L'ÉVALUATION EN RÉANIMATION

Fonction musculaire respiratoire

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réanimation 2025
PARIS 11-13 JUIN

Respiratory muscle dysfunction in acute and chronic respiratory failure: how to diagnose and how to treat?

Diego Poddighe [1,9], Marine Van Hollebeke [1,9], Antenor Rodrigues [2,3], Greet Hermans [4,5], Dries Testelmans [6], Alexandros Kalkanis [6], Beatrix Clerckx [4,5], Ghislaine Gayan-Ramirez [7], Rik Gosselink [1,8] and Daniel Langer [1]

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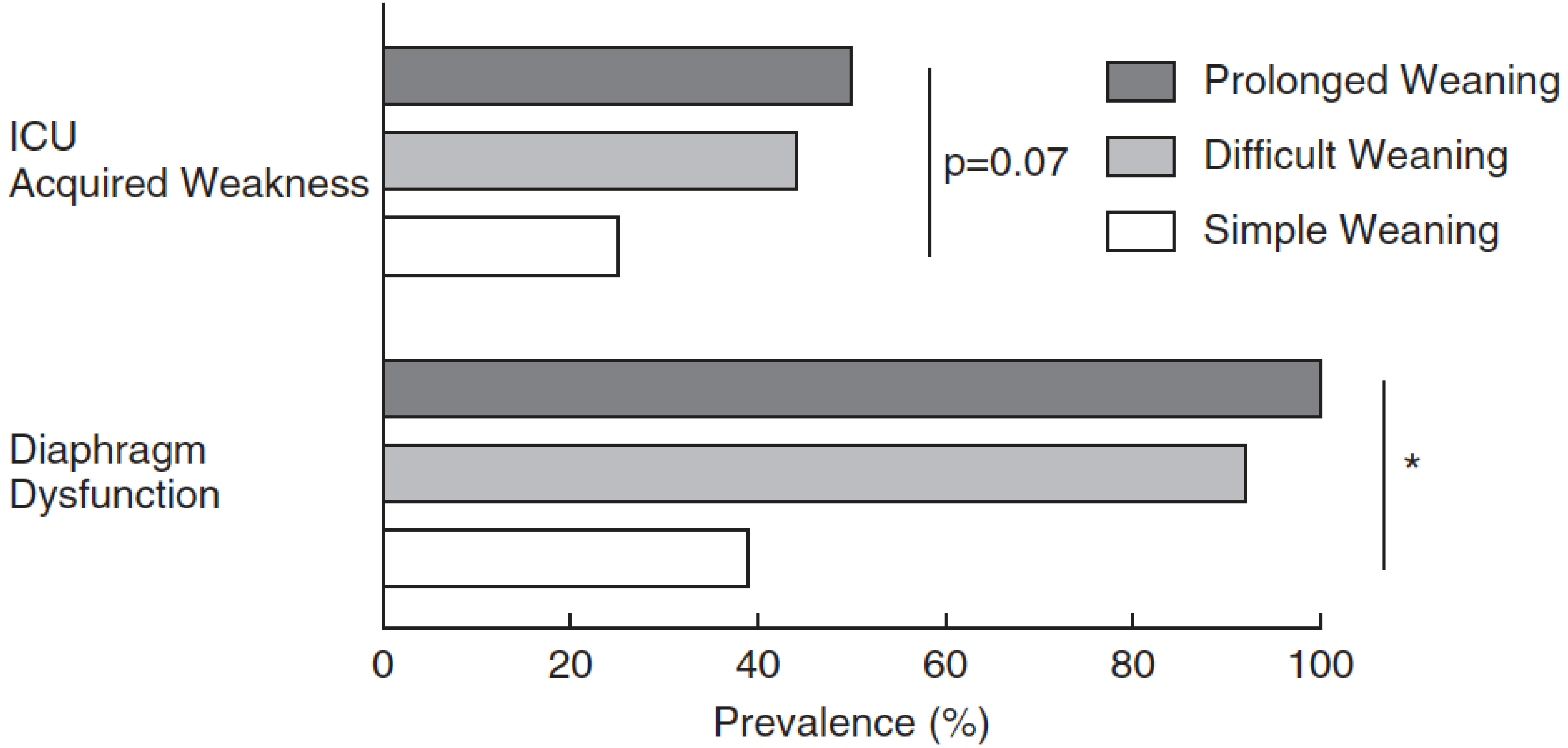
Shareable abstract (@ERSpublications)
Respiratory muscle dysfunction can be both a cause and consequence of respiratory failure. It is often reversible and should be diagnosed and treated. This review covers available assessment and treatment options in acute and chronic respiratory failure. https://bit.ly/3XZBeVa

Cite this article as: Poddighe D, Van Hollebeke M, Rodrigues A, *et al.* Respiratory muscle dysfunction in acute and chronic respiratory failure: how to diagnose and how to treat? *Eur Respir Rev* 2024; 33: 240150 [DOI: 10.1183/16000617.0150-2024].

