

Thoracic Ultrasound for Severe Pneumonia

More Than POCUS

중앙보훈병원

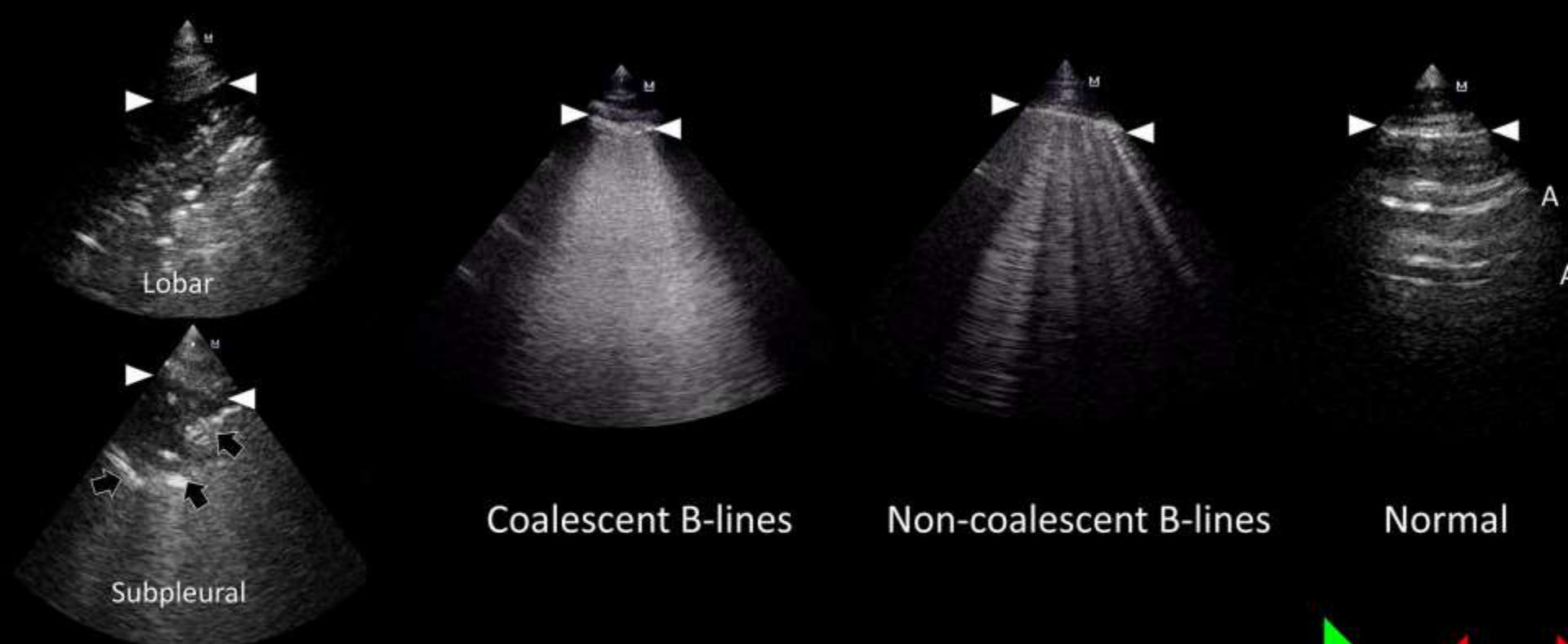
호흡기내과 양서희

Overview

1. **Why Thoracic US in severe pneumonia?**
2. **LUS Artifacts & Profiles – Beyond the Basics**
3. **Pneumonia LUS Sign**
4. **Severe pneumonia : Advanced Clinical Use**
5. **CT vs TUS – Role Demarcation**
6. **Case study**

SECTION 01

Why Thoracic US in Severe Pneumonia?



Coalescent B-lines

Non-coalescent B-lines

Normal

Consolidation

BEST AERATION

HYPERINFLATION

LOSS OF AERATION

What we are actually missing?

- Not a diagnosis problem - Monitoring and characterization problem.
- CXR vs. Chest CT vs. Thoracic US

Modality	Sensitivity	Repeatable?	Bedside?	Functional info?	Cost / Radiation
CXR	67–77%	Yes (daily limit)	Yes	None	Low / Yes
CT Chest	~95%	No — inaccessible in ICU	No — transport risk	None	High / High
Thoracic US	93–95%*	Yes — real-time, unlimited	Yes — bedside	Extensive	Very low / None

What *'Functional Information'* Actually Means in Severe Pneumonia

- **Dynamic vs static air bronchogram**
 - antibiotic response prediction
- **LUS aeration score trajectory**
 - treatment failure signal 24–48h before clinical deterioration
- **Focal vs non-focal ARDS classification**
 - PEEP strategy decision (high PEEP in focal = harm)
- **Diaphragm thickening fraction**
 - weaning readiness and extubation failure risk stratification
- **Effusion character in real-time**
 - guides timing and approach to drainage

"POCUS" in Respiratory assessment

- Diagnosis of ARF
- Recognition of complication of ARF
- Rapid therapeutic management of ARF
- Monitoring of ARF progression/resolution

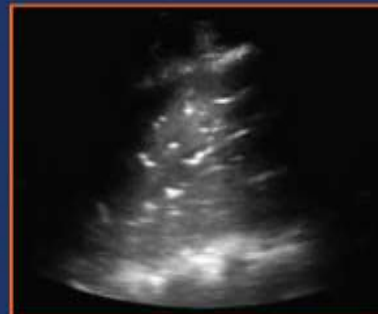
- Pleural Effusion
- Spine Sign



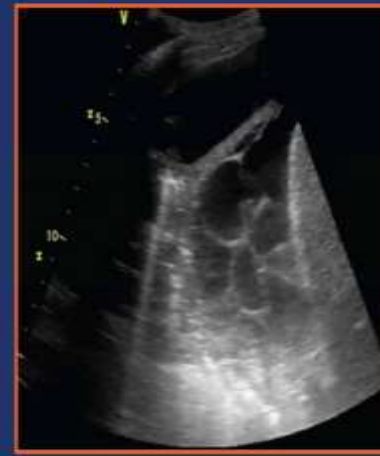
Air Bronchogram
Note: Hyperechoic Alveoli



