Ultrasound for pleural effusion and pneumothorax
: Diagnosis and Intervention

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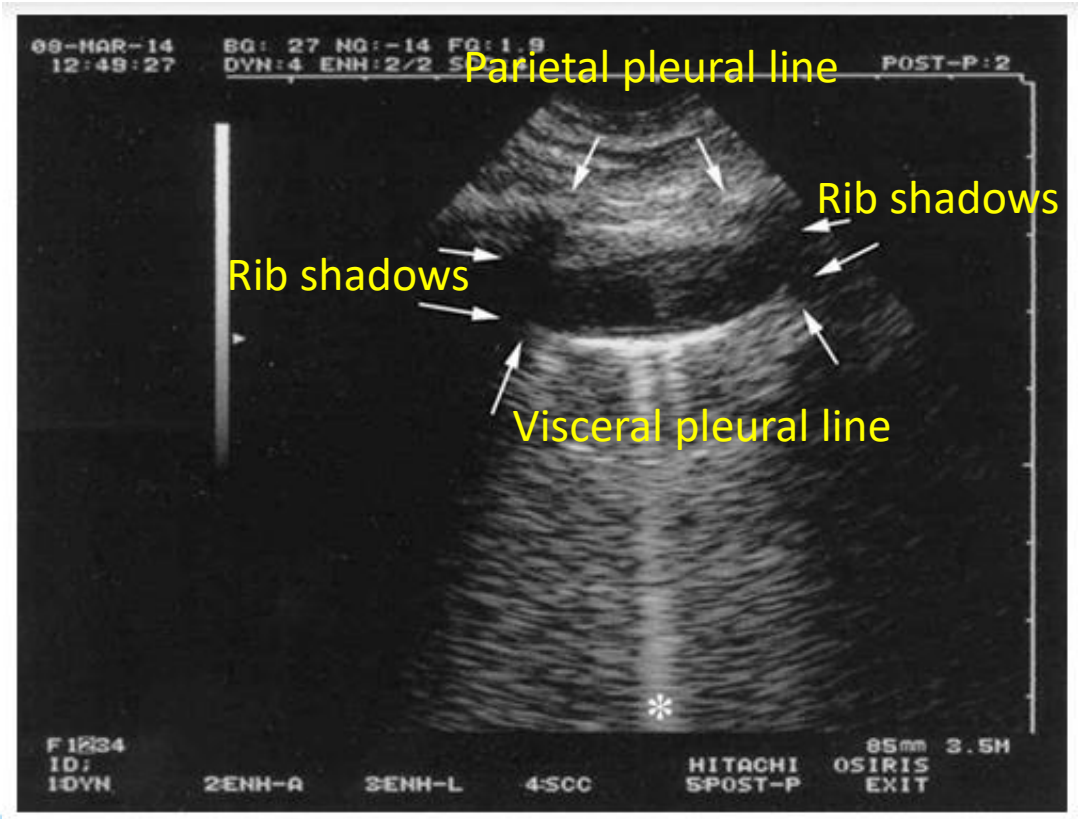
Contents

- Pleural effusion
- Pneumothorax
- Clinical applications

Pleural effusion

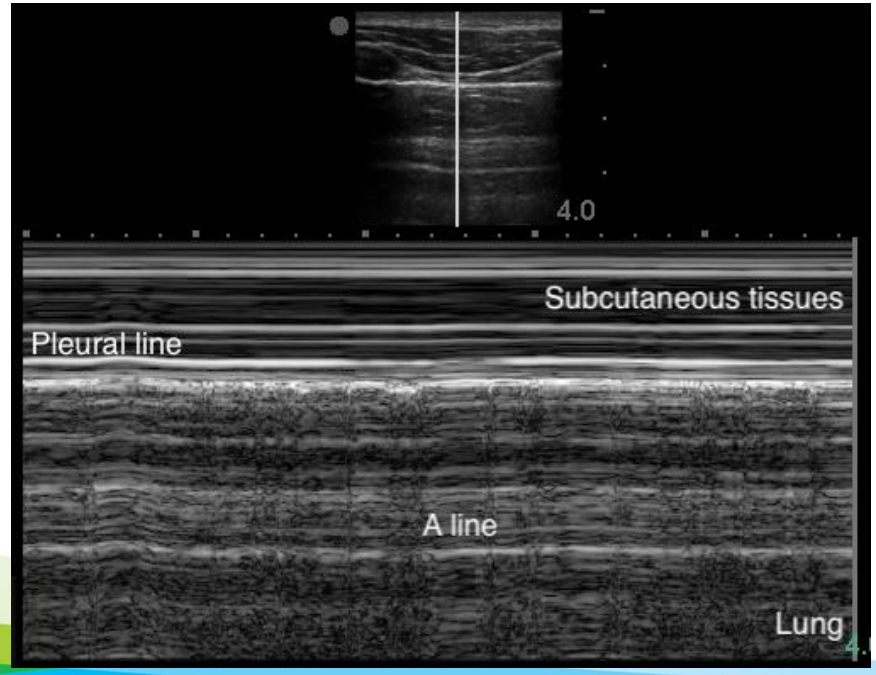
Sonographic findings of pleural effusion

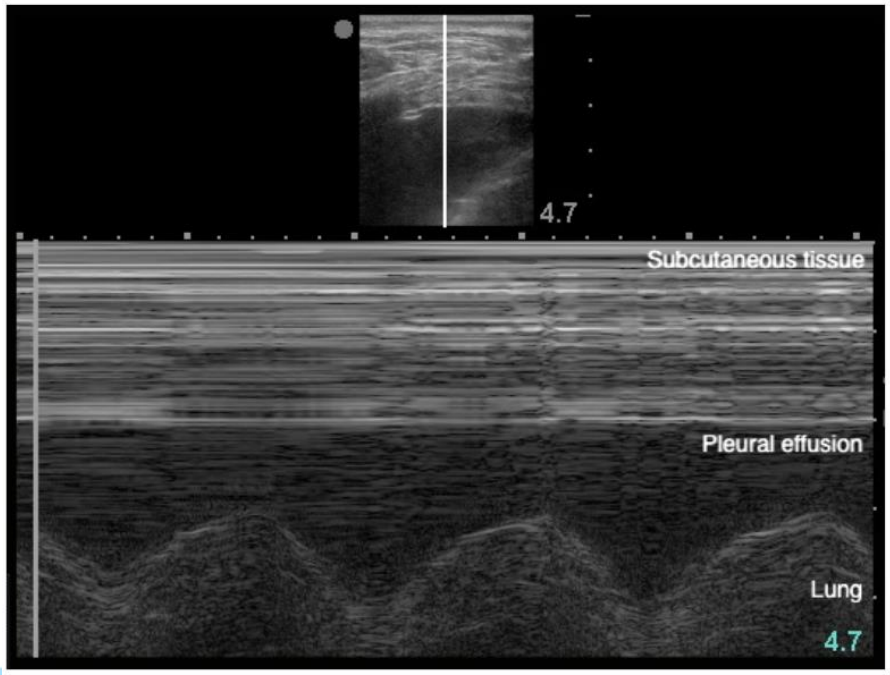
- Quad sign
  - A space between the parietal and visceral pleura
  - Usually anechoic



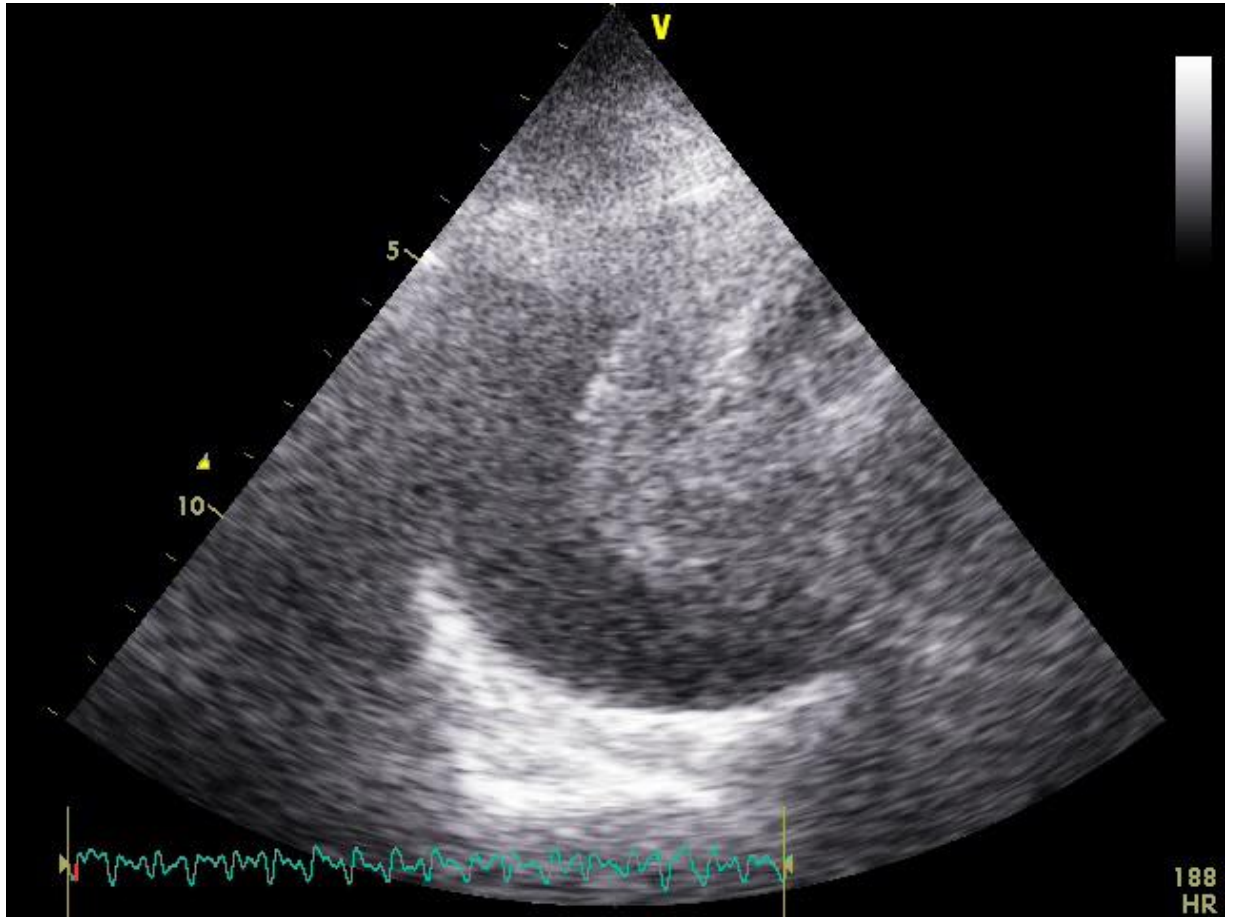
Sonographic findings of pleural effusion

- Sinusoid sign
  - M-mode
  - Dynamic sign
  - Respiratory movement of the lung within the effusion





