POINT OF CARE ULTRASONOGRAPHY IN CRITICAL CARE

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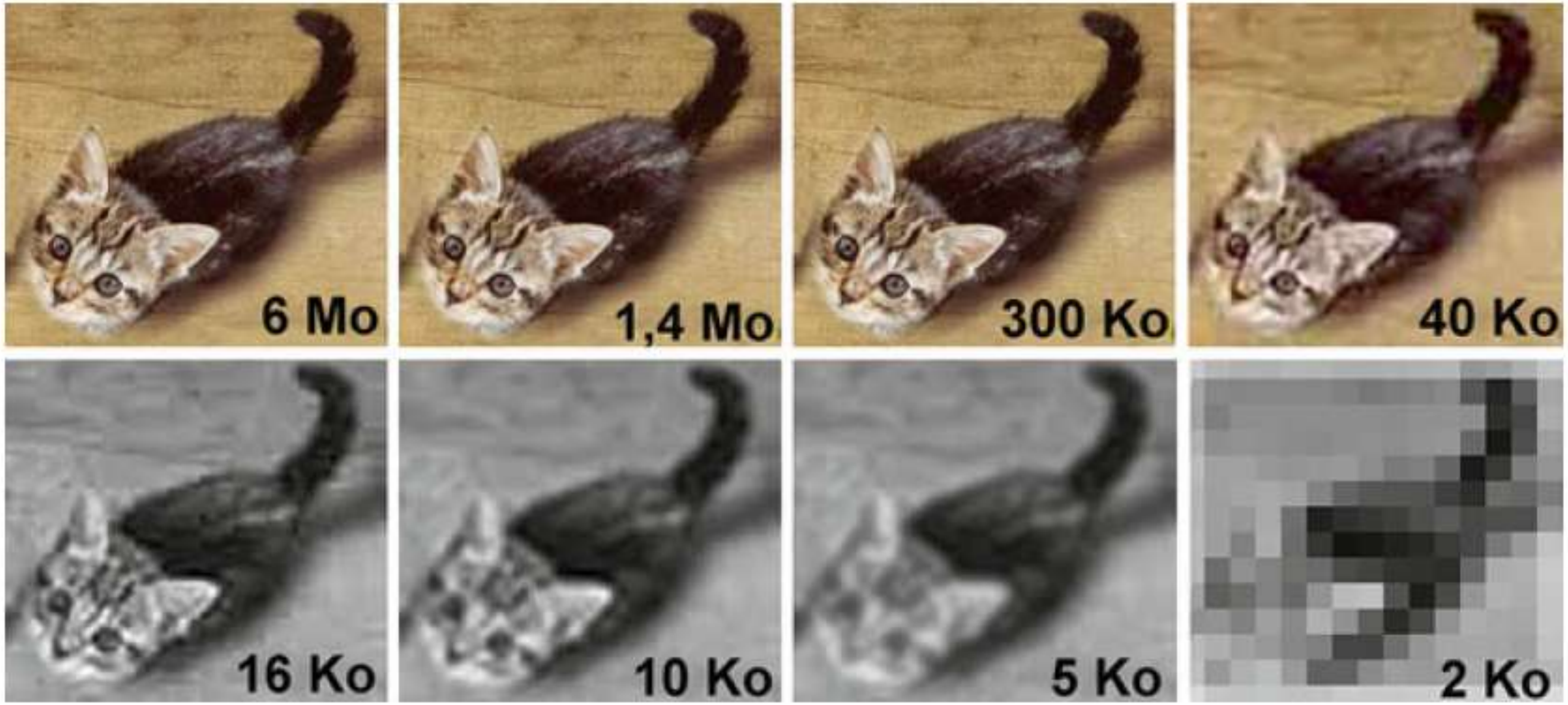
TOPICS TO BE COVERED

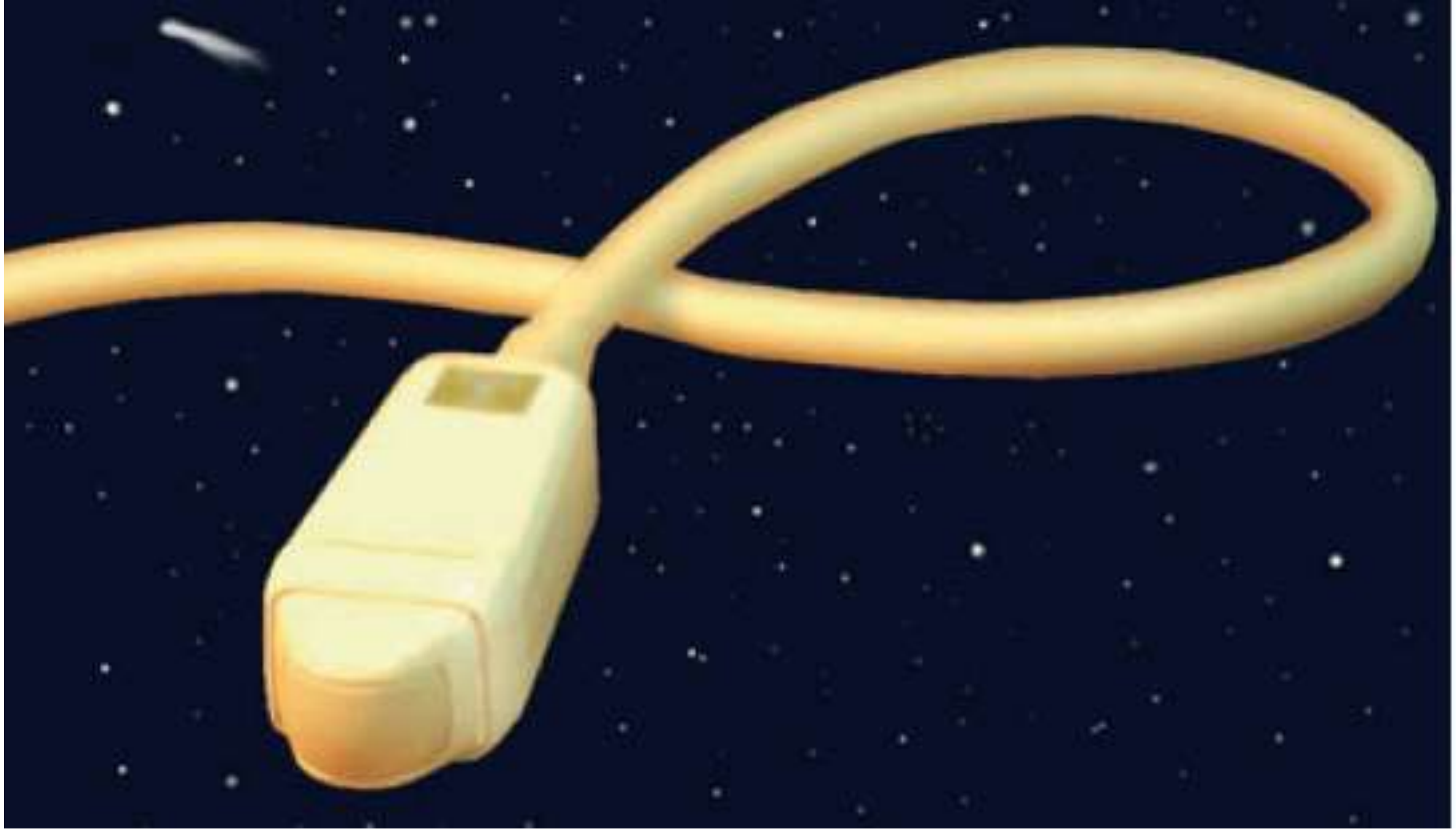
- BLUE Protocol Approach
- Clinical utility of various USG signs
- Lung ultrasound score and its application
- USG and diaphragm dysfunction
- ABCDE approach for weaning failure
- FALLS Protocol
- ECHO in Acute Pulmonary Embolism
- FOCUS
- USG in Cardiopulmonary resuscitation

BLUE PROTOCOL APPROACH

WHICH PROBE TO CHOOSE??



TARGET IS NOT TO HAVE BEAUTIFUL IMAGES BUT DIAGNOSTIC IMAGES



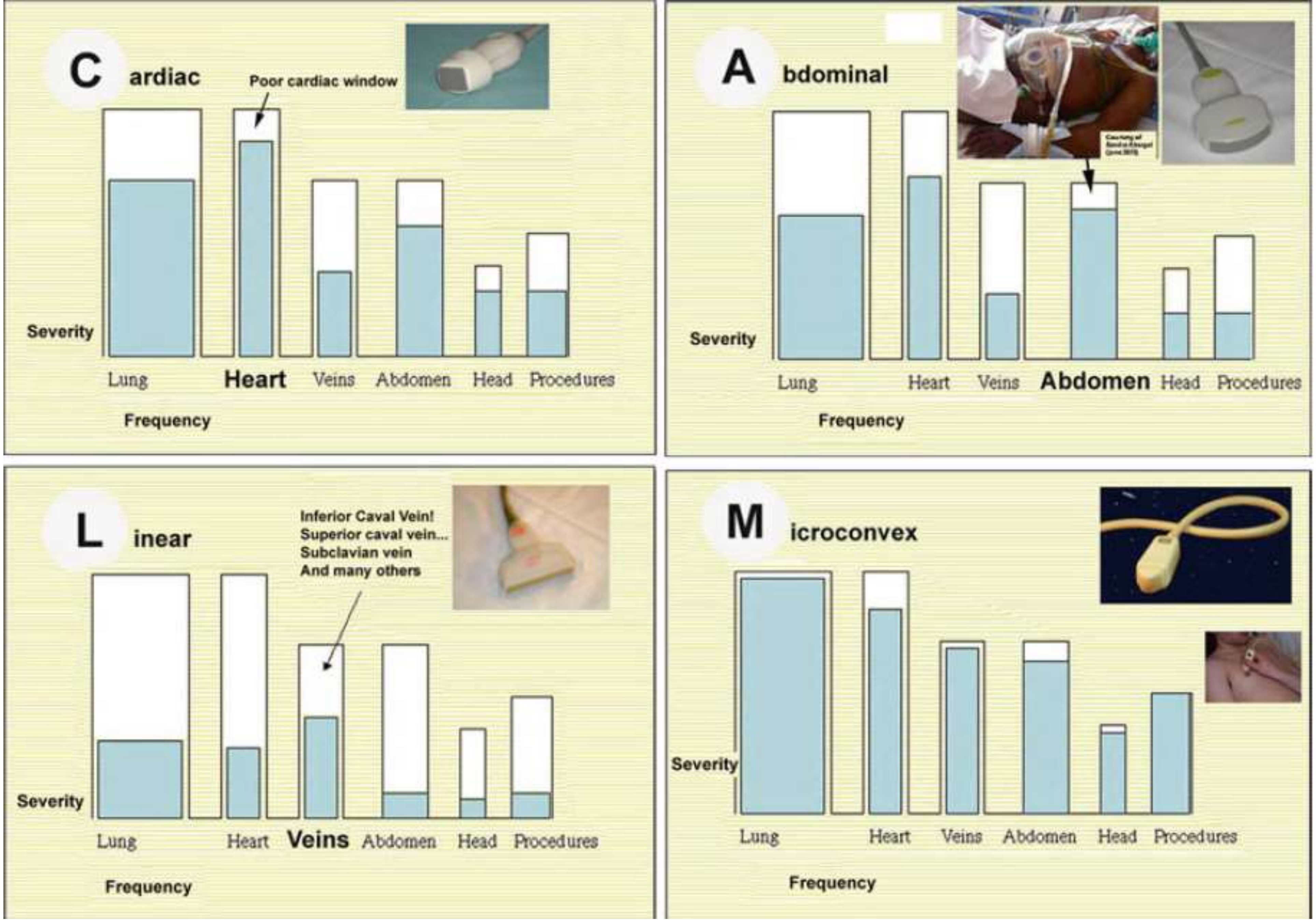
MICROCONVEX PROBE USED IN BLUE PROTOCOL

WEIGHT – 80 gms

LENGTH – 88 mm

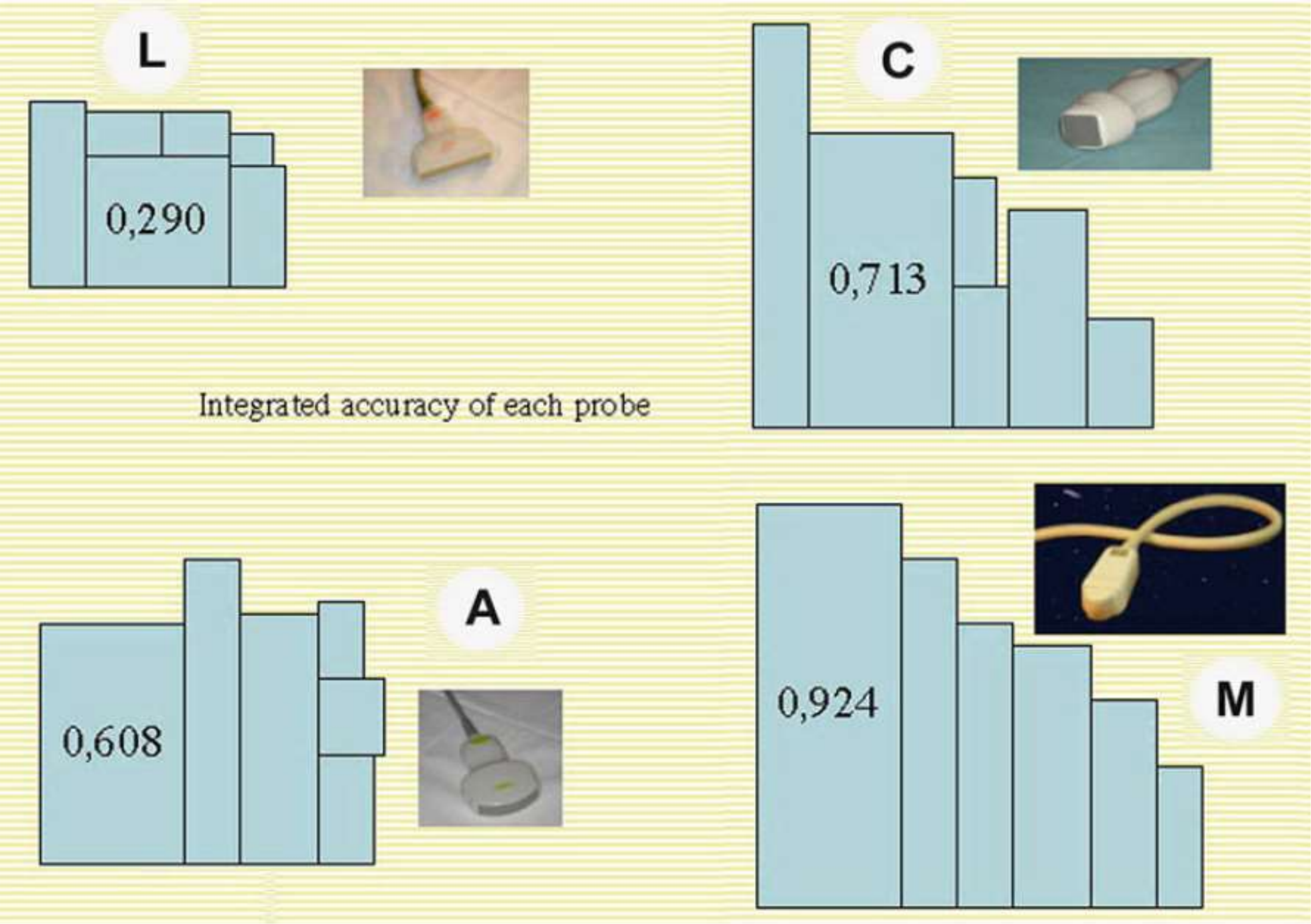
FOOTPRINT – 12 X 20 mm

FREQUENCY – 5MHz (6-170 mm penetration)



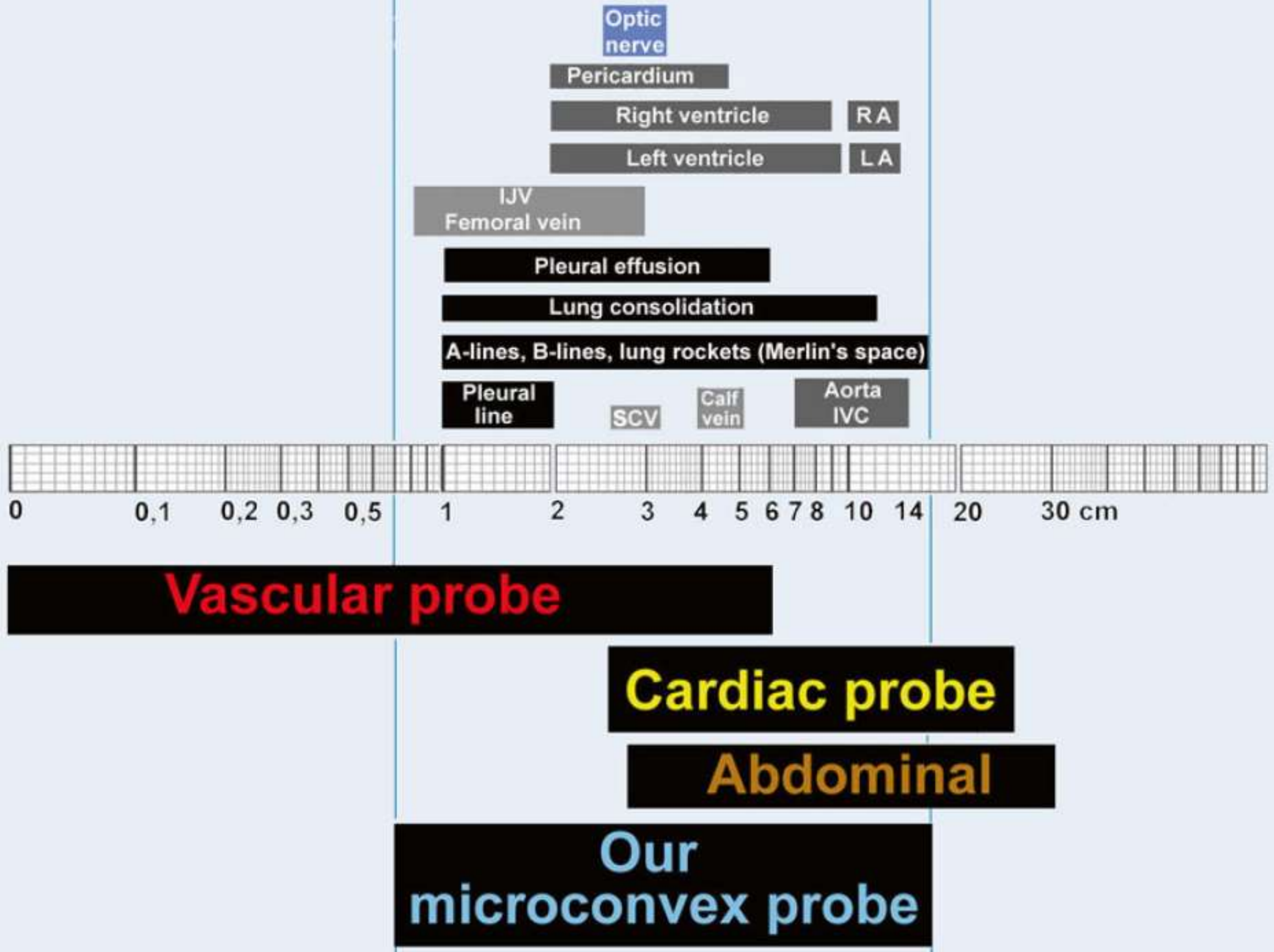
CONCEPT OF OPTIMAL COMPROMISE

LUNG ULTRASOUND IN CRITICALLY ILL BY LICHTENSTEIN,2016



INTEGRATED ACCURACY OF PROBES

LUNG ULTRASOUND IN CRITICALLY ILL BY LICHTENSTEIN,2016


Optic nerve
Pericardium
Right ventricle
RA
Left ventricle
LA
IJV
Femoral vein
Pleural effusion
Lung consolidation
A-lines, B-lines, lung rockets (Merlin's space)
Pleural line
SCV
Calf vein
Aorta
IVC
0
0,1
0,2
0,3
0,5
1
2
3
4
5
6
7
8
10
14
20
30 cm
Vascular probe
Cardiac probe
Abdominal
Our microconvex probe

