How to utilize lung ultrasound in pulmonary rehabilitation?

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Ultrasound and lung

*The lung is **a major hindrance** for the use of ultrasound at the thoracic level.*

1992, TR Harrison, Principles of Internal Medicine

*Ultrasound imaging is **not useful** for evaluation of the pulmonary parenchyma.*

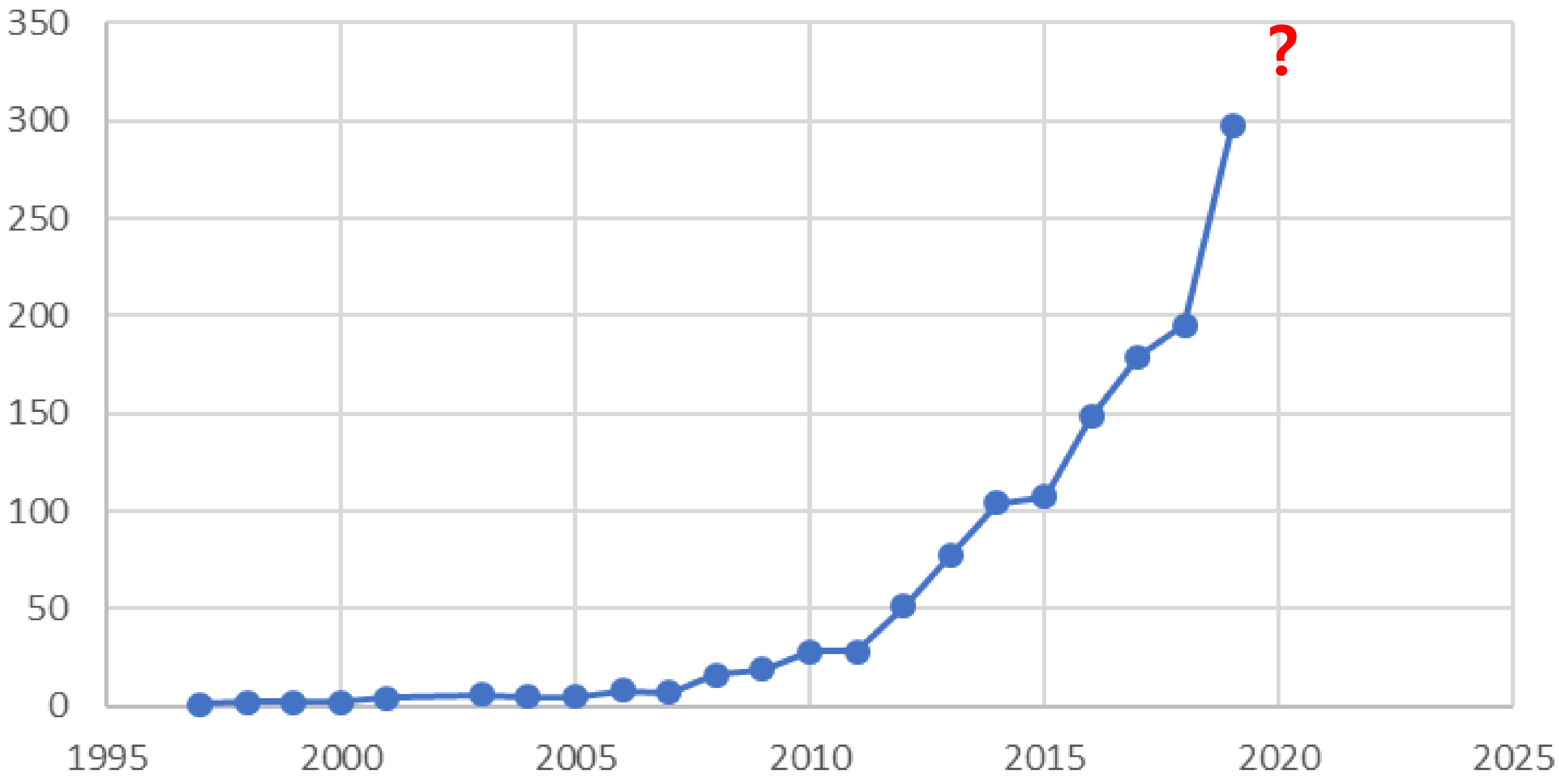
2001, TR Harrison, Principles of Internal Medicine

Ultrasound represent organs filled with fluid or tissue very well.

However, **"Air" in the lung** is a major hindrance for the use of ultrasound at thorax due to **"artifacts"**

LUS: Emerging field of pulmonology area

Pubmed search: # lung ultrasound # thoracic ultrasound



Why we use LUS?

Breathing

- Evaluation : ‘inspection’, ‘palpation’, ‘percussion’, ‘auscultation’
- More information from other modality (see how patient breathe)

Personal experience about LUS

- 2017: SECCI → "BLUE protocol", "A-line", "B-line"... artifacts
- 2018: Application LUS in diverse fields (Airway disease, ILD, Pleural disease, ICU)
- 2019: Diaphragm muscle, Intercostal muscle
  - Co-work with Department of Rehabilitation Medicine
  - Respiratory muscle power: thickening fraction and excursion of diaphragm

Today`s main issue

Today`s Contents

- What is the lung ultrasound (LUS)?
    - LUS basics
    - LUS advanced

- LUS in pulmonary rehabilitation
    - LUS in pulmonary diseases
    - Screening
    - Follow-up

- Others

Chapter 1

- What is the lung ultrasound (LUS)?
  - LUS basics
  - LUS advanced

- LUS in pulmonary rehabilitation
  - LUS in pulmonary diseases
  - Screening
  - Follow-up

- Others

What is the lung ultrasound (LUS)?

- Thoracic ultrasound
  - Lung ultrasound (LUS)
  - Pleura: pleural thickness, irregularity, pleural effusion
  - Respiratory muscle
    - Diaphragm ultrasound (DUS)

      : diaphragm thickness, diaphragm thickening fraction, diaphragm excursion
    - Intercostal muscle
    - Others

Volpicelli et al 2019 ERS handbook - Thoracic ultrasound

What is the lung ultrasound (LUS)?

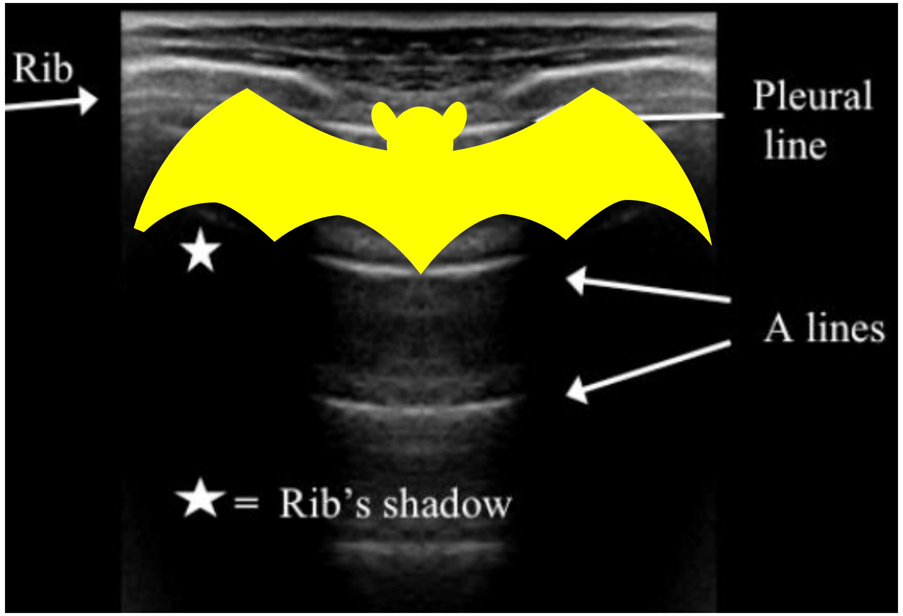
- Lung ultrasound (LUS)
  - Integrated understanding between "Real images" and "Artifact images"
  - Real images : lung consolidation, pleural effusion etc.
  - Artifacts : **<u>Reverberation</u>** artifacts (A-line, B-line), comet-tail signs etc.

Real image + Artifacts = Integrated interpretation!

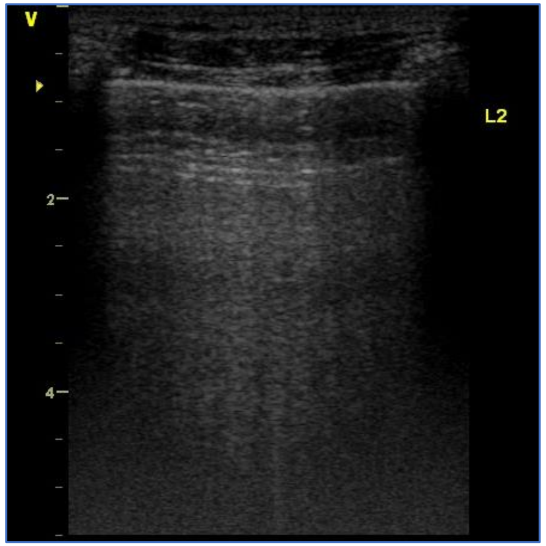
Basic: Lung sliding and Bat-sign

- Bat sign
  - Images of two ribs and intercostal space
  - Visceral–parietal pleura interface

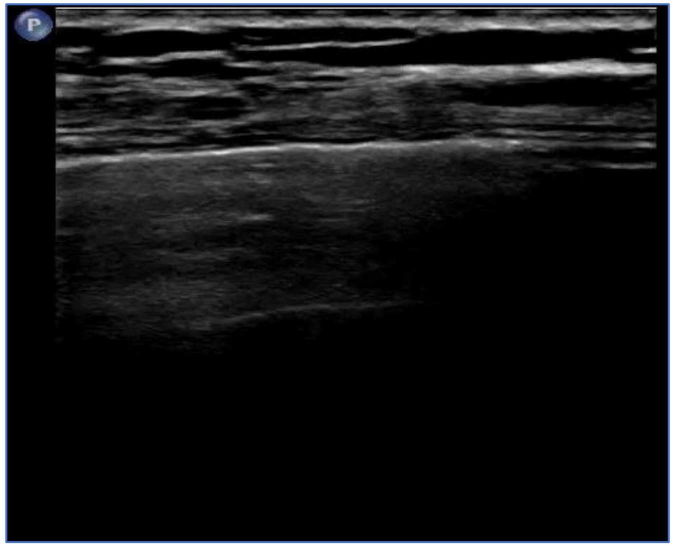
- Lung sliding
  - Opposite direction movement of pleura and chest wall
  - Shimmering appearance of the pleura
  - Lung sliding (+) = intact VPPI
  - Curtain sign at basal lateral



Lung sliding in anterior lung

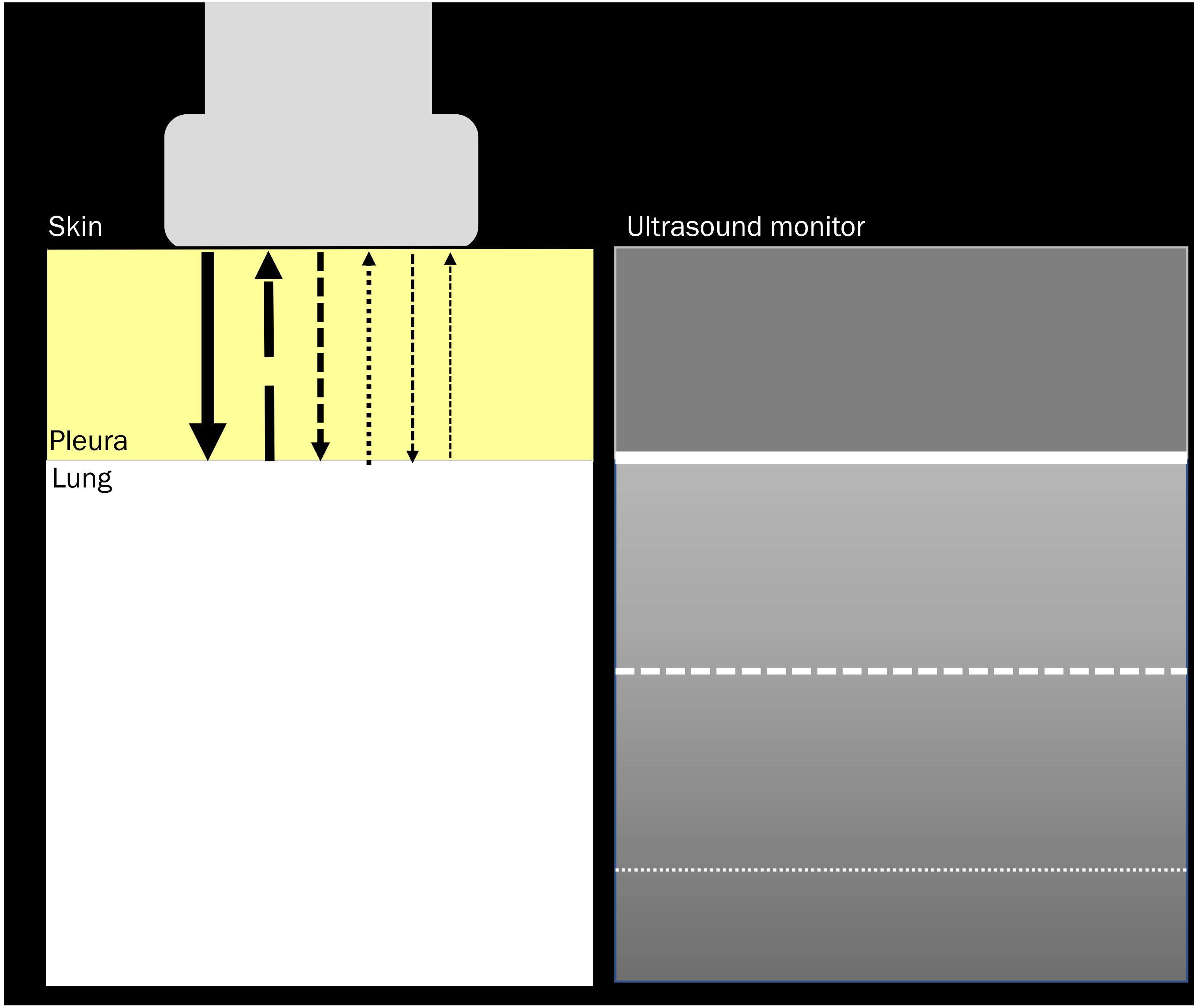


Lung sliding in posterior-lateral area

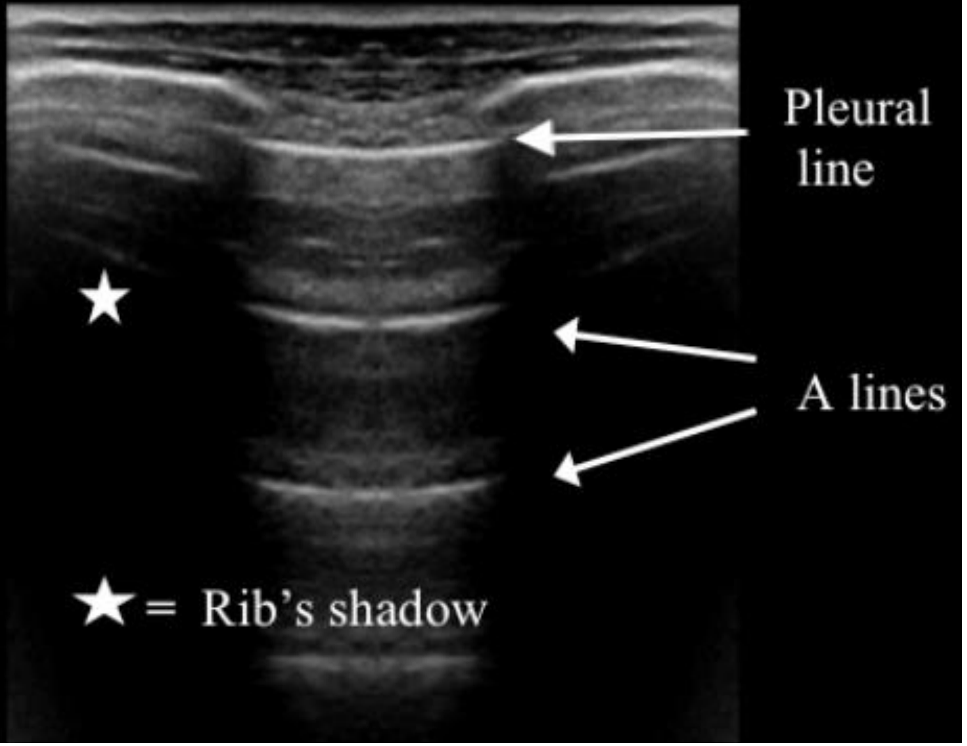


F Mojoli et al. AJRCCM Vol 199. No 6, March, 2019
H.R.W. Touw et al. The Netherlands Journal of Medicine, 2015

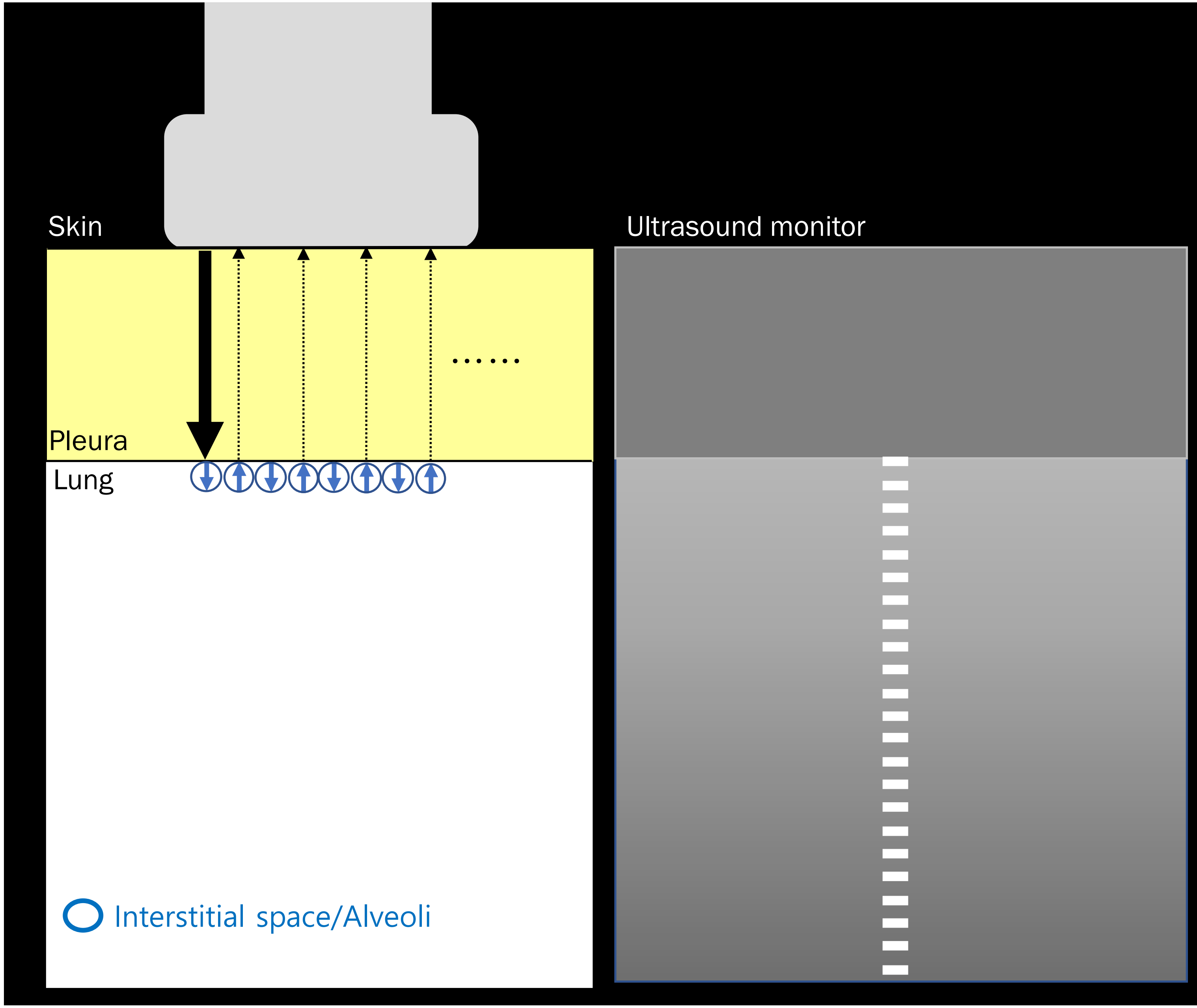
Basics: A-line (reverberation artifacts, normal artifacts)