Sonographic findings of pleural effusion



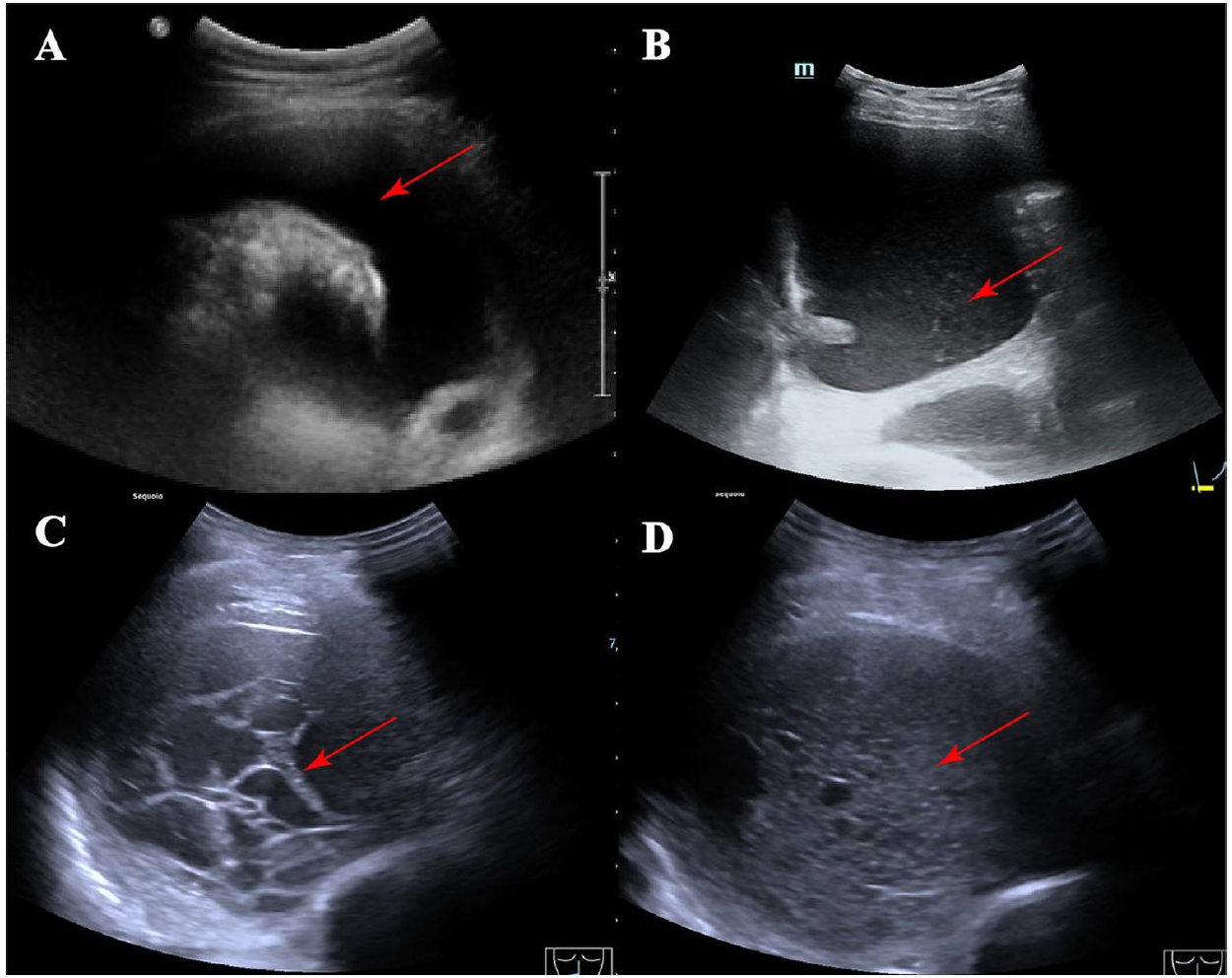
Nature of pleural effusion

- Internal echogenicity
  - Anechoic : echo-free
  - Complex non-septated

    : echogenic material inside the effusion
  - Complex septated

    : floating fibrin stands or seta inside the effusion
  - Complex homogenous

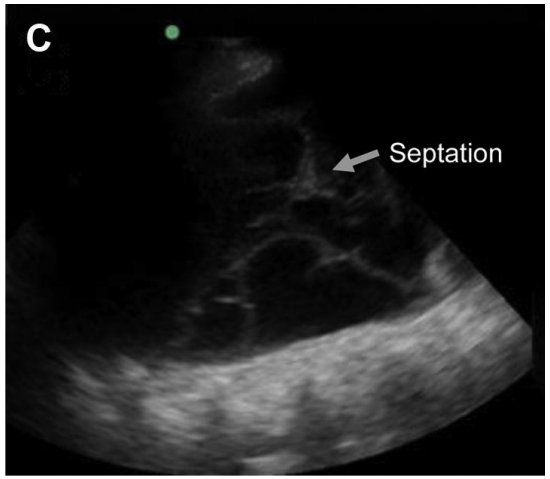
- Pleural thickening : >3mm

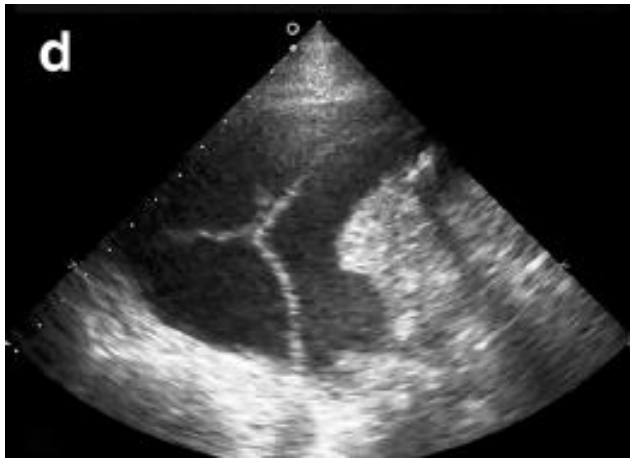


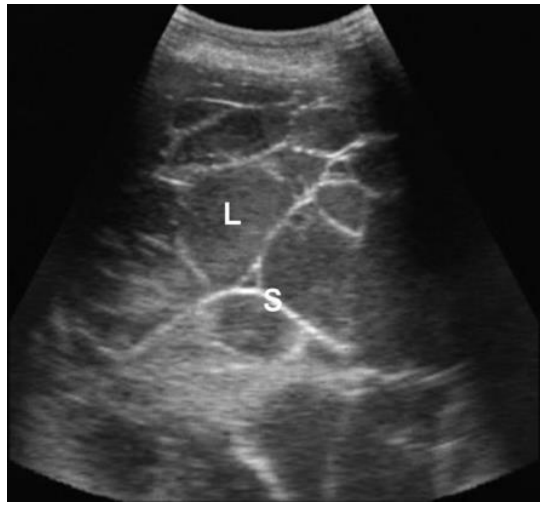
Nature of pleural effusion

	Exudate	Transudate	Hemothorax	Empyema	Malignant effusion
Internal echogenicity	Complex non-septated or septated Anechoic	Anechoic	Echogenic	Echogenic Often septated	Complex septated or non-septated
Homogeneity	Homogenous Non-homogenous	Homogenous	Homogenous	Homogenous	Homogenous
Pleural thickness	Thickness	Normal	Thickness	Thickness	Irregular thickness
Other findings	Parenchymal lesions (consolidation)	Bilateral	Pneumothorax, atelectasis, consolidation	Parenchymal lesions (consolidation)	Pleural nodules, diaphragmatic abnormalities

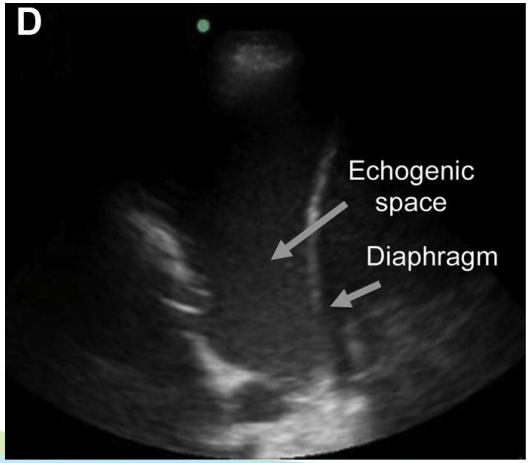
- Transudate => anechoic
- Anechoic => transudate or exudate
- Septation, internal echogenicity, pleural thickness => exudates





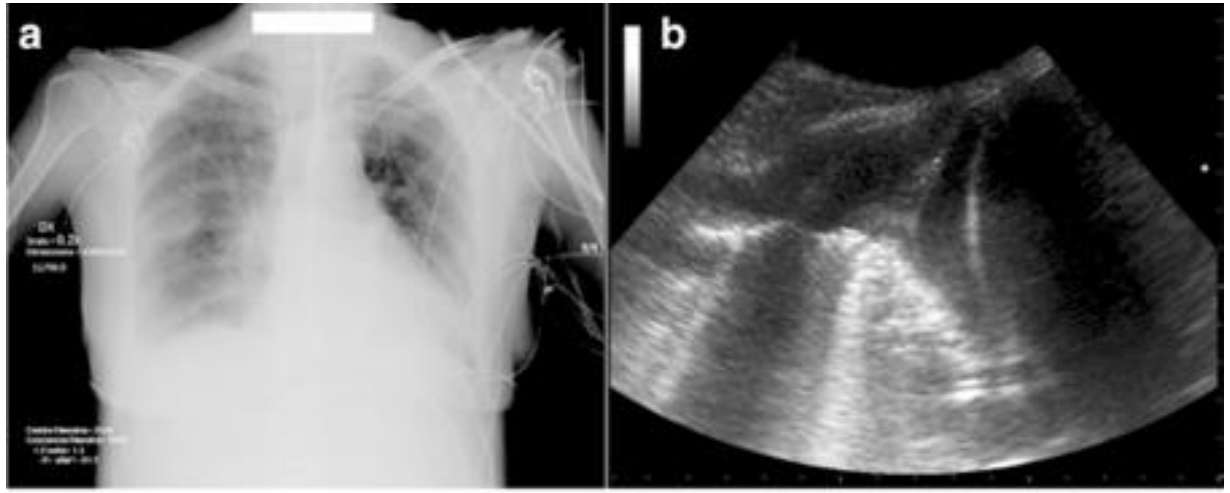


- Homogenously echogenic => hemothorax or empyema

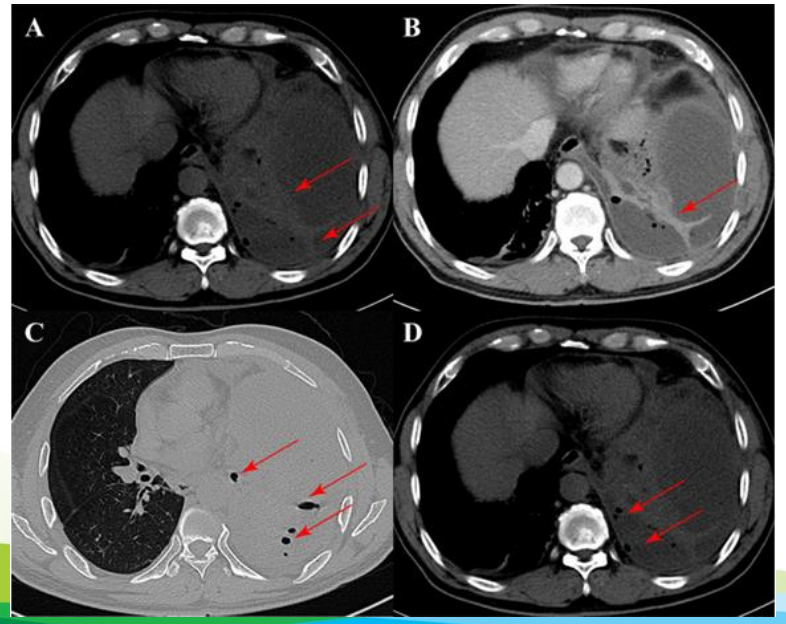


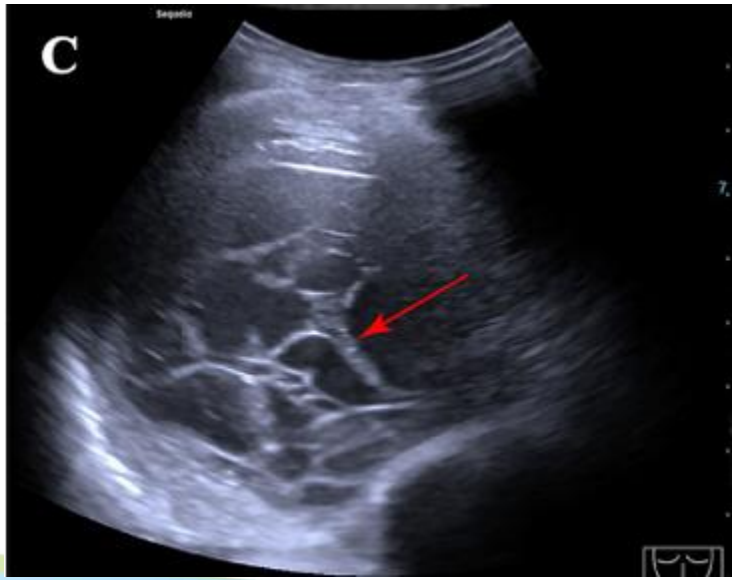
Accuracy

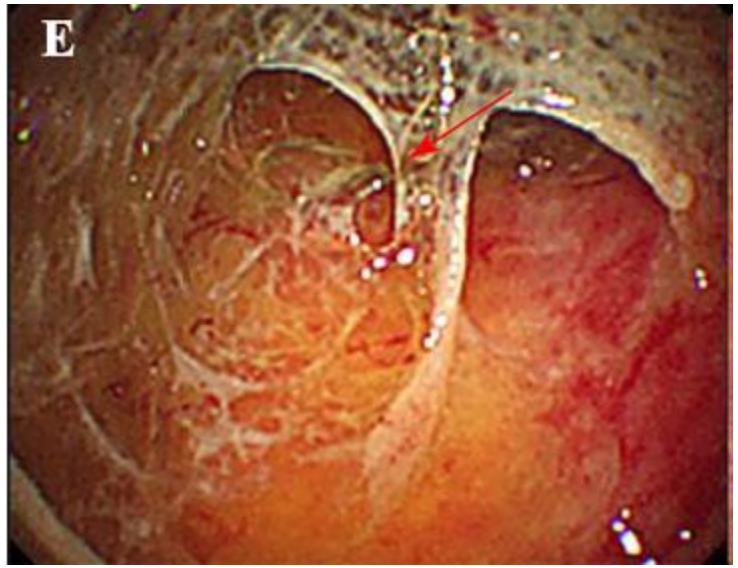
- Higher than chest radiography
  - For detection of effusion
  - In distinguishing between effusion and consolidation
- As good as CT scan
  - Better than CT in identifying septated effusion



Sensitivity %, (95% CI)	82.6 (73.3–89.7)	59.8 (49.0–69.9)
Specificity %, (95% CI)	100.0 (98.1–NaN)	87.0 (81.5–91.4)
Positive predictive value %, (95% CI)	100.0 (95.3–100.0)	68.8 (59.0–77.4)
Negative predictive value %, (95% CI)	92.3 (87.5–NaN)	82.0 (74.6–87.8)
AUC (95% CI)	0.913 (0.874–0.952)	0.734 (0.678–0.790)