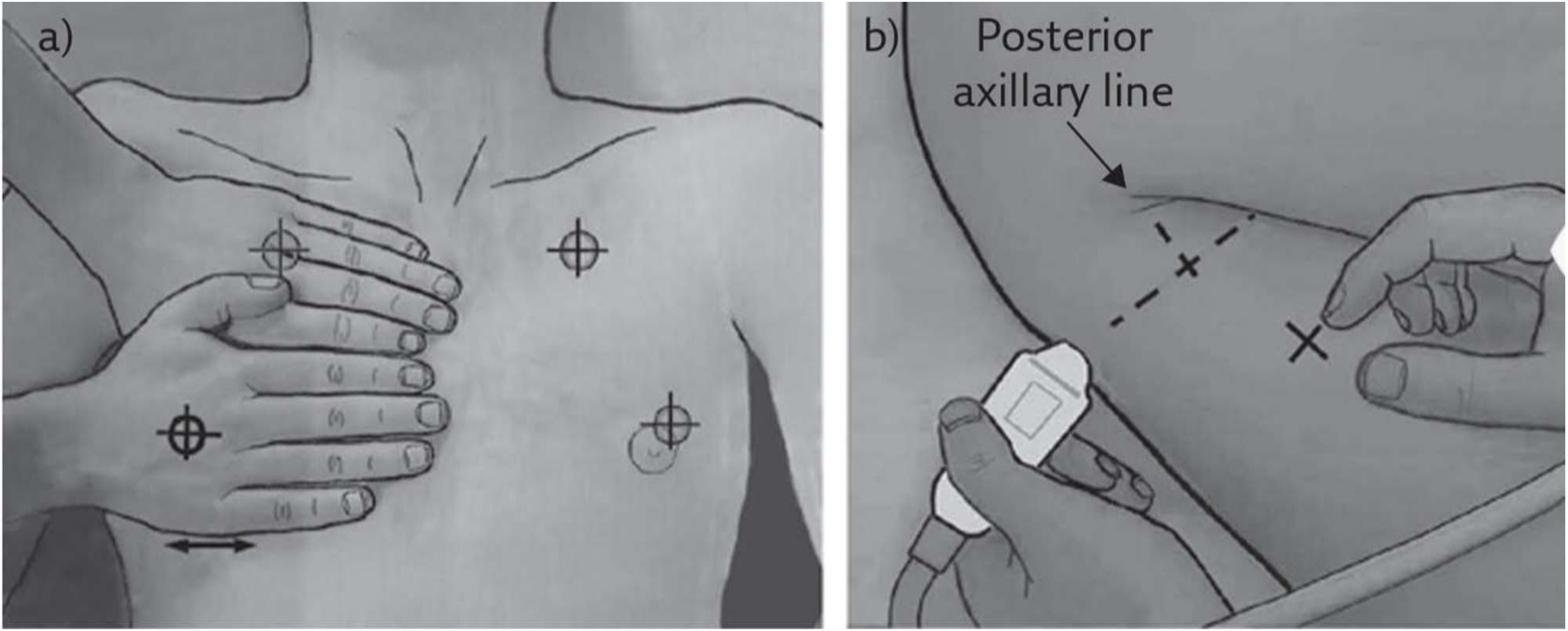
COUPLING SYSTEM – ECOLIGHT®

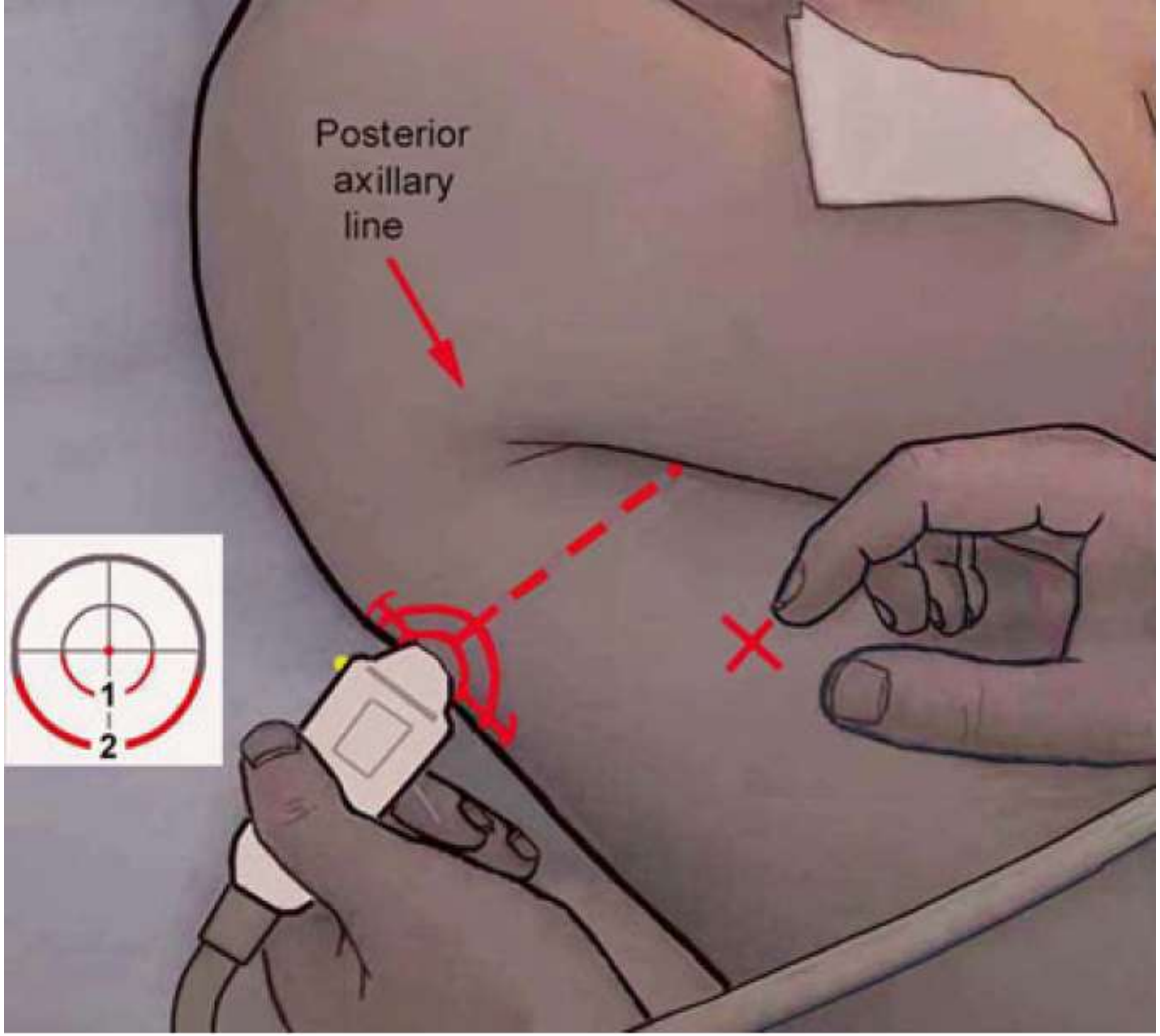
- GELLESS GEL
- Adiabatic substance
- Non slippery substance, well applied to skin by just gentle pressure
- Self vanishes after usage (1-2 minutes)

LUNG ULTRASOUND IN CRITICALLY ILL BY LICHTENSTEIN,2016

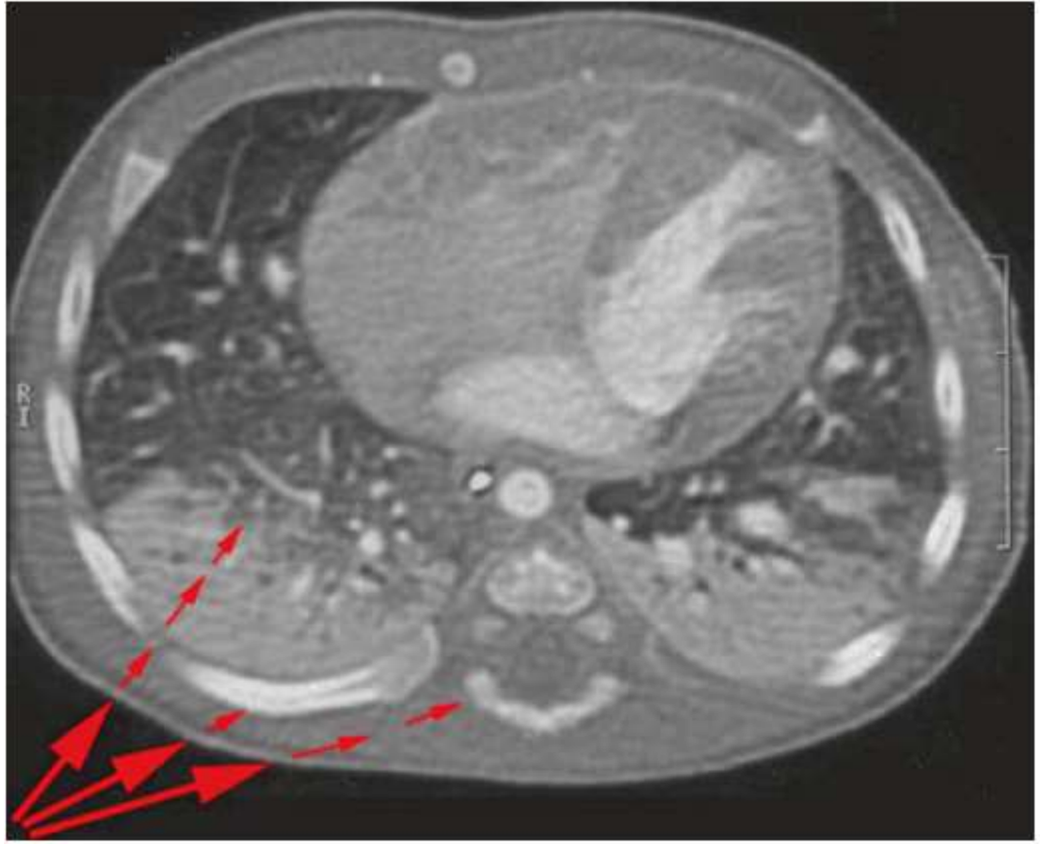
POINTS OF INTEREST

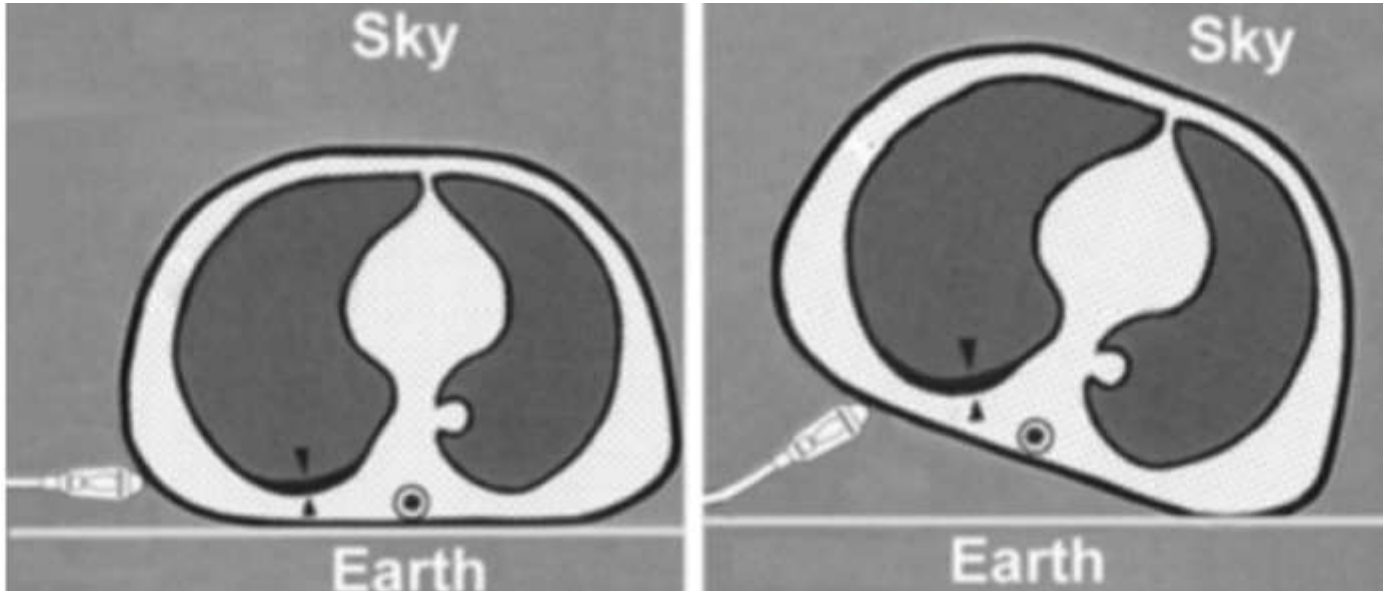
- BLUE PROTOCOL – “BLUE POINTS” – 3 points of interest per lung



