réanimation 2023
PARIS 14-16 JUIN
Palais des Congrès de Paris
Porte Maillot

Respiratory muscles ultrasound

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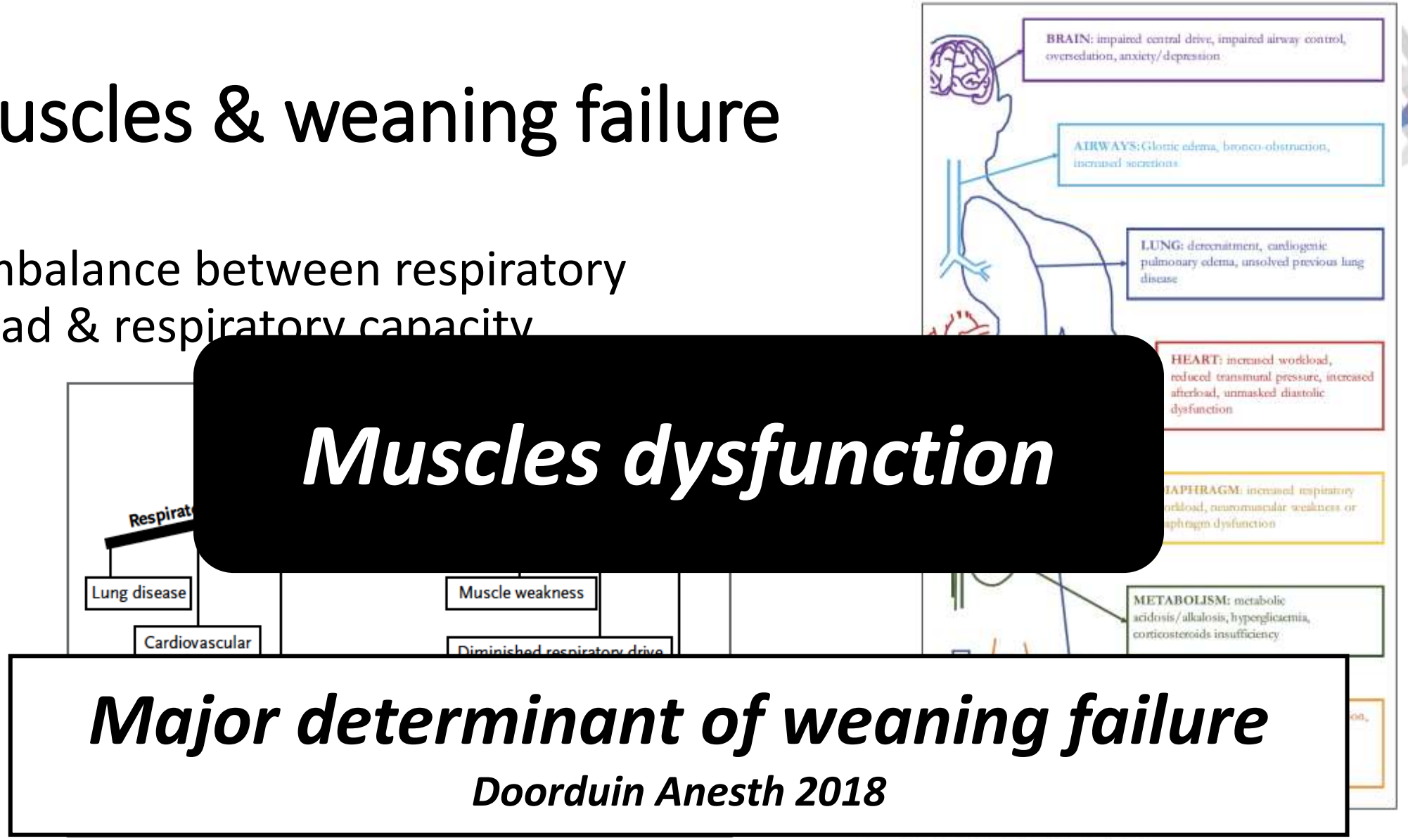
SOCIÉTÉ DE RÉANIMATION DE LANGUE FRANÇAISE

Aymeric LE NEINDRE, Hôpital Férolles-Attilly

☑ Je n’ai pas de lien d'intérêt à déclarer

Muscles & weaning failure

- Imbalance between respiratory load & respiratory capacity



Muscles dysfunction

Major determinant of weaning failure

Doorduin Anesth 2018

McConville JF et al., NEJM 2012

Santangelo E et al., Curr Opin Crit Care, 2022

Pathophysiology of muscle weakness

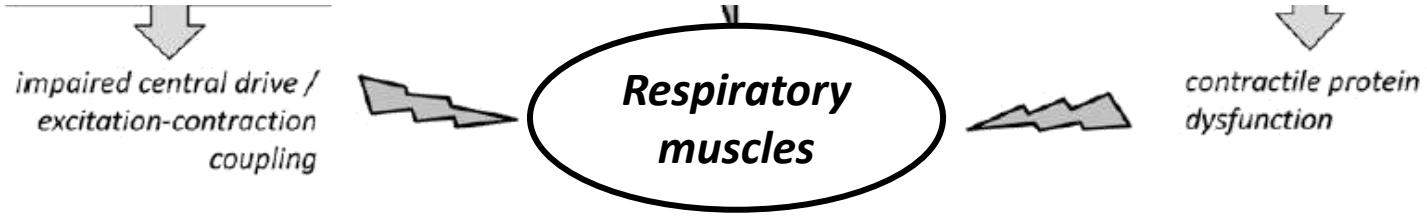
EDITORIAL

Doorduin

Bedside Ultrasound for Weaning from Mechanical Ventilation

The Diaphragm Is Not Enough!

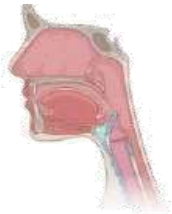
Emmanuel Vivier, M.D., Ph.D., Armand Mekontso Dessap, M.D., Ph.D.

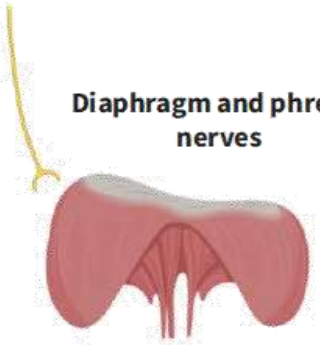


Respiratory muscles, which ones?

Shi ZH et al., Intensive Care Med 2019

Extradiaphragmatic inspiratory muscles
- scalene muscles (ventral, middle and dorsal)
- sternocleidomastoid muscles
- external parasternal intercostal muscles
- internal intercostal muscles





Diaphragm
Extradiaphragmatic muscles
Abdominal muscles

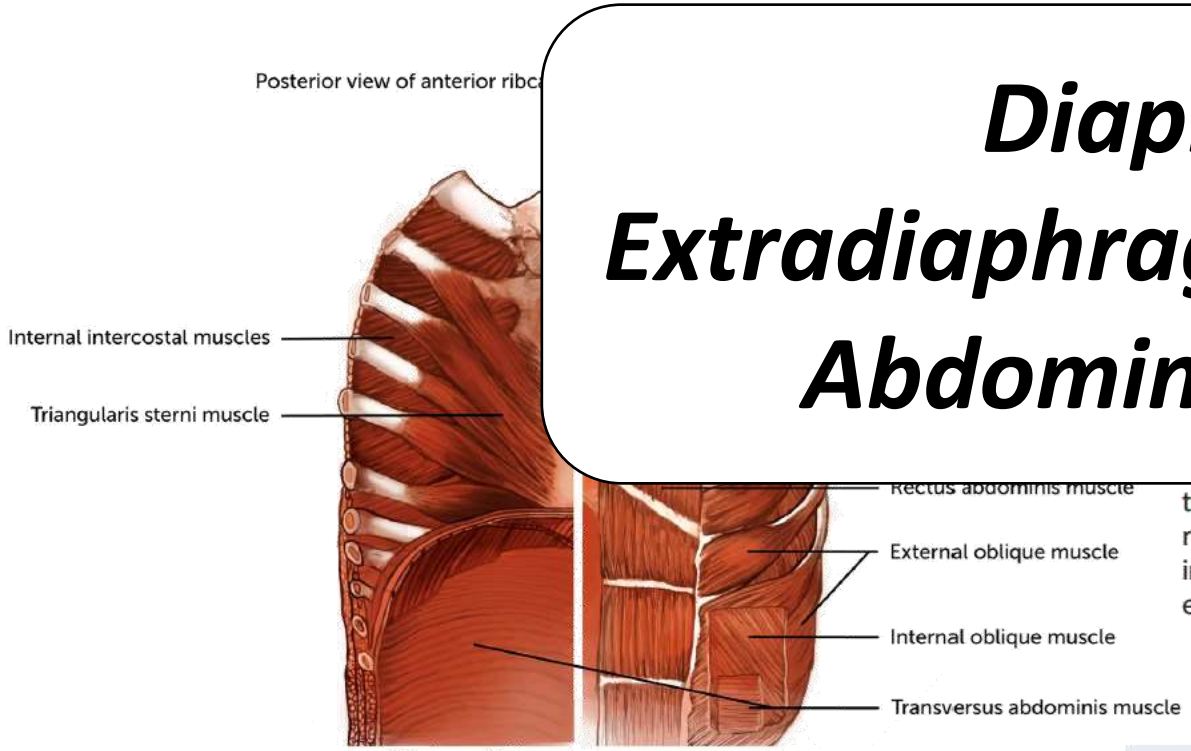
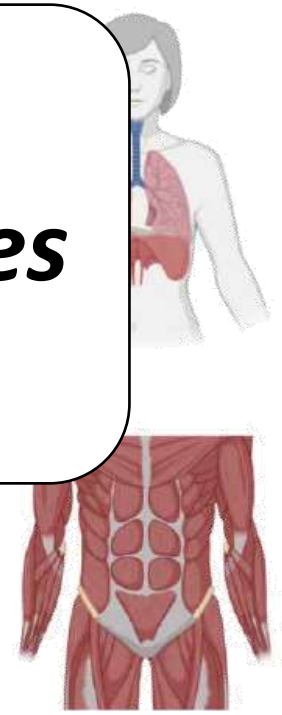


Fig. 1 The expiratory muscles of the respiratory muscle pump.



transversus abdominis
rectus abdominis
internal oblique
external oblique

FIGURE 1 The respiratory muscles involved in the generation of respiration. Figure created using BioRender.