Probes

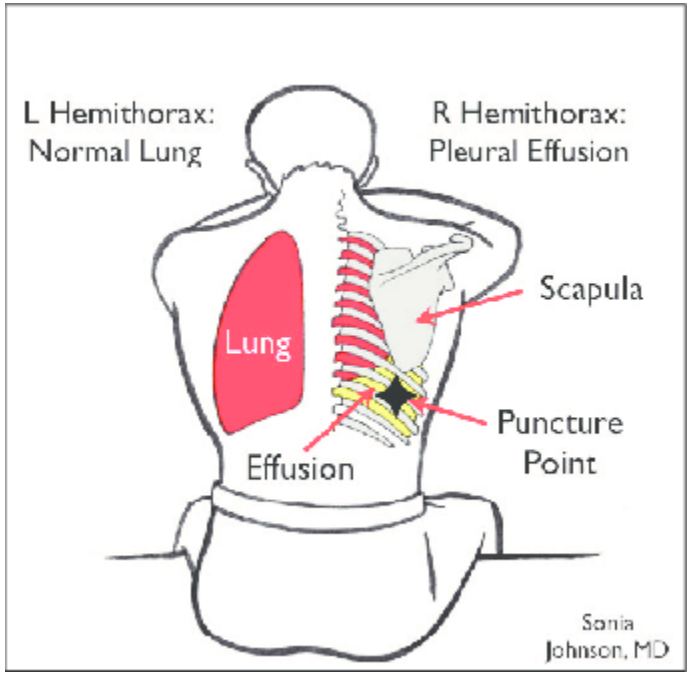
- Microconvex is preferable
  - small, good resolution, PLAPS point exploration 가능
- If not available, phased array or convex
  - Phased array
    - Effusion detection 쉬움
    - Lung sliding이 잘 안보이기도 함
  - Convex
    - Pleural-alveolar characterization, effusion evaluation, artifacts assessment에 최적
    - Bulky -> PLAPS point exploration 어려움
  - Linear probe
    - Pleural line, subpleural space valuation 에 최적
    - Lung artifacts, pleural effusion assessment에는 적합하지 않음

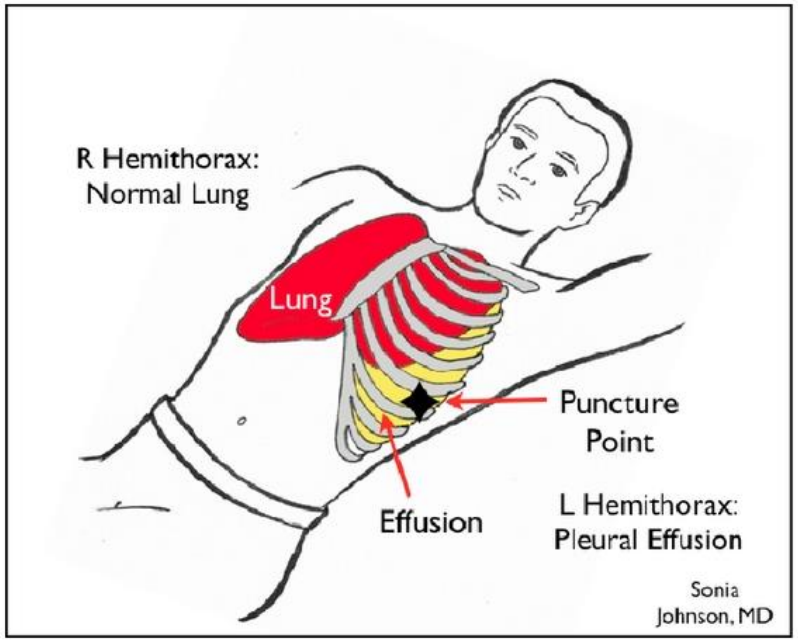
Position

- Upright sitting position with arms elevated
- Supine position with trunk elevation of 40–45° with arm elevated behind the head
- Supine, arms be fixed to the other side of the bed in a direction to the opposite shoulder
- Never rotate patient to the opposite site

→ fluid moves towards the paravertebral zone

  - Puncture might be more dangerous
  - Patient could lie on the insertion site -> infection





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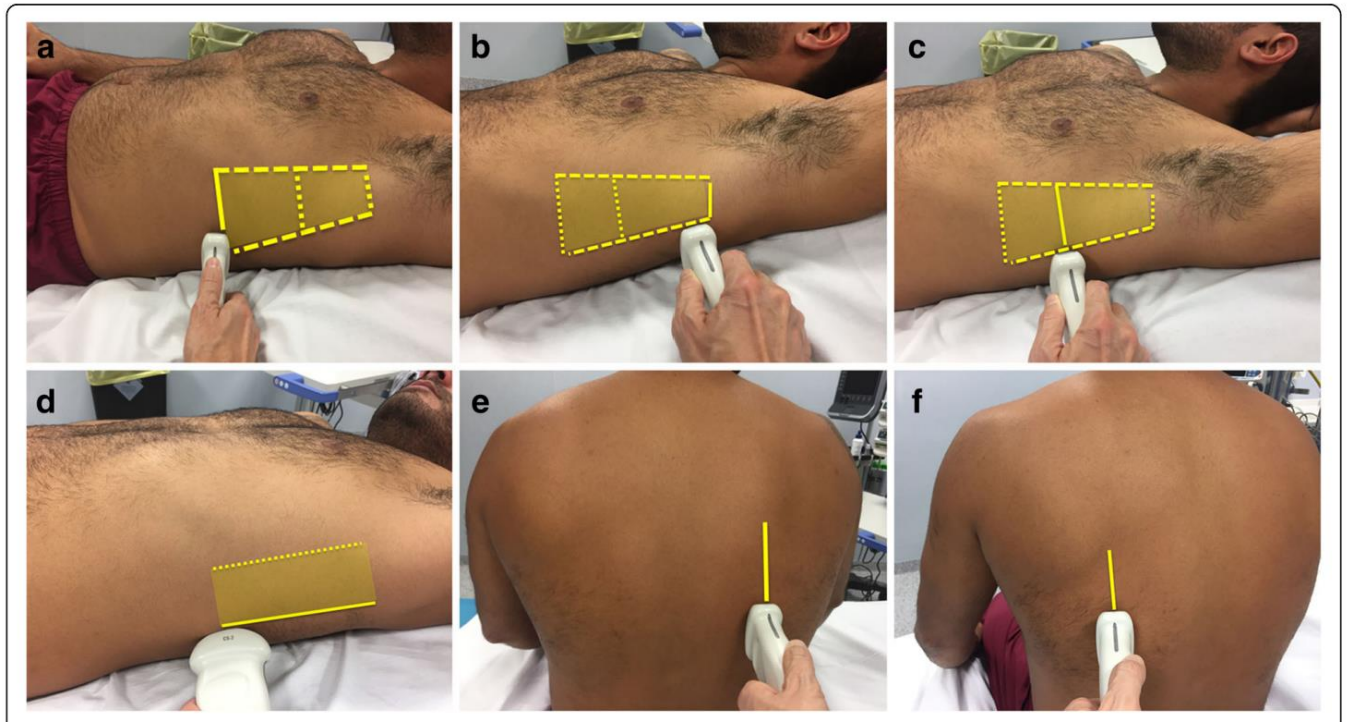
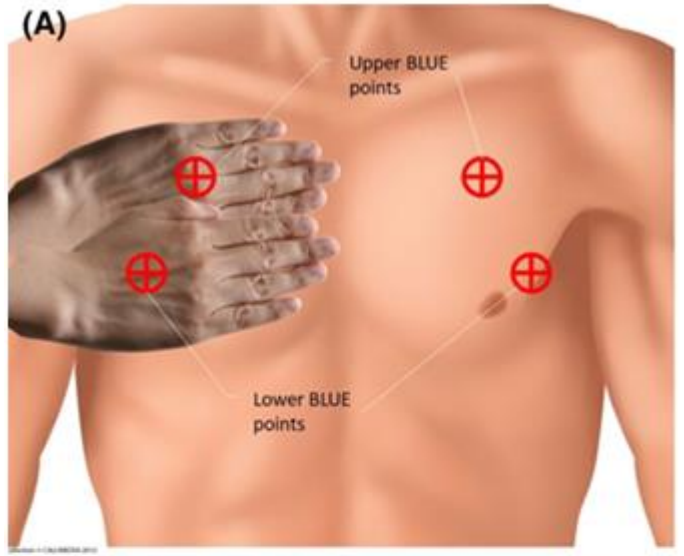
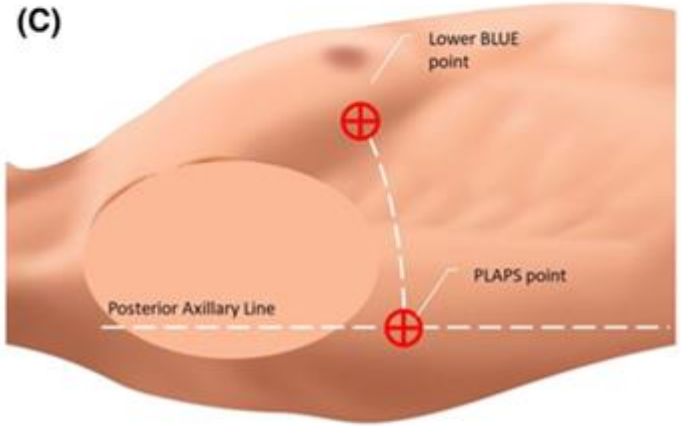
Position







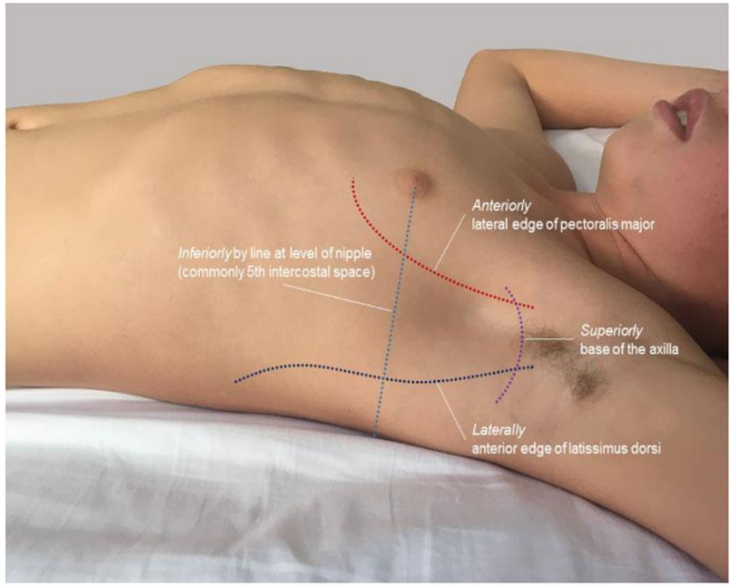
- Supine or sitting
- Transverse or longitudinal scan
- PLAPS point 확인 : effusion이 가장 잘 고이는 곳

Optimal site

- where the operator best visualizes each anatomical structures (diaphragm, pleural, organs)
- where the operator can measure the maximum distance between visceral and parietal pleural (increasing the safety margin)

Table 2 Position of the probe and indications on how to measure pl

Authors	Probe position
Vignon et al. [29]	Along the dorsolateral part of the chest wall, as posteriorly as possible between the mattress and the patient's back without lifting the hemithorax, in all IC from the base to the apex
Roch et al. [30]	Along the posterior axillary line between the ninth and eleventh ribs to identify the liver on the right side, the spleen on the left side, and the diaphragm To visualize the effusion, the transducer was advanced cranially and a longitudinal view was chosen
Balik et al. [31]	Along the posterior axillary line moving the probe cranially, obtaining transverse sections perpendicular to the body axis
Usta et al. [32]	Along mid-scapular line moving cranially (dorsal scanning)
Remérand et al. [33]	Along each paravertebral intercostal space, slipping the probe between the patient's back and mattress



Assessment of fluid volume

Table 1 Assessment of fluid volume

Authors	Patients	Position	Derived formula
Vignon et al. [29]	Mechanically ventilated and not ventilated patients	Supine	NA
Roch et al. [30]	Mechanicall ventilated patients	Supine with arm abducted	NA
Balik et al. [31]	Mechanically ventilated patients	Supine with mild trunk elevation at 15°	V(ml) = 20 × Sep (mm)
Usta et al. [32]	Spontaneous breathing patients after cardiac surgery	Sitting	V (ml) = 16 × D (mm)
Remérand et al. [33]	Critically ill patients	Supine	V (ml) = L_{US} × A_{US}

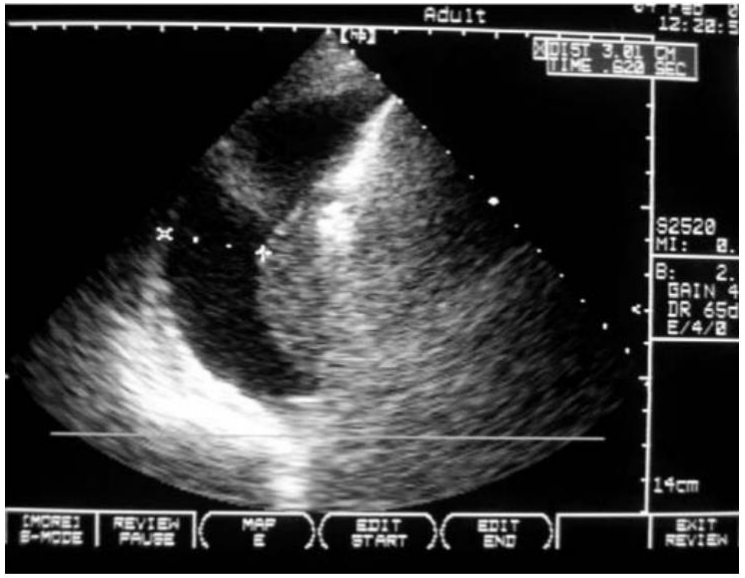


Fig. 1 Sep measurement (Sep maximal separation at lung base)