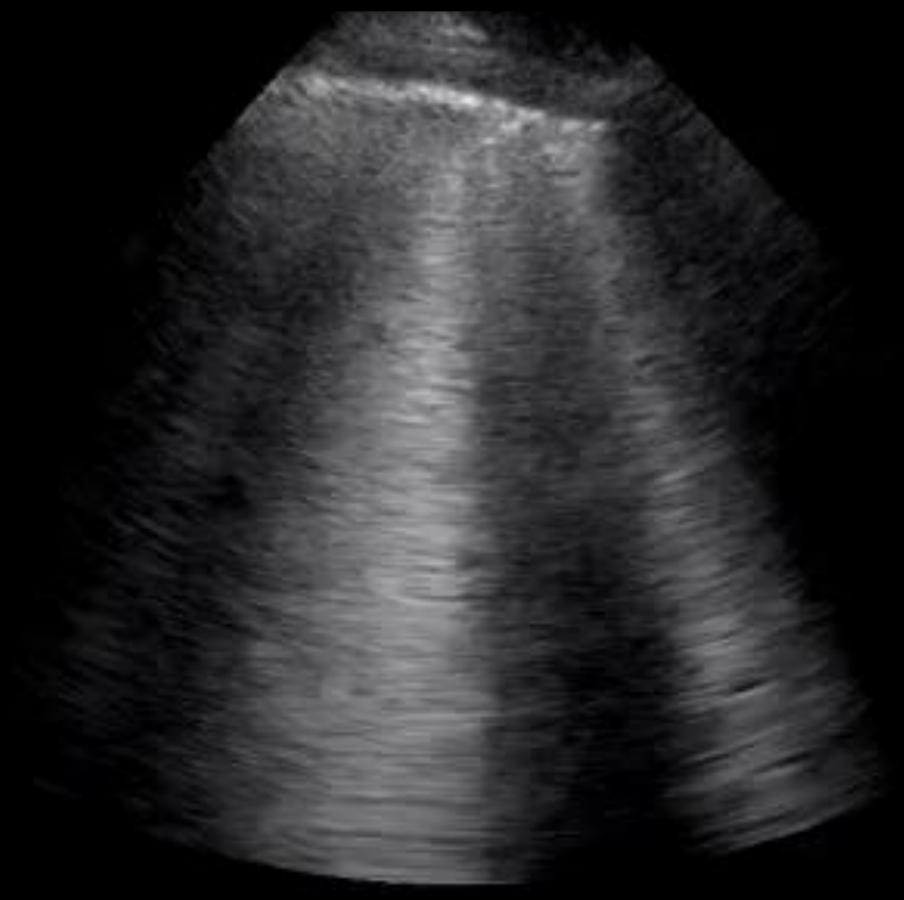


A-line = Air



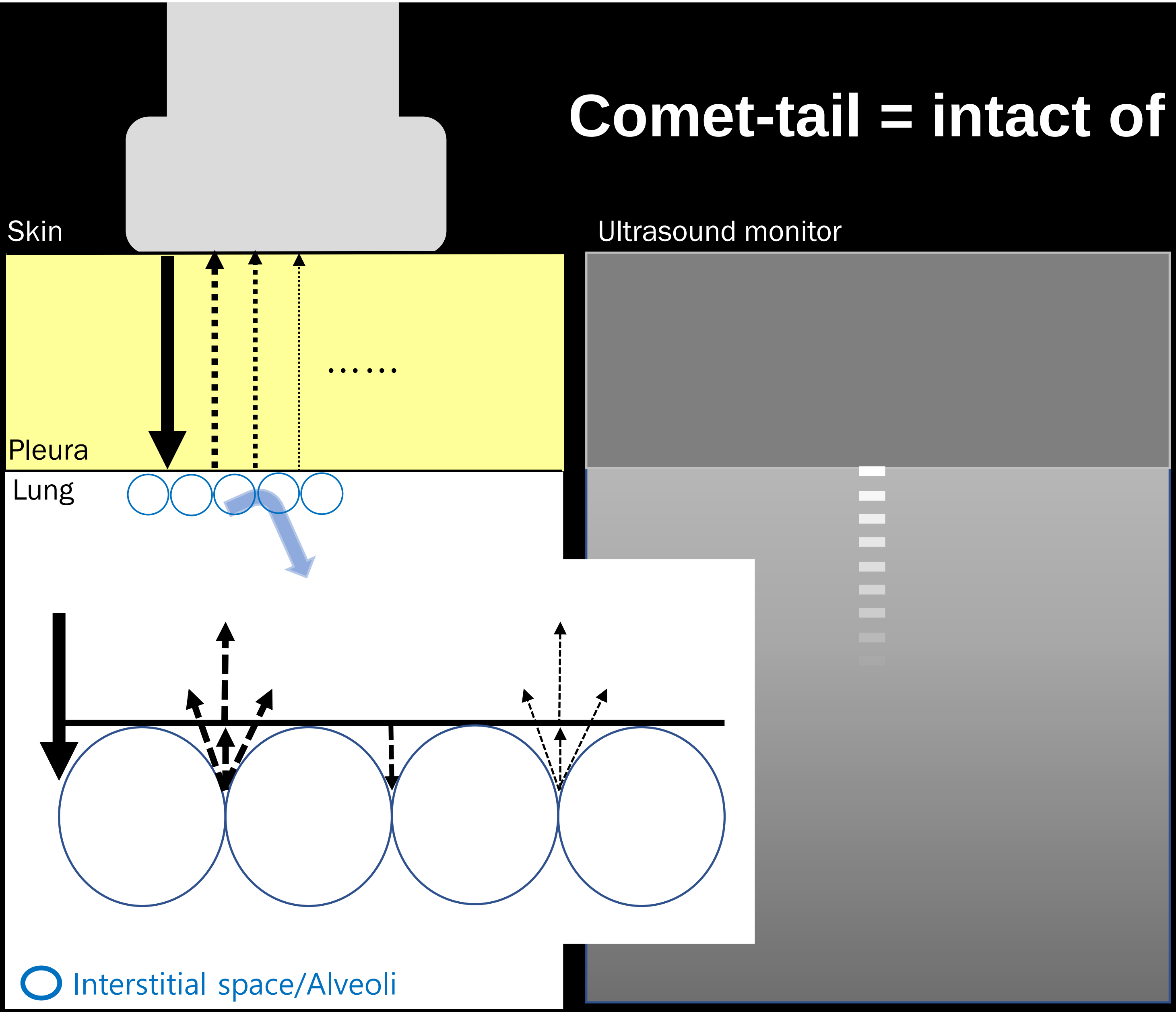
Basics: B-line (reverberation artifacts, abnormal artifacts)

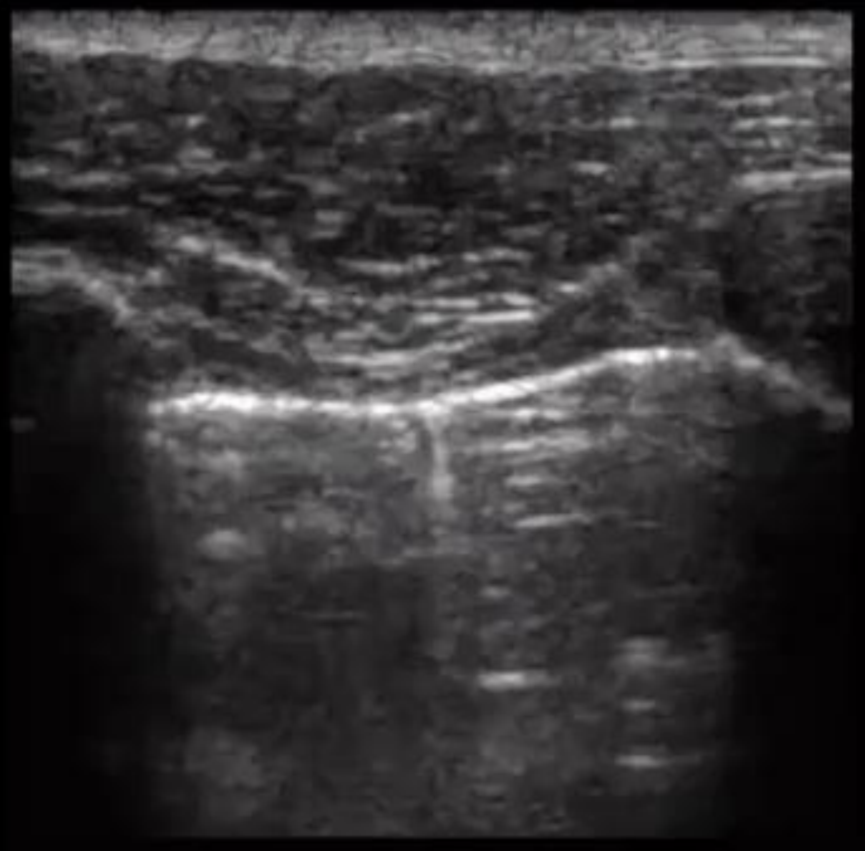




Basics: other artifacts (reverberation – comet-tail)

Comet-tail = intact of VPPI = No pneumothorax!





Basics: Lung sliding and A-line

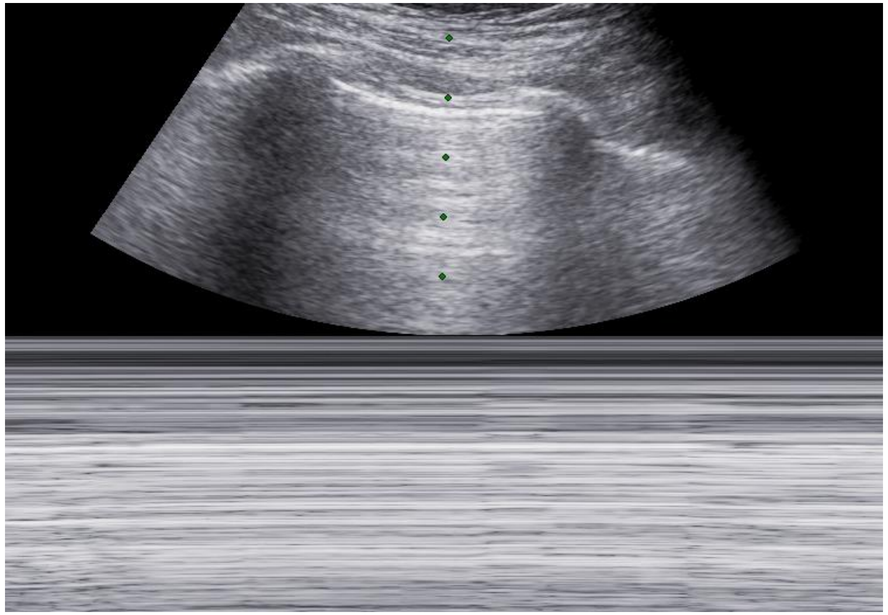
- Lung sliding (+) + A-line (+)
    - Normal aerated, normal movement of lung
    - Seashore sign

F Mojoli et al. AJRCCM Vol 199. No 6, March, 2019

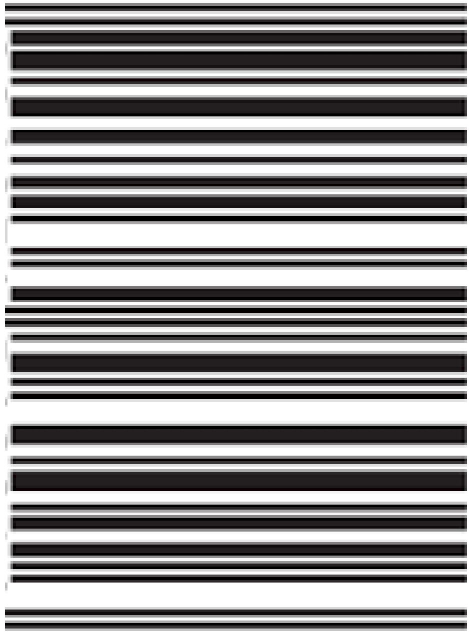
Basics: Lung sliding and A-line

- Lung sliding (-) + A-line (+) = No movement of pleura + much air beneath the pleura

  → Suspect pneumothorax first! → 1st chest M-mode and find lung point!



Barcode sign

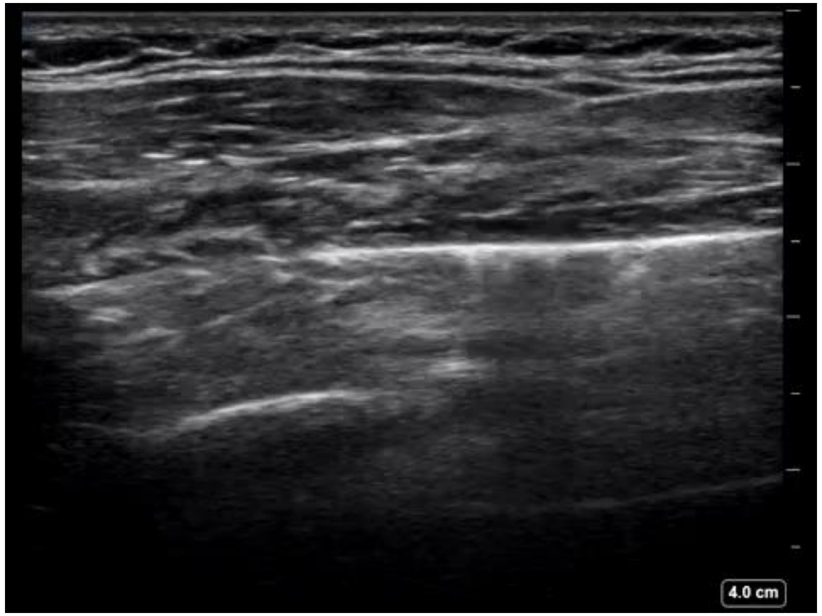


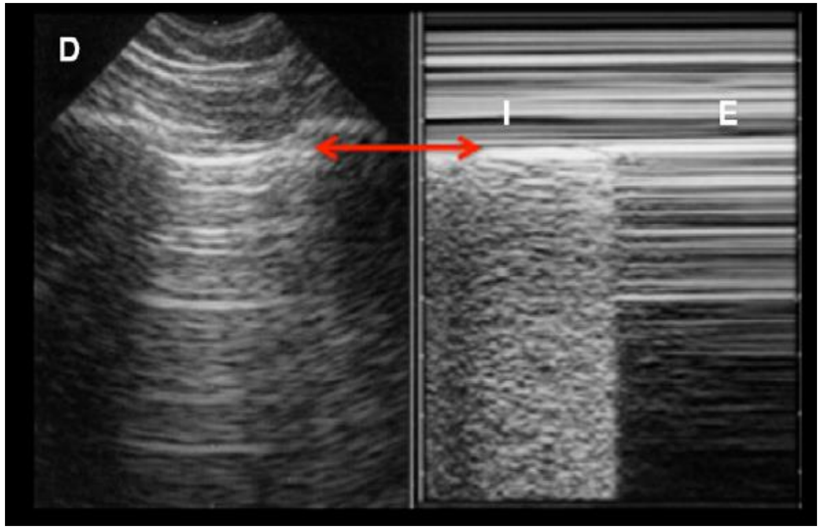
Stratosphere sign

Basics: Lung point (Pneumothorax)

- Lung point: The point of lung sliding pattern change
  - Point at which visceral and parietal pleura meet
  - Highly accurate for diagnosis of *pneumothorax*
  - Dynamic point
    - Affected by

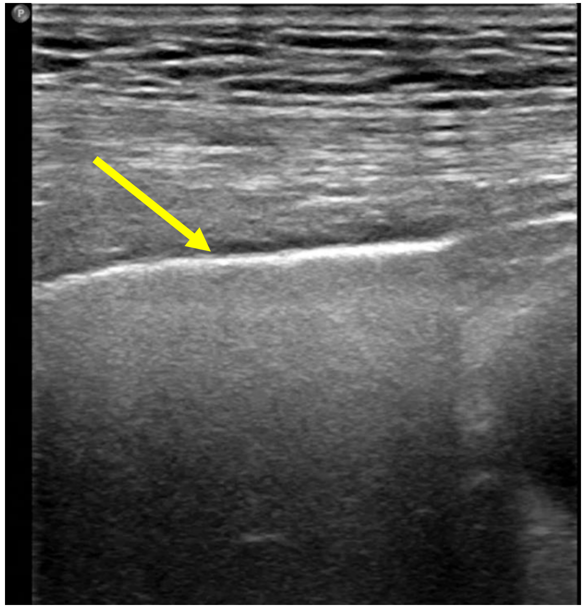
      body position, size of pneumothorax, and pleural adhesion
  - Detected in both B-mode and M-mode





F Mojoli et al. AJRCCM Vol 199. No 6, March, 2019

Advanced: Pleura & Pleural effusion



- Pleural Thickness
  - Normal pleura: 0.3mm, hyperechoic band
  - Not possible distinguish visceral and parietal pleura
  - Diffuse pleural thickening → pleurisy, malignancy
  - Pleural nodularity, pleural thickening (> 7mm) → malignancy

- Irregularity
  - evidence of recent inflammation
  - Comet tail artifacts (can be seen in elderly)
  - Subpleural consolidation

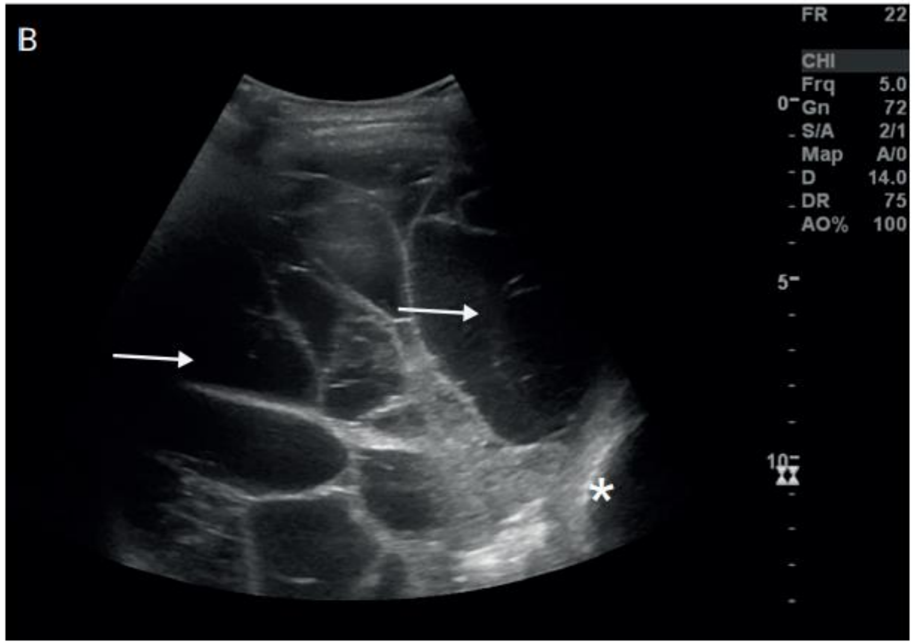
NR Qureshi et al. Thorax, 2009;64:139-43

Advanced: Pleura & Pleural effusion

Pleural effusion

- Identifying: fluid features, septation, plankton sign

Large pleural fluid with plankton sign
Passive atelectasis with static air-bronchogram
Ascites