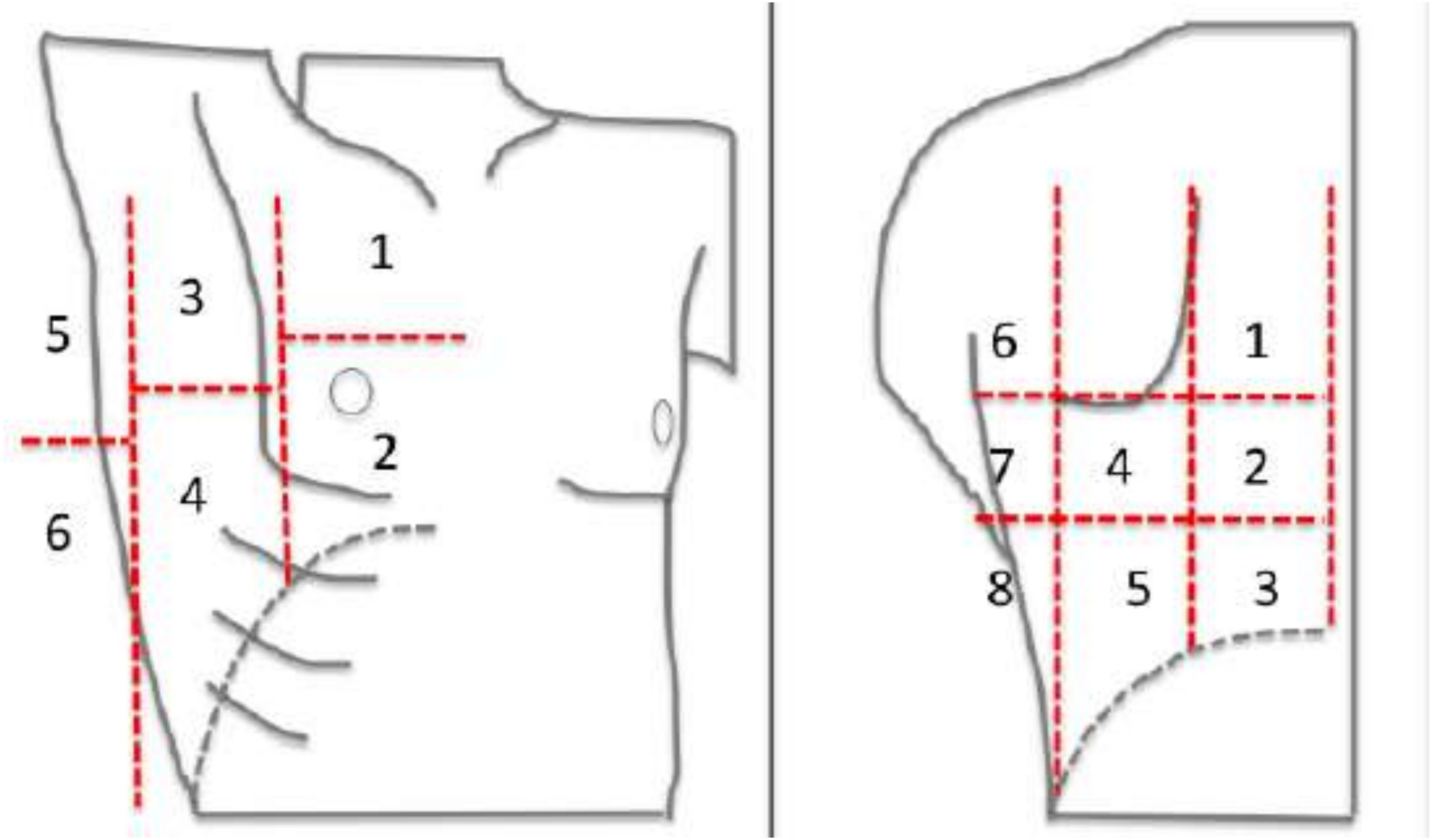


THE PROBE HEAD AS PERPENDICULAR AS POSSIBLE AND MOSTLY POINTING (AS FAR AS POSSIBLE) TO THE SKY



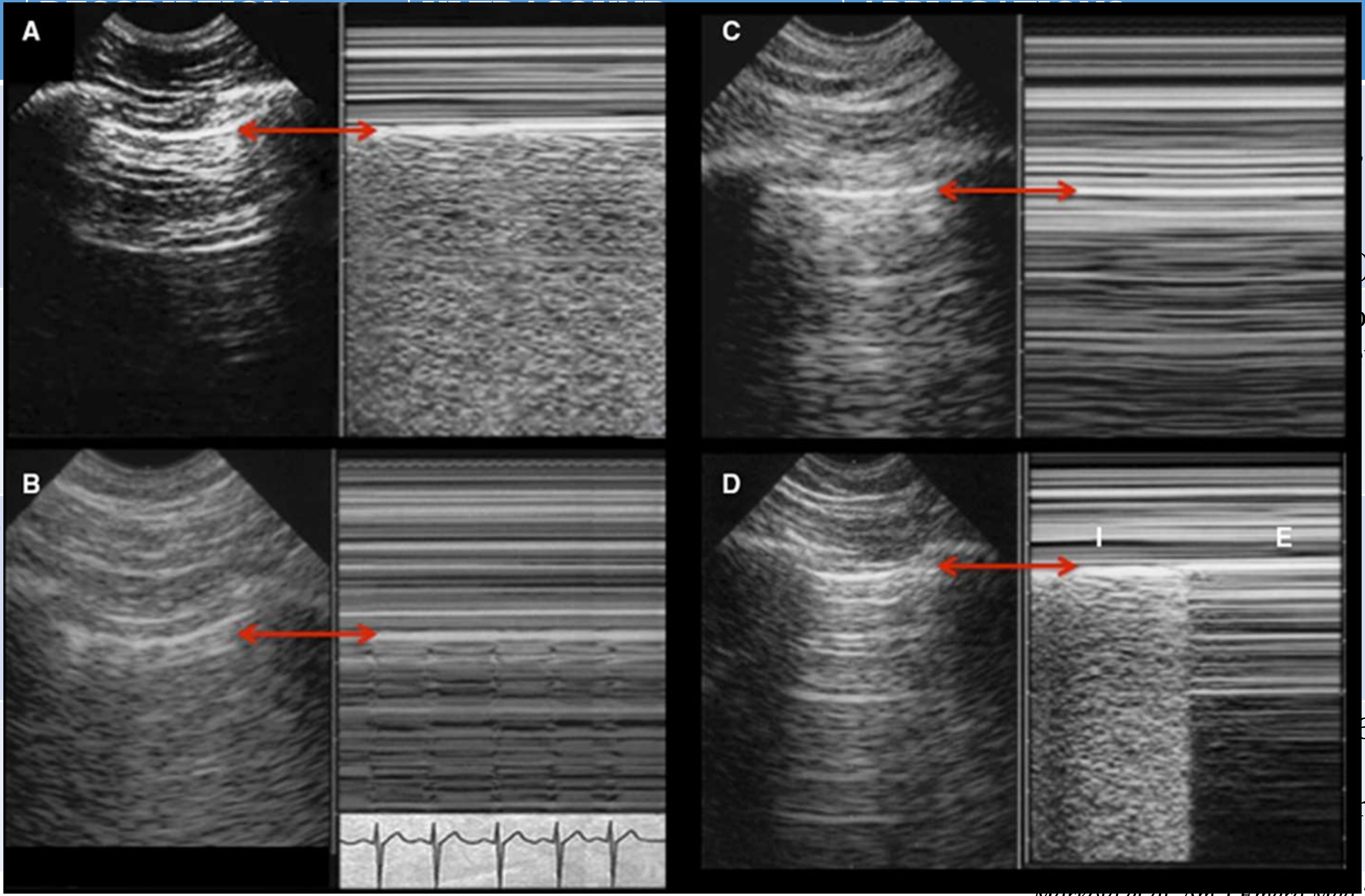

Sky
Earth
Sky
Earth

TWELVE REGION EXAMINATION

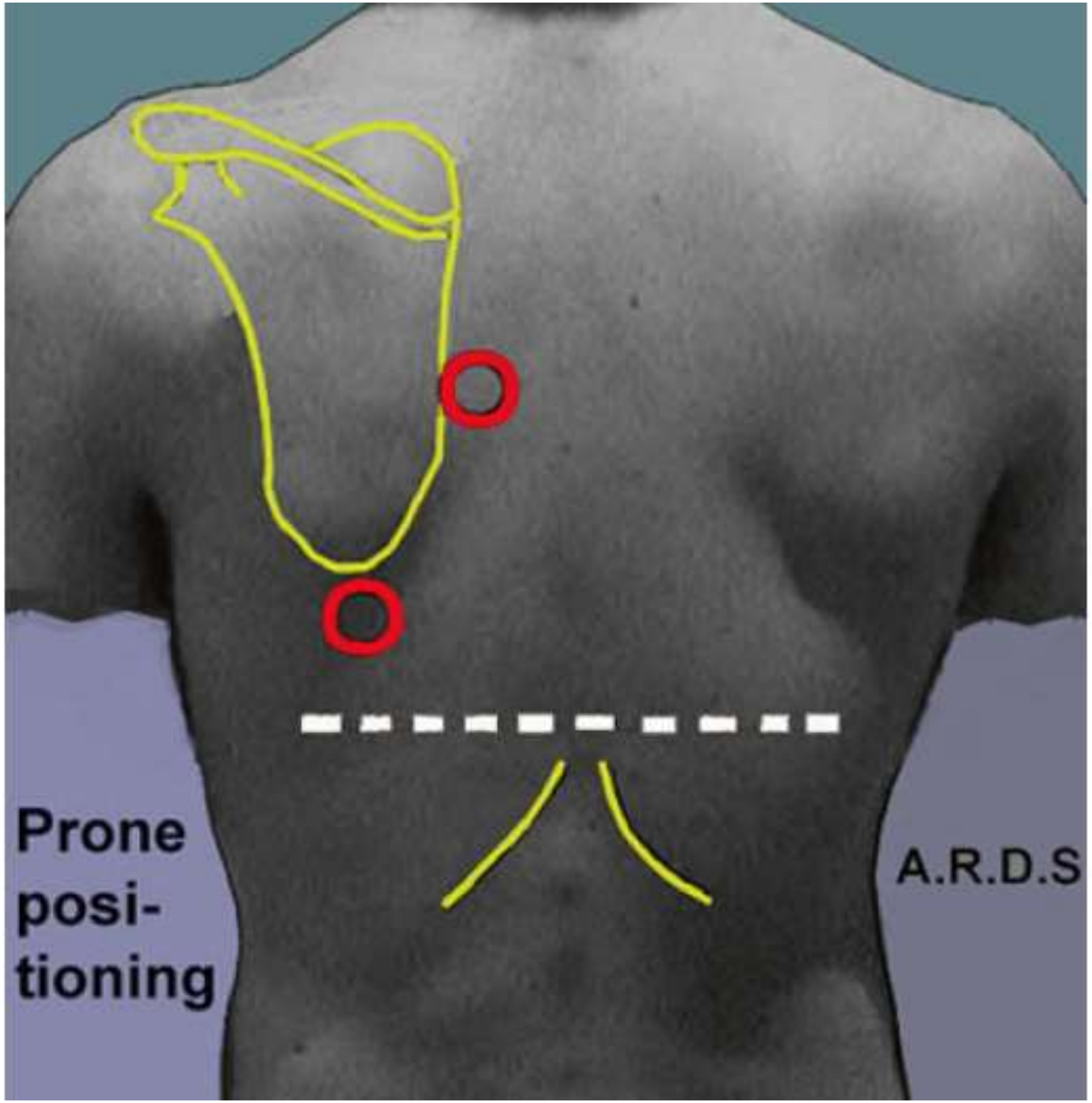


APPROACH ADVISED IN CRITICAL CARE SETTING

SIGNS	
Lung sliding Reduced sliding	NPV)
LUNG PULSE	on ural
STRATOSPHERE SIGN	
LUNG POINT	66% , rger



Markold et.al. Am J Emerg Med 2016
Volpicelli G Intensive Care Med 2014



LUNG ULTRASOUND IN CRITICALLY ILL BY LICHTENSTEIN,2016

SIGNS	DESCRIPTION	ULTRASOUND INTERPRETATION	APPLICATIONS
ARTIFACTS A lines	Reverberation artifacts as horizontal hyperechoic lines below pleural line and repeated at constant distance equal to distance between pleural line and probe surface	High gas-volume ratio below parietal pleura A profile: A-lines with maximum 2 B lines and lung sliding in anterior fields A lines with no lung sliding but lung pulse A lines with no lung sliding but no lung pulse	Corresponds to normal aeration (strong correlation with regional tissue density measured by quantitative CT scan; r – 0.79) Rules out pneumothorax (sensitivity – 95.3%, specificity – 91.1%; NPV - 100%) Confirms absence of regional ventilation (obstructed airway, hyperinflation, pleural adherence or bullae) with sensitivity 93% and specificity 100% Suggest absent regional ventilation

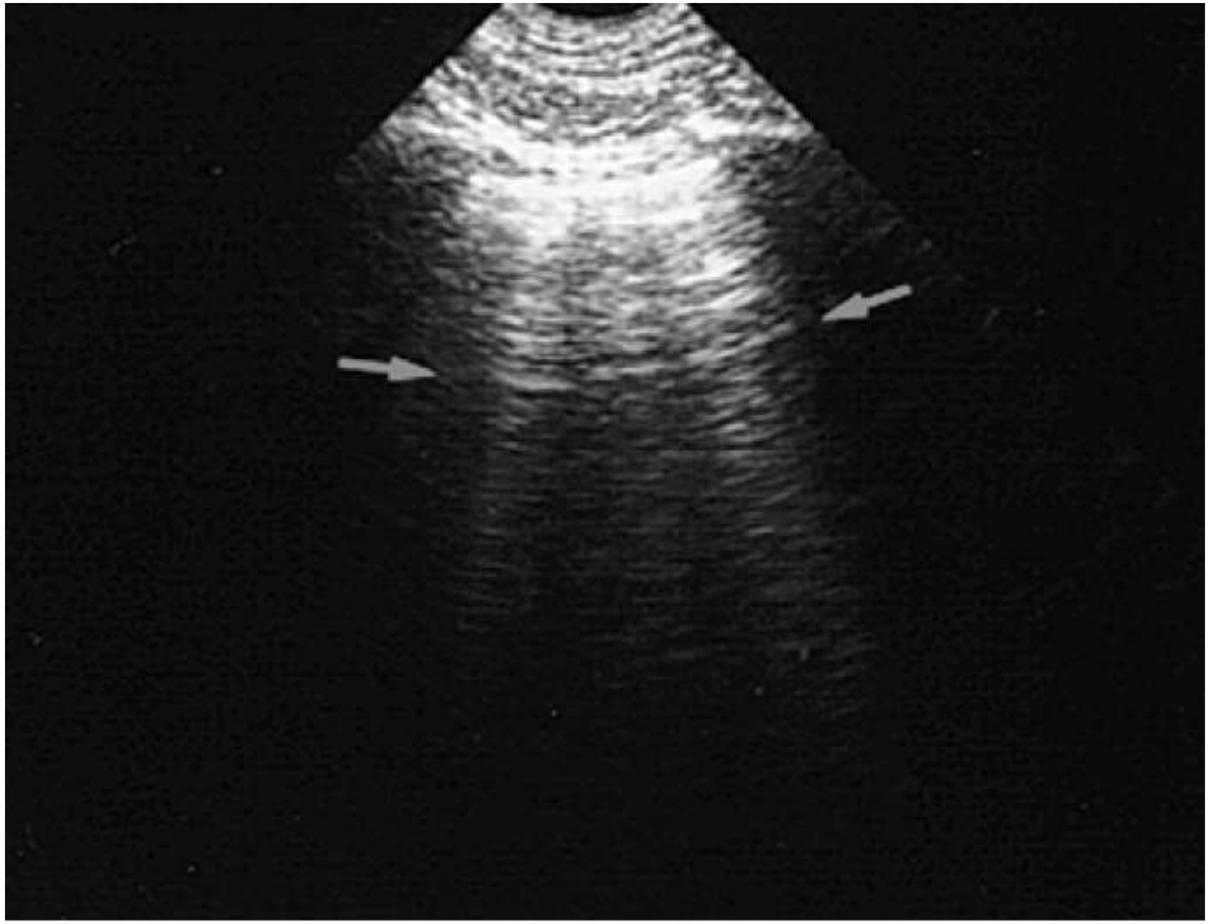
Lichtenstein DA et al. CHEST 2009
Chiumello et al. Crit Care Med 2018

SIGNS	DESCRIPTION	ULTRASOUND INTERPRETATION	APPLICATIONS
B lines	Vertical hyperechoic comet tail artifacts deriving from pleural line, moving synchronously with it, erasing A lines	Max. of 2 B lines per scan visualized in healthy lung Originate from **visceral pleura**	Normal lung Rules out pneumothorax (sensitivity 100%, specificity 60%, NPV – 100%)
		B pattern (lung rockets): ≥3 B lines per scan	Allows differentiation between COPD exacerbation and cardiogenic edema Sensitivity- 100% specificity – 92%
		Focal B lines	May corresponds to pneumonia, atelectasis, lung contusion, PE, pleural disease or neoplasia
		Diffuse B-pattern (Atleast 2 regions per hemithorax):	
		Homogeneous distribution, regular thin pleura, normal sliding and eventual b/l pleural effusion	Orients to cardiogenic edema
		Non homogeneous distribution, irregular thickened pleura, subpleural and posterior consolidations	Orients to ARDS
		Homogeneous distribution, irregular thickened pleura	Present in 85-100% of cases of DPLD (fibrosis, sarcoidosis, silicosis)

SIGNS	DESCRIPTION	ULTRASOUND INTERPRETATION	APPLICATIONS
B lines	Vertical hyperechoic comet tail artifacts deriving from pleural line, moving synchronously with it, erasing A lines	Number and type of B-lines allows quantification of lung aeration by computation of lung ultrasound score: Substantial agreement between LUS and quantitative CT classification (k=0.7) Strong association between global lung ultrasound score and tissue density measured by CT (R_2 = 0.62-0.78) Strong correlation between global lung ultrasound score and EVLW measured by PiCCO ($r2$ = 0.906)	Allows monitoring aeration in patients receiving ECMO and fluid resuscitation in ARDS Lung ultrasound reaeration score allows monitoring of VAP response to antibiotics and PEEP induced recruitment as measured by PV curve (correlation with CT r = 0.85 and r = 0.88 respectively) Lung ultrasound score variations not correlated with PEEP-induced recruitment as measured by quantitative CT (R2 = 0.01) Normal anterior fields allow distinguishing pronation responders (sensitivity – 58%, specificity – 100%, PPV – 100%)

ARTIFACTS – Z LINE

- Should not be confused with B-line
- Comet-tail artifact and arises from pleural line
- Ill defined and not hyperechoic
- Short and rapidly vanish after 3-4cms
- Doesn’t erase A-lines
- Not synchronized with lung sliding, it is standstill
- Are grey at onset with respect to pleural line



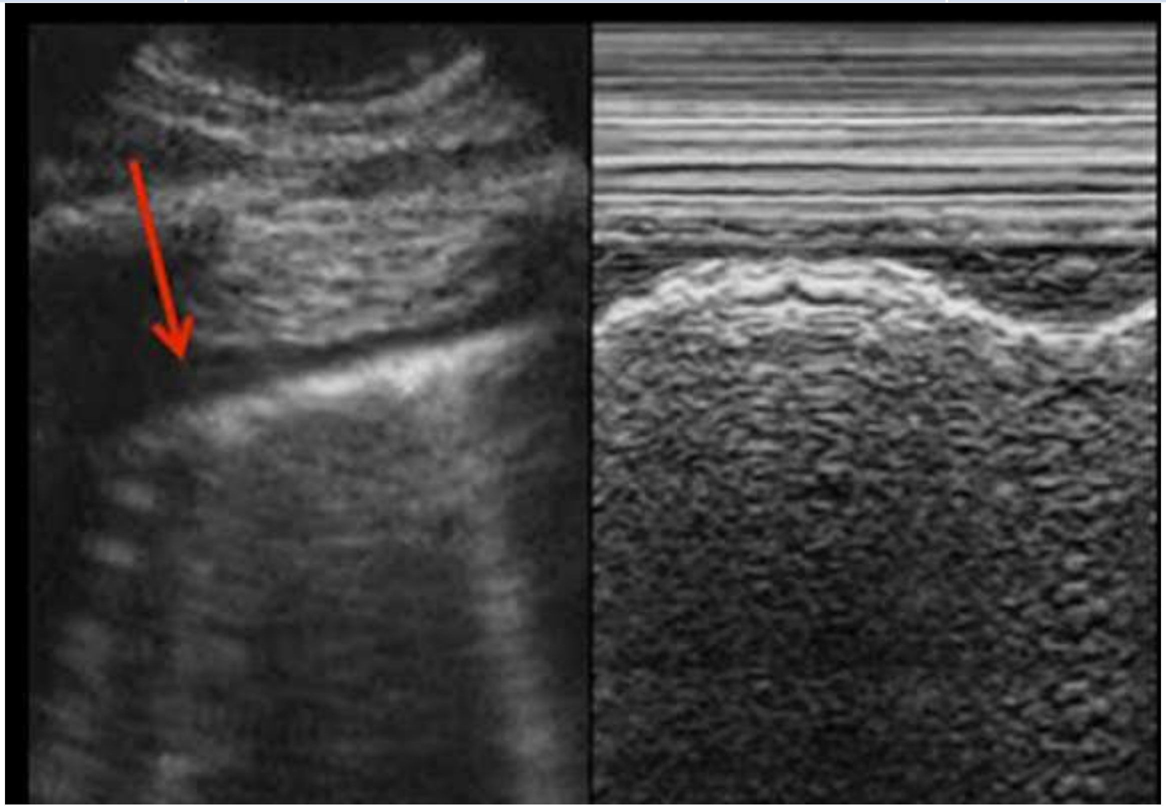
LUNG ULTRASOUND IN CRITICALLY ILL BY LICHTENSTEIN,2016

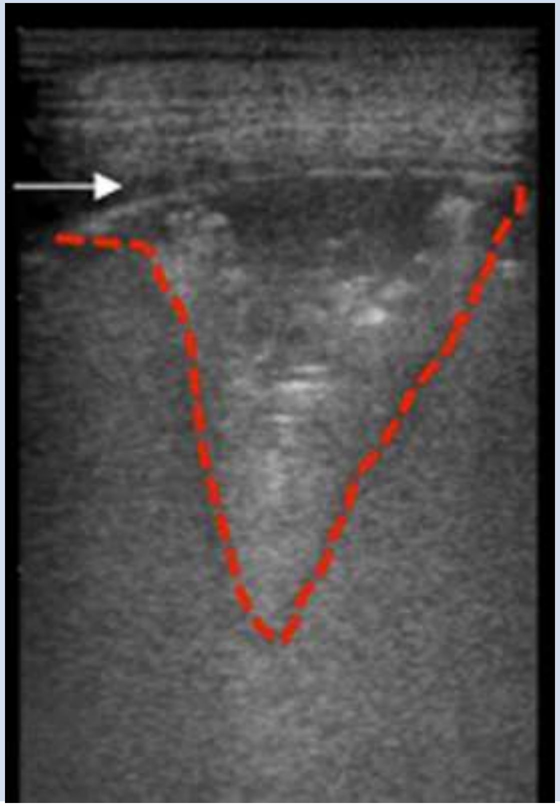
ARTIFACTS – E LINE

- Well defined comet-tail artifacts
- Spread to edge of screen
- Difference – no bat sign, no rib identified
- Hyperechoic horizontal line from which comet tails arise not pleural line
- E-lines resulting because of subcutaneous emphysema

LUNG ULTRASOUND IN CRITICALLY ILL BY LICHTENSTEIN,2016

SIGNS	DESCRIPTION	ULTRASOUND INTERPRETATION	APPLICATIONS
REAL IMAGES SINUSOID SIGN	Sinusoid aspect of visceral pleura movement within effusion in M mode	Confirms free collection	Allow distinction of echo poor regions (free effusion and focal collection)



SIGNS	DESCRIPTION	ULTRASOUND INTERPRETATION	APPLICATIONS
CONSOLIDATIONS SHRED SIGN/FRACTAL SIGN	Subpleural echo poor images delimited by irregular borders	Small juxtapleural consolidations 	Present in 37% of cases in diffuse parenchymal lung diseases (fibrosis, sarcoidosis, interstitial pneumonia, silicosis) May correspond to pulmonary subpleural infarcts in pulmonary embolism (alone sensitivity 61%; specificity 96% combined with vascular and cardiac ultrasound: sensitivity – 90% and specificity – 86.2% Supports diagnosis of VAP (alone: sensitivity – 71%, specificity – 41% combined with VPLUS ≥ 2: sensitivity – 81%, specificity – 69%)

Mongodi et al. CHEST 2016
Nazerian P et al. Chest 2014

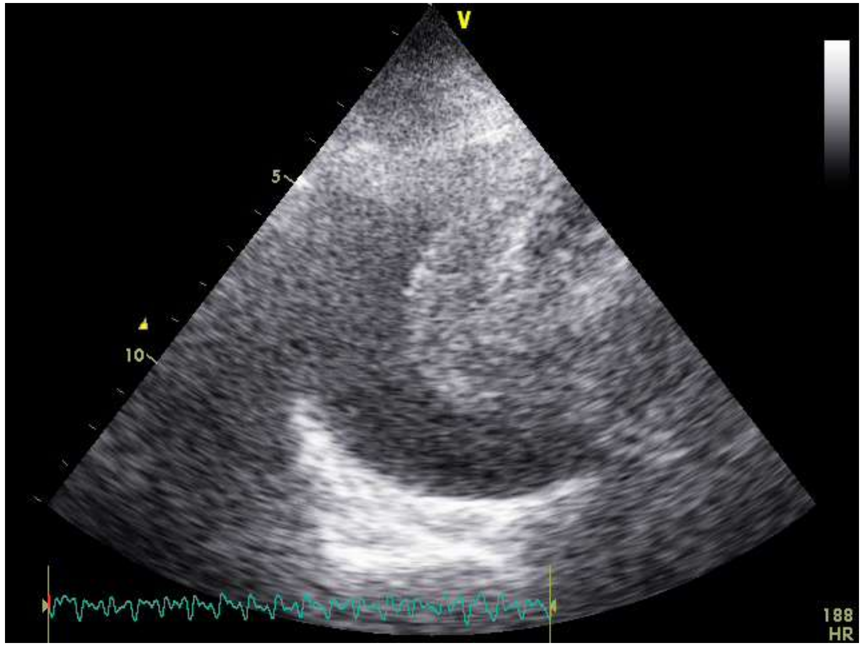
SIGNS	DESCRIPTION	ULTRASOUND INTERPRETATION	APPLICATIONS
CONSOLIDATIONS TISSUE- LIKE PATTERN	Homogeneous texture of lobe	Corresponds to complete loss of aeration  	Confirms diagnosis of Community Acquired Pneumonia (sensitivity 93.4-99%, specificity 95-97.7%)

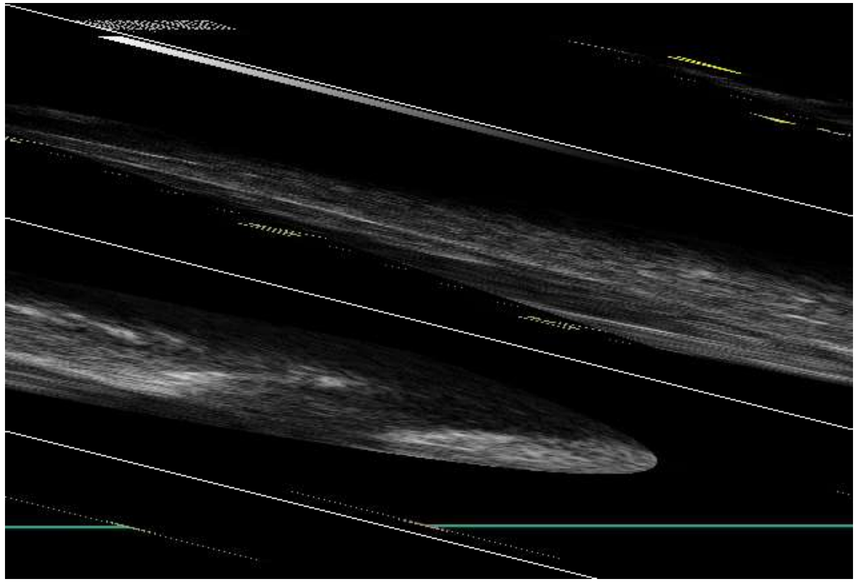
Reissig A et al. CHEST 2012
Cortellaro F et al. Emerg Med J 2012

SIGNS	DESCRIPTION	ULTRASOUND INTERPRETATION	APPLICATIONS
Air Bronchogram	Hyperechoic intraparenchymal images visualized within tissue like pattern	Corresponds to air trapped within consolidation	
		If absent	Corresponds to complete air reabsorption and potentially non patent airway
		If static	Corresponds to potentially not patent airway, incomplete air resorption Presents in 40-90% of pneumonia
		If dynamic	Corresponds to patent airways Rules out atelectasis (sensitivity-64%, specificity-94%) Present in 87-97% of pneumonia
		Linear/arborescent	Supports diagnosis of VAP (alone: sensitivity – 44%, specificity- 81%; combined in VPLUS $\geq$ 2 sensitivity- 71% and specificity- 69%
		Punctiform	Not specific for diagnosis