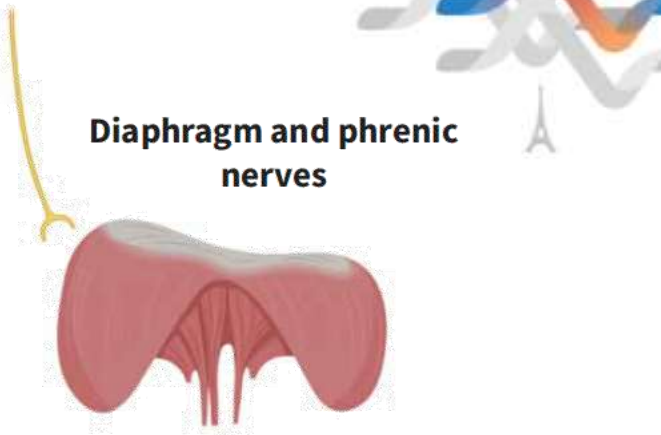
Bureau C et al., Eur Resp Rev 2023

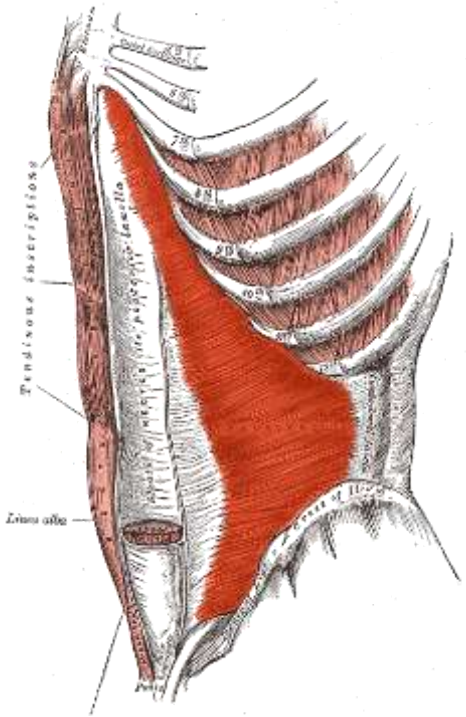
Respiratory muscles, which ones?

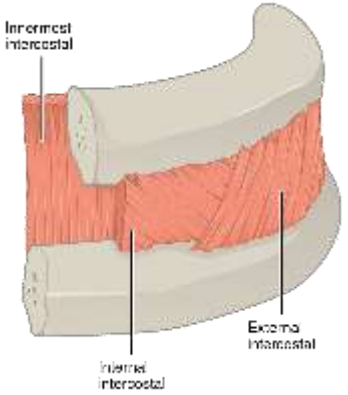
- Diaphragm

- Extra-diaphragmatic inspiratory muscles
  - Parasternal intercostal muscles

- Expiratory muscles
  - Transversus abdominis
  - Internal & external obliques
  - Rectus abdominis

