Thoracic Ultrasound in Chronic Pulmonary Diseases

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Today`s Topics

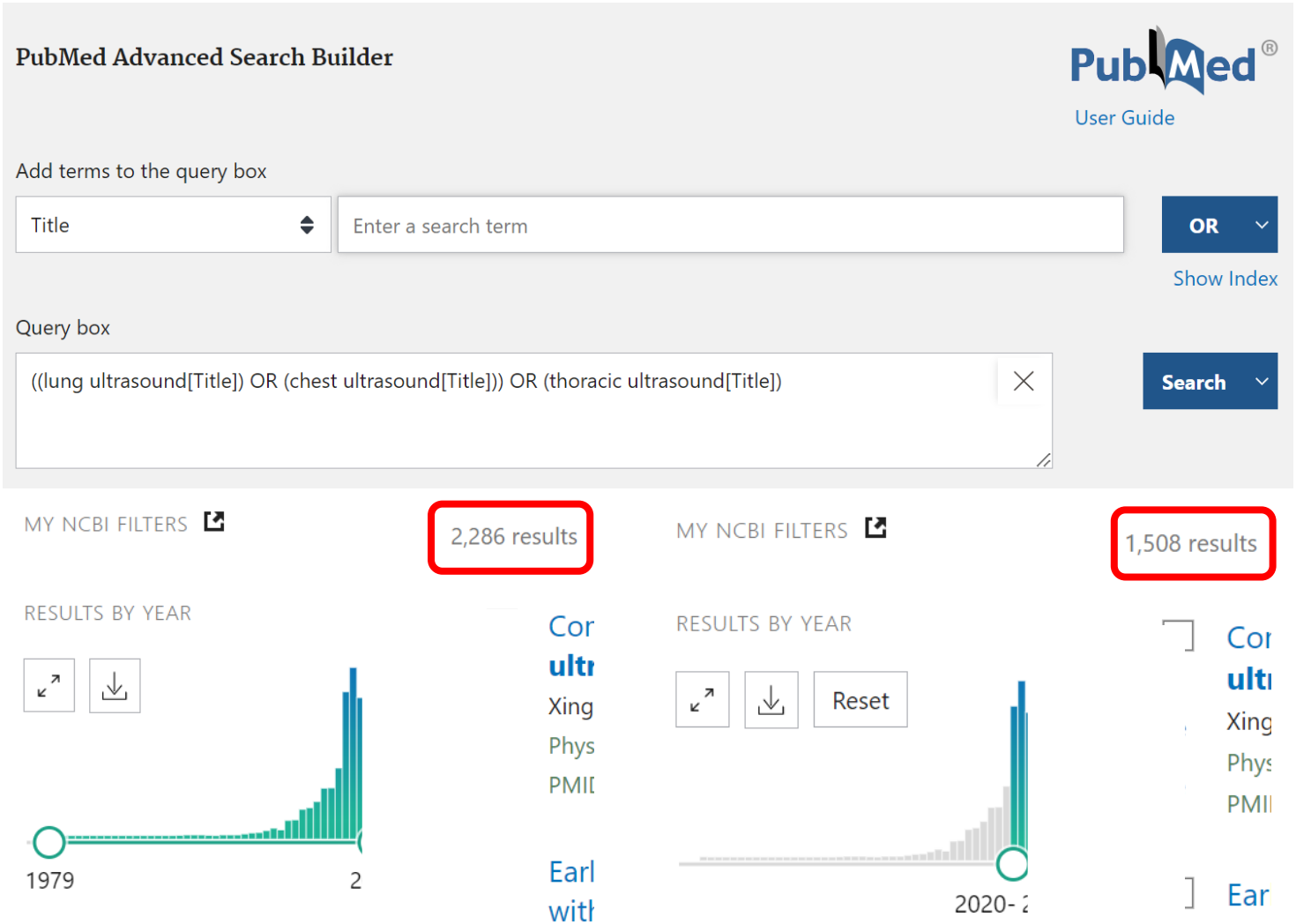
- Introduction
- Pneumonia/Infection
- Pleural effusion
- IPF/ILD
- COPD
- Protocols and novel technique

Introduction

History and Milestone of Thoracic Ultrasound

1995~1998
Bedside ultrasound : Dr. Lichtenstein and others

History and Milestone of Thoracic Ultrasound



History and Milestone of Thoracic Ultrasound

BTS guidelines

Pleural procedures and thoracic ultrasound: British Thoracic Society pleural disease guideline 2010

Tom Havelock,[1] Richard Teoh,[2] Diane Laws,[3] Fergus Gleeson,[4] on behalf of the BTS Pleural Disease Guideline Group

Intensive Care Med (2012) 38:577–591
DOI 10.1007/s00134-012-2513-4

CONFERENCE REPORTS AND EXPERT PANEL

Giovanni Volpicelli
Mahmoud Elbarbary
Michael Blaivas
Daniel A. Lichtenstein
Gebhard Mathis
Andrew W. Kirkpatrick

International evidence-based recommendations for point-of-care lung ultrasound

CONCISE CLINICAL REVIEW

CME ATS

Lung Ultrasound for Critically Ill Patients

Francesco Mojoli[1,2], Bélaid Bouhemad[3,4], Silvia Mongodi[2], and Daniel Lichtenstein[5]

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ORCID ID: 0000-0002-6031-6336 (F.M.).

ERS OFFICIAL DOCUMENTS
ERS STATEMENT

European Respiratory Society statement on thoracic ultrasound

ESC European Society of Cardiology
European Heart Journal - Cardiovascular Imaging (2022) **23**, 447–449
https://doi.org/10.1093/ehjci/jeab241

HOW TO

How to do lung ultrasound

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Radiology: Cardiothoracic Imaging

Lung Ultrasound: The Essentials

Thomas J. Marini, MD • Deborah J. Rubens, MD • Yu T. Zhao, BA • Justin Weis, MD • Timothy P. O'Connor, MD • William H. Novak, MD • Katherine A. Kaproth-Joslin, MD, PhD

From the Departments of Imaging Sciences (T.J.M., D.J.R., Y.T.Z., K.A.K.J.), Medicine (J.W., W.H.N.), and Emergency Medicine (T.P.O.), University of Rochester Medical Center, School of Medicine and Dentistry, 601 Elmwood Ave, Box 655, Rochester, NY 14642. Received October 24, 2020; revision requested January 5; revision received January 16; accepted February 5. **Address correspondence to** T.M. (e-mail: *RochesterRadiology2021@gmail.com*).

Conflicts of interest are listed at the end of this article.

Radiology: Cardiothoracic Imaging 2021; 3(2):e200564 • https://doi.org/10.1148/ryct.2021200564 • Content codes: CH US

Insurance of Thoracic Ultrasound in South Korea

[행위] 고시 제2021-104호「요양급여의 적용기준 및 방법에 관한 세부사항」 일부개정

급여관리부 | 2021-03-31 | 2,993

1. (제2021-104호) 흉부 초음파 검사의 급여기준 첨부파일 다운로드

2. (제2021-104호) 흉부 초음파 검사의 급여기준 관련 질의응답(QnA) 첨부파일 다운로드

1. 흉부(흉벽, 흉막, 늑골 등) 초음파 검사는「초음파 검사의 급여기준」에서 정하는 비급여 대상이라 할지라도 진료의사의 의학적 판단에 따라 **질환이 있거나 질환이 의심되어** 의사가 직접 시행한 경우 다음과 같이 요양급여함. 다만, 의사가 동일한 공간에서 방사선사의 촬영하는 영상을 동시에 보면서 실시간으로 지도하고 진단하는 경우도 포함함.

1) 표준영상의 범위

가) 흉벽,흉막 등

좌·우측 각각의 전면 및 측면 흉곽을 4개 이상의 구역으로 나누어 각 구역의 횡스캔, 종스캔 또는 시상면 스캔.

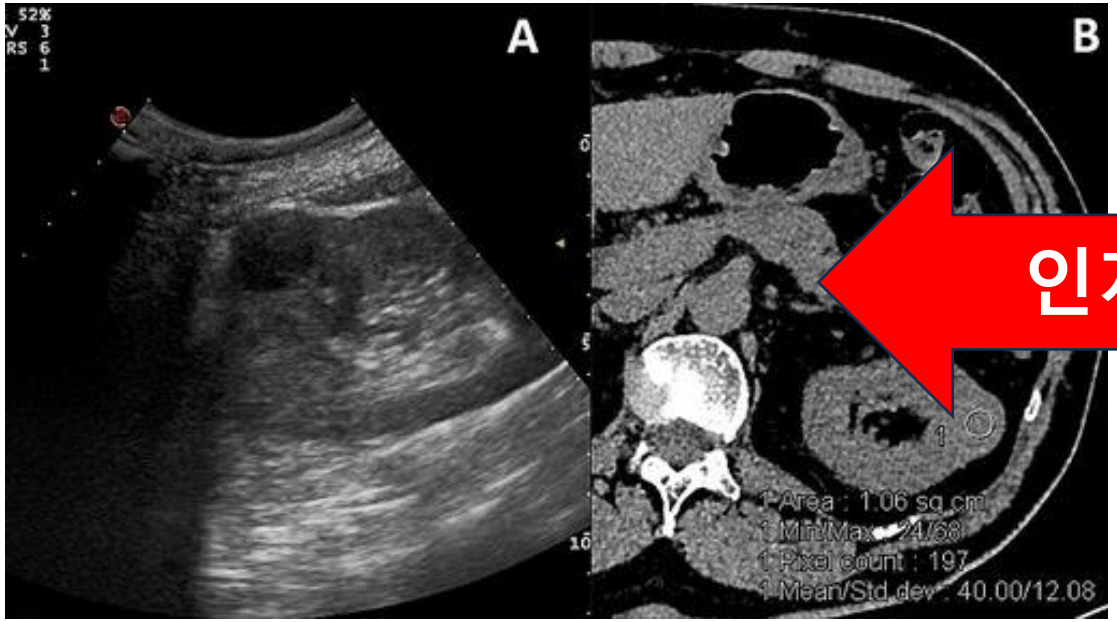
필요시 후면 흉곽을 2개 구역으로 나누어 각 구역의 횡스캔, 종스캔 또는 시상면 스캔

2) 판독소견서

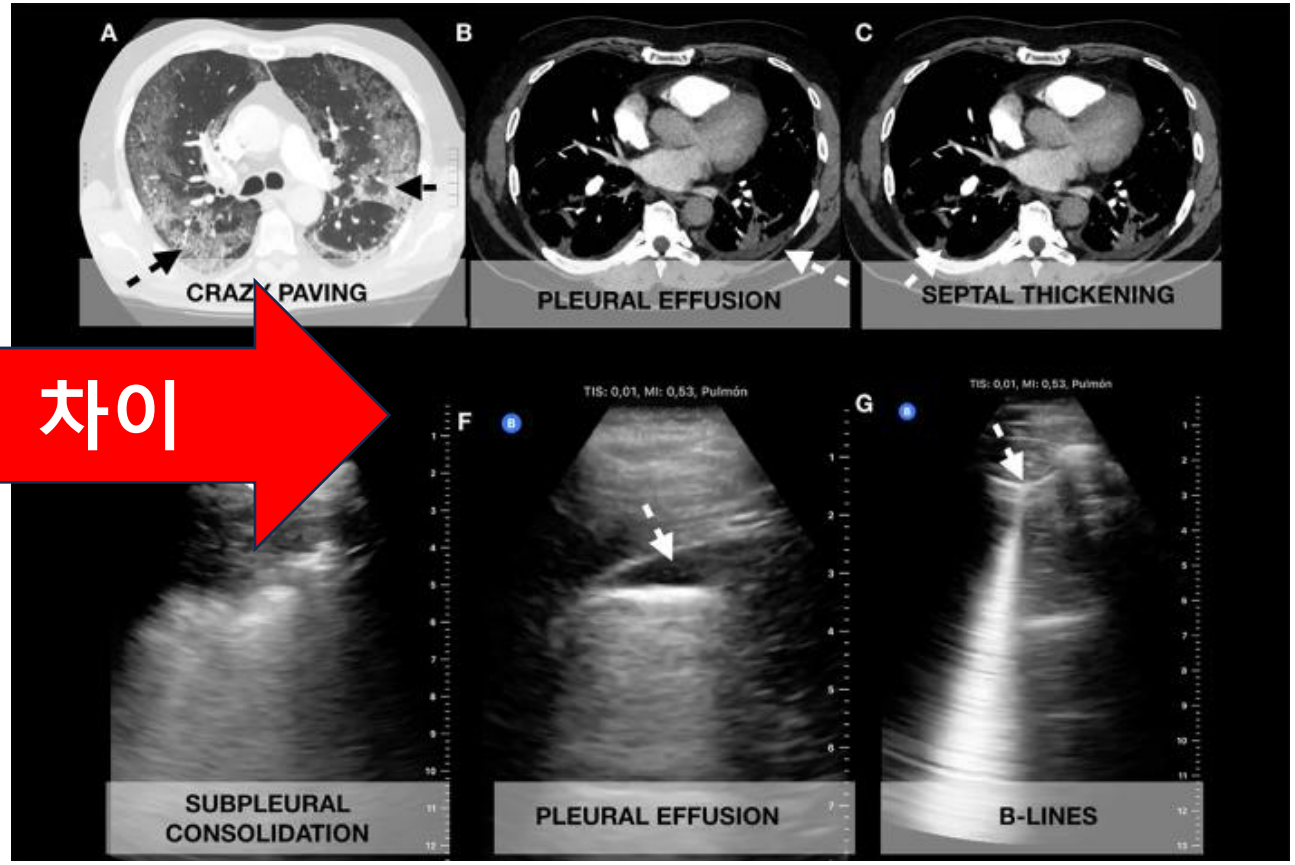
(1) 흉벽,흉막 등

기흉의 유무, 기흉의 위치, 흉수의 유무, 흉수의 양과 위치, 흉수의 성상, 흉벽, 흉막 내 국소병변 유무, 국소병변의 크기, 위치, 초음파 특성, 흉막 두께의 이상 유무를 포함해야 하며 이상소견이 있는 경우 세부내용을 상세 기술해야 함

Before we start, true image vs. artifacts

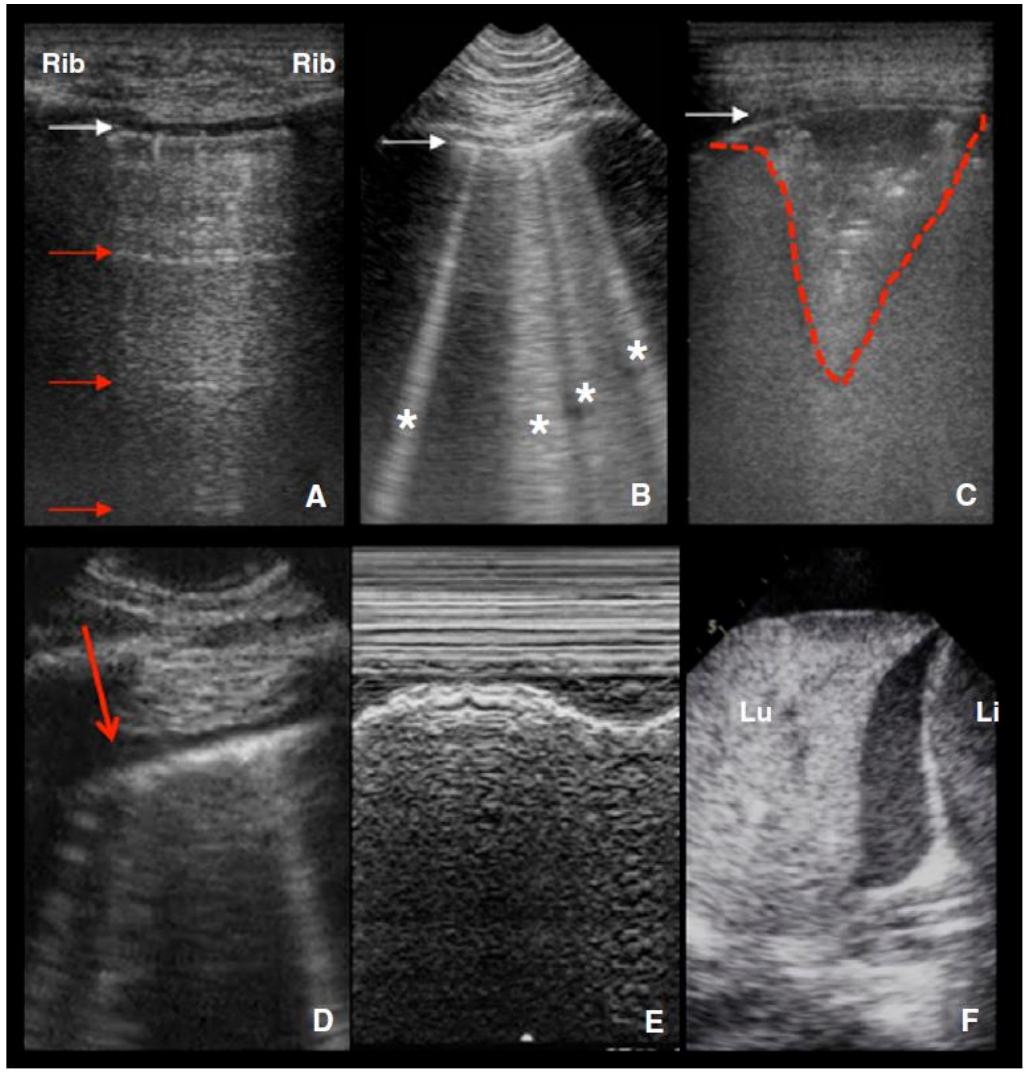


인지의 차이



가톨릭대학교
THE CATHOLIC UNIVERSITY OF KOREA

TUS start with memorizing findings



A
- White arrow : Pleural line
- Red arrow : Long Reverberation artifacts (A-line)

B
- Star : Short Reverberation artifacts (B-line)

C
- Dashed red line : Shred sign (Subpleural consolidation)

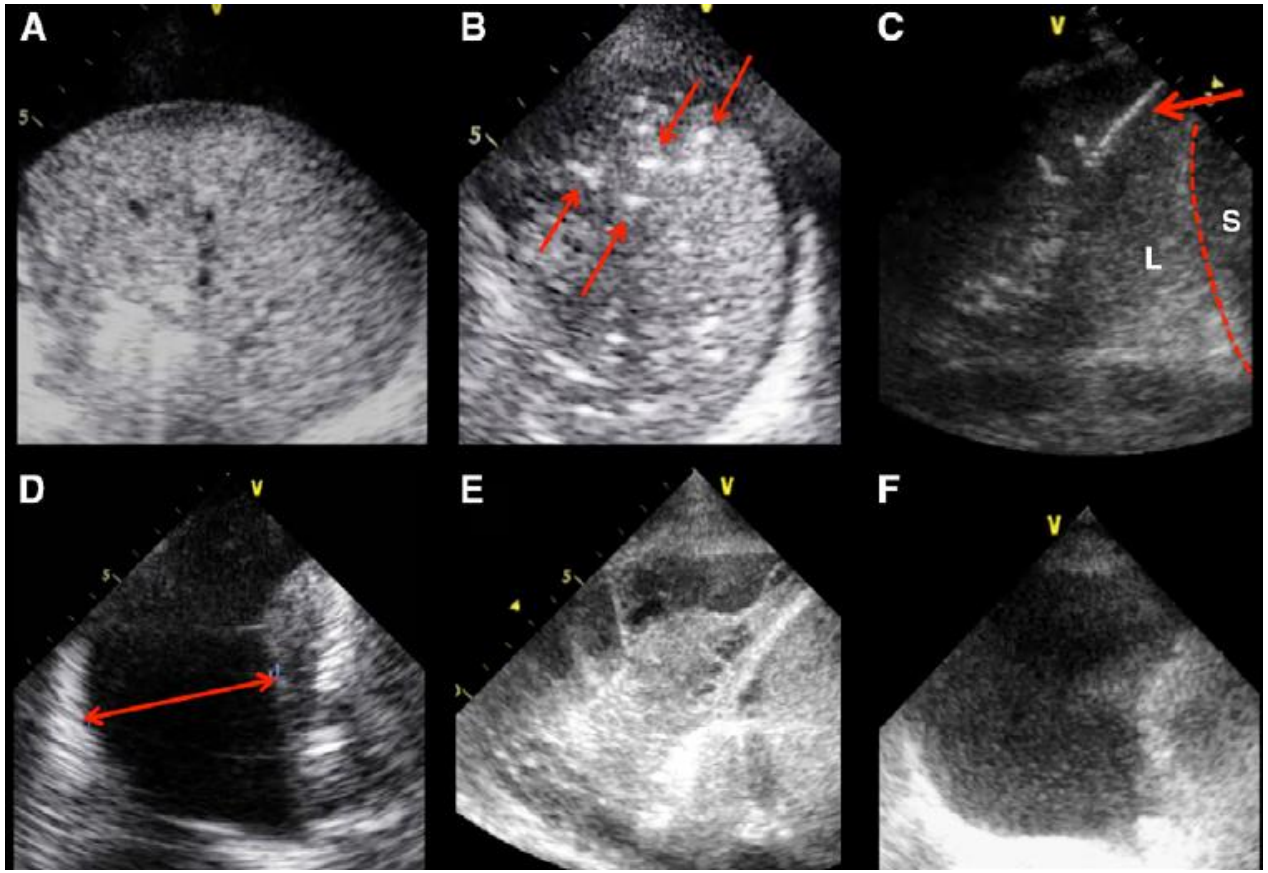
D
- Red arrow : Small pleural effusion

E
- Sinusoidal sign

F
- Tissue like lesion, pleural effusion

AJRCCM Vol 199. No 6, March, 2019

TUS start with memorizing findings



A: Tissue like lesion without air-bronchogram

B (transverse) & C (longitudinal)
: Tissue like lesion with air-bronchogram (red arrow)
: Dynamic air-bronchogram : moves with tidal ventilation
: Static air-bronchogram : no changes during tidal ventilation