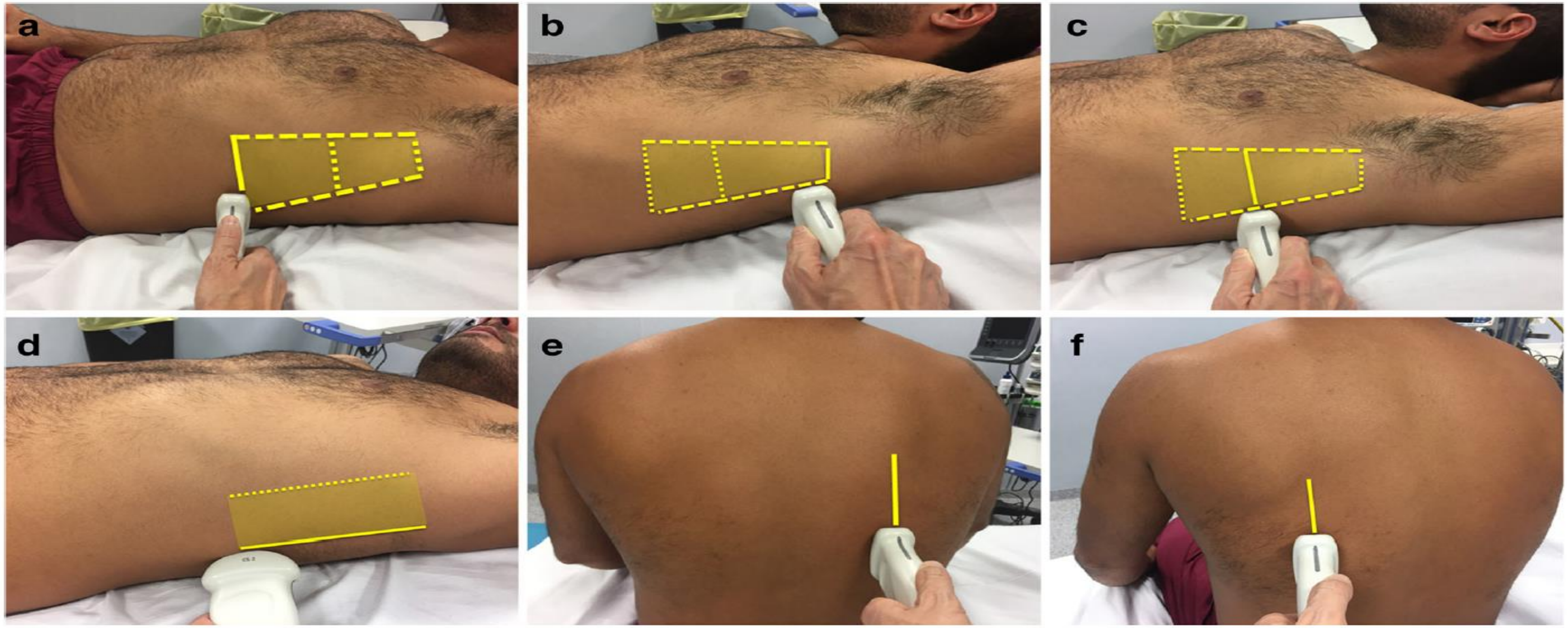
Multiple and thin-walled septation

M.R. Vial et al. US Respiratory & Pulmonary disease, 2017;2(1):23-25

Advanced: Pleura & Pleural effusion

Pleural effusion

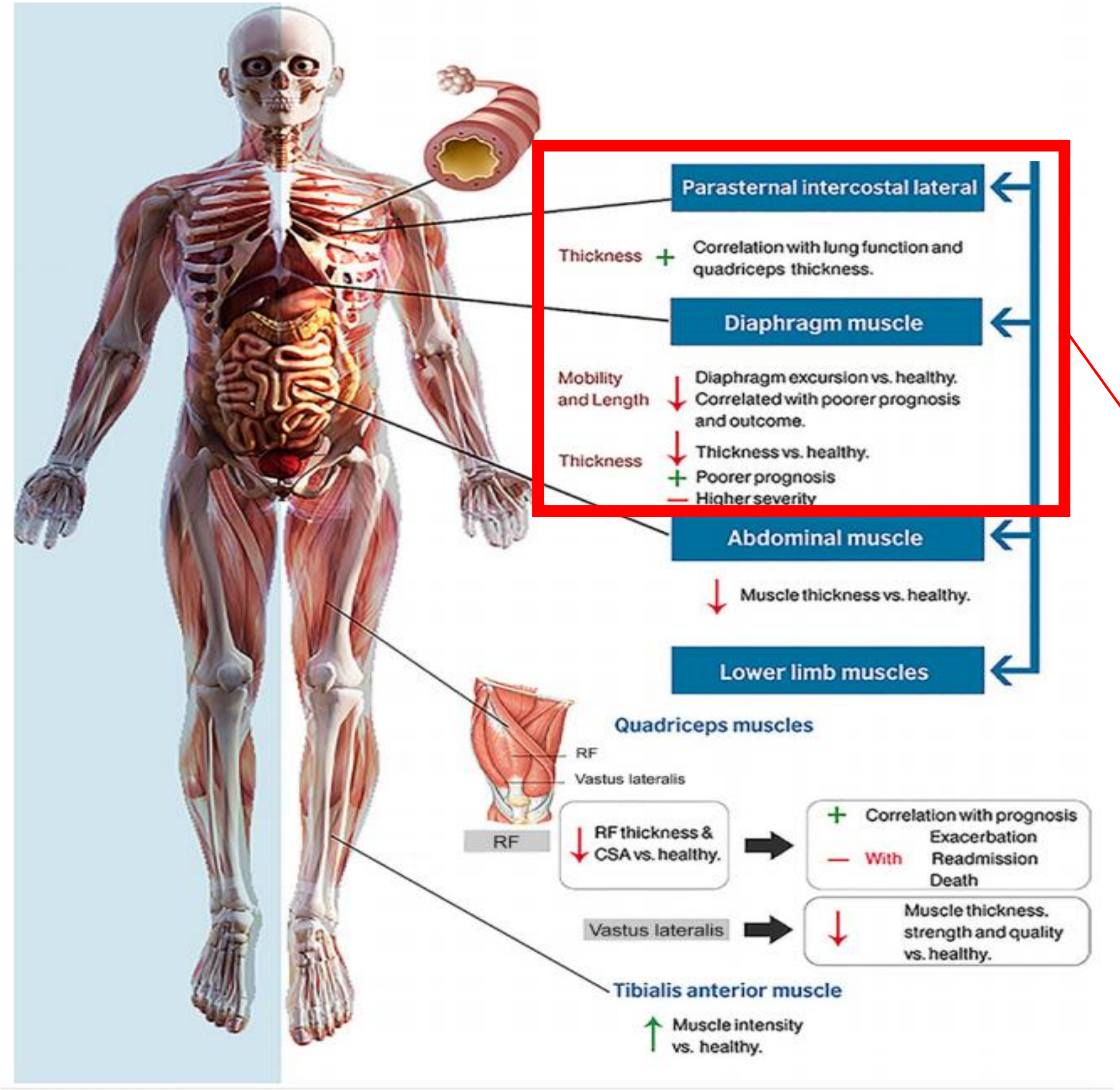
- Quantifying: amounts of fluid



Better than counting daily drainage or Chest X-Ray

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

Non-cardiac US in pulmonology



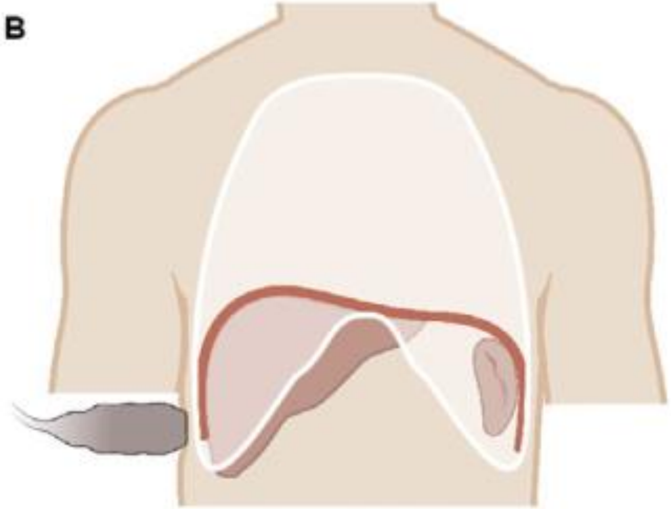
Outcome measures assessed by US	Studies assessed in this outcome, n (references)
Diaphragm muscles	35 [13–26 28–32 34–41 43–46 74–76]
Quadriceps (rectus femoris)	10 [39 47–55]
Quadriceps (vastus lateralis)	4 [53 57–59]
Endobronchial ultrasonography	3 [62–64]
Ankle dorsiflexor muscle (tibialis anterior)	2 [54 56]
Abdominal muscle	1 [61]
Bone mineral density	1 [65]
Parasternal intercostal lateral muscle	1 [60]

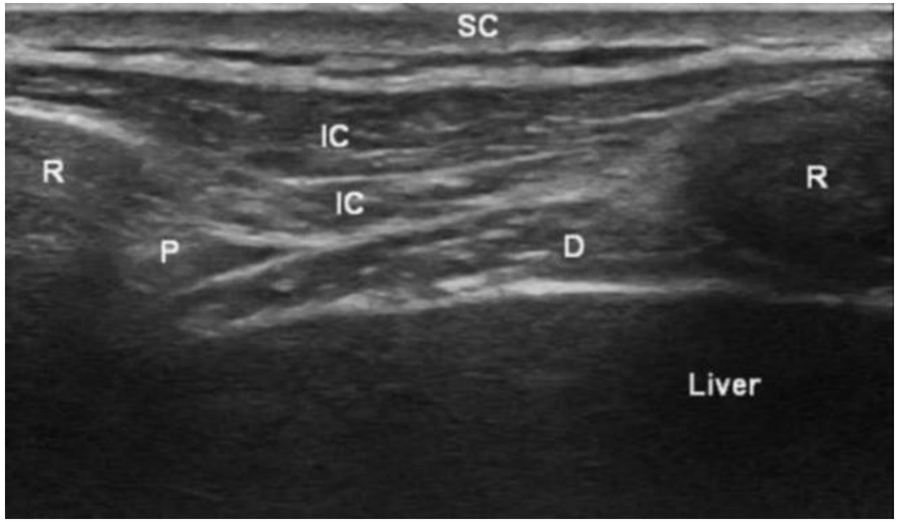
Alqahtani JS et al. BMJ open Resp Res 2020;7

Advanced: Diaphragm ultrasound (DUS)

Diaphragm ultrasound

- High frequency linear probe (7~18MHz)
- Intercostal view at 8th to 10th intercostal space (zone of apposition)
- Measurement
  - Diaphragm thickness (muscle mass, no significant Rt. to Lt. difference)
  - Diaphragm thickening fraction (contractility)
  - Diaphragm excursion (mobility)

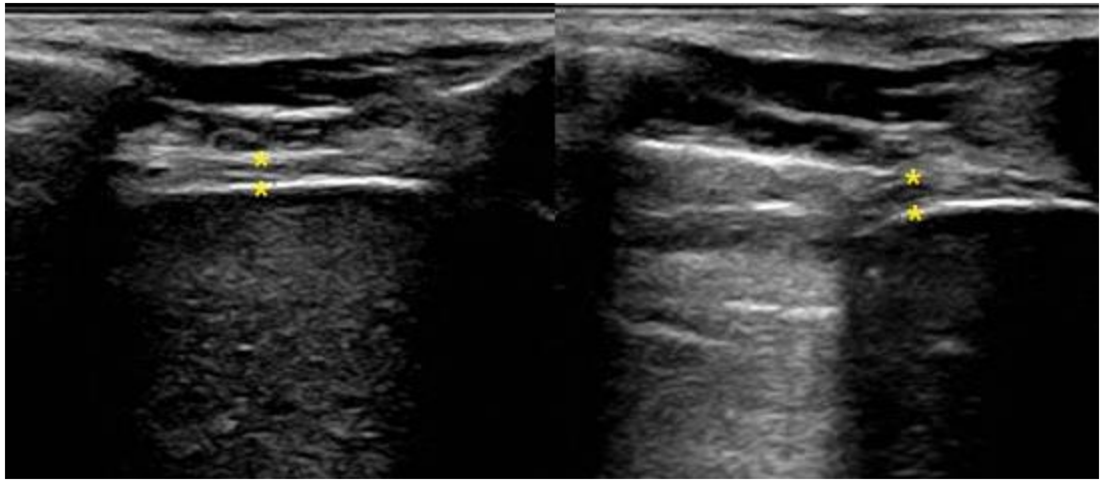




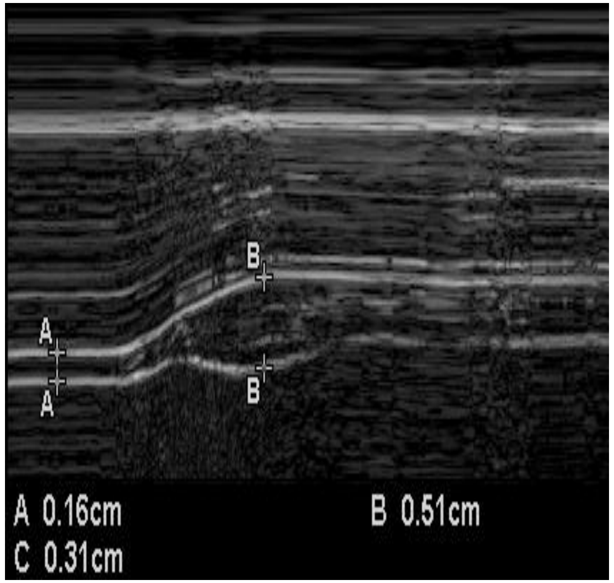
Intensive Care Med 2015;41:642-649

Advanced: Diaphragm thickness & Thickening fraction

B-mode measurement



M-mode measurement



A) end-expiration
B) peak inspiratory muscle contraction

Diaphragm thickening fraction (= Change in thickness)

$$\frac{(\text{Thickness at peak}-\text{inspiration})-(\text{Thickness at end}-\text{expiration})}{(\text{Thickness at end}-\text{expiration})} \times 100(\%)$$

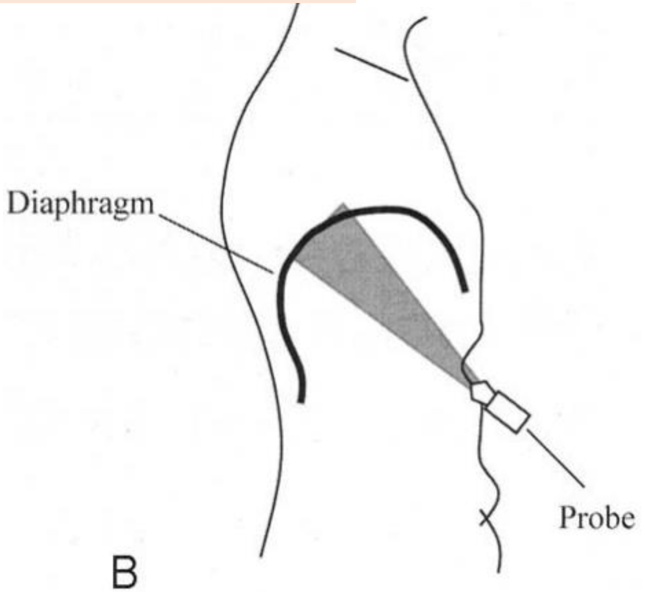
Cut-off value of successful extubation

	Thickening Fraction (TF) (%)
Ferrari et al. 2014	36%
DiNino et al. 2014	30%
Dube et al. 2014	29%
Pirompanich et al. 2018	26%
Blumhof et al. 2016	20%

TJ An et al. Under review
J Appl Physiol 1997:83:291-296
J Othop Sports Phys Ther 2013;43:927-931
Intensive Care Med 2015;41:642-649

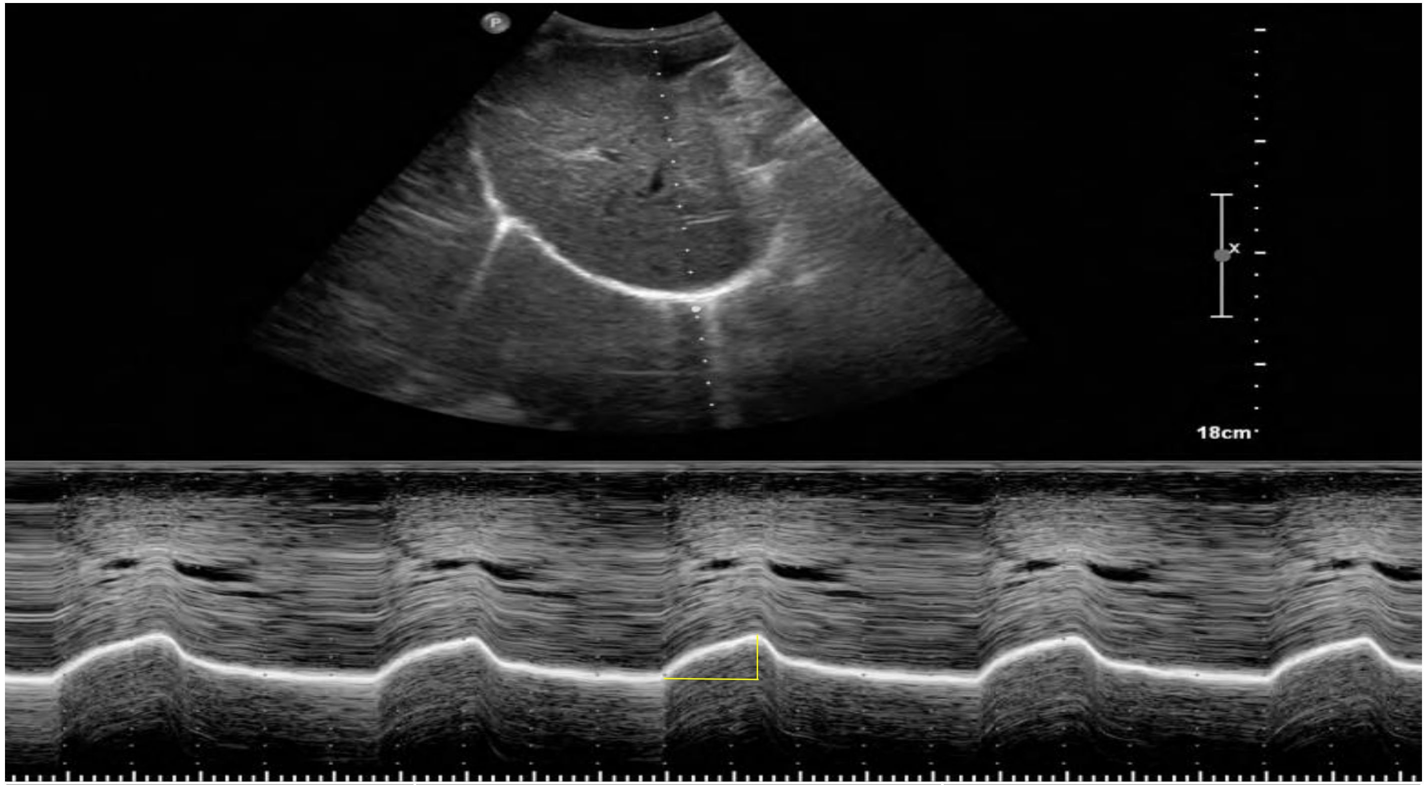
Advanced: Diaphragm excursion

Position of probe



Anterior subcostal view (mid-clavicular line)

- 2-6MHz (low frequency)
- Diaphragm excursion (mobility)
- Sniff inspiratory velocity (power)



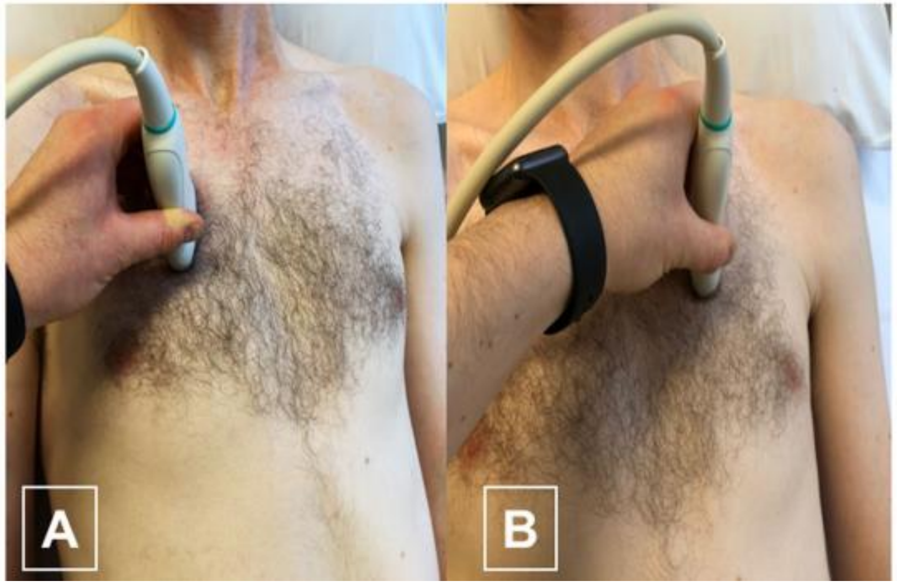
	Mean normal values ± SD	Pathologic values
Tidal excursion	Female: 16±3 mm Male: 18±3 mm	Female: < 9mm Male: < 10mm
Sniff test	Female: 26±5 mm Male: 29±6 mm	Female: < 16mm Male: < 18mm
Maximal deep breath	Female: 57±10 mm Male: 70±11 mm	Female: < 37mm Male: < 47mm

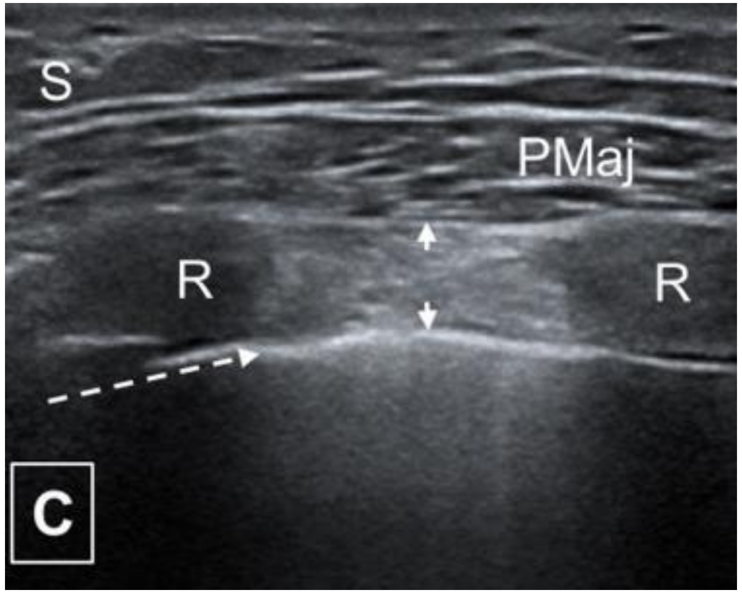
TJ An et al. Under review
Boussuges et al. CHEST 2009;135:391-400

Advanced: Intercostal muscle

Intercostal muscle

- Chest wall musculature
- Affect chest mechanics
- In animal model, intercostal muscle ↔ lung volume
- In previous study, intercostal muscle in 2nd and 3rd intercostal space is important





Chapter 2

- What is the lung ultrasound (LUS)?
  - LUS basics
  - LUS advanced

- LUS in pulmonary rehabilitation
  - As assessment tool of pulmonary diseases
  - Screening
  - Follow-up

- Others

Pulmonary rehabilitation

- Exercise capacity in chronic respiratory diseases
  : powerful indicator of health status impairment

- Pulmonary rehabilitation (PR)
  : Specialized program of exercise and education
  : Comprehensive intervention
    a) Exercise training + Education + Self-management
    b) Patient assessment with "Patient-tailored therapy"

→ How we evaluate chronic respiratory diseases?