- The maximal distance between parietal and visceral pleura at the lung base, after freezing the image in end-expiration
- Clear visualization of diaphragm, liver, and spleen
- Estimated amount of pleural fluid: V (ml) = 20 x Sep (mm)

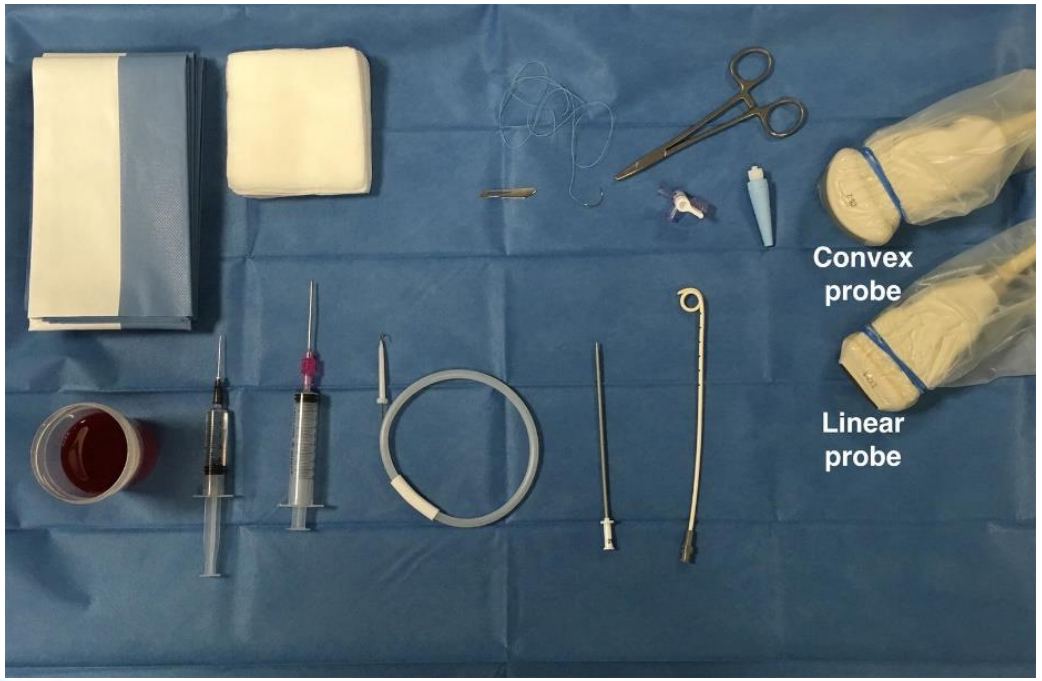
Ultrasound-guided effusion drainage

Indications	Contraindications (relative)
• Recurrent malignant pleural effusion • Symptomatic patients caused by the effusion • Massive transudative or exudative pleural effusion • Parapneumonic effusion • Weaning from mechanical ventilation	• Coagulopathy, thrombocytopenia • Small to medium size pleural effusion in cardiac patients with more than moderate left ventricular dysfunction • Pulmonary bullae • Pulmonary, pleural or thoracic adhesions • Loculated pleural effusion or empyema • Recurrent pleural infections • Skin infection over the chest tube insertion site

Preparation

- Full aseptic technique
- Large-bore needles should be avoided
- Small drains as first-line therapy for pneumothorax, free flowing pleural effusions and pleural infection

For the operator	Over the tray
Medical hat	Sterile drapes
Medical mask	Sterile towels
Hand disinfection	Syringes (5–10 mL)
Sterile gown	Local anaesthetics
Sterile gloves	Sterile water
	Phased array probe or convex and linear probe Sterile US probe cover
	Introducer needle
	Guidewire
	Scalpel and dilator
	Catheters (8–14F)
	Trocar
	Suture and medical dressing



Thoracentesis technique

Real-time needle guidance

- Position of the needle is monitored by ultrasound constantly
- More technically challenging
- did not seem to be a safer procedure in comparison to the site marking technique

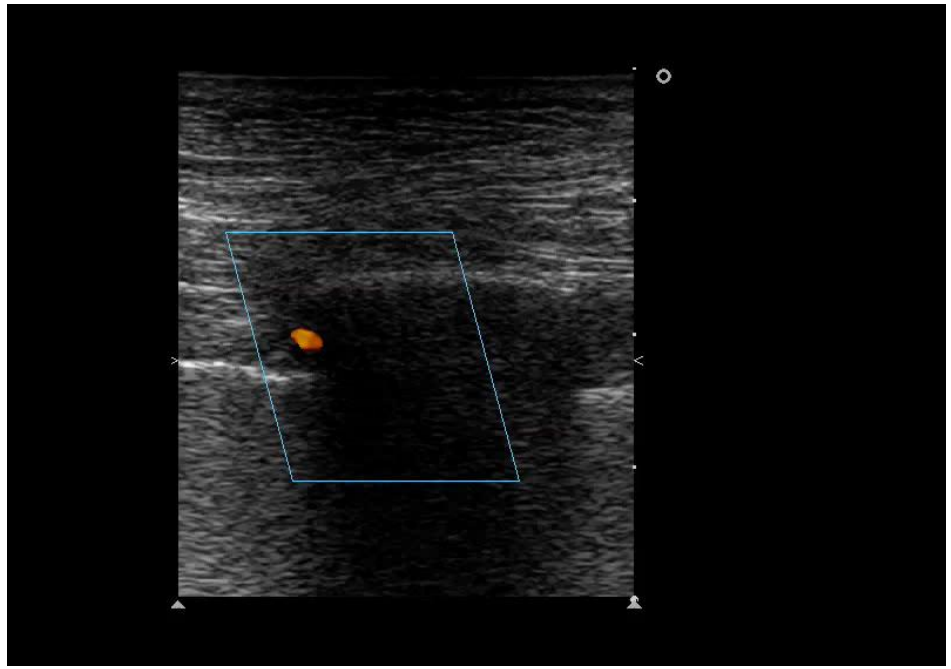
Site-marking

- Define optimal location point, without using real-time visualization
- Drain insertion should be performed instantly after site marking
- As long as done correctly, very low complication rate, even in mechanically ventilated patients

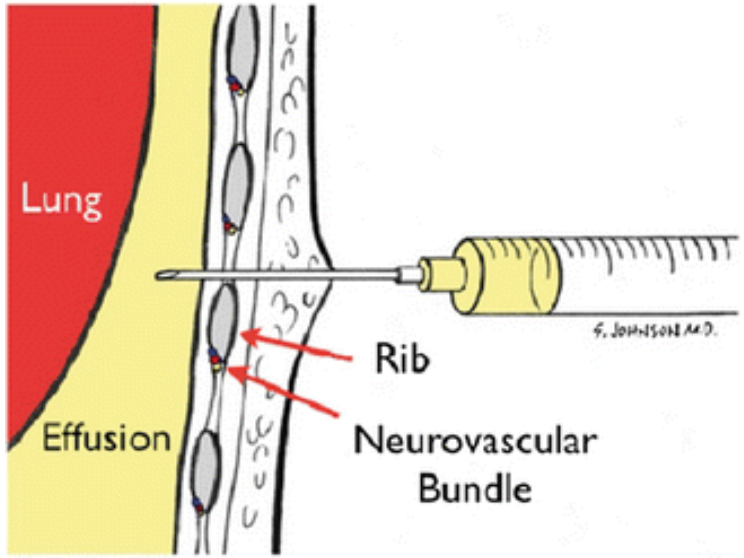
Procedure

1) Identify the best site for the puncture

- Anatomical structures
- Maximal distance (> 1~1.5cm)
- Low-frequency -> shift to high-frequency probe
- Identification of intercostal artery by color doppler

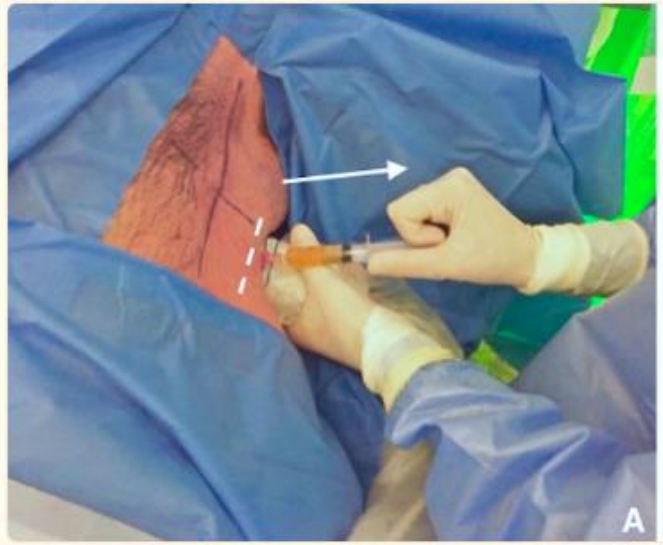


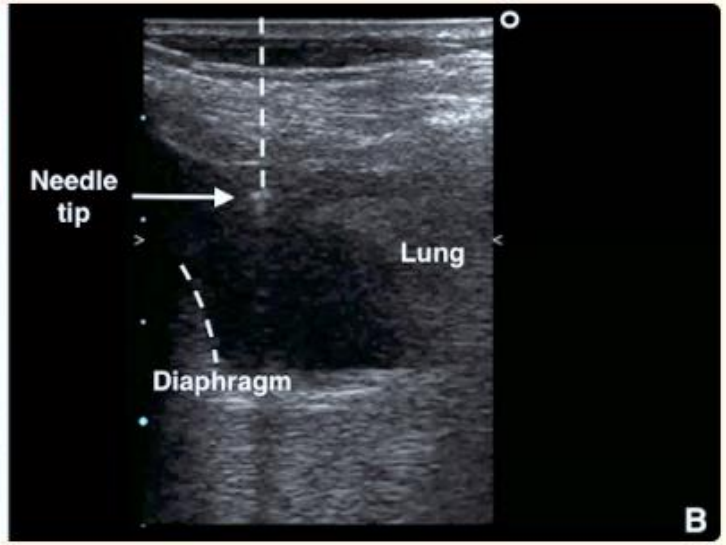
Procedure



2) Ultrasound-guided puncture

- Needle insertion : upper margin of the lower rib perpendicular to pleura
- Slow needle advance under direct visualization
- Confirming the correct position
  - Real-time needle guidance : visualization of needle tip
  - Site marking : aspiration of fluid

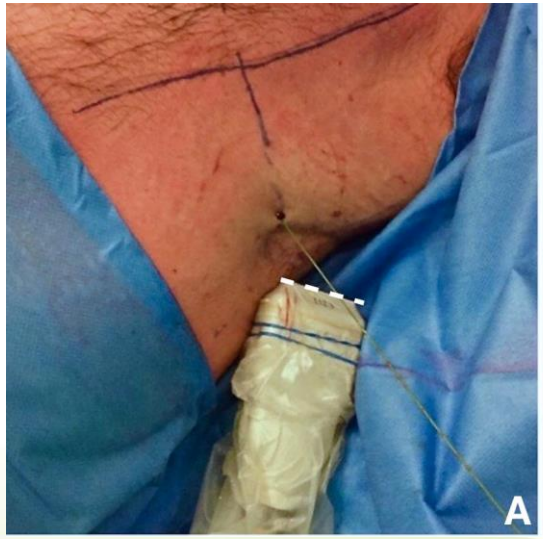


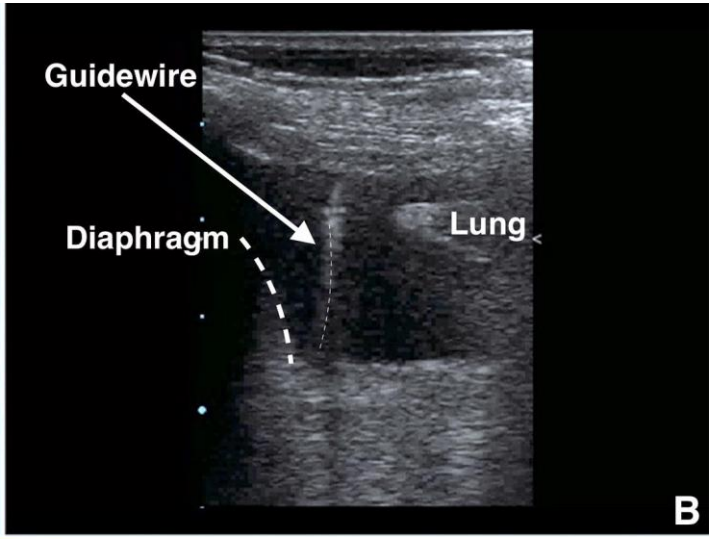


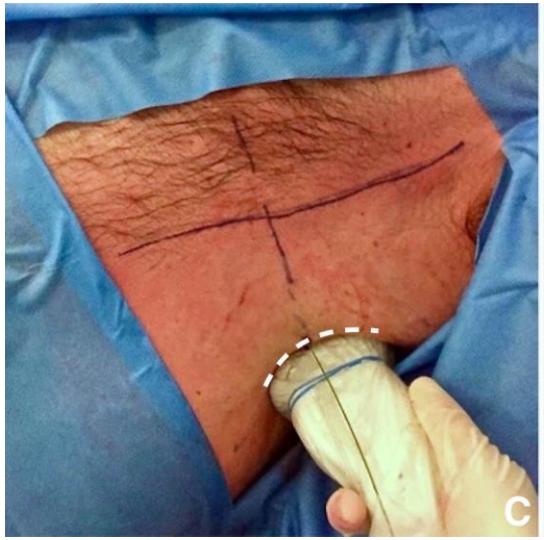
Procedure

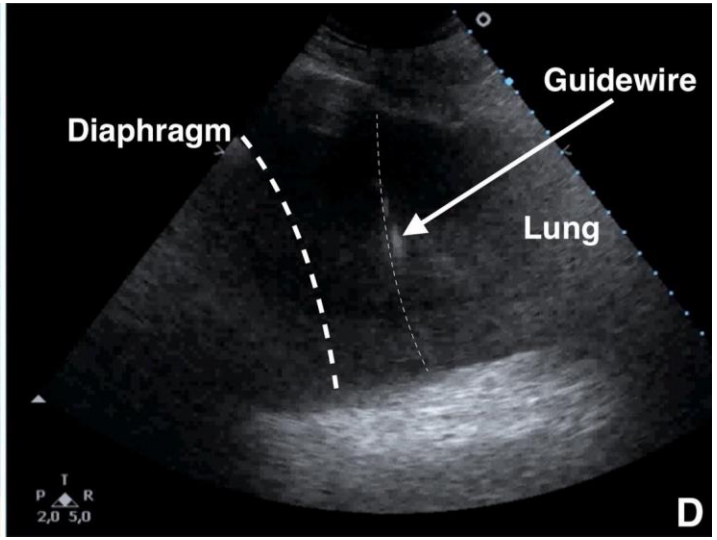
3) Guidewire insertion & position check

- Remove the syringe, pass the guidewire through the needle
- Remove the needle, leaving the guidewire in place
- Define the final position of the guidewire