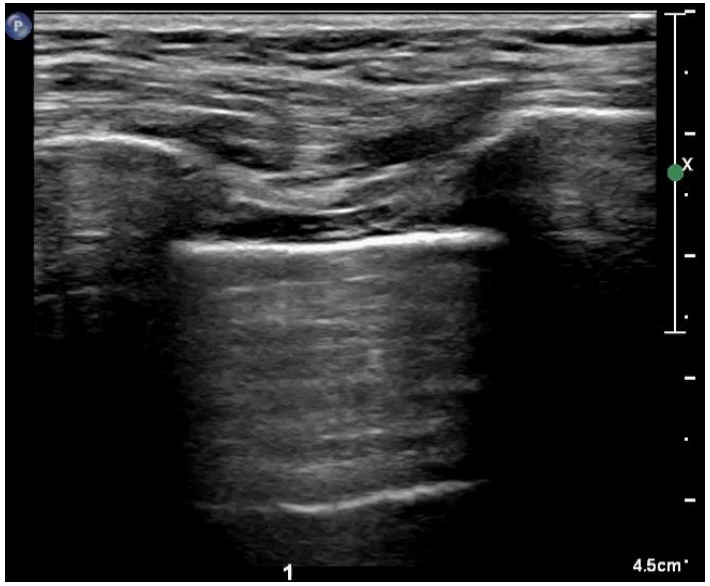
D: Red arrow : Pleural effusion

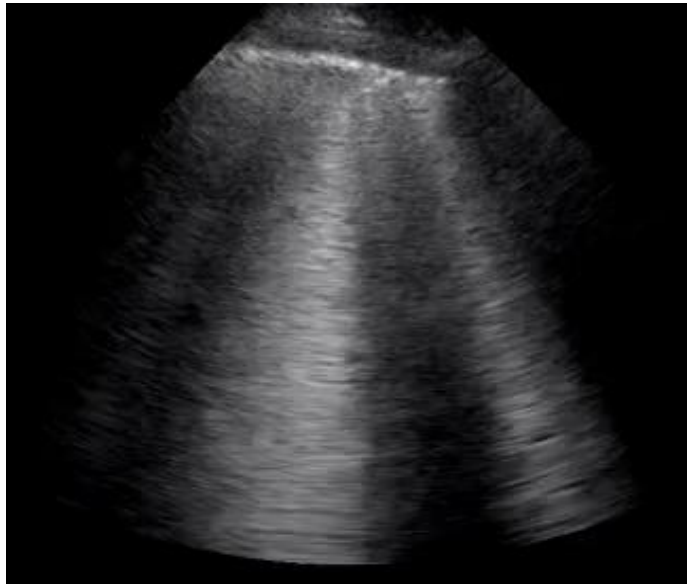
E: Multiple septa and adherence

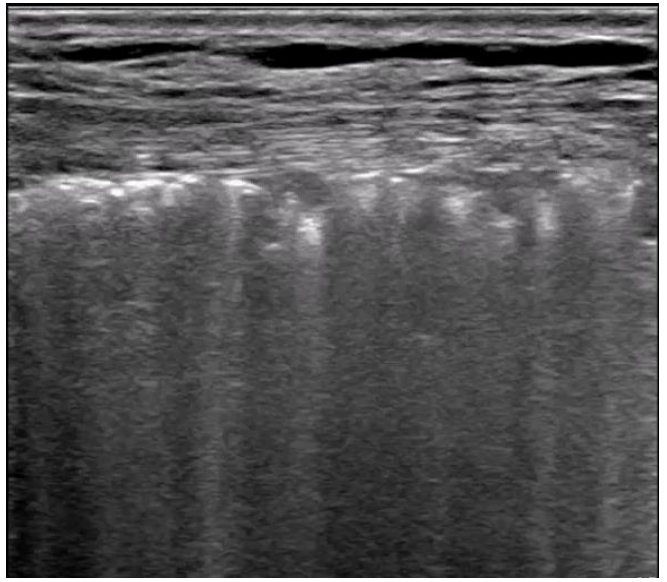
F: Pleural effusion with collapsed lung

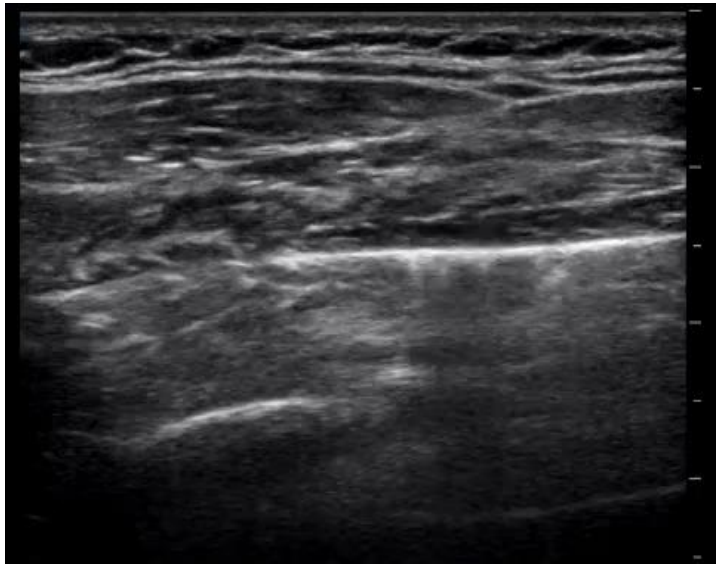
AJRCCM Vol 199. No 6, March, 2019

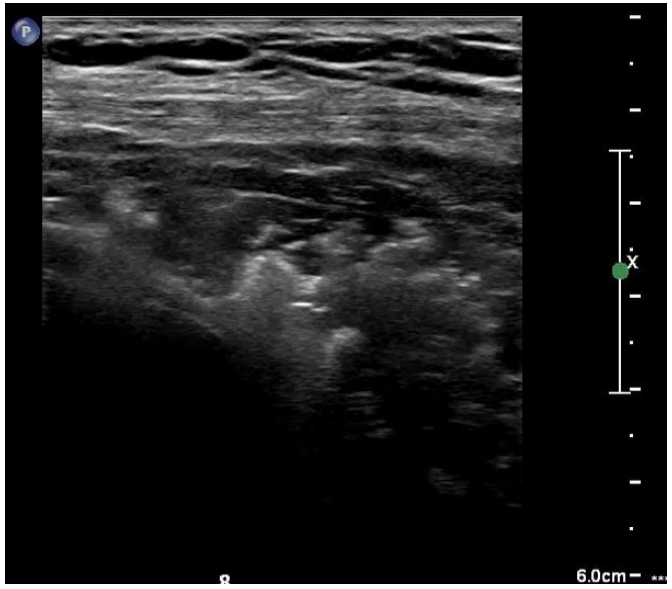
TUS start with memorizing findings

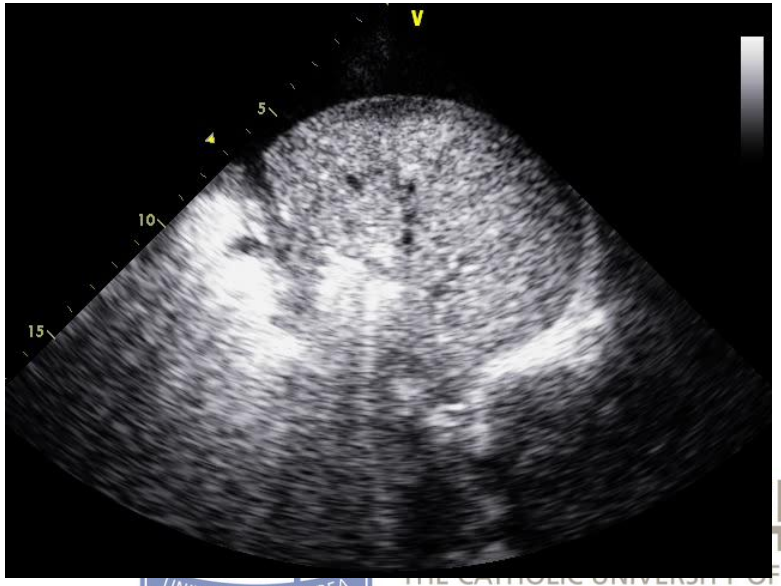




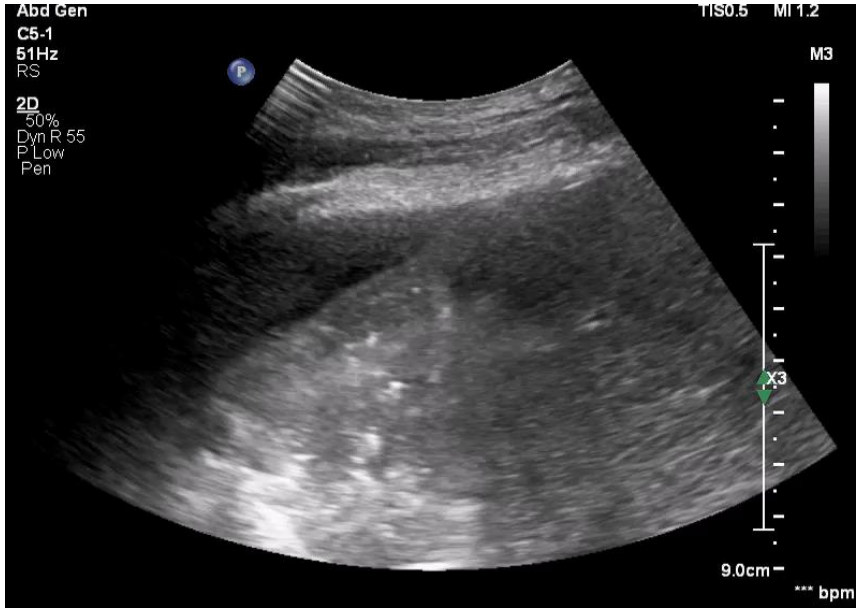


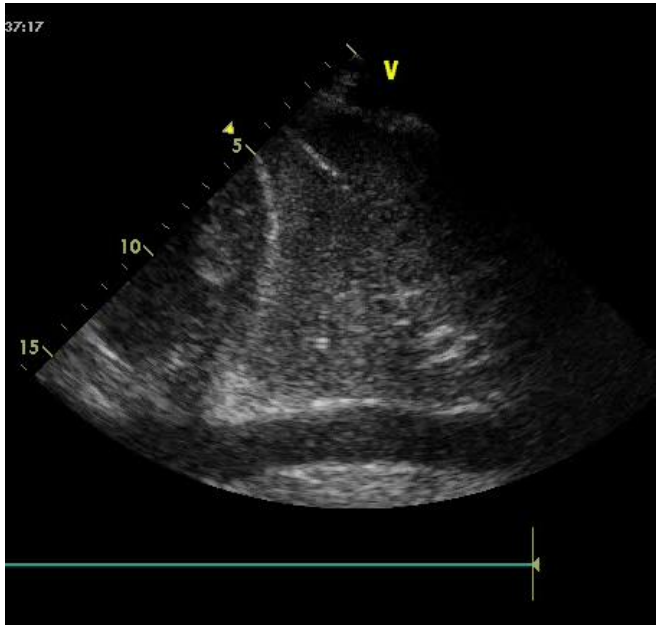


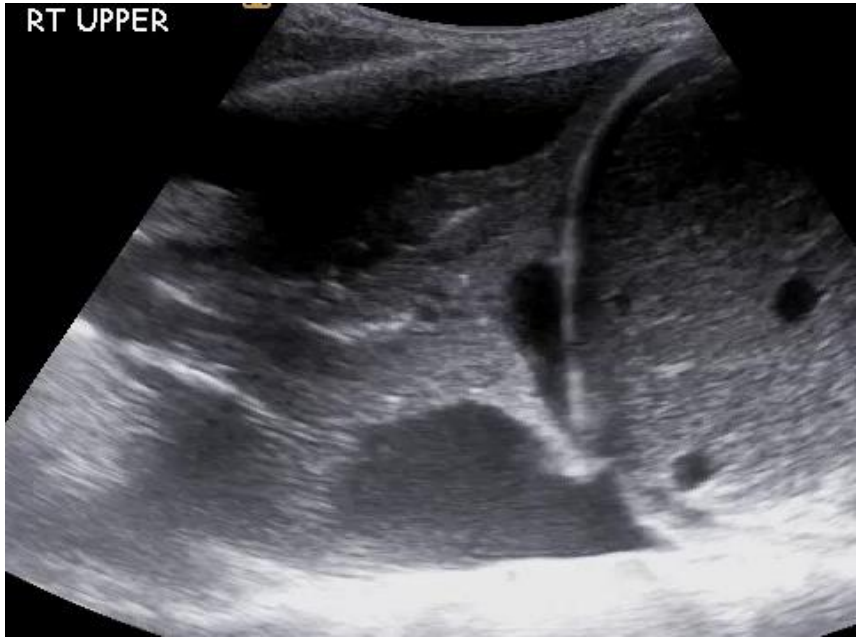




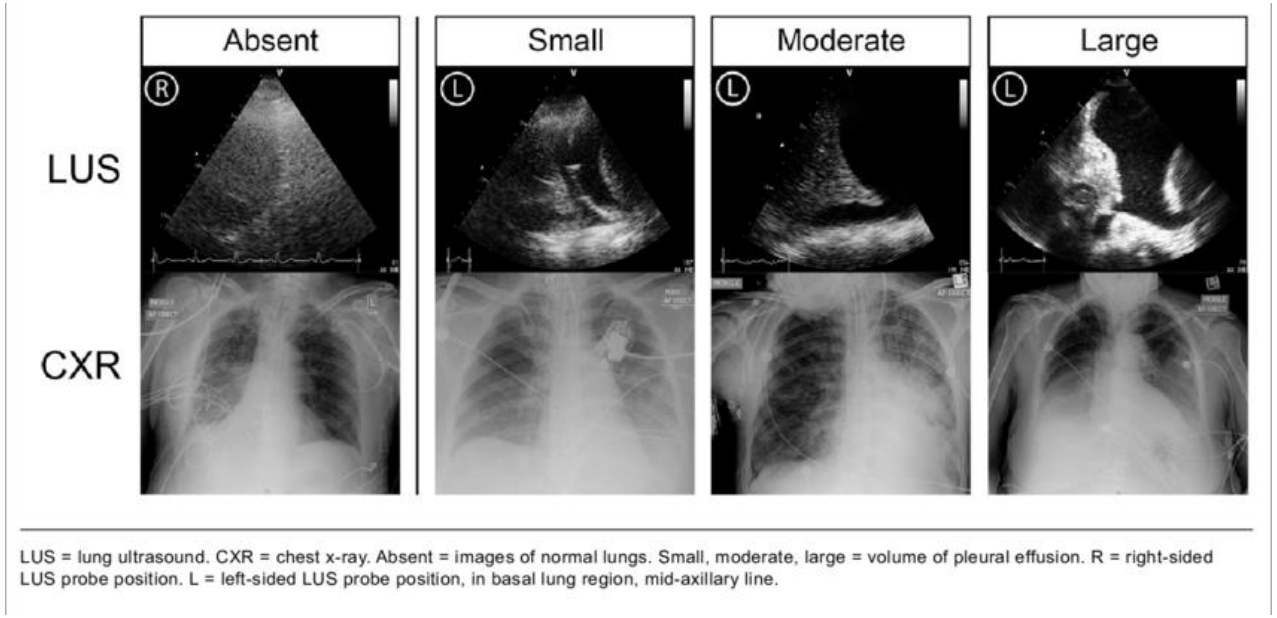
TUS start with memorizing findings



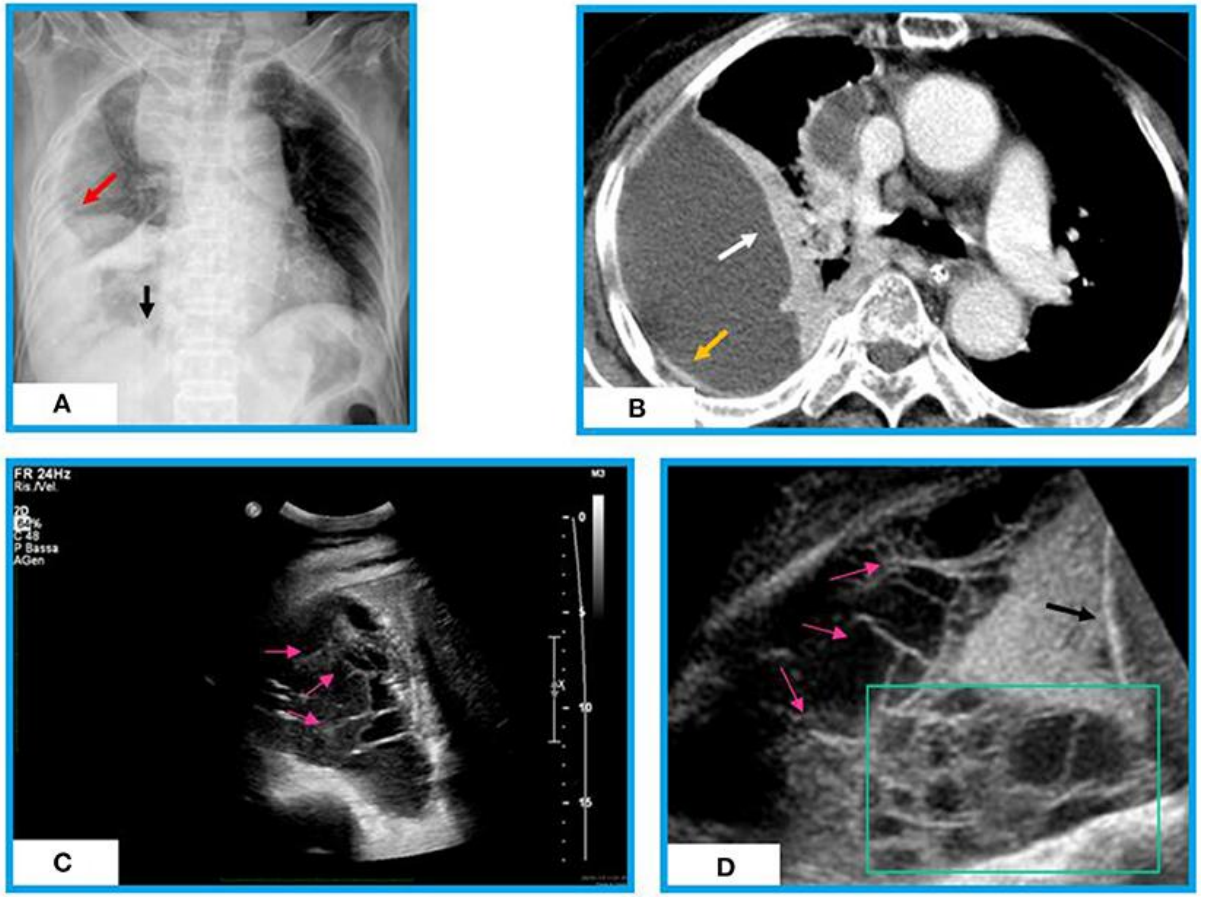




Resolution: US vs. CT



LUS = lung ultrasound. CXR = chest x-ray. Absent = images of normal lungs. Small, moderate, large = volume of pleural effusion. R = right-sided LUS probe position. L = left-sided LUS probe position, in basal lung region, mid-axillary line.



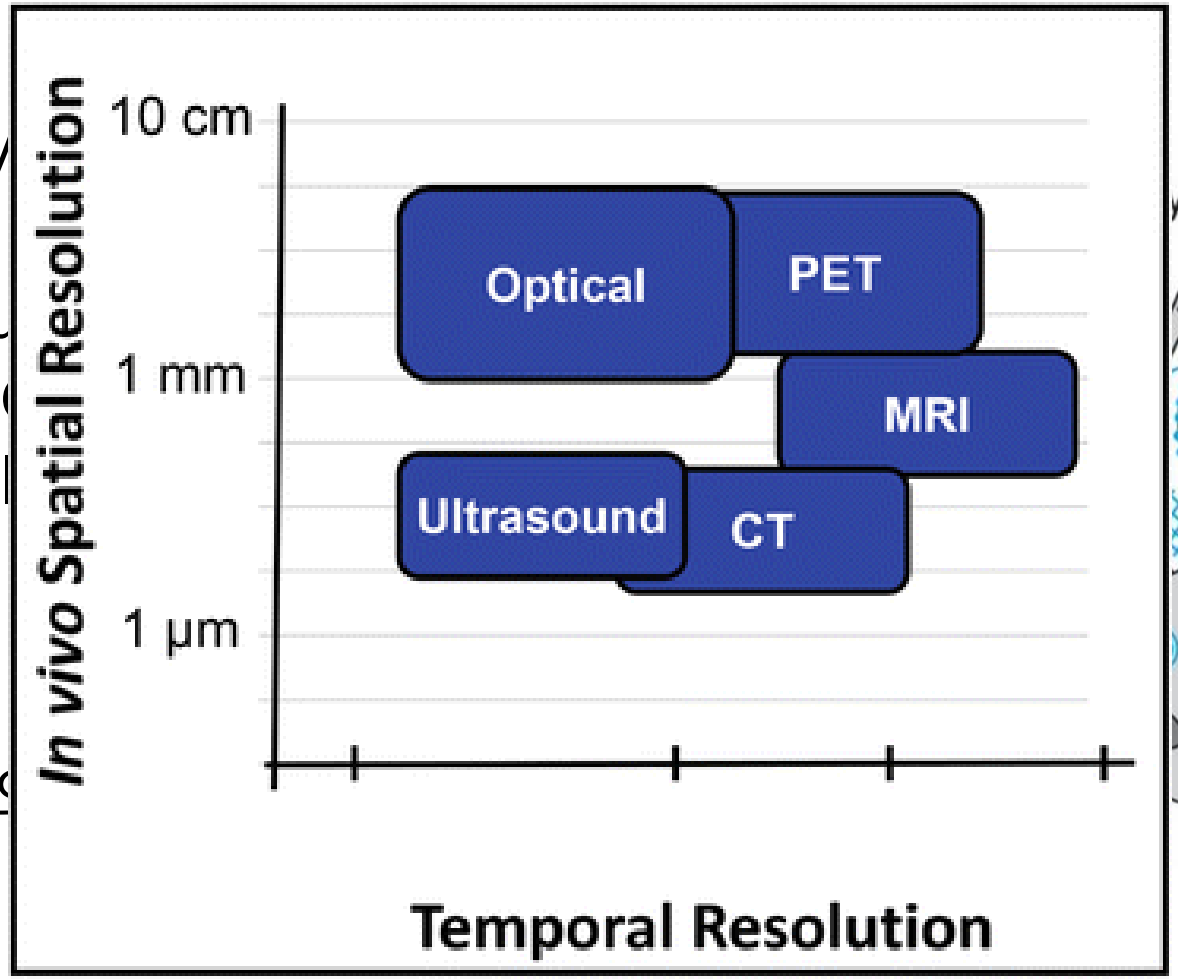
해상도가 낮지 않을까?

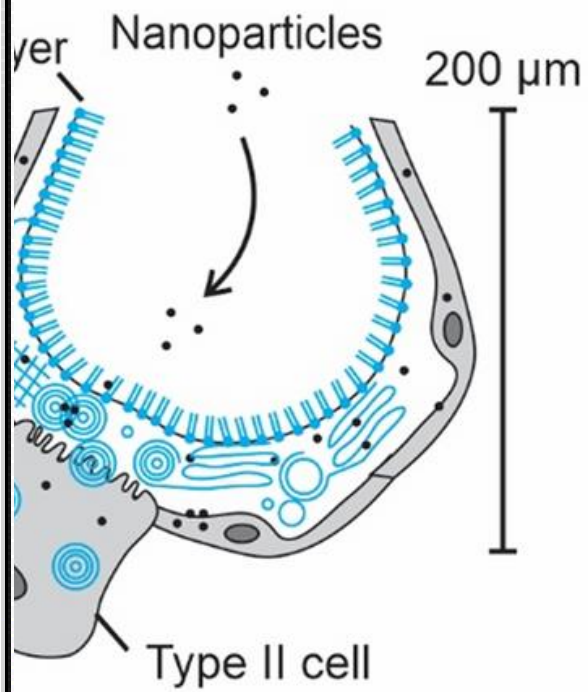
Resolution of US

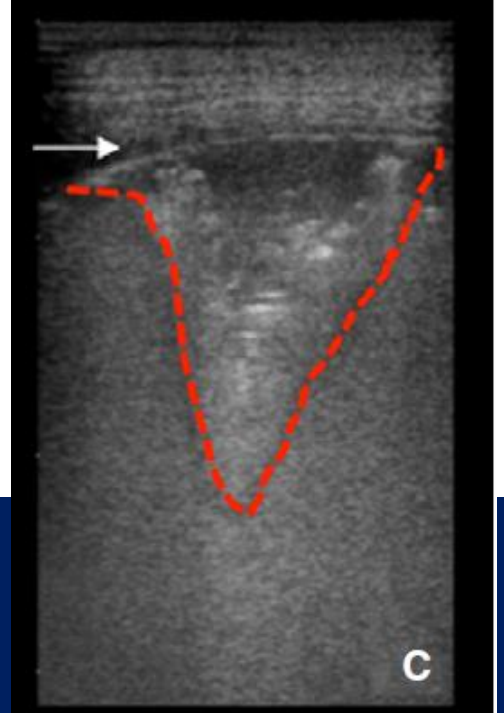
Resolution

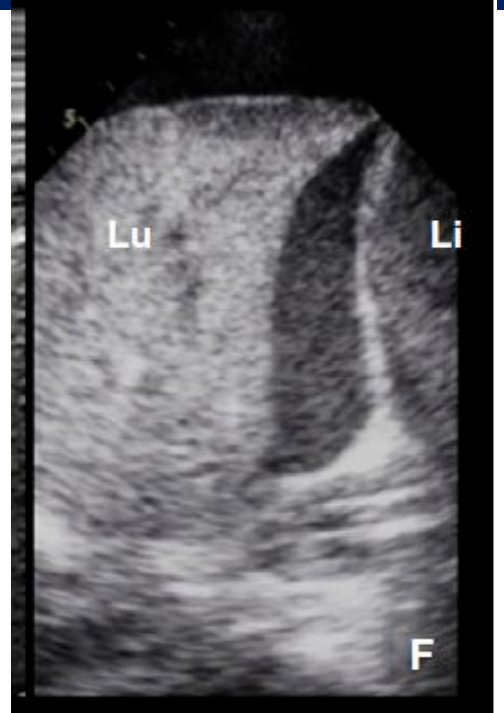
= Sound Velocity

- 1MHz → 770 μ
  - 2~12MHz (
  - 8~15MHz (
  - 1~6MHz (p
    μm
- Cf) alveoli 1개









Pneumonia/Infection

Pneumonia – TUS vs. CXR/CT

Table 5
Analysis of diagnostic Accuracy.

Analysis	PPV	NPV	Sensitivity	Specificity	AUC (95% CI)	
Radiographically-Confirmed Clinical Pneumonia vs. finding a consolidation on lung ultrasound	100	91.3	88.5	100	0.94	(0.92–0.97)
Radiographically-Confirmed Clinical Pneumonia vs. finding any abnormality on lung ultrasound	94.1	93.6	92.2	95.2	0.94	(0.91–0.96)

Table 2 Results of CXR and lung ultrasound compared with the diagnosis at discharge

	BPN + (81)	BPN − (39)
CXR		
Positive	54 (67%)	6 (15%)
Negative	27 (33%)	33 (85%)
Ultrasound		
Positive	80 (99%)	2 (5%)
Negative	1 (1%)	37 (95%)

BPN, pneumonia; CXR, chest x-ray.

Table 4 Results of thoracic CXR and ultrasound compared with CT

	CT + (26/30)	CT − (4/30)	Total
CXR +	18	1	19
CXR −	8	3	11
Lung ultrasound +	25	1	26
Lung ultrasound −	1	3	4
Total	26	4	30

CXR, chest x-ray.