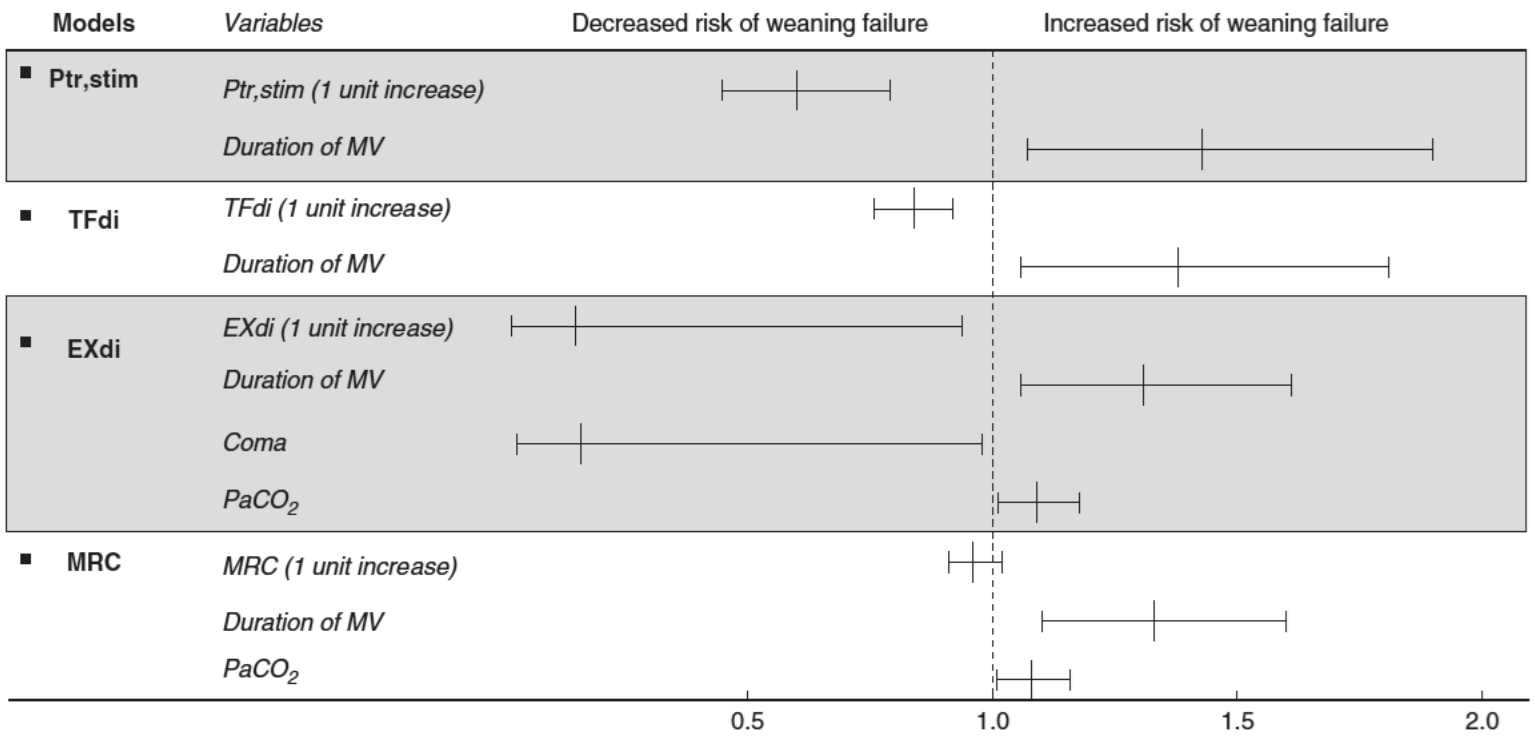


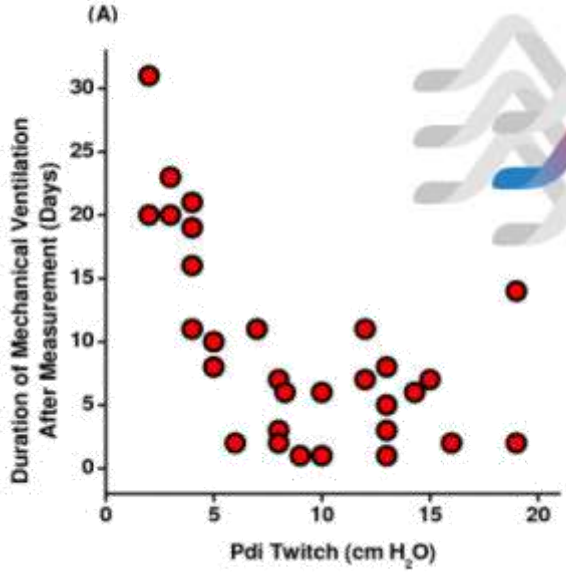


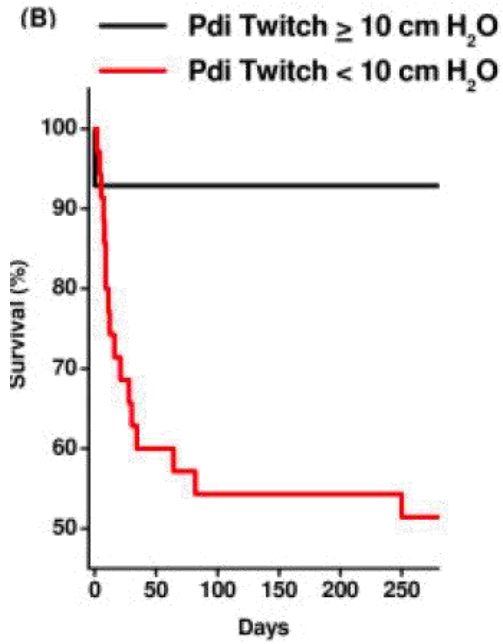


Diaphragm & weaning

Dres M et al., Am J Respir Crit Care Med 2017

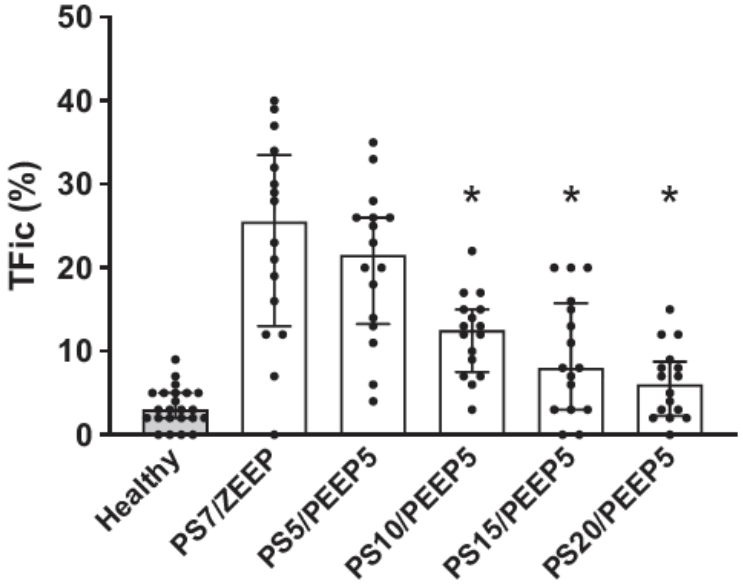


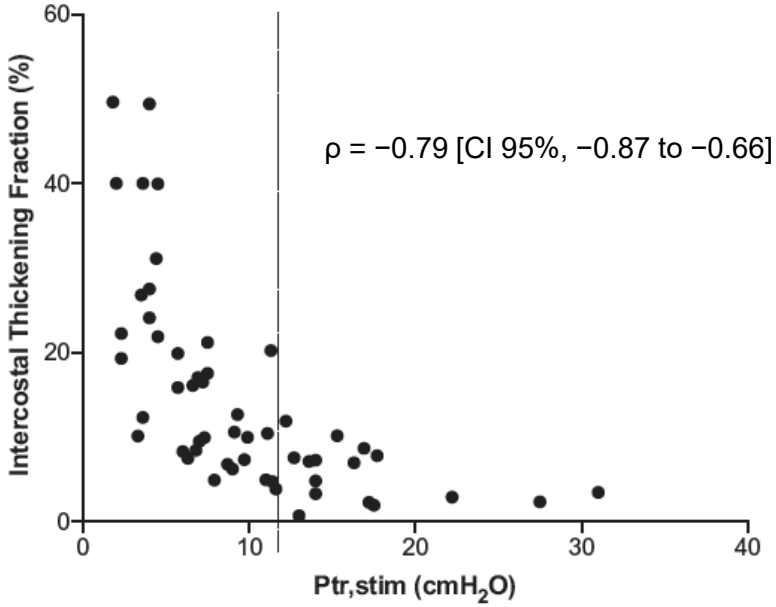




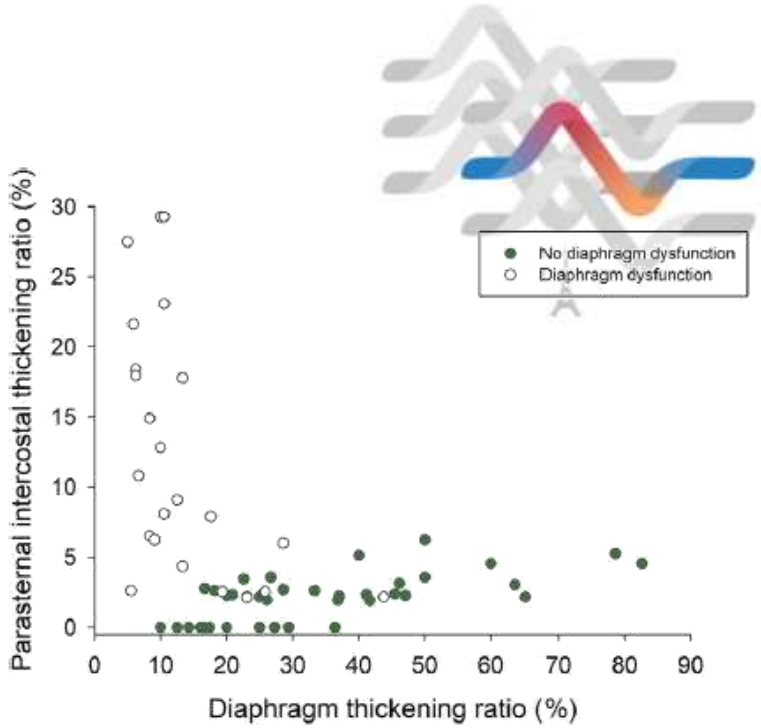
Supinski GS et al. Critical Care. 2013

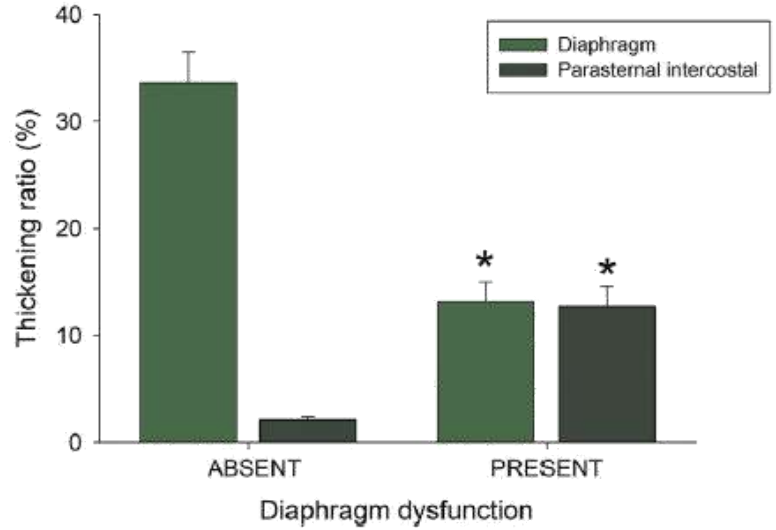
Parasternal IC muscles & weaning





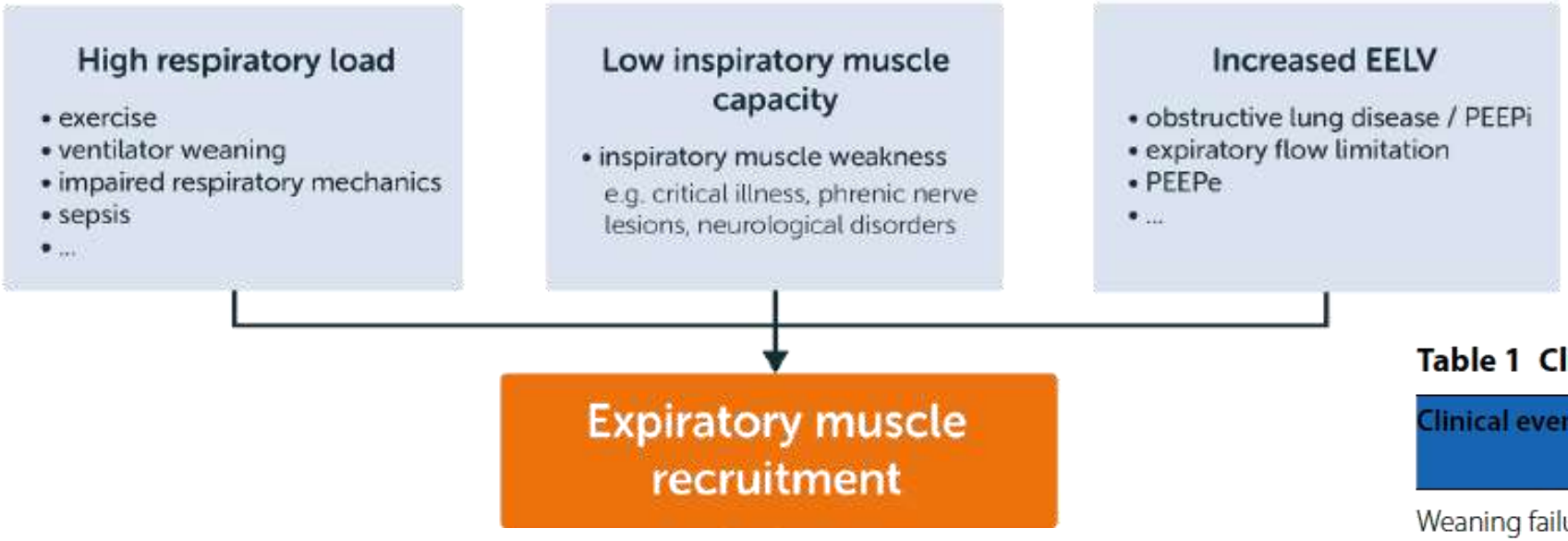
Dres M et al., Anesthesiology. 2020





Umbrello M et al., Brit J Anaesthesia.