Dynamic Air Bronchogram
Note: On video, Echogenic air will move with respiration



Complex
Loculated
Effusion →



"More Than POCUS" : The Six Domains of Thoracic US in Severe Pneumonia

- ✓ *POCUS = binary screening tool*
- ✓ *Thoracic US in severe pneumonia = characterization + prognostication + therapy guidance*

Diagnosis

- 93–95% sensitivity
- Equivalent to CT in ICU
- No transport risk

Etiology Typing

- Dynamic vs static AB
- Infectious vs atelectasis
- Real-time characterization

Prognostication

- LUS score at baseline
- ICU mortality correlation
- Respiratory failure severity

Treatment Monitoring

- 48–72h score delta
- Early failure signal
- Antibiotic stewardship

Complication Detection

- Parapneumonic effusion
- Empyema characterization
- Necrotizing features (limit)

Ventilation Strategy

- Focal vs non-focal ARDS
- PEEP & recruitment decisions
- weaning readiness

SECTION 02

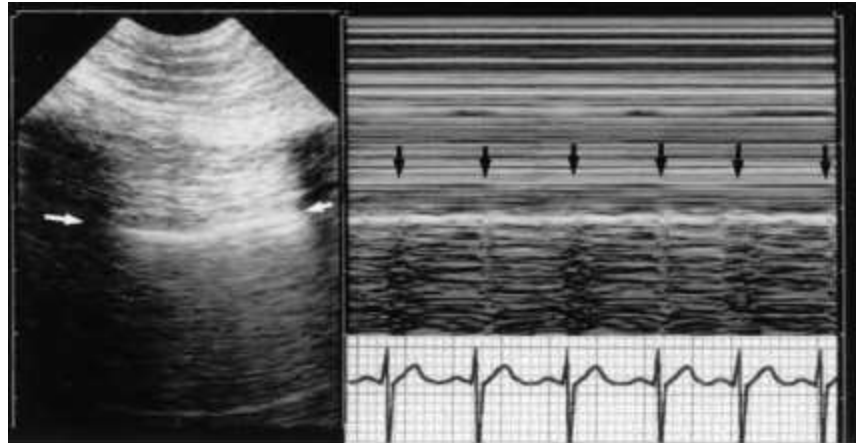
LUS Artifacts & Profiles — Beyond the Basics

The Artifact Spectrum — Each Signal Has Diagnostic Weight

- ✓ *POCUS = Reading individual artifacts*
- ✓ *Thoracic US in severe pneumonia = Reading the full spectrum together*

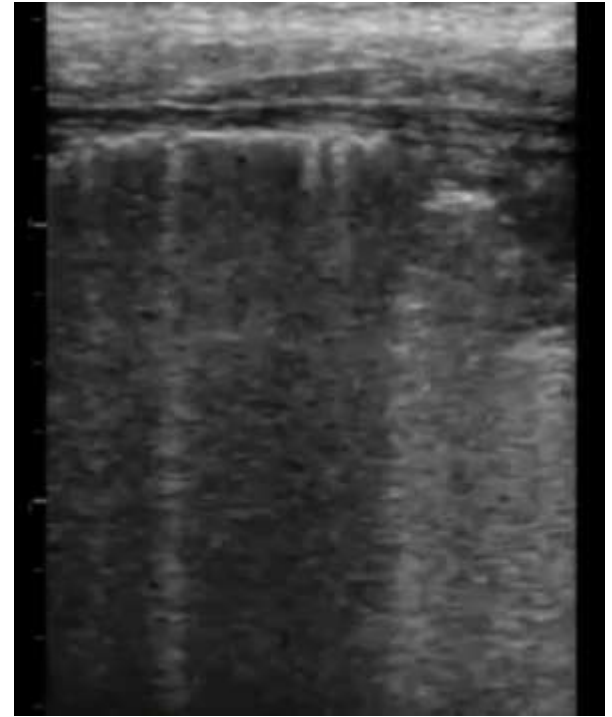
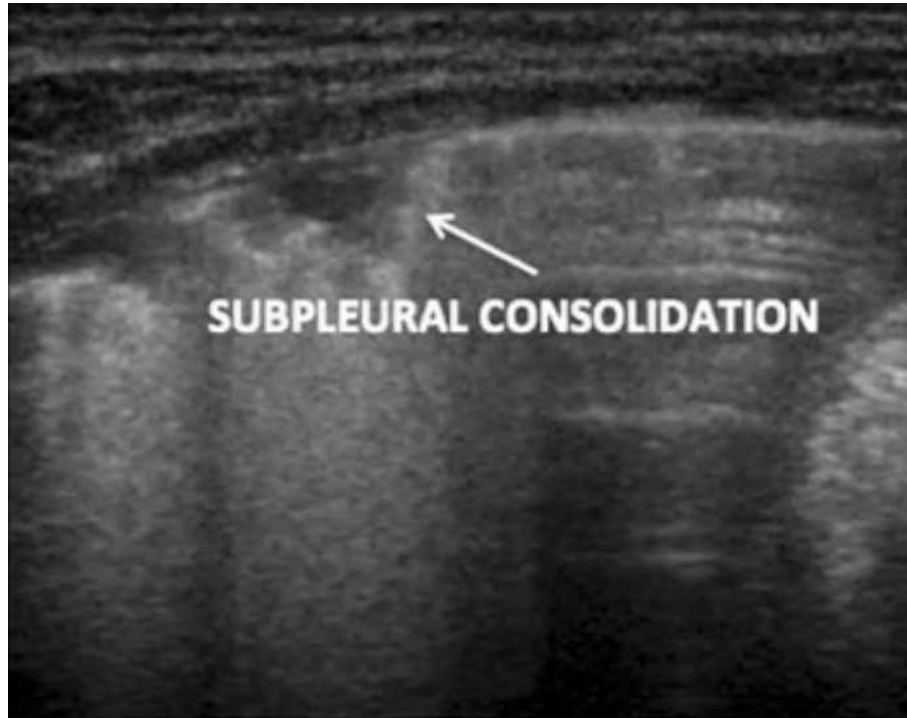
Lung Pulse

Pleural line transmitted cardiac motion without respiratory excursion → complete main bronchus occlusion. Earliest TUS sign of consolidation — appears before hepatization is visible.



