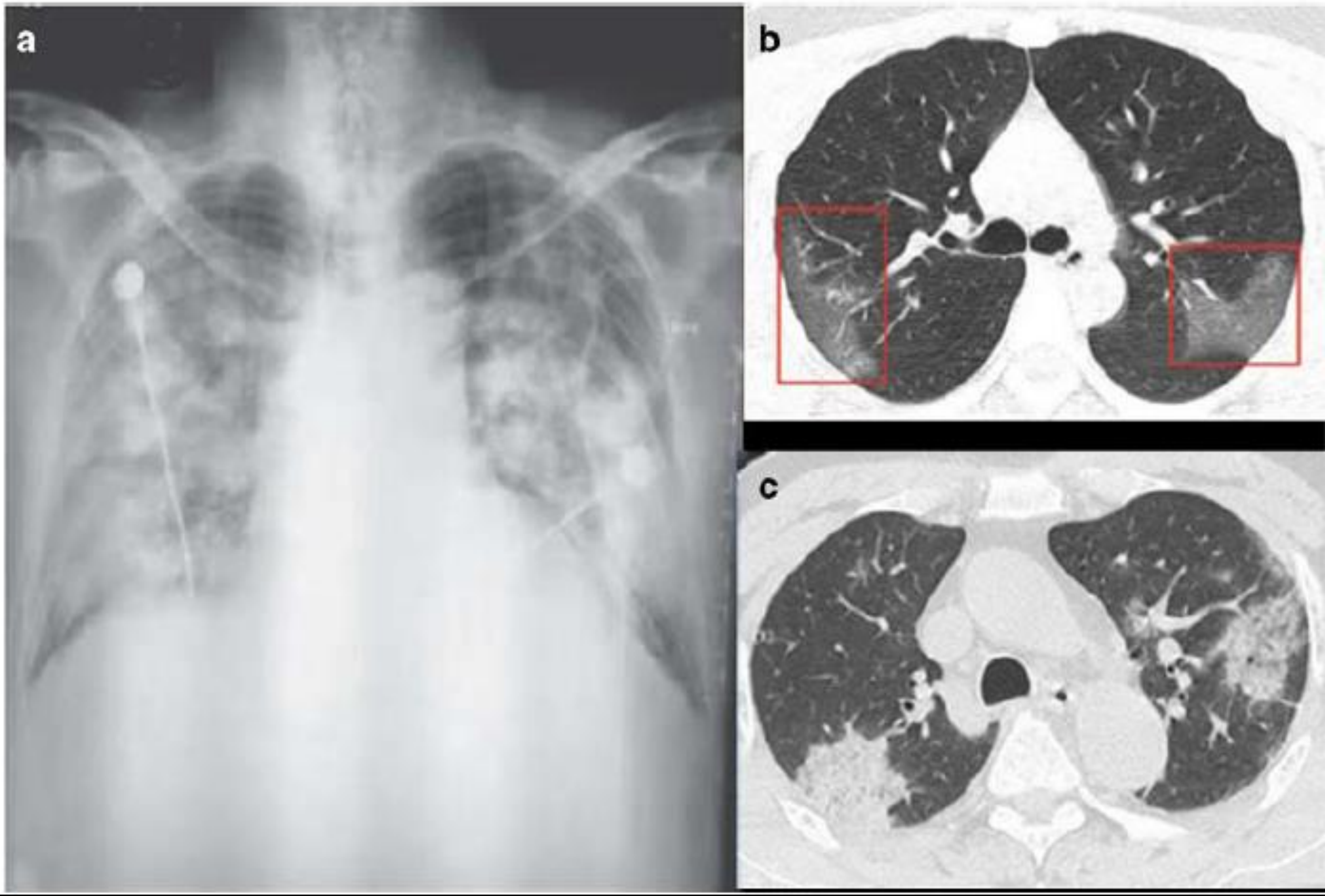

Fig. 3 Typical CT findings of COVID-19. Chest CT (**a**) in a 75-year-old male show multiple patchy areas of pure ground glass opacity (GGO) and GGO with reticular and/or interlobular septal thickening [25]. Chest CT image of a 38-year-old male (**b**) shows multiple patches, grid-like lobule, and thickening of interlobular septa, typical "paving stone-like" signs [19]. An axial CT image obtained in 65-year-old female (**c**) shows bilateral ground glass and consolidative opacities with a striking peripheral distribution [23]. CT image of a 65-year-old male (**d**) shows large consolidation in the right middle lobe, patchy consolidation in the posterior and basal segment of right lower lobe, with air bronchogram inside [19]

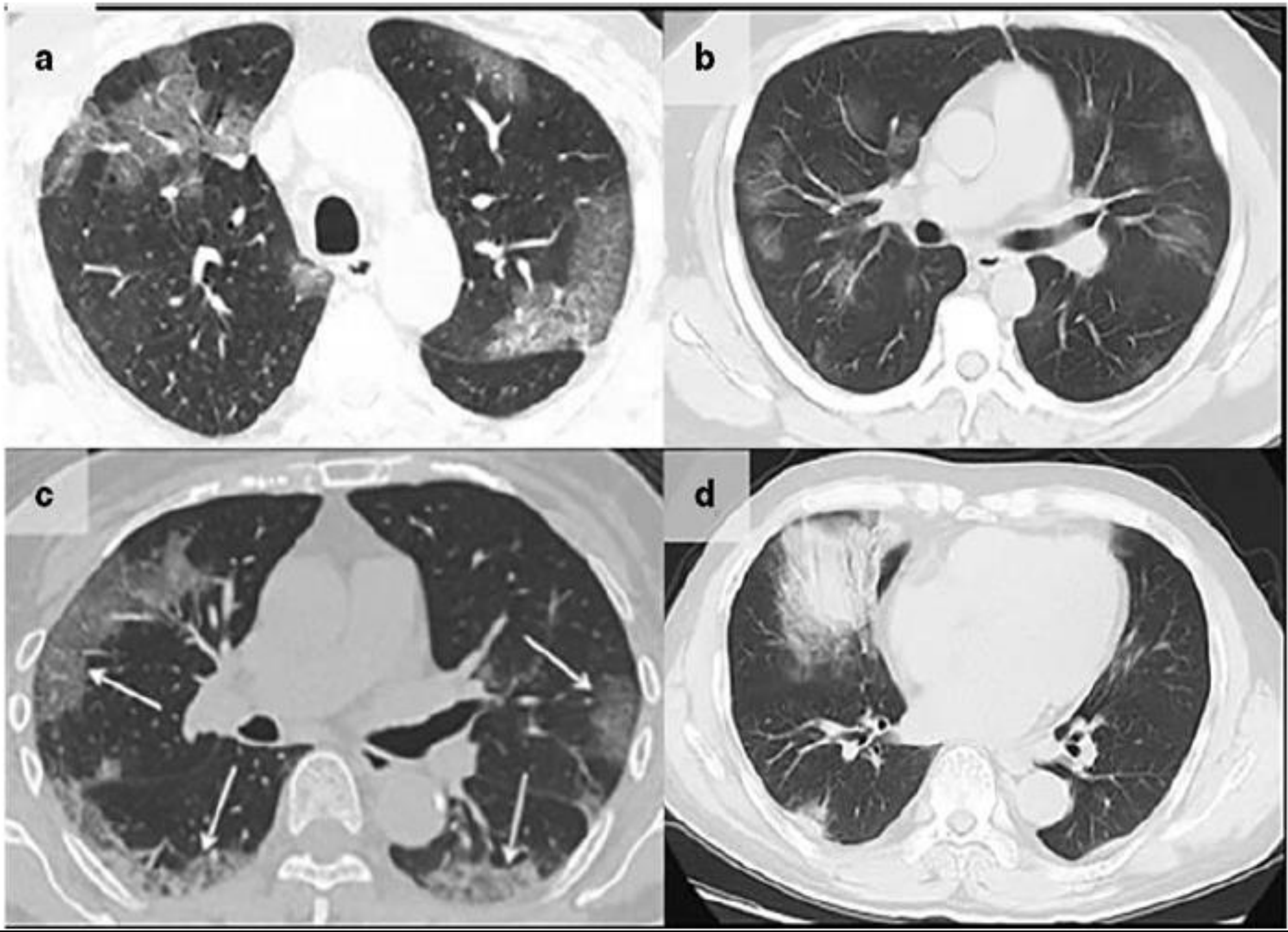

Table 4 Differential diagnosis of different viral pneumonia

Virus	Imaging characteristics
MERS-COV	Ground glass lesions in the subpleural and basal portions of the lung parenchyma with areas of consolidation; fibrotic changes can be present after healing
H1N1	Ground glass opacity, interlobular septal thickening, and centrilobular nodules
H7N9	Ground glass opacity and consolidation with air bronchograms and interlobular septal thickening
Human parainfluenza virus	Centrilobular nodules with bronchial wall thickening, findings which differentiate it from other viral infections
Respiratory syncytial virus	Small centrilobular nodules and areas of parenchymal consolidation; asymmetrically distributed in the lungs
Adenovirus pneumonia	Bilateral multifocal ground glass opacities, patchy consolidation in a lobar and/or segmental distribution

Respiratory Medicine 141 (2018) 26–36

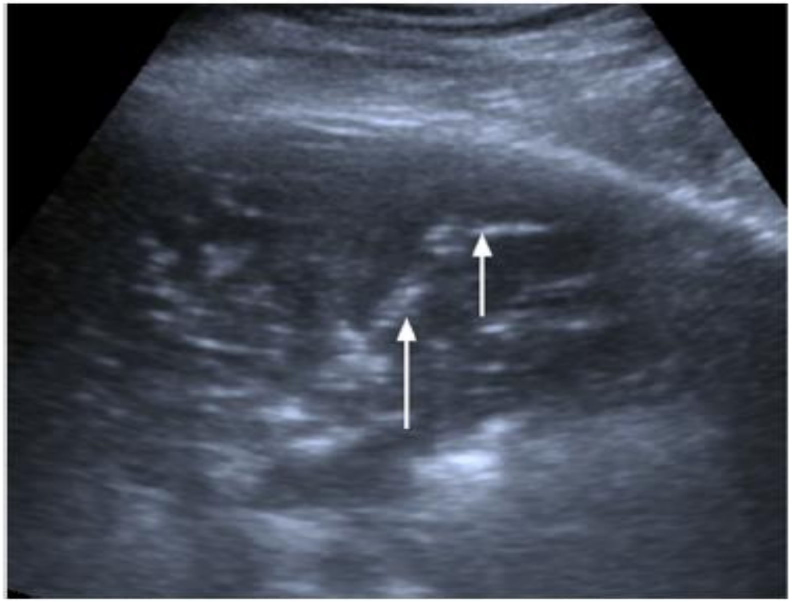

Fig. 5. Consolidated lung. Air bronchograms (white arrows) on background of increased echodensity with serrated distal margin.

Table 1
Diagnostic characteristics of thoracic ultrasound for common ARF aetiologies.

Clinical Pattern	Ultrasound Findings	Differential Diagnoses	Sensitivity[a] (inc 95% CI)	Specificity[a] (inc 95% CI)	Comments
Pneumothorax [19–22]	Absent lung sliding	Lung bullae	88% (85–91) [19]	99% (98–99%) [19]	Studies typically in trauma (high prevalence)
	Absence of B-lines	Localised fibrosis	91% (86–94) [20]	98% (97–99%) [20]	Heterogeneity on meta-analysis
	Lung-point	ARDS	79% (68–98) [21]	98% (97–99) [21]	
	'Stratosphere sign'	Mainstem intubation	87% (81–92%) [22]	99% (98–99) [22]	Clinical significance of pneumothorax not detected on CXR unclear
	Ruled out by presence of 'lung pulse'				
Pleural effusion [36,37]	Hypoechoic space: 'quad sign'	Pleural thickening	93% (89–96) [36]	96% (95–98) [36]	High prevalence of effusion in included studies
	'Sinusoid sign'	Intra-parenchymal fluid	94% (88–97) [37]	98% (92–100) [37]	
Pneumonia [41,45–47]	Increased echogenicity	Atelectasis	*All comers:*	*All comers:*	Studies report high prevalence of pneumonia (clinical context important)
	Loss of pleural line	Pulmonary infarction	97% (93–99) [45]	94% (85–98) [45]	
	Air-bronchograms	Pulmonary contusion	94% (92–96) [46]	96% (94–97) [46]	
	Hypo-echoic/serrated distal edge	Neoplasm	95 (93–97) [47]	90% (86–94) [47]	Sensitivity of US in ARF depends on unit of analysis (per patient or per region) [41]
	Hypoechoic vascular structures		*ARF:* 91% (81–97) to 100% (95–100) [41]	*ARF:* 78% (52–94) to 100% (99–100) [41]	
Pulmonary embolism [50,51]	Peripheral wedge-shaped consolidation	Pneumonia	87% (76–92) [50]	82% (71–89) [50]	Poor performance as both 'rule-in' and 'rule out' test [51]
	Lower limb DVT	Neoplasm	85% (78–90) [51]	83% (73–90) [51]	
	Right ventricular dysfunction				
	Pleural effusion				
Pulmonary oedema and interstitial lung disease (ILD) [67,68]	Increased B-lines ("interstitial syndrome")	*Diffuse:* Cardiogenic pulmonary oedema, ARDS, Infection, Interstitial lung disease	*Cardiogenic pulmonary oedema:* 94% (81–98) [67] 85% (83–88) [68]	*Cardiogenic pulmonary oedema* 92% (84–96.) [67] 93% (91–94) [68]	Poorly predicts pulmonary occlusion pressure [37]
		Non-cardiogenic pulmonary oedema	*Non-cardiogenic pulmonary oedema/ ILD:*	*Non-cardiogenic pulmonary oedema/ ILD:*	Predicts extravascular lung water [37–39]
		Focal: Pneumonia, pulmonary contusion, fibrosis, lymphangitis	N/A	N/A	
Diaphragm dysfunction [79,81,82]	Reduced thickness	Direct trauma	N/A	N/A	Thickening ratio has modest predictive value for weaning outcome, with lower accuracy for excursion [87].
	Reduced thickening ratio	Surgery			
	Reduced/paradoxical excursion	Adjacent consolidation, malignancy or atelectasis			
		Fluid (pleural/ascites)			
		COPD			
		Neuromuscular disease			
		Denervation (neck/chest)			

Solution to the issue of growing irradiation

All intensivists prefer the least invasive tool, all else being equal. Ultrasound is an answer to the longstanding dilemma: "Radiography or CT in the ICU?" Radiography is a familiar tool that lacks sensitivity [60]: 60-70%, all fields considered [61-63]. CT has a high accuracy but severe drawbacks: cost (a real problem for most patients on Earth), transportation of critically ill patients, delay between CT and the resulting therapy, renal issues, anaphylactic shock, mainly high irradiation [64,65]. Ultrasound has quite similar performances to CT [12,17,20,30,37], being on occasion superior: better detection of pleural septations, necrotic areas [66], real-time measurement allowing assessment of dynamic signs: lung-sliding, air bronchogram [67], diaphragm [68,69]. Ultrasound should be considered as reasonable, bedside "gold standard." For all assessed disorders, it provides quantitative data (Figures 3, 4, and 7). Pleural effusions can be quantified [14,70-72]. Lung consolidation can be monitored, which is useful for those who want to increase end-expiratory pressure [73]. The volume and progression of a pneumothorax are monitored using the lung-point location [34,37,38]. Lung ultrasound will favor programs allowing decrease in bedside radiographs and CTs in the next decades.

ULTRASOUND FUNDAMENTALS

Many types of probes (also known as **transducers**) have been developed. A few examples are shown below:

CONVEX PROBE

LINEAR PROBE

PHASED-ARRAY PROBE

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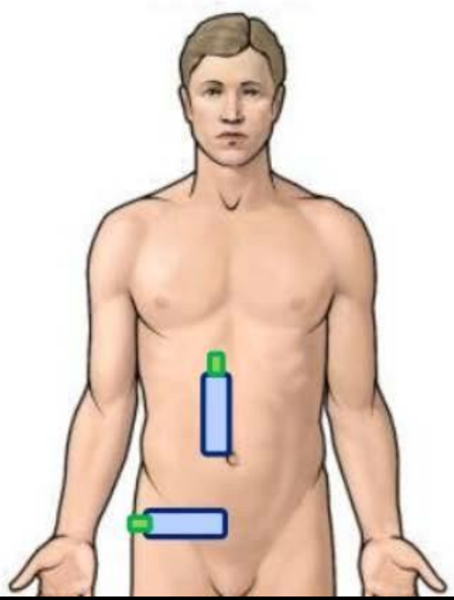
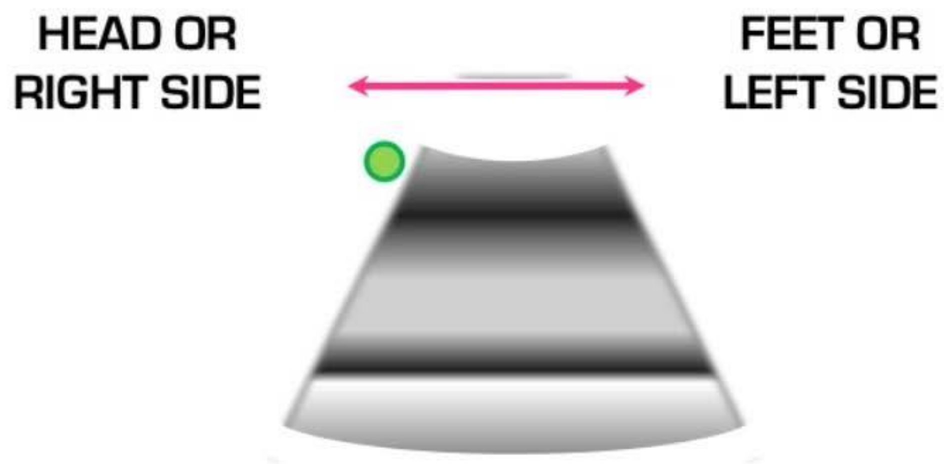
ULTRASOUND FUNDAMENTALS

The **convention** when the screen marker is on the left of the screen is that the probe marker should be directed to the patient's **head** or to the patient's **right side** when scanning.





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ULTRASOUND FUNDAMENTALS

Every ultrasound probe has an **orientation marker** that correlates with another **marker** displayed on the ultrasound screen.

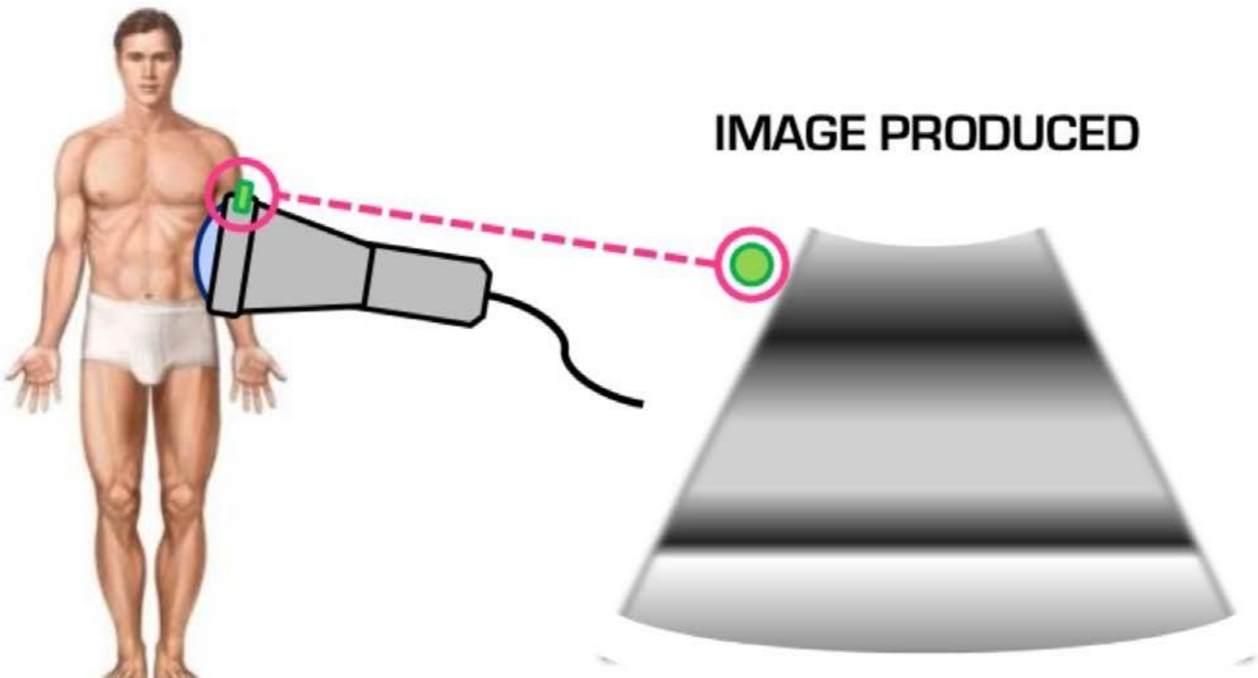

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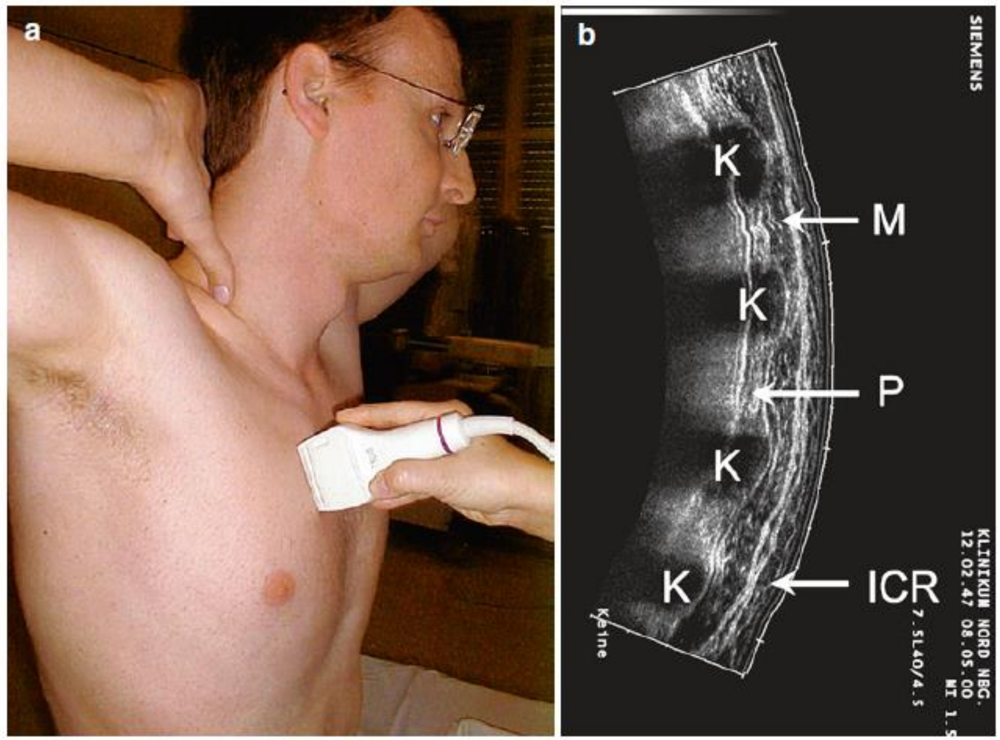
Fig. 1.4 Examination of the seated patient. (**a**) Linear probe placed longitudinally on the right parasternal line. (**b**) Corresponding sonographic longitudinal panoramic image (SieScape). *K* cartilage at the point of insertion of the rib, *ICR* intercostal space, *M* muscle, *P* line of the pleura