As assessment tool of pulmonary diseases

- When meet patients with dyspnea…

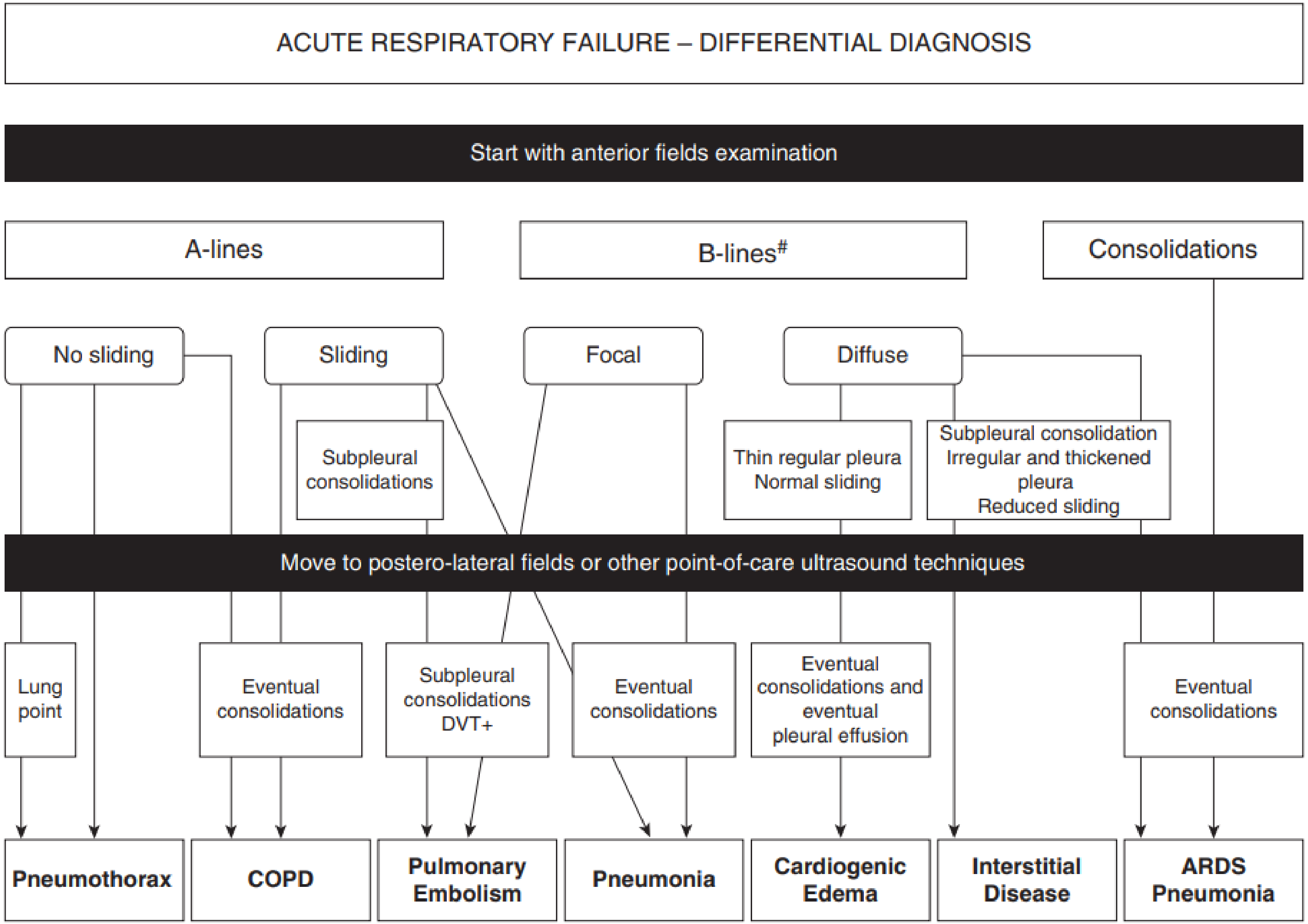


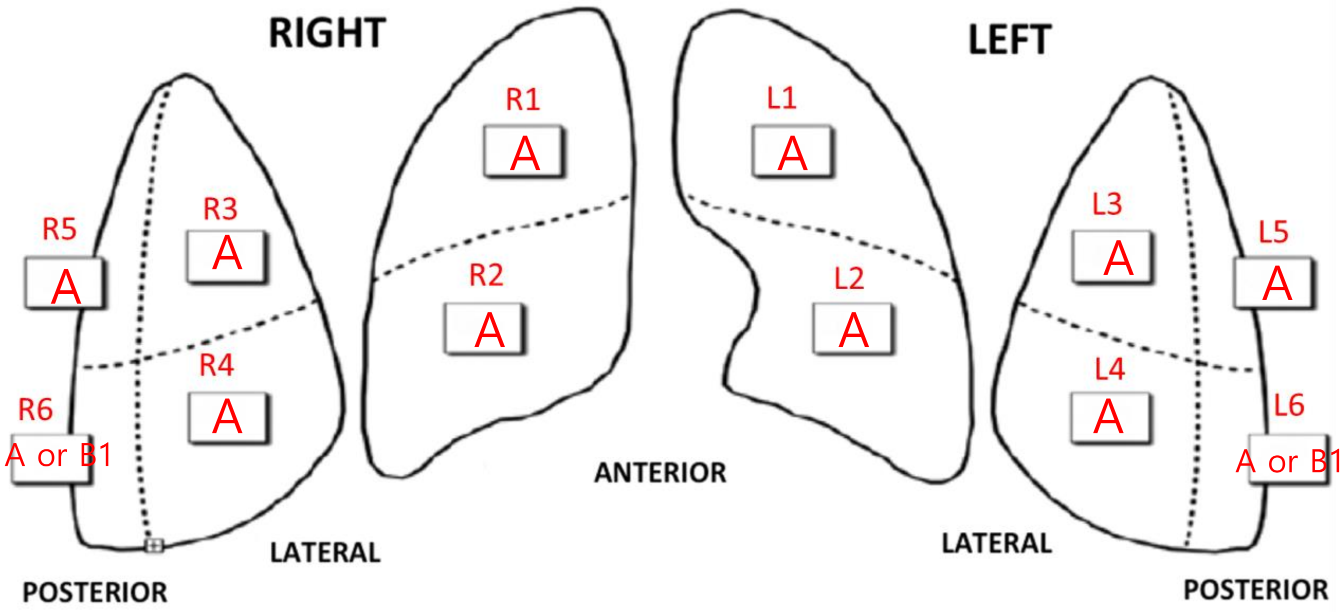
Figure 4. A proposal for a systematic diagnostic approach to acute respiratory failure based on literature findings (ARDS = acute respiratory distress syndrome; COPD = chronic pulmonary obstructive disease; DVT = deep venous thrombosis). #At least three B-lines per scan.

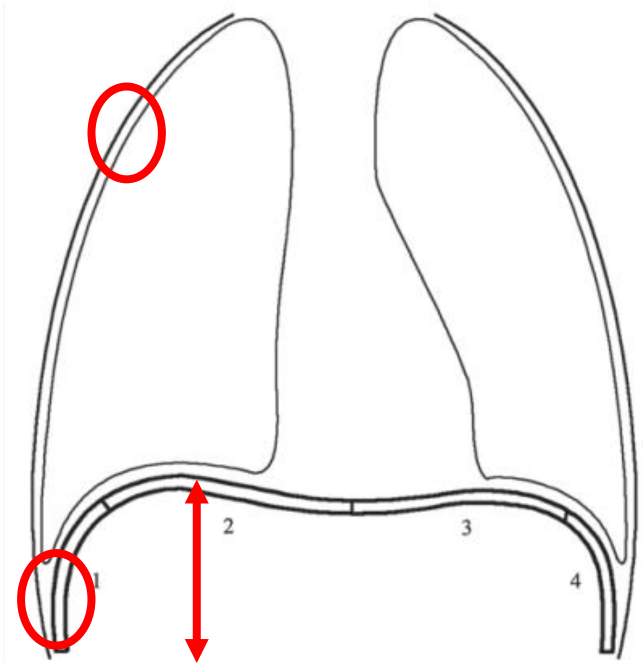
F.Mojoli et al. AJRCCM 2019;199(6):701-714

As assessment tool of COPD

LUS in COPD

- Similar A-line pattern
- Combined with focal B-line or subpleural consolidation
- Frequently combined with pneumothorax and pulmonary congestion
- Different status diaphragm and intercostal muscle



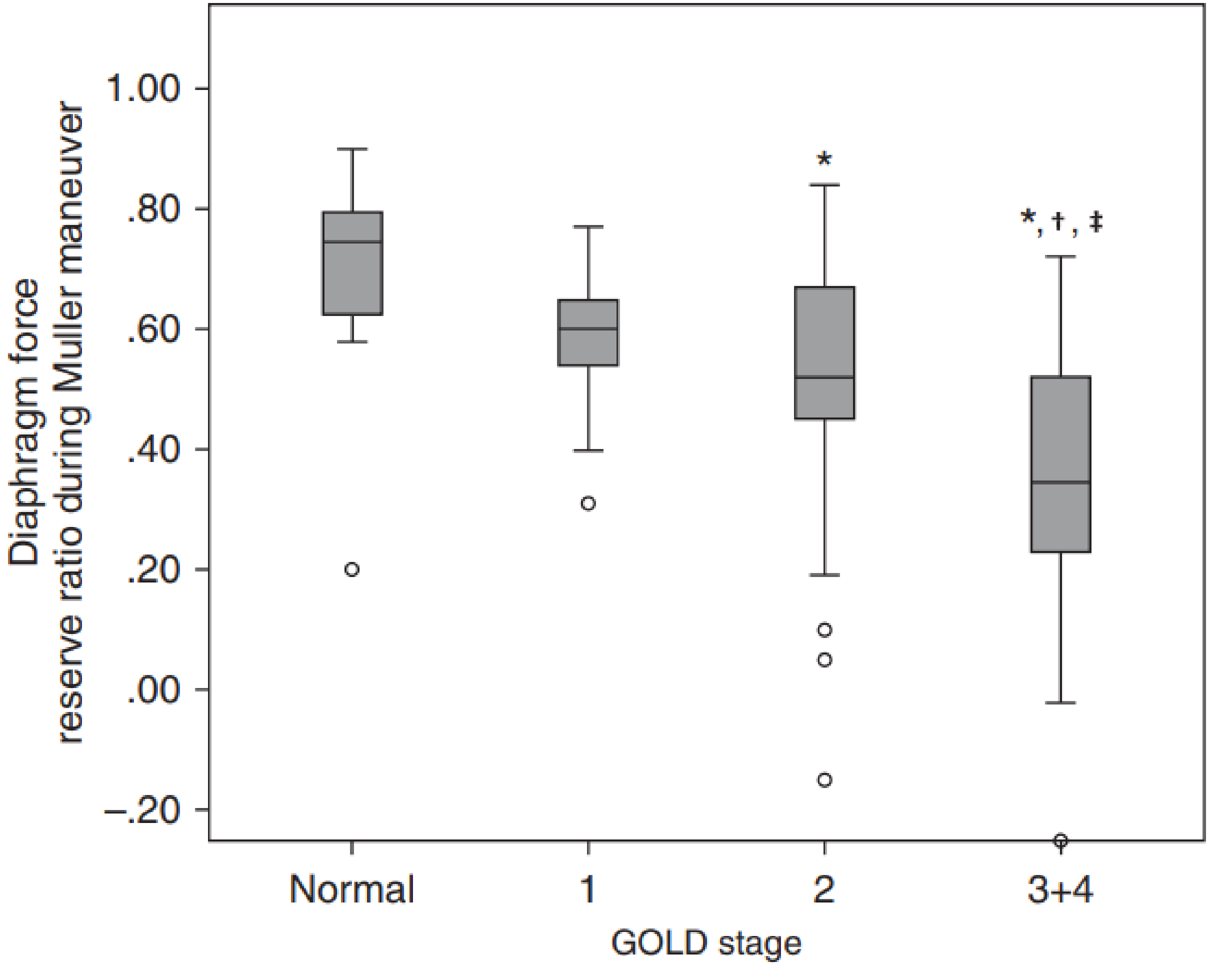


As assessment tool of COPD

LUS in COPD

- Healthy vs COPD: Different status of stable condition of diaphragm muscle

Variables	*P* Value
TFdi-tidal, %	0.002
TFdi-max, %	
Muller	0.006
Sniff test	0.104
DE-max, cm	
Muller	0.003
Sniff test	0.456
Diaphragm force	
Muller	<0.001
Sniff test	<0.001

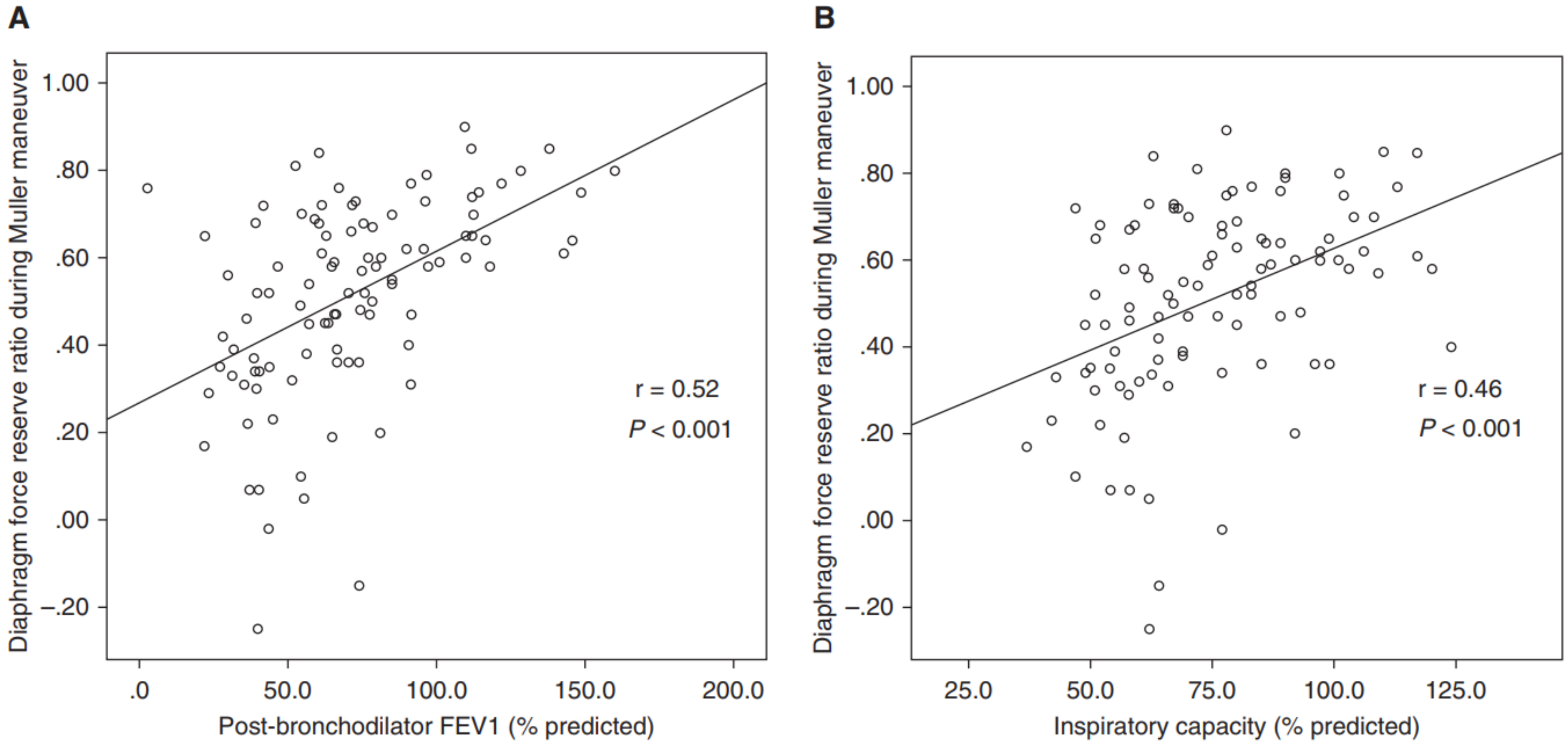


N.Rittayamia et al. AnnalsATS 2020;17:10

As assessment tool of COPD

Lung functions

- Correlation between diaphragm force reserve ratio and lung functions



N.Rittayamia et al. AnnalsATS 2020;17:10

As assessment tool of COPD

Stable vs. AE

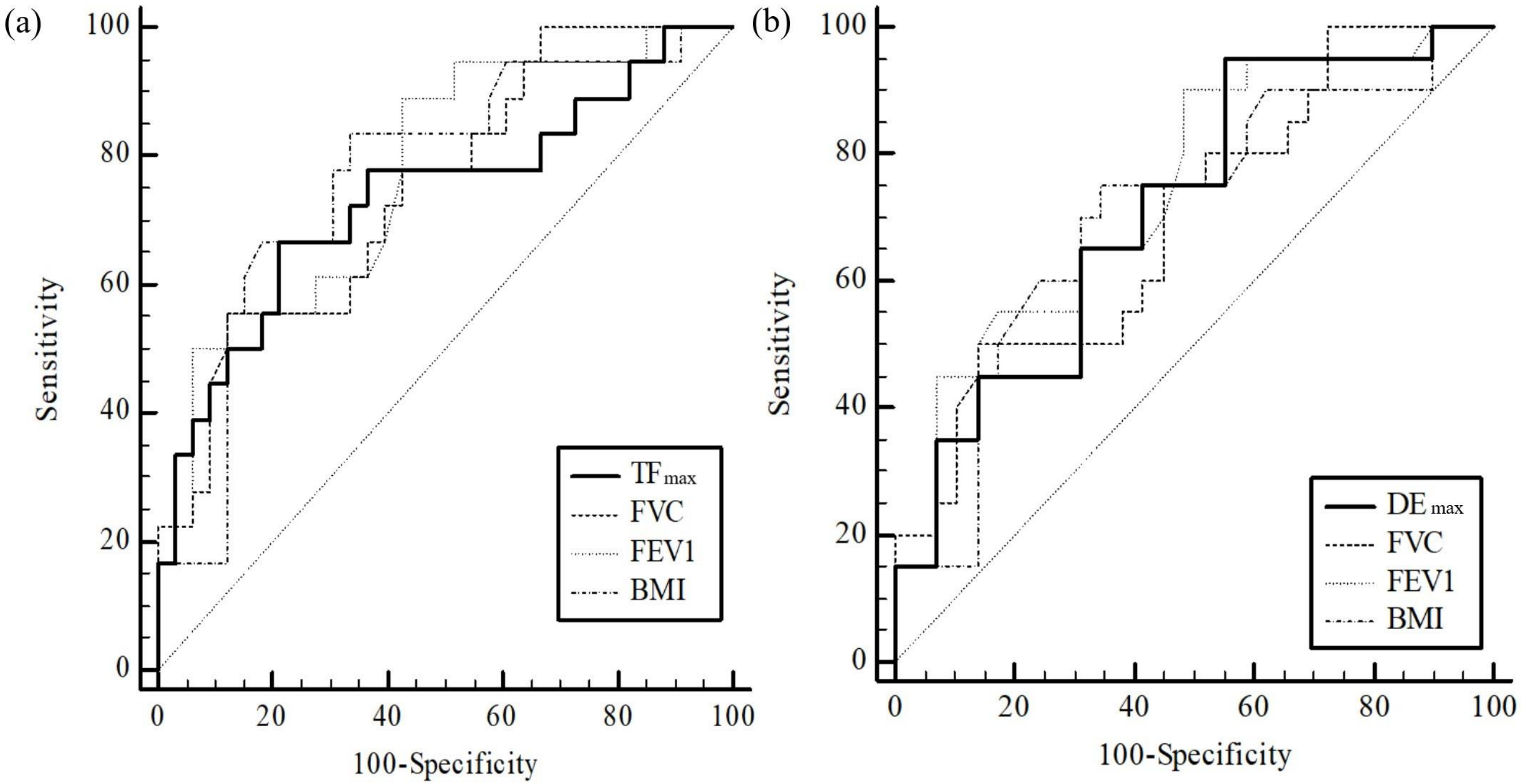
- Maximal values were different between stable and AE condition, not tidal volume.