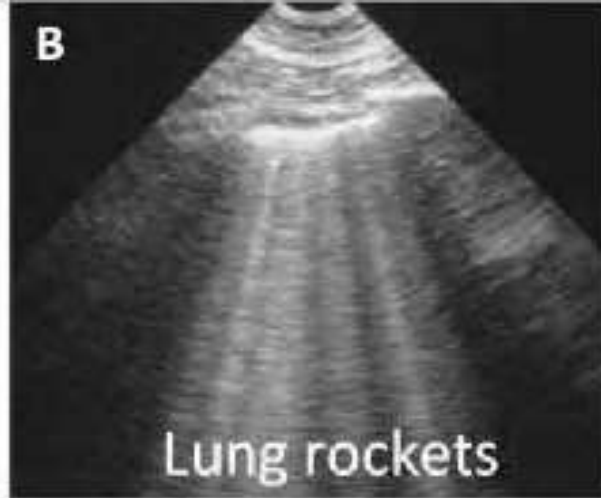
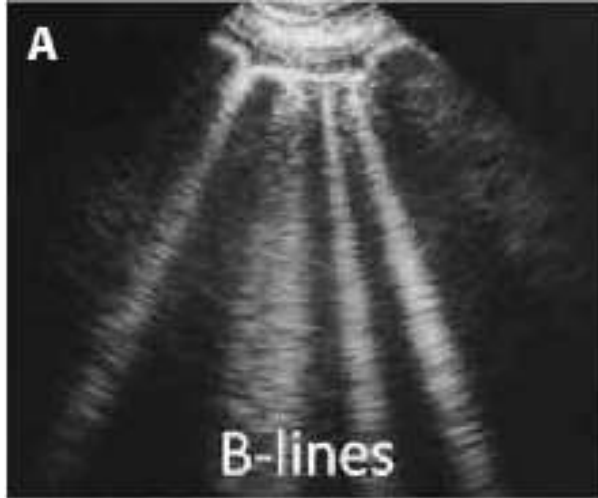
Subpleural Consolidation <1cm

- Hypoechoic nodules at pleural surface. High specificity for pneumonia.
- Frequently missed on POCUS (requires linear probe + systematic scan).
- Always assess alongside irregular pleural line.



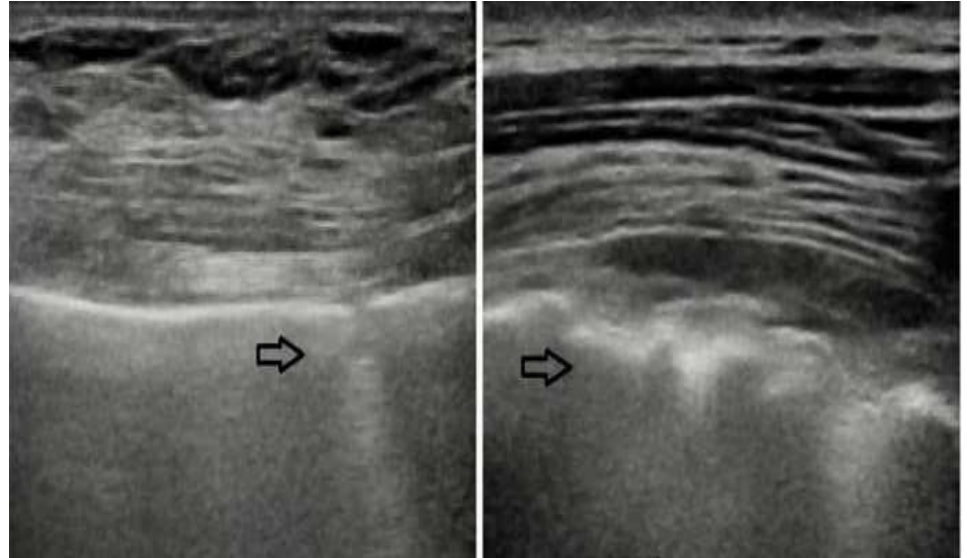
Z-line vs B-line

- Z-lines : $<3\text{cm}$, non-comet, no A-line erasure, no movement — NORMAL variant.
- B-lines : Extend to screen edge, erase A-lines. Move synchronously with pleura.
Confusing these inflates false-positive rate for pneumonia.



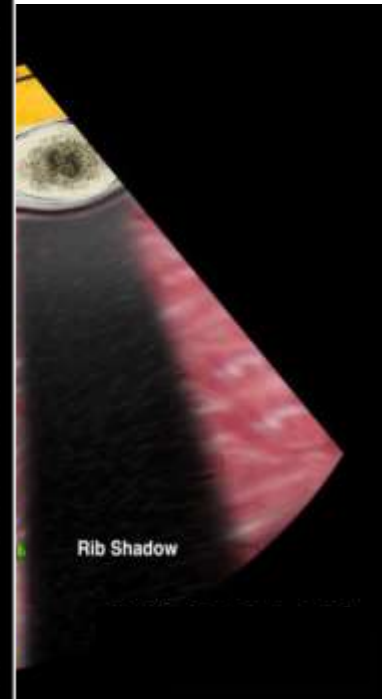
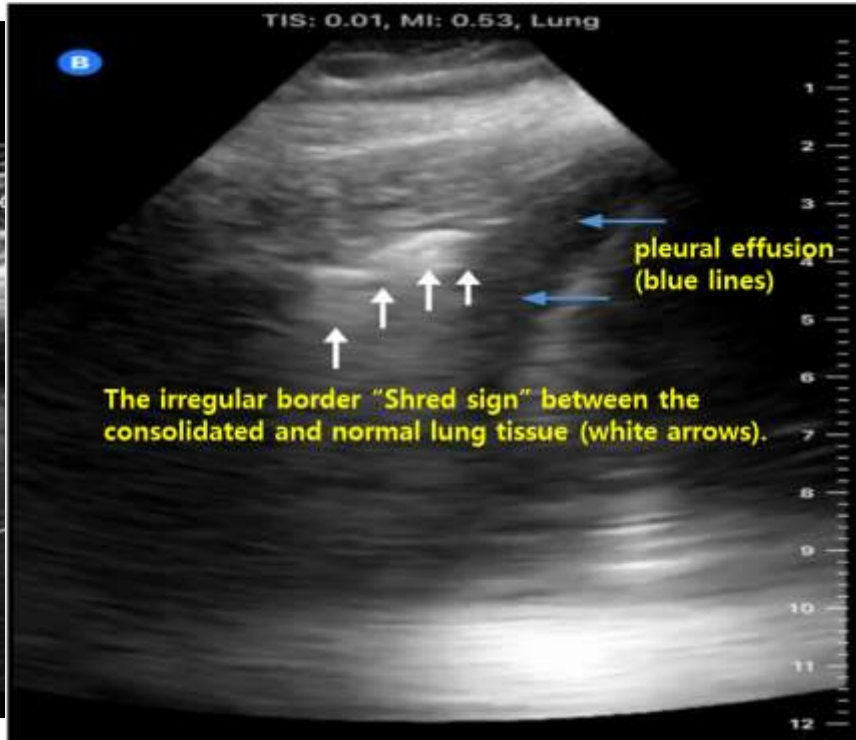
Pleural Line Fragmentation