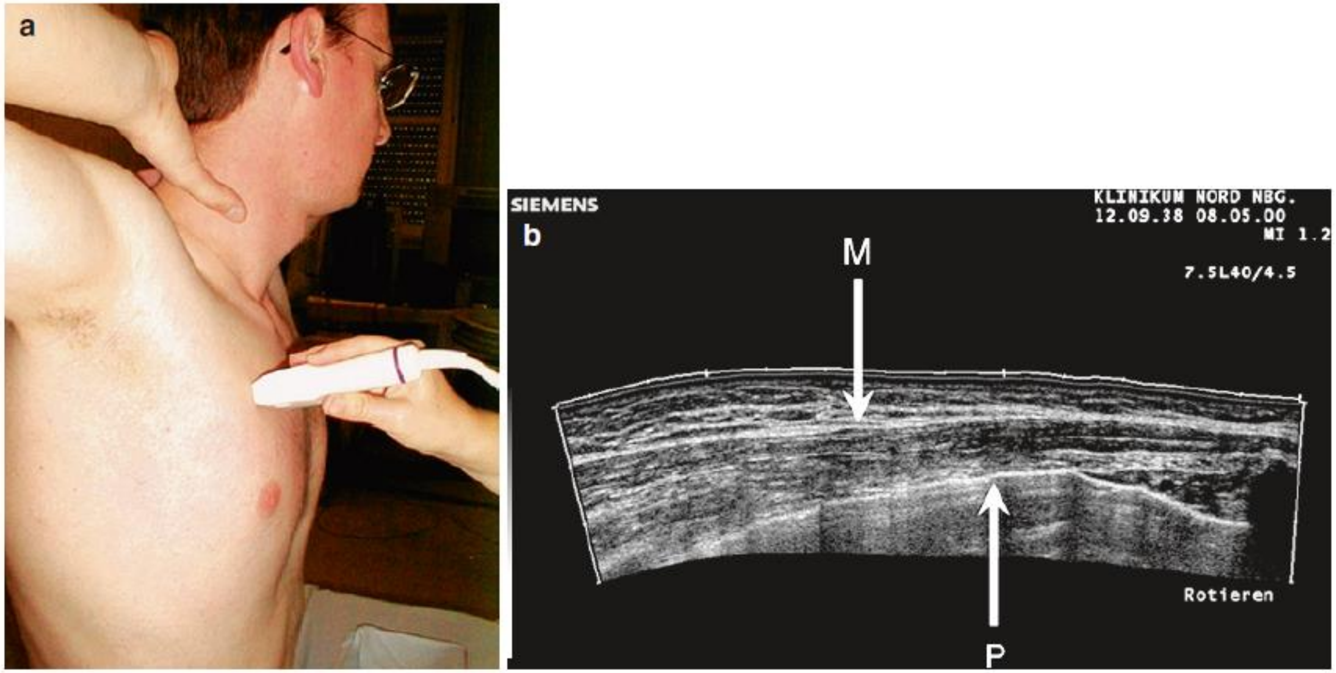


Fig. 1.5 Examination of the seated patient. (**a**) Linear probe placed parallel to the ribs in the third intercostal space. (**b**) Corresponding sonographic transverse panoramic image (SieScape). *M* muscle, *P* line of the pleura

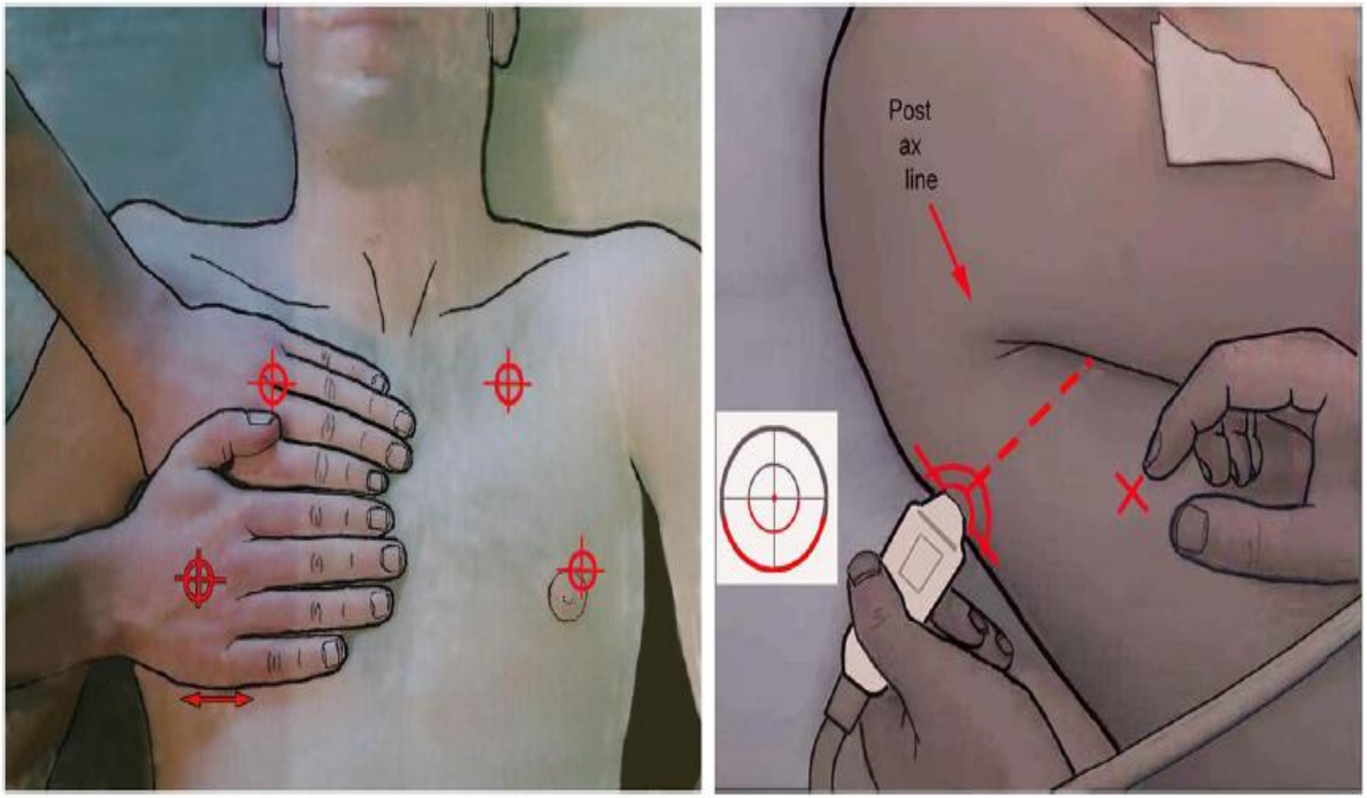
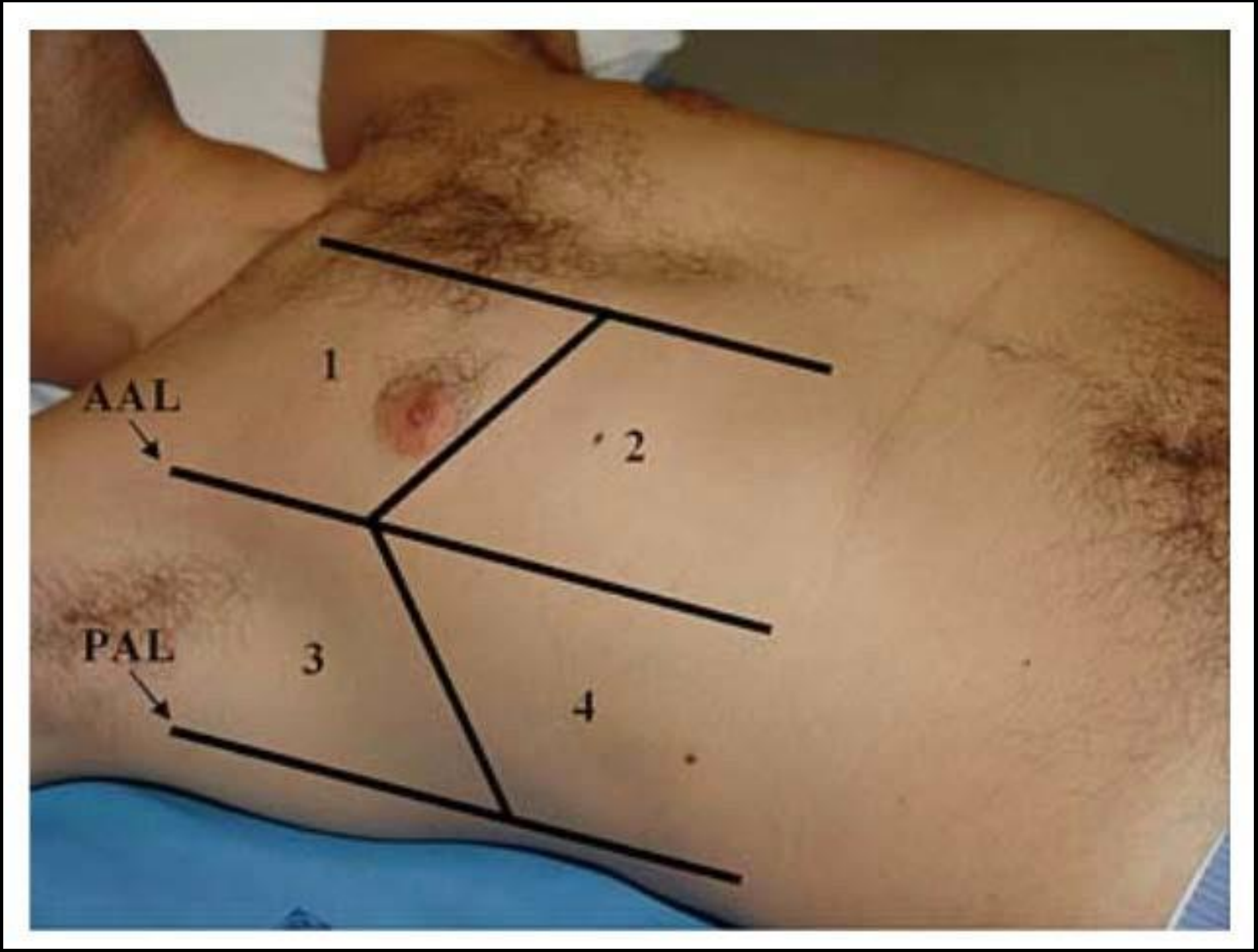


Figure 1 Areas of investigation and the BLUE-points. Two hands placed this way (size equivalent to the patient's hands, upper hand touching the clavicle, thumbs excluded) correspond to the location of the lung, and allow three standardized points to be defined. The upper-BLUE-point is at the middle of the upper hand. The lower-BLUE-point is at the middle of the lower palm. The PLAPS-point is defined by the intersection of: a horizontal line at the level of the lower BLUE-point; a vertical line at the posterior axillary line. Small probes, such as this Japanese microconvex one (1992), allow positioning posterior to this line as far as possible in supine patients, providing more sensitive detection of posterolateral alveolar or pleural syndromes (PLAPS). The diaphragm is usually at the lower end of the lower hand. Extract from "Whole body ultrasonography in the critically ill" (2010 Ed, Chapter 14), with kind permission of Springer Science.

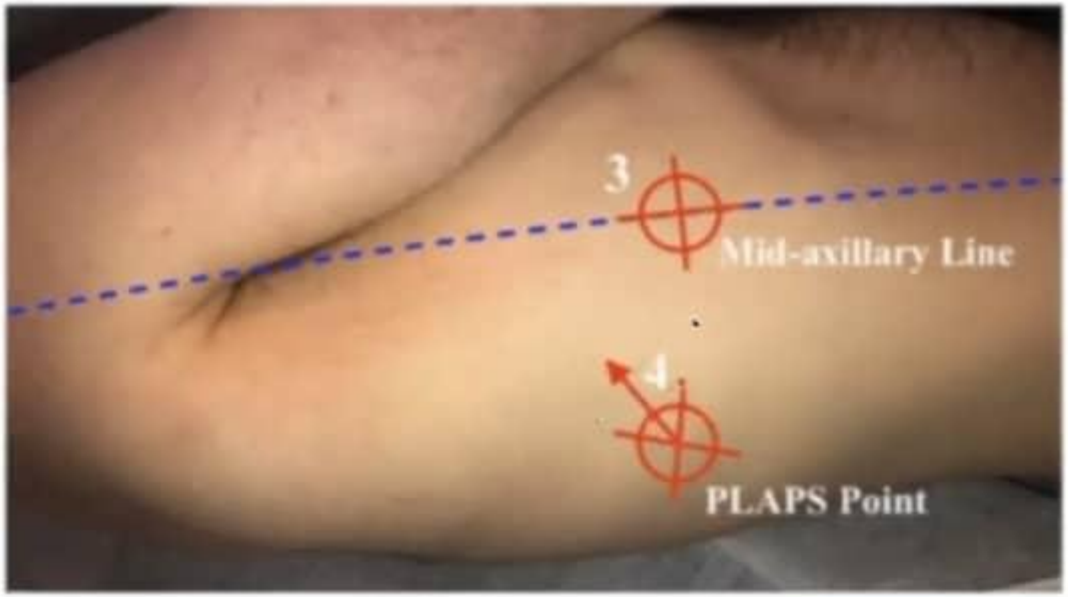
Thoracic Ultrasound:
Probe Location:



Volpicelli, G., Emerg Radiol, 2008: 15:145-51

BLUE Protocol

1 is located on the mid-clavicular line, at the second intercostal space; Point 2 is located on the anterior axillary line, at the fifth intercostal space; Point 3 is located along the diaphragm, at the mid-axillary line; and Point 4 (known as the posterolateral alveolar pleural syndrome (PLAPS) point) is located on the most posterior point along the diaphragm, where the transducer is tilted anteriorly (arrow)



1. Lichtenstein DA, Meziere GA (2008) Relevance of lung ultra- sound in the diagnosis of acute respiratory failure: the BLUE protocol. Chest 134:117–125
2. Islam M et al. Lung Ultrasound for the Diagnosis and Management of Acute

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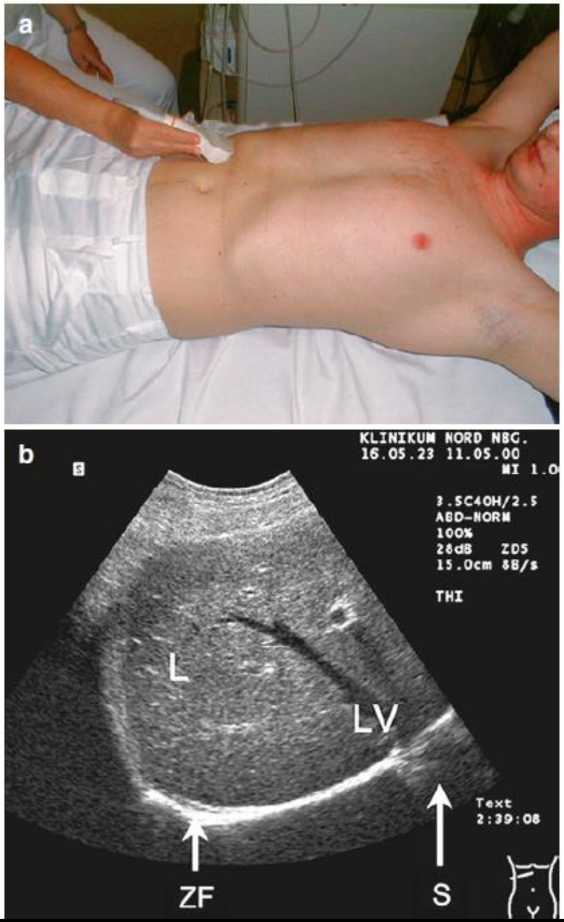
Fig. 1.6 Position of the patient when structures behind the scapula are examined



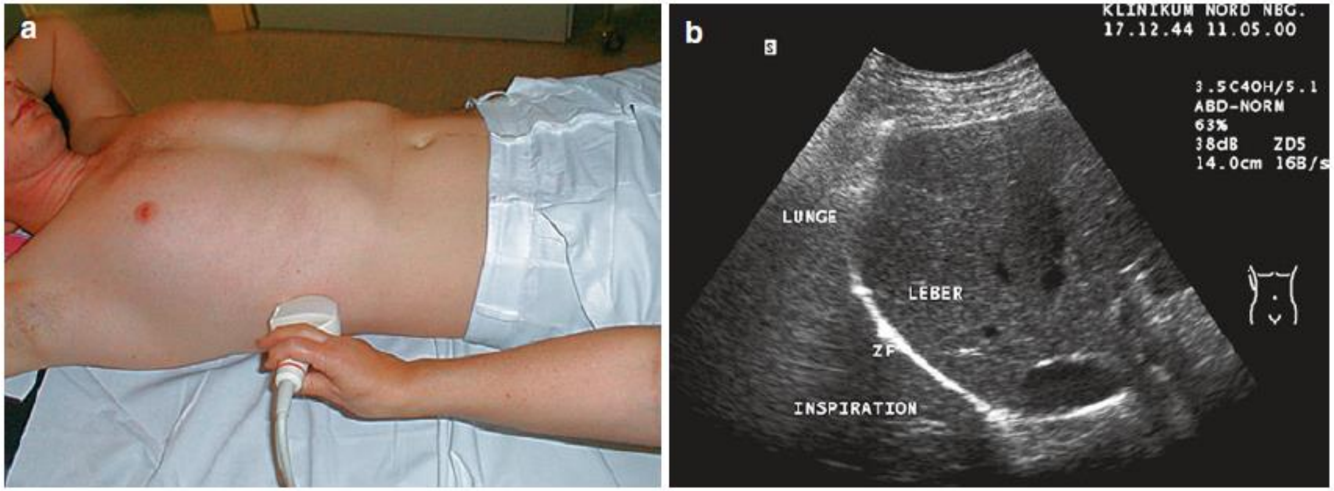
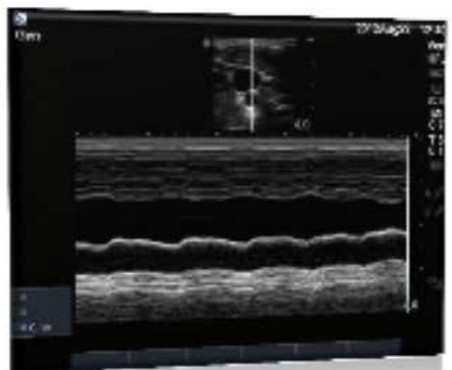


Fig. 1.8 Examination from the lateral aspect. (**a**) Convex probe placed longitudinally in the mid portion of the right axillary line. (**b**) Corresponding sonographic image. *D* diaphragm. The normal mobile lung is shifted during inspiration into the phrenicocostal recess and covers the upper margin of the liver

UNDERSTANDING THE IMAGE

There are a variety of scanning modes used in point of care ultrasound. Here we will discuss **B-** or **brightness mode**, **M-mode** or **motion mode** and **D-** or **doppler mode**.