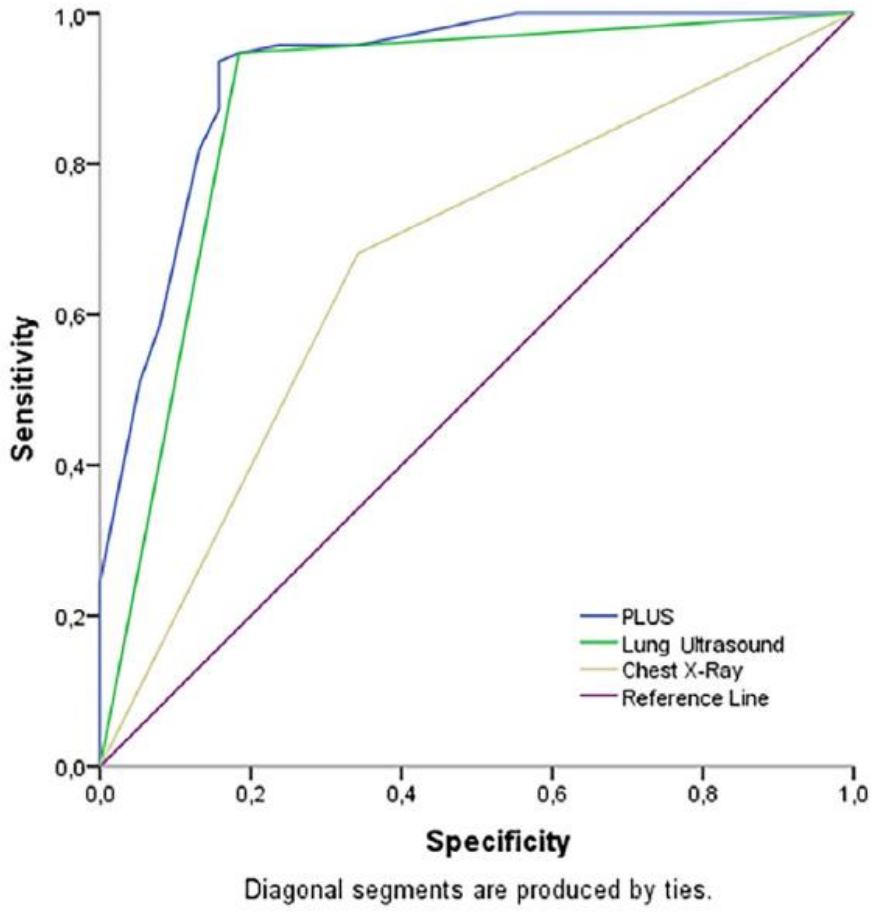
Respiratory Medicine 128 (2017)
Emerg Med J 2012;29

Pneumonia – TUS vs. CXR in elderly, immobilized patients

Pneumonia Lung Ultrasound Score (PLUS): A New Tool for Detecting Pneumonia in the Oldest Patients

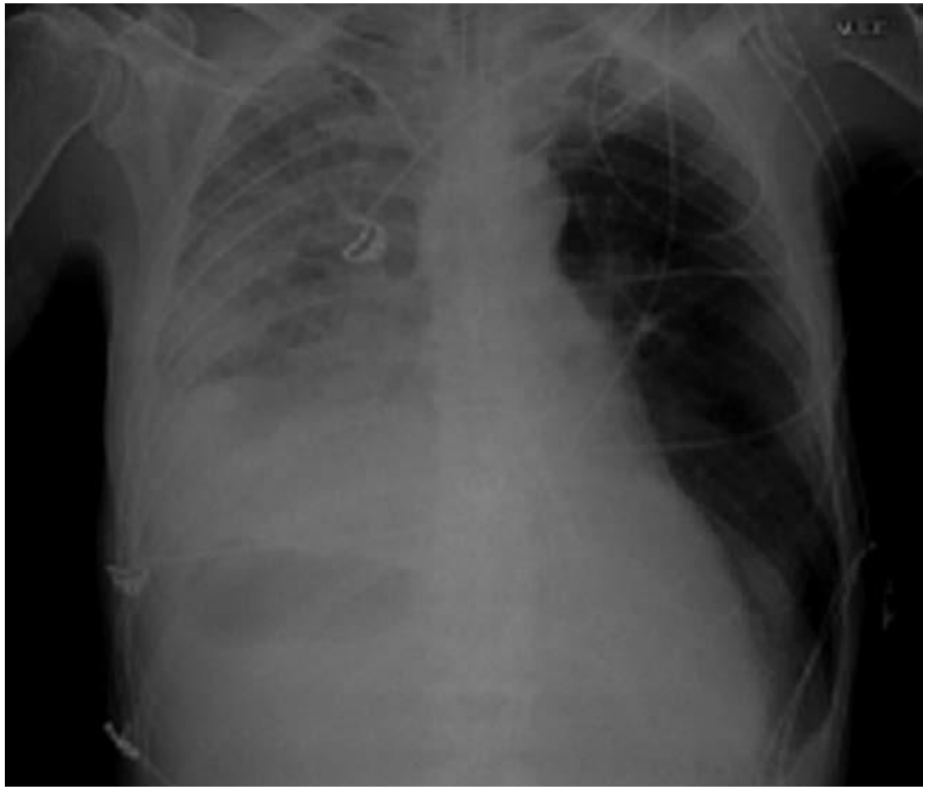
Giuseppe Linsalata, Chukwuma Okoye,* Rachele Antognoli,* Daniela Guarino,* Virginia Ravenna,† Eugenio Orsitto,† Valeria Calsolaro,* and Fabio Monzani**

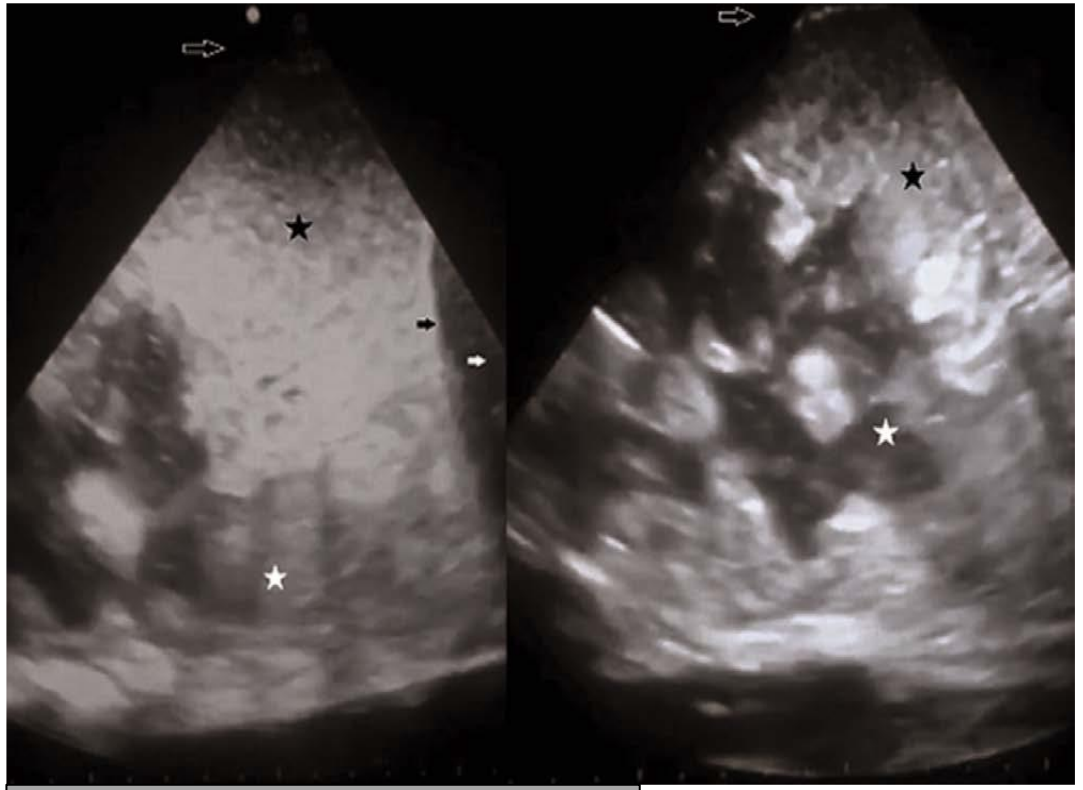
- 65세 이상
- Respiratory failure 동반
- Dyspnea, Cough etc.
- X-ray vs TUS



J Am Geriatr Soc 68:2855-2862, 2020.

Pneumonia – Detection of severe pneumonia

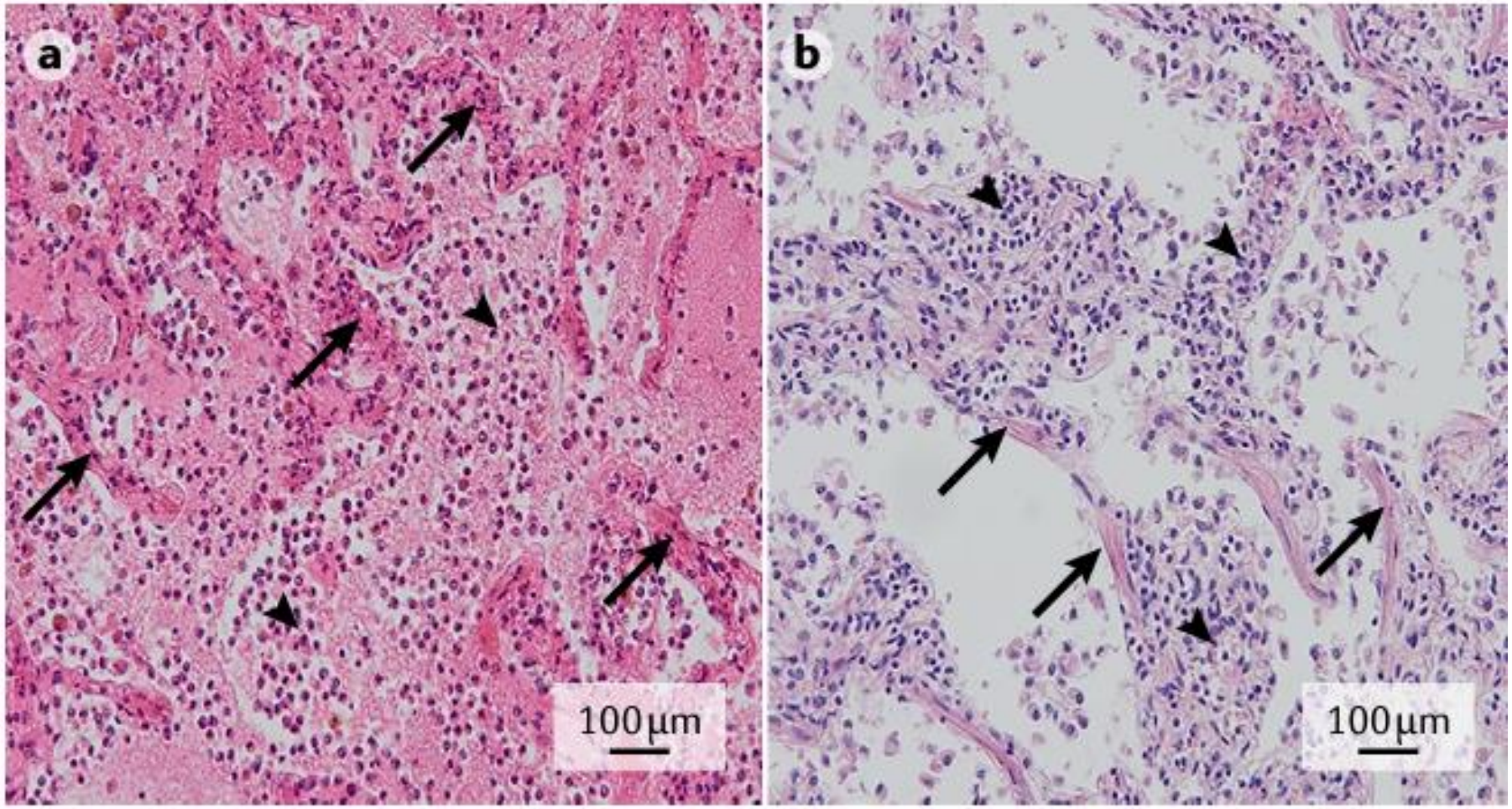




Pulmonary gangrene by TUS

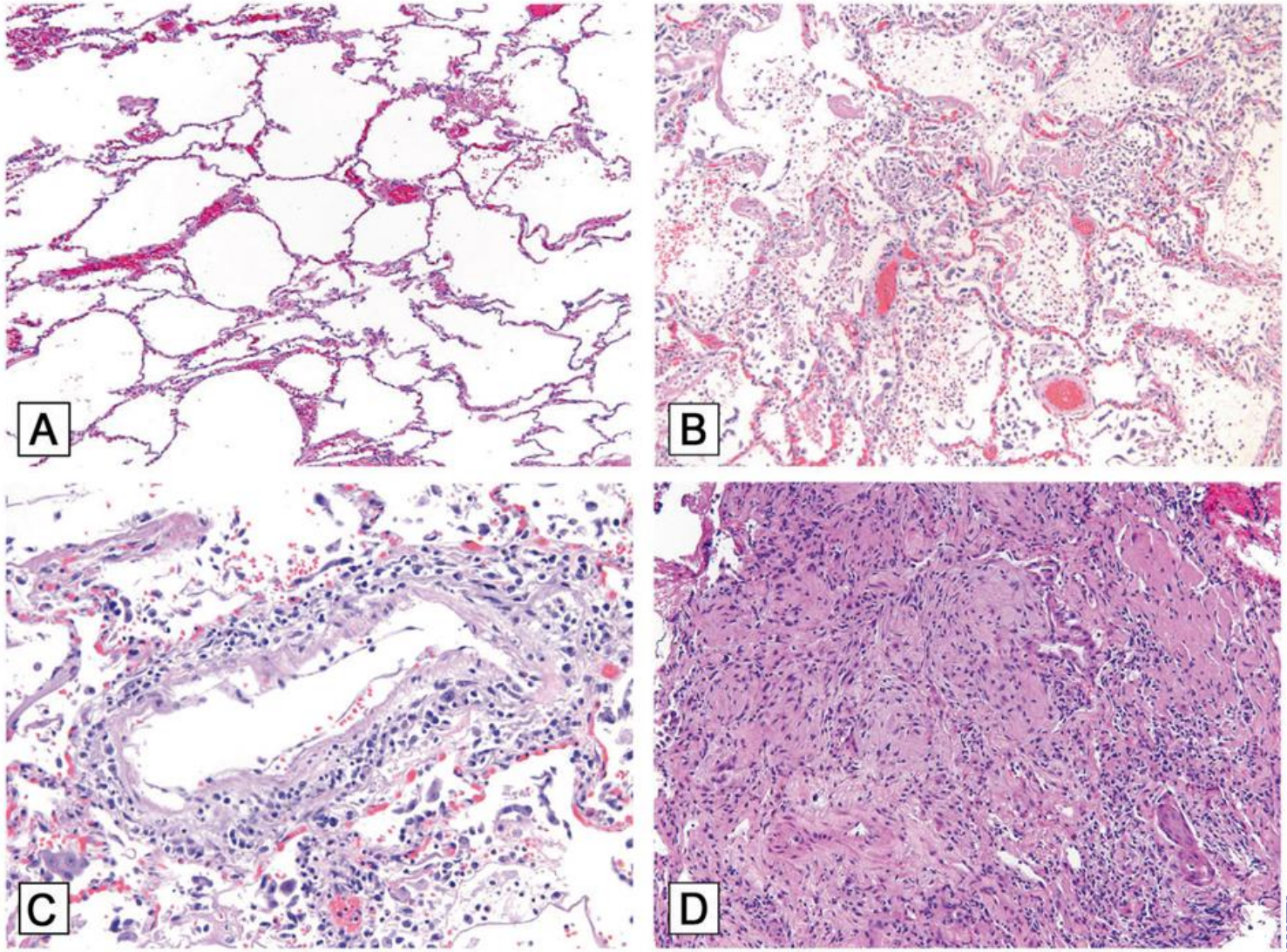
Critical Care Medicine (2019)

Pneumonia – Bacterial vs. Viral



Nat Rev Dis Primers **7**, 25 (2021).

Pneumonia – Severity of COVID19



Modern Pathology (2021) 34:1614–1633

Pneumonia – Severity of COVID19

[Education and Clinical Practice Original Research]

CHEST

Feasibility of a New Lung Ultrasound Protocol to Determine the Extent of Lung Injury in COVID-19 Pneumonia

Check for updates

Giovanni Volpicelli, MD FCCP; Thomas Fraccalini, MD; Luciano Cardinale, MD; Giuseppe Stranieri, MD; Rouslan Senkeev, MD; Guido Maggiani, MD; Alberto Pacielli, MD; and Domenico Basile, MD

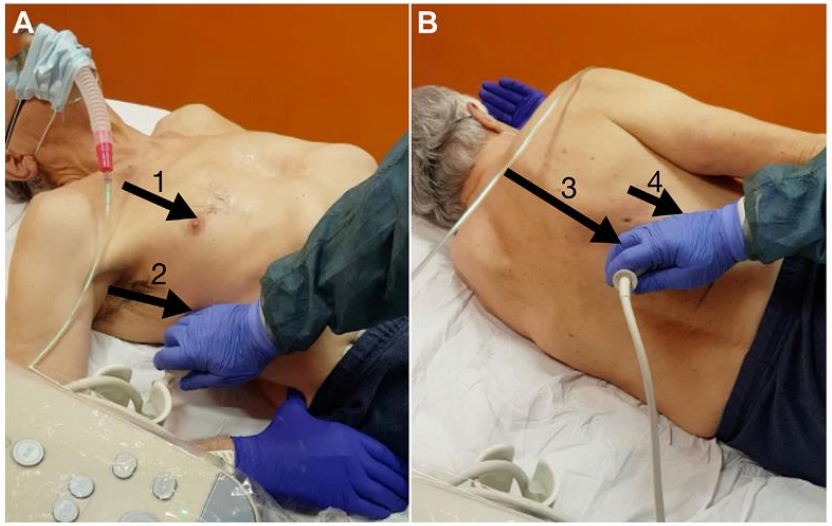


Figure 1 – *A and B, The four chest areas that were examined to assess the extension of the pulmonary lesions in patients with COVID-19 pneumonia. A, Patient is first placed in the supine position: area 1 is scanned longitudinally between the sternum and the anterior axillary line; area 2 is scanned longitudinally between the anterior axillary line and the posterior axillary line. B, Patient is then turned in the lateral decubitus: area 3 is scanned longitudinally between the spine and the medial margin of the scapula; area 4 is scanned in oblique (along the intercostal spaces) below the inferior margin of the scapula. The same procedure is then repeated on the other side.*

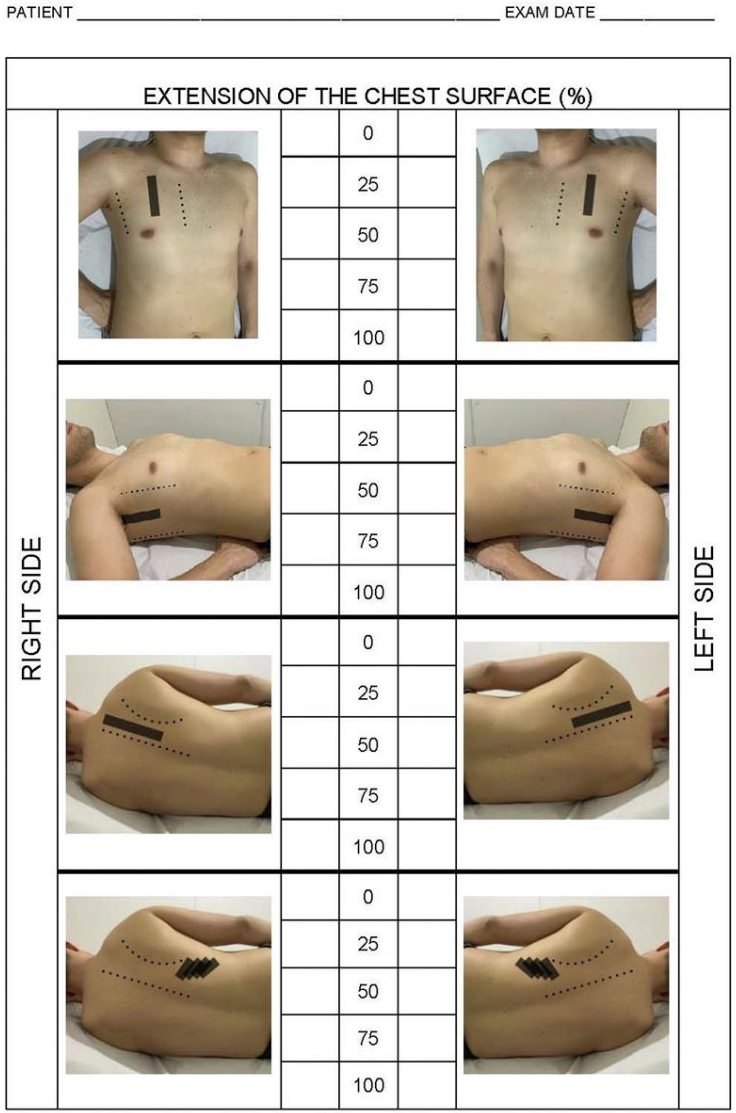


Figure 2 – *The scheme for collection of the data on the visual extension in percentage of the COVID-19 pulmonary lesions, visible by lung ultrasound examination on the chest wall. Each area is examined, and a percentage of 0-25-50-75-100% is assigned visually. The final score in percentage is given by the sum of the percentage of each area divided for the total of eight scans.*

CHEST 2023; 163(1):176-184

Pneumonia – Severity of COVID19

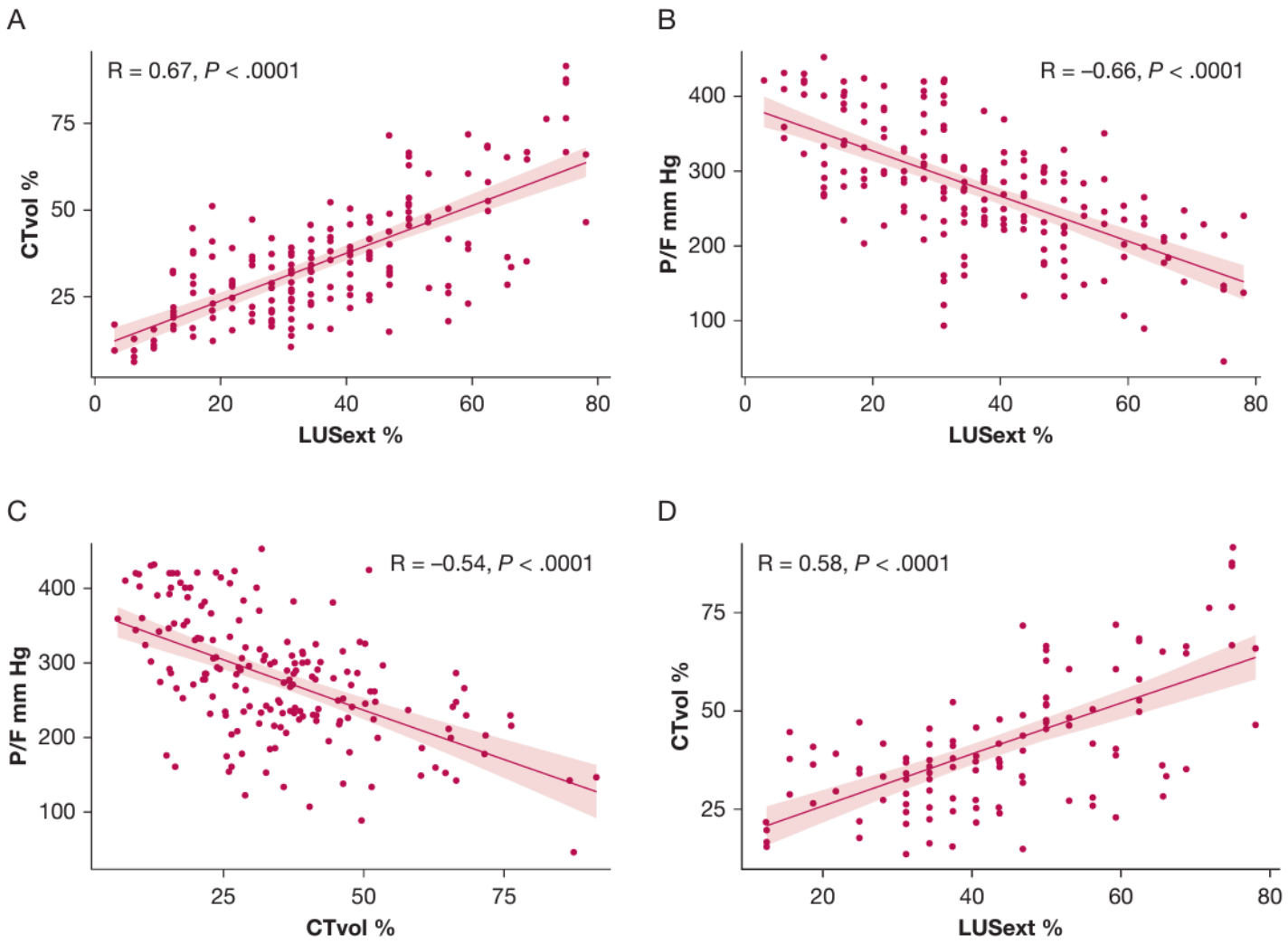
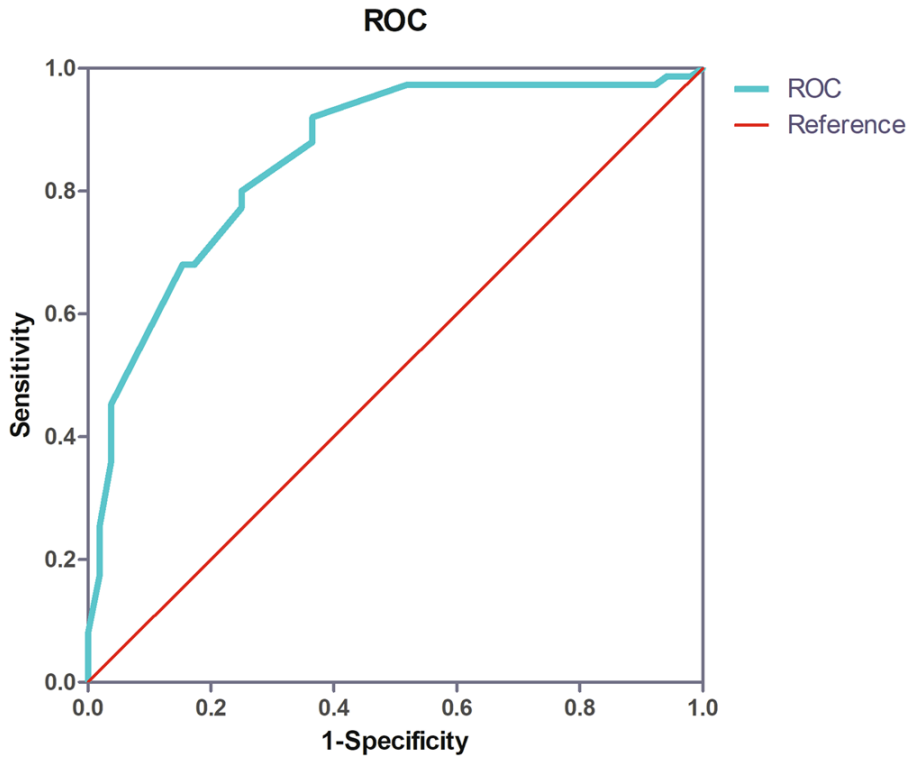


Figure 4 – *A-D, Correlations between A, lung ultrasound extension score and the CT scan volumetry of pulmonary lesions; B, lung ultrasound extension score and Pao_2/Fio_2 ratio; and C, CT scan volumetry of pulmonary lesions and Pao_2/Fio_2 ratio, in 179 patients with COVID-19 pneumonia. D, Correlations between lung ultrasound extension score and the CT scan volumetry of pulmonary lesions in a subgroup of 114 patients with Pao_2/Fio_2 ratio <300 mm Hg at presentation. CTvol = CT scan volumetry; LUSext = lung ultrasound extension score; P/F = Pao_2/Fio_2 ratio.*

Pneumonia – Pathogen ?