- Degree of fragmentation correlates with consolidation severity.
- Small breaks = early pneumonia.
- Complete fragmentation = advanced consolidation or ARDS.



Shred Sign (Non-translobar consolidation)

- Irregular deep border of consolidation with alternating hyperechoic air pockets
- Distinguishes partial pneumonic consolidation from pure absorptive atelectasis — different management implication.



Dynamic Air Bronchogram

- Centrifugal movement of hyperechoic air signal within consolidation during inspiration.
- Most specific TUS sign for infectious etiology (Spec 97%).



BLUE Protocol

- ✓ **B'-profile is the most underdiagnosed pneumonia signature.**
- ✓ Lower sensitivity than C-profile but combined diagnostic power reaches 89%.

Profile	TUS Pattern	Sensitivity	Specificity
A-profile	Bilateral A-lines (normal or obstructive)	—	—
B-profile	Bilateral B-lines (smooth pleural line)	—	—
B'-profile	B-lines + fragmented/irregular pleural line	37%	95%
C-profile	Anterior consolidation (tissue-like sign)	22%	99%
A/B profile	Asymmetric B-lines (unilateral)	11%	93%
<i>Any pneumonia profile</i>	<i>B', C, or A/B combined</i>	89%	90%

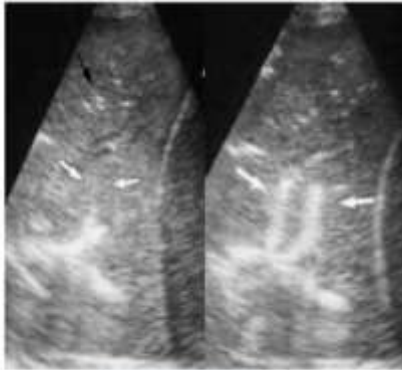
SECTION 03

Pneumonia LUS Signature

Common pneumonic LUS signature

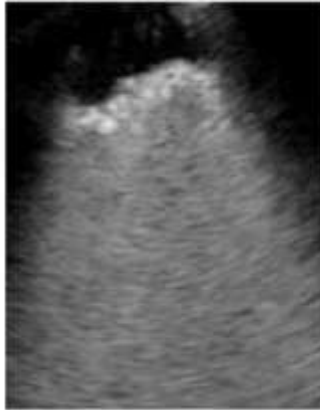


static



Dynamic

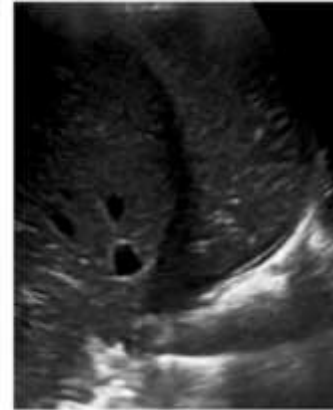
Air bronchogram



C-Lines



Shred sign



hepatization

Consolidation

: Reading Hepatization Beyond 'Tissue Sign Present'

- ✓ **Tissue sign = entry point.**
- ✓ What is inside the consolidation determines etiology, severity, and prognosis.

Subpleural (<1cm)

- Irregular hypoechoic nodules. High specificity for pneumonia.
- Use linear probe (7–15 MHz). Missed routinely on POCUS.

Large consolidation (>1cm)

- Hepatization pattern. Sharp inferior border (compressed aerated lung interface).
- Irregular superior margin (disease front).

Shred Sign

- Irregular deep border + alternating air pockets.
- Partial consolidation vs pure atelectasis → different management.

Consolidation

: Internal echo = key discriminators

1. **Hyperechoic signals** = air bronchograms (→ next slide)
2. **Anechoic foci** = fluid-filled bronchi or necrosis (★)
 - Fluid-filled bronchi (secretion-filled)
 - Liquefaction / early necrosis (before CT changes appear)
 - Sensitivity for necrotizing pneumonia: ~50%
 - Specificity: >90% when combined with clinical context
3. **Heterogeneous** = mixed aeration (partial consolidation)

Air Bronchograms

— The Single Most Clinically Actionable TUS Finding

	DYNAMIC Air Bronchogram	STATIC Air Bronchogram
Appearance	<ul style="list-style-type: none">• Hyperechoic air signal moves• centrifugally during inspiration	<ul style="list-style-type: none">• Hyperechoic signal stationary;• no movement with breathing cycle
Mechanism	<ul style="list-style-type: none">• Patent, open bronchus• Air pushed by diaphragm contraction	<ul style="list-style-type: none">• Mucus plug or bronchial occlusion• Trapped, non-mobile air column
Etiology	<ul style="list-style-type: none">• Infectious consolidation• (bacterial, viral pneumonia)	<ul style="list-style-type: none">• Obstructive atelectasis• Absorptive collapse or secretions
Antibiotic response	<ul style="list-style-type: none">• Strongly predicts response• LR+ 7.1 (Lichtenstein 2009)	<ul style="list-style-type: none">• Predicts failure• Consider bronchoscopy / suction
Sens / Spec	<ul style="list-style-type: none">• Sensitivity 61% / Specificity 97%• for infectious etiology	<ul style="list-style-type: none">• Absence of dynamic movement• is itself a clinical signal
Clinical action	<ul style="list-style-type: none">• Continue current regimen• Monitor LUS score at 72h	<ul style="list-style-type: none">• Re-evaluate: Is this pneumonia?• Escalate physiotherapy ± scope