Cortellaro F et al. Emerg Med J 2012
Lichtenstein D. CHEST 2009

1


V
5
10
188
HR



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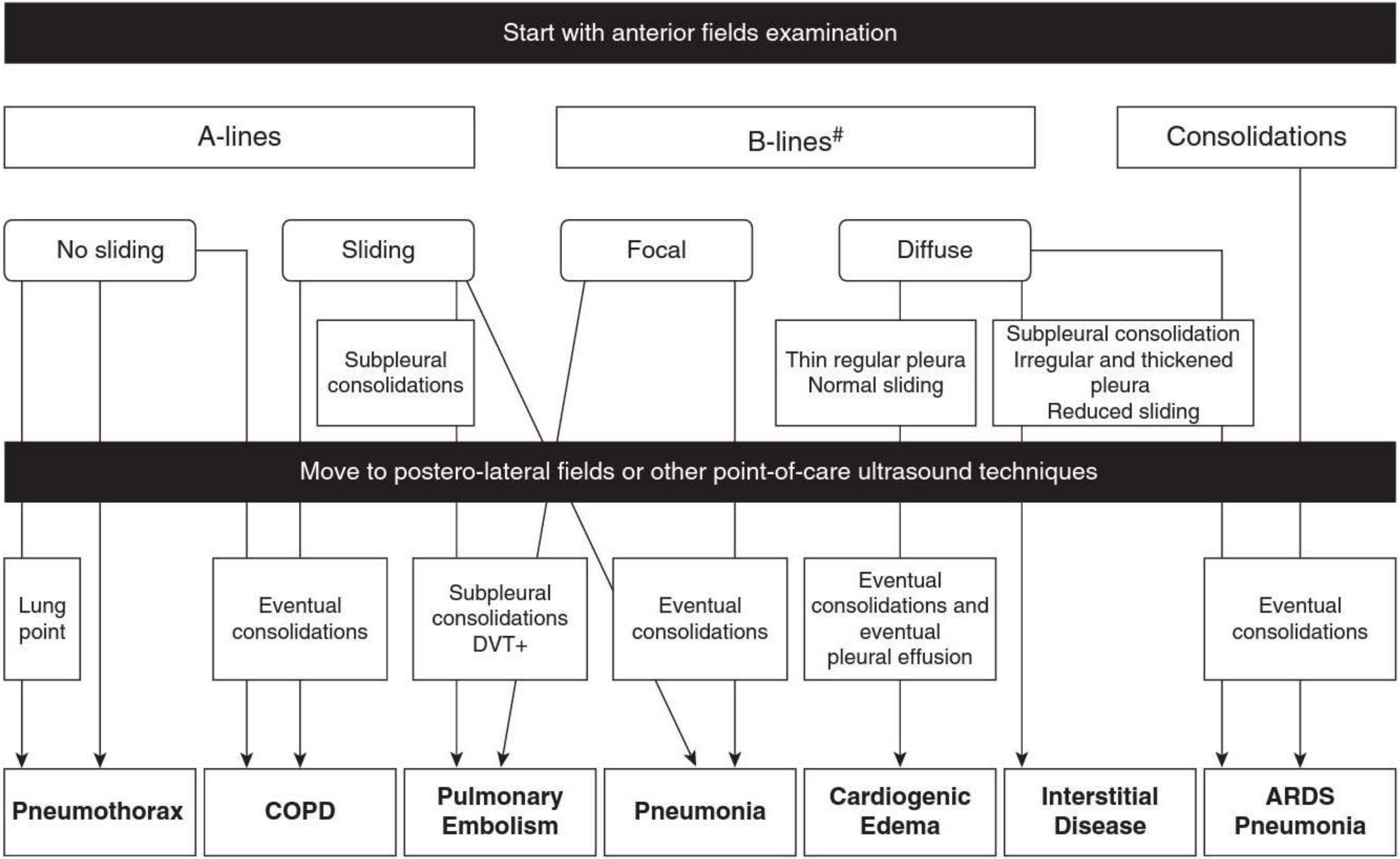
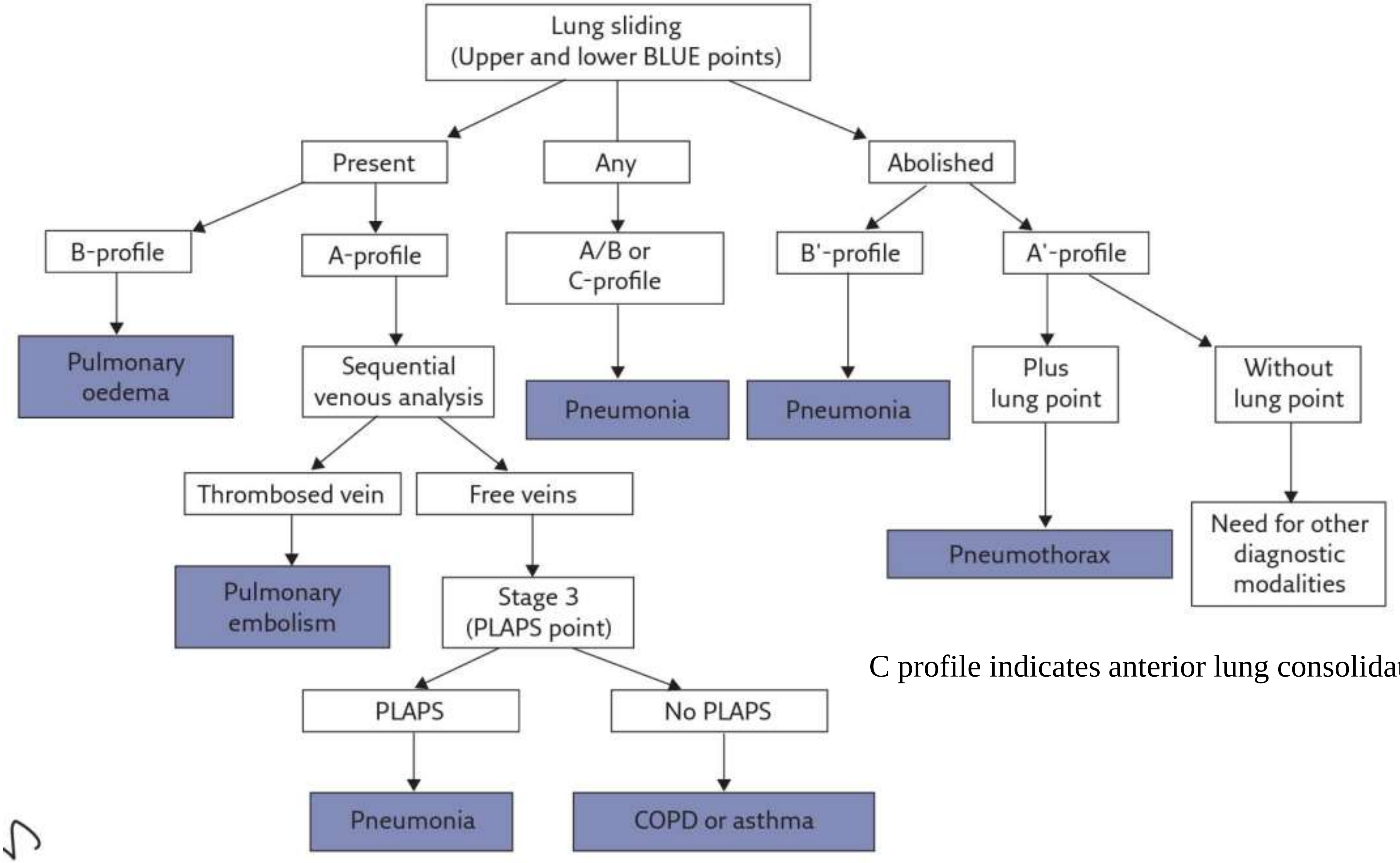


Mojoli et al. Am J Respir Crit Care Med 2019



C profile indicates anterior lung consolidation

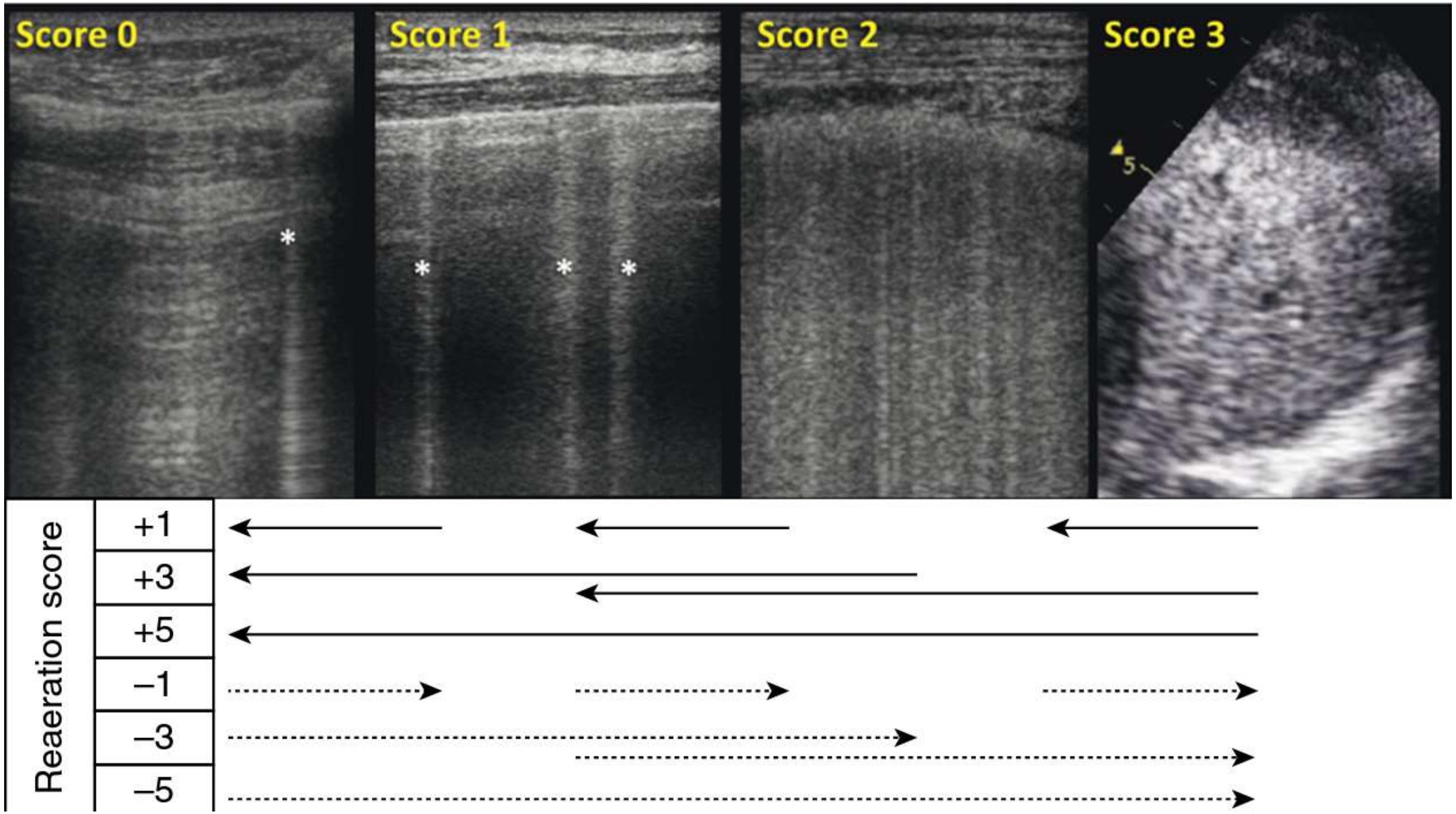
Lichtenstein D et.al. Breathe 2017

Mechanism of dyspnoea	BLUE protocol profile	Sensitivity	Specificity	Positive predictive value	Negative predictive value
Acute haemodynamic pulmonary oedema	B-profile	97%	95%	87%	99%
Exacerbated COPD or severe acute asthma	Nude profile (A-profile with no DVT and no PLAPS)	89%	97%	93%	95%
Pulmonary embolism	A-profile with DVT	81%	99%	94%	98%
Pneumothorax	A′-profile (with lung point)	88%	100%	100%	99%
Pneumonia	All profiles#	89%	94%	88%	95%
	B′-profile	11%	100%	100%	70%
	A/B-profile	14.5%	100%	100%	71.5%
	C-profile	21.5%	99%	90%	73%
	A-V-PLAPS profile	42%	96%	83%	78%

ACCURACY OF BLUE PROTOCOL

Lichtenstein D et.al. BREATHE 2017

LUNG ULTRASOUND SCORE



SCORE 0 – A-lines or two or fewer well spaced B lines

SCORE 1 – Three or more well spaced B-lines

SCORE 2 – Coalescent B-lines

SCORE 3 – Tissue like pattern

} On basis of percentage of pleura showing B-lines or subpleural consolidations

Mojoli et al. Am J Respir Crit Care Med 2019

LUNG ULTRASOUND SCORE

- Score calculated in six regions per hemithorax
- Global lung ultrasound score ranges from 0 (all regions are well aerated) to 36 (all regions are consolidated)
- In ARDS patients, regional lung ultrasound score is strongly correlated with tissue density assessed with quantitative computed tomography
- GLUS directly correlates with extravascular lung water assessed by transpulmonary thermodilution

Mojoli et al. Am J Respir Crit Care Med 2019

REAERATION SCORE

ROLE :

- Used for rating antibiotic-induced reaeration in VAP
- Increase in lung volumes induced by PEEP in patients with ARDS

Lung ultrasound for diagnosis and monitoring of ventilator-associated pneumonia *Bouhemad et. al.*

Parameter	VPLUS
Purulent tracheal secretions	1
≥ Areas with subpleural consolidations	1
≥ Area with dynamic linear/ arborescent air-bronchogram	2
EA positive quantitative/ qualitative culture*	1

Bouhemad et al. Ann Transl Med 2018

CLINICAL UTILITY

- Compared with Clinical Pulmonary Infection Score (CPIS), AUC is higher (0.743 vs 0.574)

- Improved with direct gram-stain examination or quantitative analysis of ETA (0.83 vs 0.87 respectively)

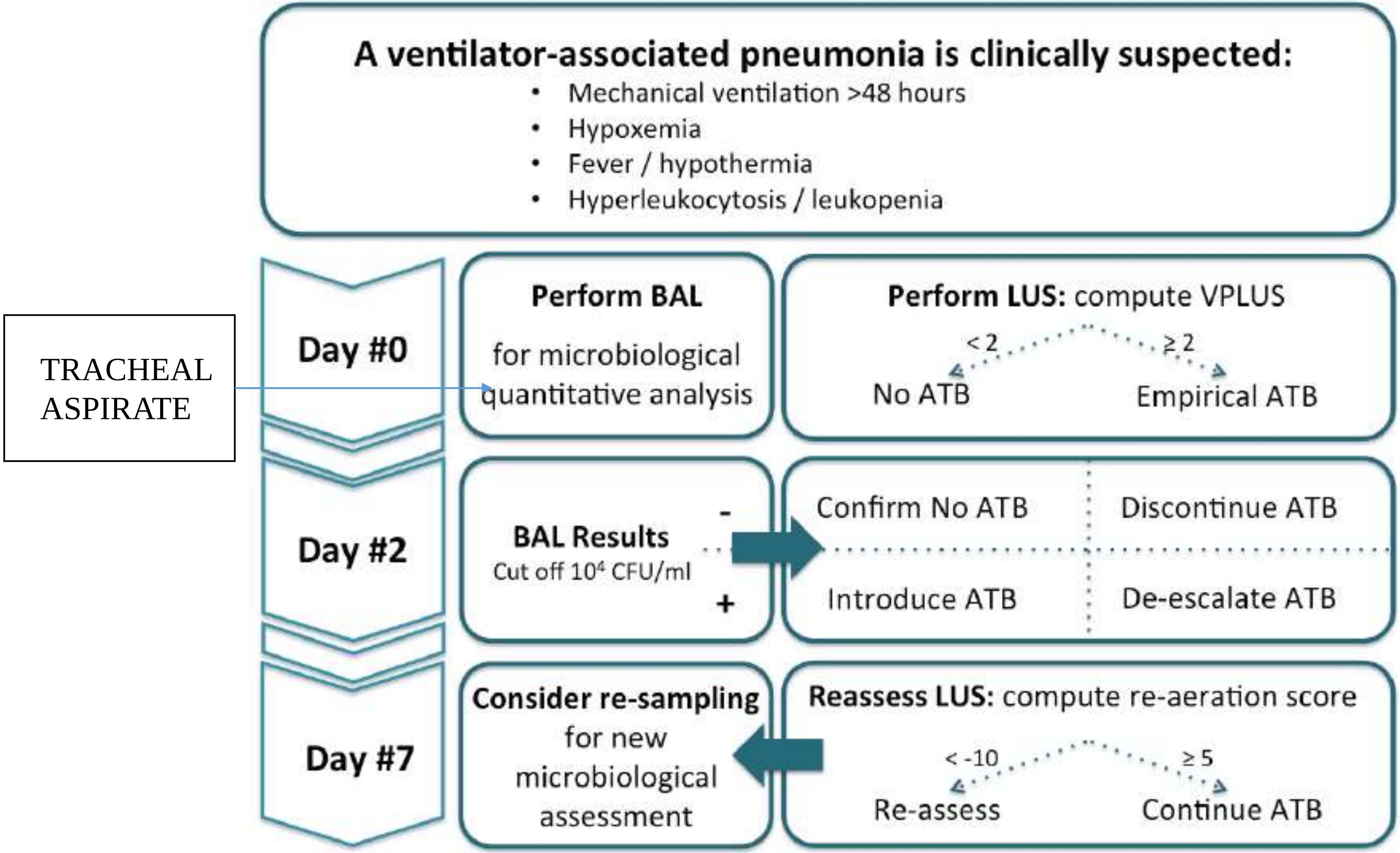
- VPLUS ≥ 2 sensitivity-71% and specificity-69%

- Normal LUS rules out diagnosis of VAP

CONS –

- Dynamic linear/arborescent air-bronchogram has specificity but poor sensitivity

Bouhemad et al.Ann Transl Med 2018

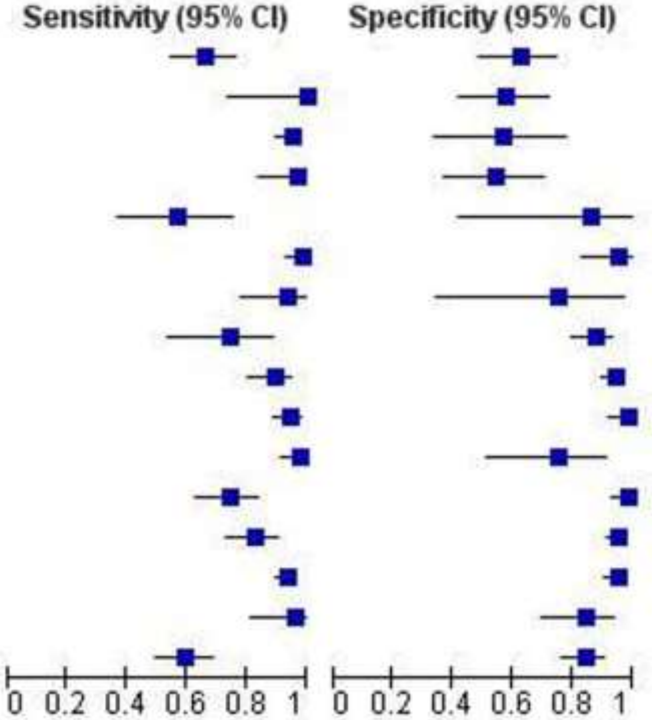


Bouhemad et al.Ann Transl Med 2018

ACCURACY OF LUNG ULTRASOUND IN DIAGNOSIS OF PNEUMONIA IN ADULTS: SYSTEMATIC REVIEW AND META-ANALYSIS *Alvarez et.al.*

- Sixteen studies included (2359 participants)
- Predominantly Cohort study (2008-2015)
- Area under ROC curve for diagnosis of pneumonia – 0.93

Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Bataille 2014	51	22	26	37	0.66 [0.55, 0.77]	0.63 [0.49, 0.75]
Berlet 2015	12	19	0	26	1.00 [0.74, 1.00]	0.58 [0.42, 0.72]
Bourcier 2014	117	9	6	12	0.95 [0.90, 0.98]	0.57 [0.34, 0.78]
Busti 2014	31	17	1	20	0.97 [0.84, 1.00]	0.54 [0.37, 0.71]
Corradi 2012	16	1	12	6	0.57 [0.37, 0.76]	0.86 [0.42, 1.00]
Cortellaro 2012	80	2	1	37	0.99 [0.93, 1.00]	0.95 [0.83, 0.99]
Fares 2015	28	2	2	6	0.93 [0.78, 0.99]	0.75 [0.35, 0.97]
Gallard 2015	20	13	7	90	0.74 [0.54, 0.89]	0.87 [0.79, 0.93]
Lichtenstein 2008	74	10	9	167	0.89 [0.80, 0.95]	0.94 [0.90, 0.97]
Liu 2015	106	1	6	66	0.95 [0.89, 0.98]	0.99 [0.92, 1.00]
Nafae 2013	78	5	2	15	0.97 [0.91, 1.00]	0.75 [0.51, 0.91]
Nazemi 2014	56	1	19	75	0.75 [0.63, 0.84]	0.99 [0.93, 1.00]
Nazerian 2015	72	9	15	189	0.83 [0.73, 0.90]	0.95 [0.92, 0.98]
Reissig 2012	214	6	15	127	0.93 [0.89, 0.96]	0.95 [0.90, 0.98]
Unluer 2013	27	7	1	37	0.96 [0.82, 1.00]	0.84 [0.70, 0.93]
Zagli 2014	67	17	46	91	0.59 [0.50, 0.68]	0.84 [0.76, 0.91]



Alvarez et al. CHEST 2016

LUS AND SUCCESSFUL WEANING

- After successful SBT, score higher than 17 predictive of postextubation distress
- Score lower than 13 highly predictive of successful weaning

Soummer A et al. Crit Care Med 2012

LUS AND PEEP RESPONSIVENESS

- Can help in making decision regarding prone positioning and recruitment maneuver

- Patients with diffuse loss of aeration (affecting anterior fields) – PEEP responders

- PEEP non responders (i.e. posterior consolidation with normal anterior fields) – considered for prone positioning

Prat G. et al. J Crit Care 2016
Haddam et al. Intensive Care Med 2016

LUS AND PRONE POSITIONING

- Amount of reaeration of posterior lung regions assessed by US after 3 hours of prone position – associated with positive clinical response- PaO_2/FiO_2 > 300mm Hg after 7 days of treatment

Wang et al. Crit Care 2016

USG AND DIAPHRAGM DYSFUNCTION

- Allows rapid diagnosis and assessment of respiratory muscle dysfunction in critically ill
- Assess patient-ventilator interaction and weaning failure in critically ill patients
- Two approaches:

- INTERCOSTAL APPROACH – For thickness and thickening fraction
- SUBCOSTAL APPROACH – For Excursion

Tuinman et al. Intensive Care Med 2020

DIAPHRAGMATIC DYSFUNCTION

- INTERCOSTAL APPROACH

- Position – Zone of apposition between mid-axillary or antero-axillary line, in 8th to 11th intercostal space
- Probe – 10-15 MHz linear array transducer in craniocaudal direction
- Appearance – At depth of two to four centimeters as three layered structure between pleural and peritoneal membrane

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DIAPHRAGMATIC DYSFUNCTION

- INTERCOSTAL APPROACH

- Thickening fraction – reflects contractile activity – calculated using M or B mode
- Tfdi = $\frac{\text{End-inspiratory thickness – end-expiratory thickness}}{\text{End expiratory thickness}}$ x 100%

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Setting	Parameter	Patient position	Reference values	Abnormal values/values related to outcome
ICU	Thickness (mm)	–	2.4 ± 0.8	
		Semi-recum	2.4 (2.0–2.9)	
		Semi-recum		< 1.7
		Semi-recum	1.9 ± 0.4	
	TFdi	Semi-recum		< 30%
	TFdi(max)	Semi-recum		< 36%
	TFdi	Semi-recum		< 34%
	Tidal excursion (mm)	Supine		< 11 (organ exc.)
		Semi-recum		Right < 14
	Maximal breath (mm)	Semi-recum		Left < 12
		Semi-recum		< 10
				< 25

SUBCOSTAL APPROACH

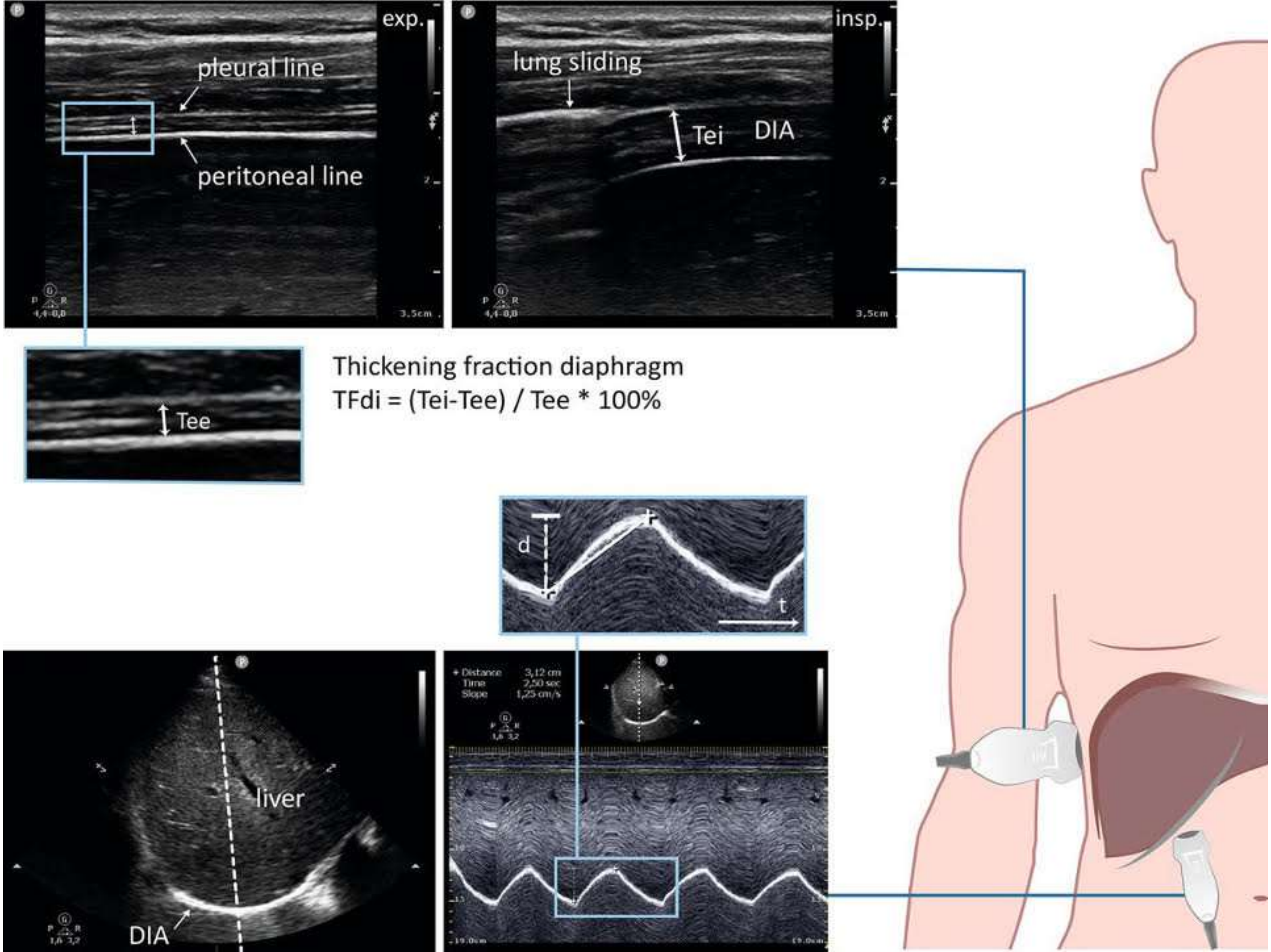
- Diaphragmatic excursion - low frequency phased array or curved-array probe (2-5 MHz)
- Position – Just below coastal arch at midclavicular line (semi-seated position) and angling beam as possible cranially and perpendicular to diaphragmatic dome

Tuinman et al. Intensive Care Med 2020

SUBCOSTAL APPROACH

- Prerequisite – Only measured during unassisted breathing (i.e. T piece or minimum tolerable CPAP level)
- Sweep speed – Adjusted to 10mm/sec to obtain minimum of 3 respiratory cycles within one image

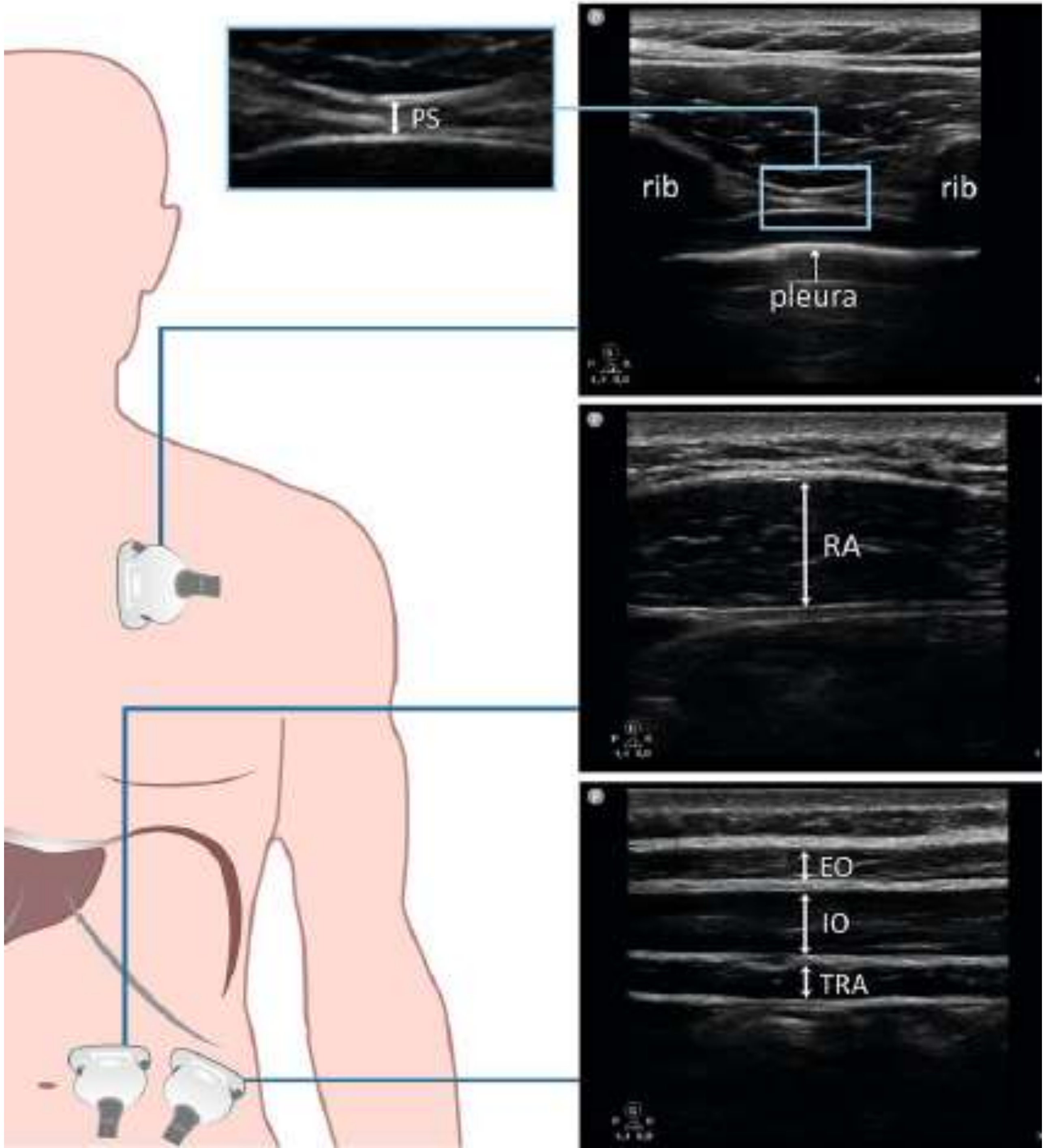
Tuinman et al. Intensive Care Med 2020


exp.
pleural line
peritoneal line
insp.
lung sliding
Tei
DIA
Tee
Thickening fraction diaphragm
TFdi = (Tei-Tee) / Tee * 100%
d
t
liver
DIA
Distance 3,12 cm
Time 2,50 sec
Slope 1,25 cm/s

EXTRA-DIAPHRAGMATIC INSPIRATORY MUSCLES

- Provides information regarding patient’s inspiratory effort and patient-ventilator assessment
- Parasternal intercostal muscle thickening- only during maximal efforts
- Probe – 10-15 MHz linear probe
- Position – Craniocaudal direction at second intercostal space

Tuinman et al. Intensive Care Med 2020


PS
rib
rib
pleura
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IO
TRA

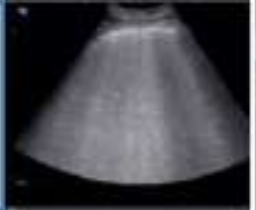
ABCDE APPROACH FOR WEANING FAILURE

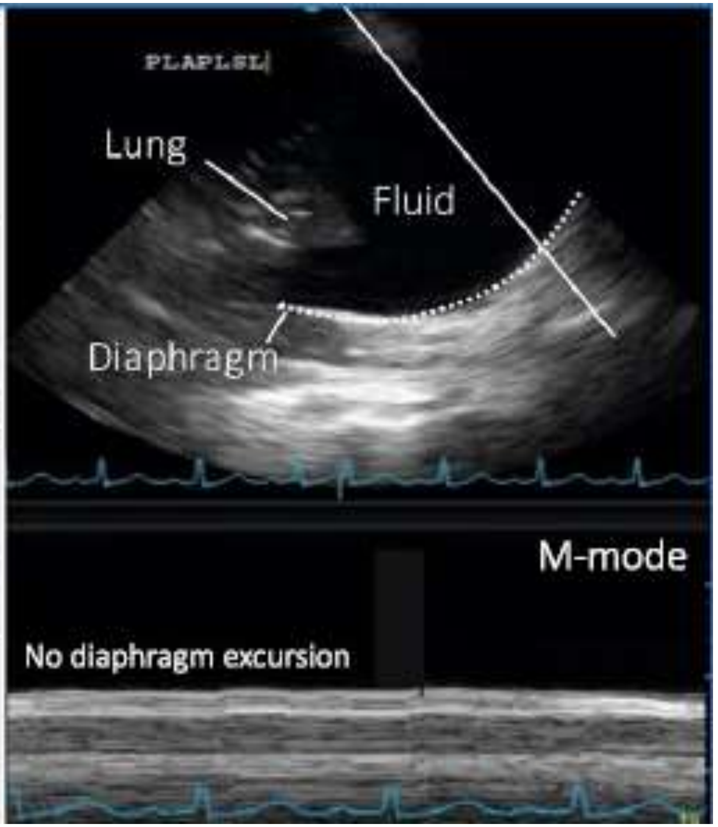
Aeration score & pleural effusion

Assess lung aeration (LUS score) and the presence of pleural fluids

Aeration score:[2] *extubation failure associated with aeration score >17 and increase in B-lines during SBT ≥6; extubation success associated with aeration score <13*

Pleural effusion: mm x 20 mL = estimated drainage amount

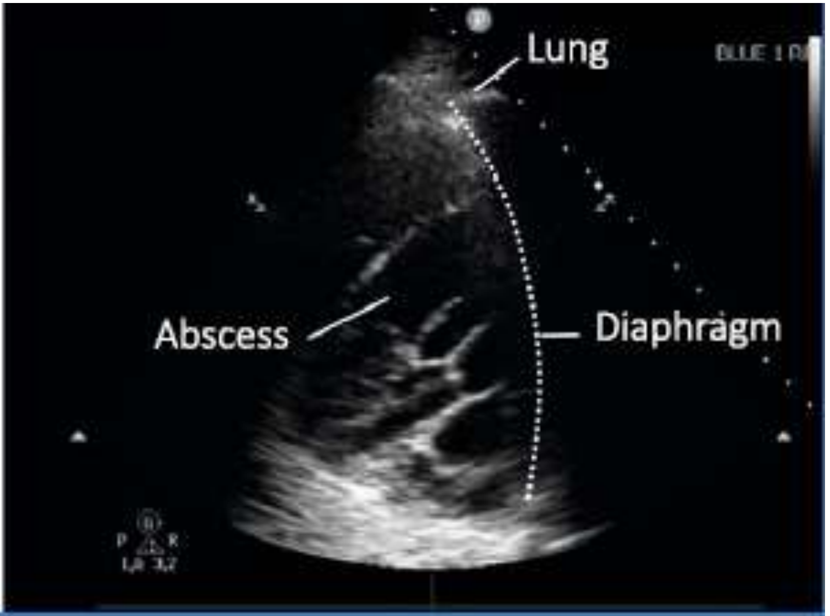
0	Normal aeration	***Horizontal A-lines*** (or no more than two B-lines)	
1	Moderate loss of aeration	***Multiple B-lines*** (either regularly spaced (7mm apart), or irregularly and even coalescent, but only visible in a limited area of the intercostal space	
2	Severe loss of aeration	***Multiple coalescent B-lines*** in prevalent areas of the intercostal spaces and observed in one or several intercostal spaces	
3	Complete loss of aeration	***Lung consolidation*** with or without air bronchograms	



ABCDE APPROACH FOR WEANING FAILURE

Below the diaphragm

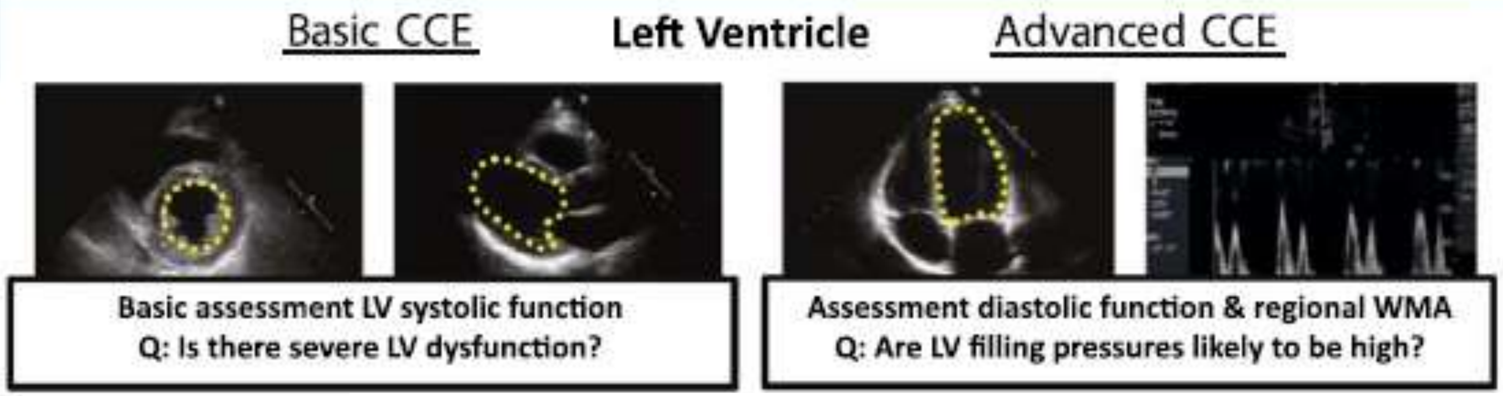
Screen for ascites or abscesses; high intra-abdominal pressures may alter respiratory mechanics



Cardiac

Assess cardiac function: LV systolic and diastolic function, preload dependency and obstructive cardiomyopathy

LV function:[2] *moderate to severe diastolic impairment: E'<8 cm/s, E/A 0.8-1.5 or >2; systolic dysfunction: LVEF <40%*