B-MODE



M-MODE

DOPPLER

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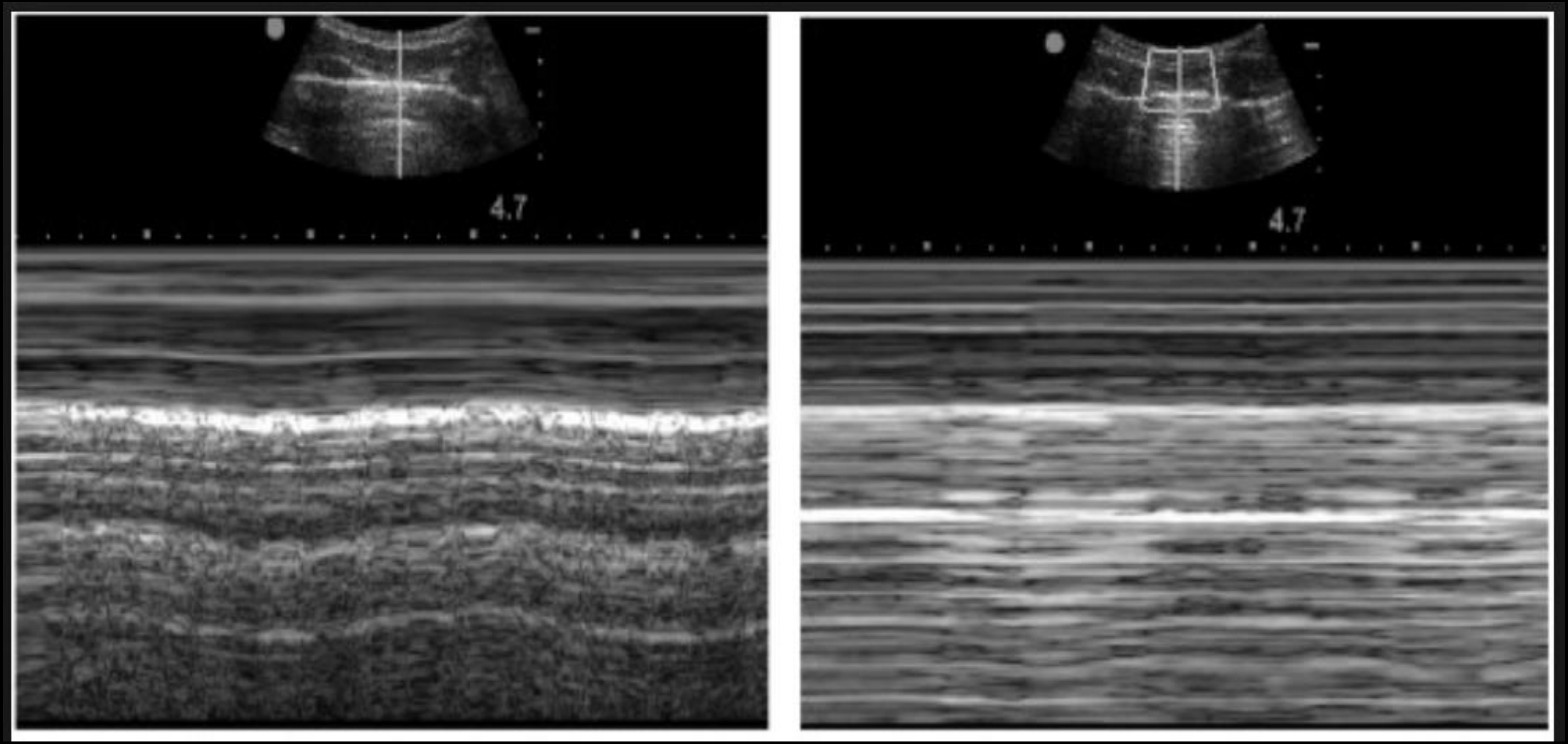
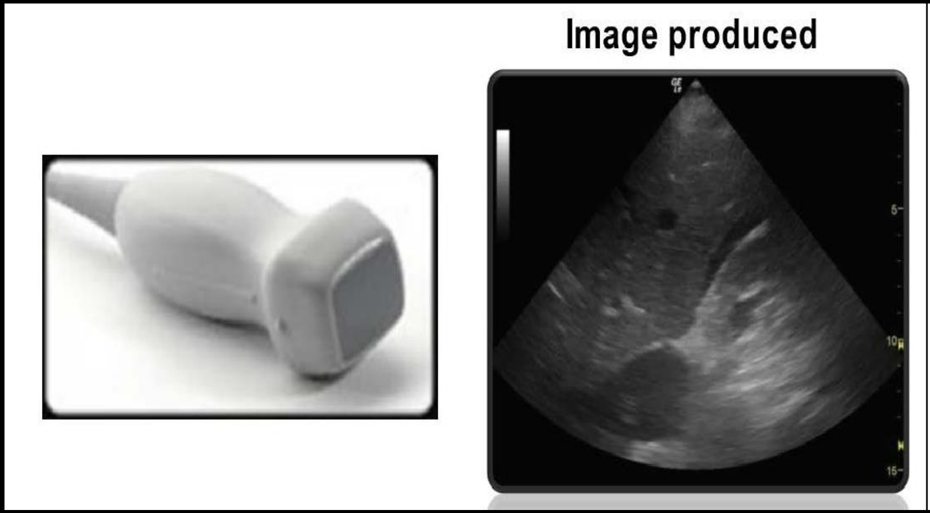
Thoracic Ultrasound:
M-mode:



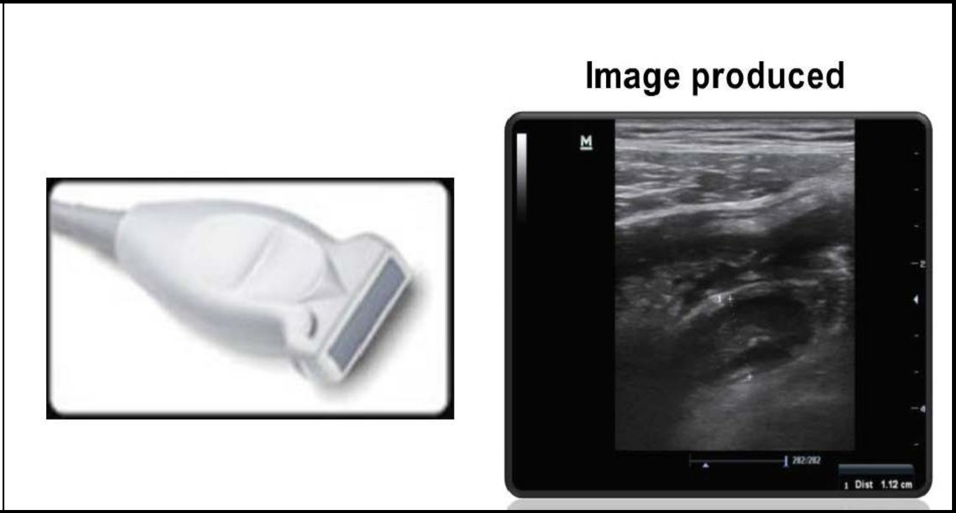
http://www.icmteaching.com/ultrasound/lung%20ultrasound/styled--125

Thoracic Ultrasound:
Probes:

Phased Array Probe



Linear Vascular Probe



http://westernsono.ca/tutorials-3/lung-ultrasound-basics-tutorial

Thoracic Ultrasound:

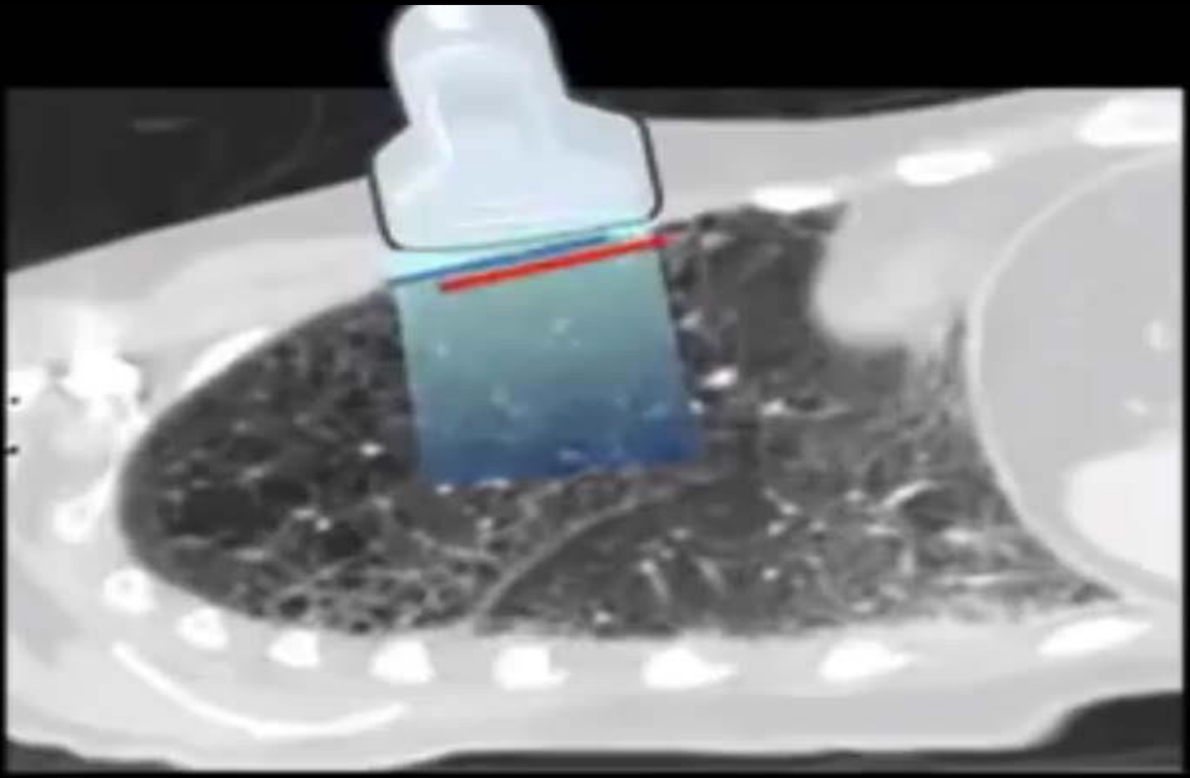
5 sonographic "signs" used in the BLUE Protocol:

- Sliding Lung
- A Lines
- B Lines
- Alveolar Consolidation
- Pleural Effusion

Thoracic Ultrasound:

Lung Sliding:

Present

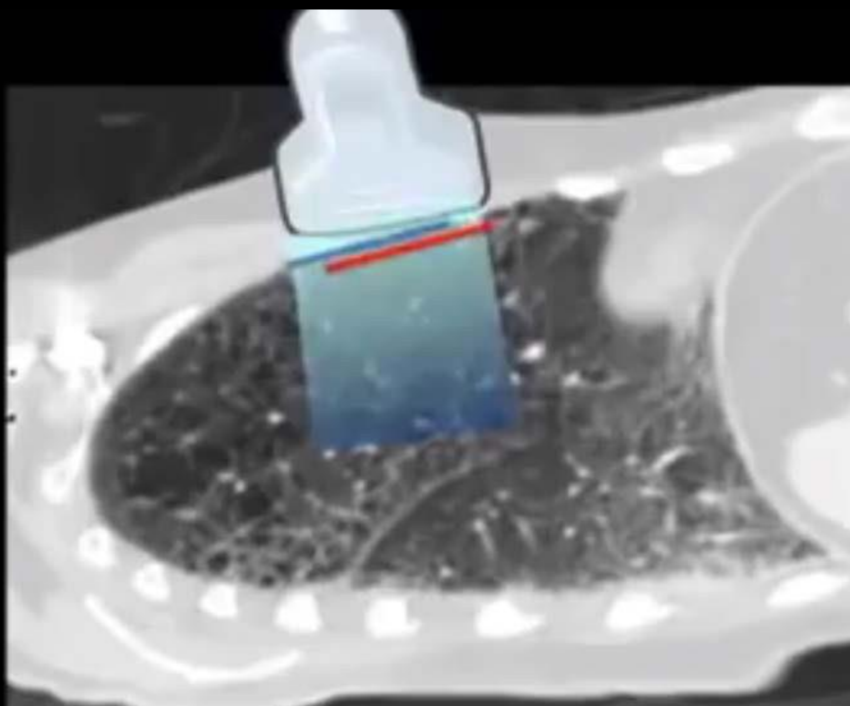


http://westernsono.ca/tutorials-3/lung-ultrasound-image-interpretation-tutorial

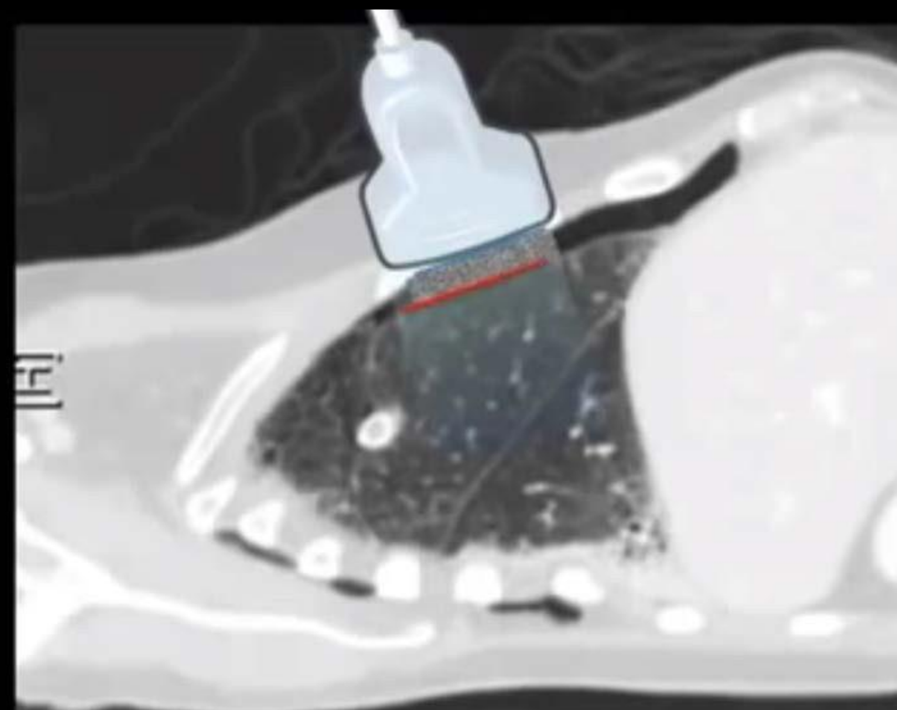
Thoracic Ultrasound:

Lung Sliding:

Present?



Absent



Thoracic Ultrasound:

Lung Sliding, B-mode:

Thoracic Ultrasound:

A Lines:

- Horizontal “reverberation” artifacts
- Generally seen in Aerated Lungs
- Parallel to the pleural line
- Decay with increasing depth
- Obliterated by B Lines

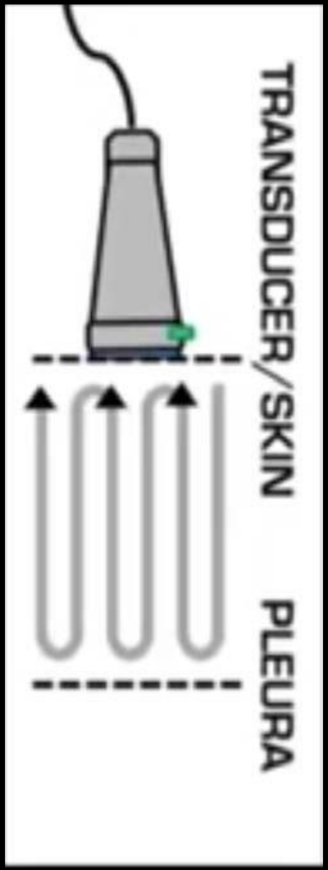
Thoracic Ultrasound:

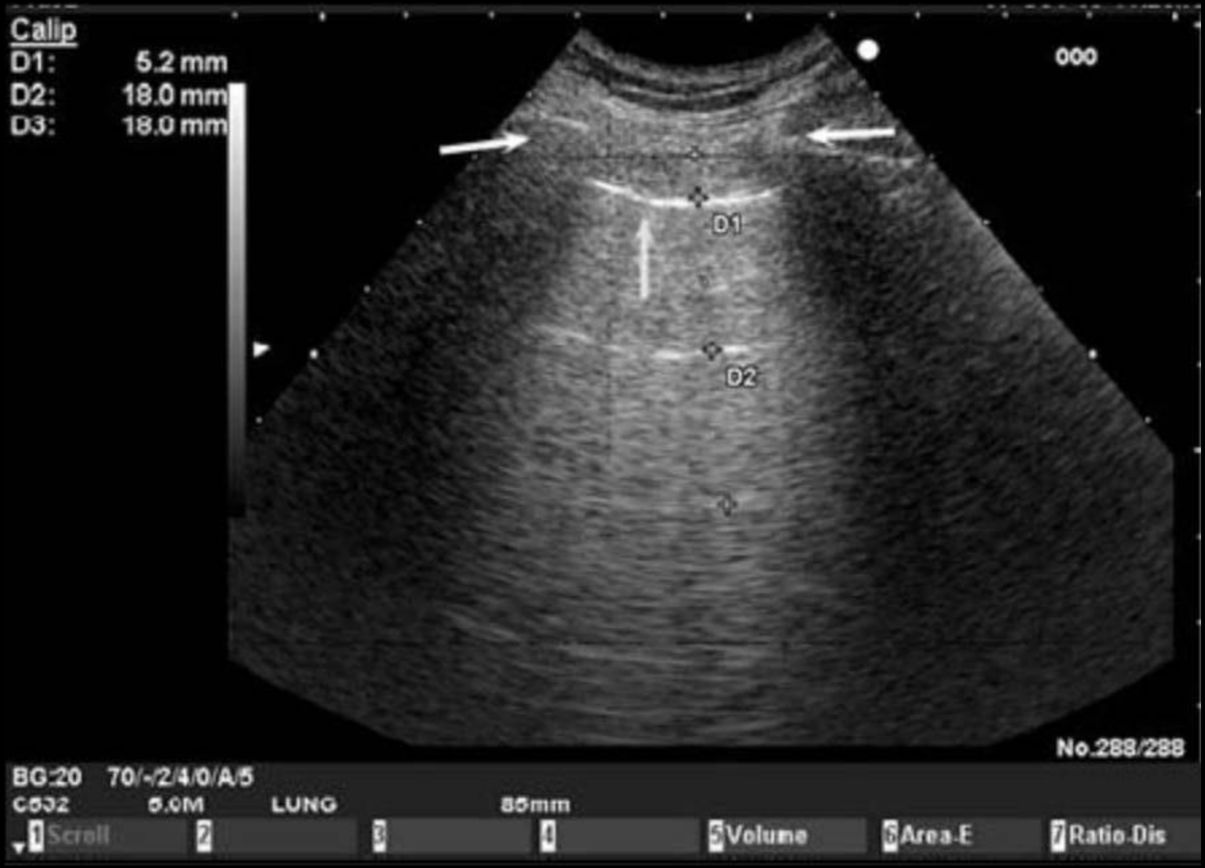
A Lines:

- Seen in normal lung parenchyma
  - $P_AOP < 13$ mmHg
- DD(x):
  - Obstructive Lung Disease (COPD/Asthma)
  - Pulmonary Embolism
- *A Lines* can be seen without lung sliding
  - search for pneumothorax

Thoracic Ultrasound:

A Lines:





Thoracic Ultrasound:

Absent *Lung Sliding, B-mode:*

Enghard *et al. Critical Care* (2015) 19:36
DOI 10.1186/s13054-015-0756-5

CRITICAL CARE

RESEARCH Open Access

Simplified lung ultrasound protocol shows excellent prediction of extravascular lung water in ventilated intensive care patients

Philipp Enghard[1], Sibylle Rademacher[1], Jens Nee[1], Dietrich Hasper[1], Ulrike Engert[2], Achim Jörres[1] and Jan M Kruse[1*]

ARDS	v. Pulm. edema
- Ant. consolidation (C-profile)	- no consolidation
- ∅ or ↓ lung sliding (B' profile)	- normal lung sliding
- "spared areas" / nonhomogeneous distrubition of B-lines (A/B profile)	- diffuse, relative homogeneous B-lines (B profile)
- pleural line abnormalities (C-lines)	- Thin, smooth pleural line
- lung pulse at times (Atelectasis) (C-profile)	- No lung pulse

Copetti R, Soldati G, Copetti P. Chest sonography: a useful tool to differentiate acute cardiogenic pulmonary edema from acute respiratory distress syndrome. Cardiovascular ultrasound. 2008; 6:16.

Seven principles of lung ultrasound

1) Lung (and critical) ultrasound is performed at best using simple equipment.
2) In the thorax, gas and fluids have opposite locations, or are mingled by pathologic processes, generating artifacts.
3) The lung is the most voluminous organ. Standardized areas can be defined [8].
4) All signs arise from the pleural line.
5) Static signs are mainly artifactual [9,10].
6) The lung is a vital organ. The signs arising from the pleural line are foremost dynamic.
7) Almost all acute life-threatening disorders abut the pleural line, explaining the potential of lung ultrasound.