Air Bronchograms

DYNAMIC Air Bronchogram



STATIC Air Bronchogram



Parapneumonic Effusion

- ✓ *TUS characterization of effusion determines urgency and approach to drainage.*
- ✓ *Not just 'effusion present.'*

Feature	Simple Parapneumonic	Complex / Exudative	Empyema
Echogenicity	Anechoic	Low-level echoes	Frank echoes / pus
Septation	None	Possible	Often present (loculated)
Fibrin	None	Rare	Fibrinous strands visible
Mobility	Freely mobile	Partially mobile	May be fixed/loculated
pH / LDH	Transudate pattern likely	Exudate (Light's)	pH <7.2 → immediate drain
TUS guidance	Optional but safer	Strongly indicated	Mandatory
Management	Monitor / drain if large	Drain promptly	Urgent drain ± VATS

- **Anechoic ≠ transudate: 30% of exudates are anechoic on TUS.**
- **Echogenic ≠ always empyema: blood, chyle also echogenic.**

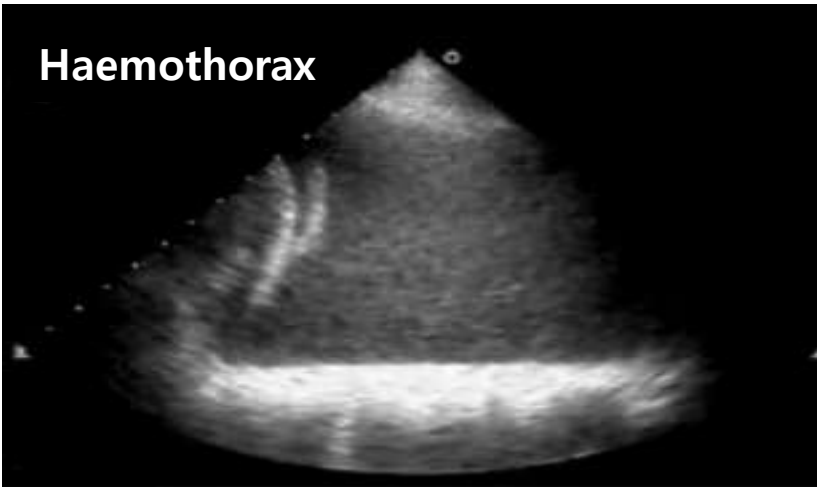
Exudate



Empyema



Haemothorax



Complex septation



SECTION 04

Severe Pneumonia: Advanced Clinical Applications

HAP/VAP

— TUS Diagnostic Accuracy & Monitoring

- ✓ **VAP diagnosis by CXR alone: Sensitivity 67%, Specificity 68%.**
- ✓ TUS substantially changes diagnostic performance in the ICU.
- ✓ New posterior consolidation + Clinical deterioration = VAP

Parameter	CXR	Thoracic US	CT (reference)
Sensitivity (VAP)	67%	77%	~95%
Specificity	68%	86%	—
Posterior zone**	Poor (supine artifact)	Excellent (PLAPS accessible)	Excellent
Serial monitoring	Yes (radiation cost)	Yes — daily, no cost	No — impractical daily

TUS Monitoring for VAP/HAP

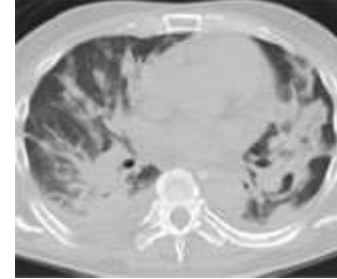
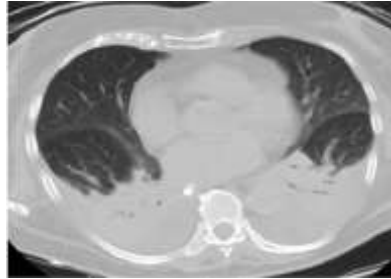
Day 0 : Baseline TUS (Posterior zone , PLAPS point mandatory) + LUS aeration score

Day 3 : Air bronchogram type reassessment

Day 5–7: LUS score reassessment ≥4pt decline from baseline = favorable response

Focal vs Non-Focal ARDS

— TUS Changes Ventilation Strategy



Focal ARDS

Non-Focal ARDS

TUS pattern

- Consolidation limited to 1–2 zones
- Adjacent zones: A-lines preserved
- **Posterior dominant distribution**
- **B-lines focal or absent elsewhere**

- **B-lines diffuse and bilateral**
- Consolidation bilateral posterior
- **No preserved A-line zones**
- Pleural line diffuse fragmentation

Ventilation Strategy

- **Lower PEEP**
(avoid overdistension of spared zones)
- Prone positioning highly effective
- Driving pressure optimization