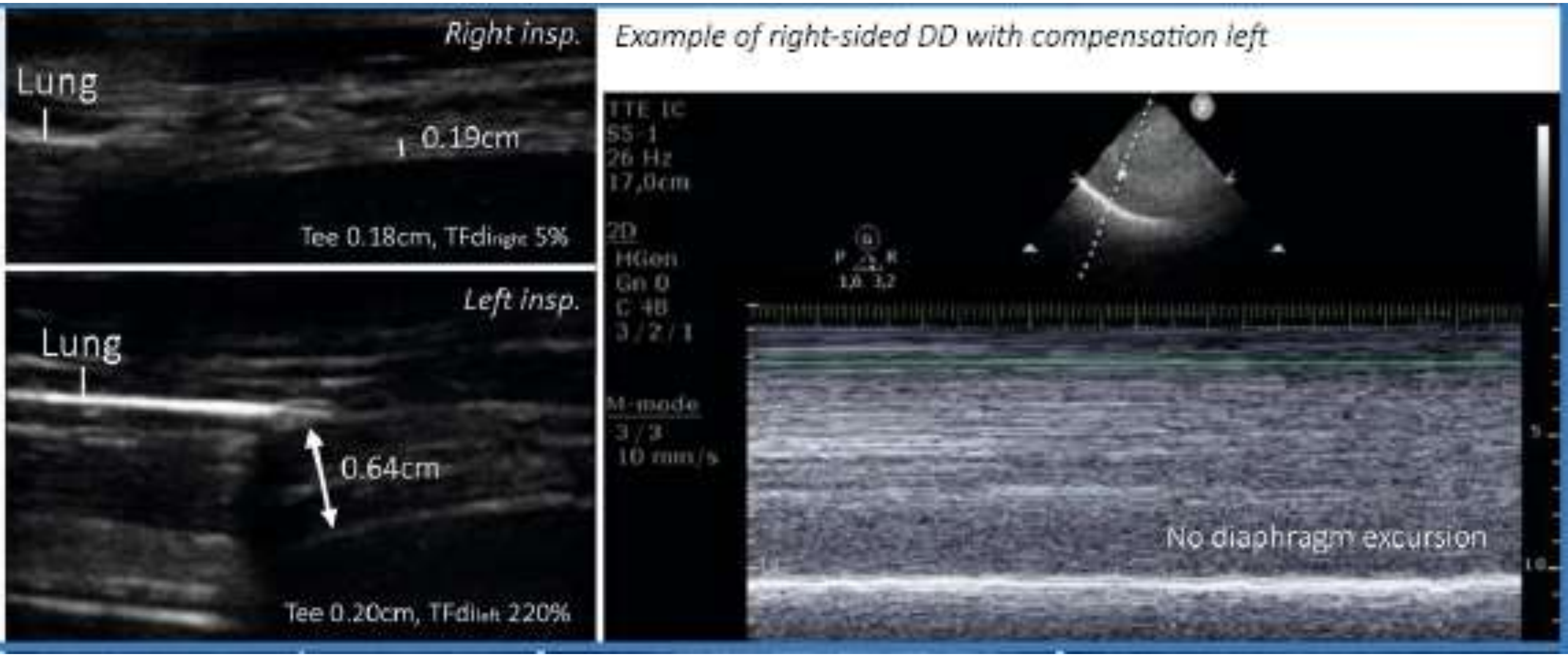


ABCDE APPROACH FOR WEANING FAILURE

Diaphragm

Measure thickness, TFdi and excursions during tidal breathing and maximal effort; assess symmetry

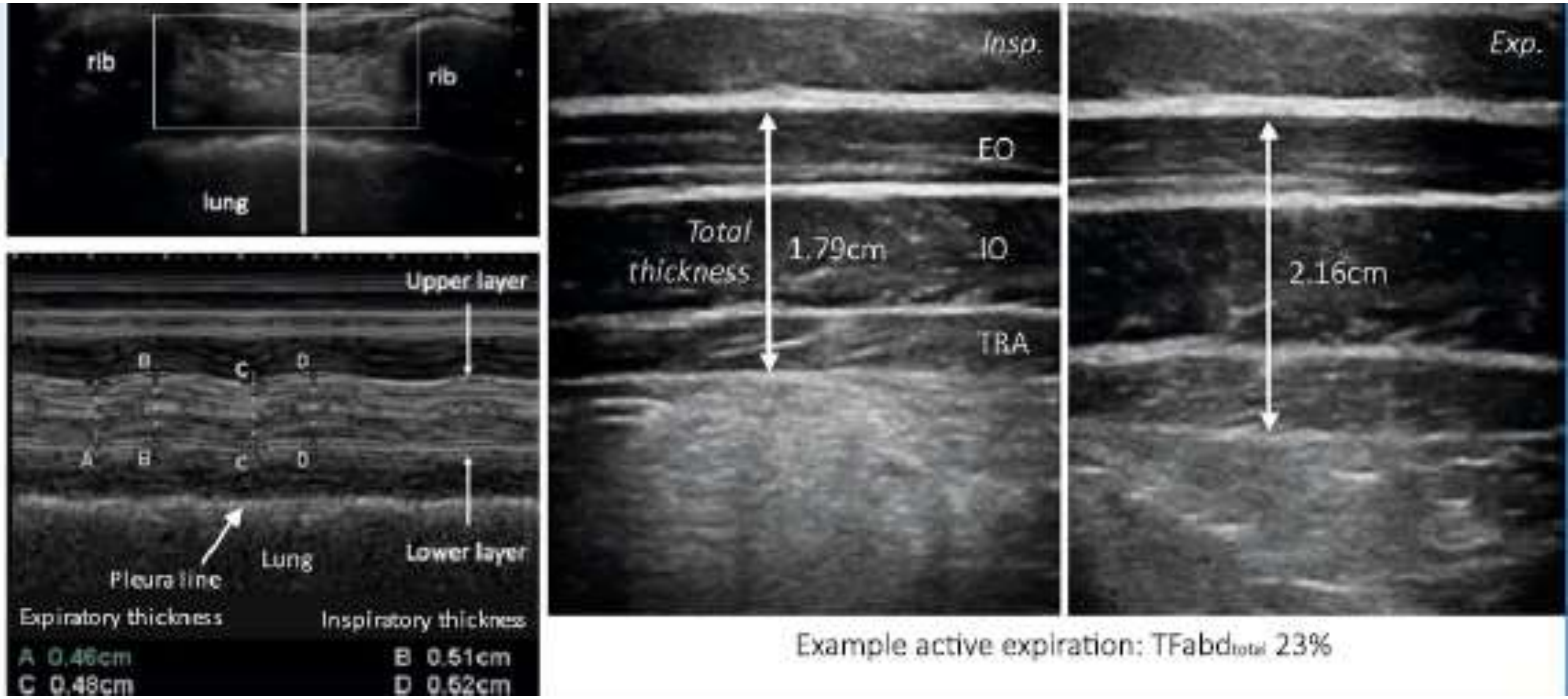
Extubation success: TFdi >30-36%, >10mm excursions (bilateral DD) and >25mm excursions (unilateral DD, unaffected side during max. effort)



ABCDE APPROACH FOR WEANING FAILURE

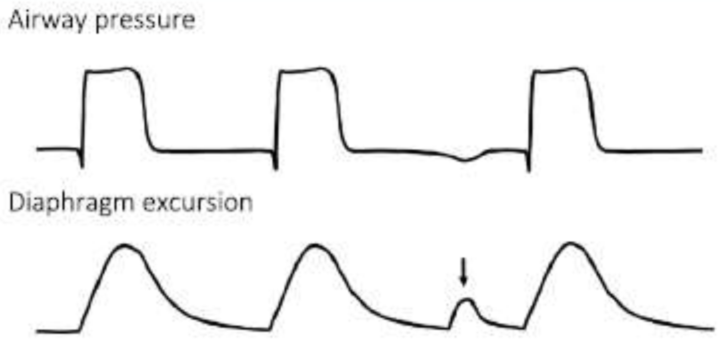
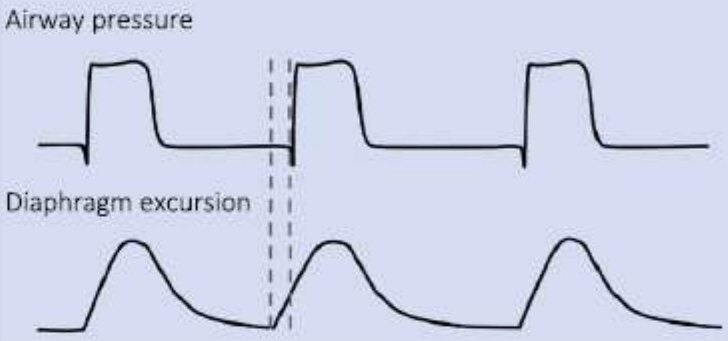
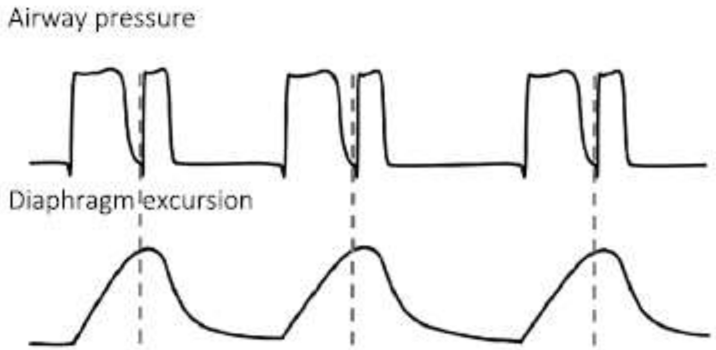
Extra-diaphragmatic respiratory muscles

Evaluate accessory respiratory muscles during SBT; active use indicates high work of breathing / low diaphragm capacity

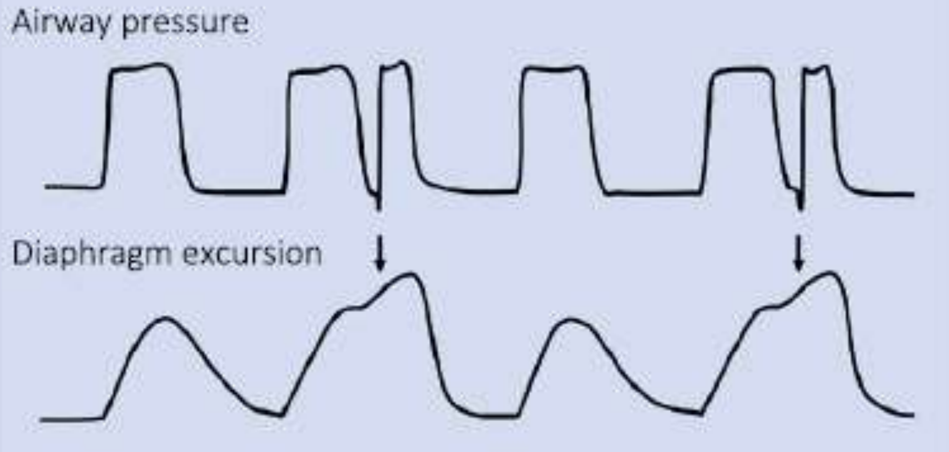
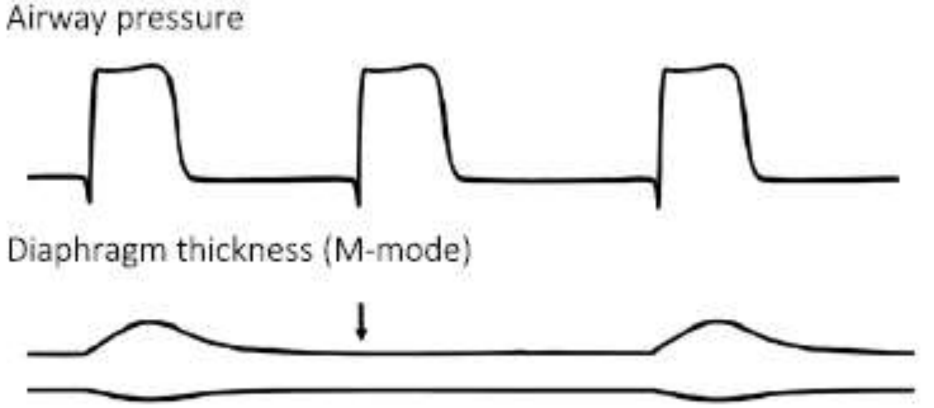


Example active expiration: $TFabd_{total}$ 23%

PATIENT–VENTILATOR ASYNCHRONY

Asynchrony	Ultrasound correlate	Comments	Illustration
Wasted effort	Diaphragm excursion w/o ventilator triggering	Subcostal view M-mode Easy to perform	
Trigger delay	Delay between diaphragm excursion and ventilator triggering	Subcostal view M-mode Requires ventilator waveform display on ultrasound screen	
Double trigger	Diaphragm displacement during ventilator expiration, thereby triggering a second breath	Subcostal view M-mode During assisted modes	

PATIENT–VENTILATOR ASYNCHRONY

Reverse trigger	Active diaphragm excursion after passive displacement, leading to a higher excursion amplitude and change in displacement slope	Subcostal view M-mode Fixed pattern Additional demonstration RT: TFdi during RT breath, no TFdi during a passive breath	
Auto-trigger	Absence of diaphragm thickening with mechanical assist	Intercostal view During assisted modes No thickening compared to other breaths	

PRACTICAL UTILITY

- Ultrasound Corollary of respiratory paradox – Cranial excursion of diaphragm

RESPIRATORY MUSCLE ULTRASOUND IS EXCELLENT MODALITY TO DIAGNOSE (UNILATERAL) DIAPHRAGM WEAKNESS OR PARALYSIS IN ACUTE RESPIRATORY FAILURE

fraction of accessory respiratory muscles

- Diaphragm weakness – Diagnosis – Excursion of < 10-15 mm during tidal breathing or TFdi(max) < 20%
- For unilateral diaphragm paralysis, left to right ratio for thickness <0.5 or >1.6 - abnormal

Intercostal Muscle Ultrasound Activity: A Feasibility and Physiological Study in Mechanically Ventilated Patients *Dres et.al.*

3 studies performed:

- Study A – Exploratory evaluation of measurement of TFic in 23 healthy subjects
- Study B – Response of TFic to six pressure support (PS) conditions in 16 patients
- Study C – TFic in presence and absence of diaphragm dysfunction (evaluated change in endotracheal pressure in response to magnetic stimulation of phrenic nerves) and in case of success/failure of SBT in 54 other critically ill patients

Dres M et al. ATS 2018

- Established existence of dose-response relationship between respiratory load and parasternal intercostal thickening
- CONCLUSIONS FROM STUDY :
- Median level of TFic in healthy individuals was low [3 (0-4)%]
- TFic progressively decreased with increasing levels of PS i.e. 24 ± 12% for PS 7cmH2O to 6 ± 4% for PS 20 cm H2O
- TFic >8% identified diaphragmatic function with sensitivity and specificity – 85% and 76%
- TFic > 10% can predict failure of spontaneous breathing trial with sensitivity and specificity of 72% and 97% respectively

Dres M et al. ATS 2018

AECOPD AND NIV

- Increased diaphragm excursion during NIV (>18 mm vs 12mm) associated with NIV success and decrease in PaCO2 after one hour
- Air trapping is major factor responsible for reduced excursion
- Improved diaphragmatic excursion indicates decreased lung hyperinflation

Dos Santos et al. Respirology 2008
Sanchez – Nicolas JA et al. Emergencias 2016
Cammarota G et al. Respir Care. 2019

RESEARCH Open Access

Ultrasound-assessed diaphragmatic impairment is a predictor of outcomes in patients with acute exacerbation of chronic obstructive pulmonary disease undergoing noninvasive ventilation

Marchioni et. al.

- Single-center prospective study
- Cohort - 75 consecutive patients with AECOPD with hypercapnic acidosis
- Change in diaphragm thickness < 20% during tidal volume predefined cutoff for identifying DD+/- status
- DD+ patients had a higher risk for NIV failure than DD- patients (risk ratio, 4.4; $p < 0.001$)
- Early and noninvasive US assessment of DD during severe AECOPD is reliable and accurate in identifying

patients at major risk for NIV failure and worse prognosis

Marchioni et al. Critical Care. 2018

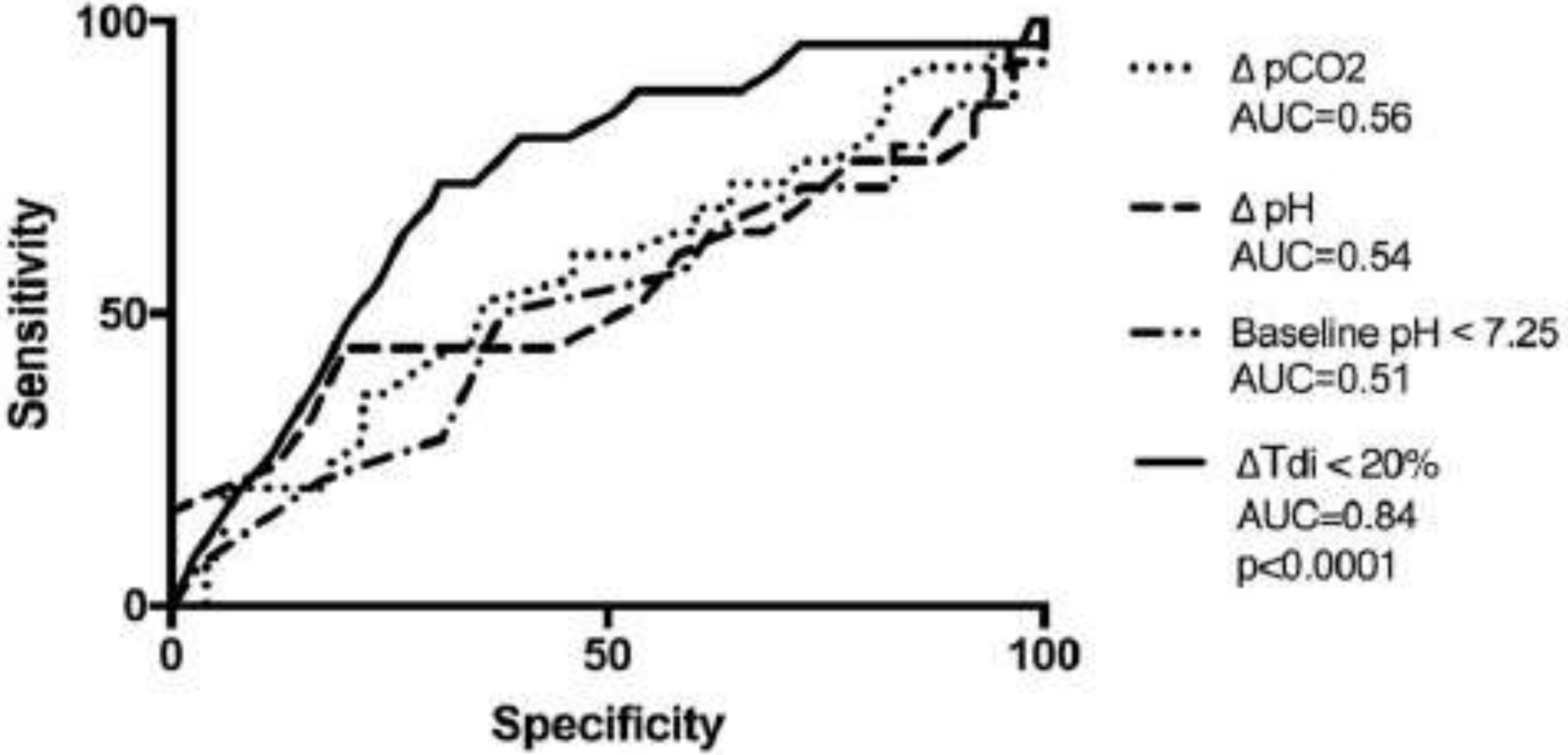
Feature	Overall	Diaphragmatic function DD+	Diaphragmatic function DD–	*p* Value
Patients	75 (100%)	24 (32%)	51 (68%)	
Age, years	78 (71–86)	77 (71–86)	78 (76–83)	n.s. (0.61)
Male sex	38 (51%)	15 (63%)	23 (45%)	n.s. (0.21)
Pneumonia	39 (52%)	14 (58%)	25 (50%)	n.s. (0.45)
Sepsis	23 (31%)	10 (42%)	13 (25%)	n.s. (0.1)
Diabetes	31 (41%)	10 (42%)	21 (41%)	n.s. (0.81)
Use of steroids	45 (46%)	17 (71%)	17 (33%)	0.005
FEV_1	47% (30–65)	43% (27–61)	49% (32–67)	n.s. (0.65)
Kelly scale score	3.4 (2.4–4.1)	3.7 (2.9–4.3)	3.2 (2.5–3.7)	n.s. (0.34)
APACHE II score	22 (16–29)	25 (18–32)	20 (16–23)	n.s. (0.09)
SAPS II	43 (35–53)	47 (40–55)	41 (33–50)	n.s. (0.28)
PaO_2/FiO_2	166 (121–198)	165 (109–196)	168 (135–188)	n.s. (0.86)
pH	7.24 (7.2–7.3)	7.24 (7.21–7.29)	7.25 (7.19–7.36)	n.s. (0.32)
$PaCO_2$, mmHg	91 (77–100)	91 (77–98)	90 (80–102)	n.s. (0.82)
Blood lactate, mg/dl	10 (5–12)	11 (4–12)	9 (5–10)	n.s. (0.72)
Respiratory rate, breaths/min	31 (29–35)	34 (30–36)	30 (28–35)	n.s. (0.07)

BASELINE CHARACTERISTICS OF THE STUDY POPULATION AS A WHOLE AND ACCORDING TO THE PRESENCE/ABSENCE OF DIAPHRAGMATIC DYSFUNCTION