Bacterial vs. Viral pneumonia in 147 children hospitalized CAP

1) Consolidation size : Viral < Bacterial (15mm vs. 20mm, p<0.001)
2) Bilateral consolidation : Viral > Bacterial (51.9% vs. 8.0%, p<0.001)



Bacterial pneumonia Cut-off : 21mm (AUC 0.85)

Sci Rep (2019) 9:17957

Pleural Effusion

Pleural effusion by TUS

[Education and Clinical Practice Special Features]

CHEST

Better With Ultrasound

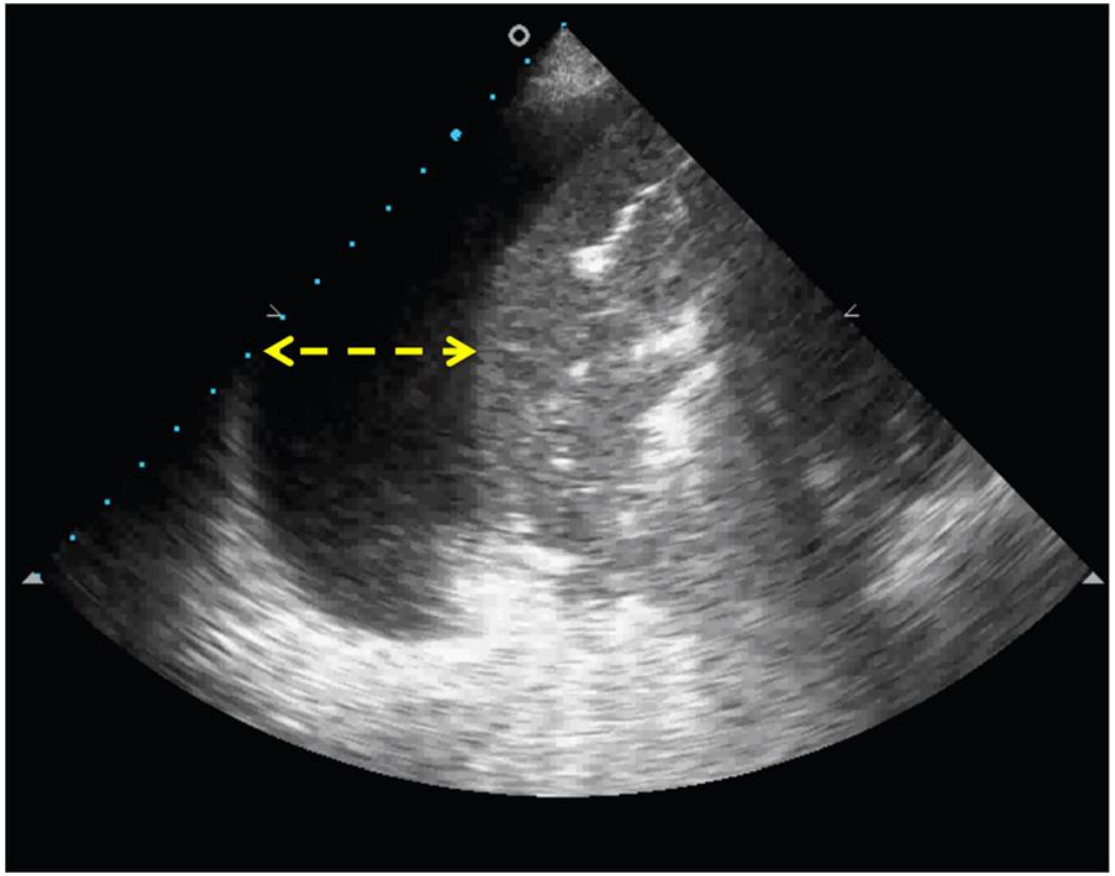
Thoracic Ultrasound

Ariel Hendin, MD; Seth Koenig, MD; and Scott J. Millington, MD

- For pleural effusion, LUS is extraordinarily sensitive and can detect fluid volumes as low as 5 to 20 mL, whereas standard upright chest radiograph typically cannot detect volumes < 150 mL.[21]
- Characterization of pleural fluid, with identification of septations, complexity, and loculations, is superior to other imaging modalities.
- Ultrasound can be used for procedural guidance, such as thoracentesis or thoracostomy tube placement.[22]

CHEST 2020; 158(5):2082-2089

Pleural effusion – Volume assessment



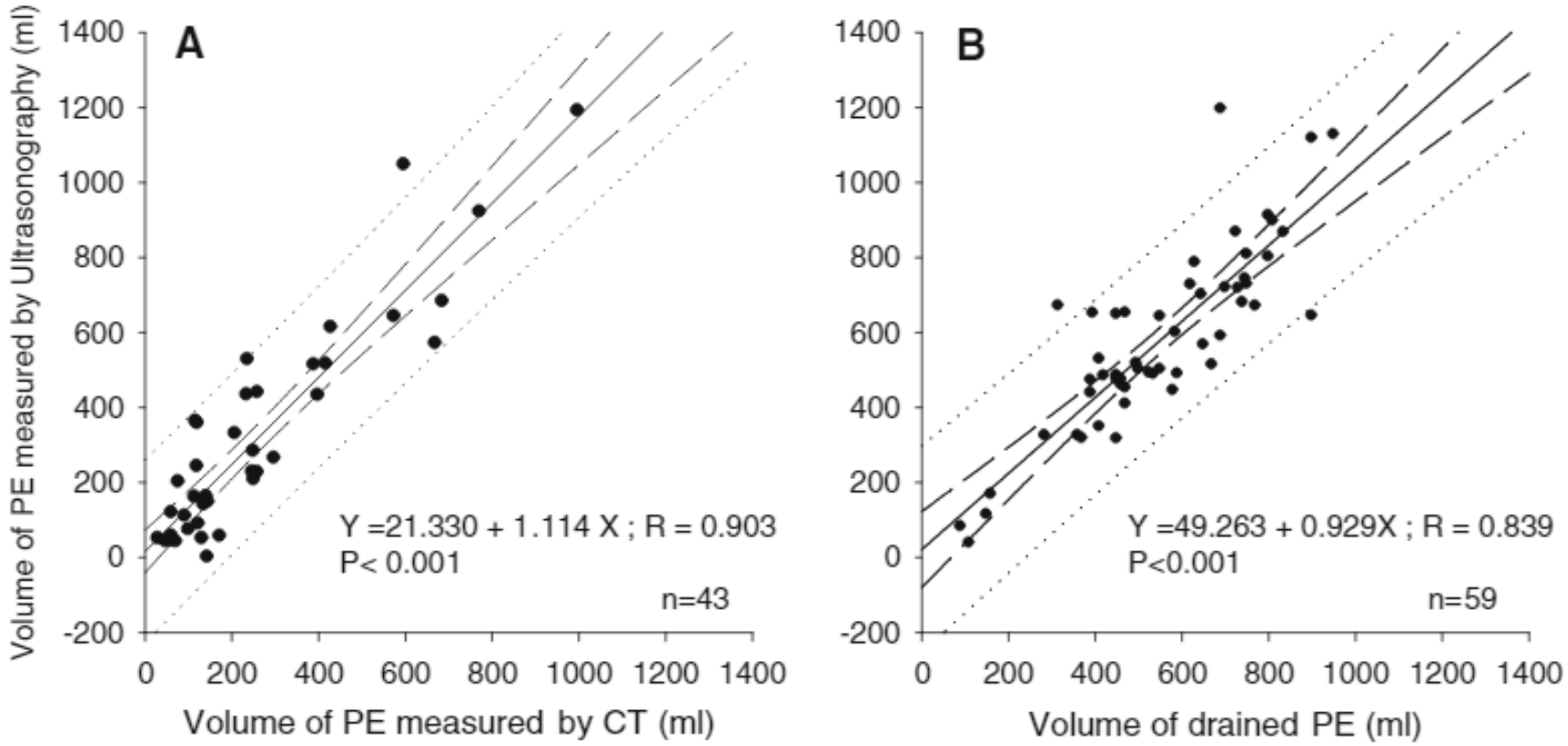
Maximal distance between mid-height of the diaphragm and visceral pleura (D)

→ V (ml) = 16 x D (mm)

Brogi et al. Critical Care (2017) 21:325

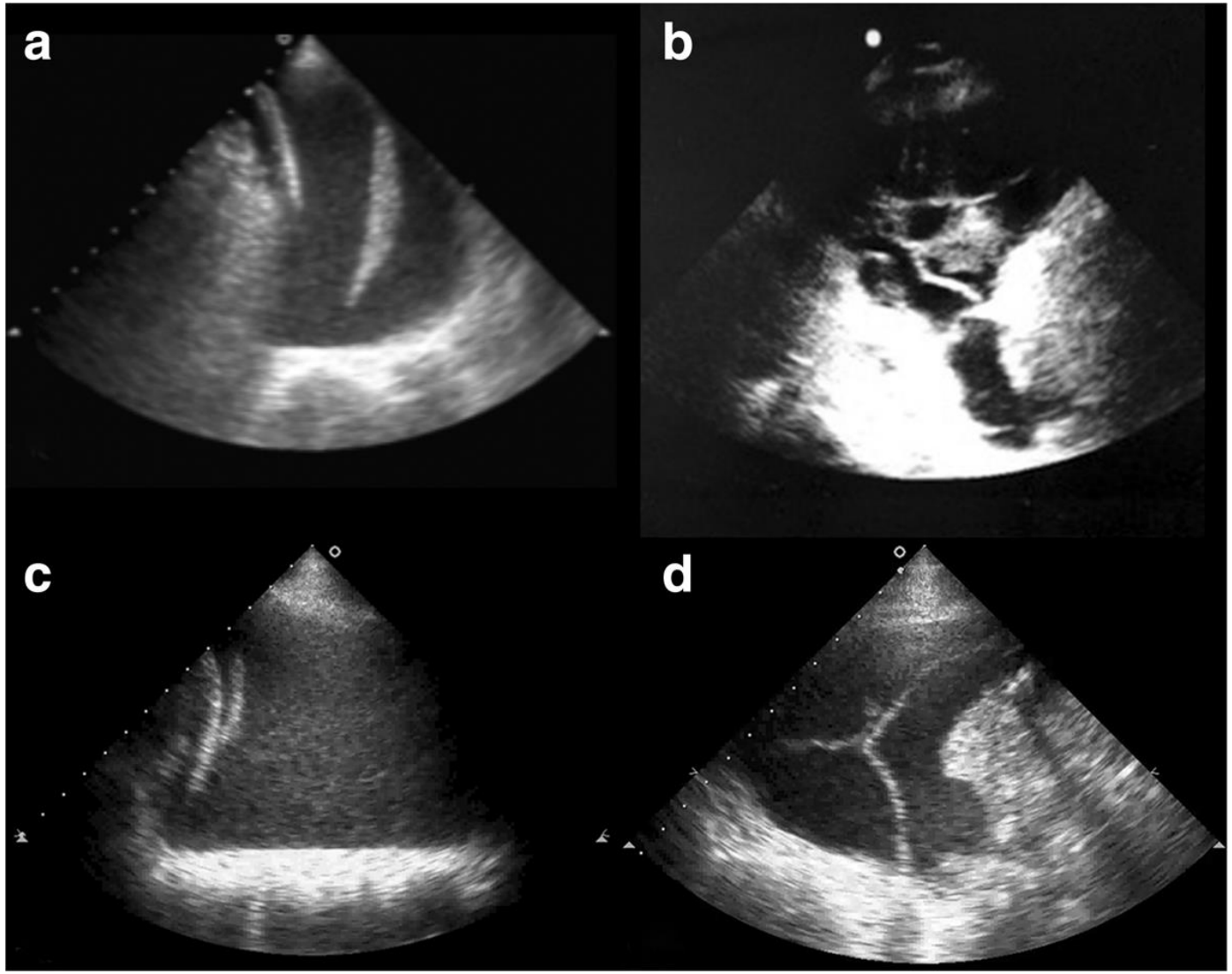
Pleural effusion – Volume assessment

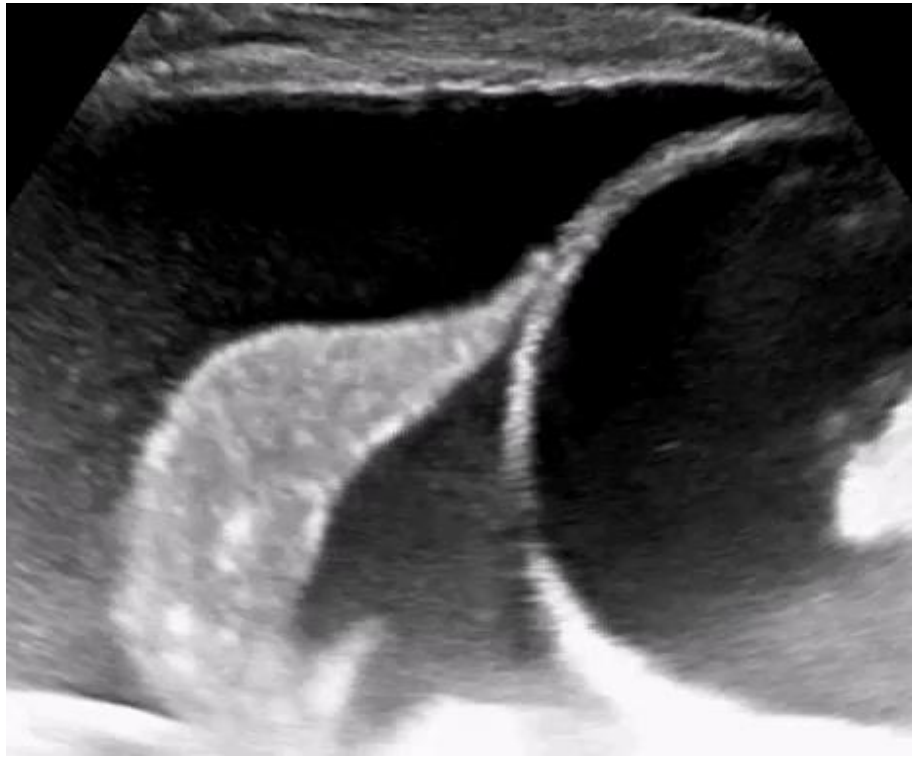
LUS is a sensitive tool for detection of pleural effusion



F. Remerand et al. ICM (2010) 36:656-664

Pleural effusion – Different types





Brogi et al. Critical Care (2017) 21:325

Pleural effusion – Malignant pleural effusions

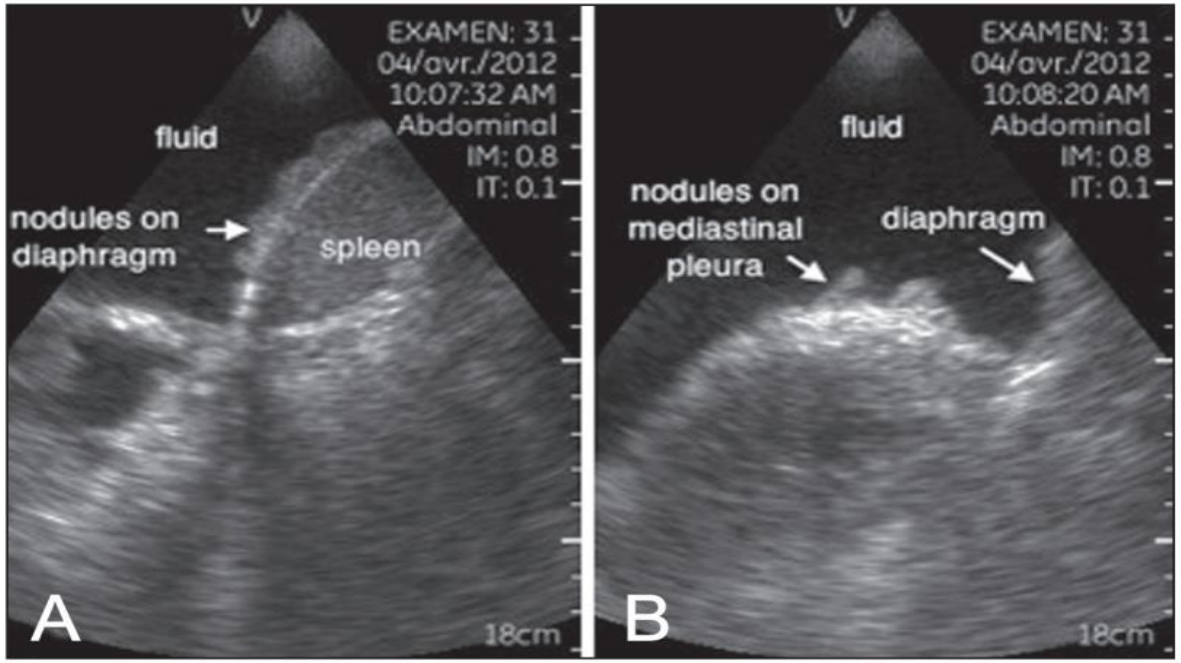


Figure 1) *Ultrasound images (Vscan, GE Healthcare, USA) (1.7 MHz to 3.8 MHz probe) of nodules on the diaphragm* (**A**) *and nodules on the mediastinal pleura* (**B**)

A & B

Malignant pleural effusion

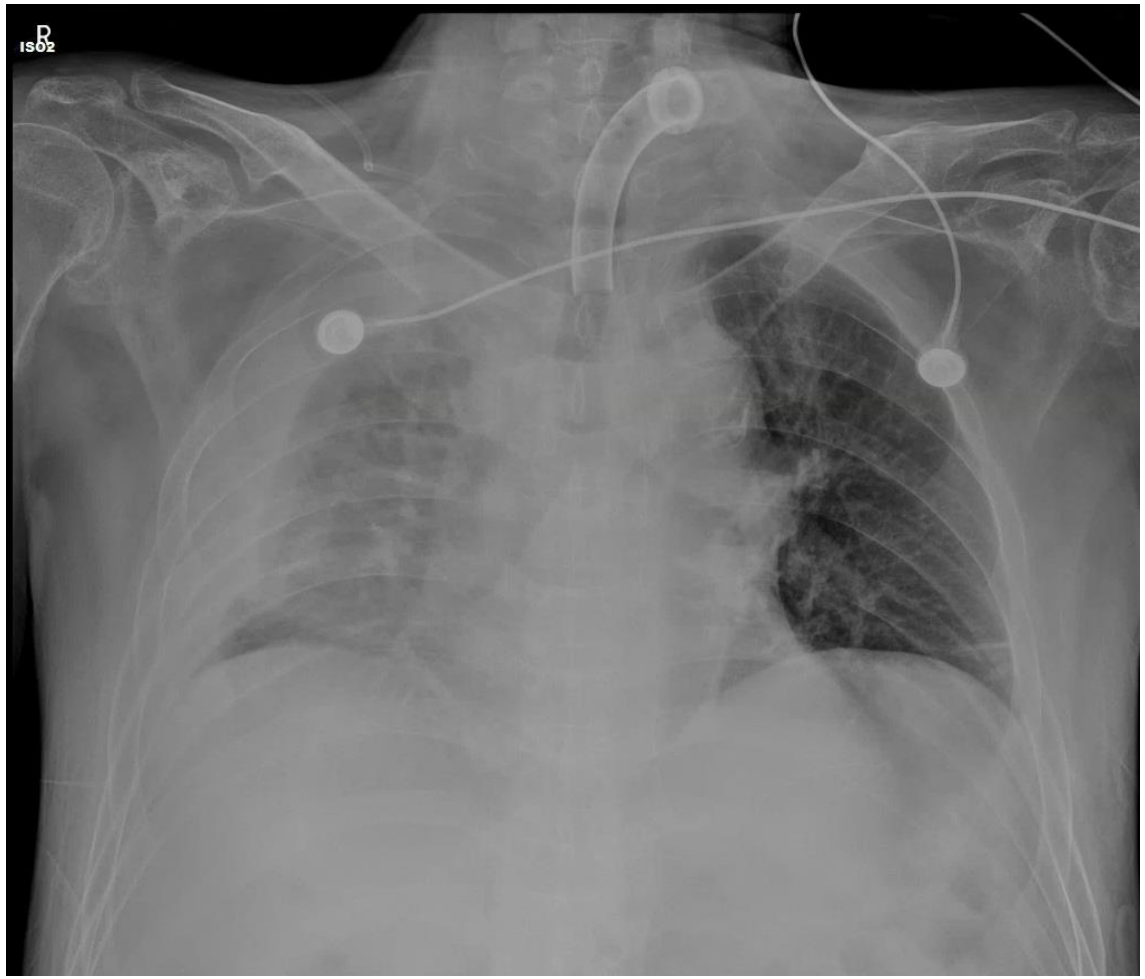
: nodules on diaphragm or nodules on parietal pleura

: pleural thickening > 1cm

: hepatic metastasis

Can Respir J Vol 20 No 1, 2013

증례 제목: 발열로 내원한 56세 남자

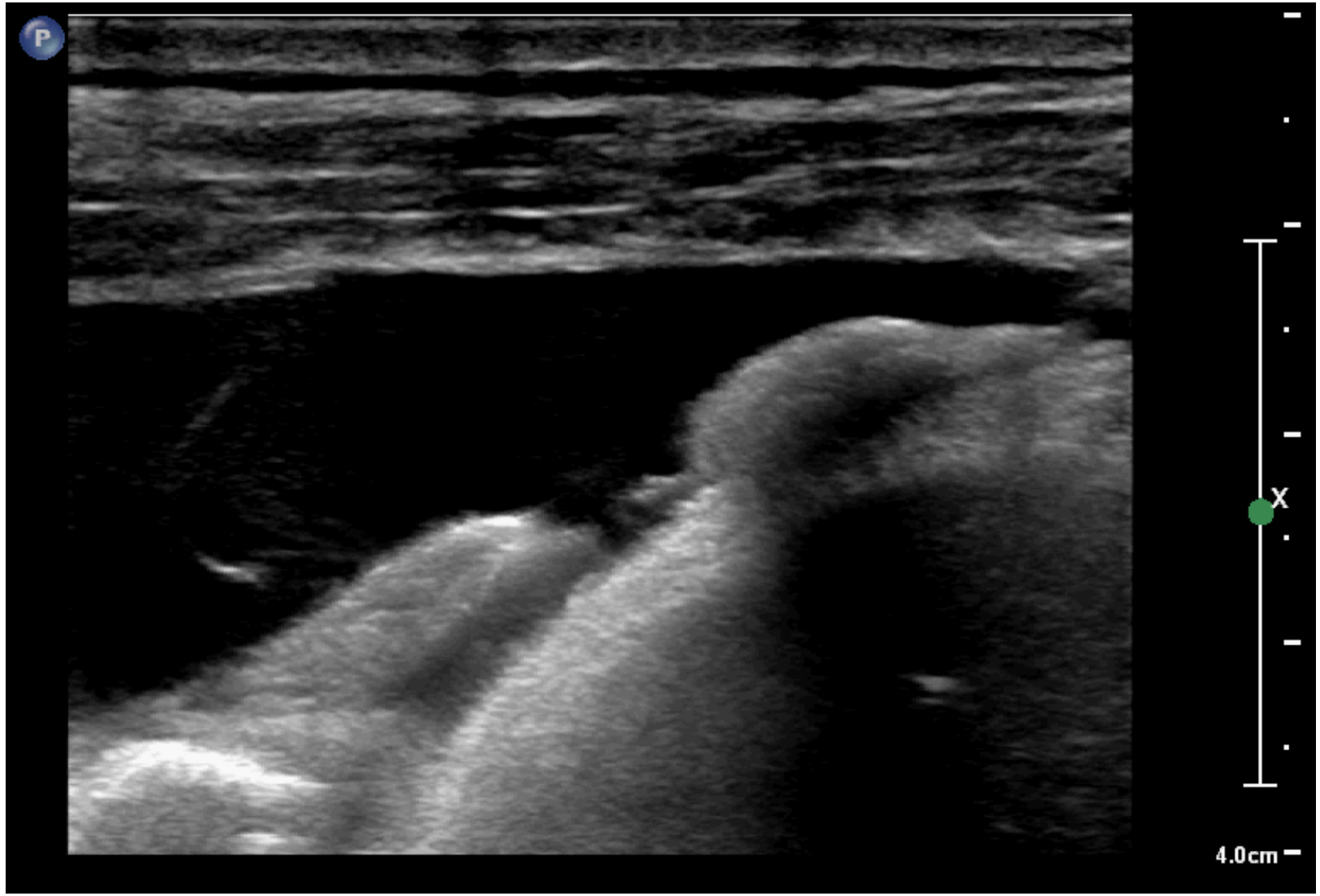


증례 요약:

#ICH, thalamus, Rt.
#Tracheostomy state

56세 남자가 발열로 내원 (BT 38.4)
내원하여 확인한 신체징후상 SBP 70mmHg로 감소
Lab. Data: WBC 16840 CRP 134
UA nitrite (-) WBC 2-3

X-ray: 우측 흉수소견
Aspiration history (-)
T-tube: yellowish sputum
흉수 소견에 대한 확인 위해 bedside US 진행함.