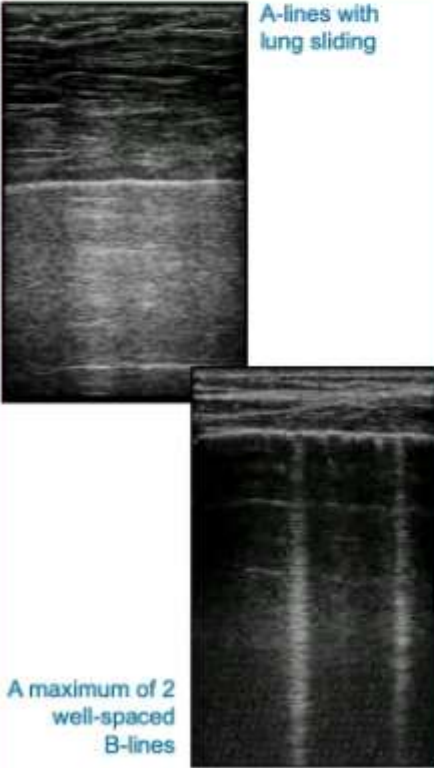
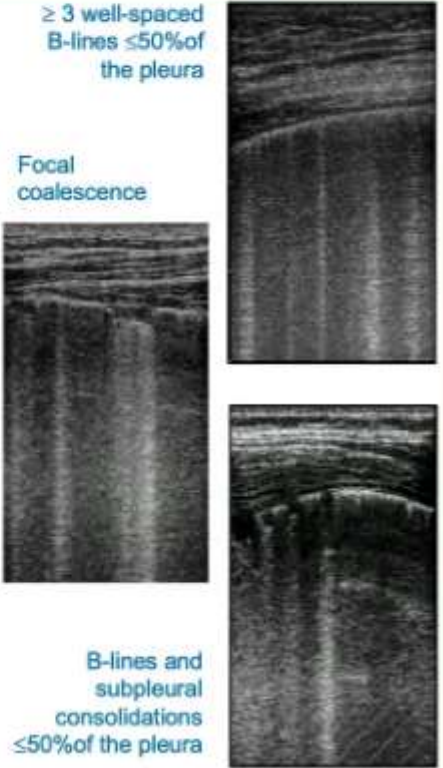
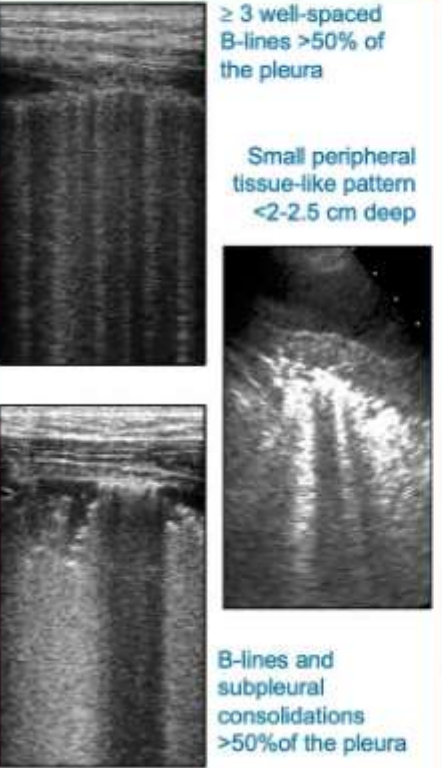
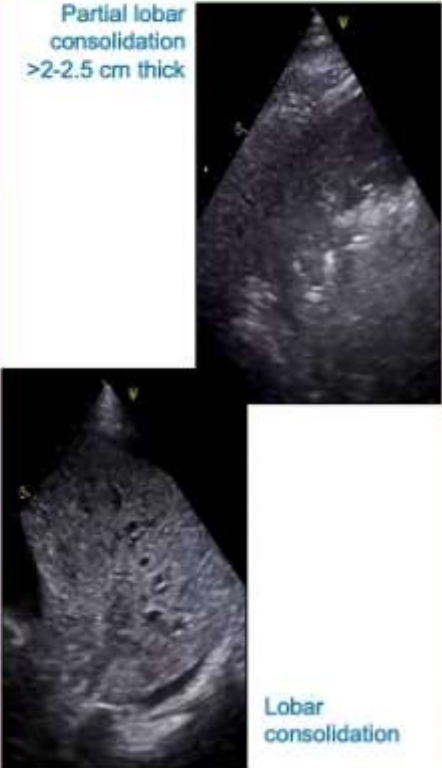
- **Higher PEEP** to prevent alveolar collapse
- Prone positioning: mandatory (>16h/day)
- **Conservative fluid strategy** essential
- NMB consideration for severe cases

LUS Aeration Score

- ✓ A single TUS score is insufficient.
- ✓ Score over time (specifically the 72-hour delta) is the treatment monitoring metric.

Score	LUS Pattern	Pathophysiology	Clinical Example
0	A-lines / ≤ 2 isolated B-lines	Normal aeration	Healthy lung
1	≥ 3 B-lines, non-coalescing	Moderate aeration loss	Early interstitial pneumonia
2	Coalescent B-lines (white lung)	Severe aeration loss	Advanced pneumonia, early ARDS
3	Consolidation (tissue-like sign)	Complete aeration loss	Full hepatization — any cause

12 zones (6 anterior + 6 posterior) \times 0–3 points = Total score 0–36

SCORE 0	SCORE 1	SCORE 2	SCORE 3
<p>Normal aeration A-lines with lung sliding Maximum 2 well-spaced B-lines</p>	<p>Mild loss of aeration ≥ 3 well-spaced B-lines or coalescent B-lines/subpleural consolidations on ≤50% of visualized pleura</p>	<p>Moderate loss of aeration ≥3 well-spaced B-lines or coalescent B-lines/subpleural consolidations on >50% of pleura or tissue-like pattern <2-2.5cm thick</p>	<p>Severe loss of aeration Large consolidation: tissue-like pattern with thickness >2-2.5 cm</p>
<p>A-lines with lung sliding</p>  <p>A maximum of 2 well-spaced B-lines</p>	<p>≥ 3 well-spaced B-lines ≤50% of the pleura</p> <p>Focal coalescence</p>  <p>B-lines and subpleural consolidations ≤50% of the pleura</p>	<p>≥ 3 well-spaced B-lines >50% of the pleura</p> <p>Small peripheral tissue-like pattern <2-2.5 cm deep</p>  <p>B-lines and subpleural consolidations >50% of the pleura</p>	<p>Partial lobar consolidation >2-2.5 cm thick</p>  <p>Lobar consolidation</p>

LUS Aeration Score

- Treatment Response Thresholds
 - ≥ 4 point decrease at 72h → Antibiotic response confirmed
 - Score plateau ($\Delta < 4$) → Failure signal — reassess
 - Score increase → Escalation required urgently
- Improving global score can mask regional progression:
 - Zone A improving + Zone B worsening = partial response
 - New consolidation despite global score decline → Complication or secondary focus
- Always analyze zone-by-zone, not aggregate alone.
- Map findings on a body diagram for trend visualization.

Diaphragm Ultrasound

— Weaning Readiness in Severe Pneumonia

- ✓ Diaphragm dysfunction occurs in 60–80% of MV patients at 5–7 days (disuse + sepsis + NMBA).
- ✓ TUS is the only bedside quantification tool.