OUTCOMES

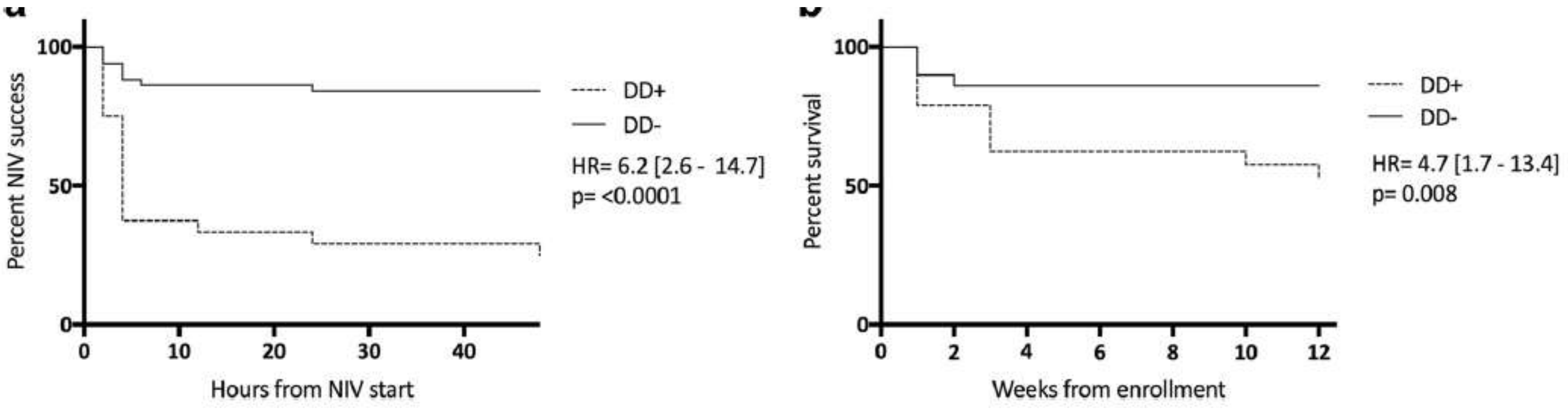
	Diaphragmatic function				
Outcome	Overall	DD+	DD−	Relative risk	*p* Value
NIV failure	26 (35%)	18 (75%)	8 (16%)	4.4 (2.3–8.7)	< 0.0001
RICU mortality	16 (21%)	10 (42%)	6 (12%)	3.1 (1.3–7.7)	0.007
In-hospital mortality	19 (25%)	11 (46%)	8 (16%)	2.7 (1.3–5.7)	0.02
90-day mortality	29 (39%)	14 (58%)	15 (29%)	1.8 (1.1–3.1)	0.04
Tracheostomy	7 (9%)	5 (21%)	2 (3.9%)	5 (1.2–21)	0.04
MV duration, days	10 (3–11)	16 (5.5–18.8)	8 (2–9)	2 (1.4–3.3)	0.03
ICU stay, days	14 (6–17)	17 (8–21)	12 (7–16)	2.8 (1.5–4.2)	0.012
Hospital stay, days	21 (10–23)	21 (10–23)	22 (10–24)	1.1 (0.5–1.3)	n.s. (0.9)

Marchioni et al. Critical Care 2018



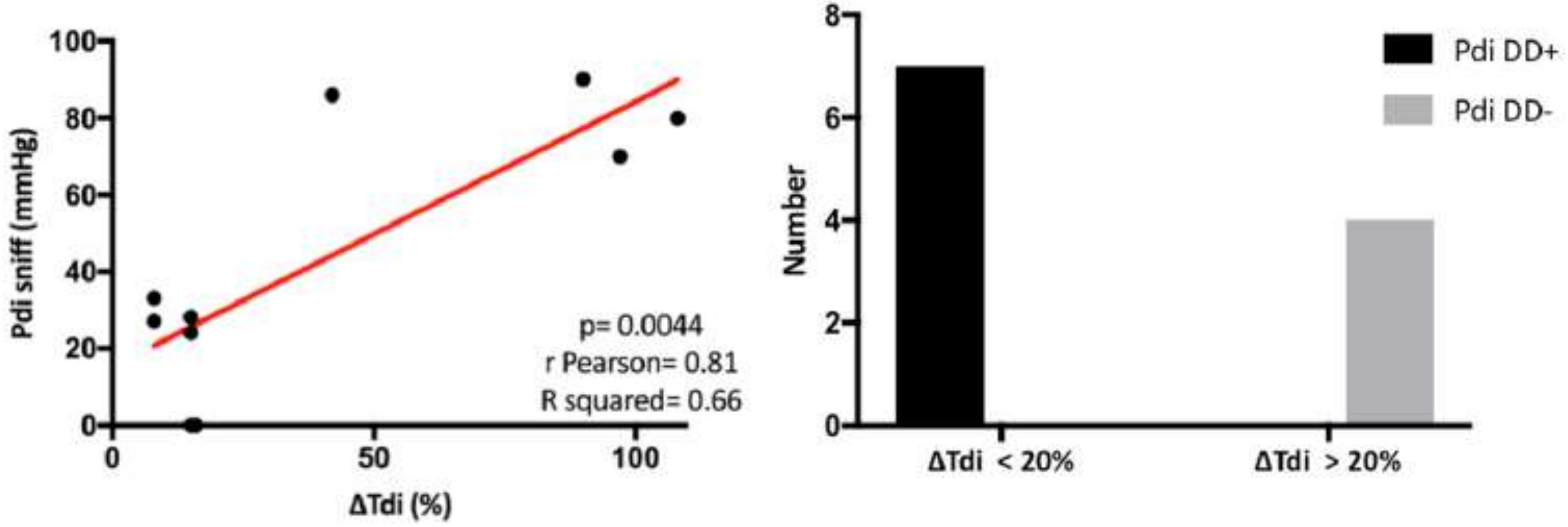
ROC analysis comparing predictors for noninvasive ventilation (NIV) failure at baseline and within 2 hours after NIV was started

Marchioni et al. Critical Care 2018



PROBABILITY OF FAIL NONINVASIVE VENTILATION (NIV) FAILURE AND DEATH WITHIN THE FIRST 48 HOURS AFTER ADMISSION ACCORDING TO THE PRESENCE (+)/ABSENCE (−) OF DIAPHRAGMATIC DYSFUNCTION (DD) AS ASSESSED BY ULTRASOUND

Marchioni et al. Critical Care 2018



(i) Correlation between change in diaphragm thickness (ΔTdi) and transdiaphragmatic pressure capacity measured at maximal inspiration using the sniff maneuver (Pdi sniff)

(ii) Accuracy of ΔTdi and Pdi sniff in identifying patients with diaphragmatic dysfunction (DD)

Marchioni et al. Critical Care 2018

Diaphragm and Lung Ultrasound to Predict Weaning Outcome

Systematic Review and Meta-Analysis

Alvarez *et.al.*

- Nineteen studies involving 1071 patients

- RESULTS

- For diaphragm fraction, area under sROC – 0.87 and DOR – 21 (95% CI, 11-40)

- For diaphragmatic excursion, pooled sensitivity and specificity – 75% (95% CI, 65-85) and 75 (95% CI, 60-85) respectively

- For lung US, area under sROC – 0.77 and DOR – 38 (95% CI, 7-198)

- CONCLUSION

- DTF by itself is modest predictor of weaning outcome in critically ill patients

- LUS accurately predicts the outcome but more studies needed to establish clinical utility

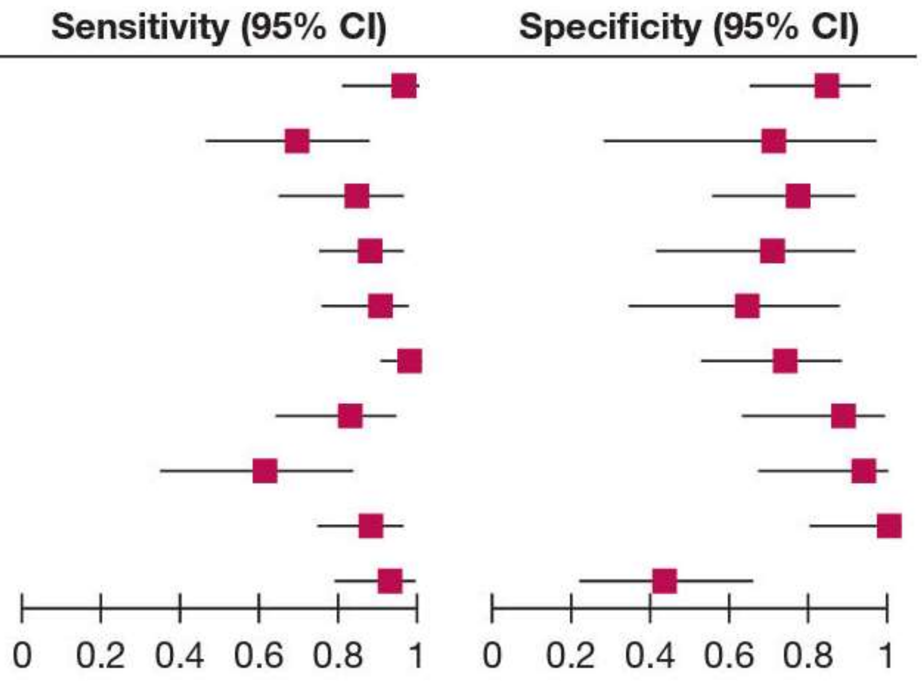
- Data not supportive for diaphragm excursion due to lower accuracy

Alvarez et al. CHEST 2019

	DTF	DE	LUS
Accuracy			
Pooled sensitivity (95% CI)	NA	75% (65 to 85)	NA
Pooled specificity (95% CI)	NA	NA	NA
AUSROC	0.87	NA	0.77
DOR (95% CI)	21 (11 to 40)	10.6 (5 to 24)	38 (7 to 198)
Correlation sensitivity-specificity			
Spearman rho (95% CI)	0.3 (−0.4 to 0.7)	−0.45 (−0.84 to 0.25)	0.2 (−0.8 to 0.9)
Heterogeneity			
Cochrane Q (*P* value)	9.5 ($P = .38$)	10.7 ($P = .29$)	5.1 ($P = .27$)
I^2	6%	15.8%	22%

A

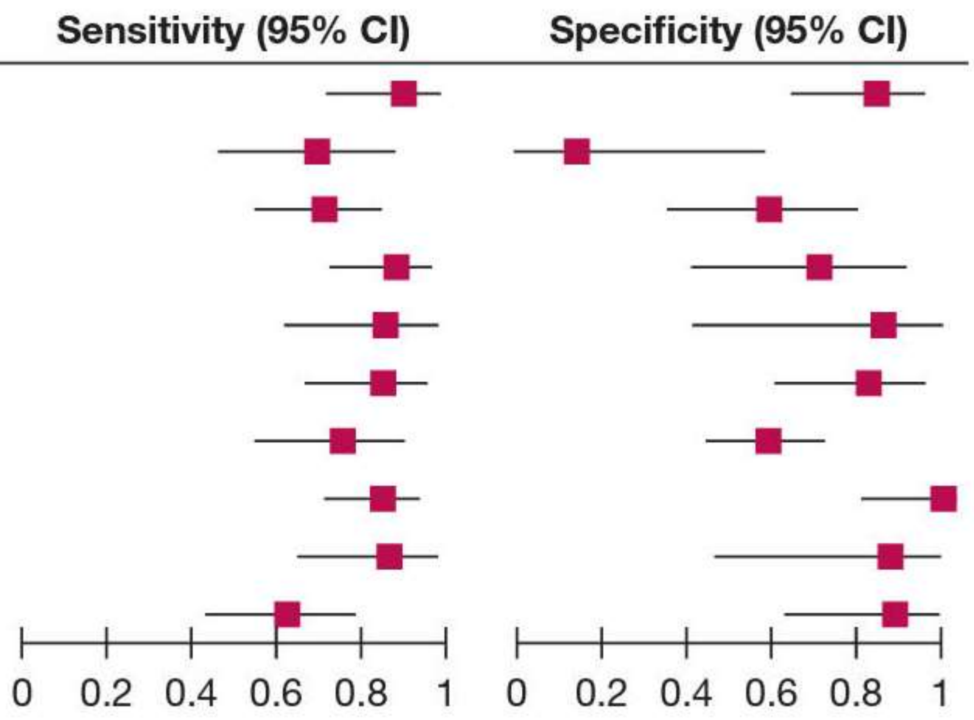
Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Ali 2016	27	4	1	22	0.96 [0.82-1.00]	0.85 [0.65-0.96]
Baess 2016	16	2	7	5	0.70 [0.47-0.87]	0.71 [0.29-0.96]
Blumhof 2016	22	6	4	20	0.85 [0.65-0.96]	0.77 [0.56-0.91]
Dinino 2014	43	4	6	10	0.88 [0.75-0.95]	0.71 [0.42-0.92]
Farghaly 2016	36	5	4	9	0.90 [0.76-0.97]	0.64 [0.35-0.87]
Fayed 2016	80	8	2	22	0.98 [0.91-1.00]	0.73 [0.54-0.88]
Ferrari 2014	24	2	5	15	0.83 [0.64-0.94]	0.88 [0.64-0.99]
Jung 2016	11	1	7	14	0.61 [0.36-0.83]	0.93 [0.68-1.00]
Osman 2017	44	0	6	18	0.88 [0.76-0.95]	1.00 [0.81-1.00]
Tenza-Lozano, unpublished data, 2017	37	13	3	10	0.93 [0.80-0.98]	0.43 [0.23-0.66]



FOREST PLOT FOR SENSITIVITY AND SPECIFICITY FOR DIAPHRAGM THICKENING FRACTION

Alvarez et al. CHEST 2019

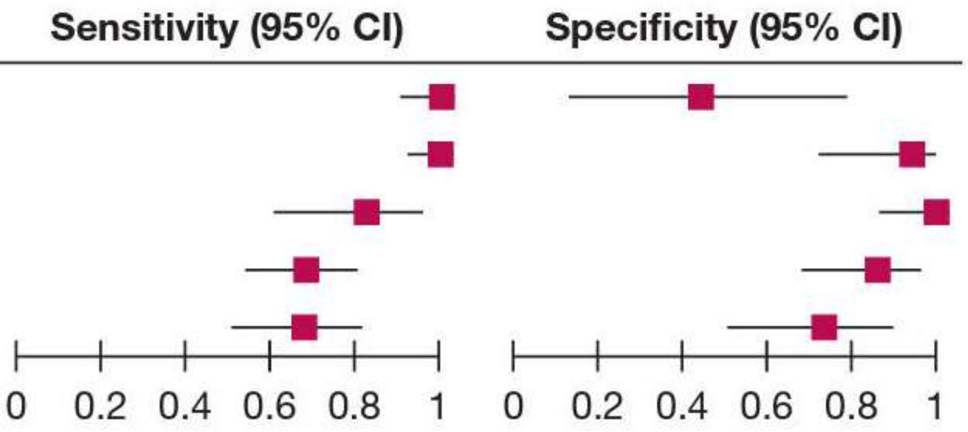
Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Ali 2016	25	4	3	22	0.89 [0.72-0.98]	0.85 [0.65-0.96]
Baess 2016	16	6	7	1	0.70 [0.47-0.87]	0.14 [0.00-0.58]
Carrie 2017	32	9	13	13	0.71 [0.56-0.84]	0.59 [0.36-0.79]
Farghaly 2016	35	4	5	10	0.88 [0.73-0.96]	0.71 [0.42-0.92]
Flevari 2016	17	1	3	6	0.85 [0.62-0.97]	0.86 [0.42-1.00]
Jiang 2004	27	4	5	19	0.84 [0.67-0.95]	0.83 [0.61-0.95]
Kim 2011	21	22	7	32	0.75 [0.55-0.89]	0.59 [0.45-0.72]
Osman 2017	42	0	8	18	0.84 [0.71-0.93]	1.00 [0.81-1.00]
Saeed 2016	19	1	3	7	0.86 [0.65-0.97]	0.88 [0.47-1.00]
Spadaro 2016	21	2	13	15	0.62 [0.44-0.78]	0.88 [0.64-0.99]



FOREST PLOT FOR SENSITIVITY AND SPECIFICITY FOR DIAPHRAGM EXCURSION

Alvarez et al. CHEST 2019

Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Binet 2014	39	5	0	4	1.00 [0.91-1.00]	0.44 [0.14-0.79]
Osman 2017	50	1	0	17	1.00 [0.93-1.00]	0.94 [0.73-1.00]
Shoaeir 2016	19	0	4	27	0.83 [0.61-0.95]	1.00 [0.87-1.00]
Soummer 2012	39	4	18	25	0.68 [0.55-0.80]	0.86 [0.68-0.96]
Tenza-Lozano, unpublished data, 2017	27	6	13	17	0.68 [0.51-0.81]	0.74 [0.52-0.90]



FOREST PLOT FOR SENSITIVITY AND SPECIFICITY FOR LUNG ULTRASOUND SCORE

Alvarez et al. CHEST 2019

FALLS PROTOCOL

1) Ruling out obstructive shock

Simple cardiac sonography:

Pericardial tamponade
Right ventricle dilatation[1]

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

↓

2) Ruling out cardiogenic shock[2]

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

↓

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

Correction of parameters of shock
under fluid administration

↓

4) Detecting distributive shock, septic shock currently

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

Lichtenstein et al. CHEST 2014

ECHO IN PULMONARY EMBOLISM

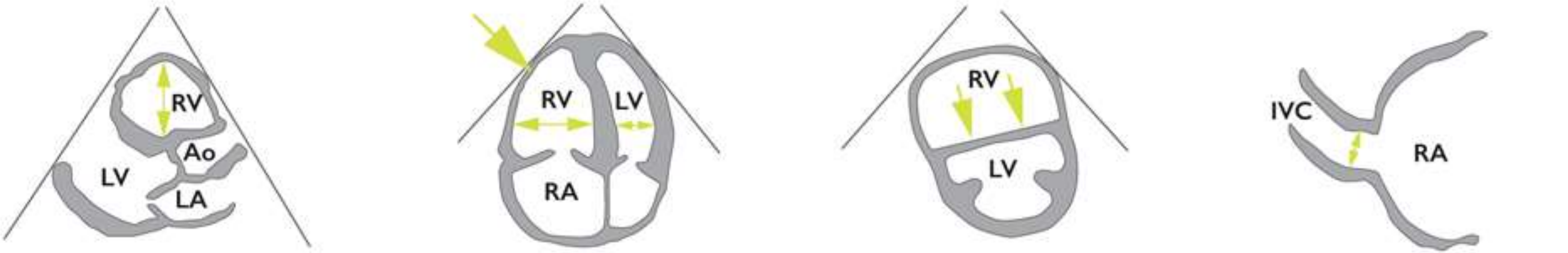
- Detection of echocardiographic signs characteristic of pulmonary embolism are of high diagnostic value:

- McConnell sign
- The 60/60 sign
- Right thrombus

Rationale:

- In retrospective study of 511 patients, high risk patients presented with atleast one typical echocardiographic sign of pulmonary embolism
- Diagnosis not be made solely on RV hypokinesia and arbitrarily defined increased RV to LV ratio

Kurnicka et al. JASE. September 2016

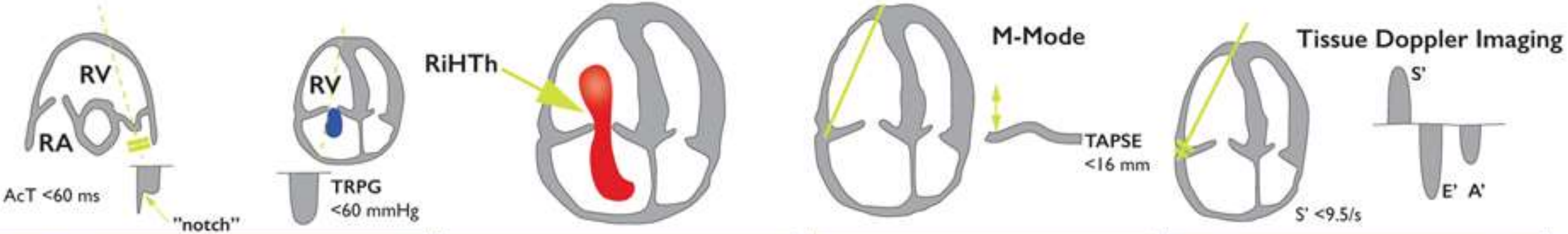


A. Enlarged right ventricle, parasternal long axis view

B. Dilated RV with basal RV/LV ratio >1.0, and McConnell sign (arrow), four chamber view

C. Flattened intraventricle septum (arrows) parasternal short axis view

D. Distended inferior vena cava with diminished inspiratory collapsibility, subcostal view



E. 60/60 sign: coexistence of acceleration time of pulmonary ejection <60 ms and midsystolic "notch" with mildy elevated (<60 mmHg) peak systolic gradient at the tricuspic valve