Expiratory muscles & weaning

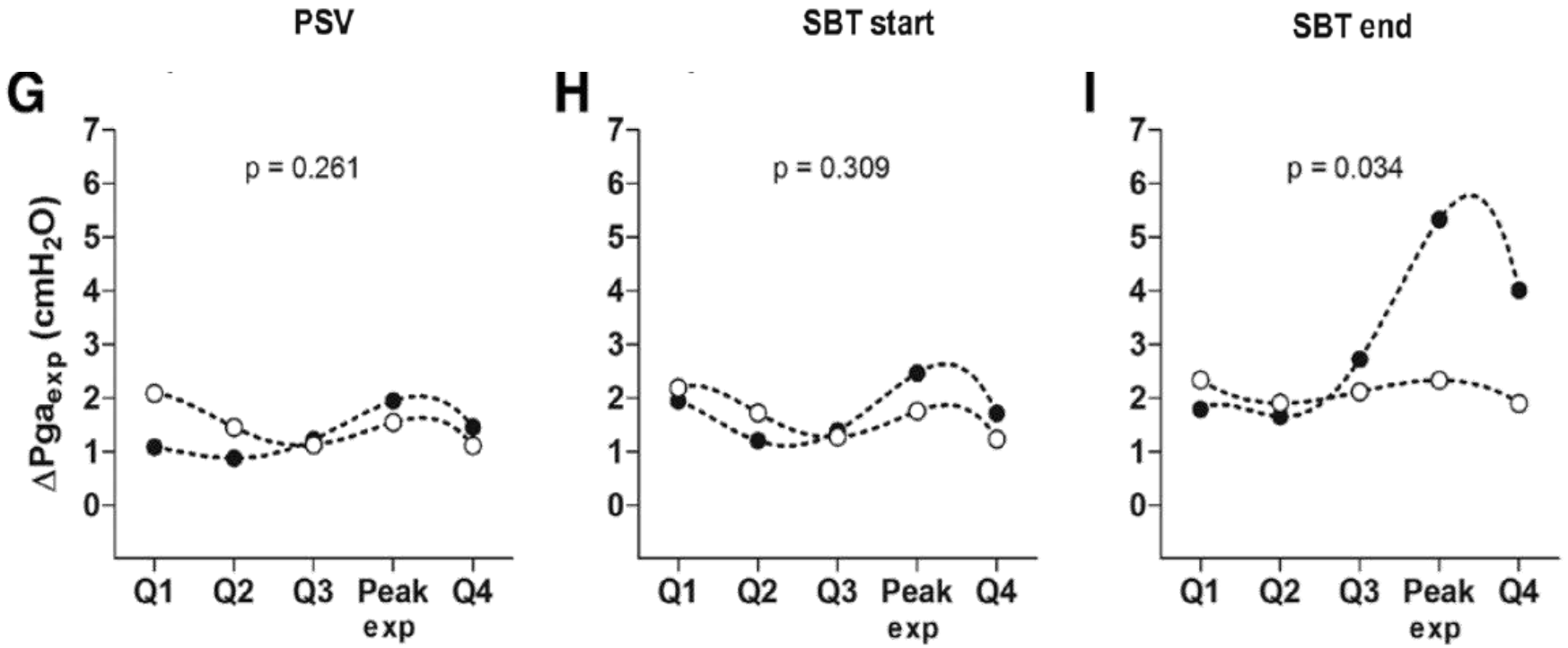


Shi ZH et al., Intensive Care Med 2019

Table 1 Clinical impact of expiratory muscle dysfunction

Clinical event	Expiratory muscles-related mechanisms
Weaning failure/extubation failure	Increased respiratory energy consumption, ineffective cough, inability to improve diaphragm efficiency
Atelectasis/pneumonia	Ineffective cough
Small airway and alveolar injury	Negative expiratory transpulmonary pressure resulting in alveolar collapse and/or airway closure
Pulmonary hyperinflation	Inability to increase expiratory flow

Expiratory muscles & weaning



Doorduin J et al., Anesth 2018

Respiratory muscles ultrasound

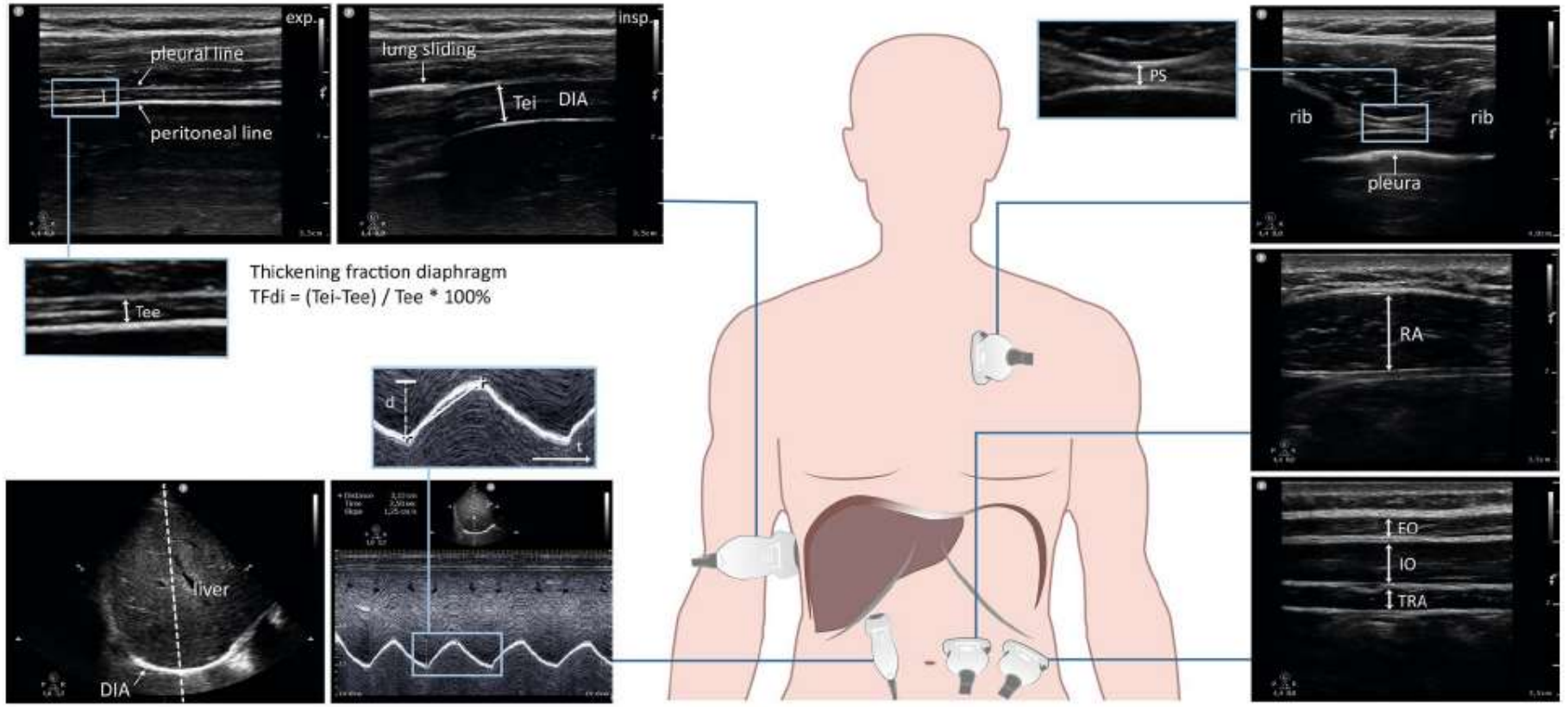


Fig. 1 Clinical application of respiratory muscle ultrasound: techniques and views

Tuinman PR et al., Intensive Care Med 2020

Parasternal intercostal muscle ultrasound

- Semi-recumbent position
- 10–15 MHz linear transducer
- Between the 2nd and the 3rd rib
- 3–5 cm laterally from the sternum, longitudinal scan
- B mode to identify the three-layered biconcave structure
- M Mode to measure the muscle thickness
  - between the two hyperechogenic layer (fascial borders)
  - at the cranio-caudal midpoint between the ribs
  - at end-expiration and end-inspiration
- Thickening fraction (TFic): calculated as the percent change in thickness between end-inspiration and end-expiration

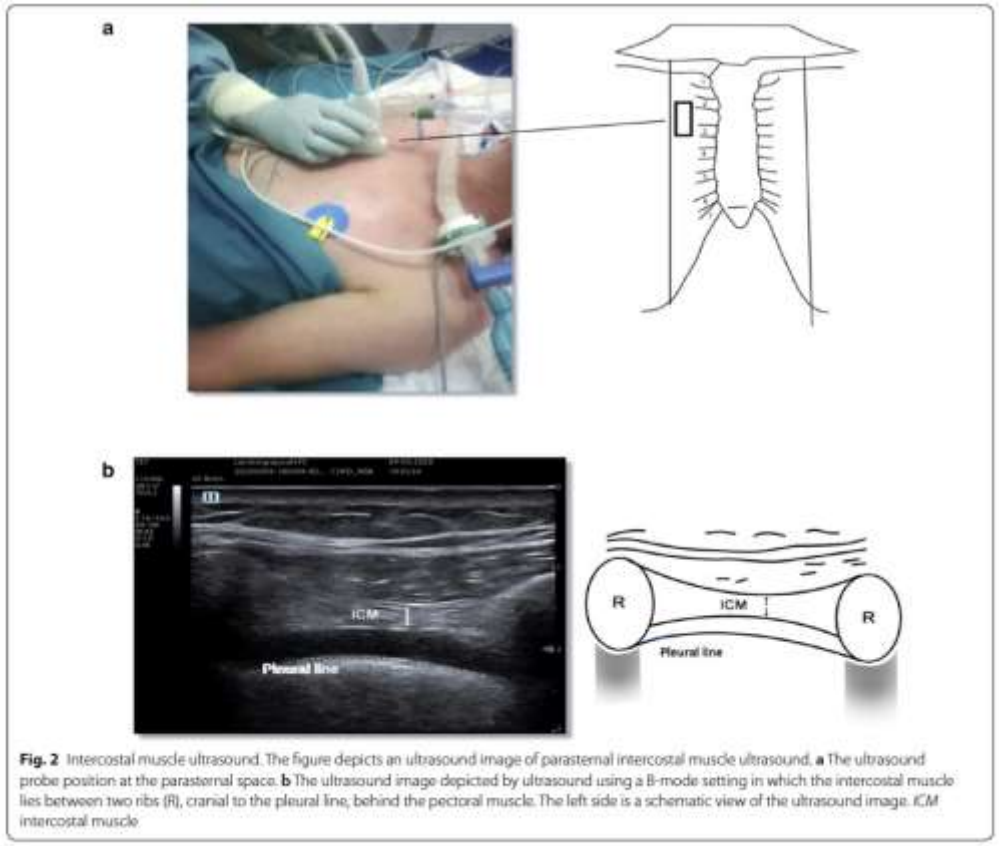


Fig. 2 Intercostal muscle ultrasound. The figure depicts an ultrasound image of parasternal intercostal muscle ultrasound. **a** The ultrasound probe position at the parasternal space. **b** The ultrasound image depicted by ultrasound using a B-mode setting in which the intercostal muscle lies between two ribs (R), cranial to the pleural line, behind the pectoral muscle. The left side is a schematic view of the ultrasound image. *ICM* intercostal muscle