Parameter	Measurement	Normal	Clinical Significance
Diaphragm Excursion (M-mode, subcostal)	Quiet breathing: >10mm Deep breathing: >25mm	>10 mm	<ul style="list-style-type: none">• Paralysis if <5mm• Paresis if 5–10mm• Iceberg tip of dysfunction
Thickening Fraction (DTF)	$(T_{\text{insp}} - T_{\text{exp}}) / T_{\text{exp}} \times 100$ Zone of apposition (8th–9th ICS, MAL)	>20%	<ul style="list-style-type: none">• DTF <20% = dysfunction• DTF <30% → extubation failure ×3• Most validated weaning metric
Resting Thickness	End-expiratory, B-mode Zone of apposition (linear probe)	2–4 mm	<ul style="list-style-type: none">• Atrophy if <2mm• Disuse atrophy: –6%/day after 48h MV• Baseline establishes reference
Assessment Timing	Pre-SBT During T-piece or PSV trial	—	<ul style="list-style-type: none">• Trend more important than single value• Improvement = readiness signal• Compare to prior day — direction matters

SECTION 05

CT vs Thoracic US — Role Demarcation

CT vs Thoracic US — Complementary, Not Competitive

✓ *The question is 'what do I need to know right now, and which tool answers that question?'*

Clinical Question	Thoracic US	CT Chest	Preferred Tool
Consolidation presence	93–95%, bedside	~95%, transport	TUS (no transport)
Air bronchogram TYPE	Unique: dynamic vs static	Cannot distinguish	TUS ONLY
Treatment response daily	Yes — repeat unlimited	No — impractical	TUS ONLY
Focal vs non-focal ARDS	Yes — real-time	Yes (not real-time)	TUS preferred
Diaphragm function	Yes — gold standard	No	TUS ONLY
Effusion guidance	Yes — real-time	Yes (static)	TUS preferred
Cavitation / necrotizing	Limited — deep structures	Gold standard	CT required
Mediastinum / nodes	No	Gold standard	CT required
Pulmonary embolism	Indirect signs only	CTA — gold standard	CT required

SECTION 06

Case study

CASE 01

67F | Severe CAP | Hemodynamically Unstable for CT Transport

Clinical Data

HR 118, BP 85/55, SpO₂ 88%
Temp 38.9°C | RR 32/min
P/F ratio: 142 → ARDS territory

CXR: Bilateral basal opacities
(poor quality, non-specific)

ATS Severe CAP Criteria:
2 major (vasopressors + MV)

CT transport: risk unacceptable

TUS 12-Zone Findings

Interpretation

CASE 01

67F | Severe CAP | Hemodynamically Unstable for C

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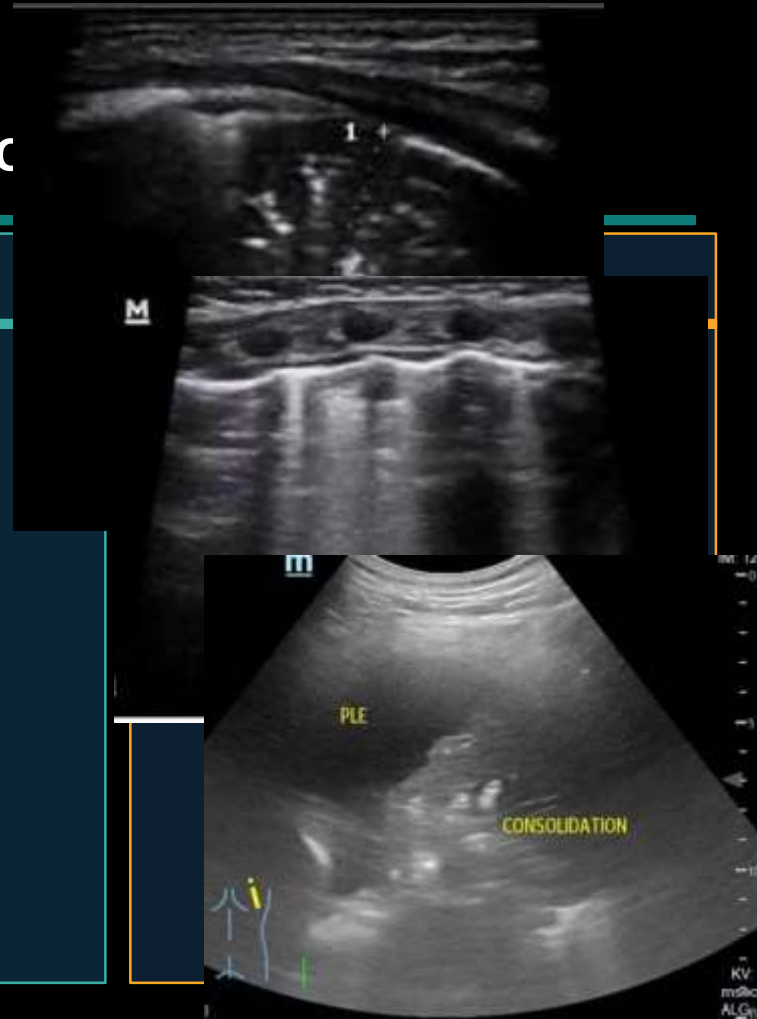
CT transport: risk unacceptable

TUS 12-Zone Findings

Right posterior: Large consolidation
+ DYNAMIC air bronchogram

Left posterior : B'-profile
(irregular pleural line + subpleural consolidation)

Right effusion: 2.8cm depth
Anechoic, freely mobile
→ Simple parapneumonic



67F | Severe CAP | Hemodynamically Unstable for CT Transport

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(irregular pleural line +
subpleural consolidation)

Right effusion: 2.8cm depth
Anechoic, freely mobile
→ Simple parapneumonic

Interpretation

**Infectious etiology confirmed
(dynamic AB)**

Antibiotics initiated

Thoracentesis planned

Ventilation: lung-protective

CASE 02

83M | Bilateral Infiltrates | dyspnea | P/F 120 — Pneumonia ARDS vs Cardiogenic Edema?

Clinical Data

HR 82, BP 106/59, SpO₂ 96%
Temp 36.5°C | RR25/min
HFS 60L/0.8 P/F ratio: 120

CXR: Bilateral basal opacities

P/Hx : CABG (2005), CKD

1week 타원 치료 후 전원.
소견서상 HF, pneumonia 악화

Diagnosis remains unclear
Cardiogenic edema not excluded.



Interpretation

83M | Bilateral Infiltrates | dyspnea | P/F 120 — Pneumonia ARDS vs Cardiogenic Edema?