Aetiology

Transudate	Exudate
Right heart failure	Pneumonia
Nephrotic syndrome	Malignant
Liver cirrhosis	Tuberculosis
Pulmonary embolism	

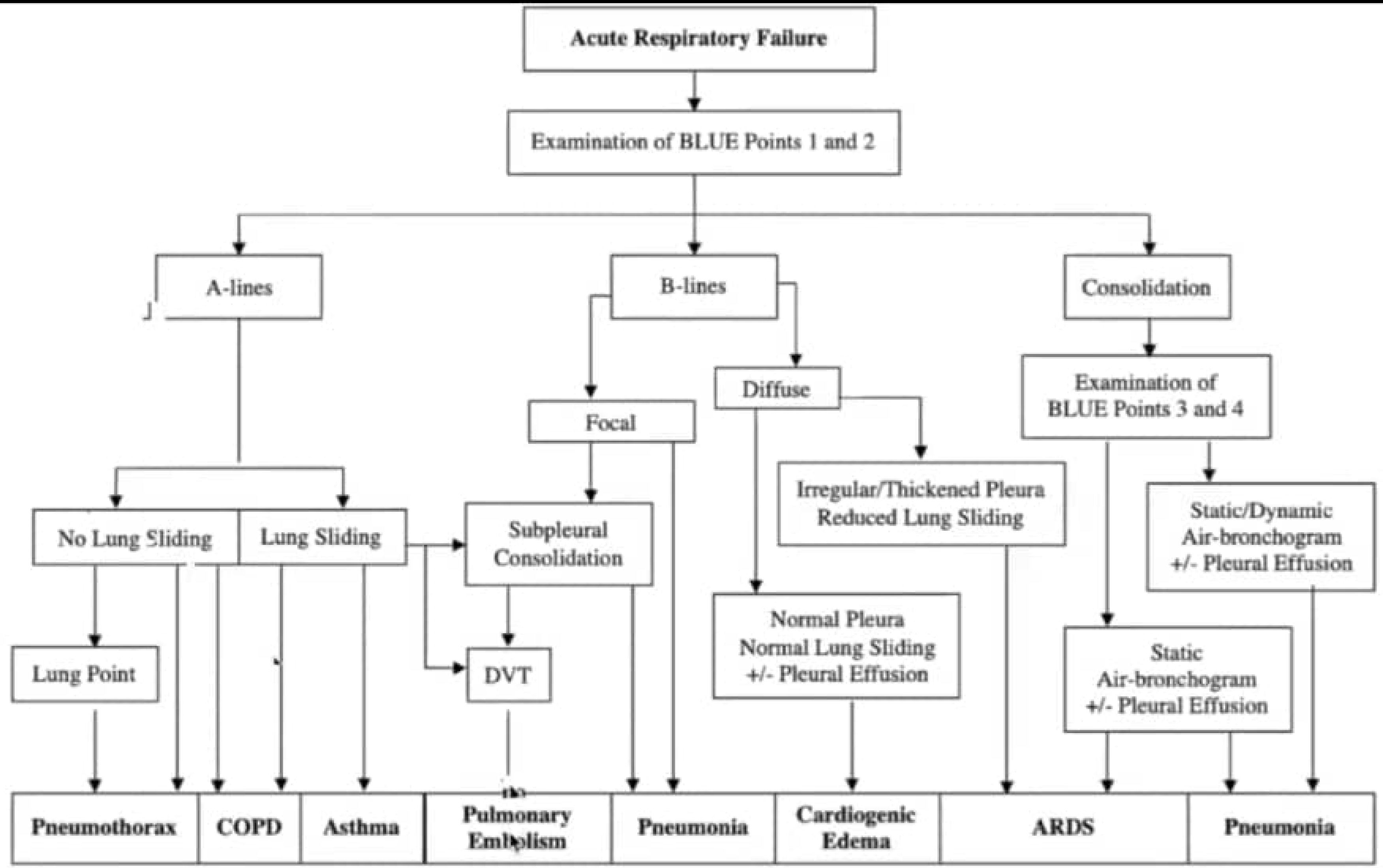


Fig. 2 Proposed algorithm for a systematic diagnostic approach to acute respiratory failure using lung ultrasound (*ARDS* acute respiratory distress syndrome, *COPD* chronic obstructive pulmonary disease, *DVT* deep vein thrombosis)

A preliminary study on the ultrasonic manifestations of peripulmonary lesions of non-critical novel coronavirus pneumonia (COVID-19)

Yi Huang[1], Sihan Wang[1], Yue Liu[1], Yaohui Zhang[1], Chuyun Zheng[1], Yu Zheng[2], Chaoyang Zhang[3], Weili Min[4], Huihui Zhou[5], Ming Yu[5], Mingjun Hu[1]

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Department of Ultrasound, Xijing Hospital, Airforce Medical University, Xi'an, 710032, China

Key Results

1. COVID-19 foci are mainly observed in the posterior fields in both lungs, especially in the posterior lower fields. → thorough scanning, 12 lung zones

2. Fused B lines and waterfall signs are visible under the pleura. The B lines are in fixed position. → B'

3. The pleural line is unsmooth, discontinuous and interrupted. → C-lines

4. The subpleural lesions show patchy, strip, and nodule consolidation. → C-profile

5. Air bronchogram sign or air bronchiologram sign can be seen in the consolidation. → C-profile

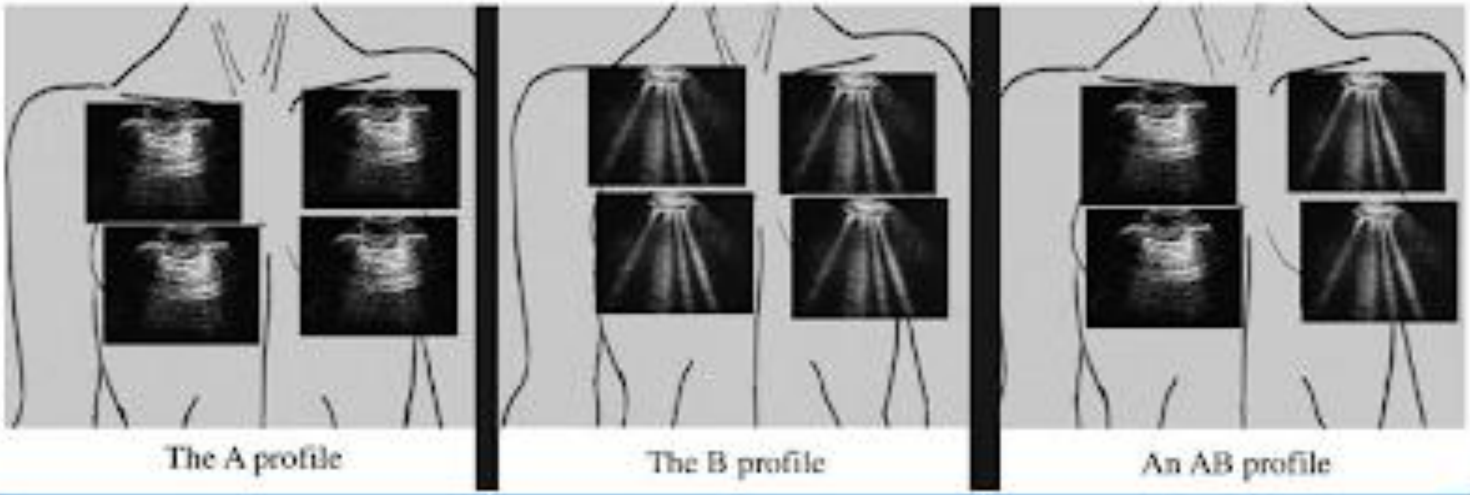
6. The involved interstitial tissues have localized thickening and edema, and there is localized pleural effusion around the lesions. → crazy-paving pattern,

7. CDFI ultrasound shows insufficient blood supply in the lesions.

8. High frequency linear array probe is suggested to be used for minor subpleural lesions, as it can provide rich information and improve diagnostic accuracy.

Characteristic findings included the following:

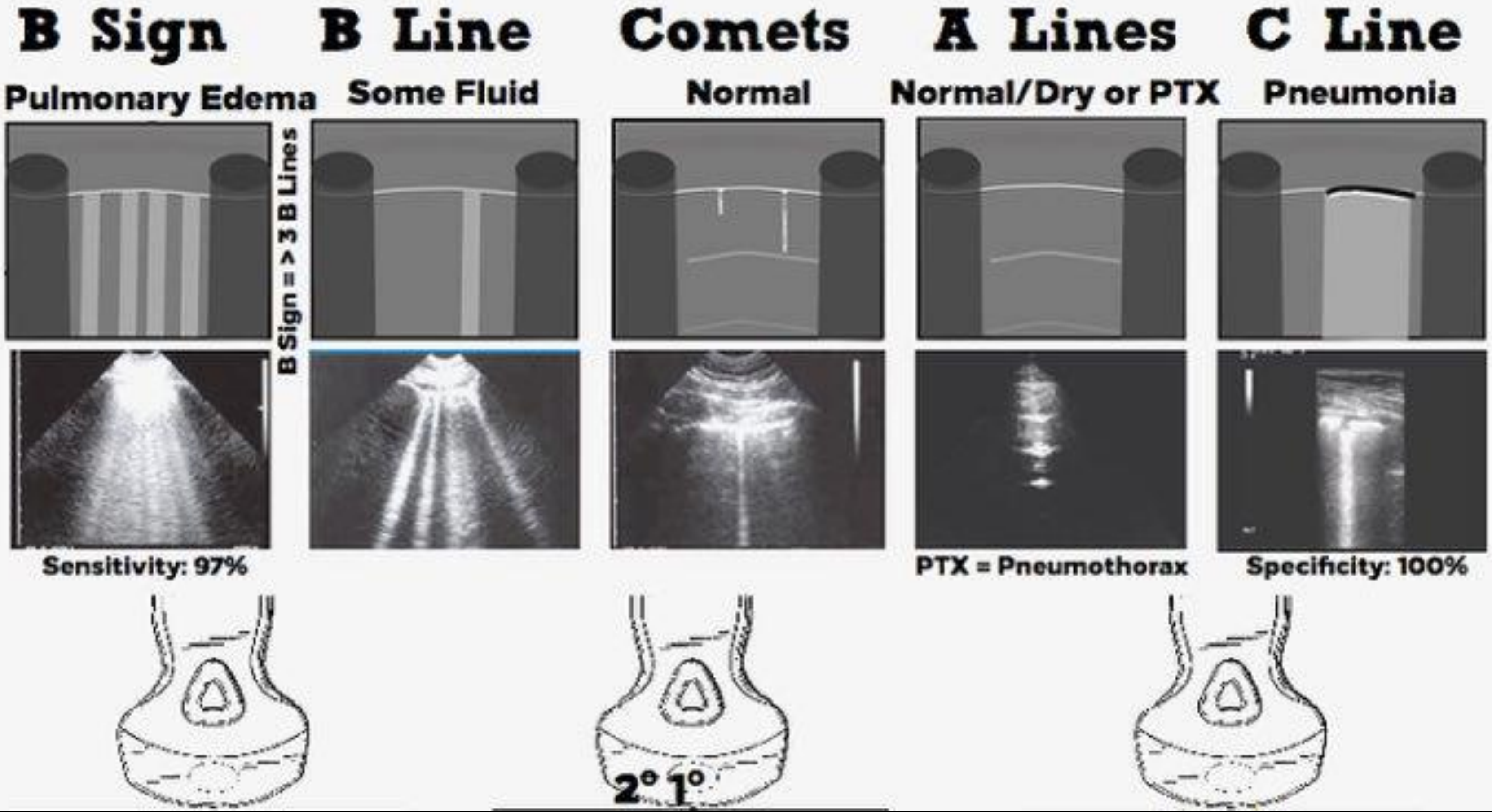
1. Thickening of the pleural line with pleural line irregularity;
2. B lines in a variety of patterns including focal, multifocal, and confluent;
3. Consolidations in a variety of patterns including multifocal small, non-translobar, and translobar with occasional mobile air bronchograms;
4. Appearance of A lines during recovery phase;
5. Pleural effusions are uncommon.



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	

+ indicates potential diagnoses
- Indicates diagnosis ruled out

Pulmonary Ultrasound



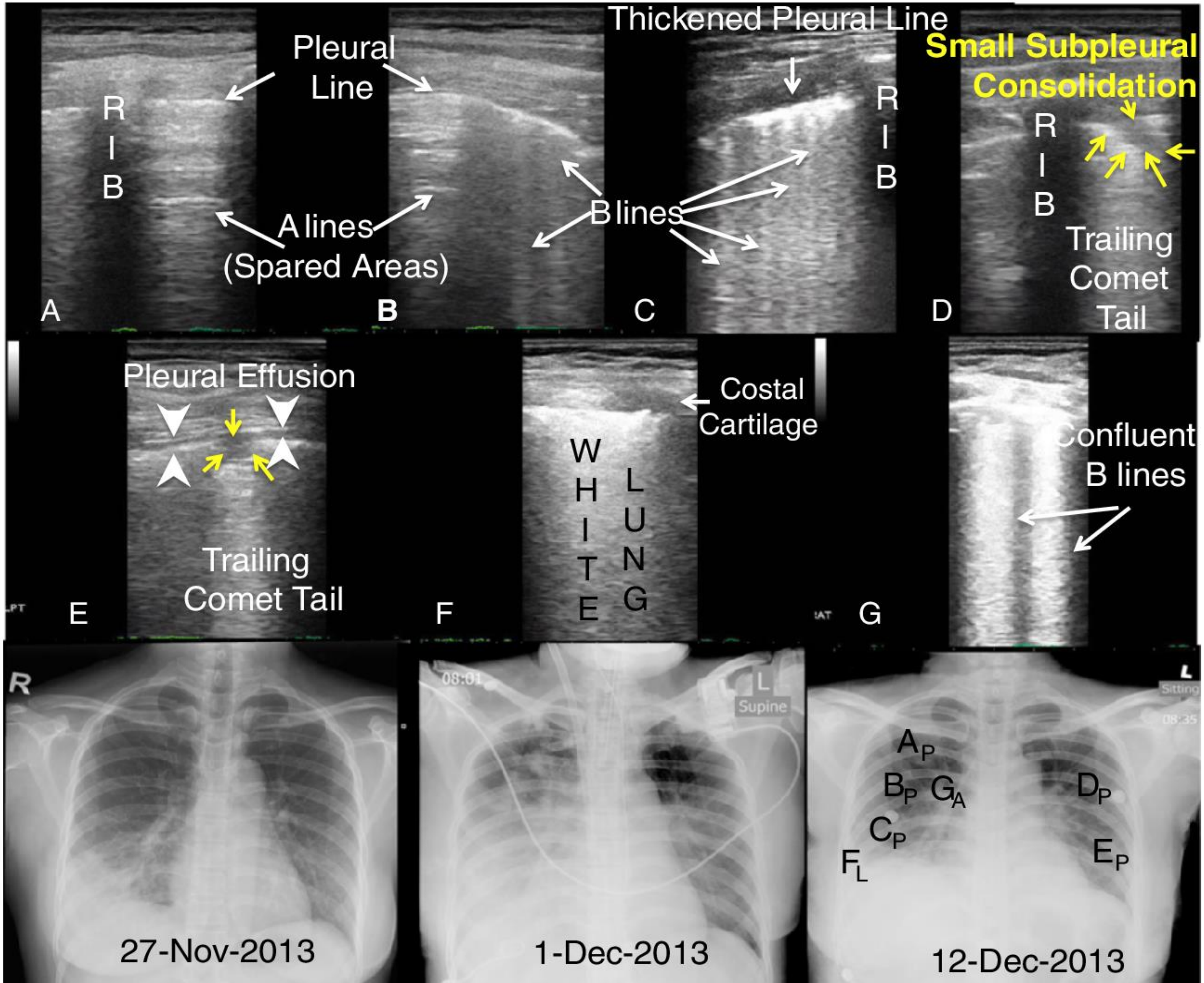
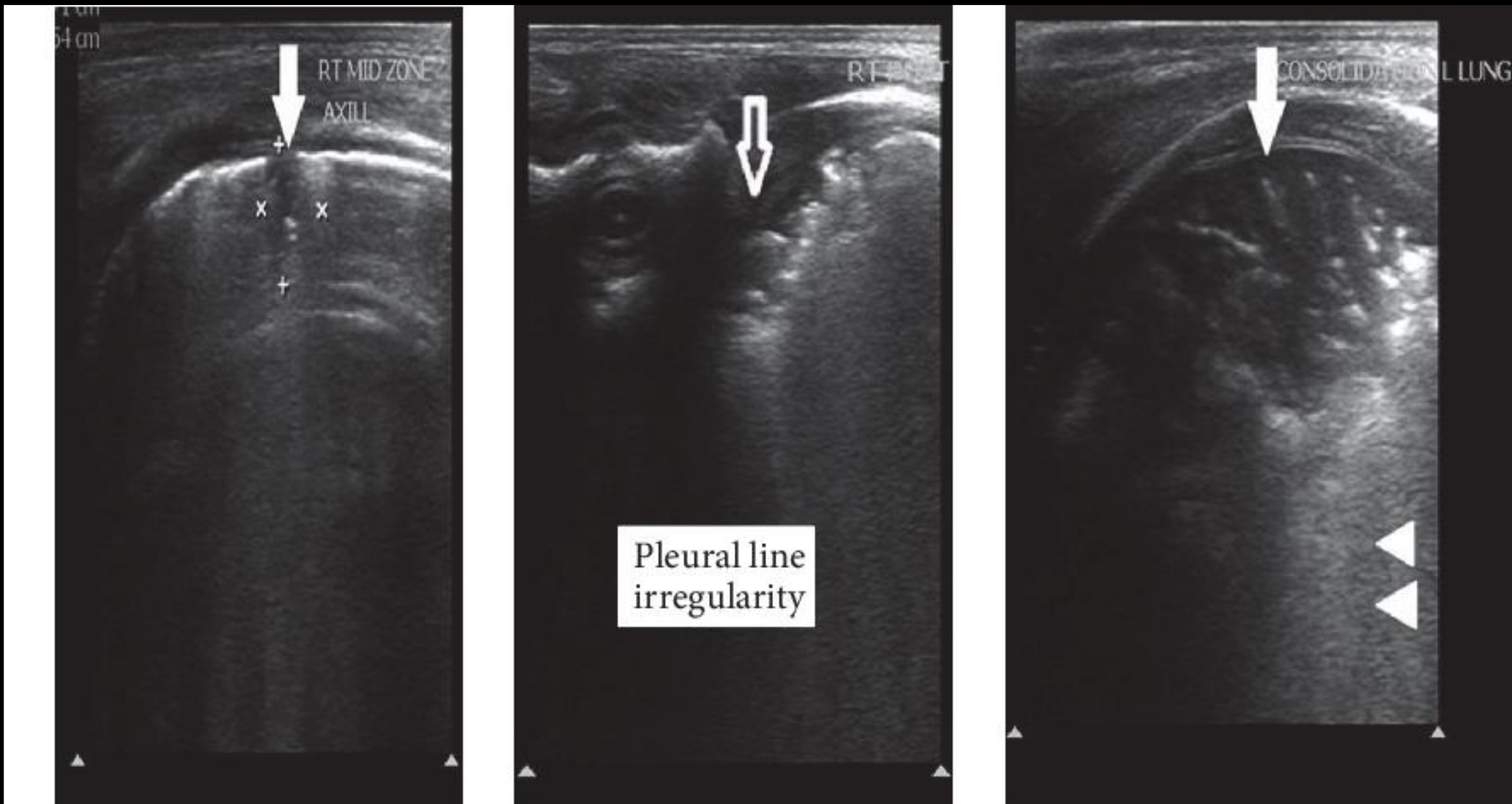
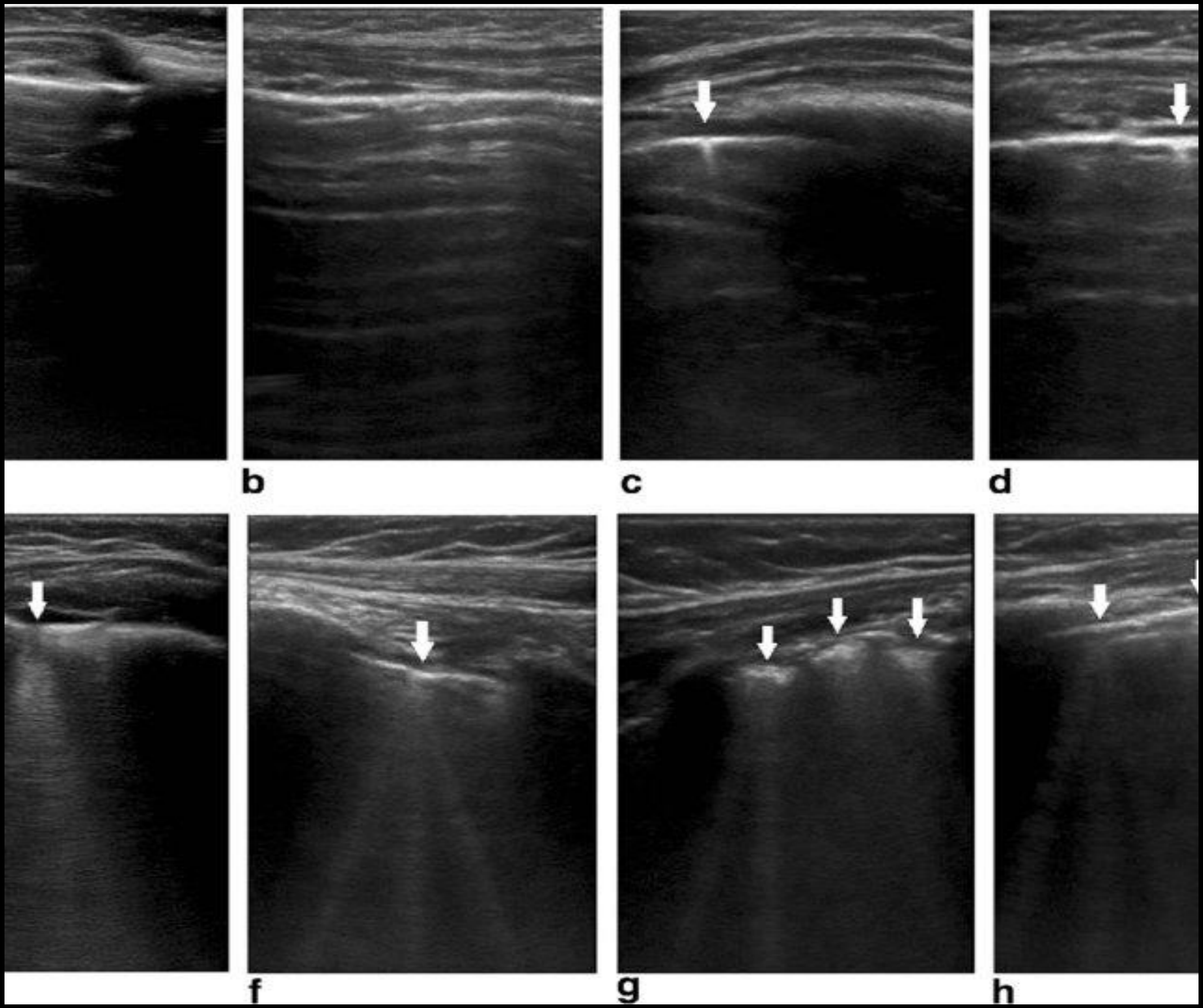