Diaphragm thickness (mm), mean ± SD	**Stable**	**AE**	***p*-value**
at end-expiration	17.0 ± 6.0	18.9 ± 7.4	0.542
at tidal inspiration	24.5 ± 7.9	24.9 ± 11.3	0.862
at maximal deep inspiration	41.8 ± 14.9	35.7 ± 14.1	0.151
TF_{di} (%), mean ± SD			
at tidal inspiration	51.3 ± 51.0	42.3 ± 45.3	0.523
at maximal deep inspiration	158.4 ± 83.5	94.8 ± 81.4	0.010
DE (mm), mean ± SD			
at tidal inspiration	19.6±5.4	20.9±8.7	1.000
at maximal deep inspiration	40.5±12.5	30.8±11.1	0.007

TJ An et al. Not published data

As assessment tool of COPD

Distinguishing AE status from stable condition



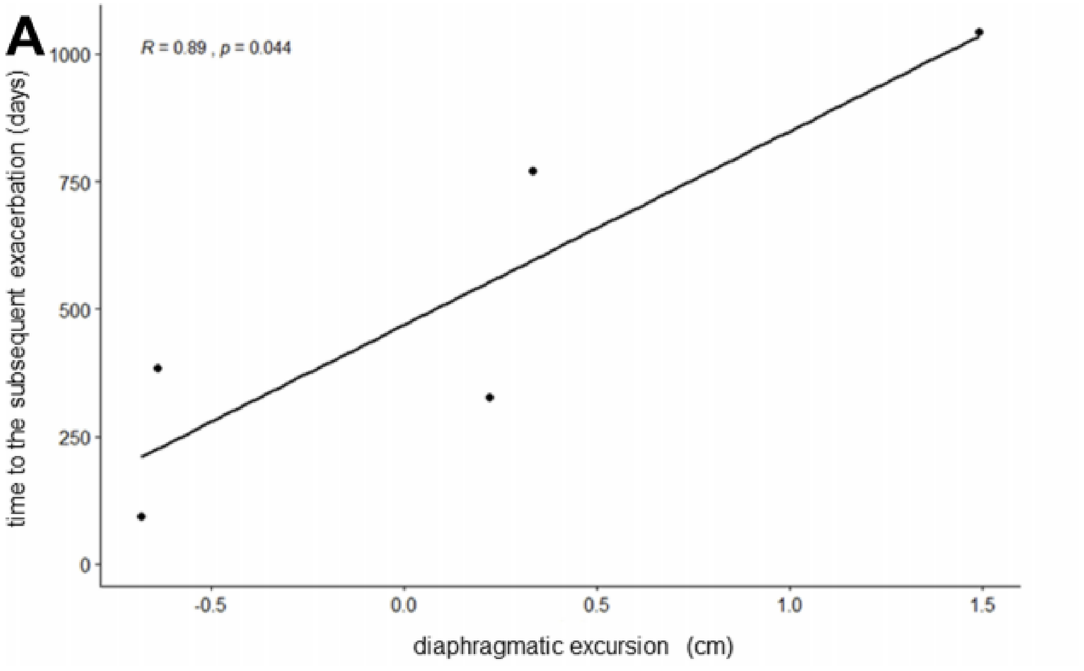
AUROC – TF (0.745), DE (0.721)

TJ An et al. Under review

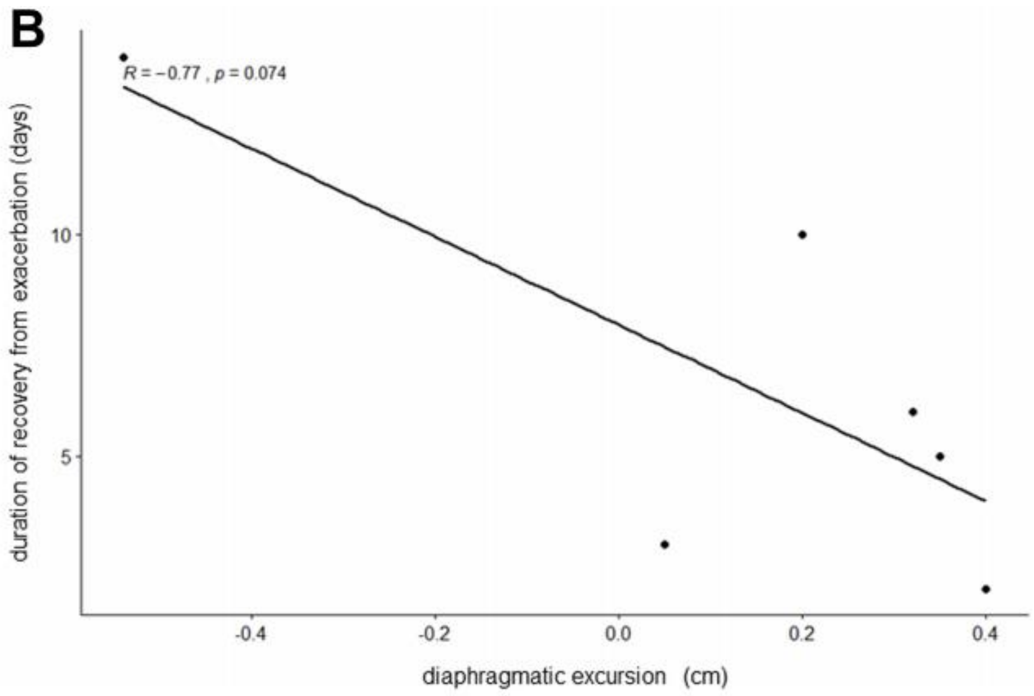
As assessment tool of COPD

Monitoring after AE

Time to subsequent exacerbation



Time taken to recover from the exacerbation



SY Lim et al. IJCOPD 2019:14 2479-2484

As assessment tool of COPD - intercostal muscle

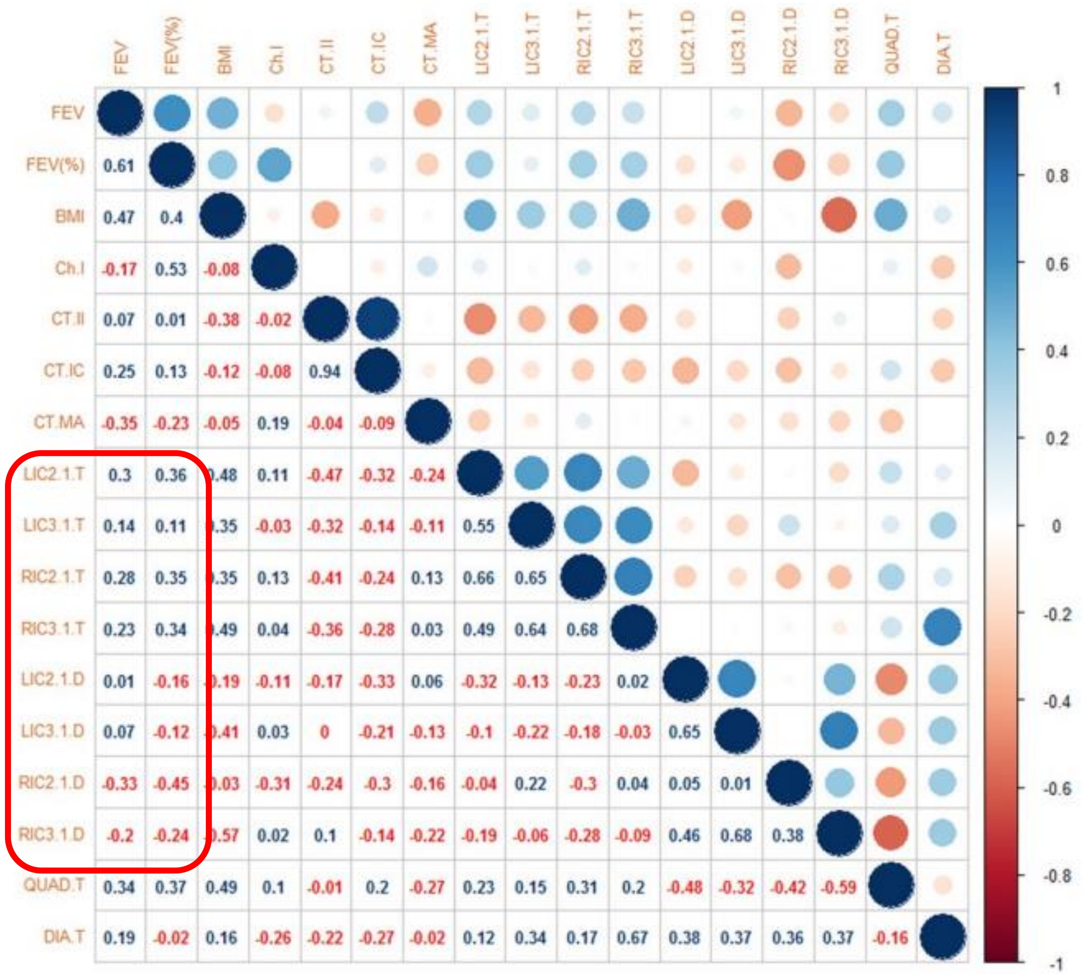
SCIENTIFIC REPORTS

OPEN

Parasternal intercostal muscle ultrasound in chronic obstructive pulmonary disease correlates with spirometric severity

Received: 8 August 2018
Accepted: 1 October 2018
Published online: 15 October 2018

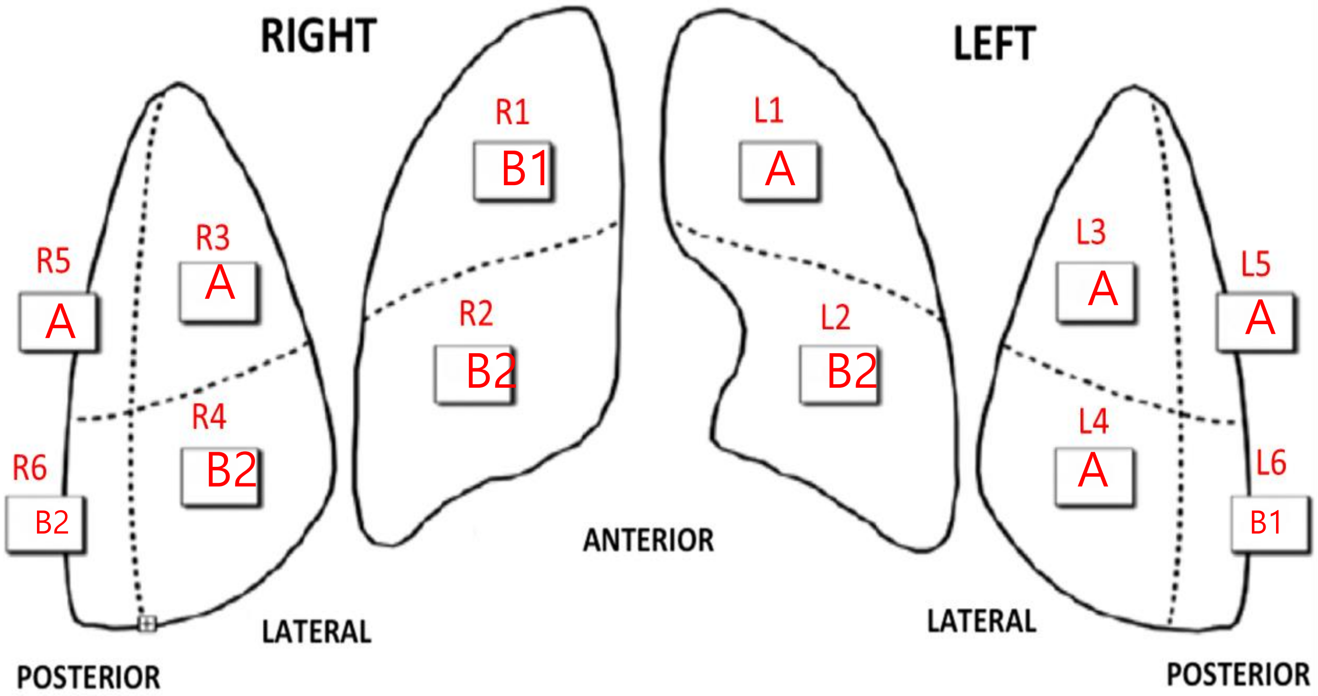
Peter Wallbridge[1,2], Selina M. Parry[3], Sourav Das[4], Candice Law[5], Gary Hammerschlag[1], Louis Irving[1,2], Mark Hew[2,6] & Daniel Steinfort[1,2]



As assessment tool of ILD

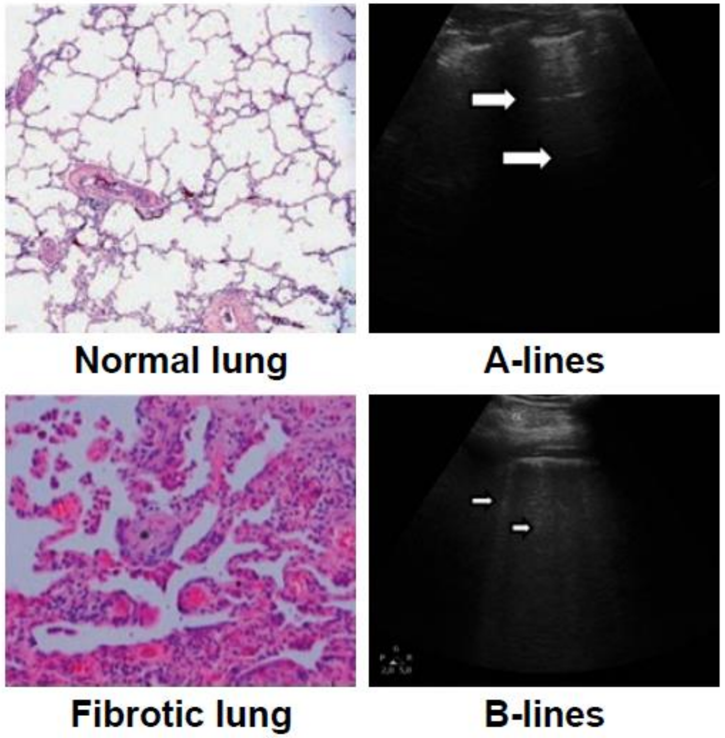
LUS in ILD

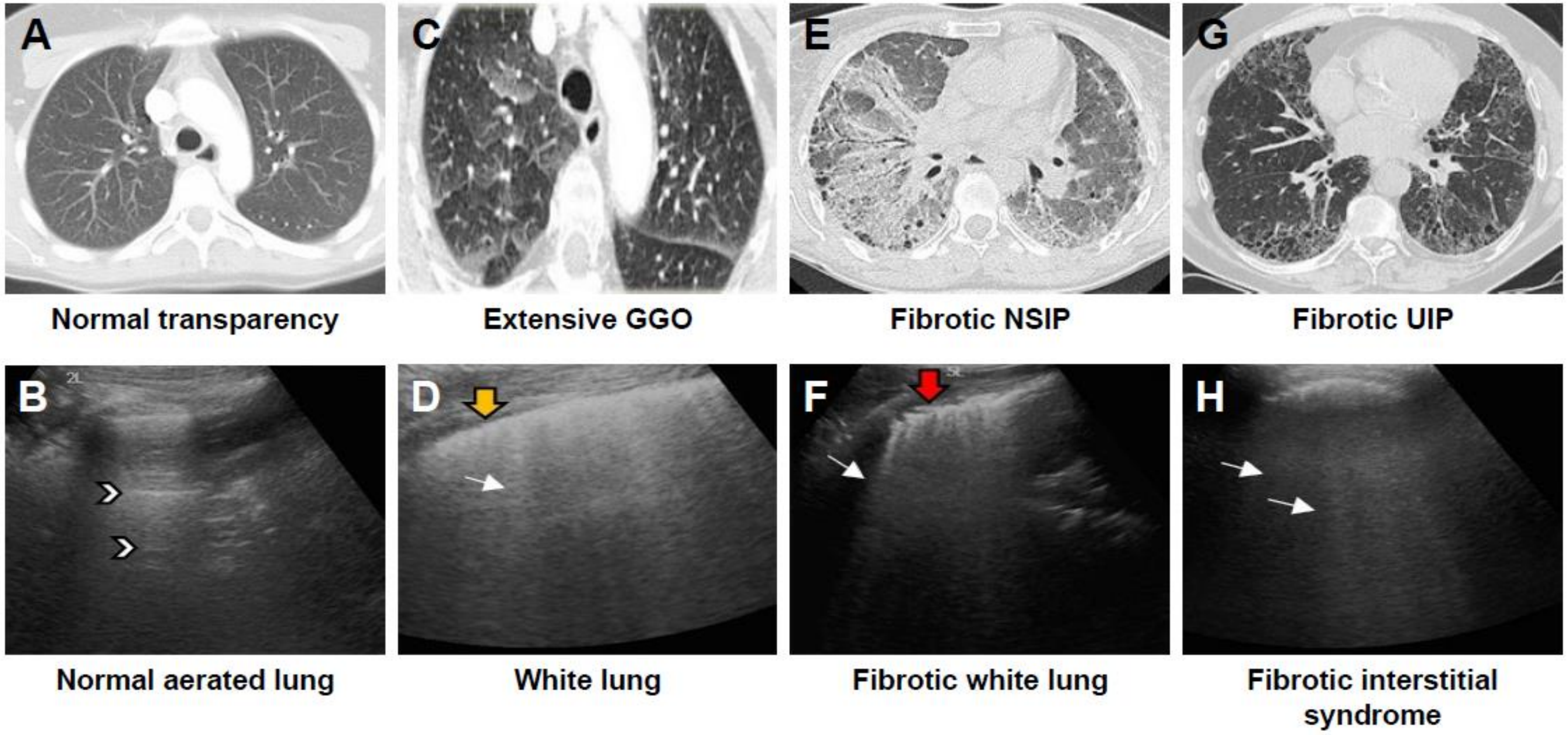
- Different distribution and degree of B-line, pleural irregularity, and combined subpleural consolidation
- Different status diaphragm muscle



As assessment tool of ILD

B-line = interstitial line

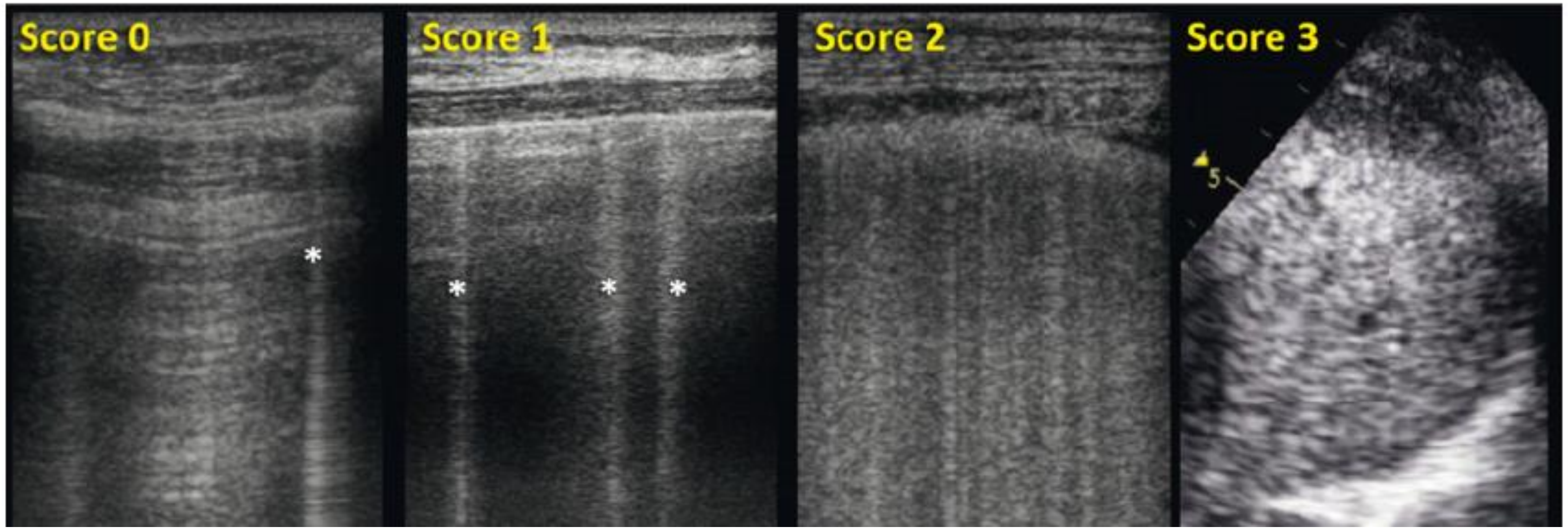


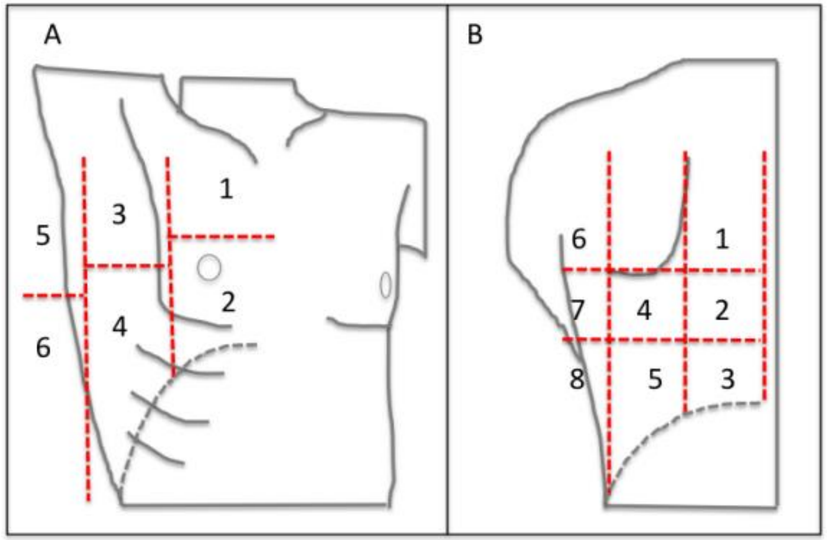


Manolescu et al. Clinical Interventions in Aging 2018:3

As assessment tool of ILD

- Lung ultrasound scoring system (lung aeration score)
  - A-line & B-lines (≤ 2) = normal aeration = score 0
  - B-lines (≥ 3) with well-spaced = moderate loss of aeration = score 1
  - Coalescent B-lines = severe loss of aeration = score 2
  - Tissue-like pattern = complete loss of aeration = score 3





Mongodi S et al. Modified Lung Ultrasound Ultraschall in Med 2017; 37: 530–537
F Mojoli et al. Am J Respir Crit Care Med 2019