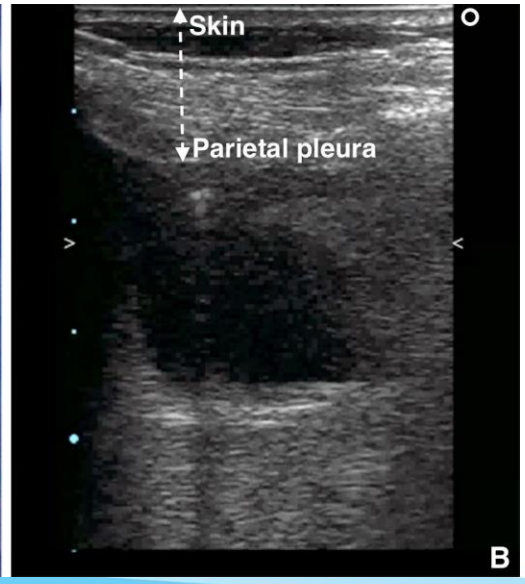


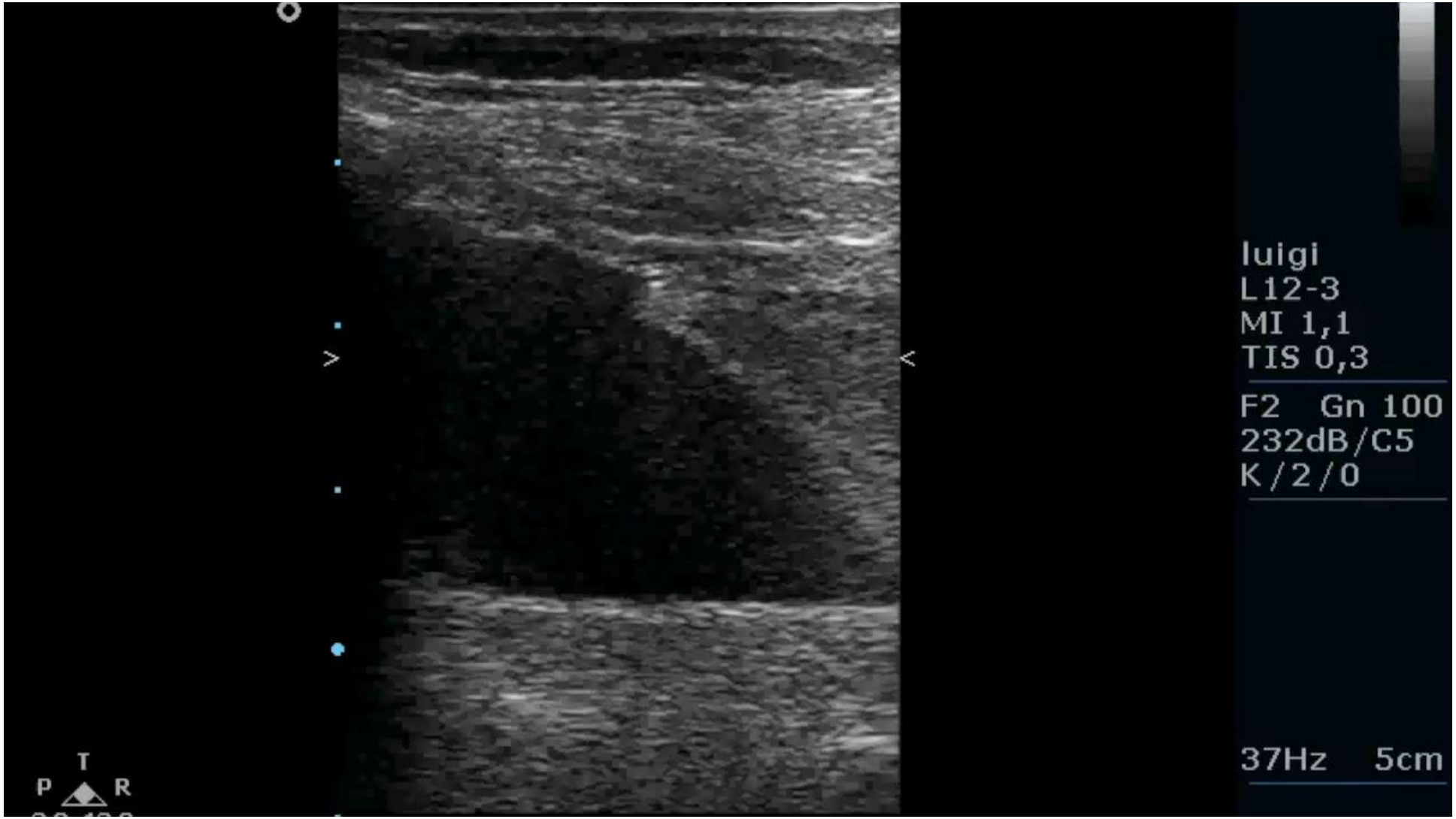


Procedure

4) Dilatation & pigtail insertion

- Small incision, pass the dilator through the guidewire
  - <1cm beyond the depth from skin to parietal pleura (excessive dilator insertion -> visceral injury risk)
- Pass the pigtail over the guidewire – <u>last side hold is within the pleural space</u>
- Remove the guidewire, and connect to the drainage system
- Suture the pigtail to the chest wall

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Complications

- Pneumothorax
  - Should have sufficient depth of pleural fluid (≥ 10 mm)
  - Ultrasound confirmation after the procedure
- Intercostal artery bleeding
  - External compression 불가 -> bleeding into a large negative pressure space
  - The risk of injury is greatest within 6cm from the spinal column
  - Identification of intercostal vessels by Color Doppler prior to needle insertion
- Re-expansion pulmonary edema
  - A maximum of 1.5L drainage in the first hour after pigtail insertion
- Subdiaphragmatic insertion, catheter malposition/blockage, wound infection..

Pneumothorax

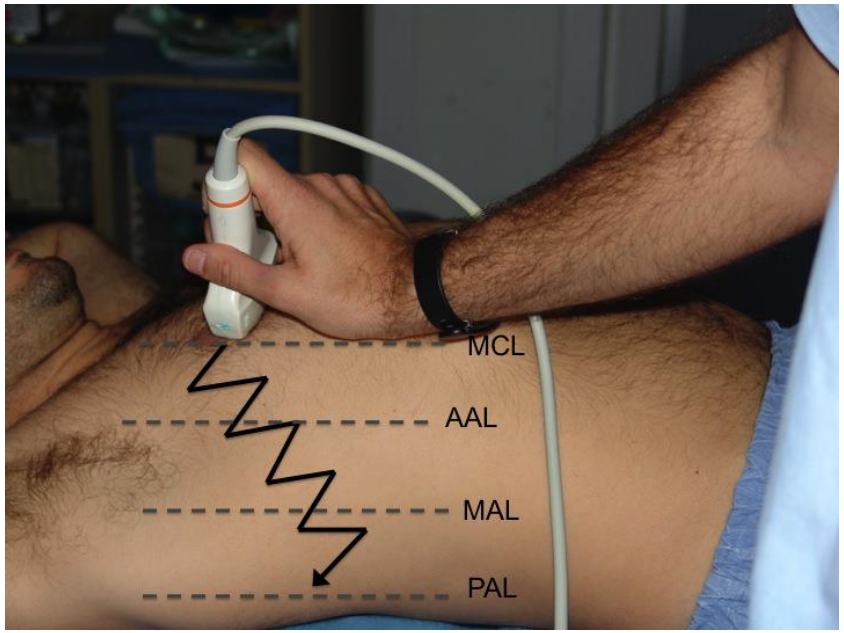
Sonographic findings of pneumothorax

- Combination of 4 sonographic signs
  - Absence of lung sliding
  - Absence of B-lines
  - Absence of lung pulse
  - Presence of lung point(s)

➔ Two steps

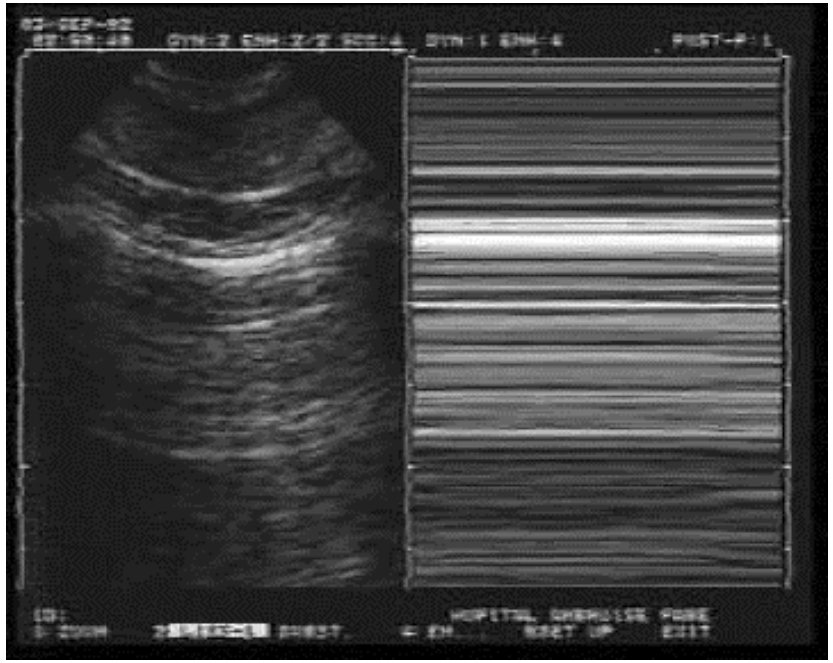
1) A'-profile (at the anterior wall)
2) Lung point (lateral, posterior)

- Exploration
  - The least gravitationally dependent areas (supine)
  - Progress more laterally
- Probes
  - Microconvex (preferred)
  - Linear array, phased array, convex (physician preference)



Absence of lung sliding (A'-profile)

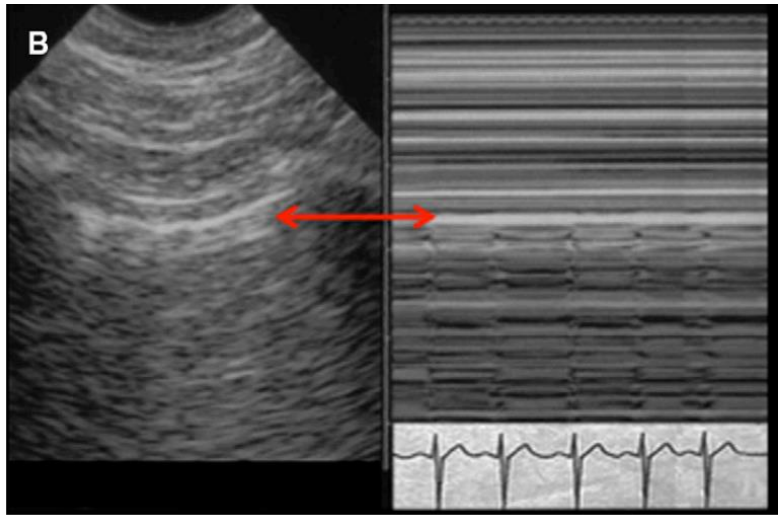
- A-lines with no lung sliding
- No B-lines
- No lung pulse
- Stratosphere sign (or barcode sign) (M-mode)
  - Straight horizontal lines above and beneath the pleural line
  - Absence of pleural line movement (lung sliding) either synchronous with tidal ventilation or with heartbeats (lung pulse)
  - Suggest pneumothorax
- Very sensitive but not specific to pneumothorax
  - False positive : extensive pneumonia, severe ARDS, history of pleurodesis..