Figure 1 LUS and CXR correlation from illness day (rows 1 & 2). Panels **A-F. (A)** A lines = normal aerated (spared) lung; **(B & C)** B lines = interstitial



(a) (b) (c)


b
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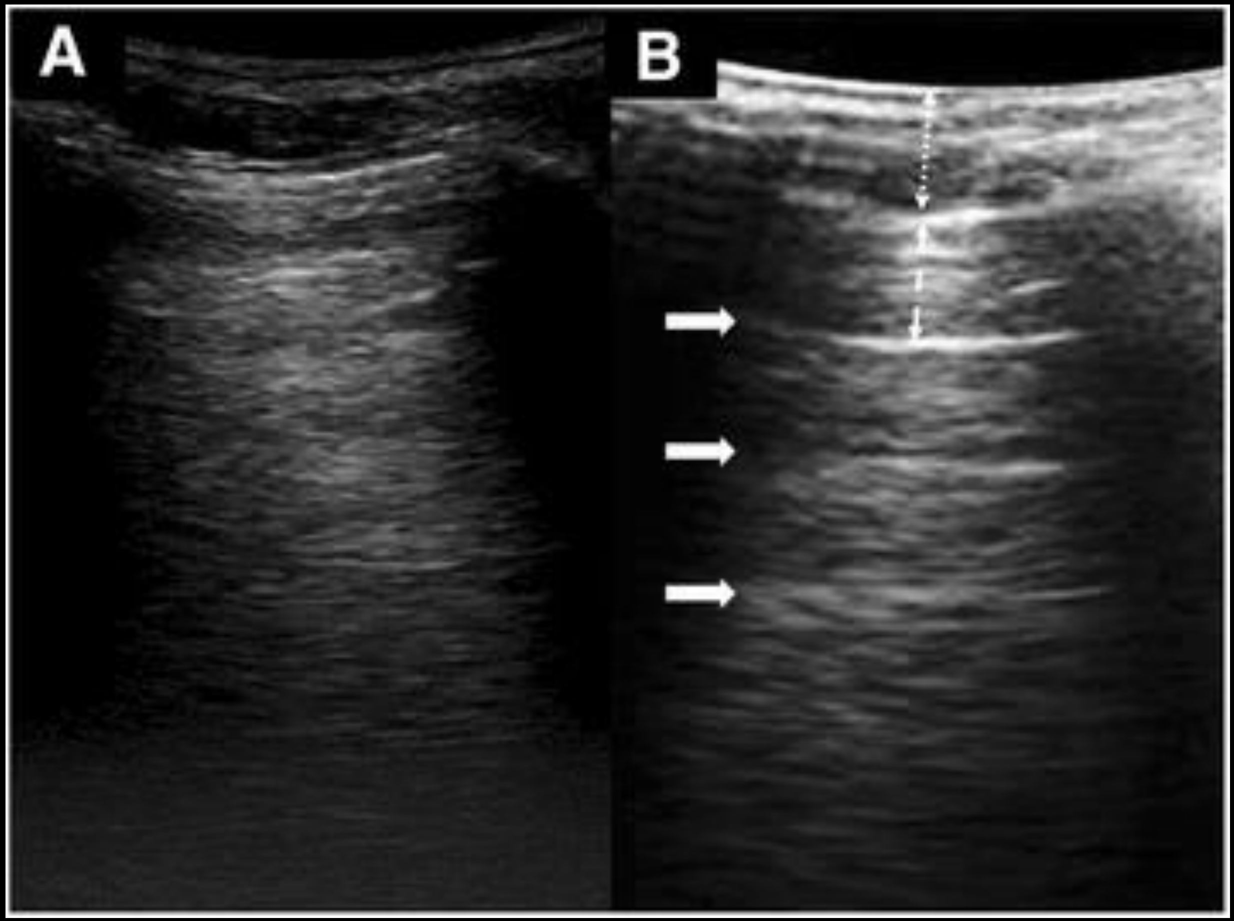

A
B

Intensive Care Med (2020) 46:849–850
https://doi.org/10.1007/s00134-020-05996-6

LETTER

Findings of lung ultrasonography of novel corona virus pneumonia during the 2019–2020 epidemic

Check for updates

Qian-Yi Peng[1], Xiao-Ting Wang[2*], Li-Na Zhang[1*] and Chinese Critical Care Ultrasound Study Group (CCUSG)

Table 1 CT and ultrasonographic features of COVID-19 pneumonia

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

BLUE-Protocol and FALLS-Protocol

Two Applications of Lung Ultrasound in the Critically Ill

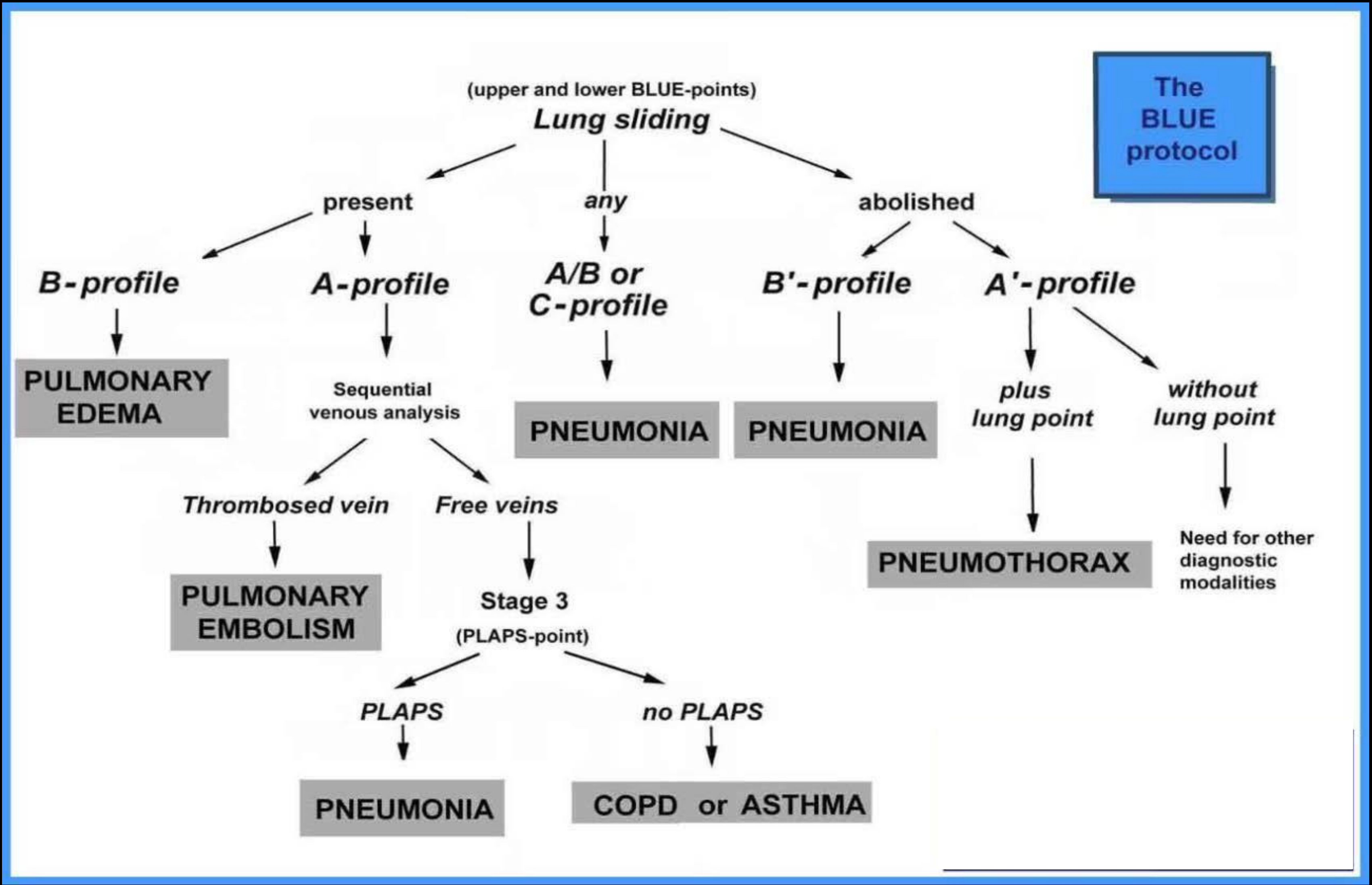
This review article describes two protocols adapted from lung ultrasound: the bedside lung ultrasound in emergency (BLUE)-protocol for the immediate diagnosis of acute respiratory failure and the fluid administration limited by lung sonography (FALLS)-protocol for the management of acute circulatory failure. These applications require the mastery of 10 signs indicating normal lung surface (bat sign, lung sliding, A-lines), pleural effusions (quad and sinusoid sign), lung consolidations (fractal and tissue-like sign), interstitial syndrome (lung rockets), and pneumothorax (stratosphere sign and the lung point). These signs have been

Table 2 Ultrasound scoring system

Ultrasound finding	Score
No B line/ICS[a]	0
One B line/ICS[a]	1
Two B lines/ICS[a]	2
Three B lines/ICS[a]	3
Four B lines/ICS[a]	4
Five B lines/ICS[a]	5
Confluent B lines >50% ICS[a]	6
Confluent B lines >75% ICS[a]	7
Confluent B lines 100% ICS[a]	8

[a]ICS, Intercostal space.

Thoracic Ultrasound:



Lichtenstein, D., CHEST 2008, 134:117

Thoracic Ultrasound:

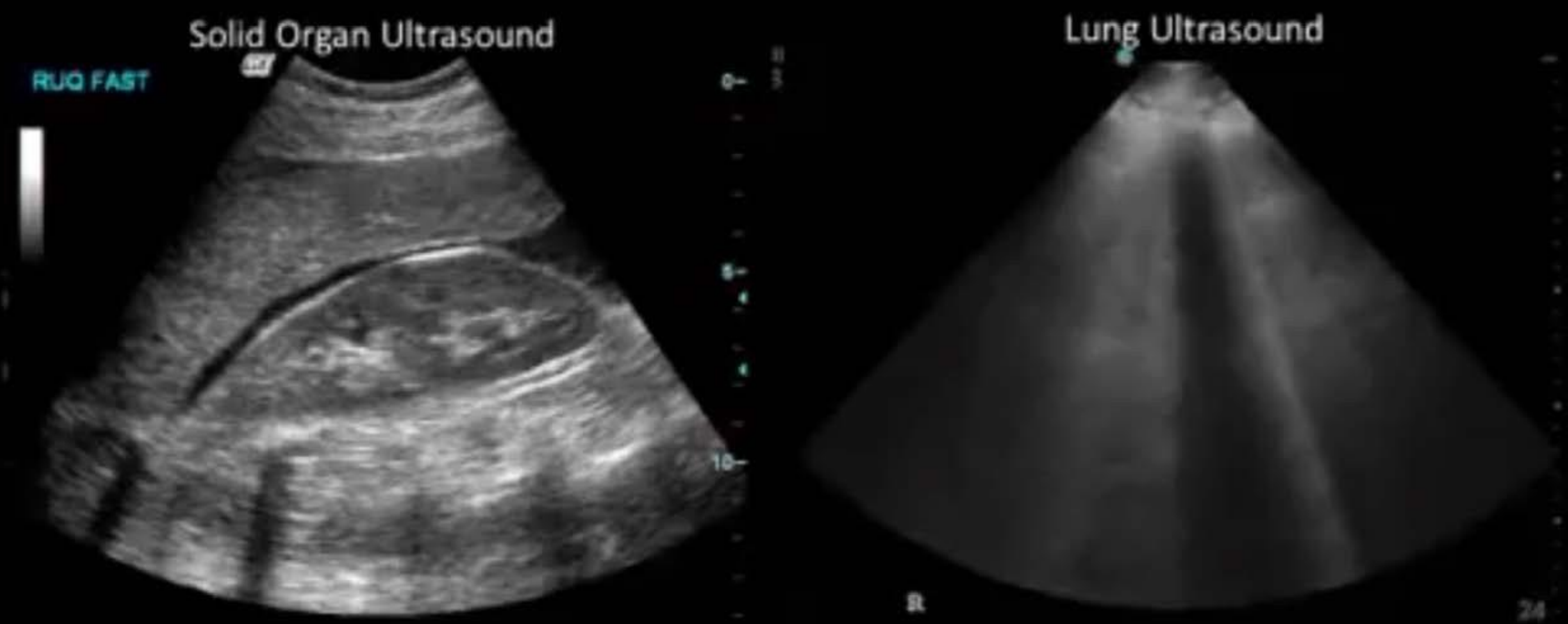
	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Pleural Effusion	94	97	95	90
Alveolar Consolidation *(Pneumonia)*	90	98	88	95
Interstitial Syndrome *(CHF, ARDS)*	93	93	87	99
Complete Pneumothorax	100	96	100	98
Occult Pneumothorax	79	100	89	99
AECOPD	89	97	93	95
Pulmonary Embolism	81	99	94	98

Lichtenstein, D., Ann Int Care, 2014; 4:1-12

Thoracic Ultrasound:

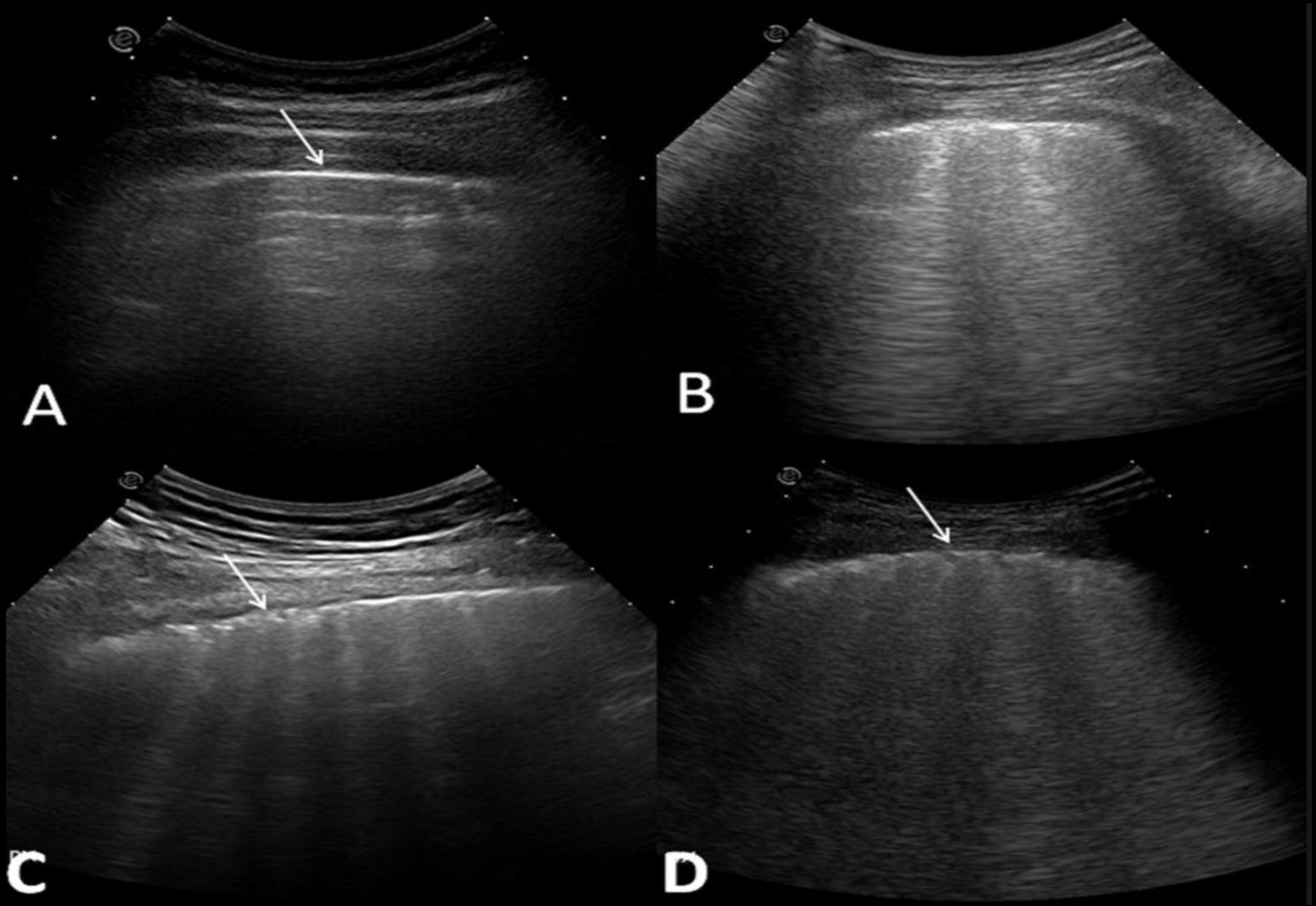
http://westernsono.ca/tutorials-3/lung-ultrasound-image-interpretation-tutorial

Thoracic Ultrasound:



http://westernsono.ca/tutorials-3/lung-ultrasound-image-interpretation-tutorial

Thoracic Ultrasound:
B-mode:



http://www.jrheum.org/content/39/8/1641

The BLUE-protocol combines signs, associates them vith a location, resulting in seven profiles (Figure 8).

The A-profile associates anterior lung-sliding with A-lines.
The A'-profile is an A-profile with abolished lung-sliding.
The B-profile associates anterior lung-sliding with lung-rockets.
The B'-profile is a B-profile with abolished lung-sliding.
The C-profile indicates anterior lung consolidation, regardless of size and number. A thickened, irregular pleural line is an equivalent.
The A/B profile is a half A-profile at one lung, a half B-profile at another.