Pleural effusion – After pleurodesis

[Original Research **Disorders of the Pleura**]

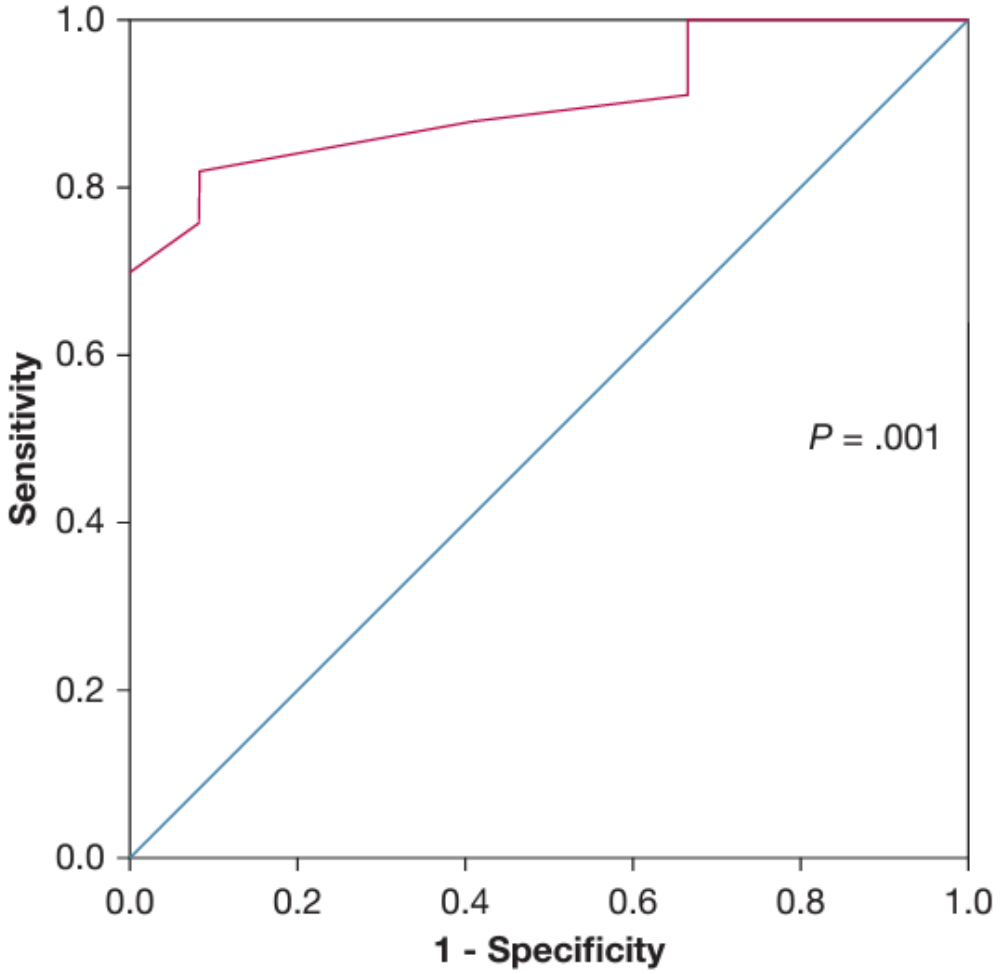
CHEST

Thoracic Ultrasound as an Early Predictor of Pleurodesis Success in Malignant Pleural Effusion

Check for updates

John P. Corcoran, BMBCh; Robert J. Hallifax, DPhil; Rachel M. Mercer, MBChB; Ahmed Yousuf, MBChB; Rachelle Asciak, MD; Maged Hassan, MBChB; Hania E. Piotrowska, BA; Ioannis Psallidas, PhD; and Najib M. Rahman, DPhil

- Total pleural adherence score
  - 24 h following talc slurry instillation
  - 9 zone (upper, middle, and lower zones in the anterior, lateral, and posterior chest wall)
  - present (0), questionable (1), or absent (2)
  - Cut off = 10 points

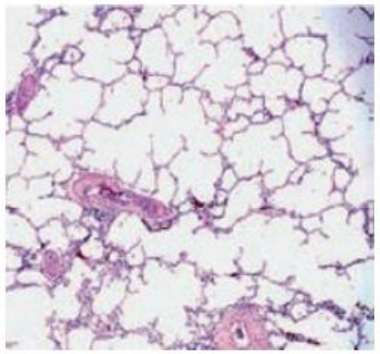


Dav 1: ROC area 0.900 (95% CI, 0.812-0.988)

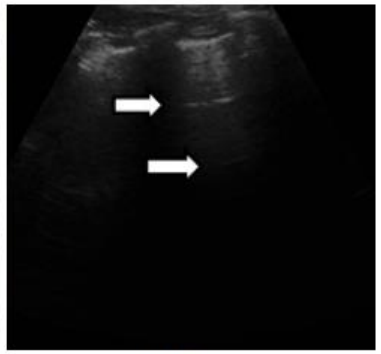
Chest. 2018 Nov;154(5):1115-1120

IPF/ILD

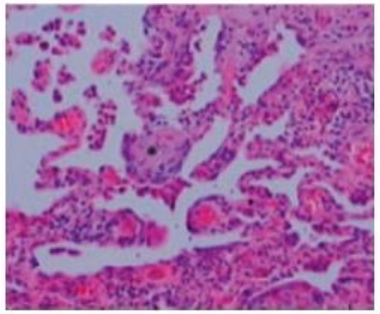
TUS findings in ILD



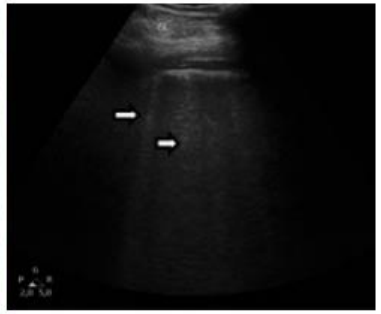
Normal lung



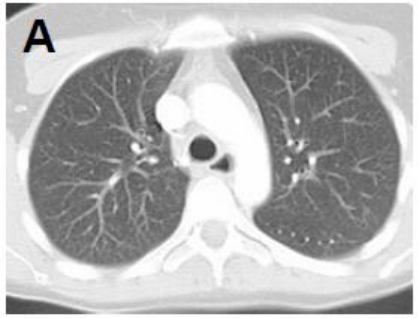
A-lines



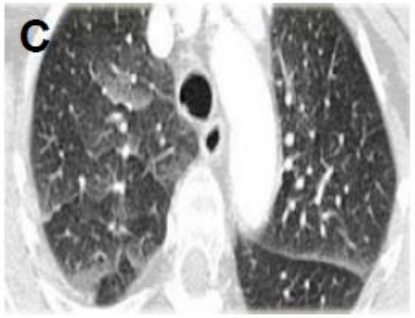
Fibrotic lung



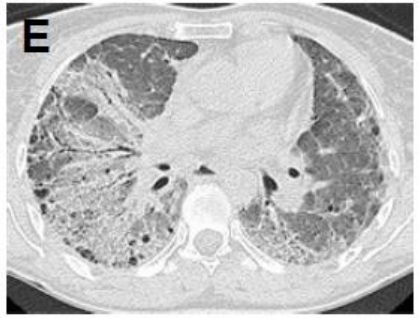
B-lines



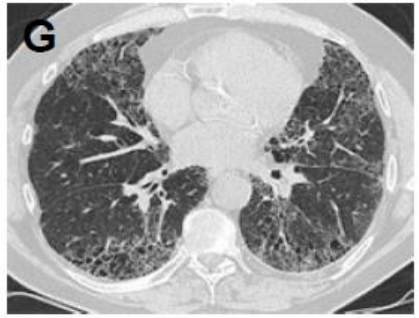
Normal transparency



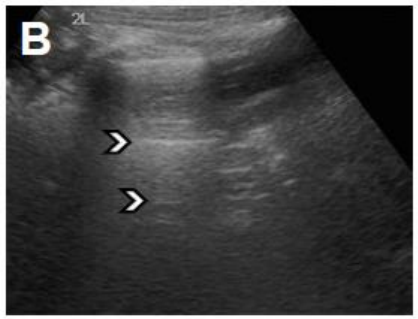
Extensive GGO



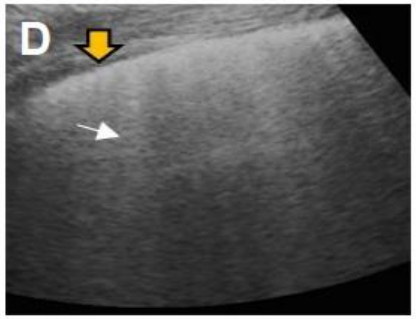
Fibrotic NSIP



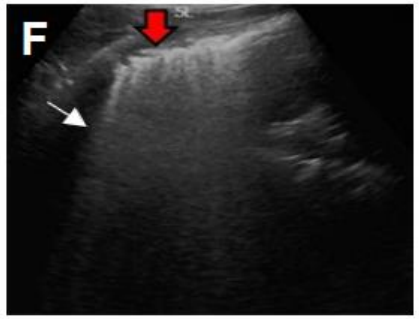
Fibrotic UIP



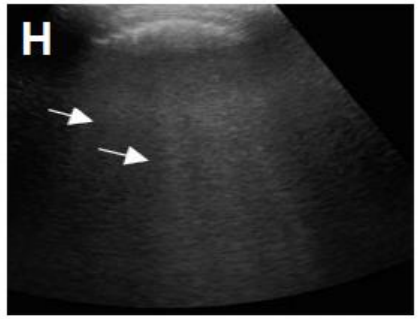
Normal aerated lung



White lung



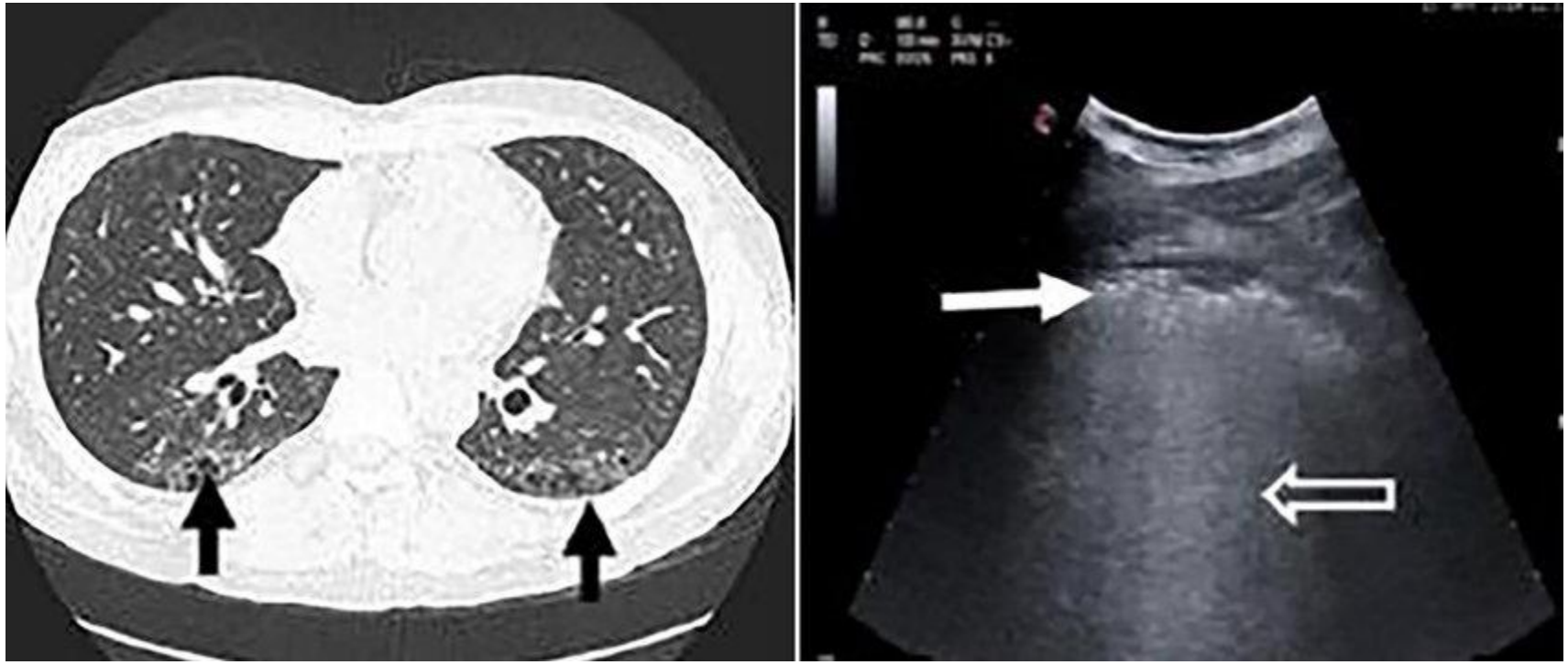
Fibrotic white lung



Fibrotic interstitial syndrome

Manolescu et al. Clinical Interventions in Aging 2018:!3

Honeycombing by TUS



Shanghai Chest 2018;2:41

TUS vs. HRCT in severity of IPF

Purpose : Compare LUS with HRCT and PFT in IPF patients

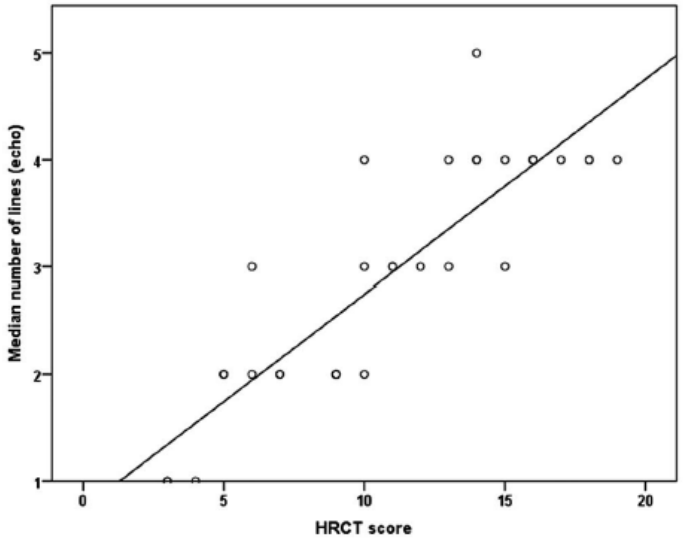
Methods : LUS (12-lung zone protocol) vs HRCT fibrosis index

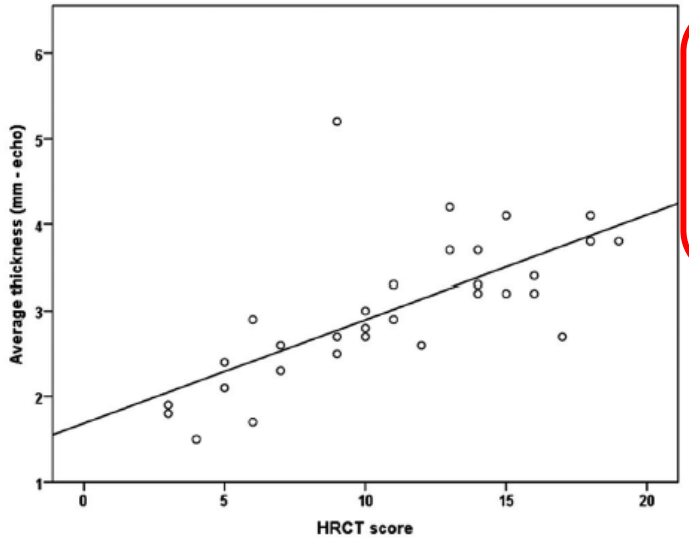
Study group : 31 patients with stable IPF (pathologic confirmed)

Results : Median number of B-lines, average thickness of pleura <-> HRCT fibrotic score (p<0.001)

: pleural thickness cut-off : 2.4mm

Conclusion : LUS is a good tool for IPF diagnosis and monitoring





	HRCT Severity			
	Mild	**Moderate**	**Severe**	***P*-value**
B-lines	2 [1-2]	3 [2-3]	4 [4-4]	<0.001*
Thickness of pleural line	1.9 [1.7-2.4]	2.8 [2.6-3.3]	3.4 [3.2-3.8]	<0.001*
FVC (%)	93 [78-108]	77 [72-84]	70 [55-72]	0.028*
FEV1 (%)	99 [76-104]	85 [73-92]	71 [66-82]	0.053
FEV1/FVC (%)	81.6 [75-86.3]	83.9 [81.3-85.2]	85.3 [83.3-89.6]	0.217
DLCO (%)	61 [58-85]	52 [41-60]	36 [32-45]	0.002*

Manolescu et al. Clin Respir J. 2019 Nov 1.

TUS in SSc ILD: PFT and Symptoms

Compare TUS B-line and HRCT in SSc: 40 SSc patients in Italy

- **At 14 lung intercostal space**

Table 3

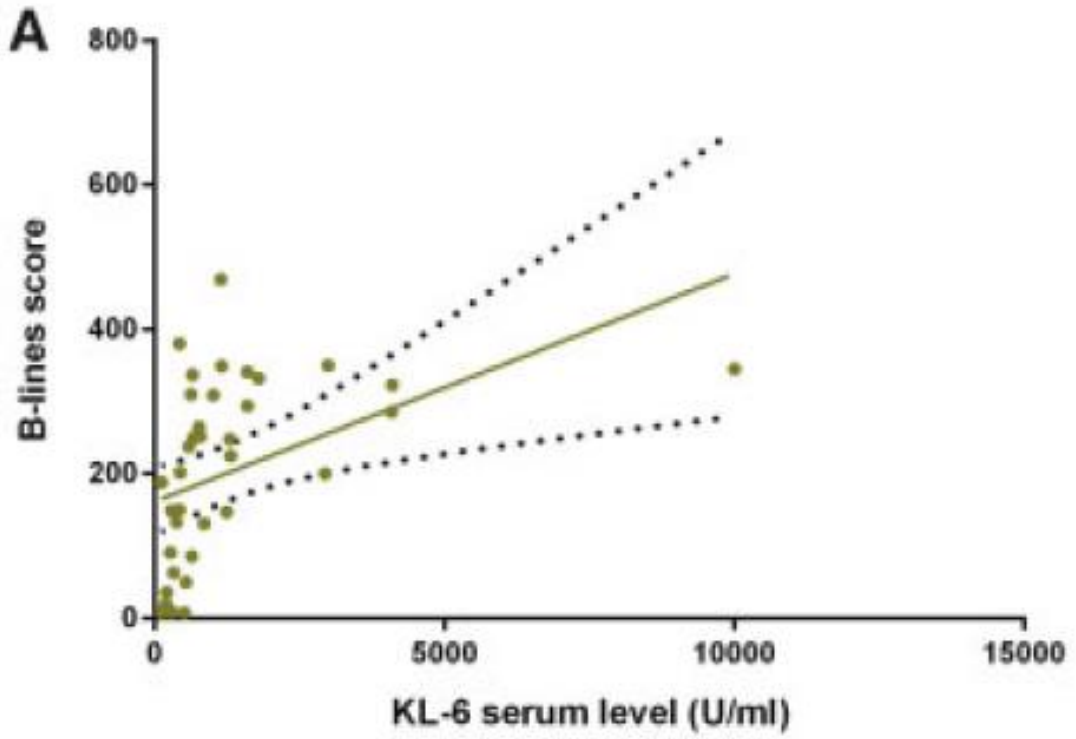
Correlation table (Spearman rank correlation coefficient) among clinical and health-related quality of life variables, pulmonary function tests characteristics, Warrick score, and lung ultrasound finding.

		DLco (%)	FEV1 (%)	FVC (%)	Rodnan skin score	SF-36 MCS	SF-36 PCS	Total LUS score	Warrick total score
Disease duration, mo	Correlation coefficient (rho)	0.175	0.137	0.085	0.436	0.234	0.105	-0.344	-0.420
	Significance Level *P*	.279	.398	.602	.005	.147	.520	.030	.007
DLco (%)	Correlation coefficient (rho)		.757	0.793	0.152	0.501	0.636	-0.600	-0.725
	Significance Level *P*		<.001	<.001	.348	.001	<.001	<.001	<.001
FEV1 (%)	Correlation coefficient (rho)			0.873	0.034	0.555	0.588	-0.439	-0.678
	Significance Level *P*			<.001	.822	<.001	<.001	.005	<.001
FVC (%)	Correlation coefficient (rho)				0.062	0.461	0.548	-0.507	-0.682
	Significance Level *P*				.706	.003	<.001	.001	<.001
Rodnan skin score	Correlation coefficient (rho)					0.070	0.051	-0.033	-0.145
	Significance Level *P*					.666	.754	.842	.373
SF-36 MCS	Correlation coefficient (rho)						0.850	-0.529	-0.667
	Significance Level *P*						<.001	<.001	<.001
SF-36 PCS	Correlation coefficient (rho)							-0.560	-0.663
	Significance Level *P*							<.001	<.001
Total LUS score	Correlation coefficient (rho)								0.819
	Significance Level *P*								<.001

DLco = diffusion capacity of carbon monoxide, FEV1 = forced expiratory volume in the first second, FVC = forced vital capacity, LUS = lung ultrasound, MCS = mental component summary scale score, PCS = physical component summary scale score, SF-36 = Short Form 36 questionnaire.