As assessment tool of ILD

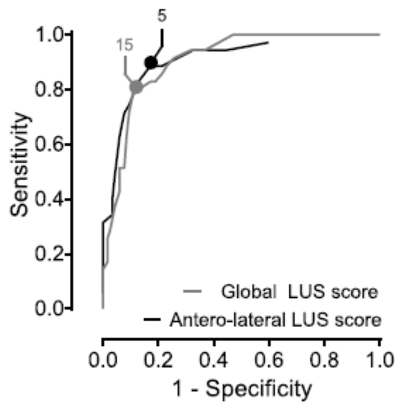
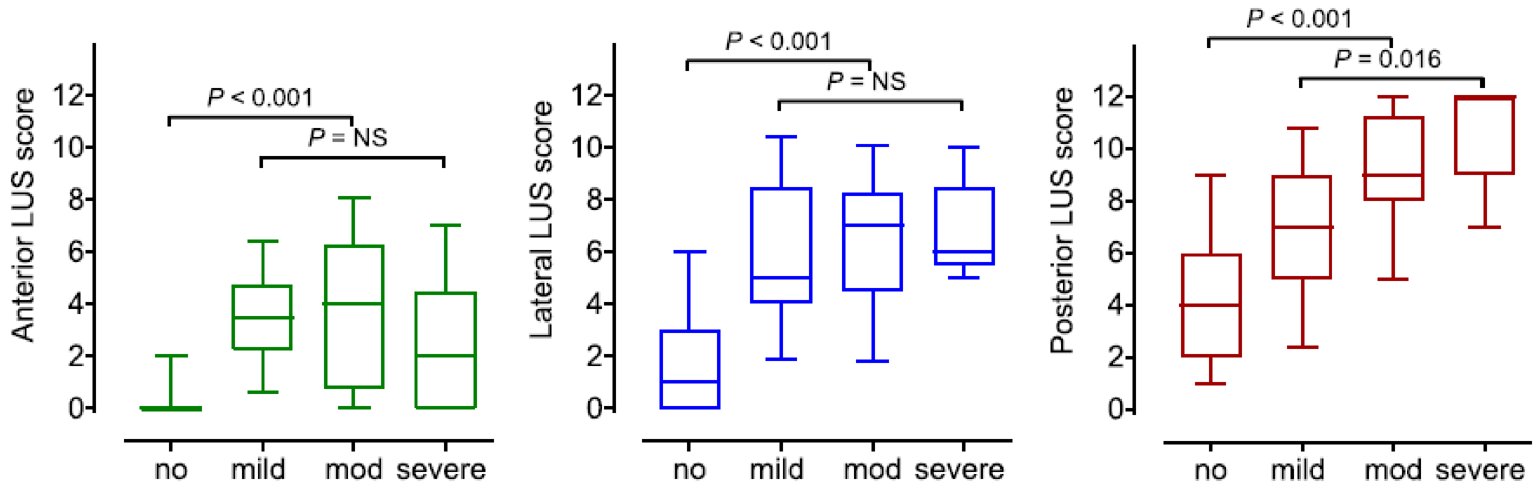


Table 2 AUROC and ROC-derived cutoffs for ARDS and their diagnostic accuracy measures

Score	AUROC	Optimal cutoff	Sensitivity	Specificity	PPV	NPV
Composite						
Global	0.91 (0.86–0.95)	15	80.0% (63.1–91.6)	88.9% (81.8–94.0)	68.3% (55.7–78.7)	93.7% (88.4–96.7)
Anterolateral	0.91 0.85–0.97)	5	88.6% (73.3–96.8)	82.9% (74.8–89.2)	60.8% (50.6–70.2)	96.0% (90.6–98.4)



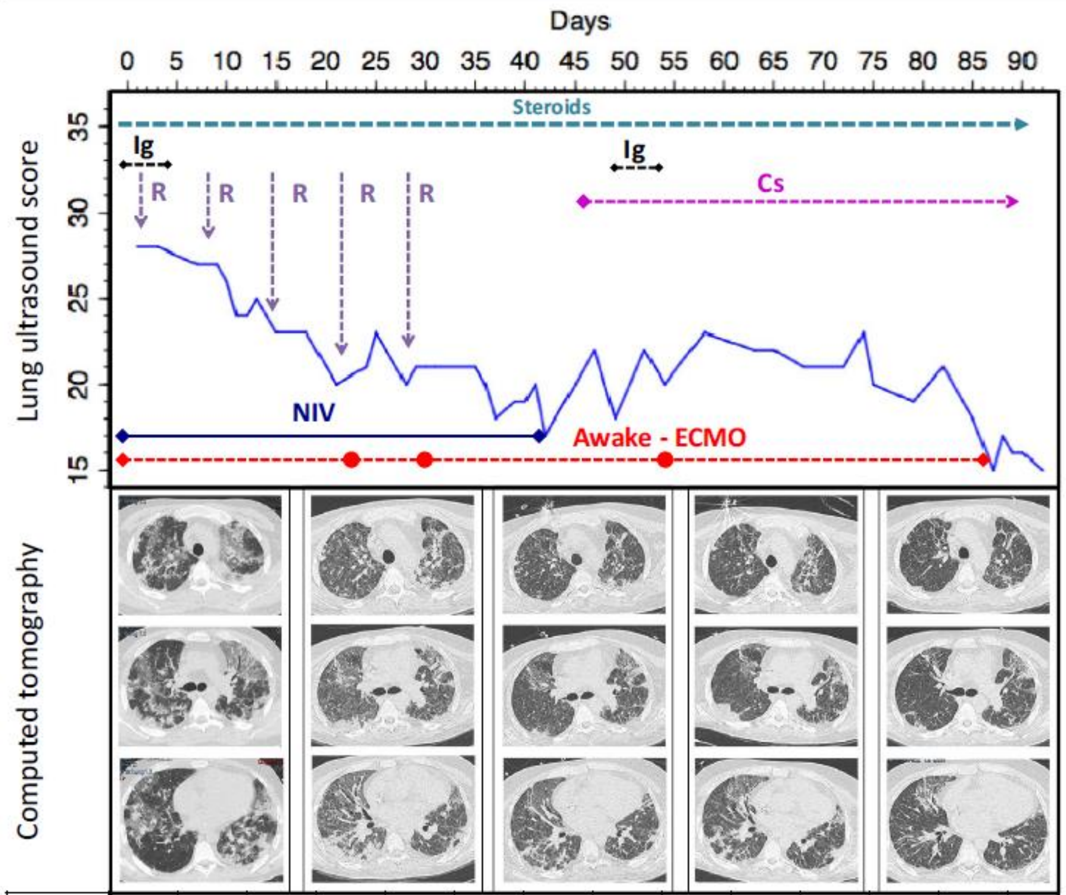
L Pisani et al. Intensive Care Medicine Experimental 2019, 7:44

As assessment tool of ILD

- 28 year-old male
- DM/PM ILD exacerbation
- Treated with R (Rituximab), Cs (Cyclosporine), and Ig (IVIG)
- LUSS at 12 regions (0~36 scores)
- LUSS daily

→ Guiding needs of CT

→ Guiding additional immunosuppressive therapy



HFNC-FiO_2	100 [100-100]	60 [70-90]	45 [45-50]	45 [45-50]	40 [40-45]	35 [35-40]	35 [35-35]	50 [35-50]	40 [40-40]	30 [30-40]	30 [30-30]	30 [30-30]	30 [30-30]	30
ML-FiO_2	100 [100-100]	100 [100-100]	70 [70-80]	60 [50-70]	40 [30-45]	21 [21-21]	35 [35-35]	50 [35-50]	40 [40-40]	40 [40-40]	40 [40-45]	40 [40-40]	21 [21-21]	
BF (L/min)	3.5 [3.5-3.6]	3.6 [3.6-3.6]	3.0 [3.0-3.1]	3.5 [3.1-3.5]	3.0 [2.9-3.2]	3.1 [2.8-3.5]	3.2 [3.0-3.3]	3.5 [3.2-3.5]	3.0 [3.0-3.1]	3.0 [3.0-3.0]	3.0 [3.0-3.1]	2.9 [2.9-2.9]	3.3 [3.0-3.5]	
SGF (L/min)	7.0 [6.5-8.0]	8.0 [6.0-8.5]	4.0 [3.5-4.5]	5.5 [4.5-5.4]	4.0 [3.0-4.0]	1.0 [0.7-1.5]	3.0 [3.0-3.0]	5.0 [4.0-6.0]	3.0 [3.0-3.0]	3.0 [2.5-3.0]	2.5 [2.5-2.5]	2.5 [2.5-2.5]	1.3 [0.5-2.0]	
PaO_2 (mmHg)	57.5 [56.5-62.2]	66.0 [63.8-79.7]	73.0 [71.5-87.9]	97.5 [82.3-103.6]	85.8 [85.1-91.0]	86.6 [84.9-101.7]	100.1 [99.7-105.2]	93.7 [88.9-102.6]	98.1 [87.3-99.9]	83.0 [82.3-97.8]	88.6 [86.0-92.9]	88.1 [85.1-92.6]	88.0 [82.8-90.1]	87.7

Mongodi *et al. Ultrasound J (2020) 12:27*

As assessment tool of ILD

Diaphragm

- Healthy vs IPF
  - 12 participants each
  - Difference in diaphragm excursion during deep inspiration, not in tidal breathing

Table 1 Anthropometric and lung function measurements

	Controls	Patients	*P*
Age	66.5 ± 11	71.6 ± 5.5	0.216
BMI	24.0 ± 4.0	28.1 ± 2.4	0.006
Smoking (%)	5 (41.7)	10 (83.3)	0.035
CT (cm)	81.3 ± 10.3	97.8 ± 4.6	< 0.001
CA (cm)	82.3 ± 12.8	96.9 ± 8.5	0.003
FVC	111.6 ± 35.2	72.5 ± 7.5	0.001
TLC	112.9 ± 27.8	55.4 ± 7.5	< 0.001
VC	117.8 ± 13.4	72.0 ± 9.0	< 0.001
DL_{CO} mL/min/mm Hg	82.1 ± 24.8	37.8 ± 8.3	< 0.001
FEV_1/FVC max	85.4 ± 7.1	85.1 ± 5.7	0.904
DE (normal breath) (cm)	1.5 ± 0.6	1.7 ± 0.7	0.503
DE (deep inspiration) (cm)	6.3 ± 1.3	3.7 ± 1.1	< 0.001

Boccatonda et al. Multidisciplinary Respiratory Medicine (2019)14:1

As assessment tool of ILD

Diaphragm excursion correlated with lower lung functions in IPF patients

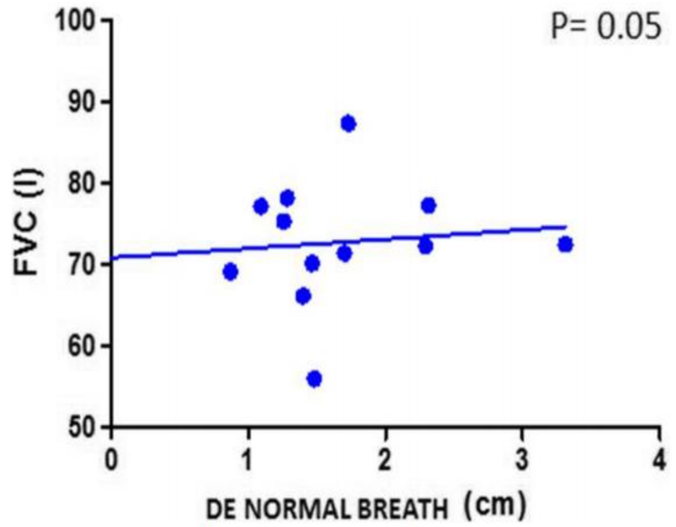


Fig. 3 Correlation between FVC and DE during normal breathing in IPF patients. *FVC*: forced vital capacity; *DE*: diaphragmatic excursion

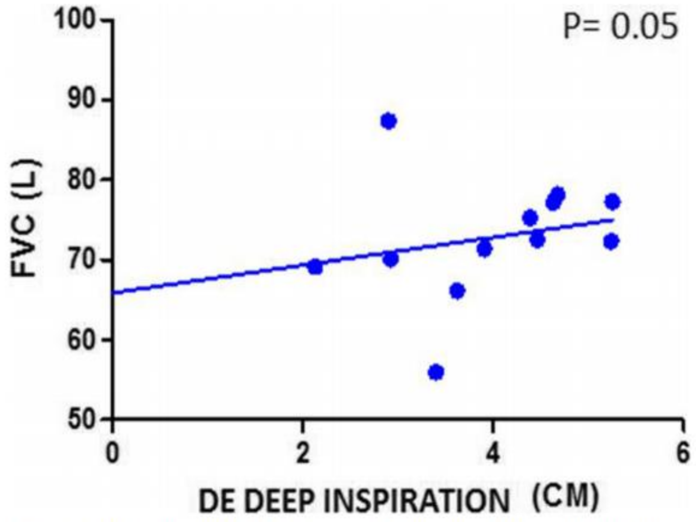


Fig. 4 Correlation between FVC and DE during deep inspiration in IPF patients. *FVC*: forced vital capacity; *DE*: diaphragmatic excursion

Boccatonda et al. Multidisciplinary Respiratory Medicine (2019)14:1

Pulmonary rehabilitation and lung ultrasound

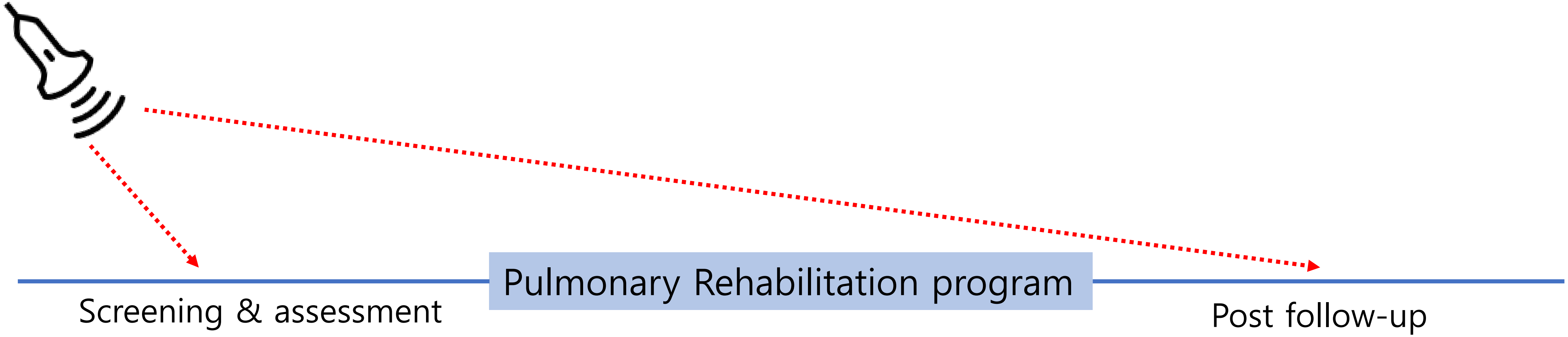
- Pulmonary rehabilitation (PR)

  : Specialized program of exercise and education

  : Comprehensive intervention

  a) Exercise training + Education + Self-management

  b) Patient assessment with "Patient-tailored therapy"



Pulmonary rehabilitation and lung ultrasound

- "Patient-tailored therapy" = Personalized medicine
  - Exercise capacity = whole body status + Lung + Heart + Muscles
    - Proper assessment tools are needed
      - Lungs and adjacent organs
        - PFT, CT, Echocardiography, and Ultrasound
      - Respiratory and peripheral muscles
        - EMG, hand-grip test, and Ultrasound
      - Whole body status
        - BIA, DXA, and Ultrasound

Current PR protocol in Yeouido St. Mary`s hospital

CMC

- For personalized treatment
- Ultrasound: LUS+DUS ± Intercostal muscle

In-patient

COPD, Asthma, ILD

CC, PI, ROS, P/Ex

X-ray, CT, LAB, PFT

→

Lung ultrasound

Basic: A-line, B-line,

Consolidation, Effusion,

Functional (Lung sliding),

Geometric (LUS mapping)

Respiratory muscles

→

Individualized PR

Consultation to

Rehabilitation Medicine

Points of lung ultrasound in PR by cases

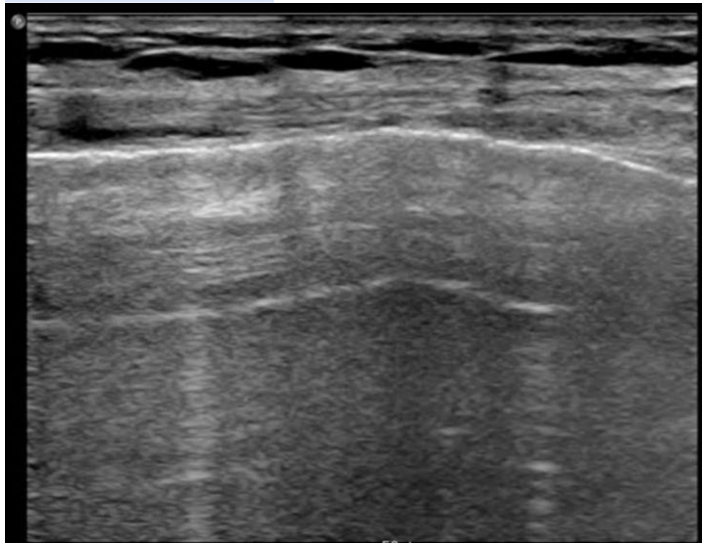
- Screening of proper patient
- Resolution of acute exacerbation status of underlying disease
- Regressed combined status, such as pneumothorax and pleural effusion
- Assessment of respiratory muscle

Screening of proper patient

Case 1. 78/F

- Patients visit hypercapnic respiratory failure → BiPAP + bronchodilator therapy
- Alert mental status but, poor general condition → cannot perform PFT
- ABGA : 7.34-74.6-46.9-40.9-82.3 (room air)
- Lung sound decreased.

LUS basics



Acute respiratory failure with Lung sliding (+), A-line (+)

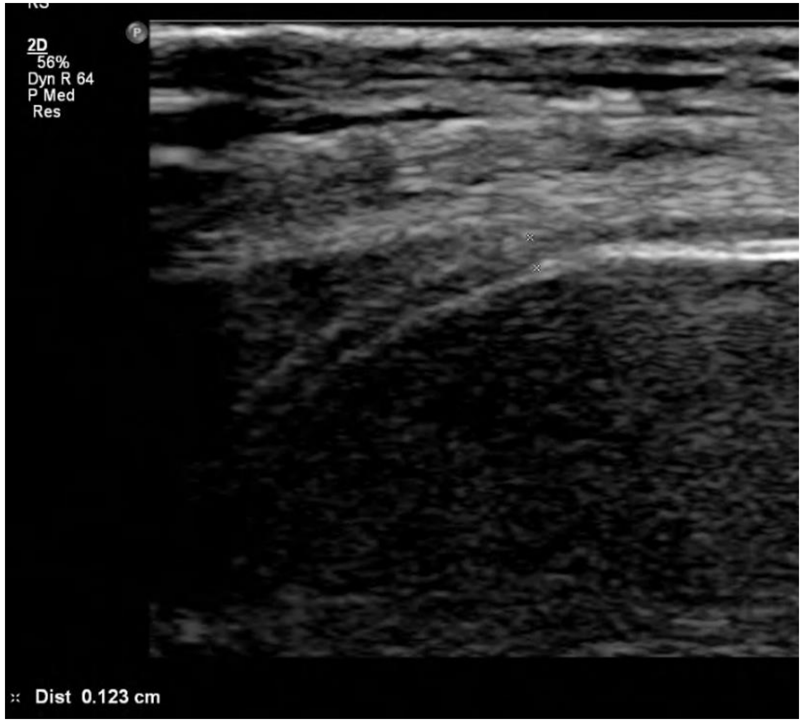
→ R/O COPD or asthma according to BLUE protocol?

→ R/O hypercapnic respiratory failure due to airway disease?

→ Early PR?

Screening of proper patient

Persistent use of accessory muscle during breathing → DUS performed



Perform NCS/EMG : Clinically definite ALS + Bulbar muscle weakness

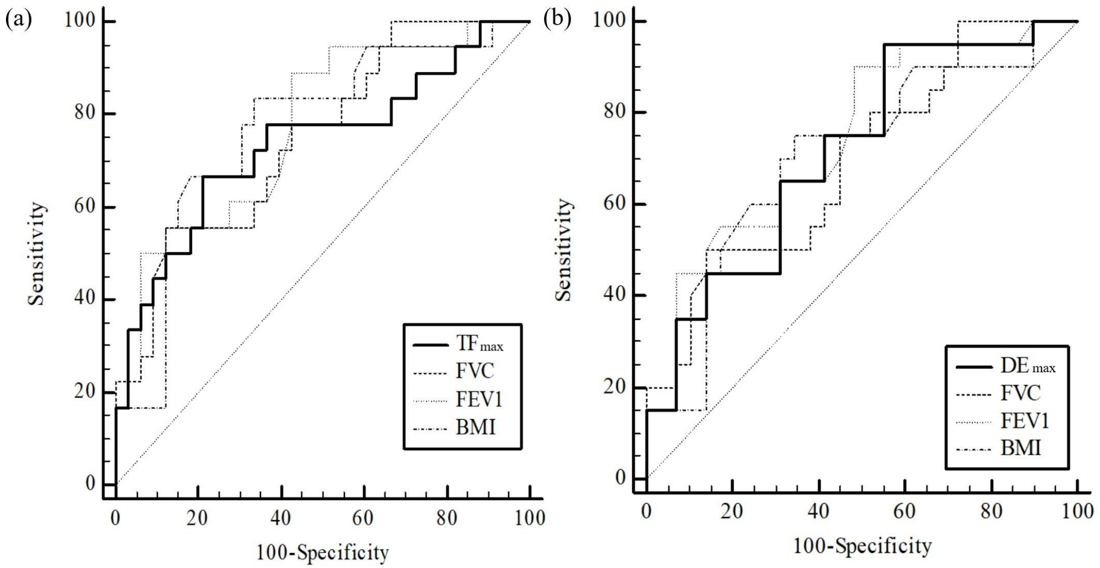
→ low grade muscle training + Tracheostomy Rec for motor neuron disease (not routine PR program)

Resolution of AE status of underlying disease

- In acute exacerbation status, dyspnea symptom is main hurdle for exercise
  - Low compliance
  - Hard to elevation of exercise level
  - Mainly training muscle power

→ Proper timing of exercise?