Formenti P et al., Ann Intensive Care. 2020

Parasternal IC muscle ultrasound accuracy

	Threshold	AUC-ROC (95% CI)	Sensitivity, % (95% CI)	Specificity, % (95% CI)	Likelihood Ratios (95% CI)		Predictive Values, % (95% CI)	
					Positive	Negative	Positive	Negative
Ptr,stim	7.5 cm H_2O	0.91 (0.80–0.97)	91 (71–99)	81 (64–93)	4.85 (2.30–10.10)	0.11 (0.03–0.40)	77 (62–87)	93 (77–98)
Diaphragm thickening	28.7 %	0.88 (0.77–0.95)	95 (77–100)	72 (53–86)	3.39 (1.90–5.90)	0.06 (0.01–0.40)	70 (57–80)	96 (77–99)
Parasternal intercostal muscle thickening fraction	9.5 %	0.88 (0.76–0.95)	91 (71–99)	72 (53–86)	3.23 (1.80–5.70)	0.13 (0.03–0.50)	69 (56–80)	92 (75–98)
Parasternal intercostal muscle thickening fraction/Diaphragm thickening fraction	0.35	0.92 (0.81–0.98)	100 (85–100)	78 (60–91)	4.62 (2.40–8.80)	0.02 (0.01–0.20)	76 (62–86)	100 (100–100)

Dres M et al., Anesthesiology. 2020

Parasternal IC muscle ultrasound accuracy

Table ESM6. Cut-offs, area under the receiver operating characteristics curves (AUC-ROC), sensitivity, specificity, positive and negative likelihood ratios and positive and negative predictive values of Intensive Care – Respiratory distress observation scale (IC-RDOS), Medical Research Council (MRC) score and diaphragm thickening fraction (TFdi) over parasternal intercostal muscle thickening fraction (TFic) ratio to predict extubation failure.

	Cut-offs	AUC-ROC (95% CI)	Sensitivity (%) (95% CI)	Specificity (%) (95% CI)	Likelihood ratios (95% CI)		Predictive Values (%) (95% CI)	
					Positive	Negative	Positive	Negative
Respiratory rate	>22	0.65 (0.57 to 0.74)	67 (43 to 85)	63 (52 to 72)	1.8 (1.2 to 2.6)	0.5 (0.3 to 1.0)	28 (20 to 36)	90 (83 to 94)
IC-RDOS	>3.3	0.74 (0.65 to 0.82)	62 (38 to 82)	82 (73 to 89)	3.5 (2.0 to 5.9)	0.5 (0.3 to 0.8)	42 (30 to 55)	91 (86 to 95)
Dyspnea-VAS	>4.0	0.78 (0.68 to 0.86)	75 (48 to 93)	72 (61 to 82)	2.7 (1.7 to 4.2)	0.4 (0.1 to 0.8)	35 (26 to 46)	93 (86 to 97)
TFic	>8.6	0.81 (0.72 to 0.88)	79 (54 to 94)	73 (62 to 82)	2.9 (1.9 to 4.4)	0.3 (0.1 to 0.7)	39 (29 to 49)	94 (87 to 98)
TFdi	<15.6	0.73 (0.63 to 0.81)	63 (38 to 84)	74 (64 to 83)	2.5 (1.5 to 4.0)	0.5 (0.3 to 0.9)	34 (24 to 46)	90 (84 to 95)
TFic/TFdi	>0.44	0.81 (0.72 to 0.88)	74 (49 to 91)	73 (62 to 82)	2.7 (1.7 to 4.2)	0.4 (0.2 to 0.8)	37 (27 to 47)	93 (86 to 96)

IC-RDOS: intensive care – respiratory distress observation scale; D-VAS: Dyspnea Visual Analogic Scale; MRC: medical research score; TFdi: diaphragm thickening fraction; TFic: parasternal intercostal thickening fraction; CI: Confidence interval.

Dres M et al., Eur Respir J. 2021

Table 2. Clinical evaluation and respiratory muscles ultrasound indices on enrollment

	Extubation Success N= 101	Extubation Failure N=21	*p*
Respiratory muscle Ultrasound indices			
Patients with measurements	88	19	
TFdi, *%*	21 (15 – 27)	11 (9 – 19)	0.001
TFic, *%*	7 (4 – 9)	13 (9 – 22)	<0.001
TFic/TFdi	0.3 (0.2 – 0.5)	0.9 (0.4 – 3.0)	<0.001