F. Right heart mobile thrombus detected in right heart cavities (arrow)

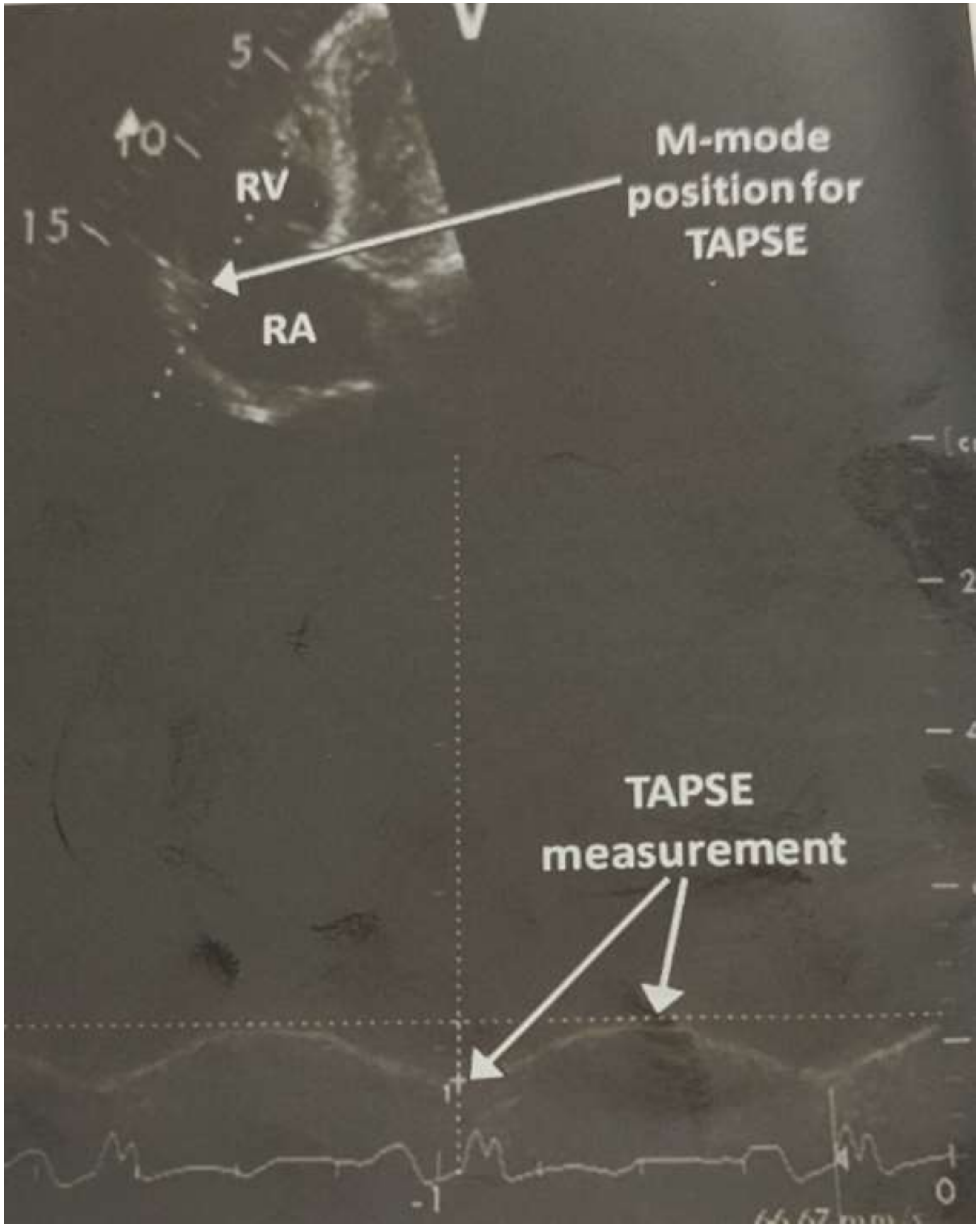
G. Decreased tricuspid annular plane systolic excursion (TAPSE) measured with M-Mode (<16 mm)

H. Decreased peak systolic (S') velocity of tricuspid annulus (<9.5 cm/s)

2019 European Guidelines for PE. European Heart Journal

TAPSE

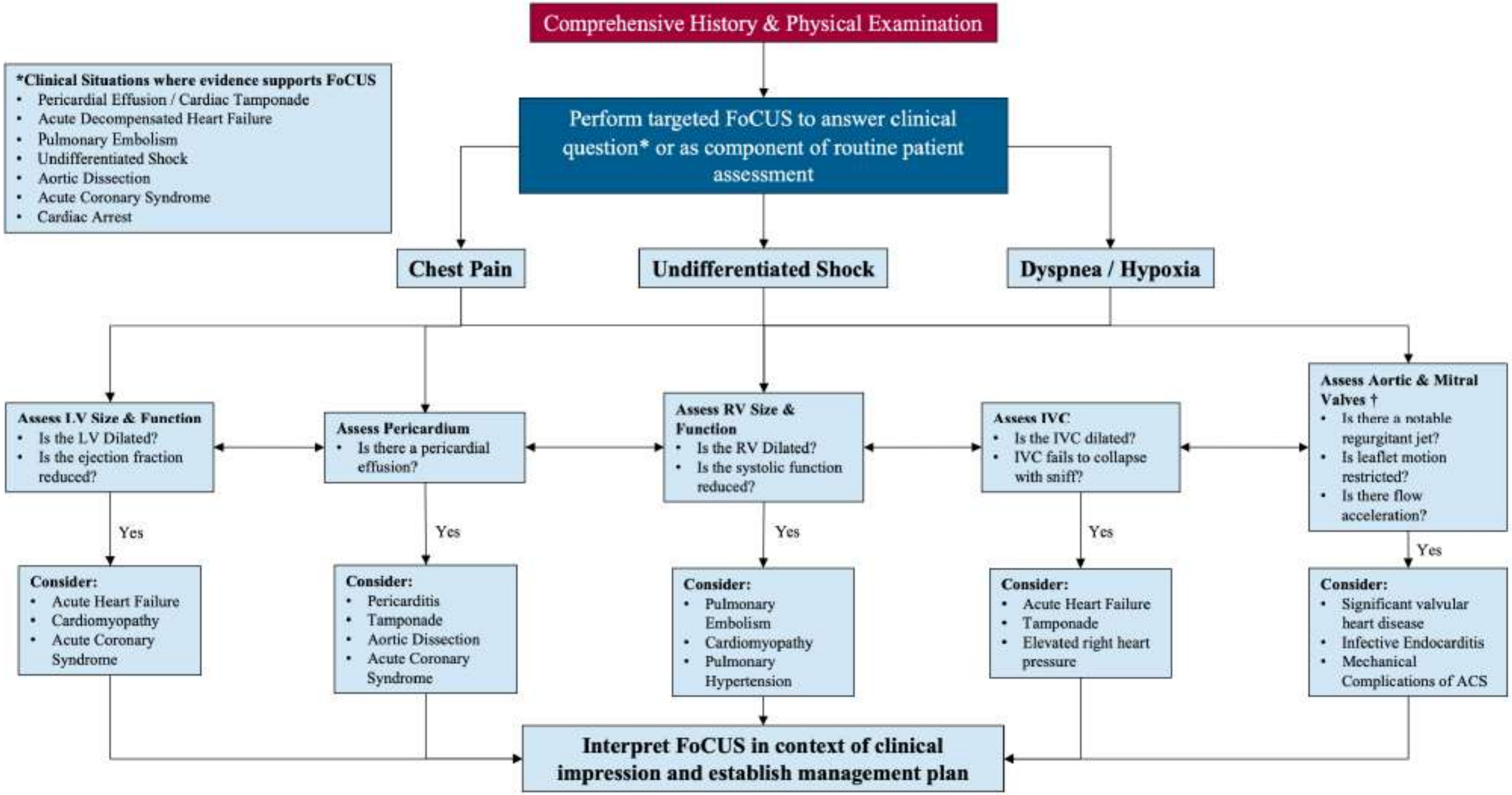
- TAPSE - Tricuspid annular plane systolic excursion
- VIEW – Apical 4 chamber
- MODE – M mode cursor oriented to junction of TV plane with RV free wall
- Interpretation – Difference in displacement of RV base during diastole and systole
- Abnormal excursion < 1.6 cm



M-mode position for TAPSE
RV
RA
TAPSE measurement

“THE SICKER THE PATIENT, THE GROSSER THE FOCUS FINDINGS”

Approach to FoCUS Guided Clinical Decision Making



OPERATOR: .... EXAM DATE: .... HOUR ....

INDICATION: ☐ PEA ☐ Shock / Hypotension ☐ Resp. failure ☐ Oliguria ☐ Screening ☐ Other

HISTORY: ....

DRUGS/TREATMENT: ....

VENTILATION: ☐ Spontaneous ☐ MV passive ☐ MV active ☐ CPAP PEEP/ Vt = .../.........

TYPE OF EXAM: ☐ FEEL (CPR/Periresuscitation) ☐ Complete FoCUS ☐ Repeated Assessment

WINDOWS, Used: ☐ SLAX ☐ SSAX ☐ SIVC ☐ PLAX ☐ PSAX ☐ A4CH ☐ A2CH ☐ ALAX

Quality: S .... P .... A .... *(2 = optimal; 1= suboptimal; 0 = inadequate)*

LEFT VENTRICLE

DIMENSION: ☐ Small ☐ Normal ☐ Dilated ☐ Markedly dilated LA: ☐ Dilated ☐ Non dilated

WALL THIKNESS: ☐ Normal ☐ Markedly hypertrophied RWMA: ☐ YES ☐ NO

KINESIS: ☐ Hyper ☐ Normal ☐ Mild Hypo ☐ Moderate Hypo ☐ Severe Hypo ☐ Card. Standstill

RIGHT VENTRICLE

DIMENSION: ☐ Small ☐ Normal ☐ Dilated ☐ Markedly dilated (bigger than LV)

KINESIS: ☐ Hyper ☐ Normal ☐ Hypo ☐ Cardiac Standstill RA: ☐ Dilated ☐ Non dilated

SEPTUM: ☐ Normal ☐ Flattened ☐ Paradoxical motion WALL THIKNESS: ☐ Normal ☐ Hypertrophied

INFERIOR VENA CAVA

DIMENSION: ☐ ≤ 10mm ☐ 10-15mm ☐ 15-20mm ☐ 20-25mm ☐ >25mm

RESPIRATORY VARIATION: ☐ collapse ☐ >50% reduction ☐ <50% reduction ☐ absent

RESPIRATORY VARIATION (MV PASSIVE): ☐ >20% distension ☐ <20% distension ☐ absent

VALVES & Intracardiac MASSES

MITRAL LEAFLETS: ☐ Normal ☐ Greatly thickened/calcified ☐ Disrupted/Flail ☐ Hypomobile

AORTIC CUSPS: ☐ Normal ☐ Greatly thickened/calcified ☐ Disrupted ☐ Hypomobile

MASSES: ☐ None ☐ On Mitral valve ☐ On Aortic Valve ☐ In Right Cavities ☐ In IVC

PERICARDIUM

☐ Normal ☐ Mild Effusion ☐ Large Circumf Effusion ☐ RA syst collapse ☐ RV diast collapse

FoCUS PROTOCOL

- Recommended targets:

• Signs of chronic heart disease

• Moderate to severe left ventricular systolic dysfunction

• Moderate to severe right ventricular systolic dysfunction

• Severe hypovolaemia

• Pericardial effusion, tamponade

• Findings of severe valve disease

• Large intracardiac masses

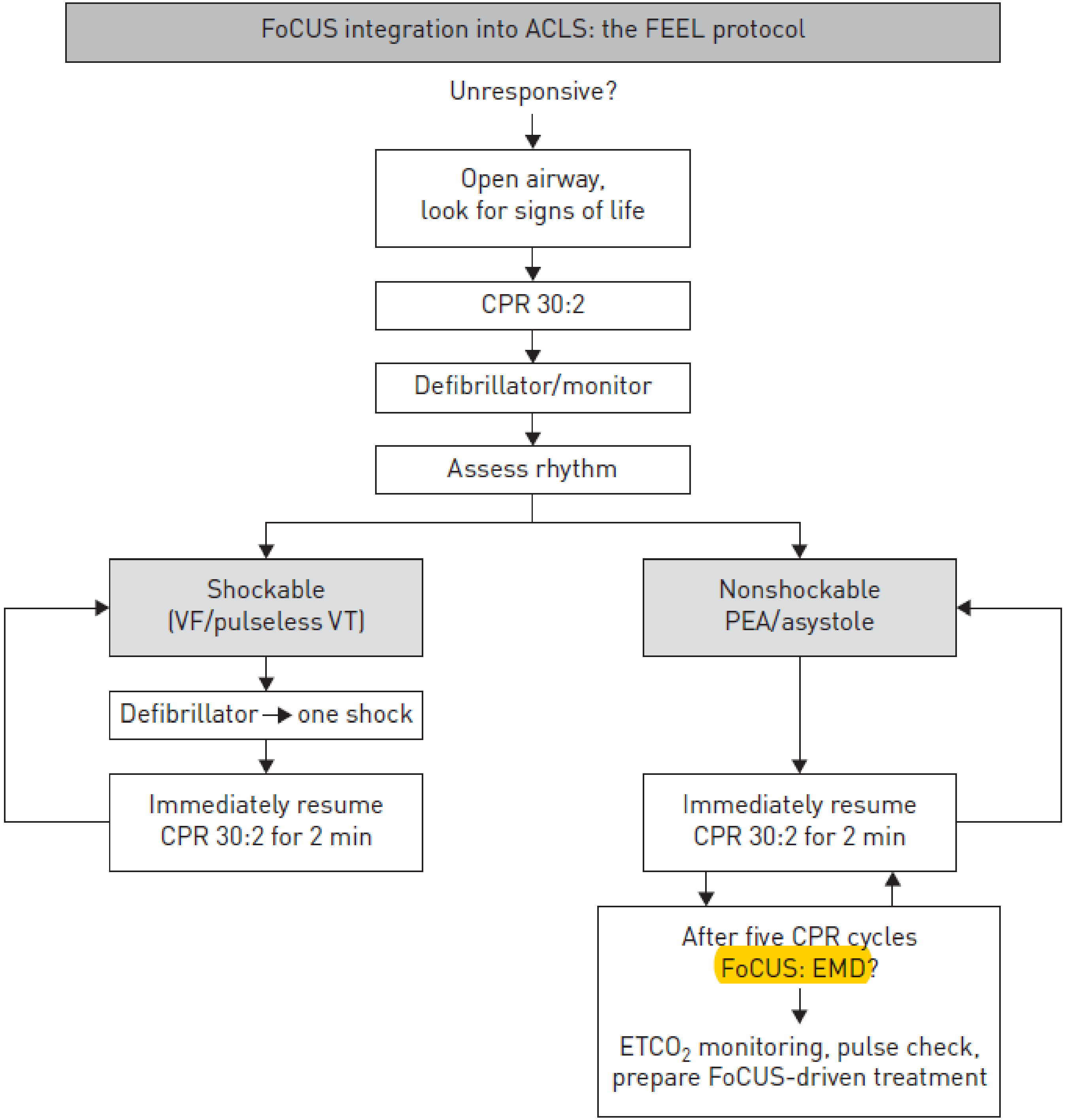
POINTS TO BE TAKEN CARE IN FoCUS

- Left ventricular size more than 11mm indicates LV hypertrophy and diastolic dysfunction
- Contracted LV cavity and hyperdynamic function – Severe hypovolemia
- Thickness of RV free wall in diastole > 5mm, chronic RV failure suspected
- End systolic reduction in LV diameter or area more than 1/3 of diastolic size corresponds to EF >60%

POINTS TO BE TAKEN CARE IN FoCUS

- IVC inspiratory collapse in spontaneously breathing patient (>40% of end expiratory size) and IVC inspiratory distensibility (>20%) in mechanically ventilated patient predicts fluid responsiveness

FEEL PROTOCOL



RESUSCITATION

US-CAB protocol for ultrasonographic evaluation during cardiopulmonary resuscitation: Validation and potential impact

Lien et. al.

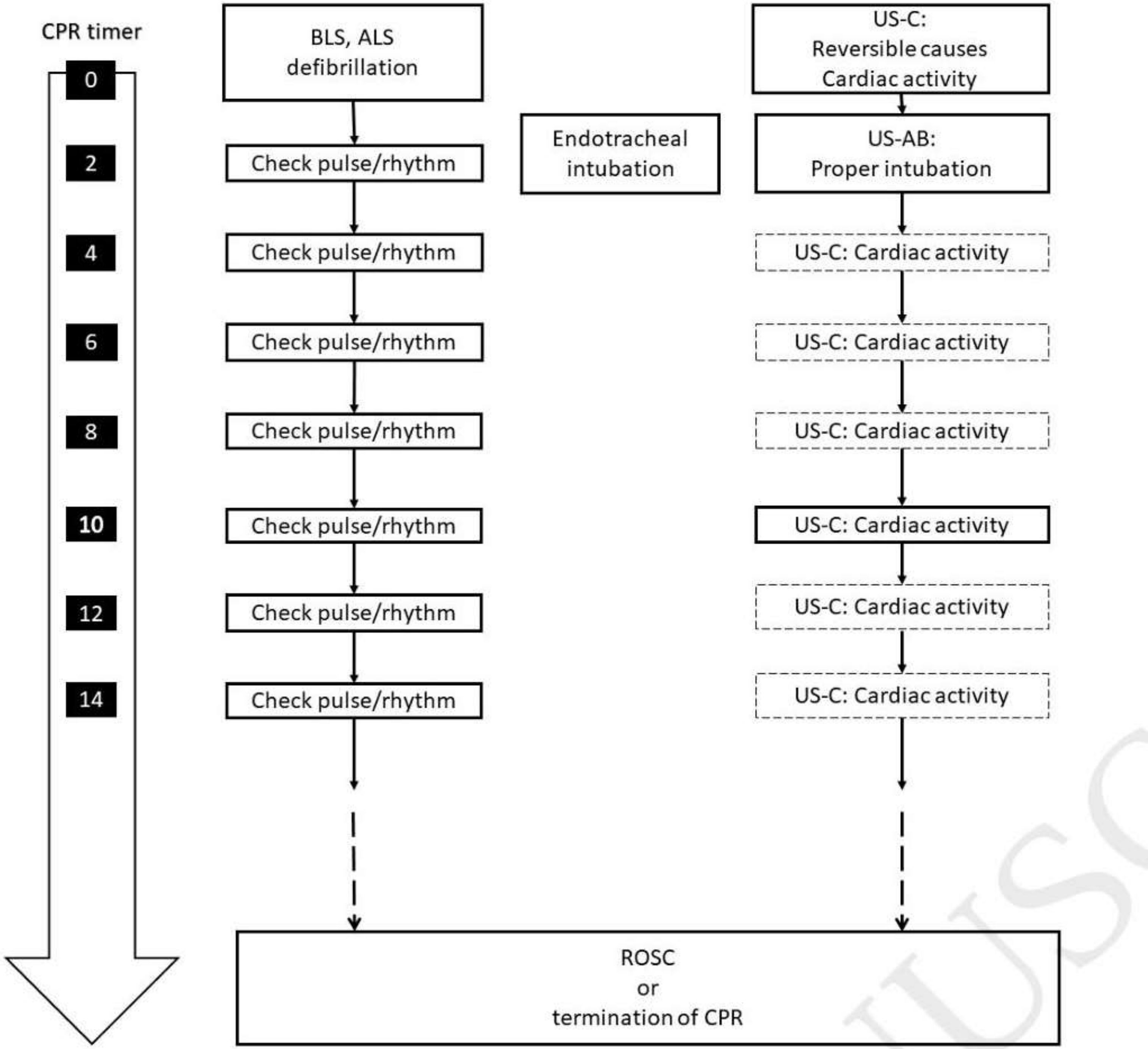
- Prospective observational study
- From Jan 2016 to March 2017
- COHORT – 177 cardiac arrest patients receiving US-CAB

- Results:

- Cardiac activity identified in 26.6% of patients with higher rates of return of spontaneous circulation (ROSC) (95.7% vs 21.5%) and survival to hospital discharge (25.5% vs 10%)
- Detection of cardiac activity after 10 minutes of CPR had 100% sensitivity, specificity, PPV and NPV

- CONCLUSION: US-CAB has diagnostic and prognostic implications in CPR

Lien et.al. j.resuscitation.2018


CPR timer
0
2
4
6
8
10
12
14
BLS, ALS defibrillation
Check pulse/rhythm
Check pulse/rhythm
Check pulse/rhythm
Check pulse/rhythm
Check pulse/rhythm
Check pulse/rhythm
Check pulse/rhythm
Endotracheal intubation
US-C: Reversible causes Cardiac activity
US-AB: Proper intubation
US-C: Cardiac activity
US-C: Cardiac activity
US-C: Cardiac activity
US-C: Cardiac activity
US-C: Cardiac activity
US-C: Cardiac activity
ROSC or termination of CPR

CONCLUSION

- Lung ultrasound is necessary bedside diagnostic modality for life threatening conditions compared to chest radiology
- Lung ultrasound has role in management of VAP, weaning difficulty
- Cardiac ultrasound has critical role in management of acute hypotension and possibly in cardiac arrest