- Recovery of smooth lung sliding
- Recovery of prominent A-line
- Recovery of multiple B-lines
- Recovery of pleural effusion or pneumothorax



Regression of combined status

Mechanism of dyspnea	Profiles of BLUE-protocol	Sensitivity	Specificity	Positive predictive value	Negative predictive value
Acute hemodynamic pulmonary edema	B-profile	97%	95%	87%	99%
		(62/64)	(187/196)	(62/71)	(187/189)
COPD in exacerbation or severe acute asthma	Nude profile	89%	97%	93%	95%
		(74/83)	(172/177)	(74/79)	(172/181)
Pulmonary embolism	A-profile (with deep venous thrombosis)	81%	99%	94%	98%
		(17/21)	(238/239)	(17/18)	(238/242)
Pneumothorax	A'-profile (with lung point)	88%	100%	100%	99%
		(8/9)	(251/251)	(8/8)	(251/252)

- Lung point: Lung sliding pattern change point
- Highly accurate for diagnosis of *pneumothorax*

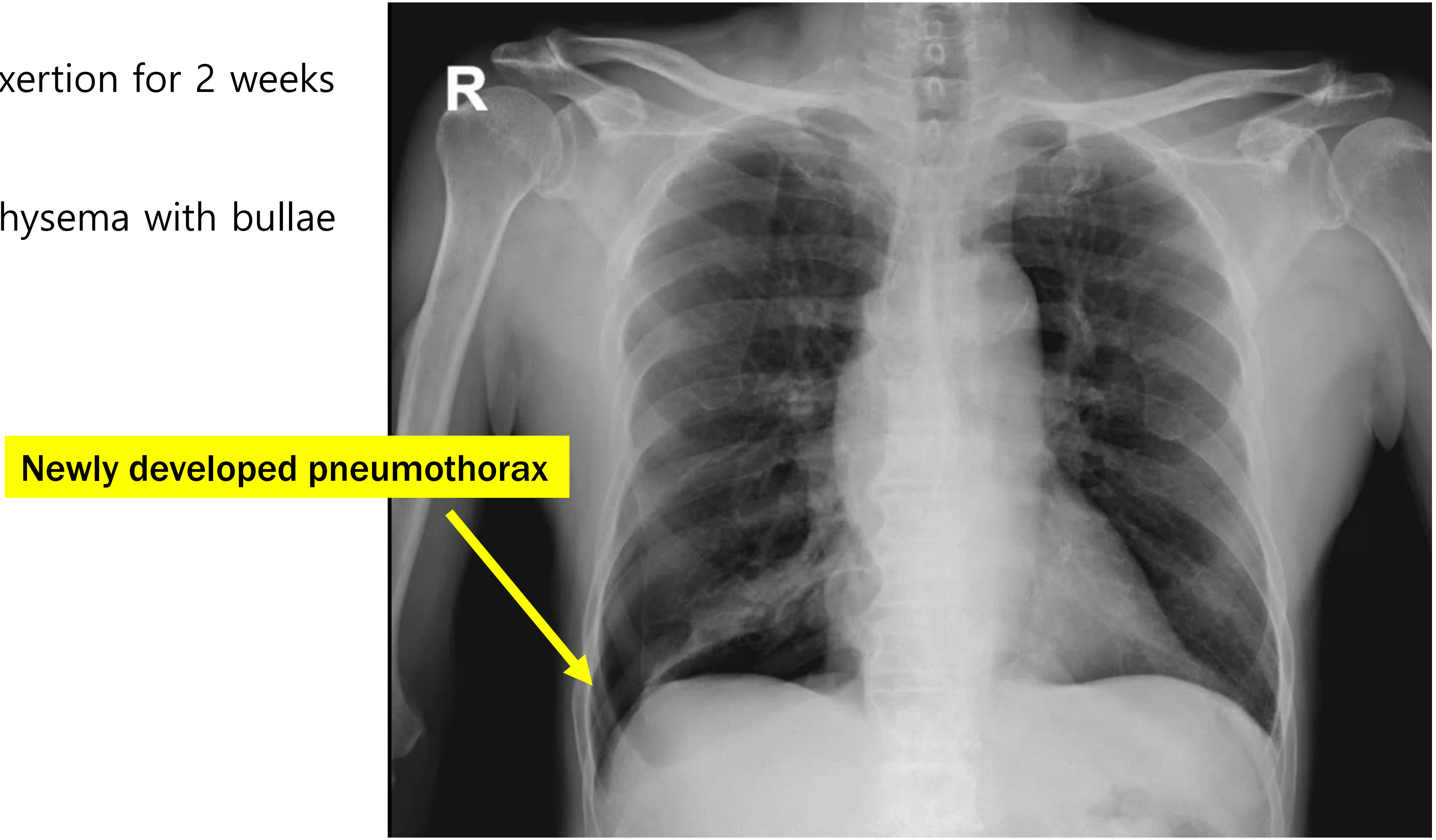
→ How to use it?

D. Lichtenstein. Annals of Intensive Care 2014, 4:1

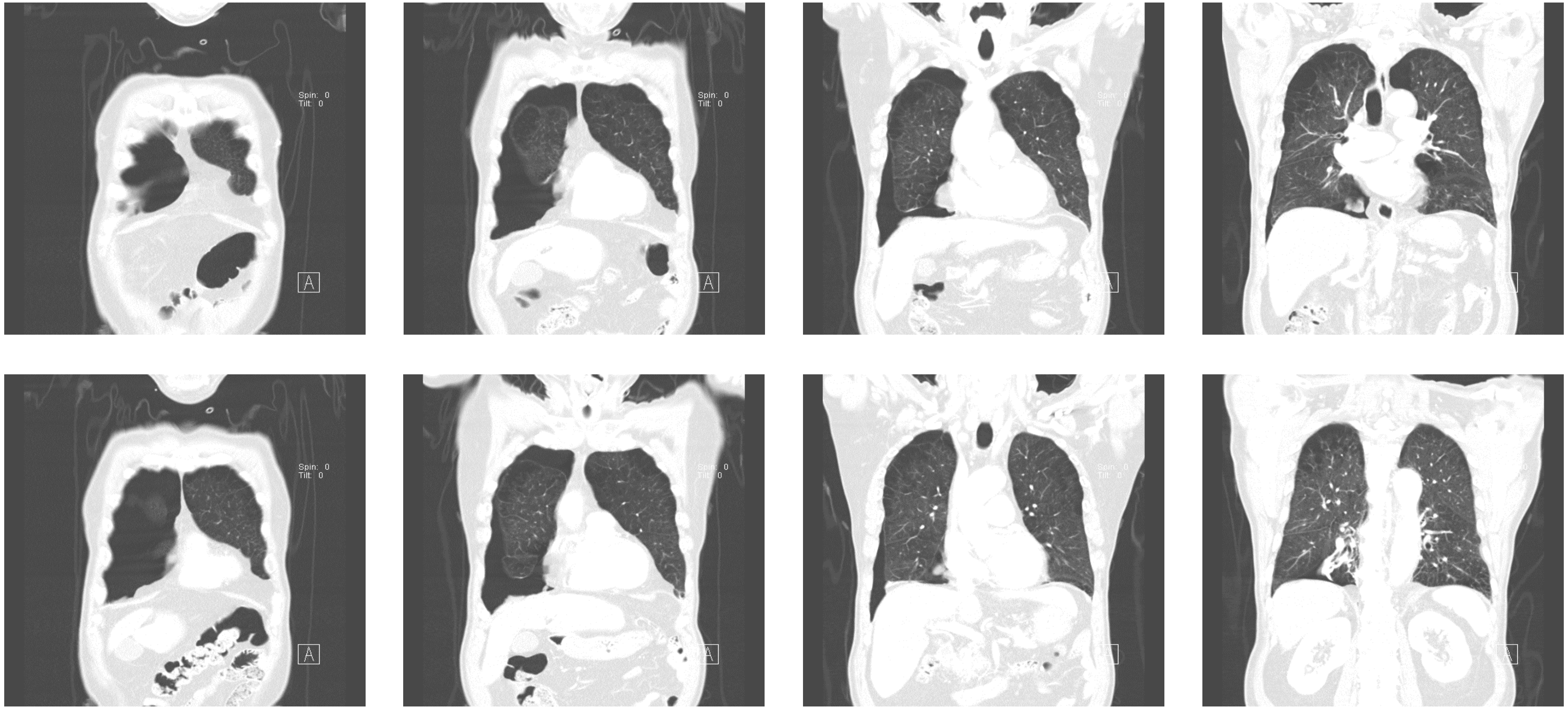
Regression of combined status

Case 2.

- CC Dyspnea on exertion for 2 weeks
- Underlying COPD
- Previous CT: emphysema with bullae



Regression of combined status



Moderate to large amount of pneumothorax with extensive emphysematous lung

→ CTD? When we begin PR in this patient?

Regression of combined status

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 | JANUARY 30, 2020 | VOL. 382 NO. 5

Conservative versus Interventional Treatment for Spontaneous Pneumothorax

S.G.A. Brown, E.L. Ball, K. Perrin, S.E. Asha, I. Braithwaite, D. Egerton-Warburton, P.G. Jones, G. Keijzers, F.B. Kinnear, B.C.H. Kwan, K.V. Lam, Y.C.G. Lee, M. Nowitz, C.A. Read, G. Simpson, J.A. Smith, Q.A. Summers, M. Weatherall, and R. Beasley, for the PSP Investigators*

Primary outcome : lung re-expansion (≤8 weeks)

→ Conservative management was non-inferior to intervention group

Table 2. Secondary Outcomes.*

Outcome	Interventional Management (N=154)	Conservative Management (N=162)	Relative Risk (95% CI)	Risk Difference (95% CI)†
One or more procedures — no. (%)	145 (94.2)	25 (15.4)	6.10 (4.24–8.77)	78.1 (72.0–85.4)
Chest drainage for ≥72 hr — no./total no. (%)	78/153 (51.0)	15/162 (9.3)	5.51 (3.32–9.14)	41.7 (32.6–50.8)
Suction — no. (%)	52 (33.8)	12 (7.4)	4.56 (2.53–8.20)	26.4 (17.9–34.9)
At least one CT scan — no./total no. (%)	28/146 (19.2)	12/154 (7.8)	2.46 (1.31–4.66)	11.4 (3.7–19.1)
Hospital revisit — no. (%)	41 (26.6)	28 (17.3)	1.54 (1.01–2.36)	9.3 (0.3–18.4)
Any adverse event — no. (%)	41 (26.6)	13 (8.0)	3.32 (1.85–5.95)	18.6 (10.5–26.7)
Any serious adverse event — no. (%)	19 (12.3)	6 (3.7)	3.30 (1.37–8.10)	8.6 (2.7–14.6)
Pneumothorax recurrence within 12 mo — no./total no. (%)	25/149 (16.8)	14/159 (8.8)	1.90 (1.03–3.52)	8.0 (0.5–15.4)
No. of chest radiographs per patient	10.9±7.1	6.4±3.9	1.7 (1.6–1.8)‡	4.5 (3.2–5.8)§
No. of surgical procedures per patient¶	0.3±0.5	0.1±0.2	4.21 (2.10–8.41)‡	
Length of hospital stay in first 8 wk — days				
Mean	6.1±7.6	1.6±3.5	2.8 (1.8–3.6)‖	
Median (IQR)	3.8 (0.8–9.3)	0.2 (0.2–0.8)		
Days off from work				
Mean	10.9±12.7	6.0±7.3	2.0 (1.0–3.0)‖	
Median (IQR)	6.0 (2.0–14.0)	3.0 (1.0–8.0)		

- Conservative management: Only 15.4% underwent CTD
- Adverse event
  - Intervention (26.6%) > Conservative (8.0%)
- Severe adverse event
  - Intervention (12.3%) > Conservative (3.7%)
- Pneumothorax recurrence in 1Y
  - Intervention (16.8%) > Conservative (8.8%)

S. Brown et al. N Engl J Med (2020)

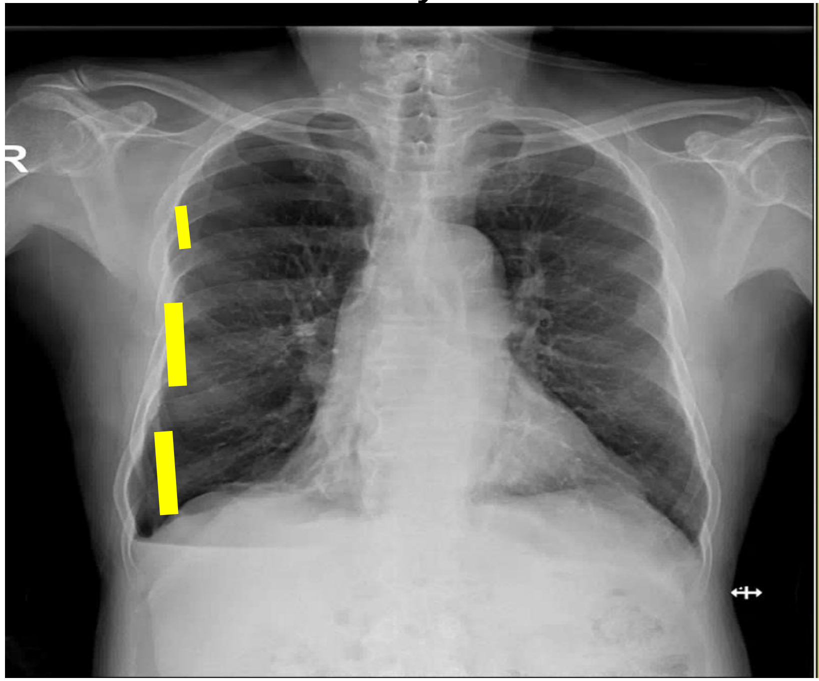
Regression of combined status

- V/S stable without hypoxia
- CTD insertion in extensive emphysema → High risk of adverse event or pneumothorax recurrence

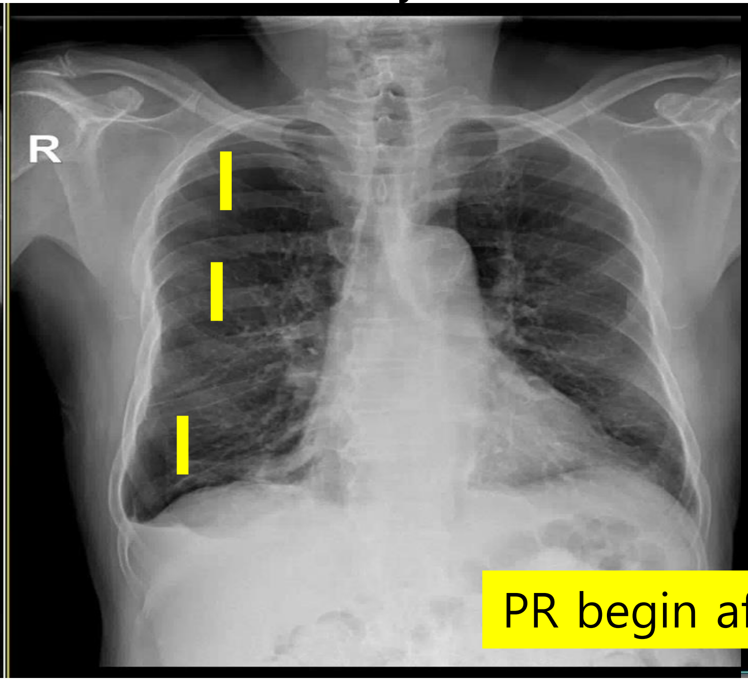
→ Conservative care → monitored by Chest X-ray → not actually relaxed d/t quite a lot of pneumothorax

→ LUS monitoring begin (drawing a map of lung point)

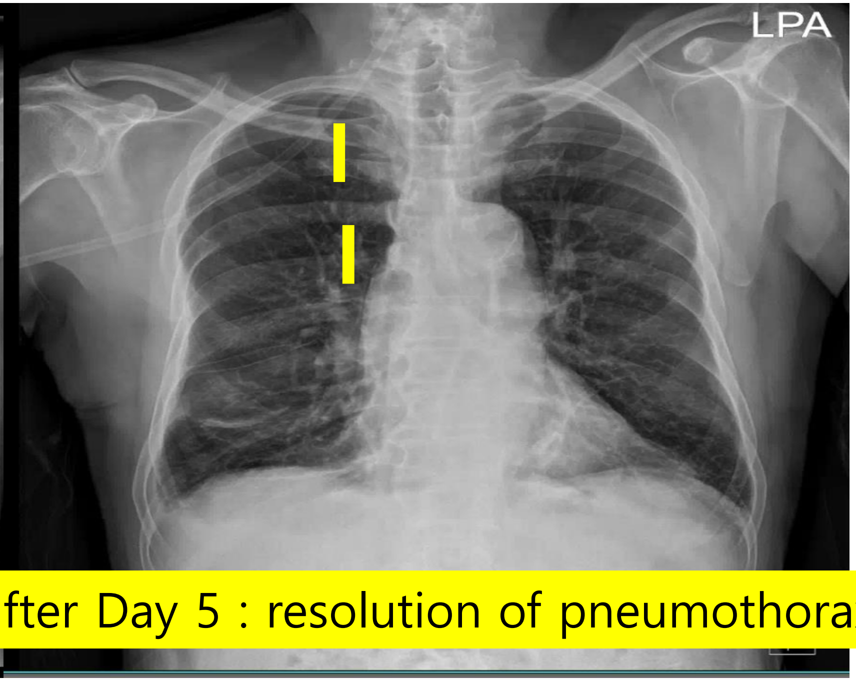
Day 1



Day 3



Day 5



PR begin after Day 5 : resolution of pneumothorax

Assessment of respiratory muscles

In-patient

COPD, Asthma, ILD

CC, PI, ROS, P/Ex

X-ray, CT, LAB, PFT

→

Lung ultrasound

Basic: A-line, B-line,

Consolidation, Effusion,

Functional (Lung sliding),

Geometric (LUS mapping)

Respiratory muscles

→

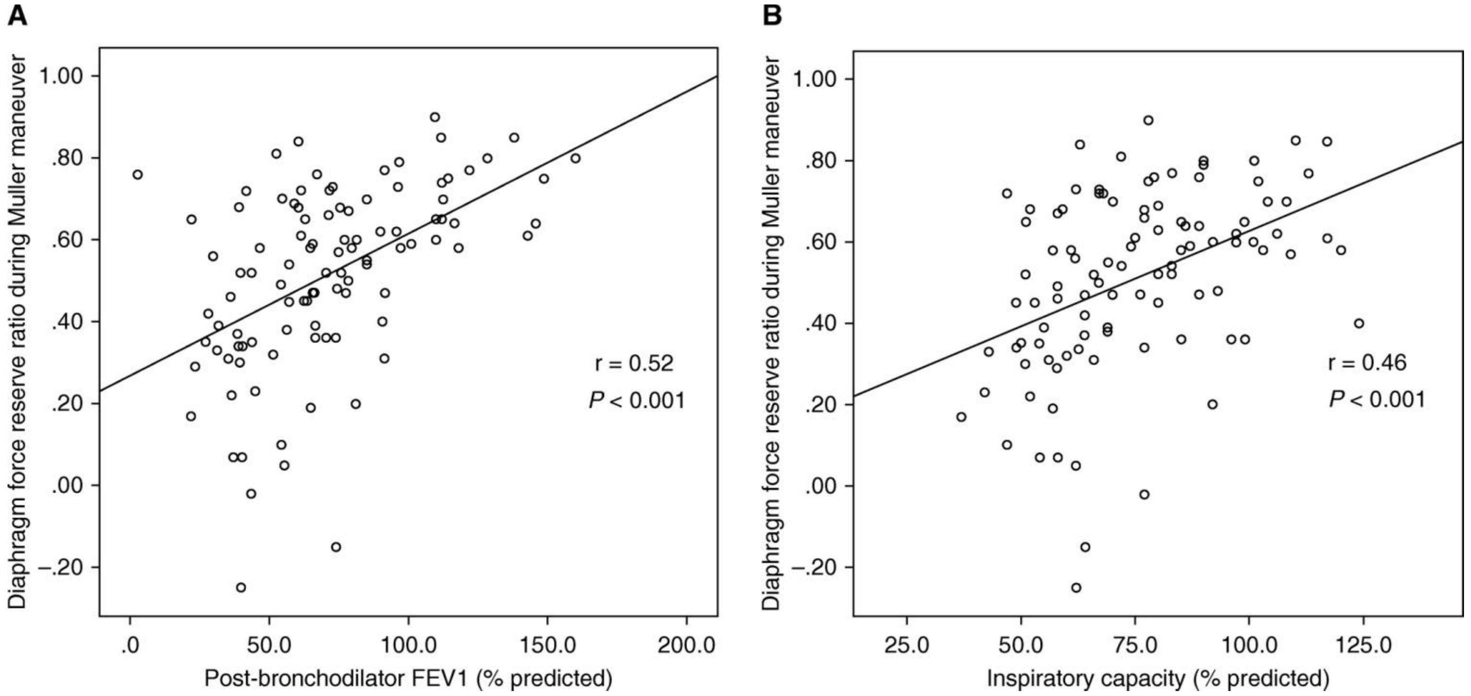
Individualized PR

- Muscles in respiration
  - Overall amount, Diaphragm, Intercostal and etc

Assessment of muscles – Diaphragm muscle

Ultrasound Evaluation of Diaphragm Force Reserve in Patients with Chronic Obstructive Pulmonary Disease