P. intercostal muscle ultrasound accuracy

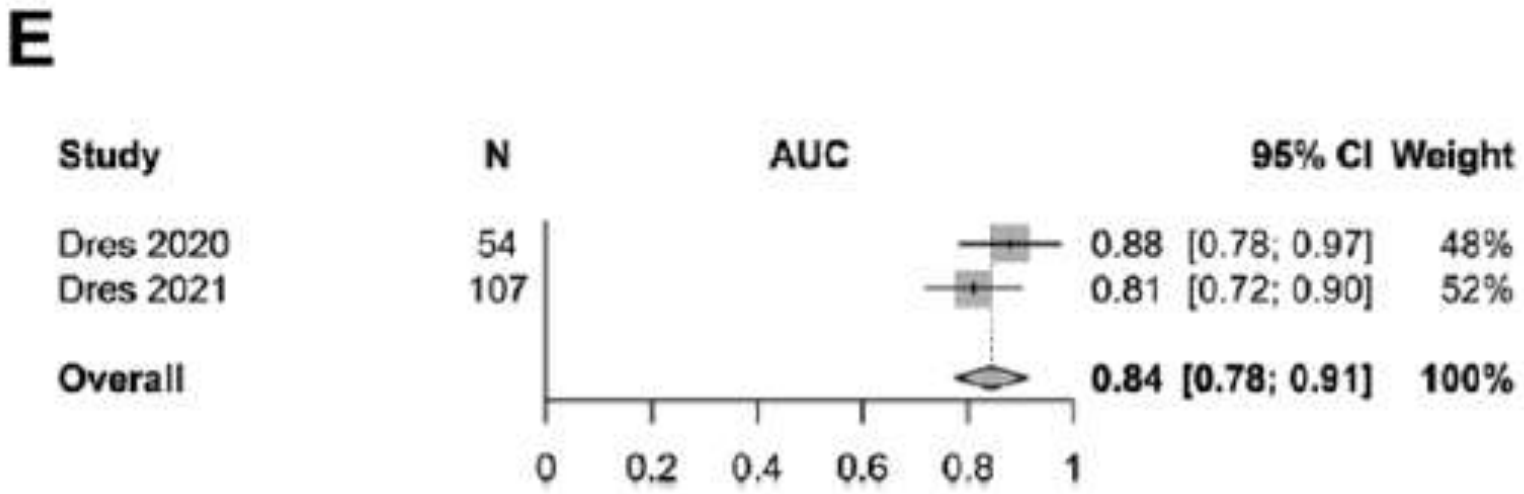
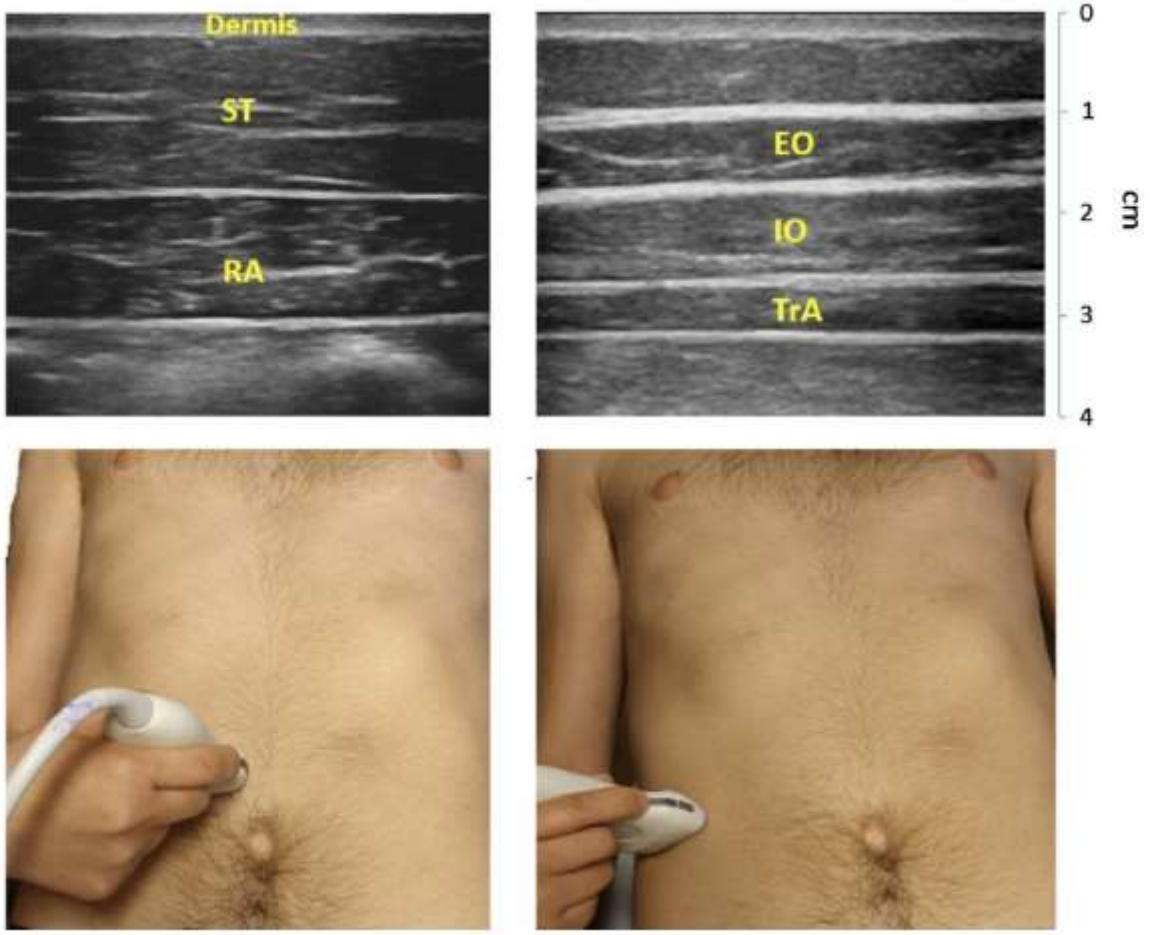
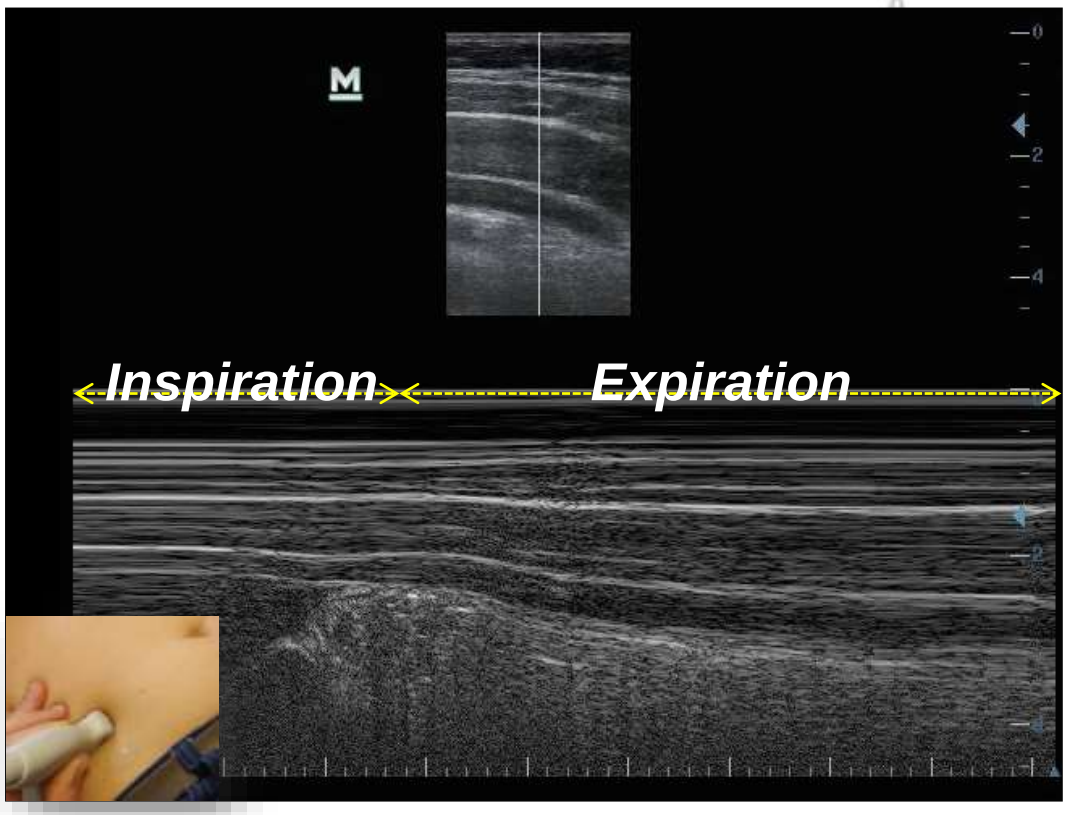


Figure 2. Meta-analysis of individual studies investigating specific ultrasound parameters of predictive ability of intercostal thickening fraction (**E**), to predict weaning outcomes within 48-72 hr postextubation.