Table 1 Detailed performances of the BLUE-protocol

Mechanism of dyspnea	Profiles of BLUE-protocol	Sensitivity	Specificity	Positive predictive value	Negative predictive value
Acute hemodynamic pulmonary edema	B-profile	97% (62/64)	95% (187/196)	87% (62/71)	99% (187/189)
COPD in exacerbation or severe acute asthma	Nude profile	89% (74/83)	97% (172/177)	93% (74/79)	95% (172/181)
Pulmonary embolism	A-profile (with deep venous thrombosis)	81% (17/21)	99% (238/239)	94% (17/18)	98% (238/242)
Pneumothorax	A'-profile (with lung point)	88% (8/9)	100% (251/251)	100% (8/8)	99% (251/252)
Pneumonia	B'-profile	11% (9/83)	100% (177/177)	100% (9/9)	70% (177/251)
	A/B profile	14.5% (12/83)	100% (177/177)	100% (12/12)	71.5% (177/248)
	C-profile	21.5% (18/83)	99% (175/177)	90% (18/20)	73% (175/240)
	A-V-PLAPS profile	42% (35/83)	96% (170/177)	83% (35/42)	78% (170/218)
	The four profiles	89% (74/83)	94% (167/177)	88% (74/84)	95% (167/176)

TABLE 2] Accuracy of the BLUE-Protocol

Mechanism of Dyspnea	Profiles of BLUE-Protocol	Sensitivity, %	Specificity, %	PPV, %	NPV, %
Acute hemodynamic pulmonary edema	B-profile	97	95	87	99
Exacerbated COPD or severe acute asthma	Nude profile (A-profile with no DVT and no PLAPS)	89	97	93	95
Pulmonary embolism	A-profile with DVT	81	99	94	98
Pneumothorax	A′-profile (with lung point)	88	100	100	99
Pneumonia	The four profiles	89	94	88	95
	B′-profile	11	100	100	70
	A/B profile	14.5	100	100	71.5
	C-profile	21.5	99	90	73
	A-no-V-PLAPS-profile	42	96	83	78

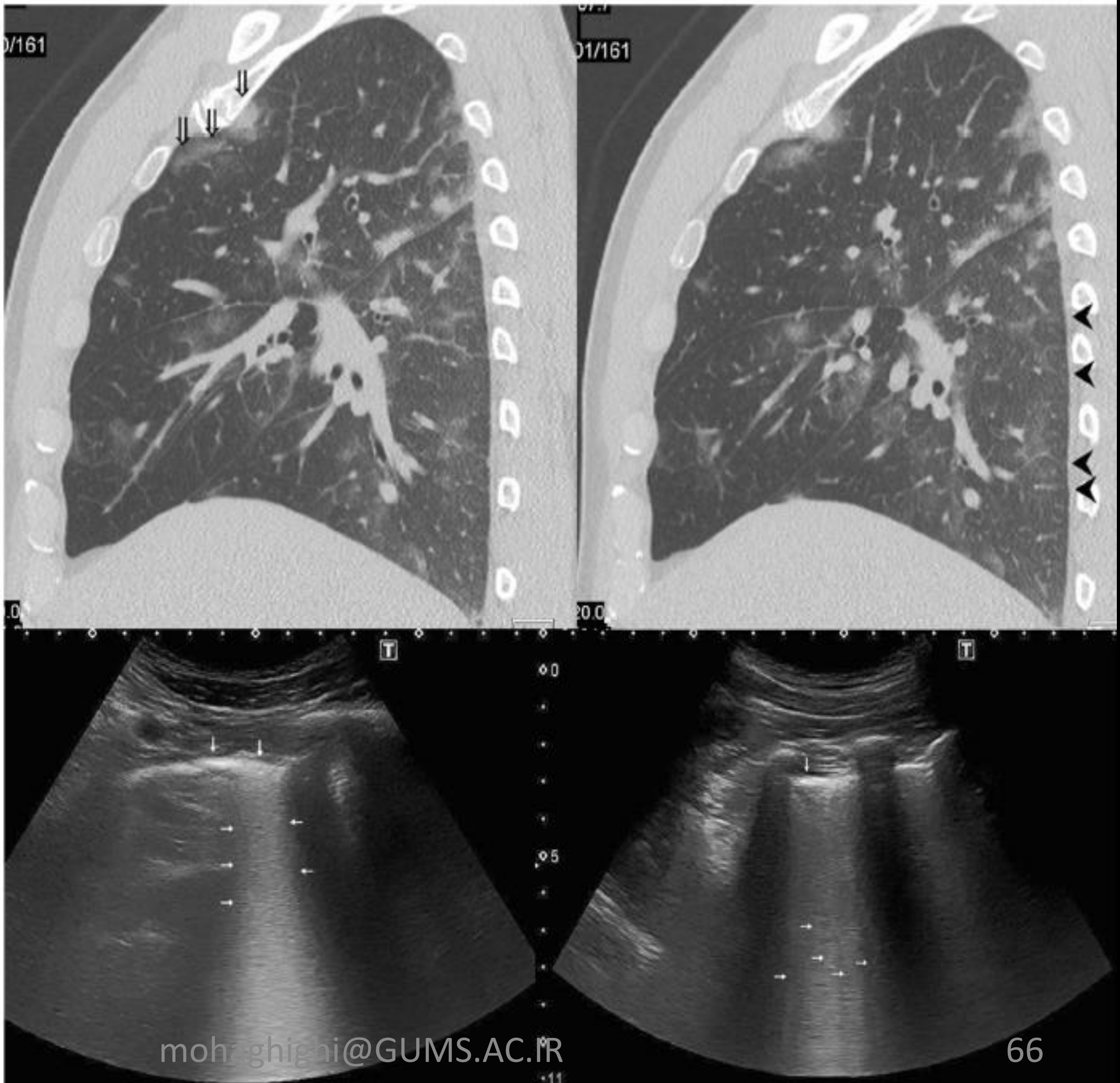
BLUE = bedside lung ultrasound in emergency; NPV = negative predictive value; PLAPS = posterolateral alveolar and/or pleural syndrome; PPV = positive predictive value. (Adapted from Lichtenstein and Mezière.[61])

TABLE 1] Published Performances of Lung Ultrasound in Critically Ill Patients Compared With CT Scanning

Ultrasound	Sensitivity, %	Specificity, %
Pleural effusion[47]	94	97
Alveolar consolidation[48]	90	98
Interstitial syndrome[49]	100	100
Complete pneumothorax[46]	100	96
Occult pneumothorax[50]	79	100

Fig. 1 Coalescent B-Lines in a COVID-19 patient: Hyperechoic artifacts (horizontal arrows) arising from the pleural line (black arrows) and extending vertically (in regard to the screen) to the bottom of the image, moving with the cycle of respiration. Any *horizontal* artifacts below the pleura that are usually seen in the healthy lung and represent reverberations of the pleural line (A-Lines) are obliterated by B-Lines, and are absent here

Fig. 2 Comparison of exemplary lesions on CT and LUS. Left: GGO in the upper lobe of the right lung (double arrows) yield very densely converging B-Lines (horizontal arrows) that seem to merge into one broad, echogenic vertical artifact arising from the irregular pleural line (vertical arrows). Right: Thickened interlobular septa (arrowheads) are visible on CT; they correlate to B-Lines in LUS (horizontal arrows) that are still distinguishable from one another. The density of B-Lines seems to correlate to the extent of thickening in interlobular septa [7]. All images were obtained on day 17 after symptom onset



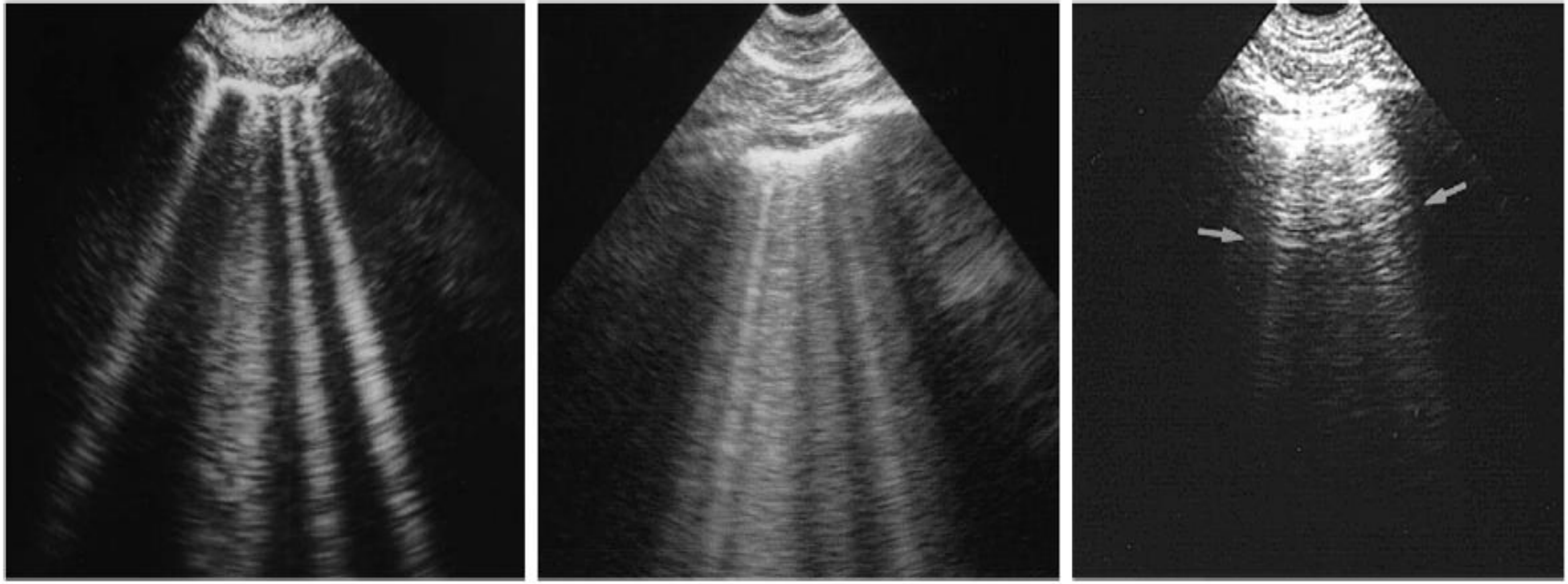


Figure 5 Interstitial syndrome and the lung rockets. Two examples of interstitial syndrome. Left: four or five B-lines (see precise description in the text) are visible, called lung rockets (here septal rockets correlating with thickened subpleural interlobular septa). Middle: twice as many B-lines, called ground-glass rockets. Two examples of pulmonary edema (with ground glass areas on CT on the middle figure). Right: Z-lines for comparison. These parasites are ill-defined, short, and do not erase A-lines (arrows), among several criteria. Extract from "Whole body ultrasonography in the critically ill" (2010 Ed, Chapter 17), with kind permission of Springer Science.

B-line is always a comet-tail artifact, always arises from the pleural line, and always moves in concert with lung-sliding. It is almost always long, well-defined, laser-like, hyperechoic, erasing A-lines (Figure 5). This

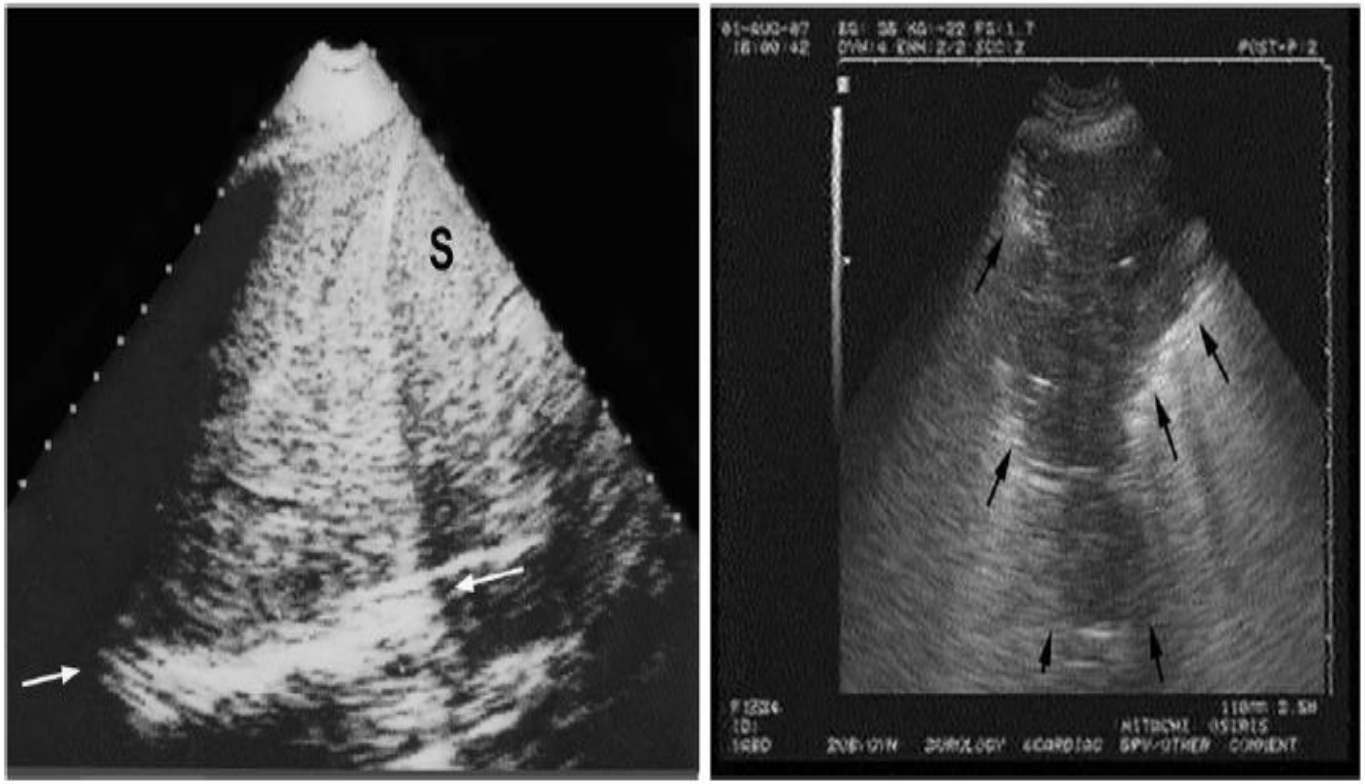


Figure 4 Lung consolidation. Two signs of lung consolidation. Left: a massive consolidation (probe at the PLAPS-point) invades the whole left lower lobe. No aerated lung tissue is present, and no fractal sign can be generated. The deep border is at the mediastinal line (arrows). The pattern is tissue-like, similar to the spleen (S). The thickness of this image is roughly 10 cm, a value incompatible with a pleural effusion. Image acquired using an ADR-4000 and a sectorial probe (1982 mobile technology) Right: a middle lobe consolidation, which does not invade the whole lobe. This generates a shredded, fractal boundary between the consolidation and the underlying aerated lung (arrows): the quite specific shred (or fractal) sign. Such an anterior consolidation generates the C-profile in the BLUE-protocol. Compare with the regular lung line of Figure 3. Note the blurred letters due to multiple transfers of this image. Quantitative data: a reasonable thickness at the right image is 5.5 cm, giving an index of 5.5 corresponding to a 165-mL consolidation, roughly. In the left image, the 10-cm depth would correspond to a volume of roughly 1 L. Adapted from "Whole body ultrasonography in the critically ill" (2010 Ed. Chapter 16), with kind permission of Springer Science.

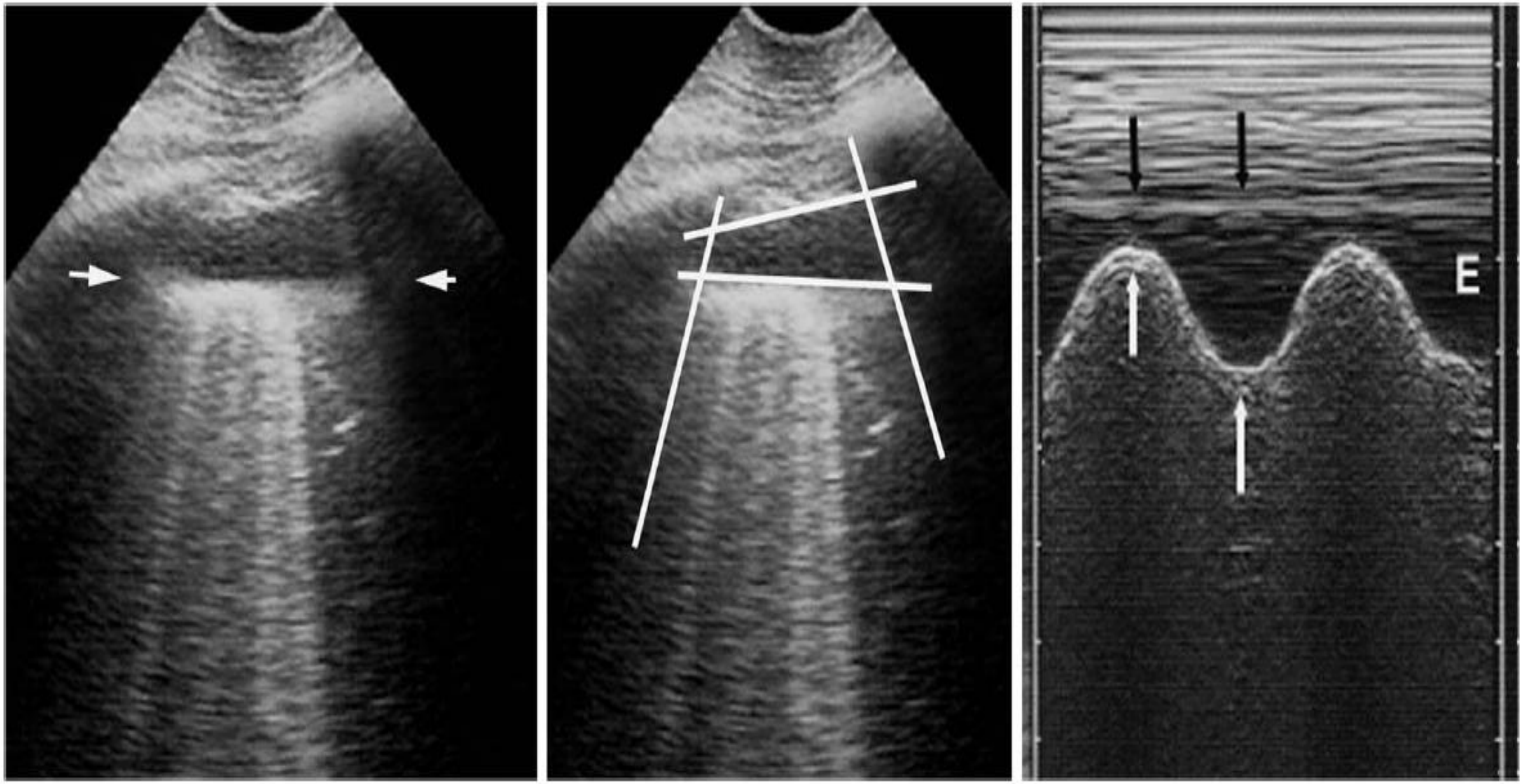


Figure 3 Pleural effusion. Left and middle: minute pleural effusion at the PLAPS-point. Below the pleural line, a line regular and roughly parallel to the pleural line can be seen: the lung line, indicating the visceral pleura (arrows). This line, together with the pleural line and the shadow of the ribs, display a kind of quad: the quad sign. Right: M-mode shows a movement of the lung line (white arrows) toward the pleural line (black arrows) on inspiration—the sinusoid sign, indicating also a free pleural effusion, and a viscosity enabling the use of small caliper needle if thoracentesis is envisaged. E, expiration. Quantitative data: this effusion found at the PLAPS-point has an expiratory thickness of roughly 13 mm, i.e., an expectedly small volume (study in progress). A 15-mm distance is our minimum required for safe diagnostic or therapeutic puncture, allowing to simplify the problem of modeling the real volume of an effusion (Ref. 14). Extract from "Whole body ultrasonography in the critically ill" (2010 Ed, Chapter 15), with kind permission of Springer Science.

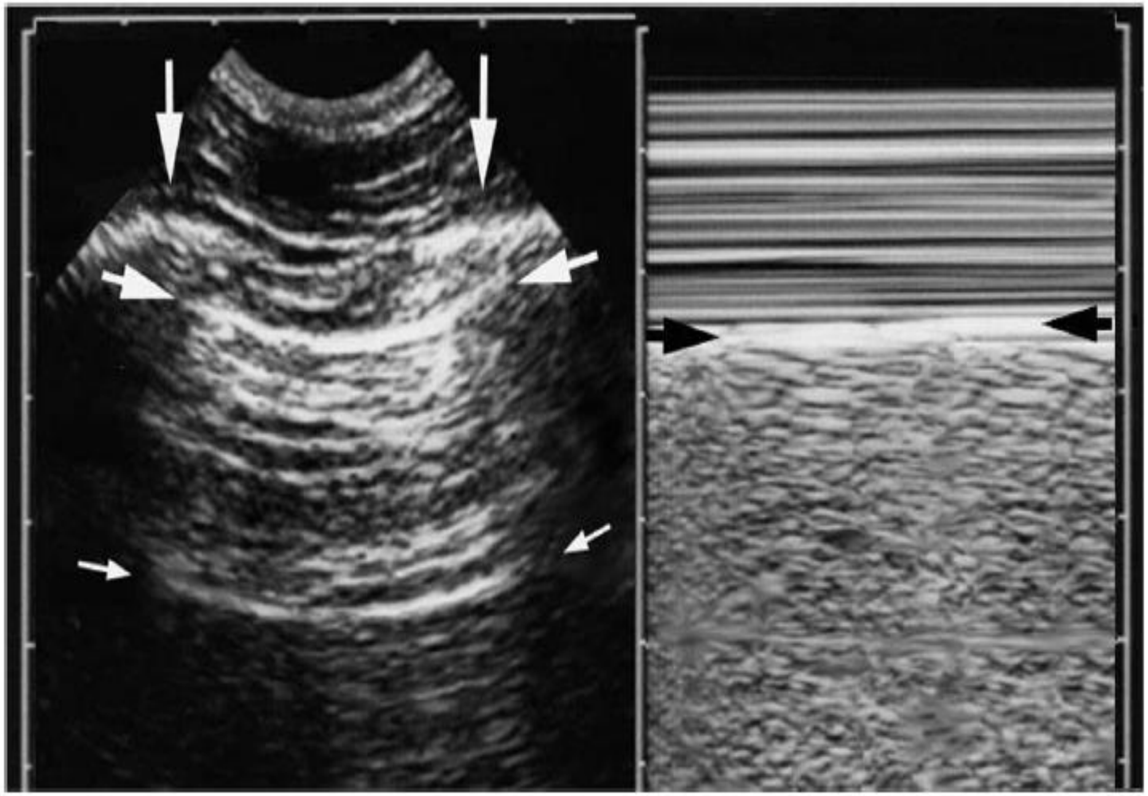


Figure 2 Normal lung surface. Left: Scan of the intercostal space. The ribs (vertical arrows). Rib shadows are displayed below. The pleural line (upper, horizontal arrows), a horizontal hyperechoic line, half a centimeter below the rib line in adults. The proportions are the same in neonates. The association of ribs and pleural line make a solid landmark called the bat sign. The pleural line indicates the parietal pleura in all cases. Below the pleural line, this horizontal repetition artifact of the pleural line has been called the A-line (lower, small horizontal arrows). The A-line indicates that air (gas more precisely) is the component visible below the pleural line. Right: M-mode reveals the seashore sign, which indicates that the lung moves at the chest wall. The seashore sign therefore indicates that the pleural line also is the visceral pleura. Above the pleural line, the motionless chest wall displays a stratified pattern. Below the pleural line, the dynamics of lung sliding show this sandy pattern. Note that both images are strictly aligned, of importance in critical settings. Both images, i.e., lung sliding plus A-lines make the A-profile (when found at the anterior chest wall). They give basic information on the level of capillary pressure. Extract from "Whole body ultrasonography in the critically ill" (2010 Ed, Chapter 14), with kind permission of Springer Science.