Nuttapol Rittayamai[1], Benjamas Chuaychoo[1], Jamsak Tscheikuna[1], Martin Dres[2], Ewan C. Goligher[3,4,5,6,7], and Laurent Brochard[7,8]



Diaphragm muscle power or reserve → Correlated with lung function

∴ Diaphragm dysfunction → correlated with poor lung function

N.Rittayamia et al. AnnalsATS 2020;17:10

Assessment of muscles – Diaphragm muscle

Diaphragm and sarcopenia

Table 3
Summary of Parameters That Can Be Assessed by Muscle Ultrasound in Older Individuals, With Main Strengths and Limitations

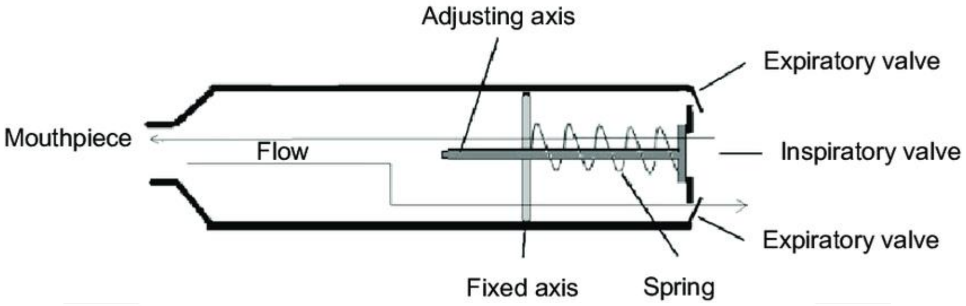
Parameter	Anatomic Site of Assessment	Strengths	Limitations
Muscle thickness	Every muscular compartment (most studies on anterior and posterior thigh)	Simple and quick Reproducible Correlated with gold standard measures of muscle mass and muscle function	Estimations of total muscle mass need multiple measurements and complex population-specific equations Fixed anatomic landmarks needed Results depend on pressure applied with the probe Site-specific sarcopenia may bias results
Muscle cross-sectional area	Lower limb muscular compartments	Simple and quick Reproducible Correlated with gold standard measures of muscle mass Both linear- and curved-array probes can be used	Technique of assessment not completely standardized Fixed anatomic landmarks needed Correlation with functional parameters still unclear
Pennation angle	Pennate muscles of the lower limb (gastrocnemius medialis)	Gives information about muscle structure and strength generation capacity	Specific training of operators needed Requires collaboration from the patient Results are influenced by articular position and degree of muscle contraction Correlation with functional parameters still unclear
Fascicle length	Pennate muscles of the lower limb (gastrocnemius medialis)	Gives information about muscle structure and strength generation capacity	Specific training of operators needed Requires collaboration from the patient Results are influenced by articular position and degree of muscle contraction Correlation with functional parameters still unclear
Echo-intensity	Every muscular compartment (most studies on anterior and posterior thigh)	Gives information about myosteatosis Correlated with measures of muscle function	Specific training of operators needed Results depending on the type of software used to interpret images Technique of assessment not completely standardized
Contrast-enhanced assessment of vascularization	Quadriceps femoris	Identifies alterations in vascularization that may contribute to the onset of sarcopenia	Requires a high level of expertise Technique of assessment not completely standardized Studies focused on elderly subjects are lacking
Diaphragm thickness at tidal volume and total lung capacity and their ratio (ΔTdi)	Diaphragm	Simple and quick Reproducible Correlated with measures of respiratory function	Technique never been studied in geriatric patients with sarcopenia

A. Ticinesi et al. JAMDA (2016)

Assessment of muscles – Diaphragm muscle

Diaphragm dysfunction was confirmed by DUS

- Lt diaphragm evaluation ± neurologic screening ± EMG
- Routine Pulmonary Rehabilitation program
- Diaphragm muscle training – inspiratory muscle training



Diaphragm atrophy was confirmed by DUS

- Routine Pulmonary Rehabilitation program
- Diaphragm muscle training – inspiratory muscle training
- Nutritional screening

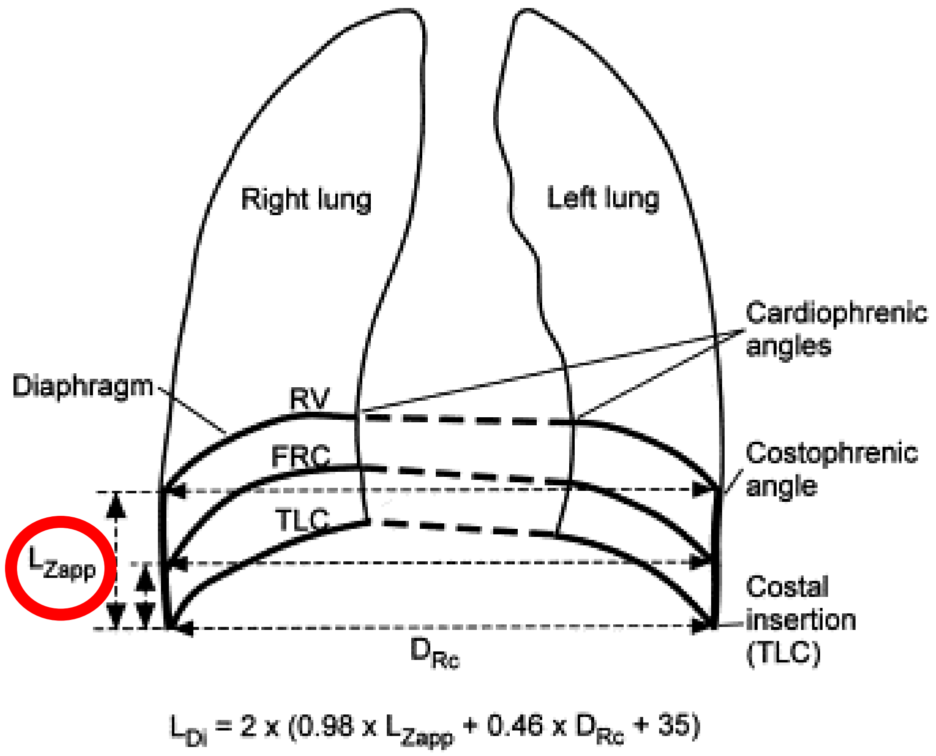
  - Oral protein supplement in sarcopenia or cachexia

Follow-up after pulmonary rehabilitation

International Journal of COPD
Dovepress
open access to scientific and medical research
Open Access Full Text Article
ORIGINAL RESEARCH

Utility of ultrasound assessment of diaphragmatic function before and after pulmonary rehabilitation in COPD patients

- Compare diaphragm US findings before and after PR
- L_{Zapp} = Length of Zone of apposition
- S_{Zapp} = Thickness of Zone of apposition



D. McKenzie et al. Respiration Physiology 123 (2000):225-234
Crimi et al. IJCOPD 2018:13 3131-3139

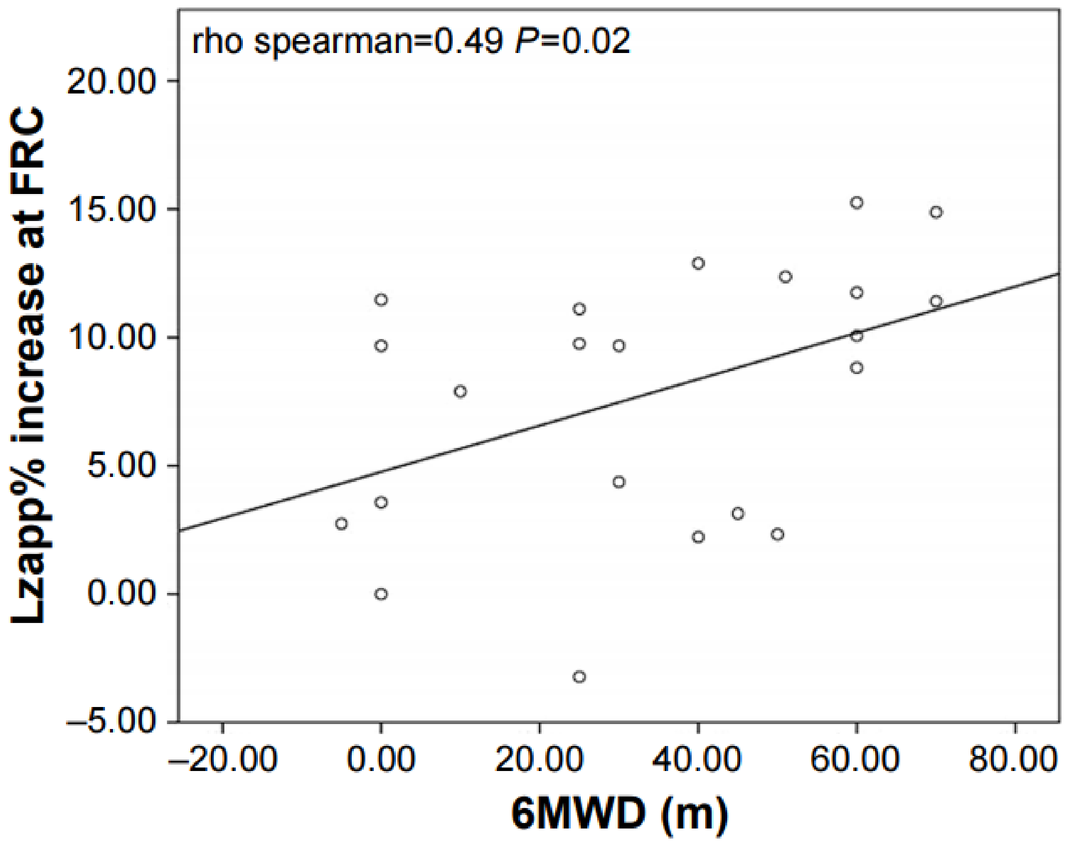
Follow-up after pulmonary rehabilitation

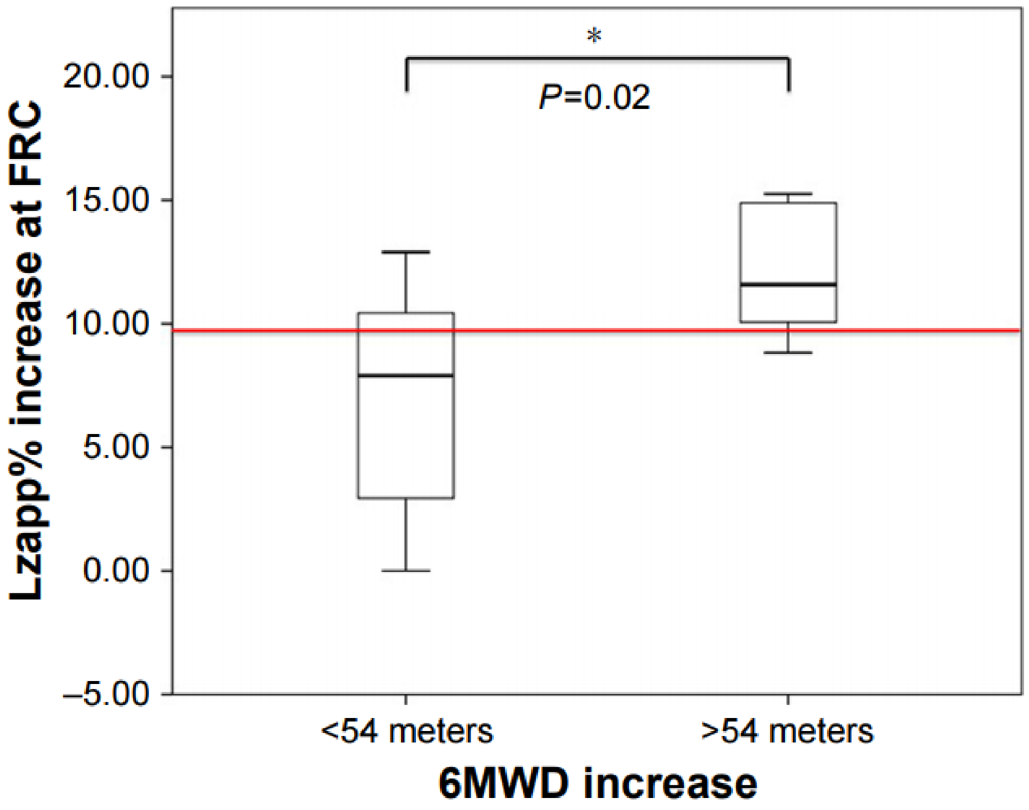
Table 3 Patients' ultrasonographic characteristics before and after pulmonary rehabilitation

N=25	Pre-PR	Post-PR	*P*-value
Diaphragm zapp (mm)			
Lzapp TLC	26 (18–31)	23 (19–26)	0.002
Lzapp FRC	38 (32–41)	41 (35–44)	<0.001
Szapp TLC	5 (3–6)	4 (3–5)	0.001
Szapp FRC	4 (3–4)	3 (3–4)	0.027
Diaphragmatic excursion (mm)			
Quiet breathing	23 (16–27)	27 (22–31)	<0.001
Deep breathing	36 (25–53)	50 (35–58)	<0.001
Rectus femoris area (m^2)	4 (3–4)	4 (3–5)	<0.001

D. McKenzie et al. Respiration Physiology 123 (2000):225-234
Crimi et al. IJCOPD 2018:13 3131-3139

Follow-up after pulmonary rehabilitation





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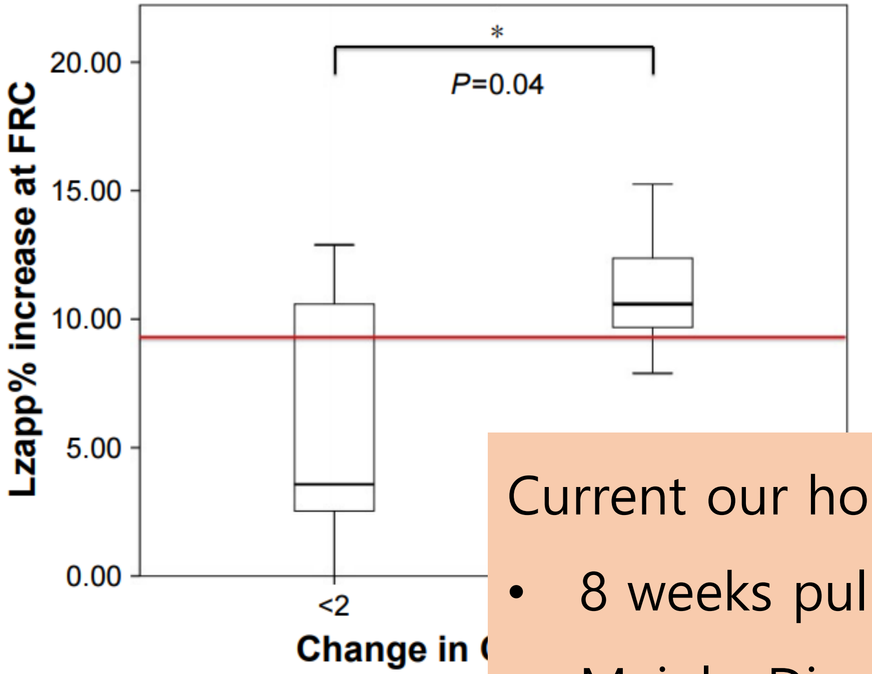
Follow-up after pulmonary rehabilitation



Ultrasonographic measurements	CAT ≥2 N=14	CAT <2 N=11	P-value
Diaphragm Zapp			
ΔLzapp TLC%	−18 (−26 to −15)	−13 (−23 to −2)	0.197
ΔLzapp FRC%	11 (10–12)	4 (2–11)	0.043
ΔSzapp TLC%	−4 (−8 to −3)	−6 (−10 to −2)	0.863
ΔSzapp FRC%	−5 (−10 to 0)	−8 (−12 to 0)	0.756
Diaphragmatic excursion			
		38 (3–60)	0.180
		17 (3–47)	0.913
		8 (4–12)	1

Current our hospital policy

- 8 weeks pulmonary rehabilitation protocol
- Mainly, Diaphragm US only F/U
- At 4 week and at 8 week

D. McKenzie et al. Respiration Physiology 123 (2000):225-234
Crimi et al. IJCOPD 2018:13 3131-3139

Chapter 2

- What is the lung ultrasound (LUS)?
  - LUS basics
  - LUS advanced

- LUS in pulmonary rehabilitation
  - As assessment tool of pulmonary diseases
  - Screening
  - Follow-up

- Others

Reimbursement of thoracic ultrasound

보건복지부 고시 제2021 - 104호

「국민건강보험법」 제41조제3항 및 제4항, 「국민건강보험법 시행령」 제19조제1항 관련 별표2 및 「국민건강보험 요양급여의 기준에 관한 규칙」 제5조제2항에 의한 「요양급여의 적용기준 및 방법에 관한 세부사항(보건복지부 고시 제2021-102호, 2021.3.30.)」을 다음과 같이 개정·발령합니다.

2021년 3월 30일
보건복지부 장관

「요양급여의 적용기준 및 방법에 관한 세부사항」 일부개정

이 고시는 2021년 4월 1일부터 시행한다.

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.

- 흉부(흉벽, 흉막, 늑골 등) 초음파 검사는 좌·우 각각 해부학적 부위의 영상을 획득하고, 검사의가 판독소견서를 작성하고 보관하여야 함. 이 경우 획득하여야 하는 표준영상의 범위를 아래와 같이 권고하고, 판독소견서에는 환자의 인적사항과 검사 관련 내용이 포함되어야 함. 다만, 제한적 초음파는 문제되는 부위 위주로 영상을 획득하고, 판독소견서를 작성·보관하여야 함.

Reimbursement of thoracic ultrasound

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

나) 검사소견

(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

Examples LUS reading paper

					Exam No.	

Lung Ultrasound in Yeouido St. Mary`s hospital (final revision 2020.05.01 by ATJ)							
Operator		ID		Sex		Age	
Exam date		Name		height		weight	

quantitative Lung UltraSound Score (qLUSS)

PA	MA	AA-MC	MC-PS	IS	MC-PS	AA-MC	MA	PA		
				II˚~III•						
				IV˚~V•					Total qLUSS	0

Diaphragm muscle

Diaphragm thickness (at MA, 8~11 th ICS, cranio-caudal)

at tidal	inspiration	mm	expiration(FRC)	mm	at maximal	inspiration (TLC)	mm	expiration (RV)	mm
	thickening fraction (TFdi/tv)			%		thickening fraction (TFdi/max)			%

Intercostal muscle

	PS, Rt	IS	PS, Lt			PS, Rt	IS	PS, Lt	
Tei at tidal		II•		(mm)	Tei at tidal		III•		(mm)
Tee at tidal		II•		(mm)	Tee at tidal		III•		(mm)
Tei at max		II•		(mm)	Tei at max		III•		(mm)
Tee at max		II•		(mm)	Tee at max		III•		(mm)
TFicm/tv		(%)		(%)	TFicm/tv		(%)		(%)
TFicm/max		(%)		(%)	TFicm/max		(%)		(%)

Summary

LUS

- Widely accepted modality of evaluation of Lung dynamic and it`s adjacent organ
- Lung sliding, A-line, B-line, Lung point etc.
- As assessment, monitoring tool

DUS

- Diaphragm motion (Excursion), Diaphragm mass (Thickness), Diaphragm contractility (Thickening fraction)
- Easy way to find diaphragm dysfunction and atrophy
- Correlated with lung functions and symptoms

LUS/DUS in PR

- Another useful tool for assessment of pulmonary disease, especially COPD and ILD (Indication of PR)
- Assessment (lung condition, pneumothorax, pleural effusion, diaphragm condition etc)
- Follow up (improvement of diaphragm dysfunction, thickness after PR)
- Well correlated with exercise capacity, symptoms, and lung functions after PR

대한결핵 및 호흡기학회

2021년도
제131차 춘계학술대회 Virtual & Onsite Conference

제50차 Workshop, 제16회 폐암 심포지엄, 제1차 Interactive Learning

일자 2021년 4월 9일(금) - 10일(토) Virtual 온라인 실시간 라이브 중계 Onsite 롯데호텔 부산

4월 9일(금) | 4월 10일(토)

Interactive Learning | 폐암 심포지엄 | Workshop | 춘계학술대회

Crystal BallRoom I | Crystal BallRoom II | Sapphire Room

09:30 ~ 12:30

연수강좌(심포지엄)

현장 Hands-on

09:30 ~ 12:30 Director : 조영재

Lung Ultrasound Hands-on

조영재 (서울의대 내과)
안태준 (가톨릭의대 내과)
이진우 (서울의대 내과)
임성윤 (서울의대 내과)

Thank you for your attention.