Truong D., Crit Care Med 2023

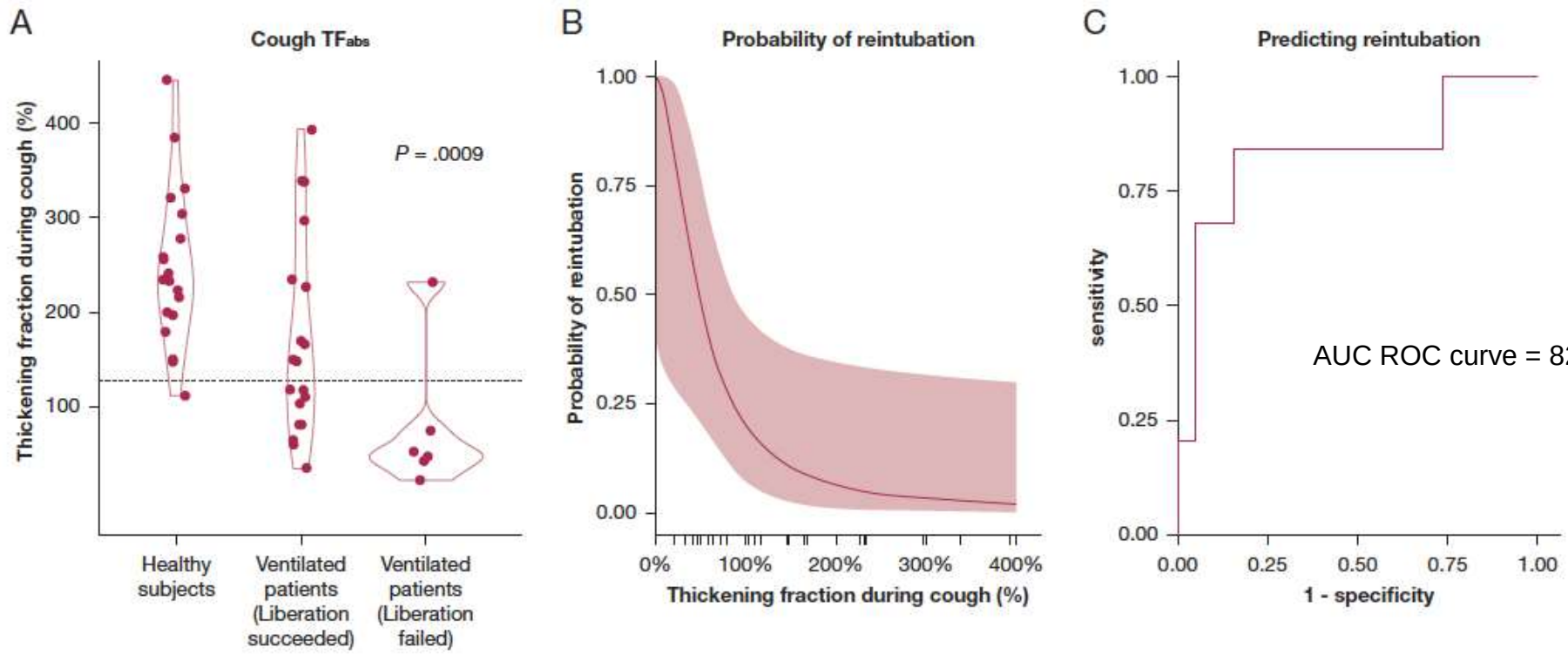
Expiratory muscles ultrasound





Shi ZH et al. Intensive Care Med 2019

Expiratory muscles ultrasound accuracy

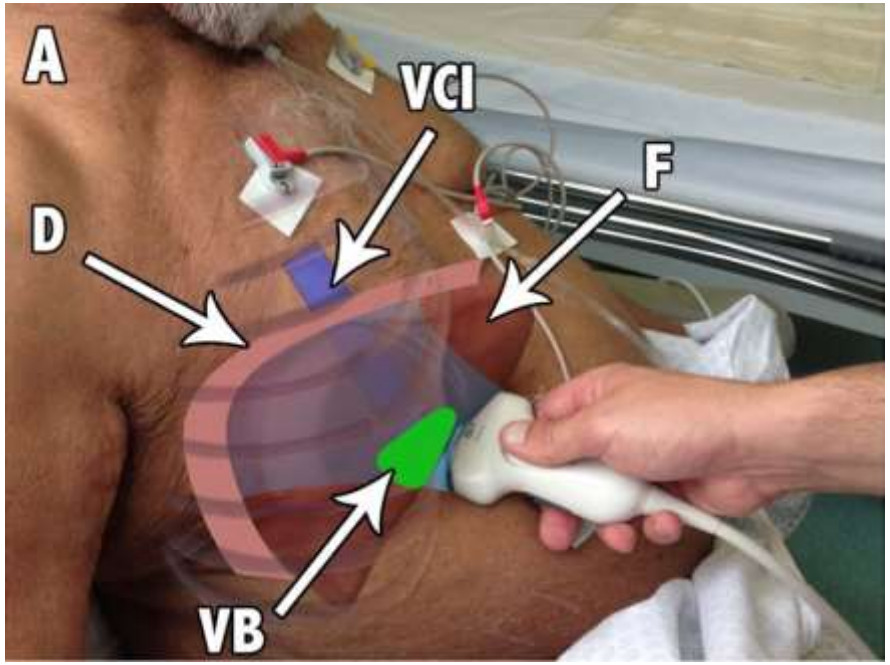


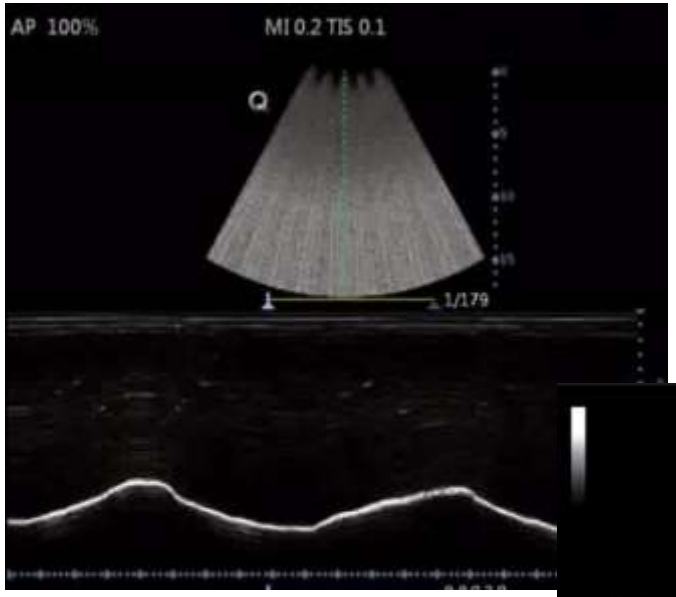
AUC ROC curve = 82% [95% CI, 59-100]

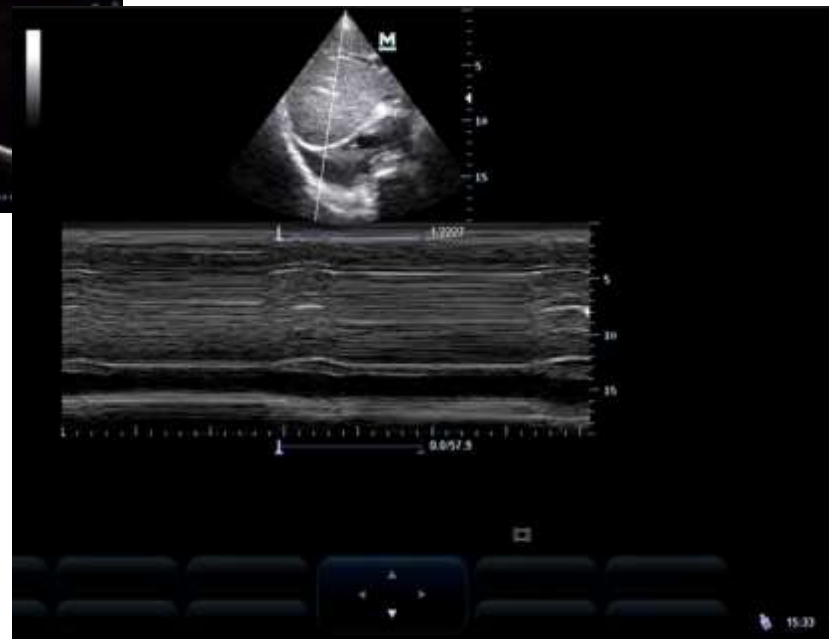
Figure 4 – *A, Combined internal oblique, transversus abdominis, and rectus abdominis TF during cough (cough TF_{abs}) in healthy subjects, patients receiving ventilation who succeeded, and patients receiving ventilation who failed liberation from mechanical ventilation within 72 h of liberation*

Schreiber AF et al. Chest. 2021

Diaphragm ultrasound - excursion







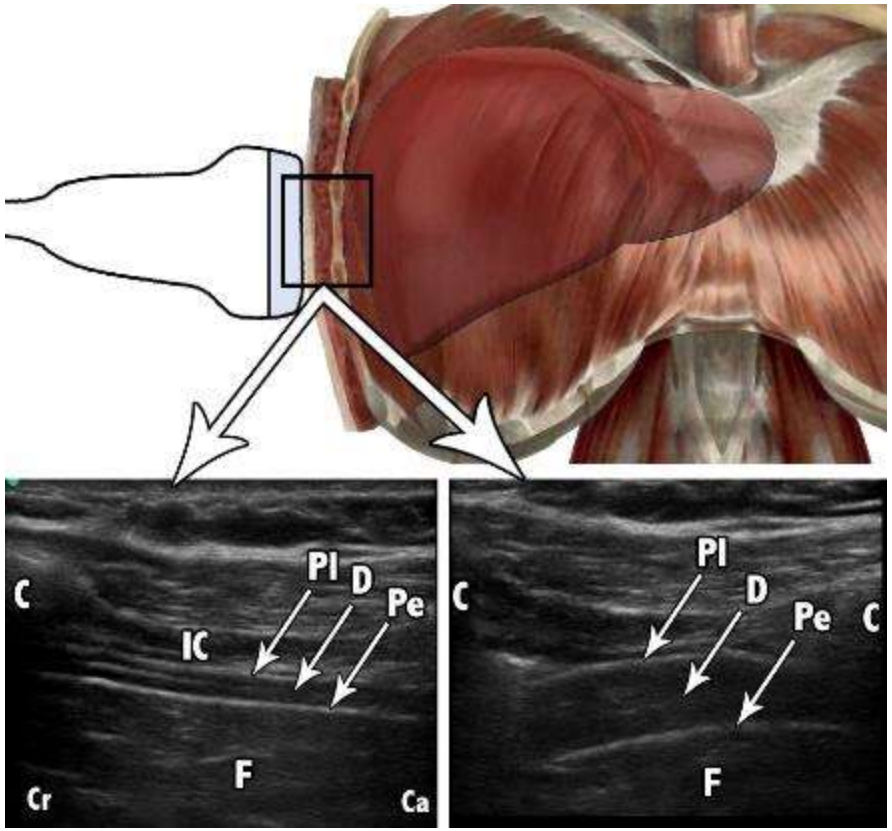
Wormser J. et al. Kinésithér Rev 2017

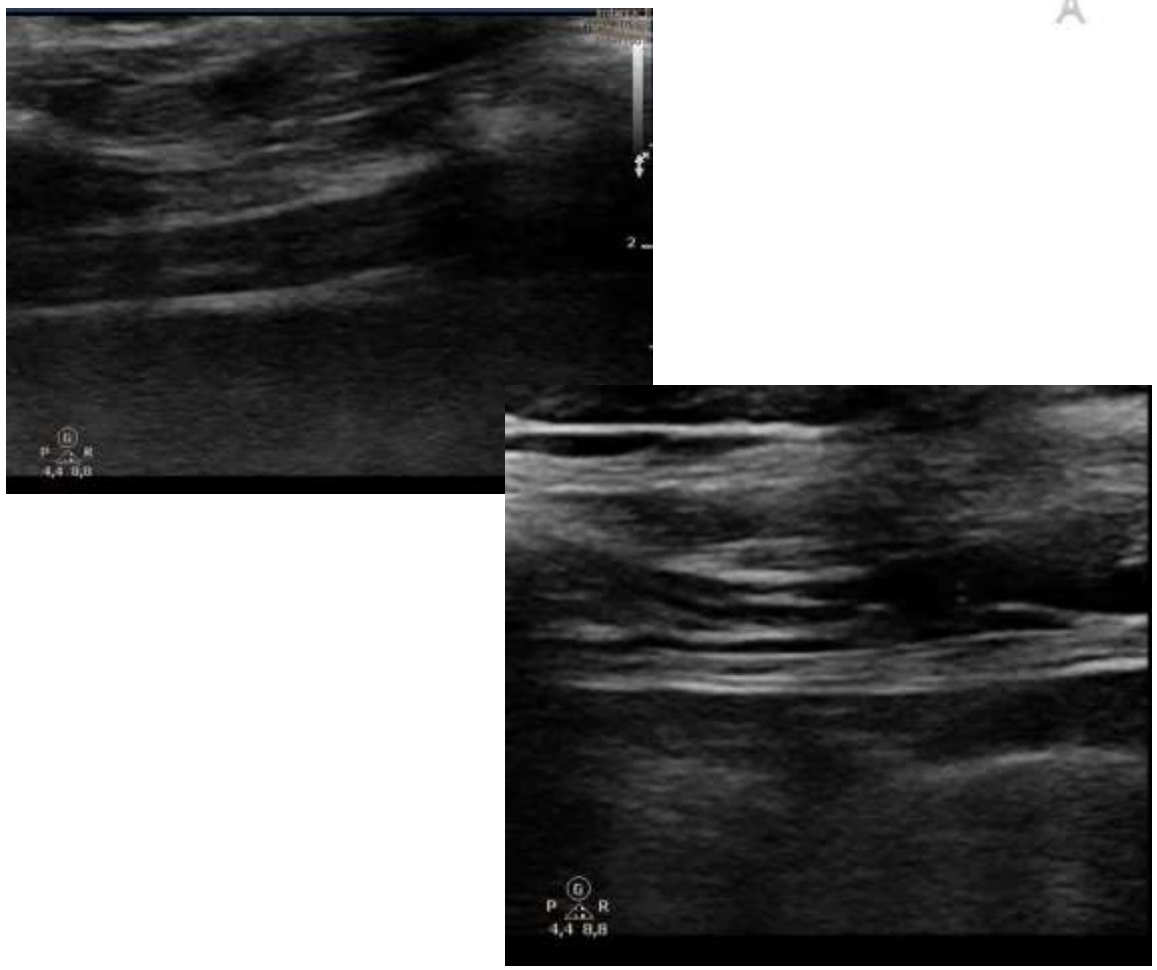
Diaphragm ultrasound - excursion

- Normal values *(Boussuges et al., 2009)* :
  - Tidal volume : 1 - 2,5 cm
  - Deep breathing : 3,6 – 9,2 cm