M. Tardella et al. Medicine (2018) 97:18

TUS vs. serum KL-6 in IBM ILD



38 patients, Inflammatory myositis-associated ILD

At 50 scanning sites

Conclusion

- correlated with KL-6 ($r=0.43$, $p<0.01$)

Yukai Wang et al. Rheumatology 2019;0:1-6

TUS for long-term outcome in SSc

[Diffuse Lung Disease Original Research]

CHEST

Prognostic Value of Lung Ultrasound B-Lines in Systemic Sclerosis

Check for updates

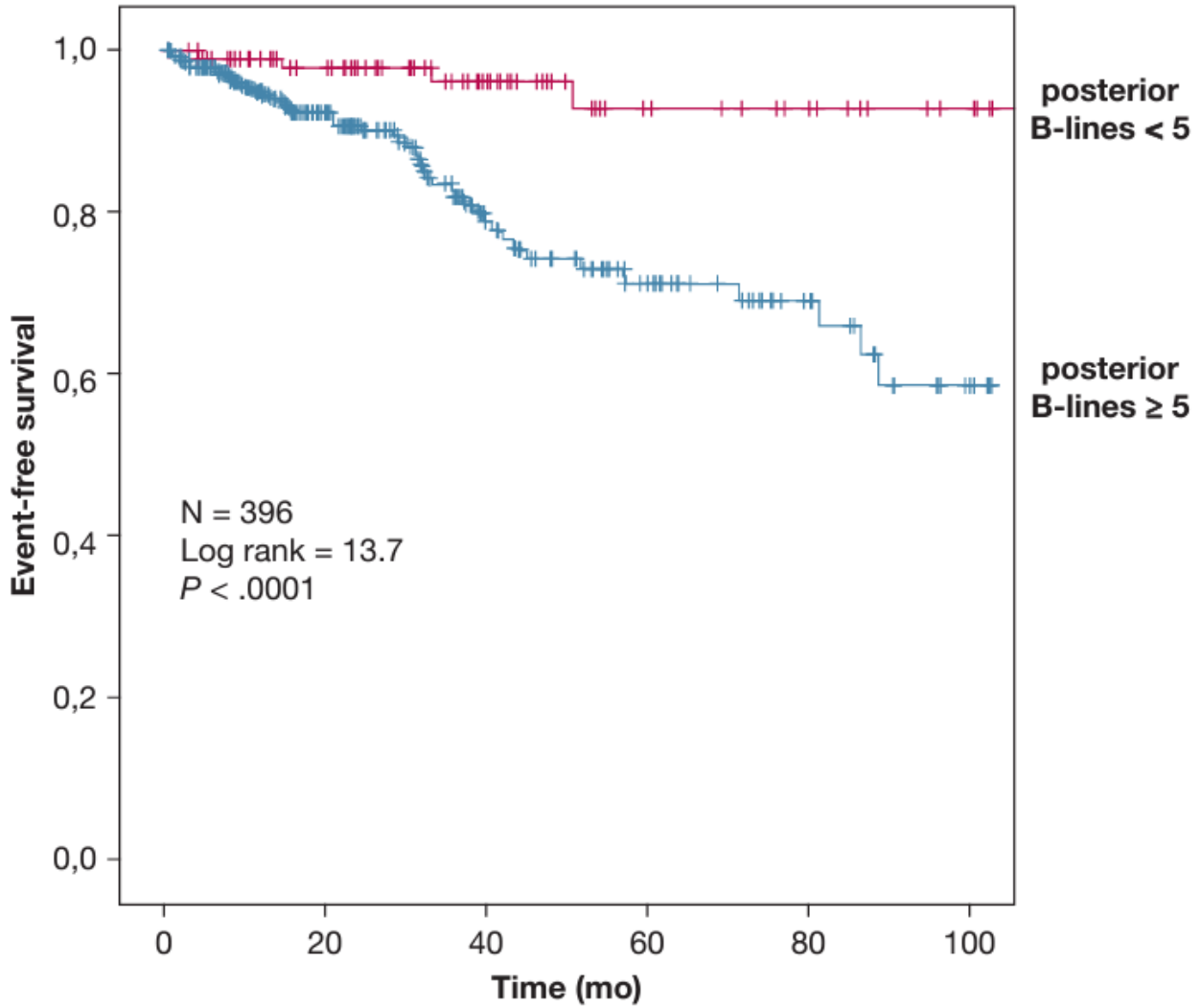
TABLE 2] Univariable and Multivariable Analysis for Association With Outcomes in the Study Population (n = 396)

Variable	Univariable, hazard ratio (95% CI)	*P* Value	Multivariable HR (95% CI)	*P* Value
Age	0.991 (0.972-1.010)	.358	…	…
Diffuse skin subset	1.119 (0.581-2.156)	.737	…	…
Anti-Topoisomerase I antibody positivity	2.886 (1.642-5.072)	.0001	2.987 (1.474-5.596)	.002
Modified Rodnan skin score	1.020 (0.989-1.052)	.216	…	…
Forced vital capacity, % predicted	0.996 (0.983-1.009)	.565	…	…
Diffusion capacity of lung oxide, % predicted	0.986 (0.970-1.002)	.081	1.010 (0.989-1.031)	.368
Total lung capacity, % predicted	0.976 (0.961-0.991)	.002	0.985 (0.967-1.003)	.101
Total posterior B-lines ≥ 5	5.557 (1.998-15.452)	< .001	3.378 (1.137-9.994)	.028

RIGHT mid-axillary	RIGHT anterior axillary	RIGHT mid-clavicular	RIGHT para-sternal	inter-costal space	LEFT para-sternal	LEFT mid-clavicular	LEFT anterior axillary	LEFT mid-axillary
				II				
				III				
				IV				
				V				

LEFT posterior axillary	LEFT linea scapularis	LEFT para-vertebral	inter-costal space	RIGHT para-vertebral	RIGHT linea scapularis	RIGHT posterior axillary
			II			
			III			
			IV			
			V			
			VI			
			VII			
			VIII			
			IX			

Chest. 2020 Oct;158(4):1515-1525



Subjects at risk

B-lines < 5	102	77	44	21	15	0
B-lines ≥ 5	294	160	71	40	23	6

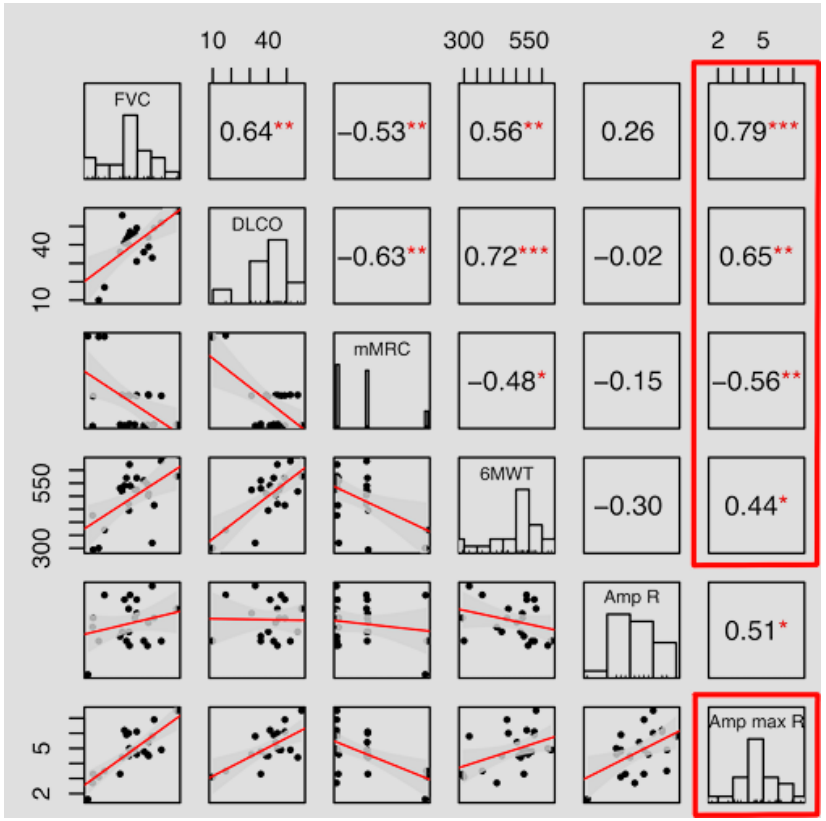
Chest. 2020 Oct;158(4):1515-1525

Diaphragm amplitude, lung functions, and lung density for IPF

STUDY PROTOCOL Open Access

Ultrasound evaluation of diaphragmatic function in patients with idiopathic pulmonary fibrosis: a retrospective observational study

Jules Milesi[1], Alain Boussuges[2], Paul Habert[3,4,5], Julien Bermudez[1], Martine Reynaud-Gaubert[1], Stéphane Delliaux[2], Fabienne Bregeon[2] and Benjamin Coiffard[1*]



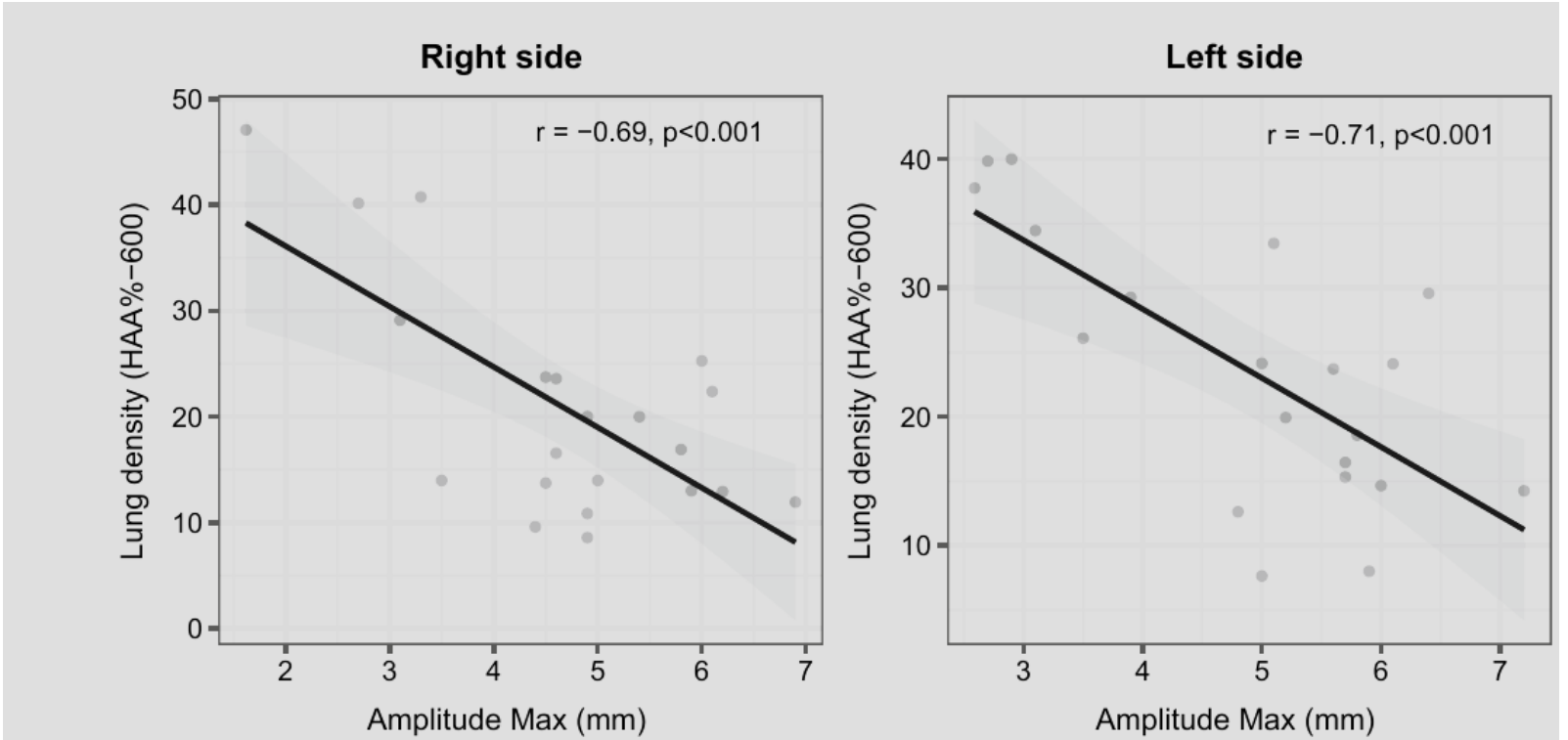
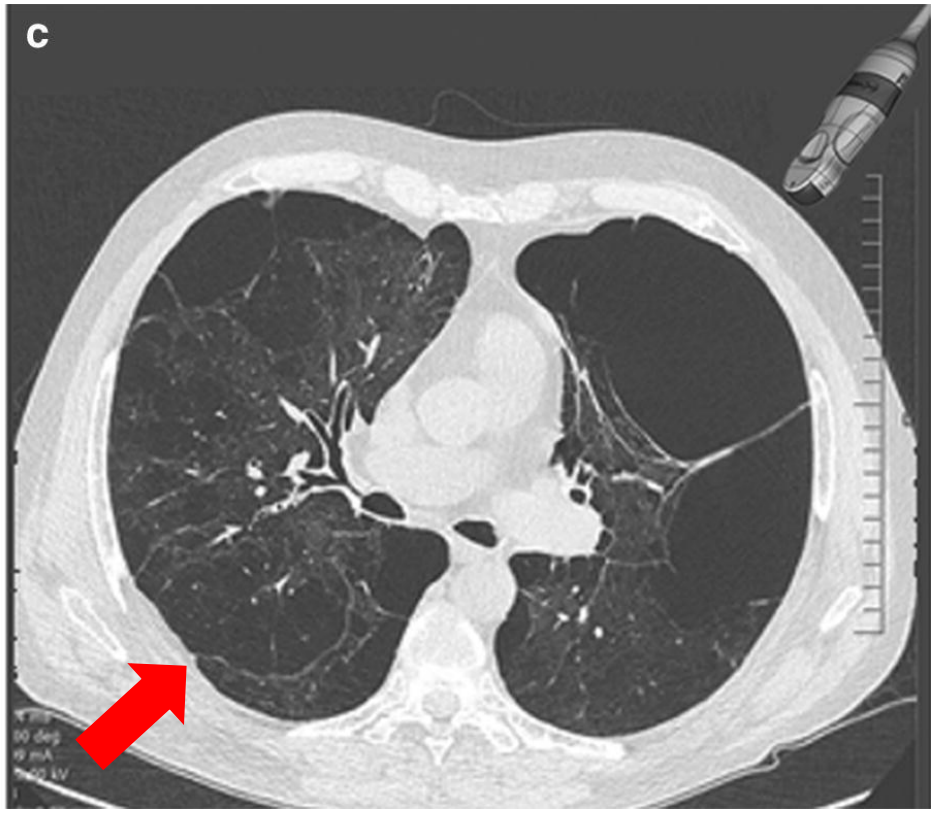
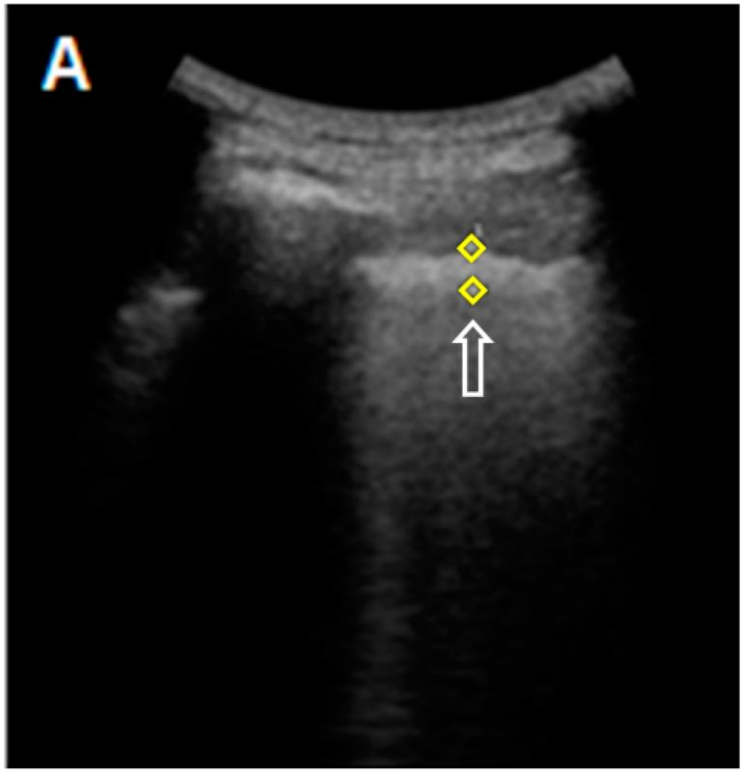


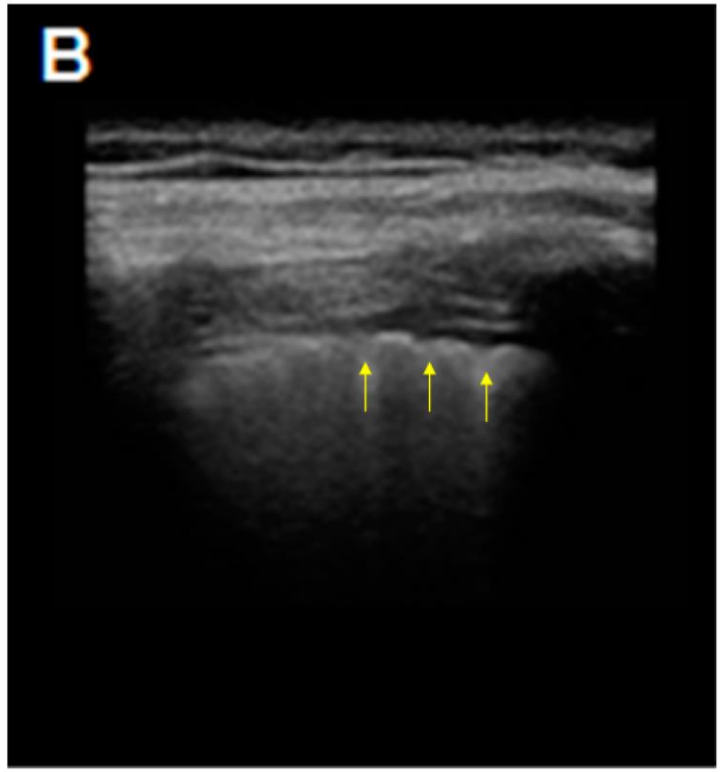
Fig. 2 Pearson correlation between HAA%-600 and maximal diaphragmatic amplitude in deep breathing in IPF patients

COPD

Emphysema, Fibrosis





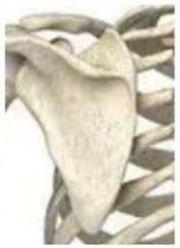


Lichtenstein et al. Intensive Care Med 2019 May;45(5):690-691

Diagnostics 2021, *11*(3), 439

Pleural slip distance and lung hyperinflation

Right midaxillary line	Right anterior axillary line	Right midclavicular line	Right Parasternal line	Intercostal space	Left Parasternal line	Left midclavicular line	Left anterior axillary line	Left midaxillary line
1	1	2	2	II	5	5	6	6
1	1	2	2	III	5	5	6	6
3	3	4	4	IV	7	7	8	8
3	3	4	4	V				

Left posterior axillary line	Left Scapular line	Left Paravertebral line	Intercostal space	Left paravertebral line	Left scapular line	Left posterior axillary line
9		11	I	13		15
9		11	II	13		15
9		11	III	13		15
9		11	IV	13		15
10		12	V	14		16
10	12	12	VI	14	14	16
10	12	12	VII	14	14	16
10	12	12	VIII	14	14	16
10	12	12	IX	14	14	16

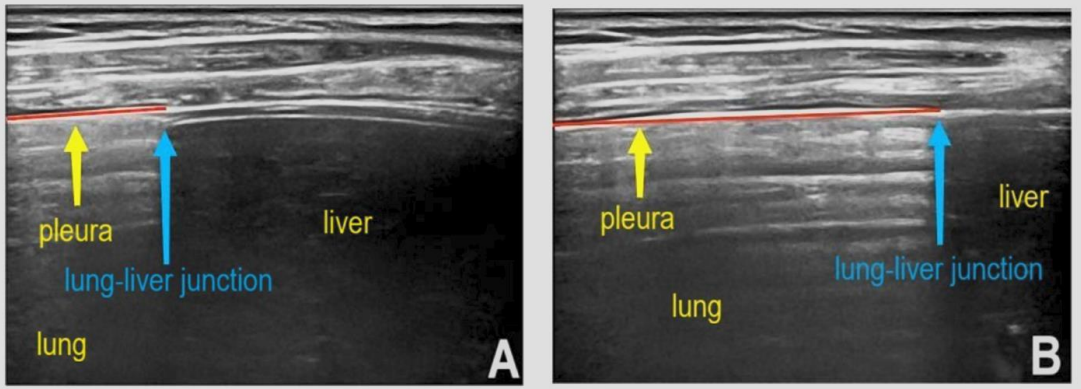


Figure 2 Pleural sliding displacement (PSD) measurement method. (**A**) The distance between the lung–liver junction and the left edge of the acoustic window of the ultrasound instrument was measured along the pleural line at the end of expiration. (**B**) The distance between the lung–liver junction and the left edge of the acoustic window of the ultrasound instrument was measured along the pleural line at the end of inspiration. The difference between the two values is the PSD.

0 points: normal pleural sliding and PSD≥ normal low
1 point: PSD < normal low + no pleural sliding sign in 2 area
2 points: PSD < normal low value + no pleural sliding (1–4 lung areas)
3 points: PSD < normal low value + no pleural sliding (5–8 lung areas)
4 points: PSD < normal low value + no pleural sliding (9–12 lung areas)
5 points: PSD < normal low value + no pleural sliding (12 lung regions)

IJCOPD 2024:19 319–330

Pleural slip distance and lung hyperinflation

Table 3 Correlation Between the Ultrasound Parameters and Pulmonary Function Indexes Reflecting LH

	Lung Ultrasound Score		PSD		DE at Tidal Inspiration		DE at Maximal Deep Inspiration	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
RV	0.72	<0.001	−0.56	<0.001	−0.11	0.08	−0.41	<0.001
TLC	0.41	<0.001	−0.28	<0.001	−0.08	0.22	−0.26	<0.001
FRC	0.70	<0.001	−0.63	<0.001	−0.02	0.74	−0.43	<0.001
IC	−0.56	<0.001	0.57	<0.001	−0.01	0.94	0.30	<0.001
RV/TLC	0.72	<0.001	−0.58	<0.001	−0.10	0.12	−0.40	<0.001
IC/TLC	−0.65	<0.001	0.62	<0.001	0.01	0.89	0.37	<0.001

Abbreviations: PSD, pleura sliding displacement; DE, diaphragm excursion; RV, residual volumetotal; TLC, total lung capacity; FRC, functional residual capacity; IC, inspiratory capacity.

Table 4 Correlation Between the Ultrasound Parameters and COPD Score

	Lung Ultrasound Score		PSD		DE at Tidal Inspiration		DE at Maximal Deep Inspiration	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
mMRC score	0.70	<0.001	−0.59	<0.001	−0.12	0.05	−0.60	<0.001
CAT score	0.69	<0.001	−0.54	<0.001	−0.12	0.05	−0.61	<0.001

Abbreviations: PSD, pleura sliding displacement; DE, diaphragm excursion; mMRC, modified Medical Research Council; CAT, COPD Assessment Test.

DUS: stable vs. AE in COPD

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Open Access Full Text Article ORIGINAL RESEARCH

Diaphragm Ultrasound is an Imaging Biomarker that Distinguishes Exacerbation Status from Stable Chronic Obstructive Pulmonary Disease

Table 4 Logistic Regression Analysis for Estimating Exacerbation of Chronic Obstructive Pulmonary Diseases

Model 1	**Univariate**		**Multivariate**	
	p-value	OR (95% CI)	*p*-value	OR (95% CI)
Age	0.722	0.99 (0.94–1.05)	0.682	0.98 (0.91–1.06)
Male sex	0.317	1.96 (0.53–7.28)	0.544	1.74 (0.29–10.34)
mCCI	0.049	1.62 (1.00–2.62)	0.157	1.73 (0.81–3.70)
BMI	0.007	0.80 (0.68–0.94)	0.002	0.70 (0.56–0.88)
Low TF_{max}	0.006	5.57 (1.64–18.94)	0.014	8.40 (1.55–45.56)
Model 2	**Univariate**		**Multivariate**	
Age	0.722	0.99 (0.94–1.05)	0.233	0.95 (0.88–1.03)
Male sex	0.317	1.957 (0.53–7.28)	0.393	2.16 (0.37–12.67)
mCCI	0.049	1.62 (1.00–2.62)	0.032	2.68 (1.09–6.60)
BMI	0.007	0.80 (0.68–0.94)	0.022	0.79 (0.64–0.97)
Low DE_{max}	0.011	16.25 (1.92–137.78)	0.038	11.51 (1.15–115.56)

Abbreviations: mCCI, modified Charlson Comorbidity Index; BMI, body mass index; TF_{max}, diaphragm thickening fraction during maximal deep breathing; DE_{max}, diaphragm excursion during maximal deep breathing.

IJCOPD 2022:17

Diaphragm excursion in COPD

Systematic Review and Meta-Analysis

Medicine

OPEN

Ultrasonographic evaluation of diaphragm function in patients with chronic obstructive pulmonary disease

A systematic review and meta-analysis

Zeng Hua-Rong, BS[a], Chen Liang, MS[b], Liu Rong, MD
Liu Zu-Lin, BS[a]

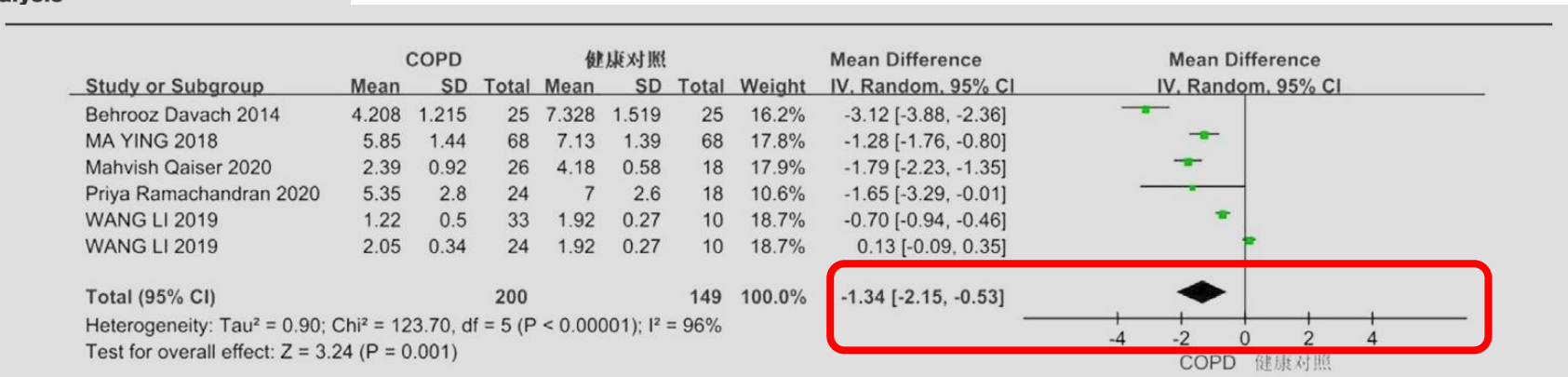


Figure 3. Diaphragm deviation in patients with chronic obstructive pulmonary disease (COPD) and healthy controls.

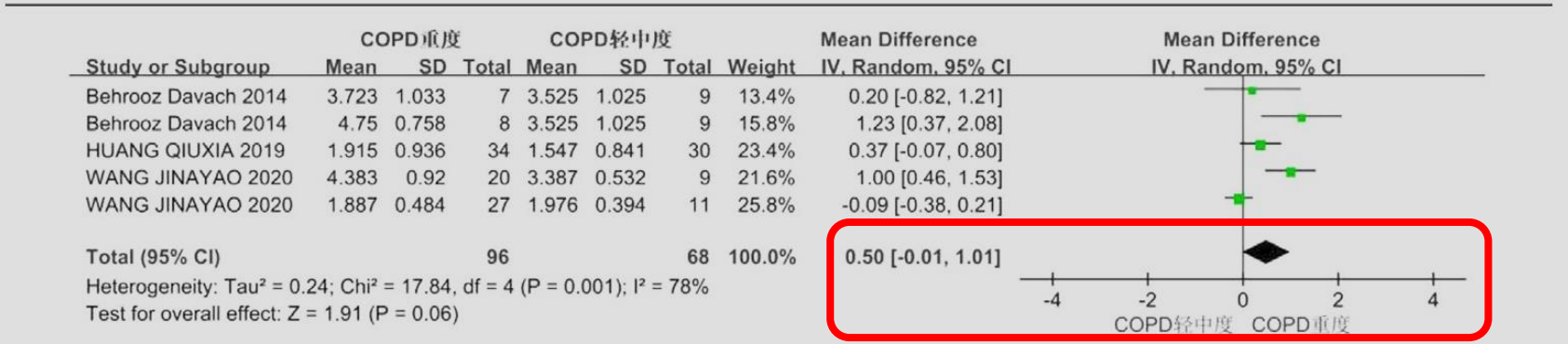


Figure 4. Diaphragm deviation in the mild-to-moderate and severe chronic obstructive pulmonary disease (COPD) groups.