Stratosphere sign

Absence of lung sliding (A'-profile)

- Lung pulse (M-mode)
  - Movement of pleural line synchronous with cardiac oscillations in absence of lung sliding
  - Parietal and visceral pleura are in touch, but regional ventilation is impaired



- A-lines with lung sliding(+) and lung pulse(+)

  ➔ Rule out pneumothorax

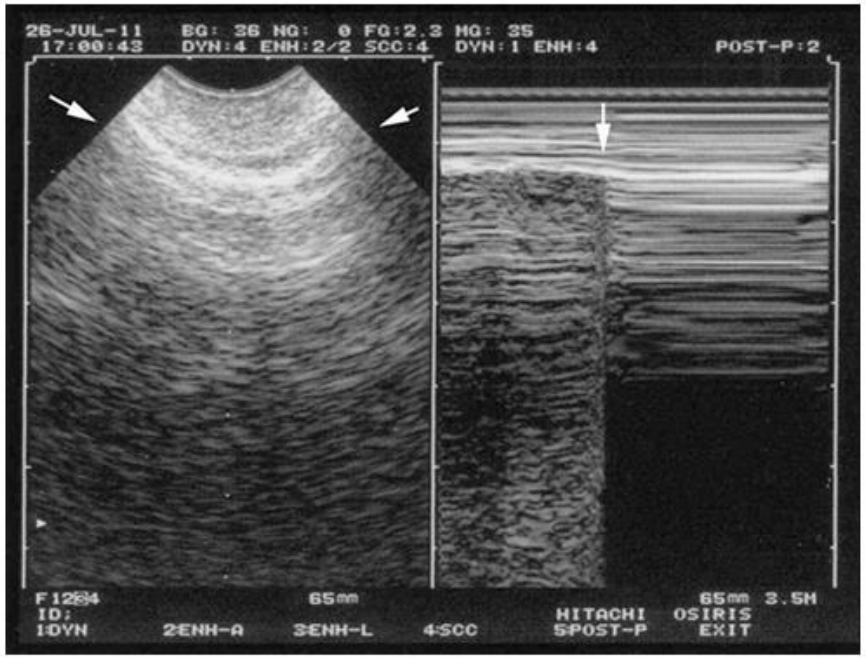
- A-lines with lung sliding (-) but lung pulse (+)

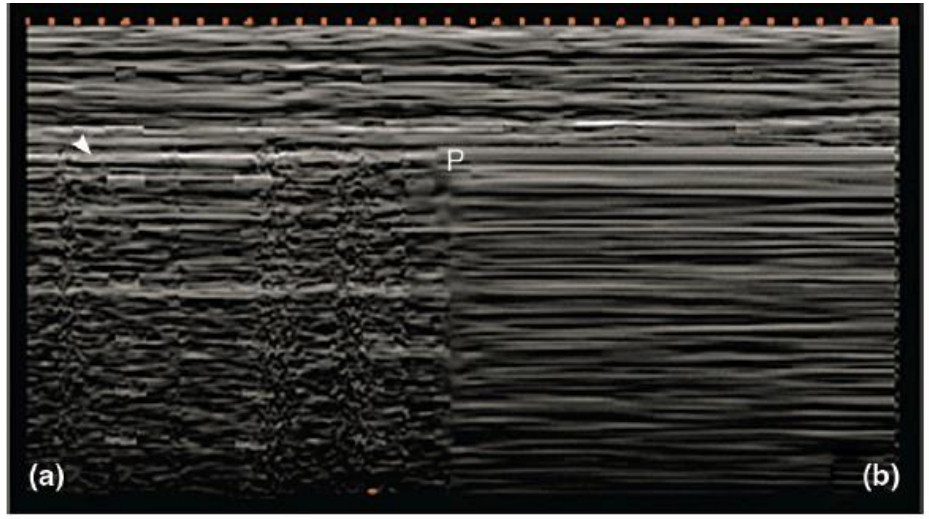
  ➔ Absence of regional ventilation (obstructed airways, hyperinflation, pleural adherence, or bullae)

  ➔ Rule out pneumothorax

Lung point

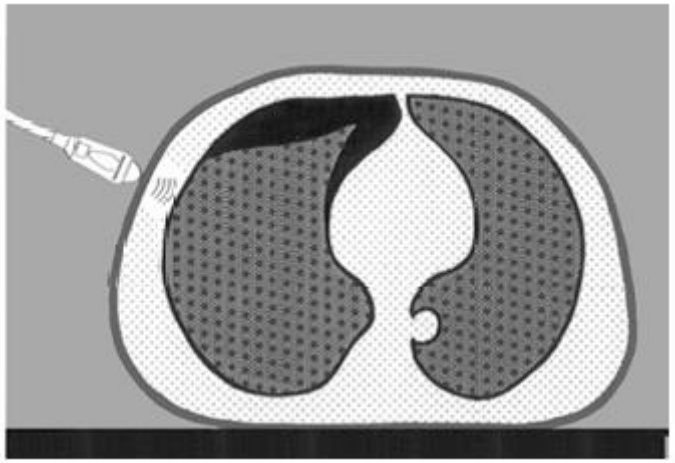
- Pathognomic for pneumothorax (sensitivity 66%, specificity 100%)
- Alteration from normal and abolished lung sliding during tidal ventilation at a critical location
- Alteration of seashore and stratosphere sign (M-mode)
- Contact point between the collapsed lung and the pneumothorax air collection



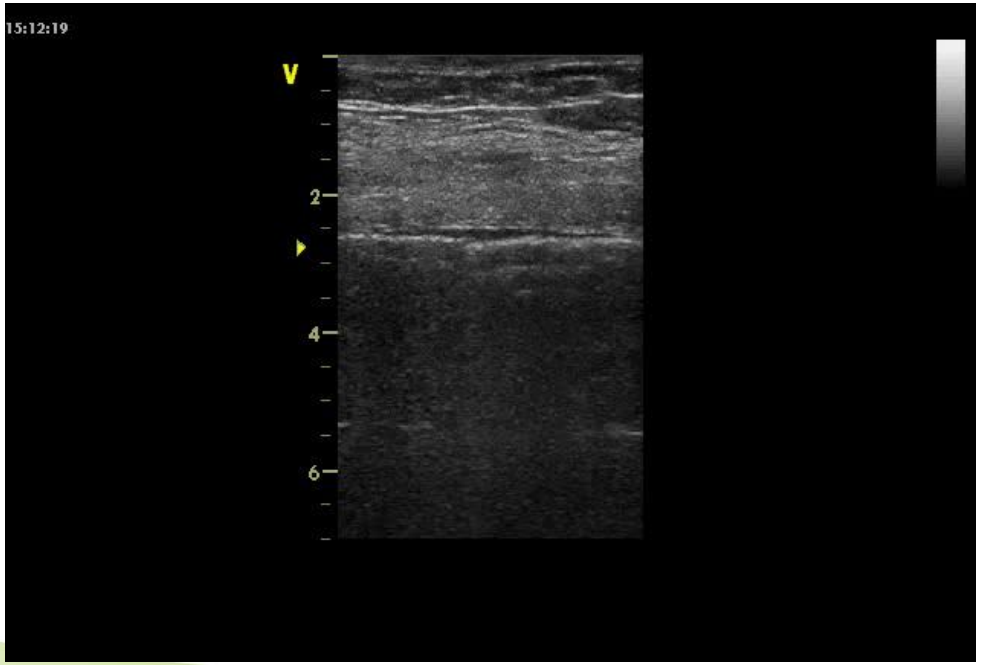


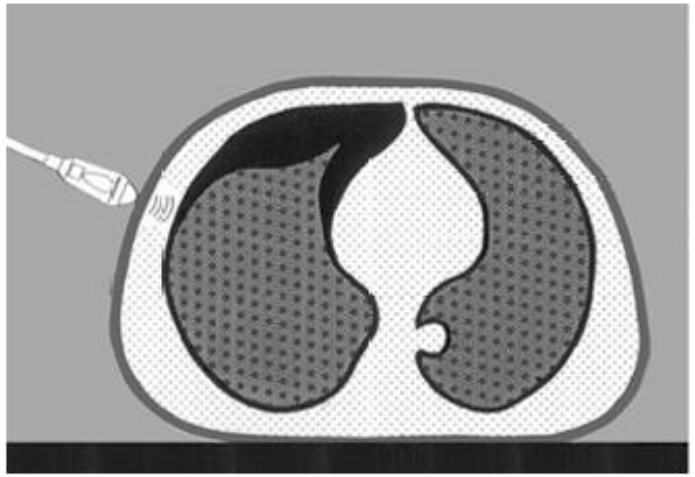
Inspiration

Expiration



Slight increase of lung volume
→ Increased parietal contact





Pneumothorax and collapsed lung

Accuracy

- More accurately rules in and rules out than chest radiography
- Compares well with CT, useful to differentiate between small and large pneumothorax