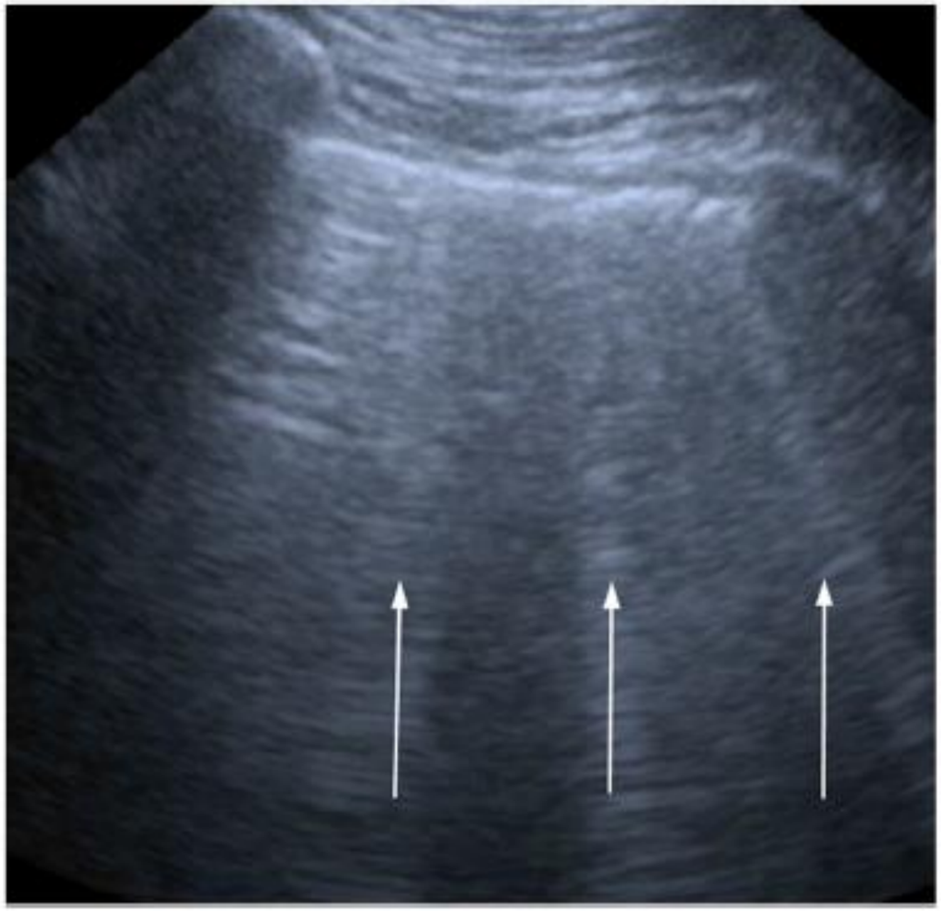
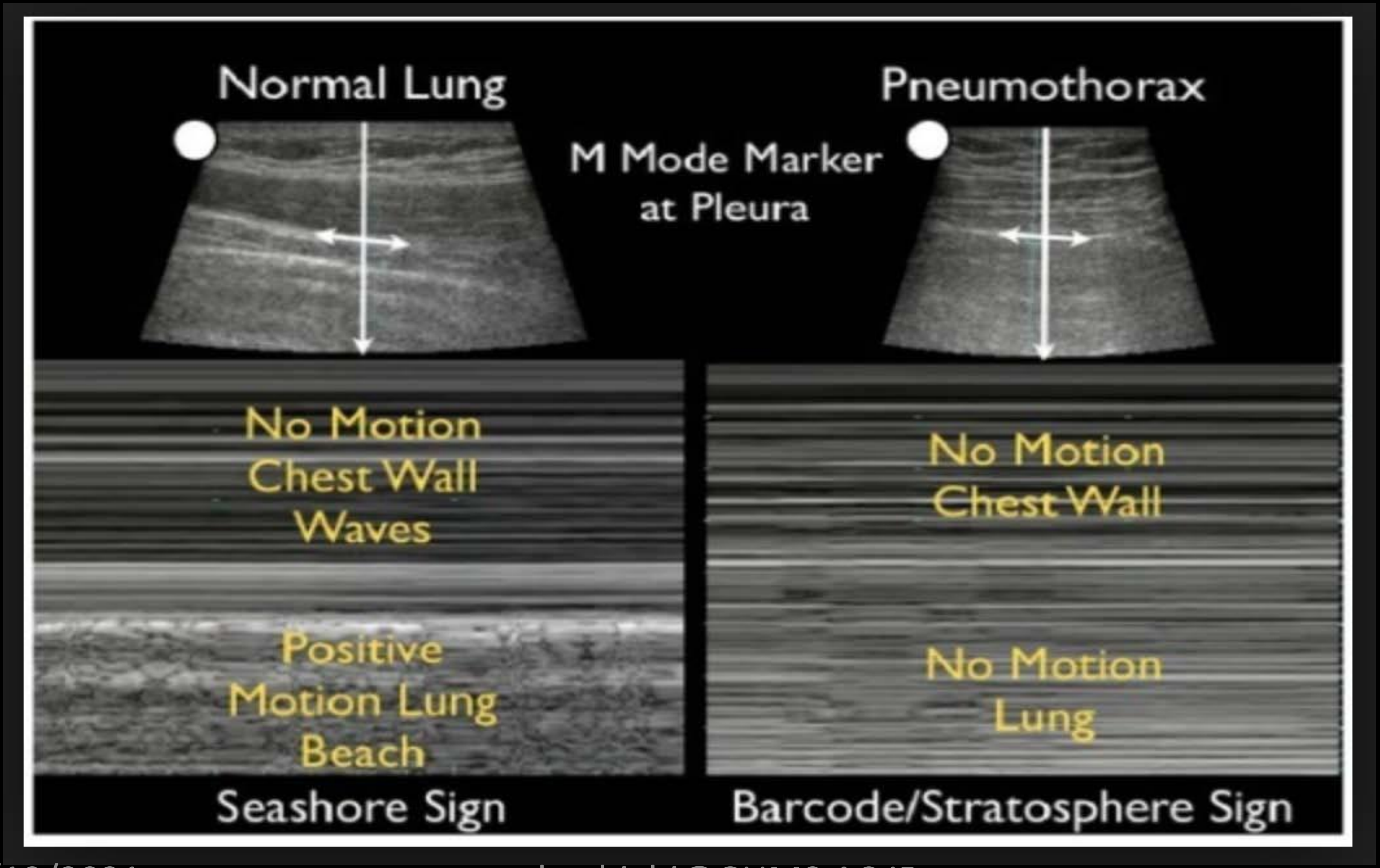


Fig. 6. Increased B-lines (white arrows) consistent with interstitial syndrome.

Thoracic Ultrasound:
Lung Sliding (B-mode/M-mode)



http://www.acep.org/

Thoracic Ultrasound:

Absent Lung Sliding:

Other causes:

- Pleural adhesion
- Atelectasis
- Lobectomy/Pneumonectomy
- Main-stem intubation

\- Compare with other lung
-Look for "Lung Point" (100% specific for pneumothorax)

Thoracic Ultrasound:

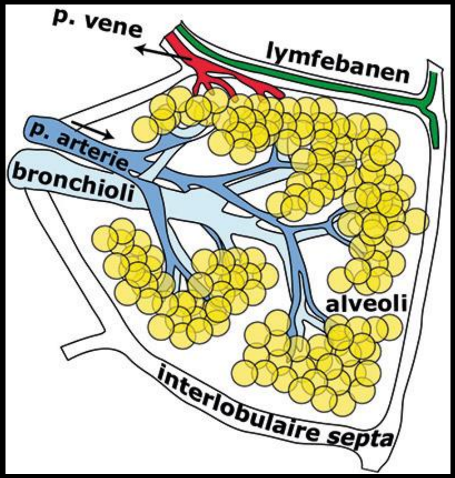
"Lung Point"

Thoracic Ultrasound:

B Lines:

- Hyperechoic rays projecting vertically from pleural line to bottom of screen
  - Obliterate *A Lines*
- Identifies fluid in interlobular septum
- "Interstitial" Syndrome
  - Bilateral
    - CHF, ARDS, ILD
  - Unilateral
    - Pneumonia

B line-آرتیفکت



Thoracic Ultrasound:

B Lines:

Thoracic Ultrasound

B Lines:

Clinical Role of *B Lines:*

Fluid "Intolerant"

vs

Fluid "Tolerant"

FALLS-protocol

1) Ruling out obstructive shock

↓

Simple cardiac sonography:

Pericardial tamponade
Right ventricle dilatation [1]

BLUE-protocol: pneumothorax *(A'-profile)*

2) Ruling out cardiogenic shock [2]

↓

BLUE-protocol: pulmonary edema *(B-profile)*

3) Ruling out hypovolemic shock *(A-profile)*

↓

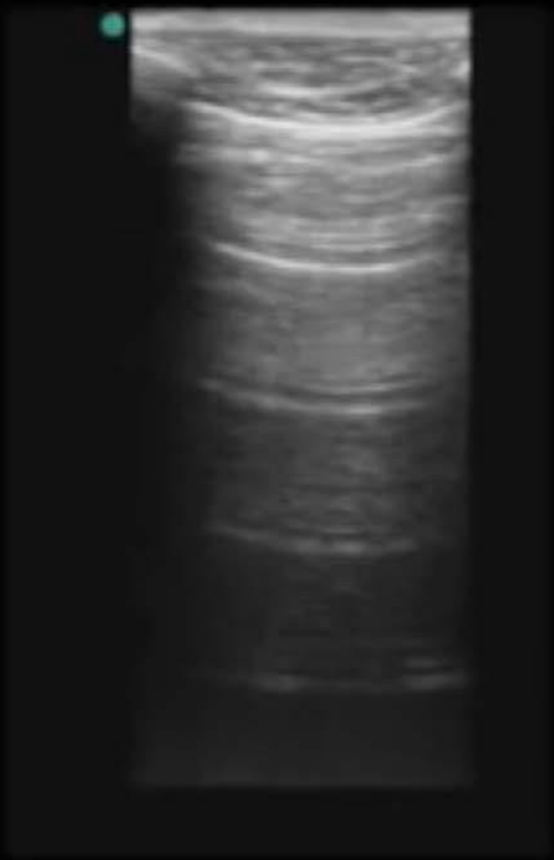
Correction of parameters of shock under fluid administration

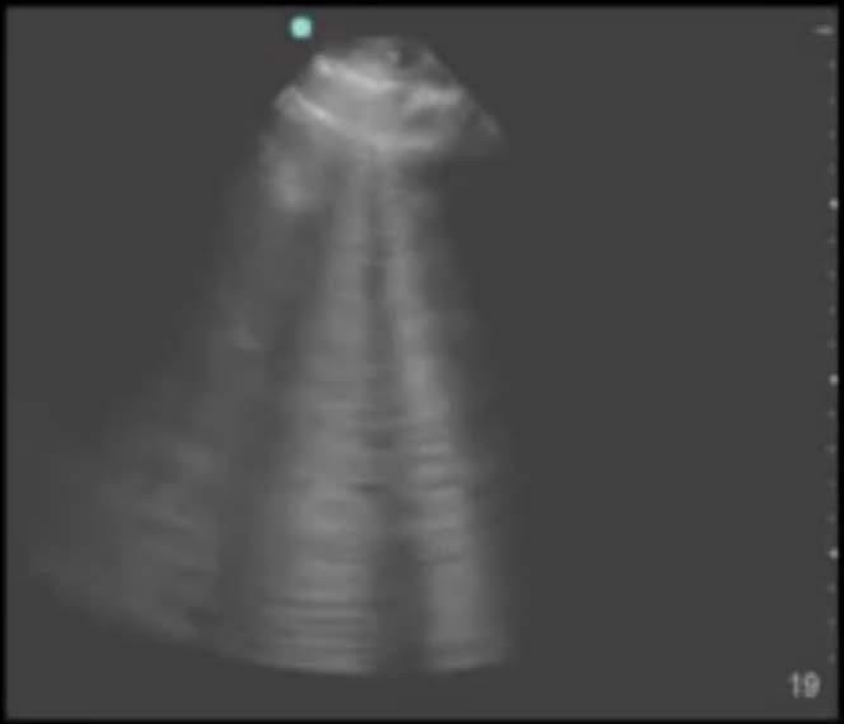
4) Detecting distributive shock, septic shock currently

Fluid therapy not able to improve circulation, eventually generating a B-profile

Thoracic Ultrasound:

A Lines vs B Lines:





http://www.scielo.br/scielo

Thoracic Ultrasound:

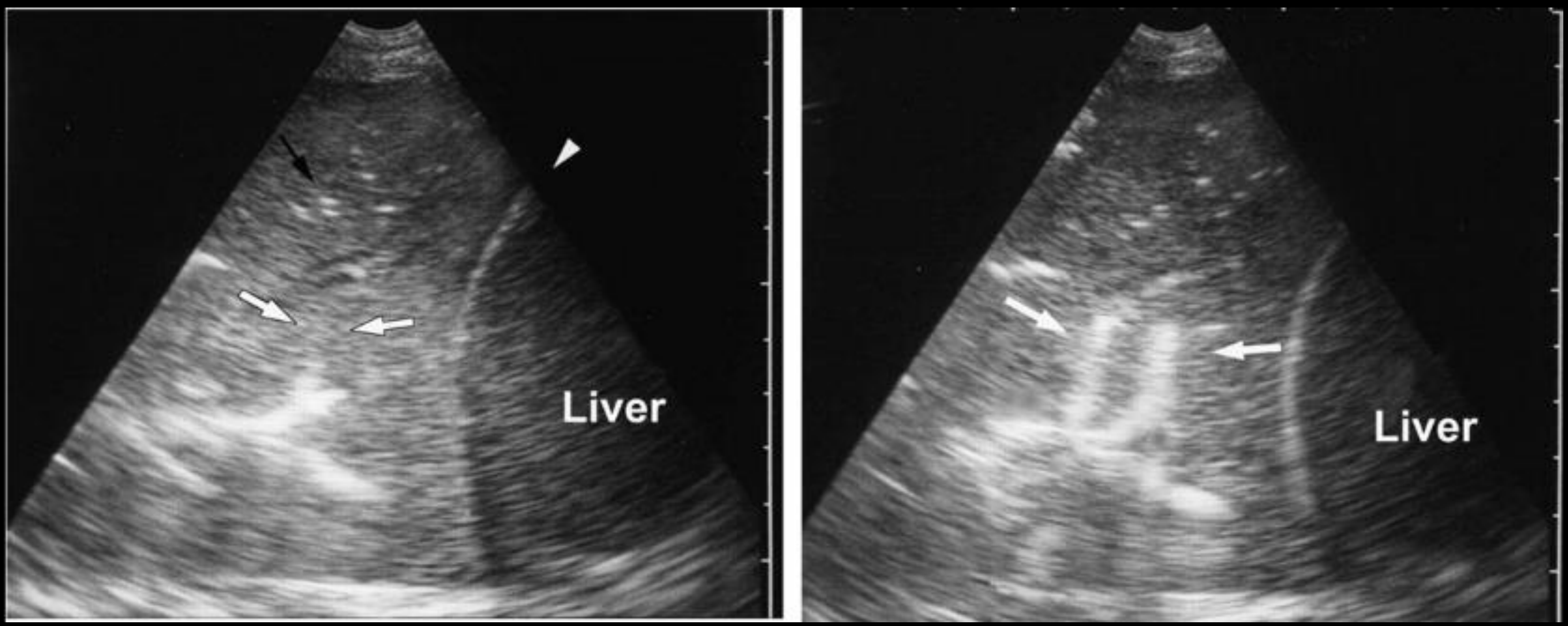
Consolidation:

http://westernsono.ca/tutorials-3/lung-ultrasound-image-interpretation-tutorial

Thoracic Ultrasound:

Consolidation:

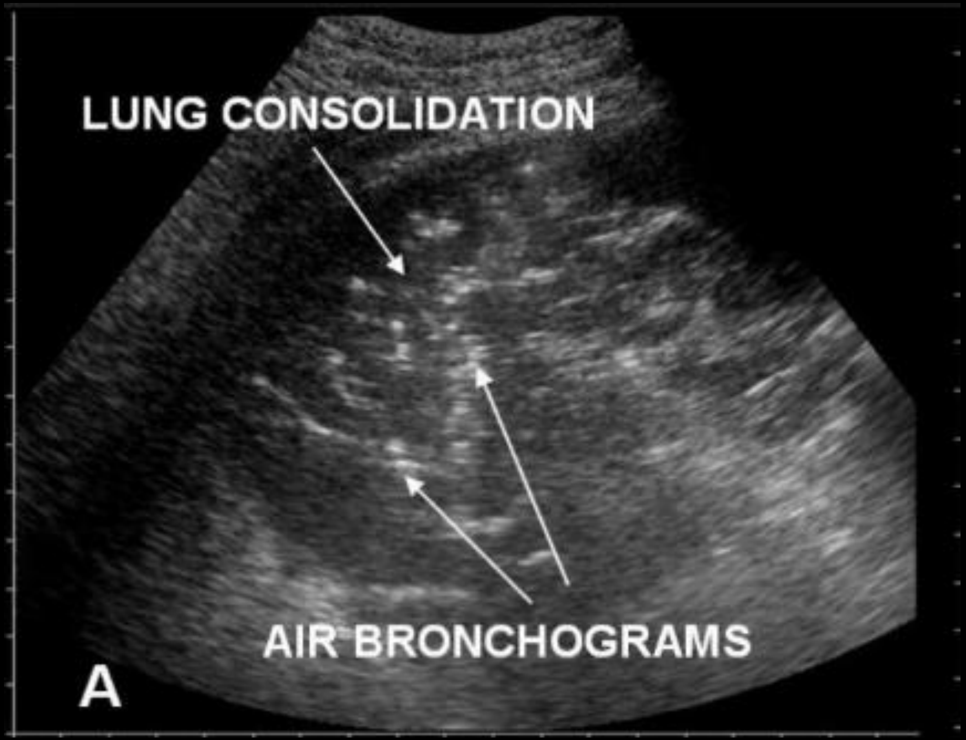
Air bronchograms



Chest. 2009;135(6):1421-1425

Thoracic Ultrasound:

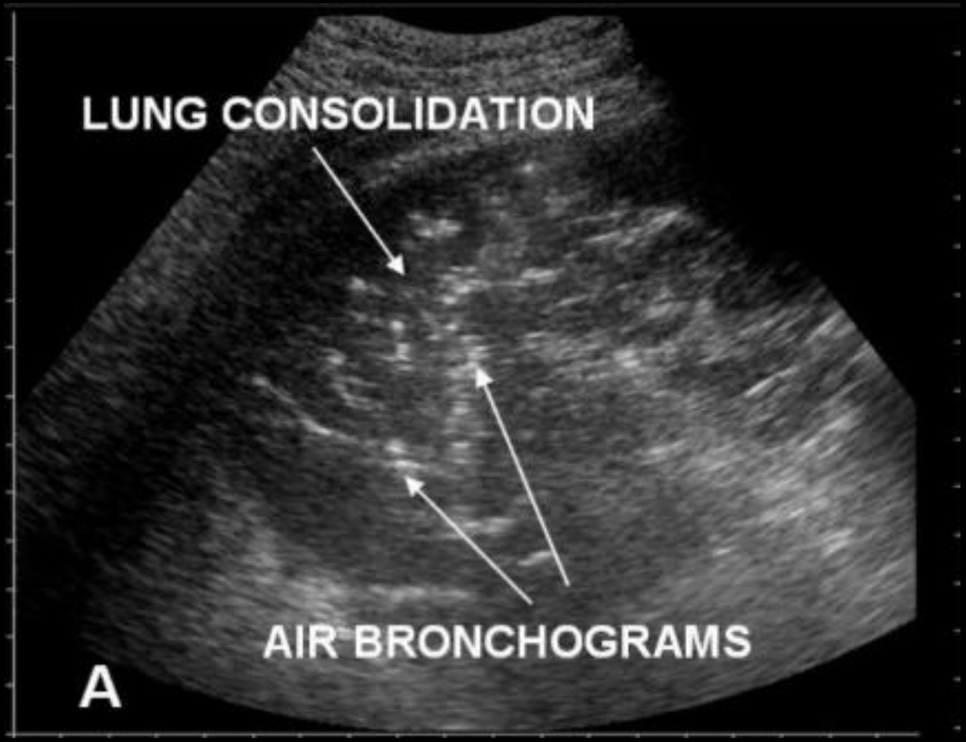
Consolidation:

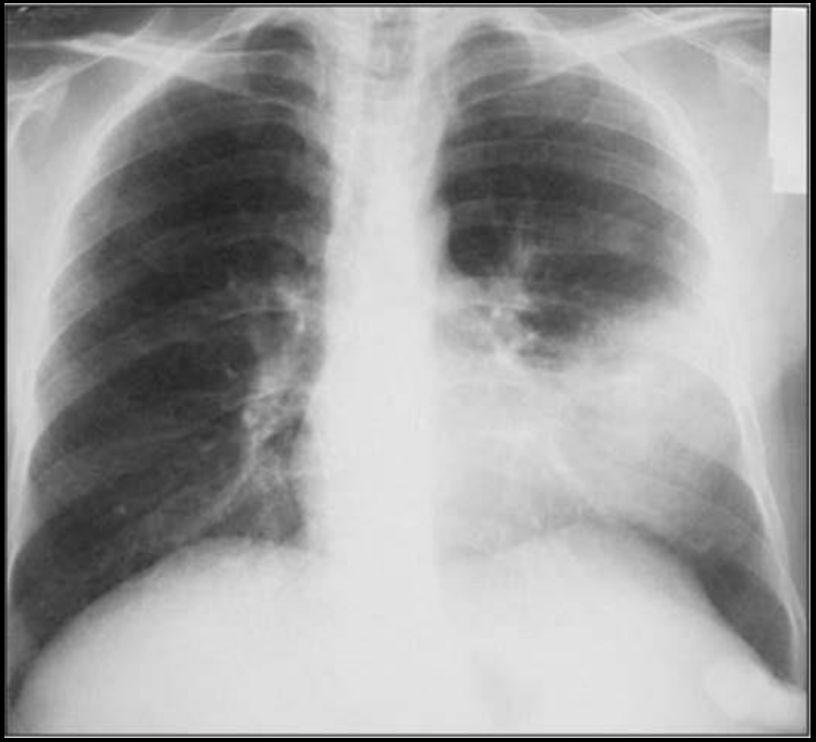


http://www.criticalecho.com/content/tutorial-9-lung-ultrasound

Thoracic Ultrasound:

Consolidation:





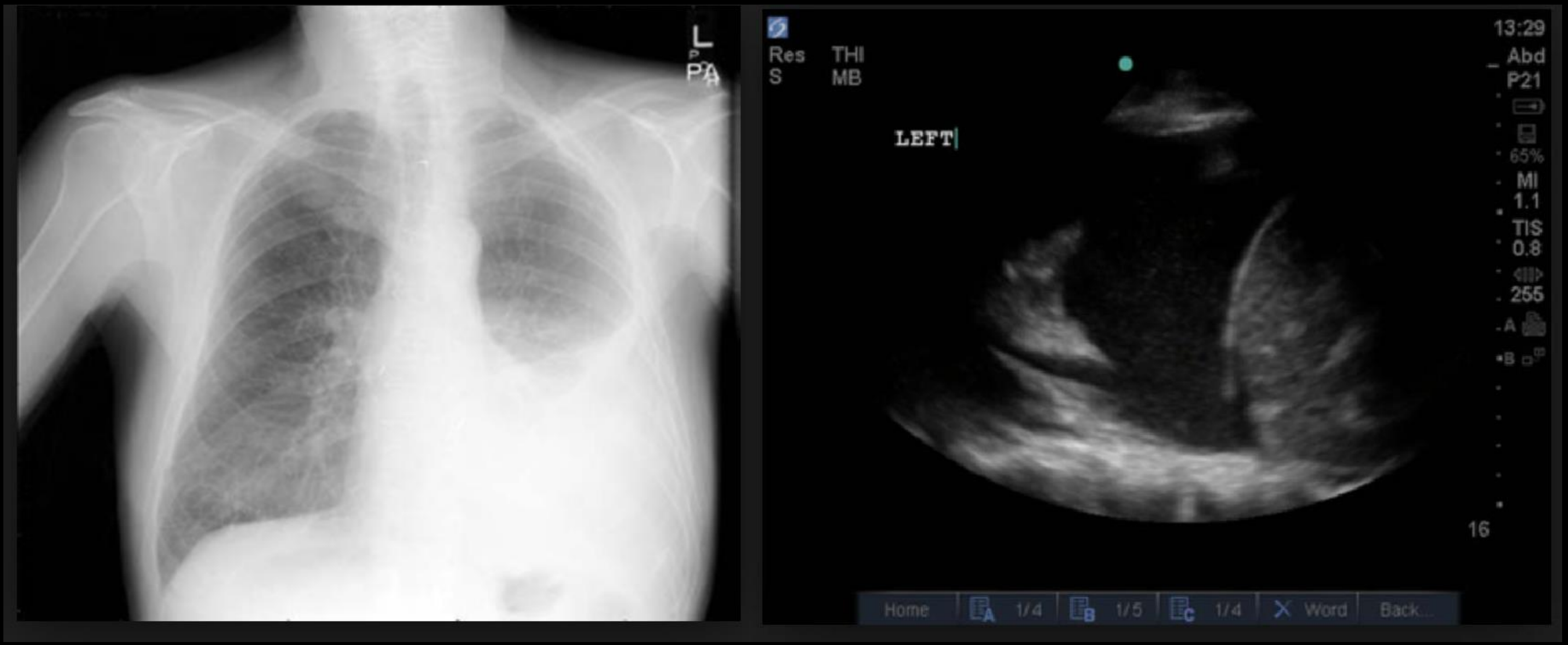
http://www.criticalecho.com/content/tutorial-9-lung-ultrasound

Thoracic Ultrasound:

Pleural Effusion:

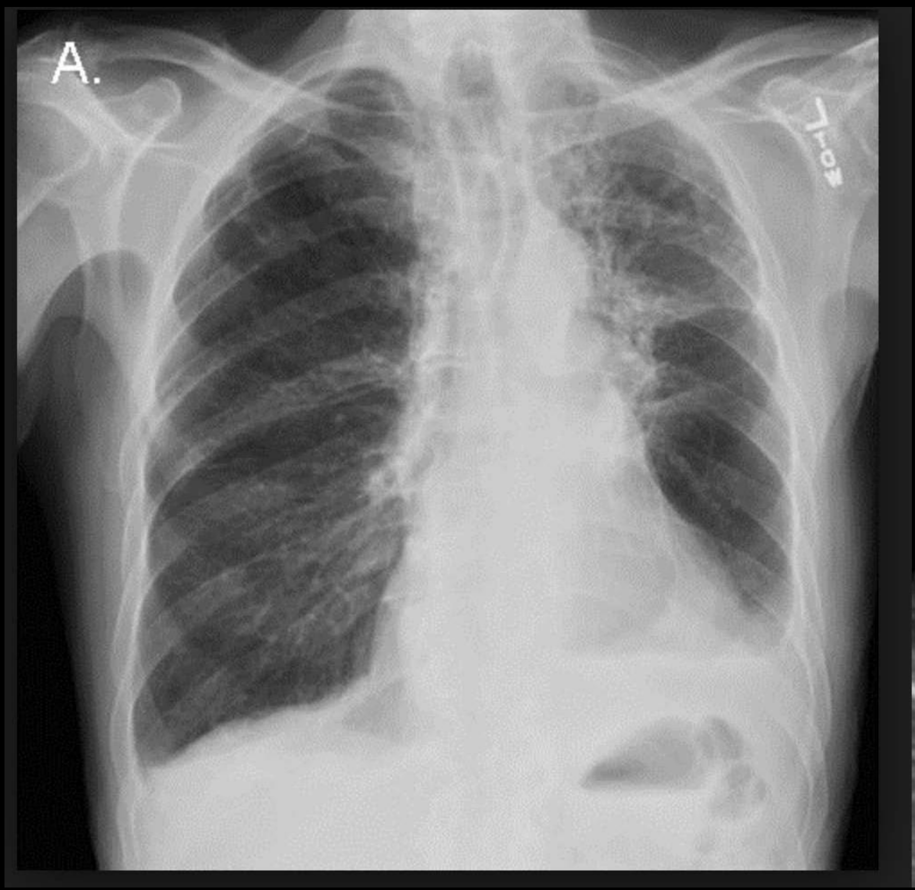
http://westernsono.ca/tutorials-3/lung-ultrasound-image-interpretation-tutorial

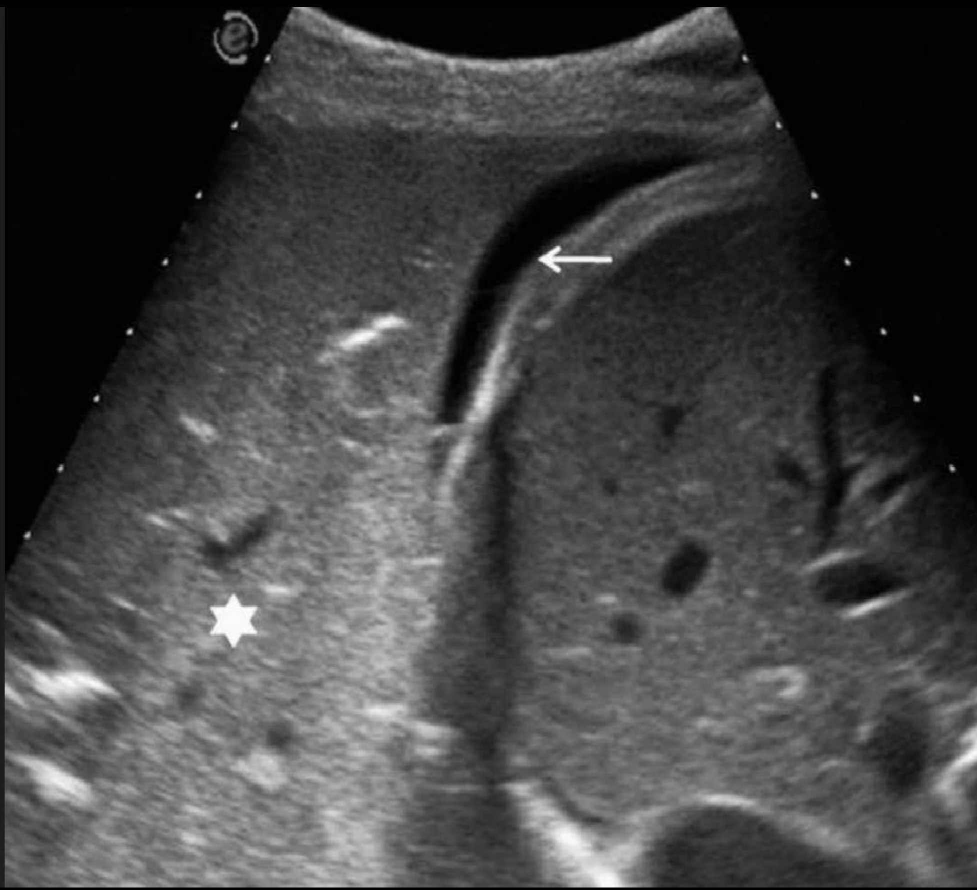
Thoracic Ultrasound:
Pleural Effusion:



Thoracic Ultrasound:

Pleural Effusion:





Thoracic Ultrasound:

Pleural Effusion:

"Jelly Fish" sign

Thoracic Ultrasound:

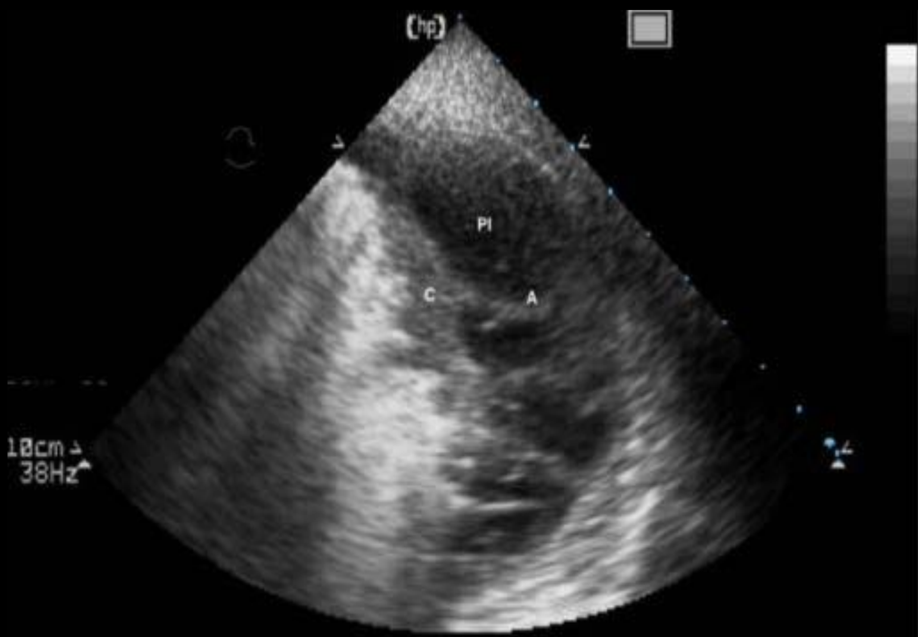
Pleural Effusion:

"Jelly Fish" sign / Lung Flapping

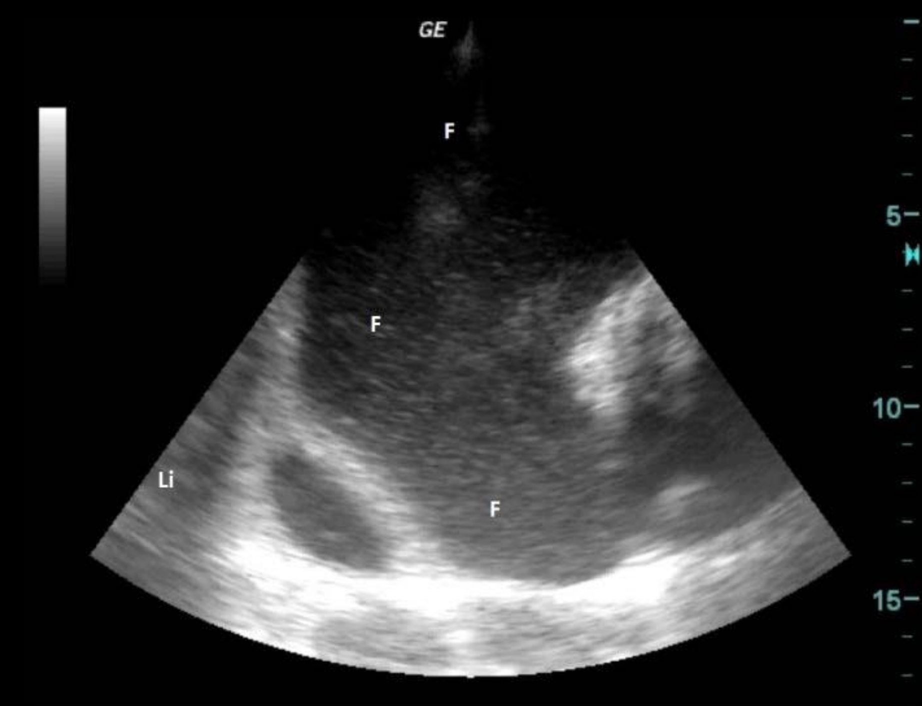
Thoracic Ultrasound:

Pleural Effusion:

Septations



"Plankton" sign



Thoracic Ultrasound:

Thoracentesis:

http://www.critcaresono.com/

Thoracic Ultrasound:

Thoracentesis:

Localize deepest "pocket" of fluid in longitudinal and transverse plane

http://www.clevelandclinicmeded.com/medicalpubs/diseasemanagement/pulmonary/bedside-applications-of-ultrasound/

Thoracic Ultrasound:

Thoracentesis:

Must Identify:

- Anechoic free space
- Chest wall
- Diaphragm
  - Above vs below
  - Respiratory Movement
- Compressed Lung
- "Flapping"

http://link.springer.com/referenceworkentry

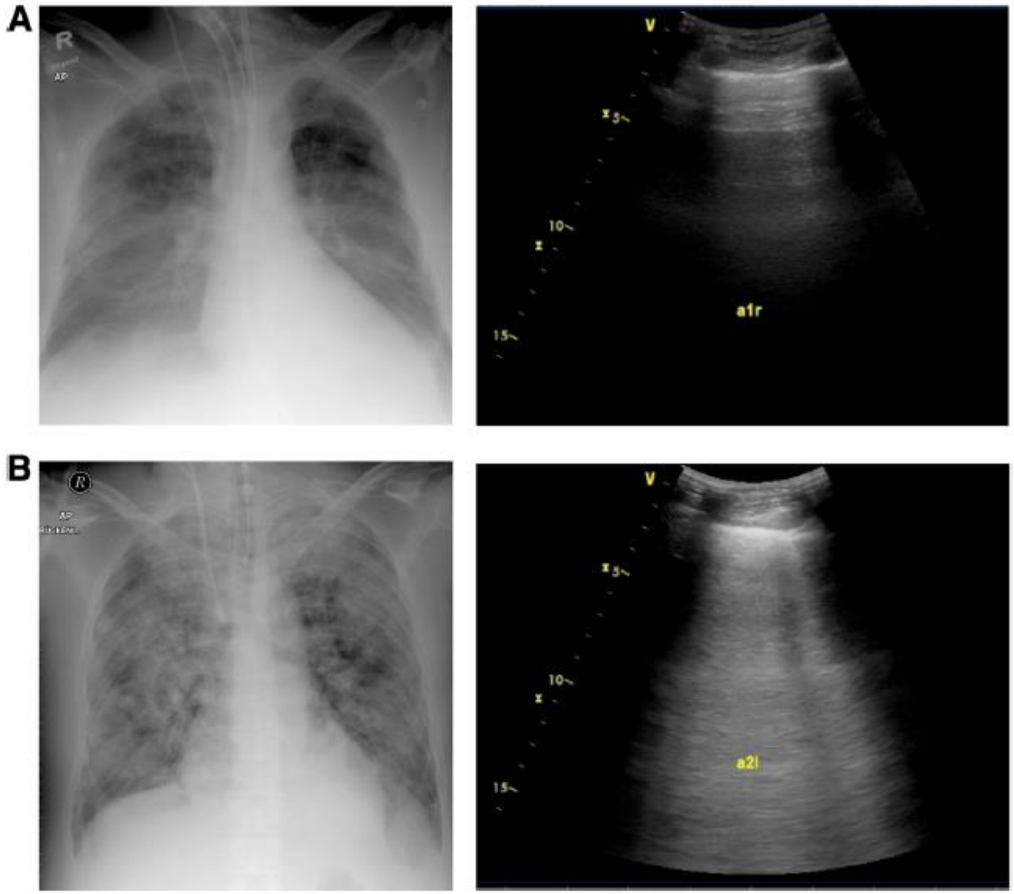


Figure 2 Chest radiographs (left) and corresponding ultrasound screenshots (right) of two study patients. (A) Dry lung with a normal extravascular lung water index (EVLWI) and predominant A lines. **(B)** Severe, non-cardiac pulmonary edema with a high EVLWI and confluent B lines.

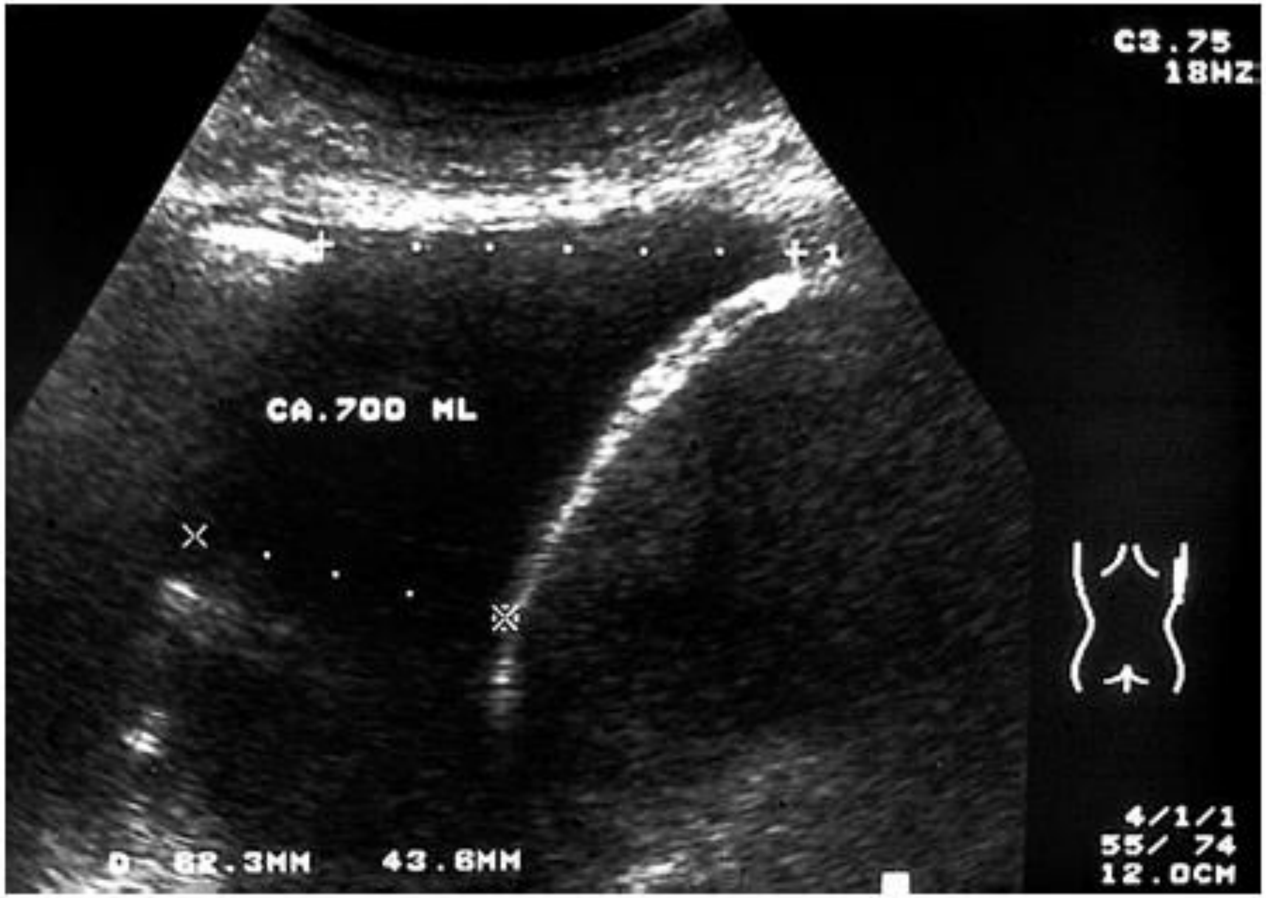


Fig. 3.10 A simple estimation of effusion volume by measuring the height of the subpulmonary effusion and the maximum height. Estimated volume 700 ml, actual volume 800 ml (From Goecke and Schwerk 1990)

Thoracic Ultrasound:
Thoracentesis:

Pearls & Pitfalls:

- Identify anatomic boundaries:
  - Anechoic free space
  - Chest wall
  - Diaphragm
    - Diaphragm movement?
  - Compressed lung
    - Lung flapping?
- R/O ascites:
  - Hepatorenal/splenorenal space vs pleural space?