Parasternal intercostal muscle in COPD

Ultrasound Evaluation of Parasternal Intercostal, Diaphragm Activity and Their Ratio in Male Patients with COPD

Nuttapol Rittayamai, MD; Vilasinee Marinpong[1], MD; Benjamas Chuaychoo[1], MD, PhD; Jamsak Tscheikuna[1], MD; Laurent J. Brochard, MD, PhD[2,3]

Table 1. Baseline characteristics, spirometry, and diaphragm and parasternal intercostal muscle ultrasound compared between patients with stable COPD and healthy subjects.

Variables	Healthy subjects (n=15)	Patients with COPD (n=30)	*P* value
Diaphragm ultrasound			
• Tdi at end-expiration, mm.	1.9 [1.7-2.1]	1.9 [1.7-2.4]	0.500
• Tdi at end-inspiration, mm.	2.3 [2.0-2.4]	2.5 [2.1-3.1]	0.046
• TFdi, %	21.5 [13.7-27.2]	29.7 [23.1-50.1]	0.002
Parasternal intercostal muscle ultrasound			
• Tic at end-expiration, mm.	1.9 [1.7-2.4]	2.1 [1.7-2.9]	0.709
• Tic at end-inspiration, mm.	2.0 [1.8-2.5]	2.3 [2.0-3.2]	0.092
• TFic, %	2.5 [1.7-4.7]	17.8 [11.1-21.6]	< 0.001

AJRCCM 2024

B-line in COPD: Why HF is important in COPD?

Original research

Cause-specific mortality in COPD subpopulations: a cohort study of 339 647 people in England

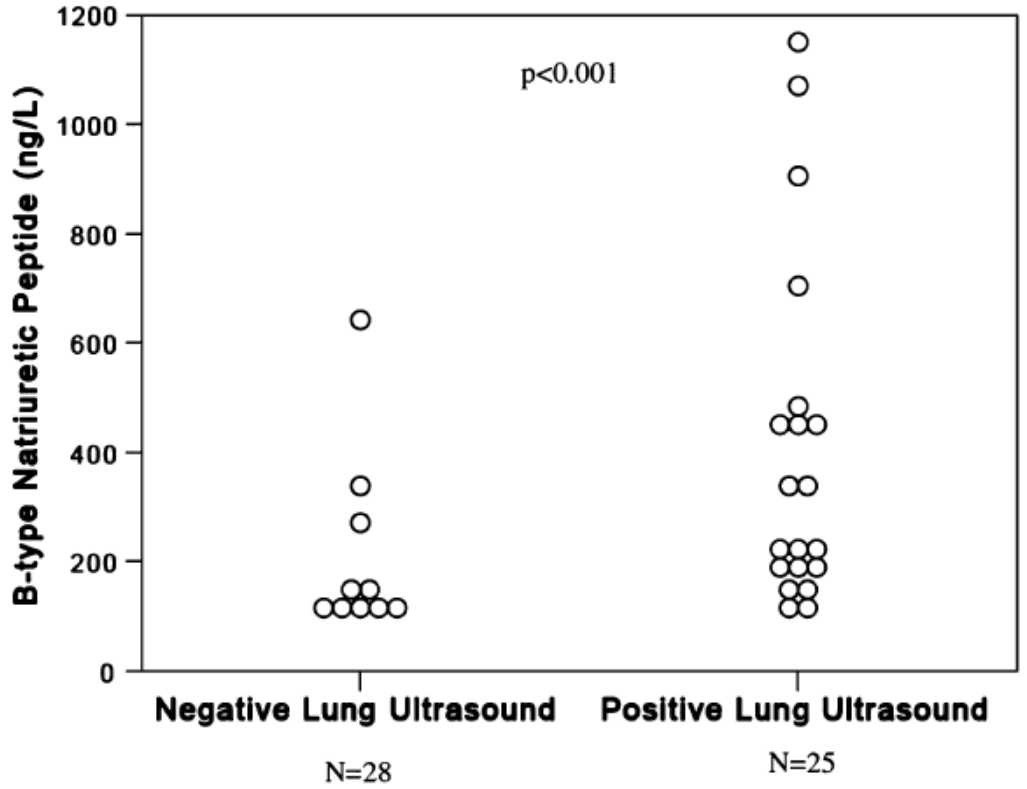
Hannah Whittaker,[1] Kieran J Rothnie,[2] Jennifer K Quint [1]

339647 people with COPD 97882 died

- 25.7% COPD
- 23.3% CV related

BMJ 2024

B-line and BNP correlation in COPD



B-line in COPD AE = COPD + increased BNP or HF

Sriram KB et al. Intern Med J. 2017 Mar;47(3):324-327

B-line in AECOPD and HF

International Journal of Chronic Obstructive Pulmonary Disease
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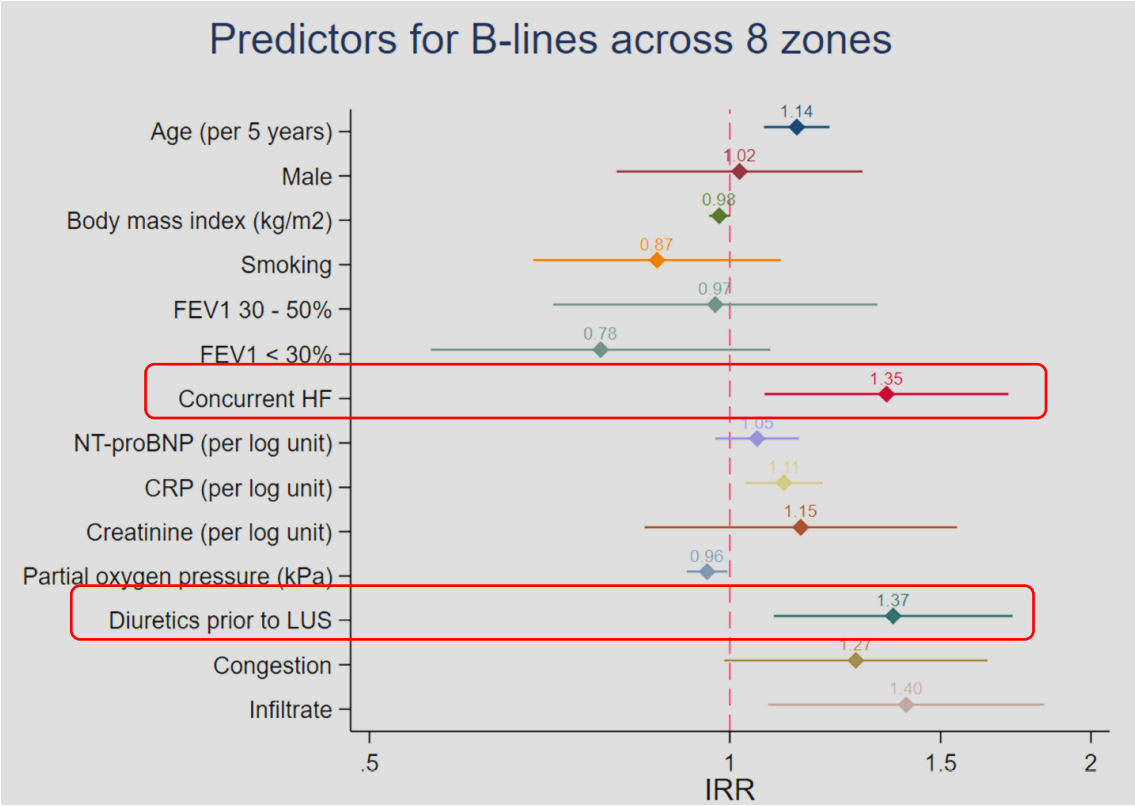
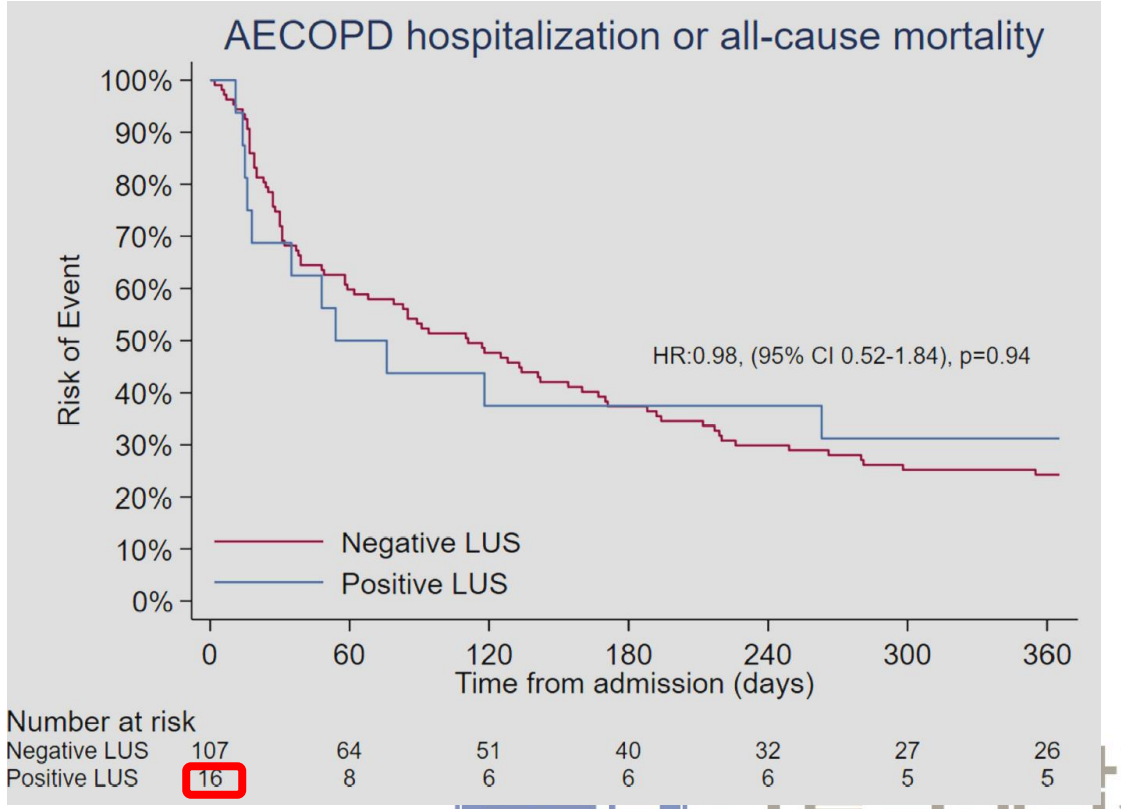
ORIGINAL RESEARCH

Lung Ultrasound to Assess Pulmonary Congestion in Patients with Acute Exacerbation of COPD





IJCOPD 2023:18 693–703

Pre-hospital B-lines for management of AE

Pre-hospital TUS in COPD

- Patients who has COPD or HF in Vicenza, Italy
- Case-Control study
- Pre-hospital TUS guided management (drugs, Oxygen, Lab tests)

Conclusion

- More appropriate pharmacologic therapy (p=0.01)
- Appropriate CPAP in COPD (p=0.011)
- TUS guided management: lower PCO2 than control (52.23mmHg vs. 42.62mmHg, p=0.049)

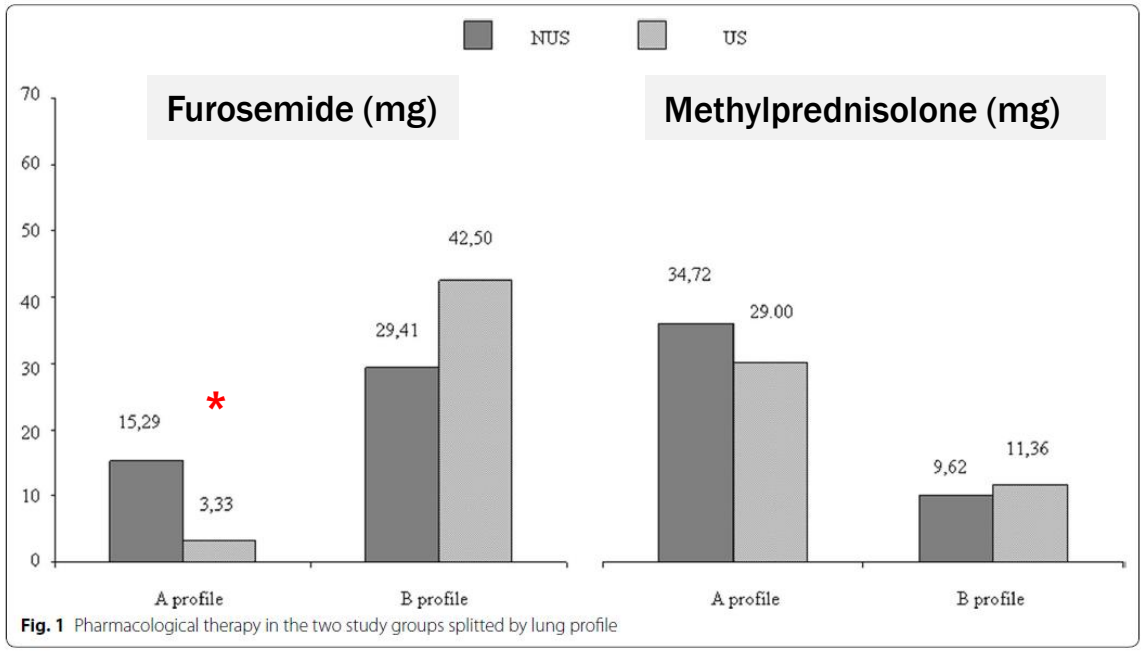


Fig. 1 Pharmacological therapy in the two study groups splitted by lung profile

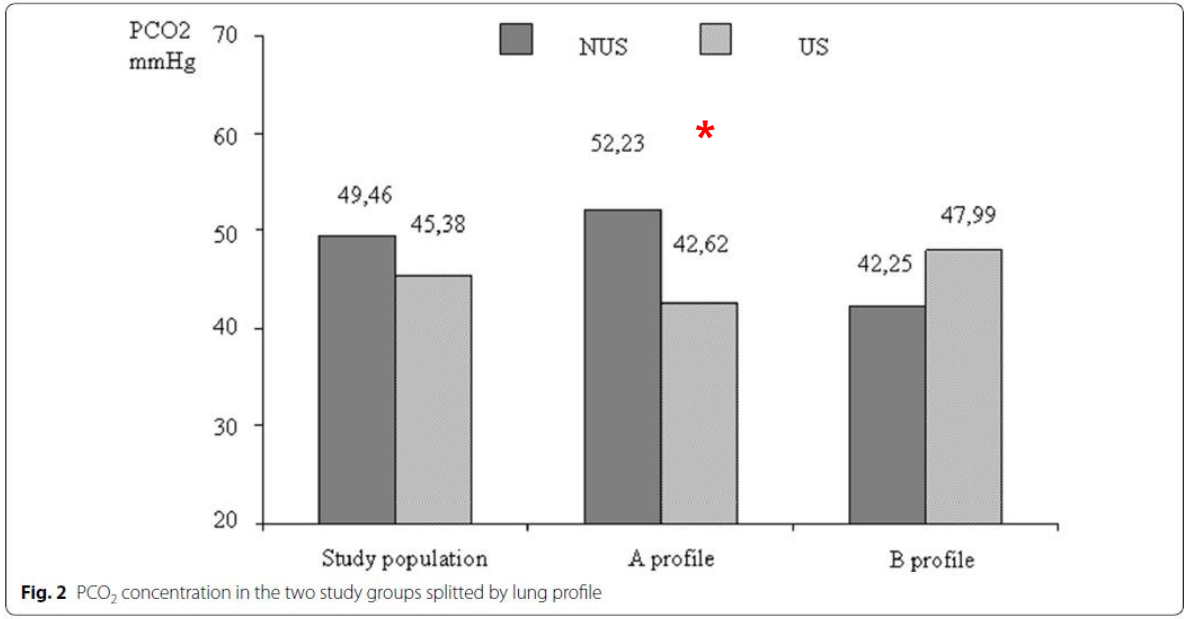
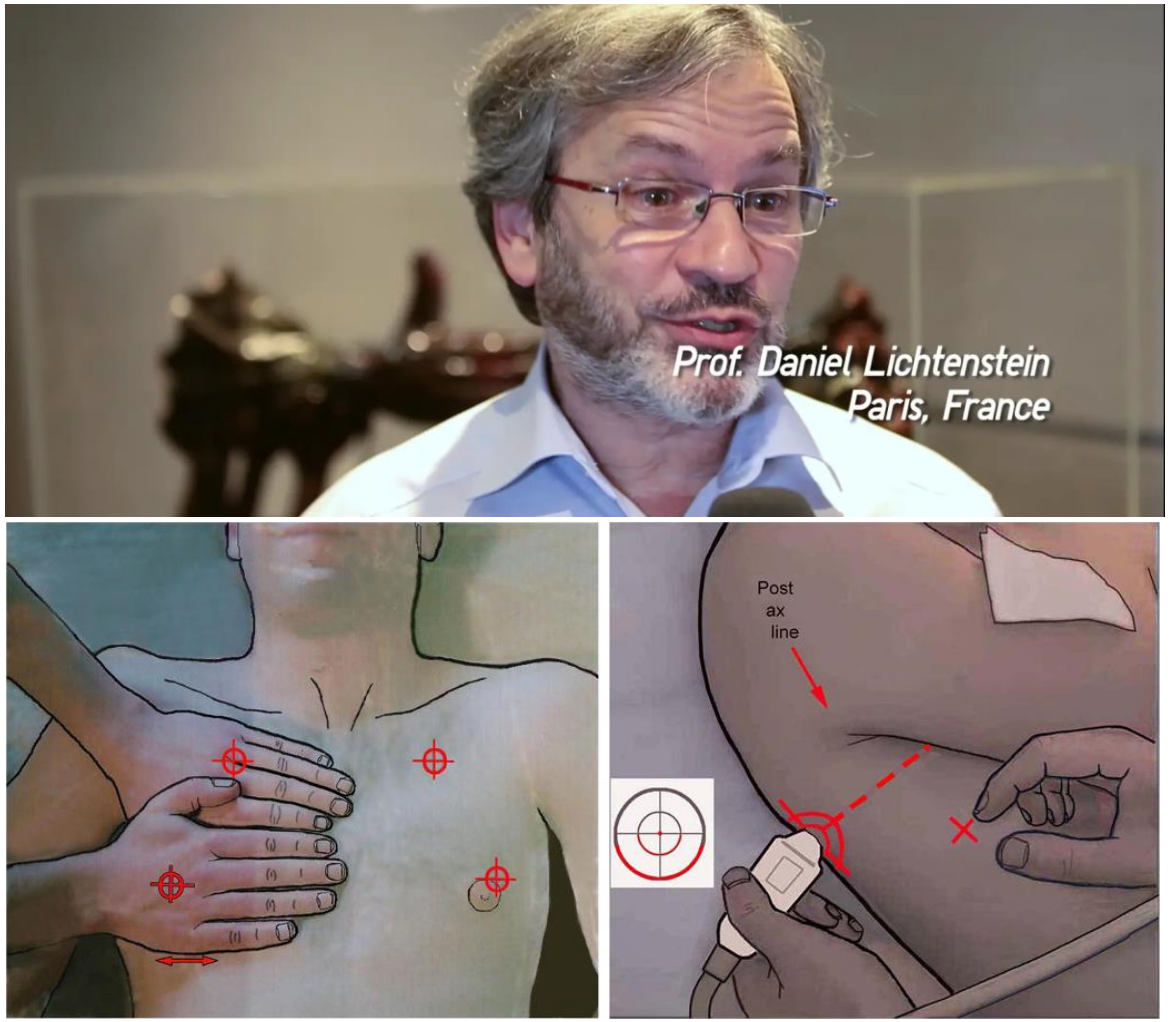


Fig. 2 PCO_2 concentration in the two study groups splitted by lung profile

Zanatta et al. Crit Ultrasound J (2018) 10:22

Protocols

BLUE protocol (Bedside Lung Ultrasound in Emergency)



Lichtenstein. Annals of Intensive Care 2014, 4:1
Lichtenstein. Acute and Critical Care 32(1):1-8, 2017

Proposal of AJRCCM review

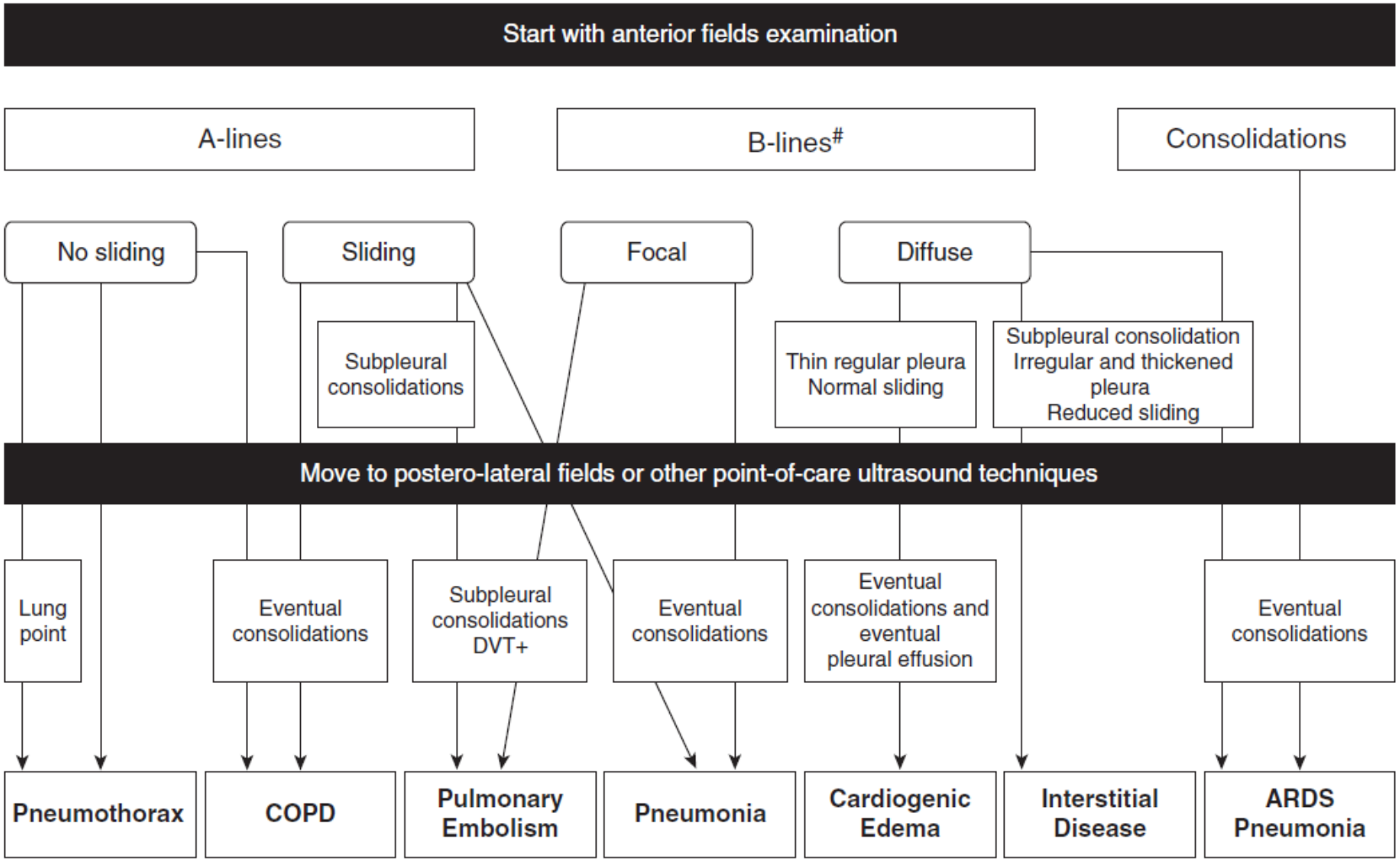
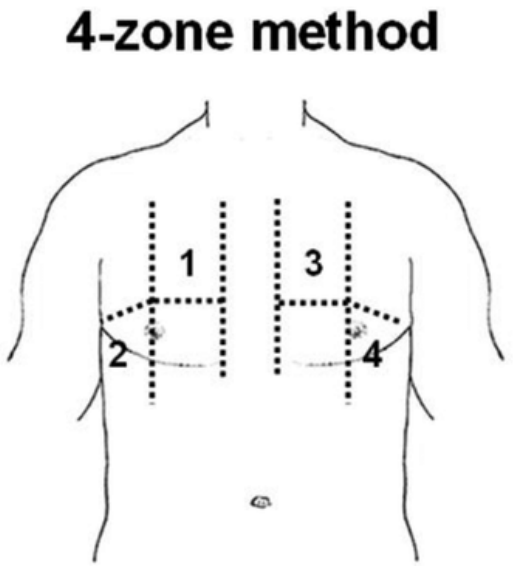


Figure 4. A proposal for a systematic diagnostic approach to acute respiratory failure based on literature findings (ARDS = acute respiratory distress syndrome; COPD = chronic pulmonary obstructive disease; DVT = deep venous thrombosis). #At least three B-lines per scan.