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

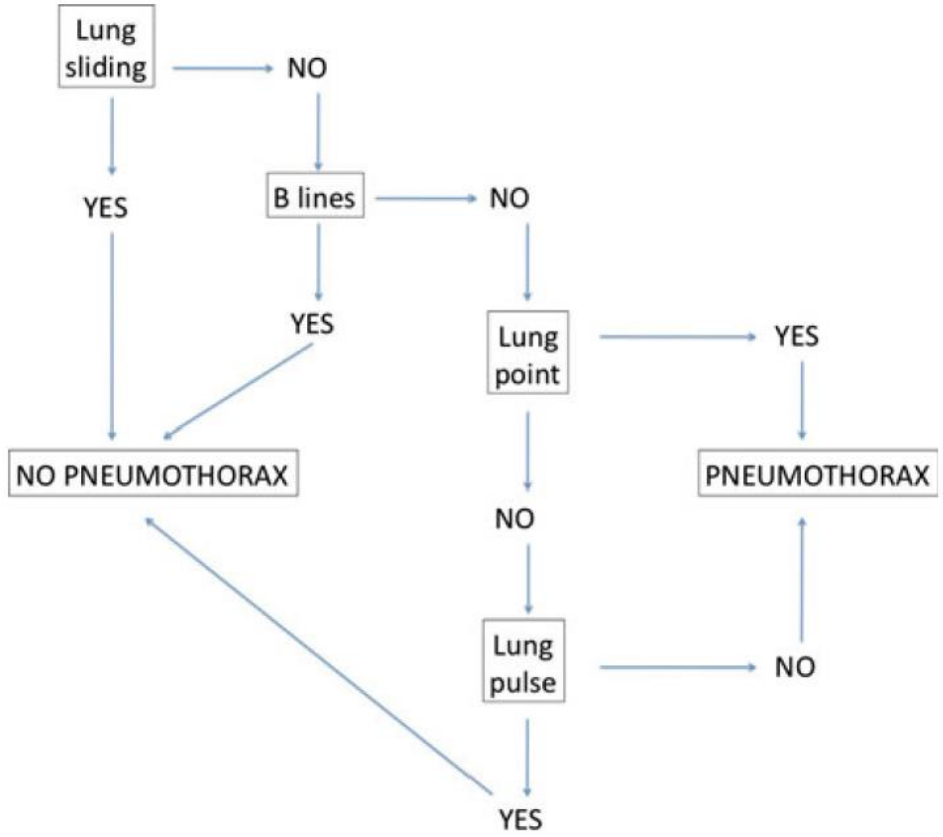
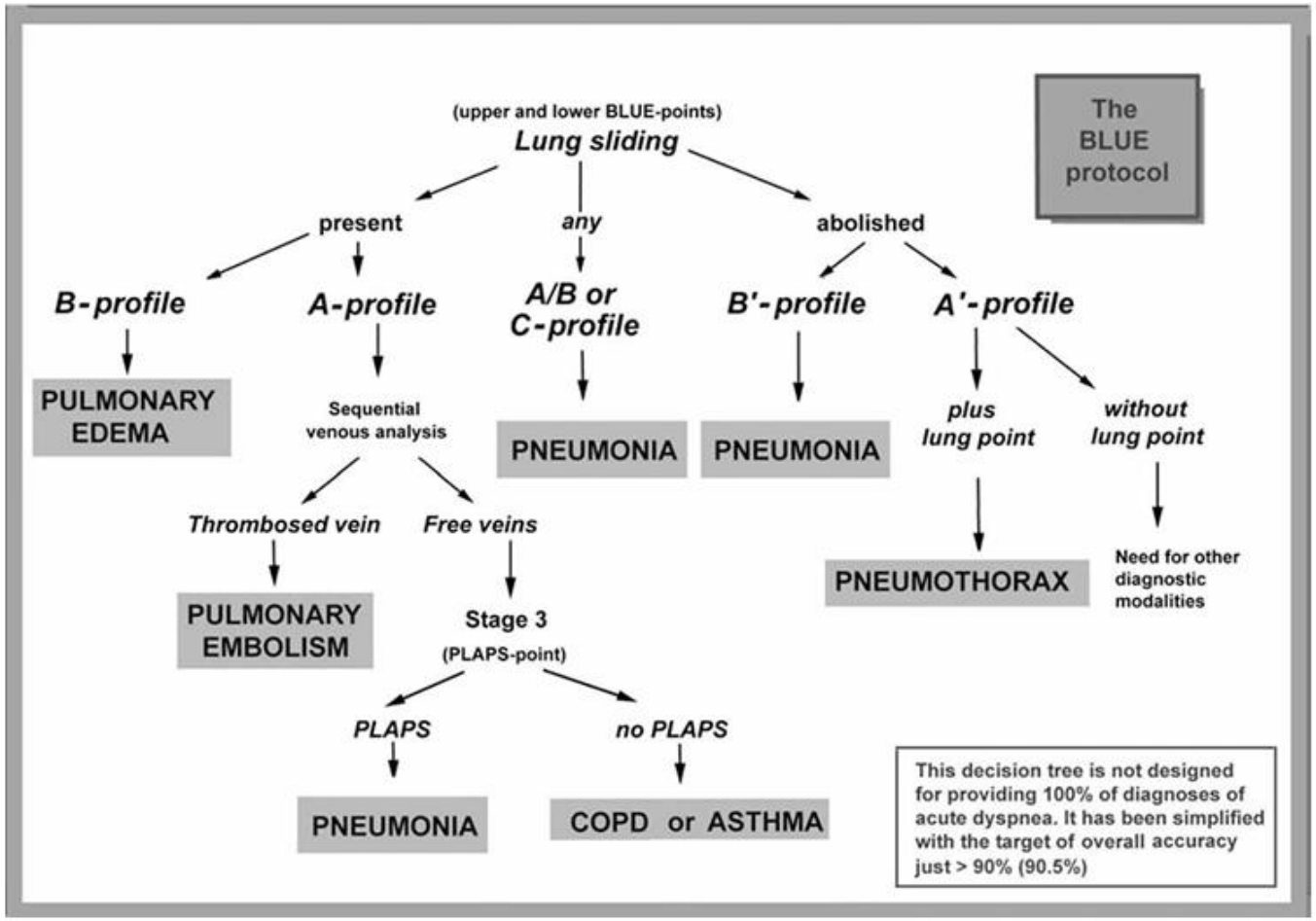
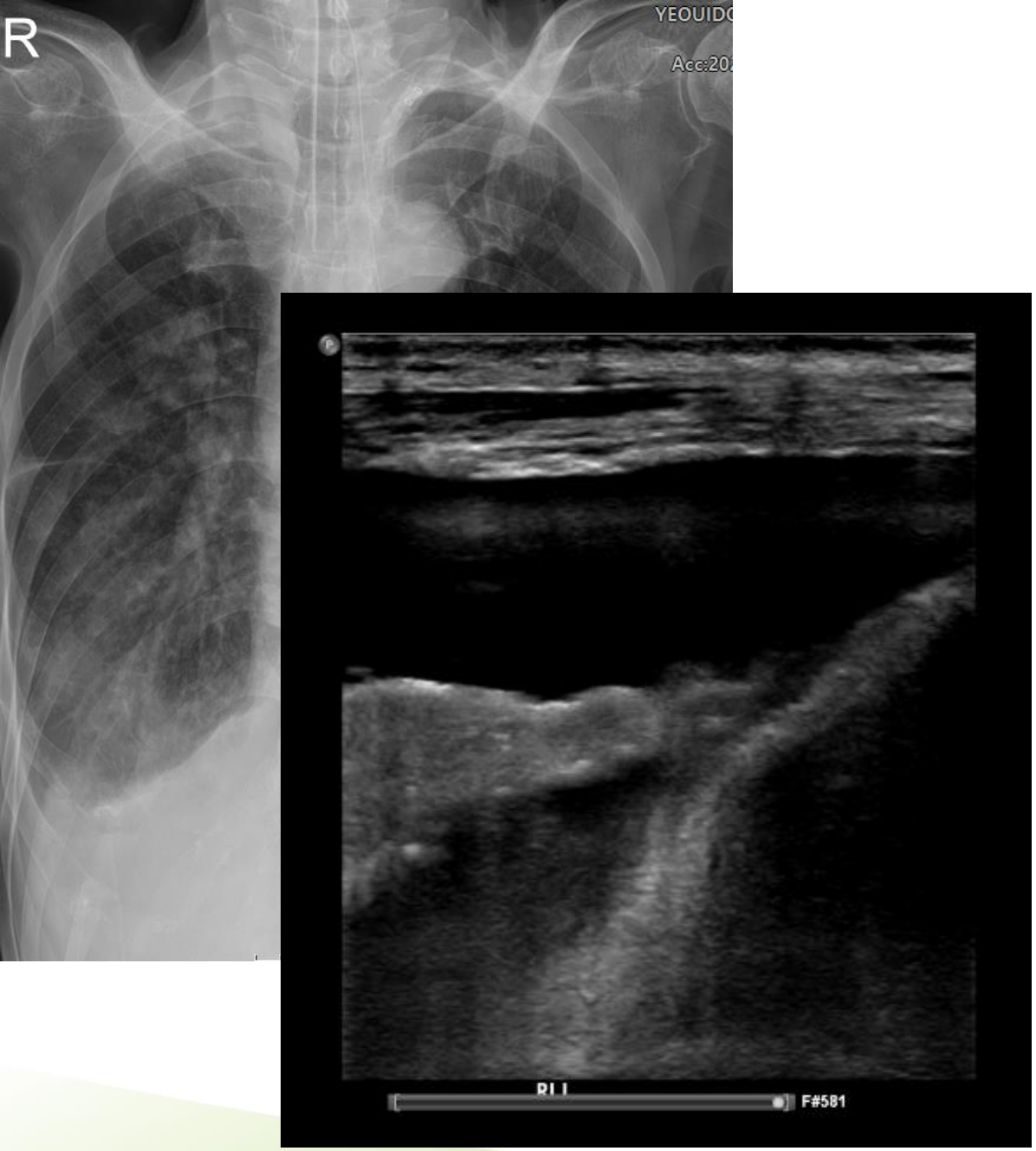


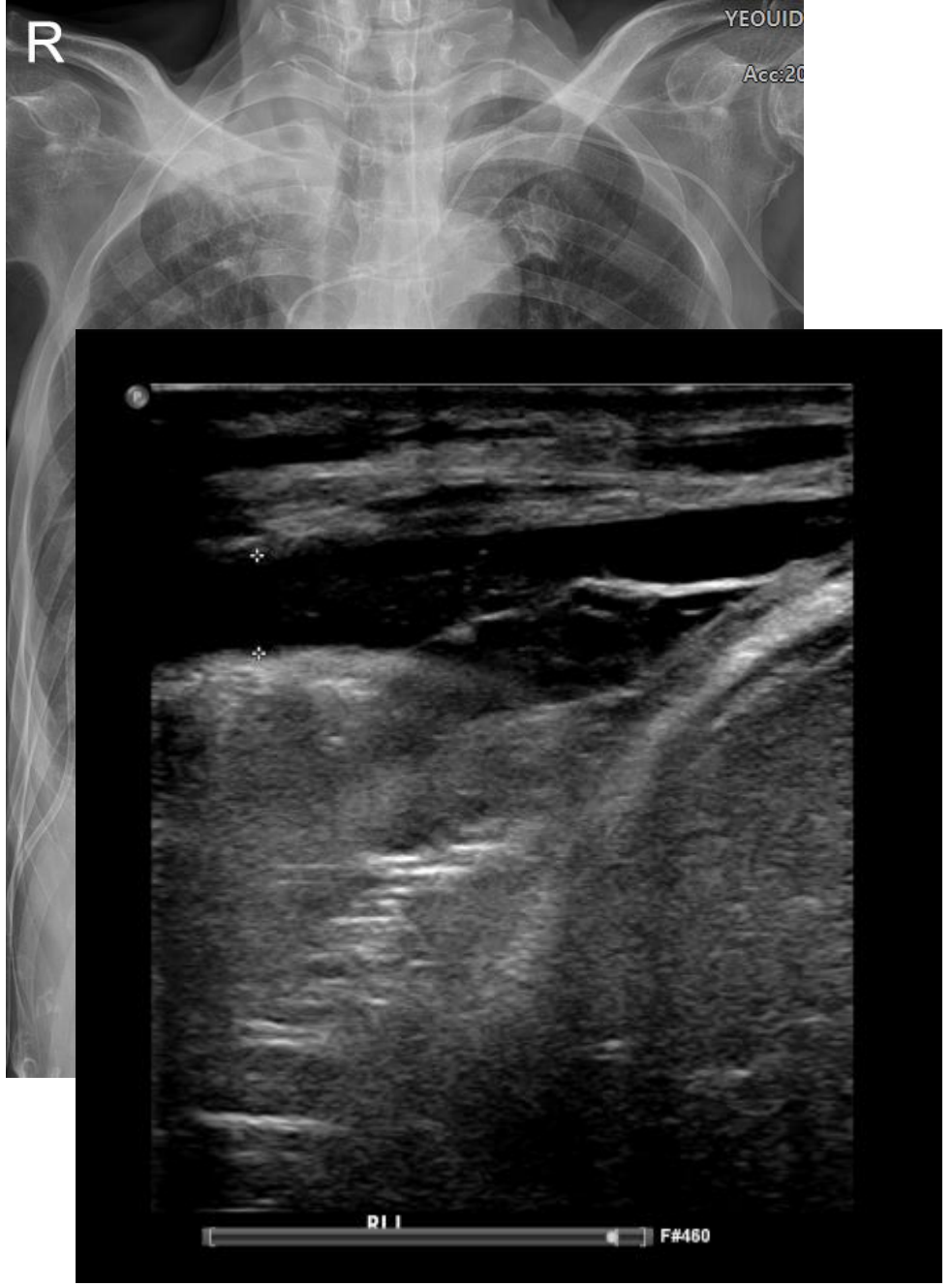
Fig. 1 Flow chart on diagnosing pneumothorax. This flow chart suggests the correct sequence and combination of the four sonographic signs useful to rule out or rule in pneumothorax