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TUS 12-Zone Findings

Anterior zones (bilateral):
multiple, long echoic B-line
Pleural line: smooth

Bilateral effusions:
Anechoic, small (<1cm), mobile



83M | Bilateral Infiltrates | dyspnea | P/F 120 — Pneumonia ARDS vs Cardiogenic Edema?

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TUS 12-Zone Findings

Anterior zones (bilateral):
multiple, long echoic B-line

Pleural line: smooth

Bilateral effusions:
Anechoic, small (<1cm), mobile

Interpretation

Pure B-profile → edema ? NO

FINAL READ:
Bilateral Interstitial pneumonia,
Progressing toward ARDS pattern.

Actions:

- 타원에서 충분한 항생제
→ Hx taking (r/o HP)
- BAL today → Steroid try
- NO aggressive diuresis
- Effusion drain hold
- Reassess score at 48h

CASE 03

54M | Bilateral Infiltrates | Fever | P/F 178 — Pneumonia vs ARDS vs Cardiogenic Edema?

Clinical Data

- Fever 38.6°C, WBC 18.4k
- Day 3 ICU, FiO₂ 60%, SpO₂ 91%
- P/F ratio: 178
- BNP: 340 pg/mL (borderline elevated)
- Echo: EF 50%, mild diastolic dysfunction
- CXR: Bilateral infiltrates (no distinguishing features)

Diagnosis remains unclear after 3 days.

Cardiogenic edema not excluded.

TUS 12-Zone Findings

Interpretation

83M | Bilateral Infiltrates | dyspnea | P/F 120 — Pneumonia

Clinical Data

- Fever 38.6°C, WBC 18.4k
- Day 3 ICU, FiO₂ 60%, SpO₂ 91%
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Diagnosis remains unclear after 3 days.
Cardiogenic edema not excluded.

TUS 12-Zone Findings

Anterior zones (bilateral): B-lines
Pleural line: FRAGMENTED bilaterally → B'-profile

R posterior: Small consolidation 2cm + DYNAMIC air bronchogram

L posterior: Coalescent B-lines (no consolidation yet)

Bilateral effusions: Anechoic, small (<1.5cm), mobile



83M | Bilateral Infiltrates | dyspnea | P/F 120 — Pneumonia ARDS vs Cardiogenic Edema?

Clinical Data

- Fever 38.6°C, WBC 18.4k
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Anterior zones (bilateral): B-lines
Pleural line: FRAGMENTED bilaterally → B'-profile

R posterior: Small consolidation 2cm + DYNAMIC air bronchogram

L posterior: Coalescent B-lines (no consolidation yet)

Bilateral effusions: Anechoic, small (<1.5cm), mobile

Interpretation

Pure B-profile → edema?
NO — pleural line is fragmented.

FINAL READ: Bilateral pneumonia (B'-profile + dynamic AB + small consolidation = infectious)
Progressing toward ARDS pattern.

Actions:

- Broad-spectrum antibiotics
- Lung-protective ventilation
- NO aggressive diuresis
- Reassess score at 48h
- Culture + BAL today

CASE 04

79M | Dyspnea, Desaturation | — Pleural effusion vs atelectasis ?

Clinical Data

- Lt. parotid gland abscess 로 I&D 하고 입원중 (HD 5)
- Rt. Pleural effusion 에 대해 PCD insertion state

흡인병력은 없고 HFS 60L/0.6
에서 SpO2 92%

PCD function 되지 않고 갑작스
러운 호흡곤란으로 ICU contact



Interpretation

79M | Dyspnea, Desaturation | — Pleural effusion vs atelectasis ?

Clinical Data

- Lt. parotid gland abscess 로 I&D 하고 입원중 (HD 5)
- Rt. Pleural effusion 에 대해 PCD insertion state

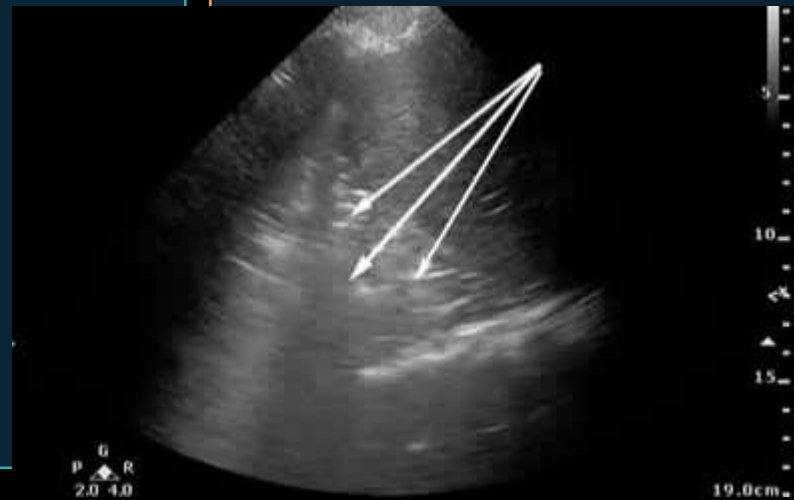
흡인병력은 없고 HFS 60L/0.6
에서 SpO2 92%

PCD function 되지 않고 갑작스
러운 호흡곤란으로 ICU contact

TUS 12-Zone Findings

- PLAPS point
- 극소량의 effusion
 - static air-bronchogram

Interpretation



79M | Dyspnea, Desaturation | — Pleural effusion vs atelectasis ?

Clinical Data

- Lt. parotid gland abscess 로 I&D 하고 입원중 (HD 5)
- Rt. Pleural effusion 에 대해 PCD insertion state

흡인병력은 없고 HFS 60L/0.6 에서 SpO2 92%

PCD function 되지 않고 갑작스러운 호흡곤란으로 ICU contact

TUS 12-Zone Findings

Effusion 증가로 인한 atelectasis 일 경우 PCD 삽입을 고려하기 위해 PLAPS point 를 관찰하였으나, 극소량의 effusion 만 관찰되었고 static air-bronchogram 을 보이는 lung 이 관찰됨.

Interpretation

Effusion 배제됨

total obstructive pneumopathy 소견으로 toilet bronchoscopy 시행 후 resolve 됨.