- Dysfonction *(Le Neindre et al., Int J Nursing Studies, 2021)* :
  - < 1 cm

Diaphragm thickening fraction





Le Neindre A. et al. Australian Crit Care 2022

Diaphragm thickening fraction

- Normal values *(Summerhill, Chest 2008)*
  - Healthy subject : 28 – 96 %

- Dysfunction *(Dubé, Thorax, 2017)*
  - < 30%
  - Well correlated with PdiTw

Diaphragm ultrasound accuracy

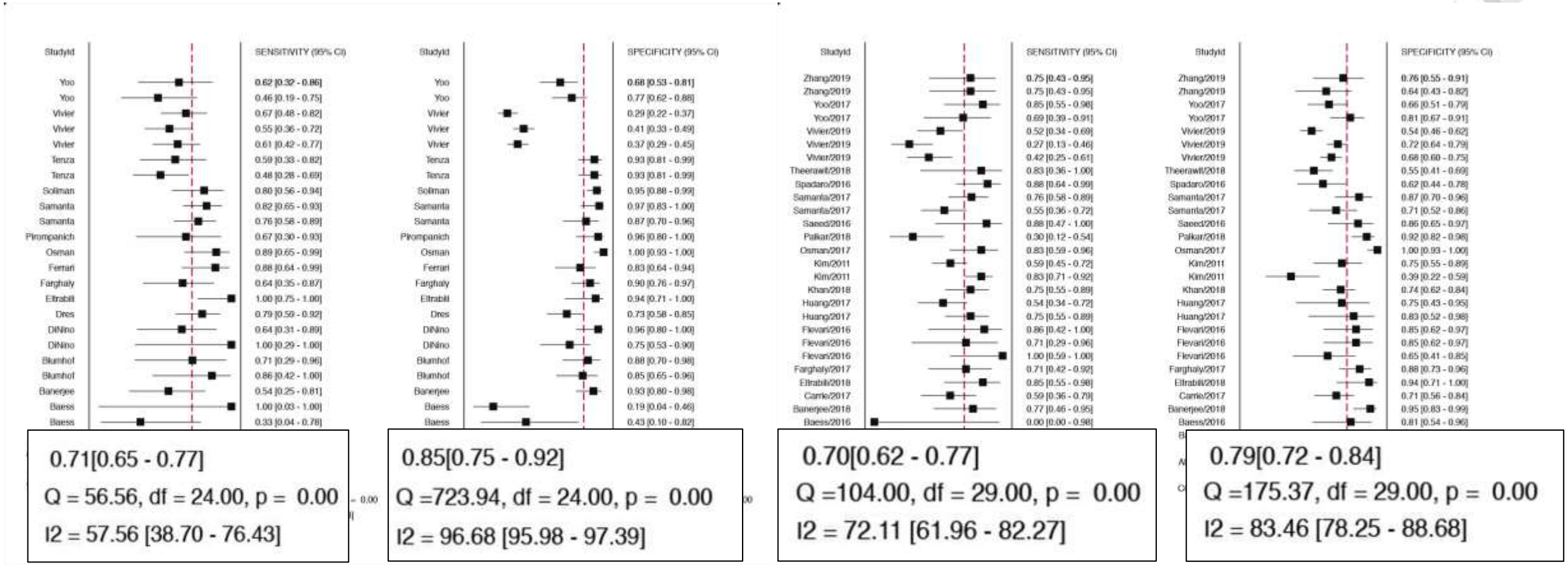


Fig. 3. Forest plot of sensitivity and specificity
(A) Forest plot of sensitivity and specificity for diaphragm thickening fraction
(B) Forest plot of sensitivity and specificity for diaphragm excursion.

Le Neindre A. et al., Int J Nursing Studies 2021

Guide to clinical practice

Mechanical Ventilation

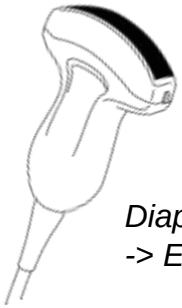
Spontaneous Breathing Trial

Tidal volume, Low PS/T-tube

SBT SUCCESS EXTUBATION

Expiratory muscles
-> thicknening at cough
-> predict reintubation

SBT FAILURE



Diaphragm, Cardiac & Lung
-> Explain failure

Inspiratory muscles
-> Otpimize PS level

LUS/Pleural & Cardiac
-> Detect high-risk patients

Expiratory muscles
-> Detect expiratory muscles « over » activation

Lung & inspiratory muscles
-> Detect DD & lung derecruitment

Santangelo E., Curr Opin Crit Care 2022

Mayo P., Intensive Care Med. 2016

Respiratory muscles within a holistic US approach

Intensive Care Med
DOI 10.1007/s00134-016-4245-3

REVIEW

Ultrasonography e
weaning process: t
pleura and the lun

P. Mayo[1*], G. Volpicelli[2], N. Lerolle[3], A. Schreiber[ ], P. Doelken[ ] and A. Vieill

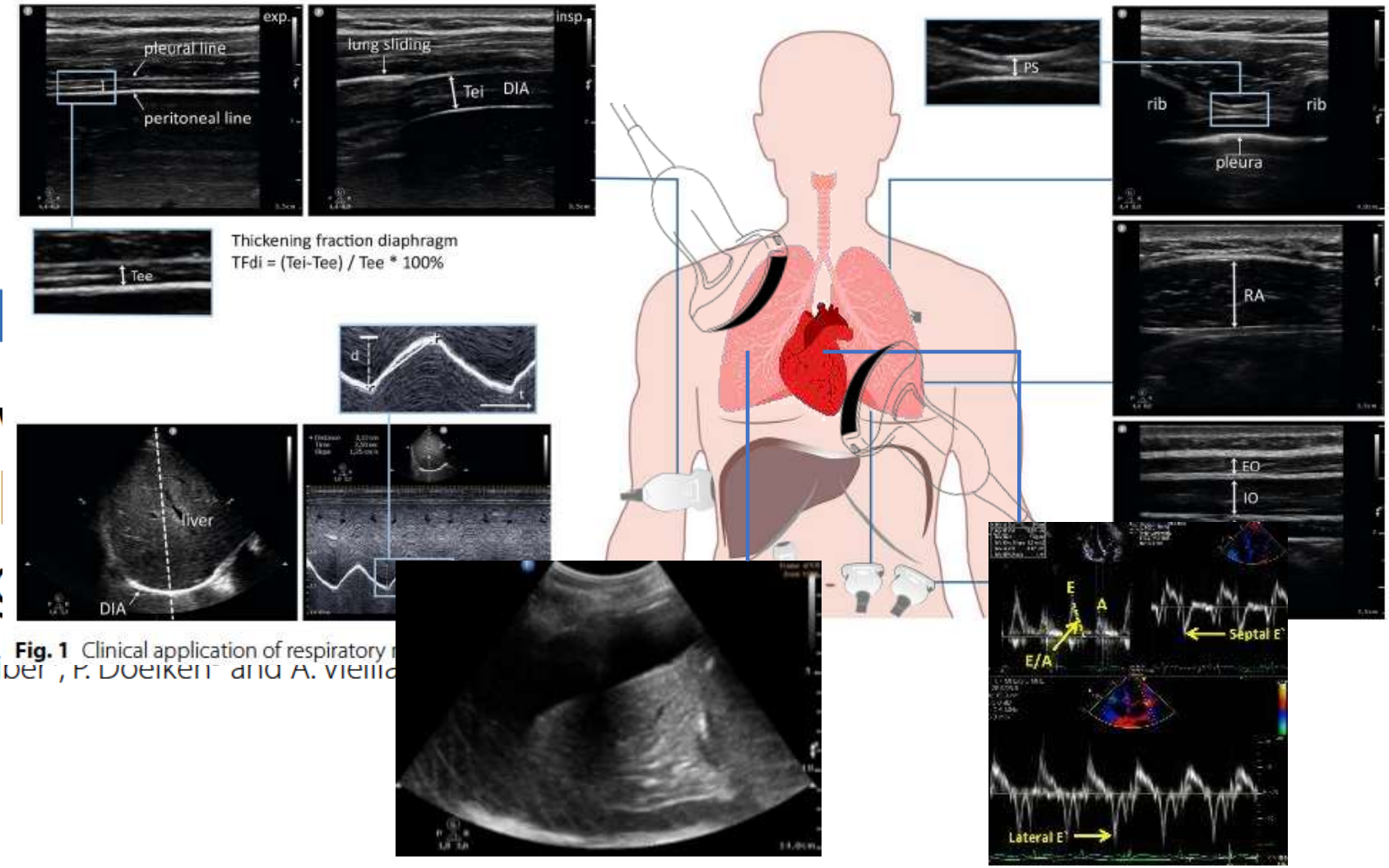


Fig. 1 Clinical application of respiratory

Thank you for your attention

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