Clinical application



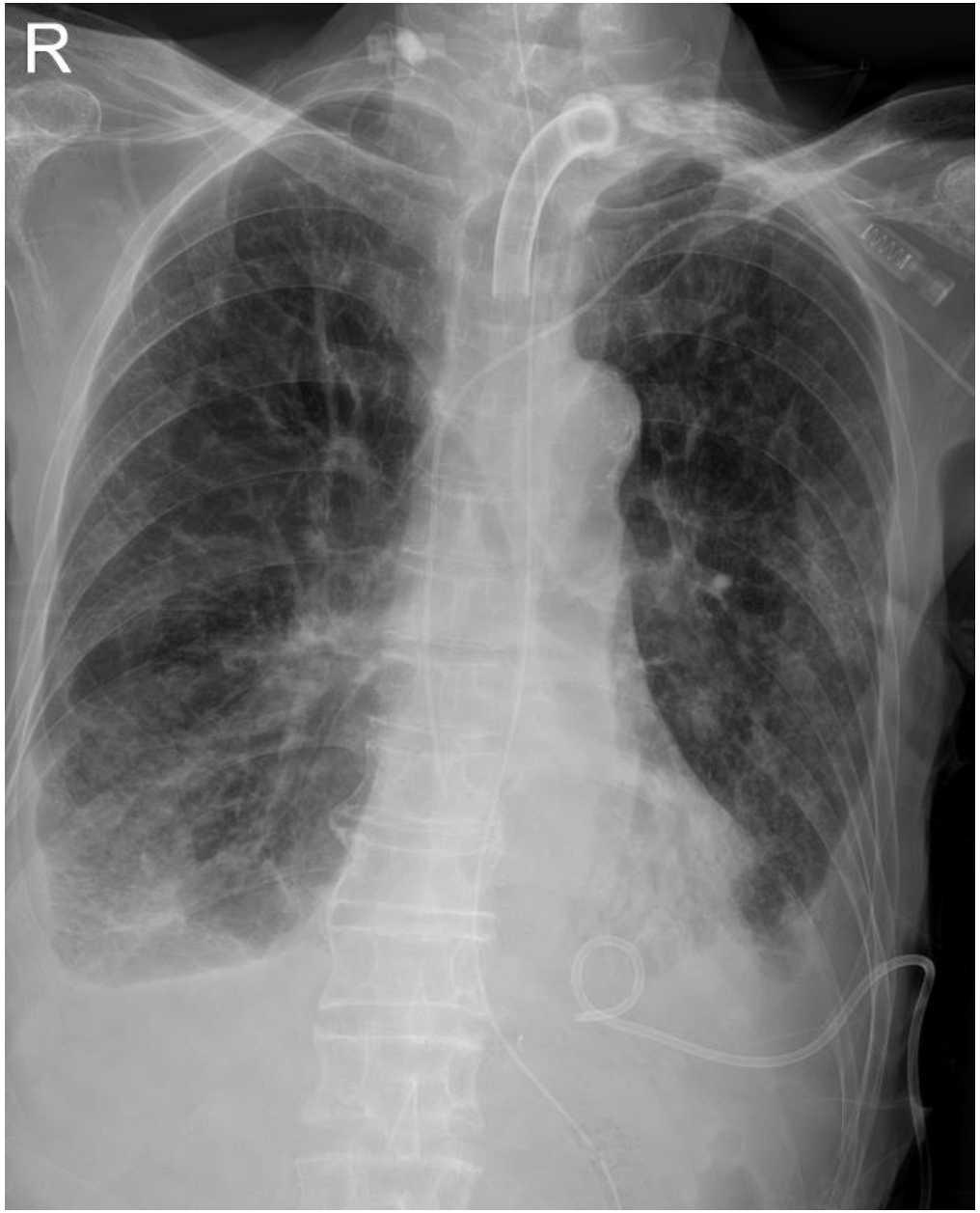
2023-03-22



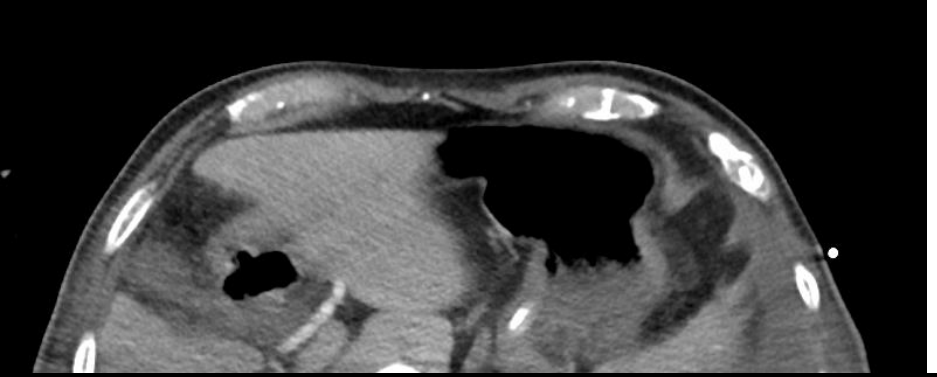
2023-06-23

Case #2

RLL

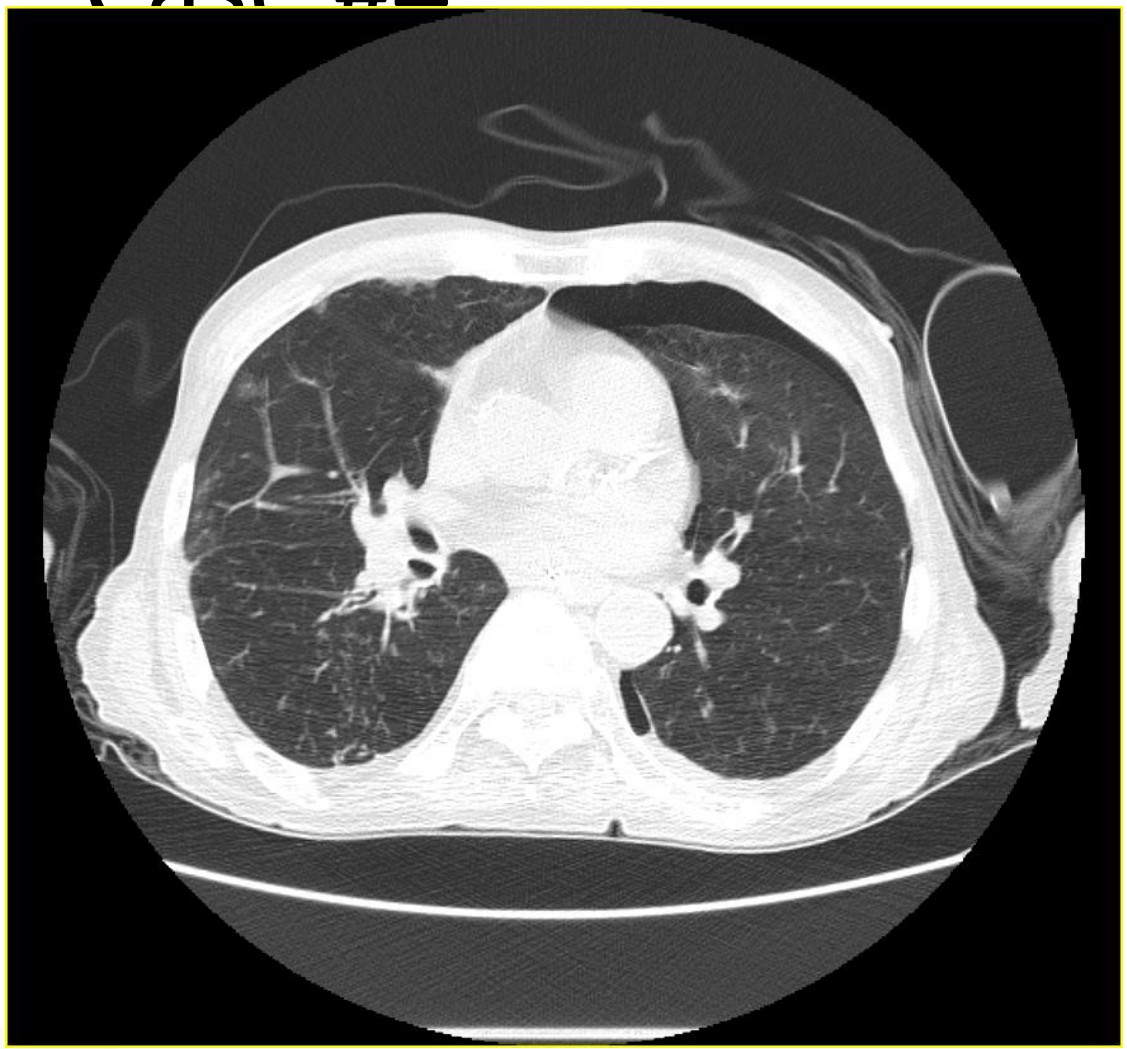


LLL




TIS0.3
TIS0.3
F# 82

Case #4



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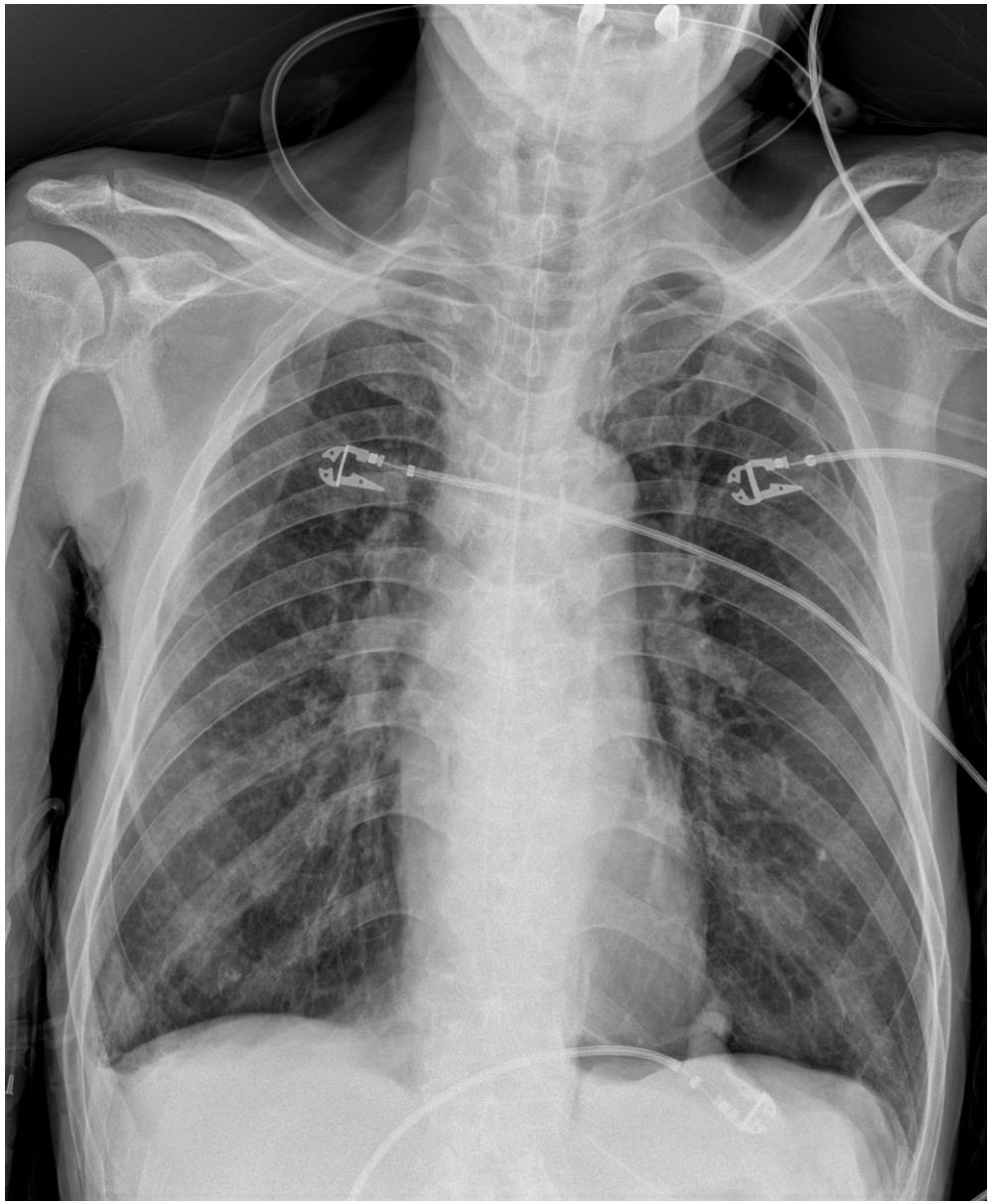

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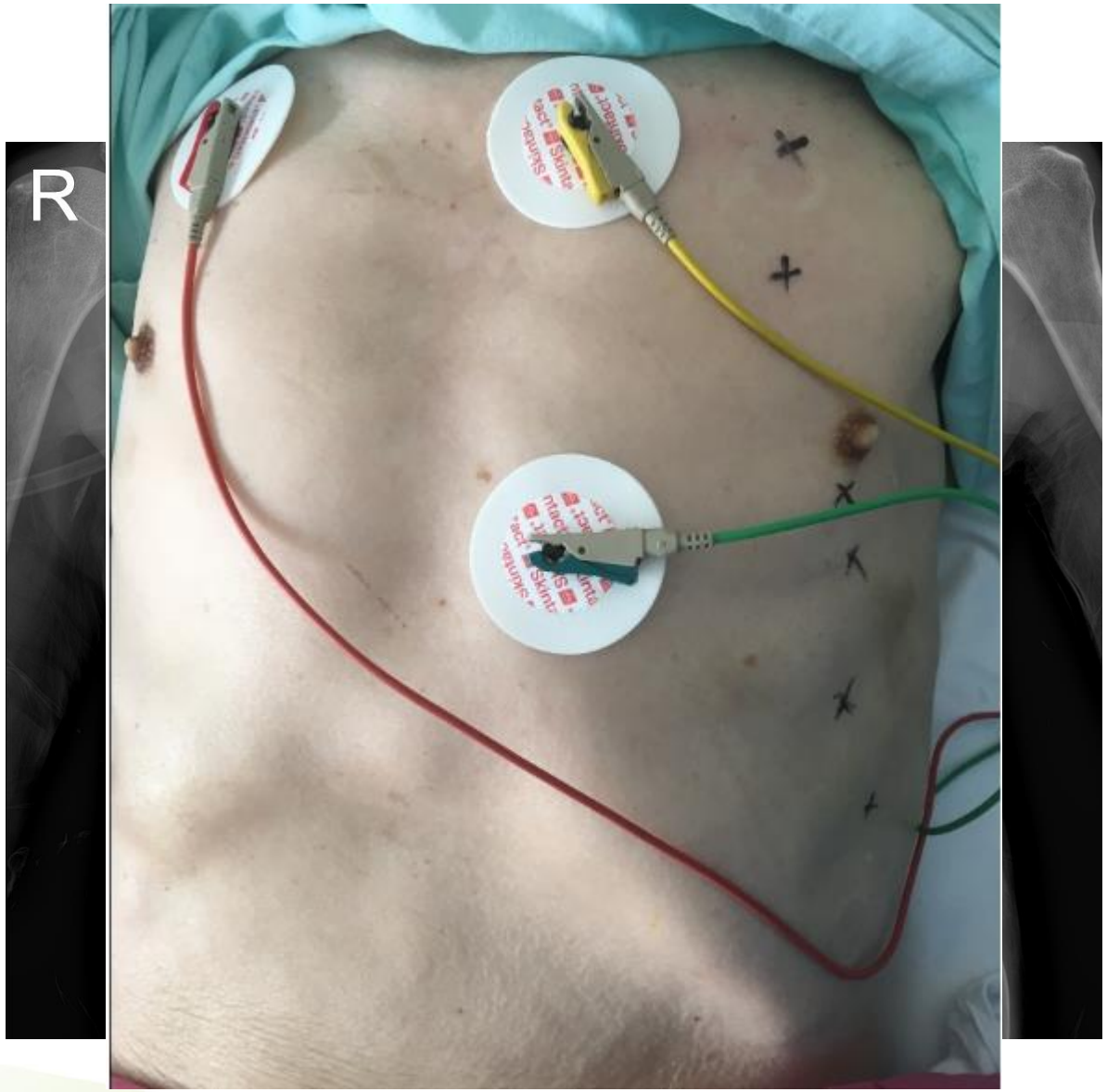

2024.06.28

2024.07.01


R


2
C5-1
82Hz
RS
2D / MM
54%
C 55
P Med
Gen
R
MI 1.0
M3
0
1
2
3
4
5

Summary

Pleural effusion

- Sonographic findings : Quad sign, sinusoid sign
- Nature : anechoic / complex non-septated / complex septated / complex homogenous / pleural thickness
- Optimal site and position : posterior axillary line, PLAPS point
- Thoracentesis technique : real-time, site-marking
- Complication : pneumothorax, intercostal vessel injury, etc.

Pneumothorax

- Sonographic findings : A-line with lung sliding(-), B-line(-), lung pulse(-), lung point(+)
- Ultrasound-guided intervention (catheter insertion)

Thank you for your listening!