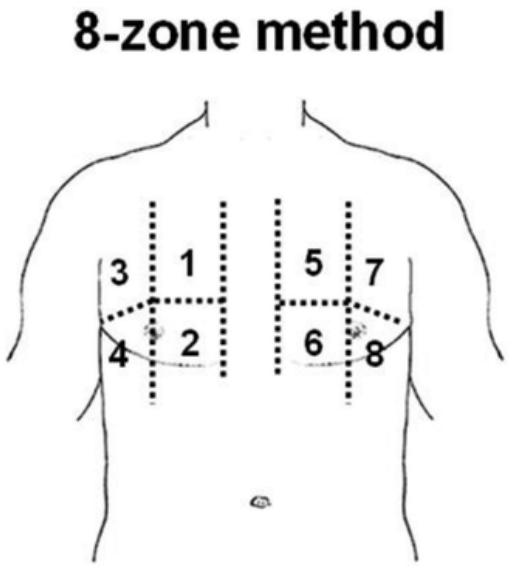
AJRCCM Vol 199. No 6, March, 2019

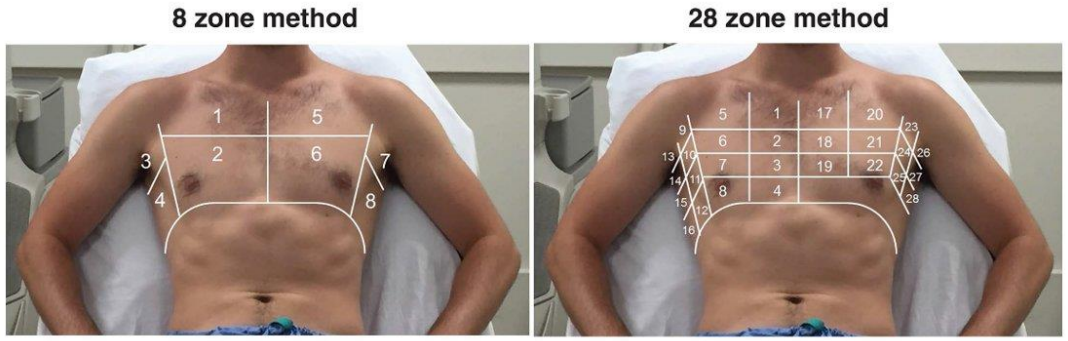
Various Scanning method

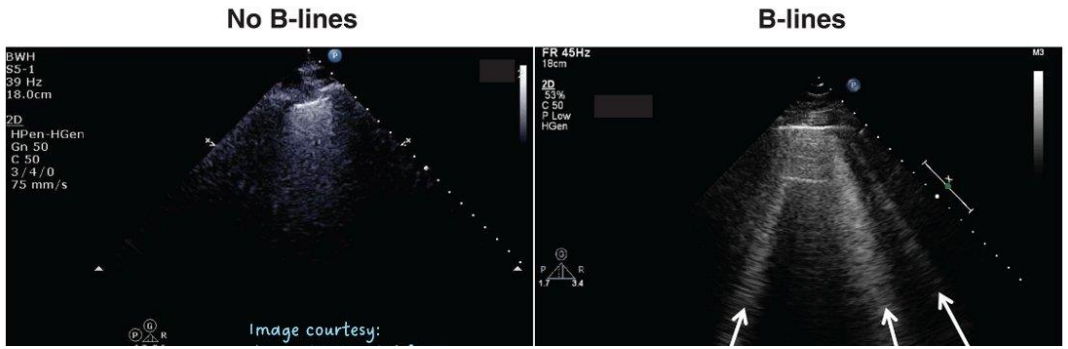
A



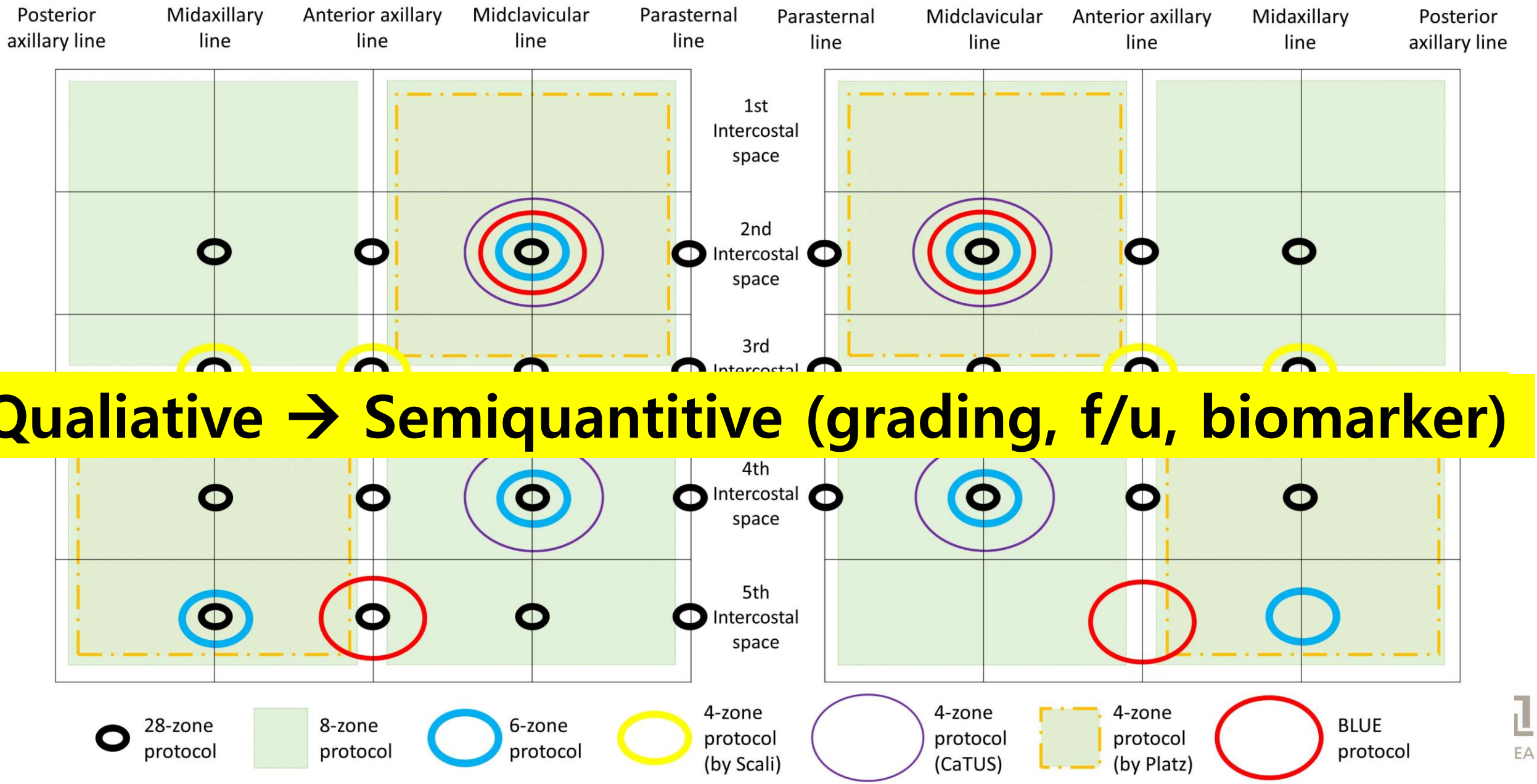
B





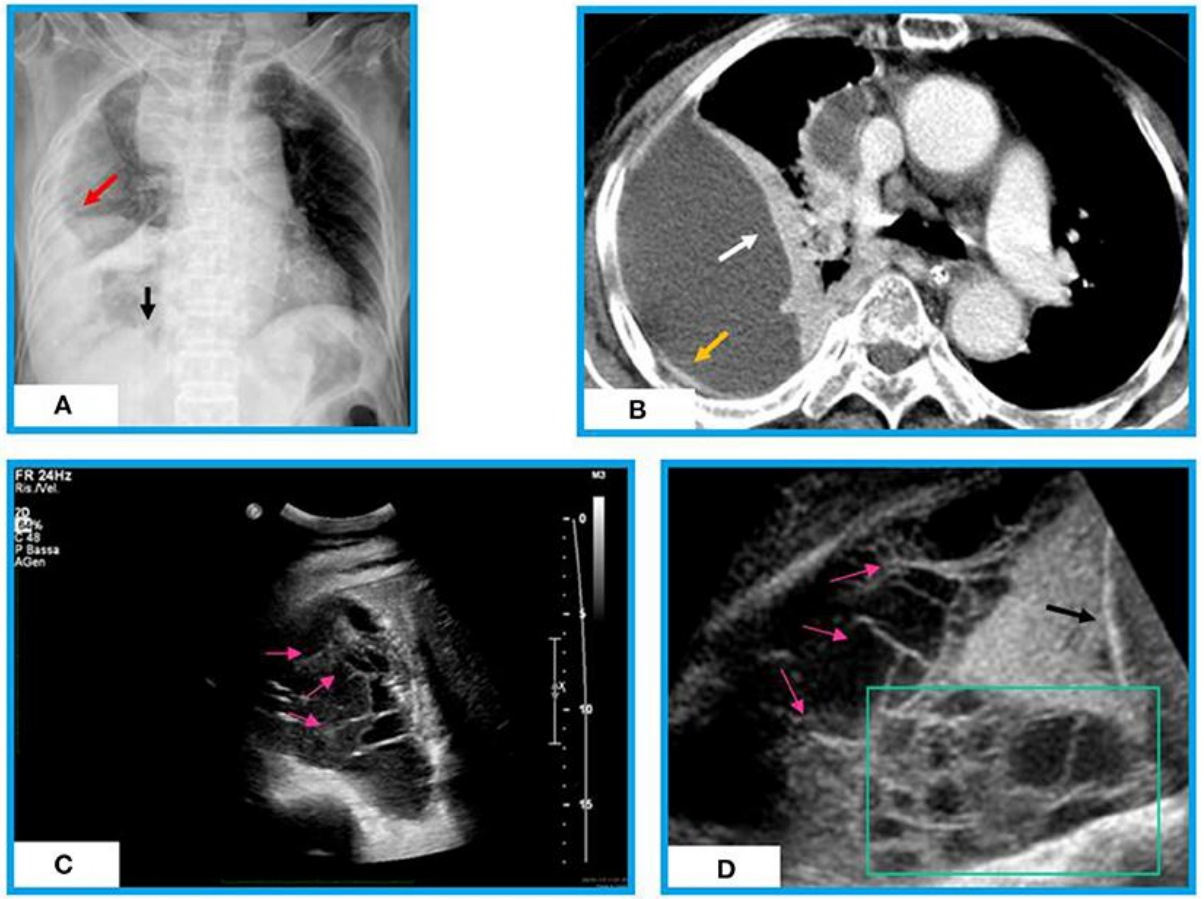


Lung ultrasound protocols: chest zone locations



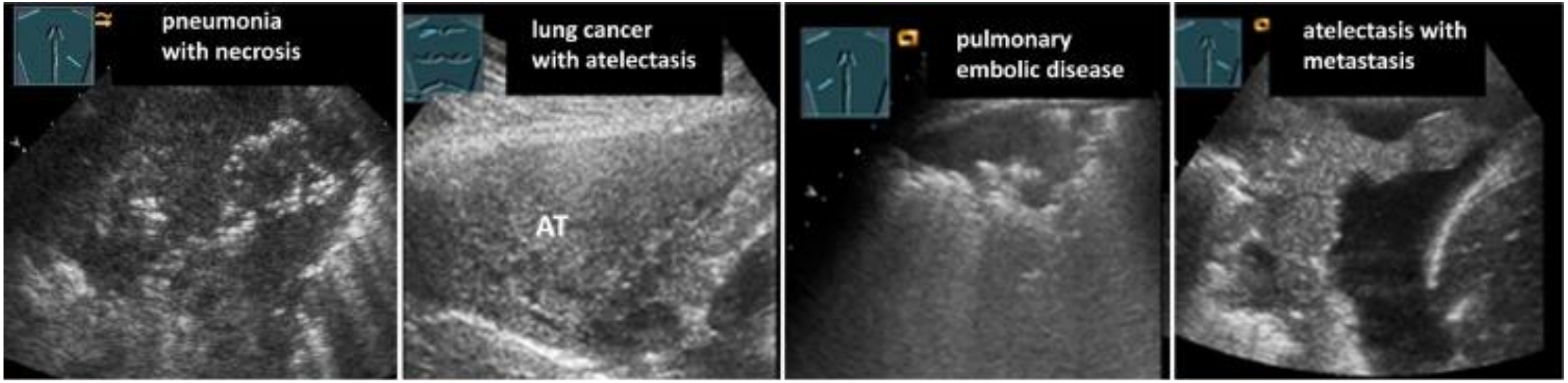
Qualiative → Semiquantitive (grading, f/u, biomarker)

Beyond POCUS, Beyond Acute care

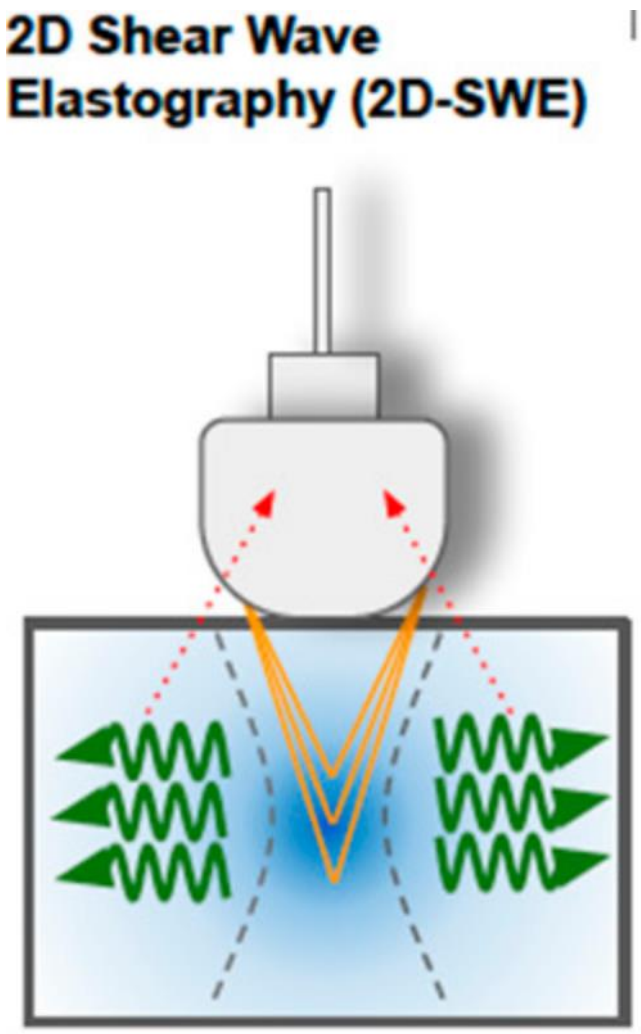


- Big hurdle for radiologic findings
  - Character of suspected lesion

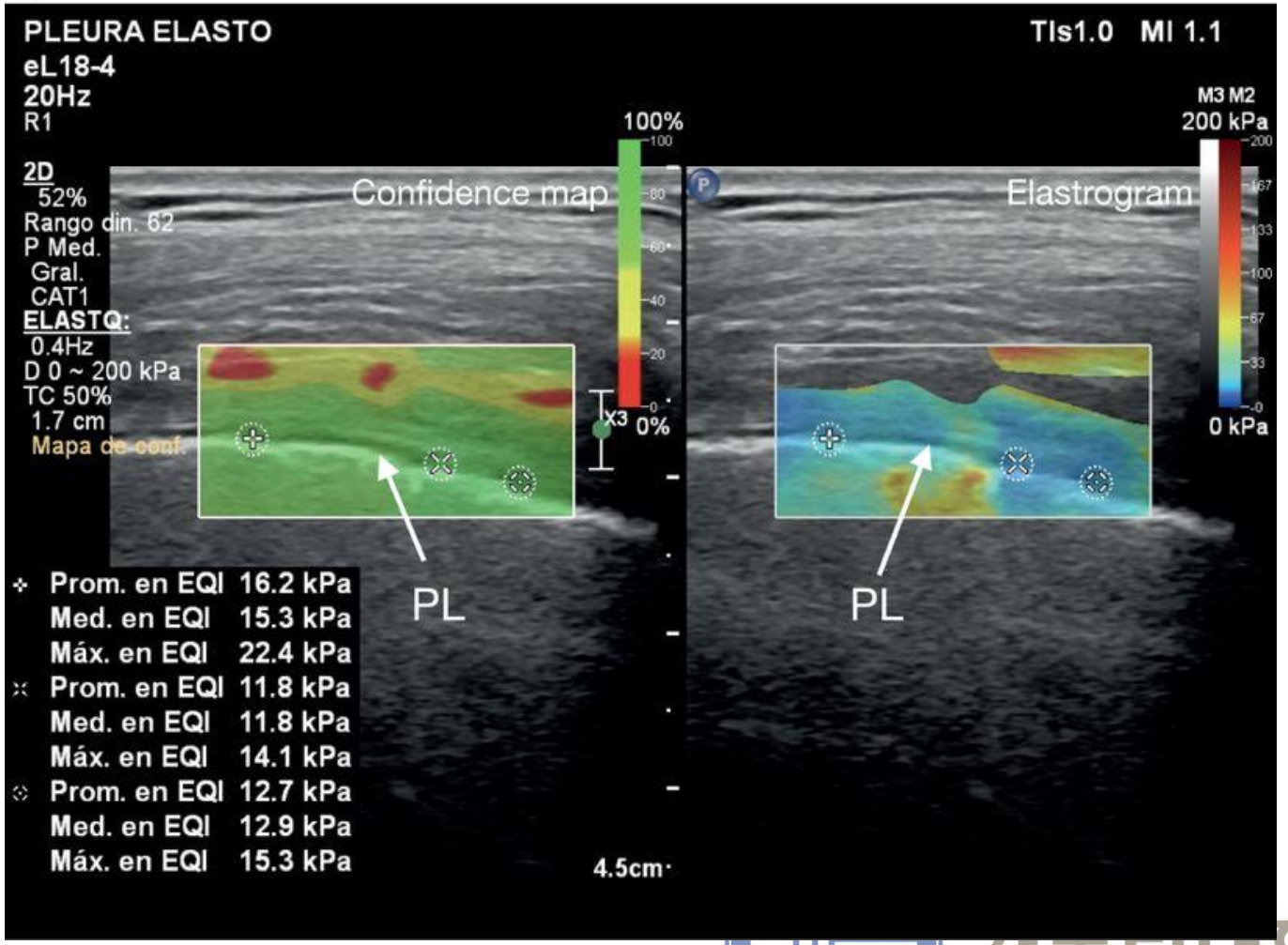
Beyond POCUS, Beyond Acute care



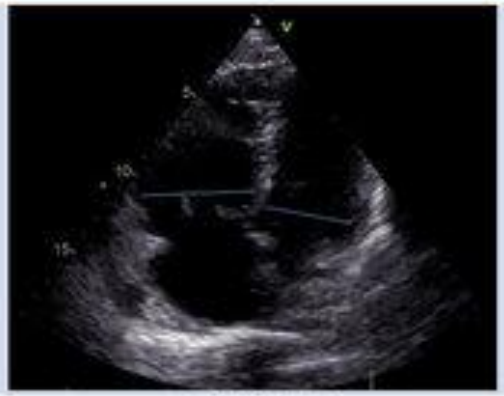
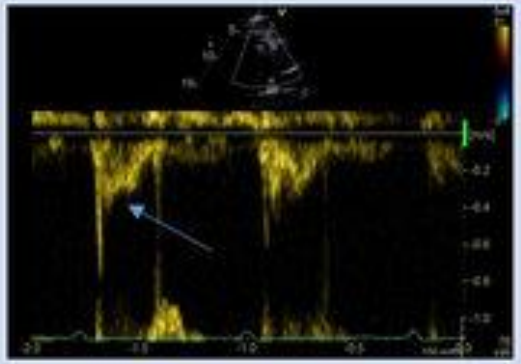
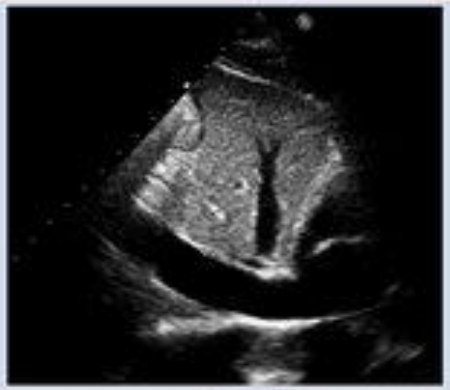
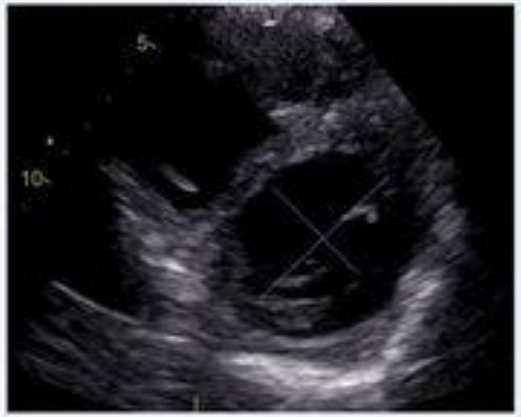
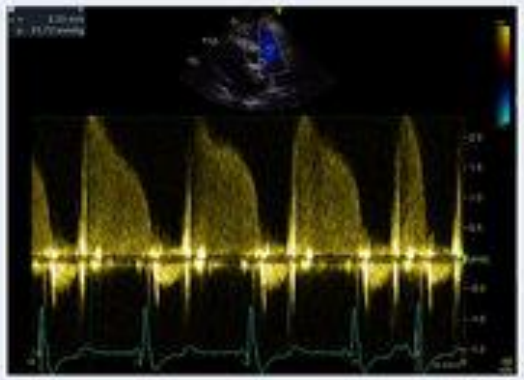
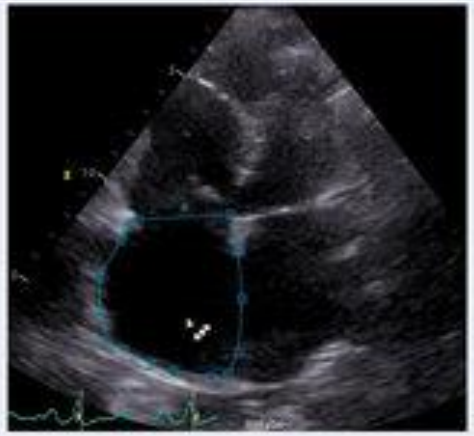
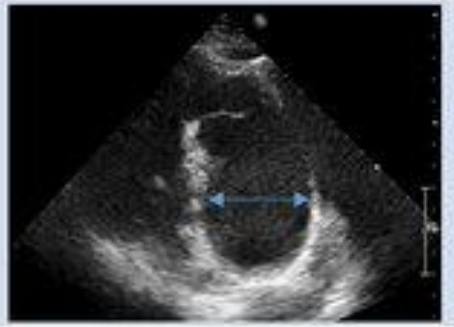
Beyond POCUS, Beyond Acute care



a)



Beyond POCUS, Beyond Acute care

1. Evaluation of ventricles		2. Evaluation of pulmonary artery		3. Evaluation of vena cava and right atrium	
Enlarged right ventrcle with Right ventricle/left ventricle basal diameter ratio >1.0		Right ventricular acceleration time <105 msec and/or midsystolic notching (arrow) (Pulsed wave Doppler sample just below pulmonic valve)		Inferior vena cava (IVC) diameter >21 mm with decreased inspiratory collapse (<50 % with a sniff or <20 % with quiet inspiration) (subcostal view, Diameter measured perpendicular to IVC long axis at end expiration, here 2.2 cm)	
Flattening of the interventricular septum (left ventricular eccentricity index >1.1 in systole and/or diastole)		Early diastolic pulmonary regurgitation velocity >2.2 m/sec (Continous wave Doppler across pulmonary valve; alignment with pulmonary regurgitation jet)		Right atrial area (end-systole) >18 cm2 (end systole, here 28.7 cm2)	
		Pulmomary artery (PA) diameter >25 mm. (PA dimension measured at end diastole, here 50 mm)			

Take Home Messages

Limitation and Benefits

Many Hurdles

1) Everyone can initiate TUS with short run-in curve, but it is ***hard to be expertise.***

2) Costs of High-end ultrasound (100,000,000 won or more)

3) Not appropriate whole lung evaluation. Time-consuming.

But Great Benefits in TUS

1) Only tools : Real-time imaging, Can evaluate lung exercise physiology

2) Sometimes better than CT, and Almost always better than X-ray

3) No harms to patients by radiation

4) Various modality (Portable to High-End)

Limitation and Benefits

In chronic pulmonary disease,

1) Pleural Effusion: amount, character, monitoring, procedure
2) Pneumonia/Infection: better than X-ray, Severity, pathogen?
3) IPF/ILD: good radiologic marker, long-term outcome, diaphragm
4) COPD: hyperinflation, Stable vs. AE, Comorbid condition (Pneumonia, HF),
5) Diaphragm: only tools for real-time diaphragm measures

Thank you (ds31316@gmail.com)