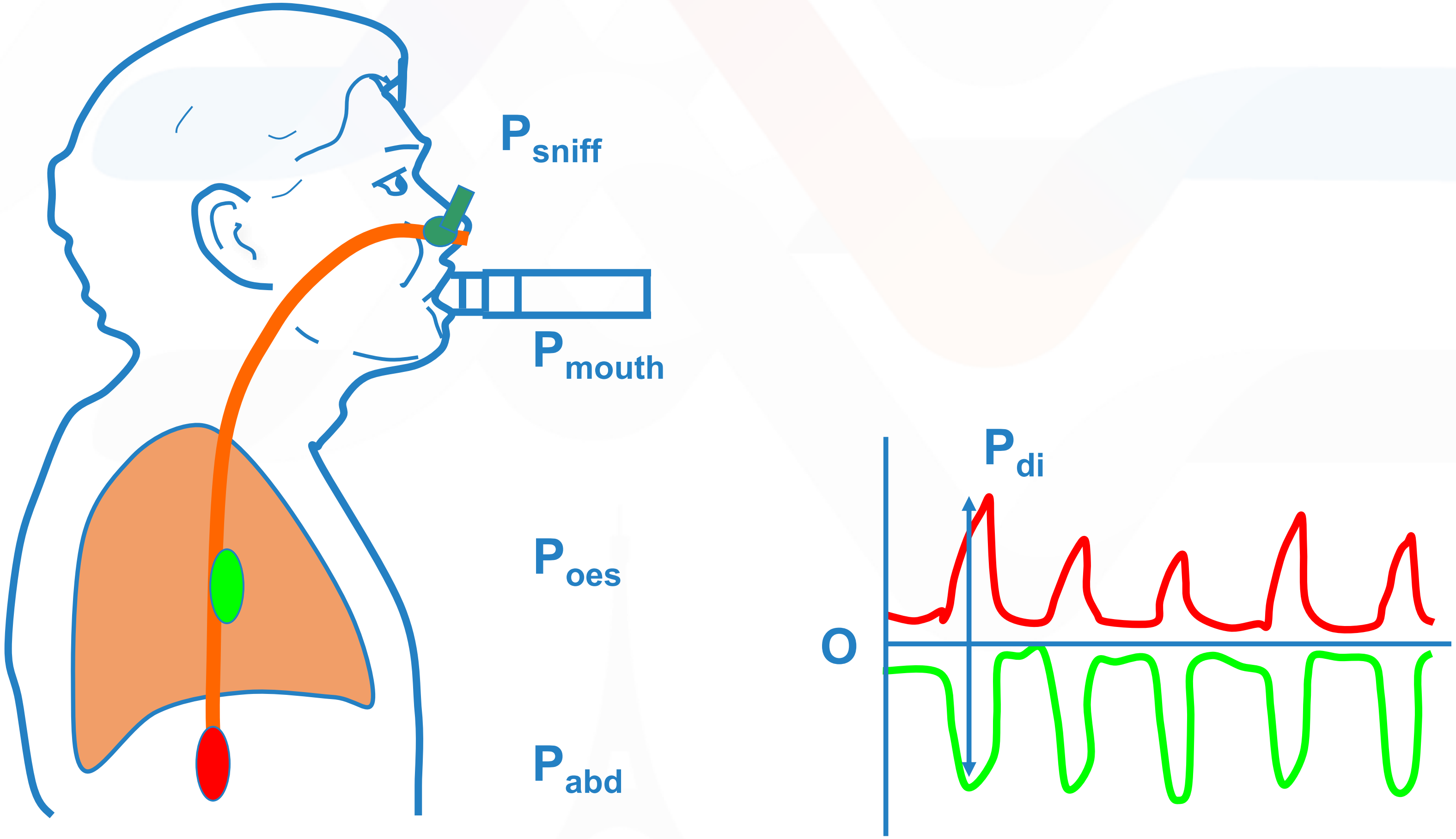
Coexistence and Impact of Limb Muscle and Diaphragm Weakness at Time of Liberation from Mechanical Ventilation in Medical Intensive Care Unit Patients

Martin Dres[1,2*], Bruno-Pierre Dubé[1,3*], Julien Mayaux[2], Julie Delemazure[2], Danielle Reuter[2], Laurent Brochard[4,5], Thomas Similowski[1,2], and Alexandre Demoule[1,2]

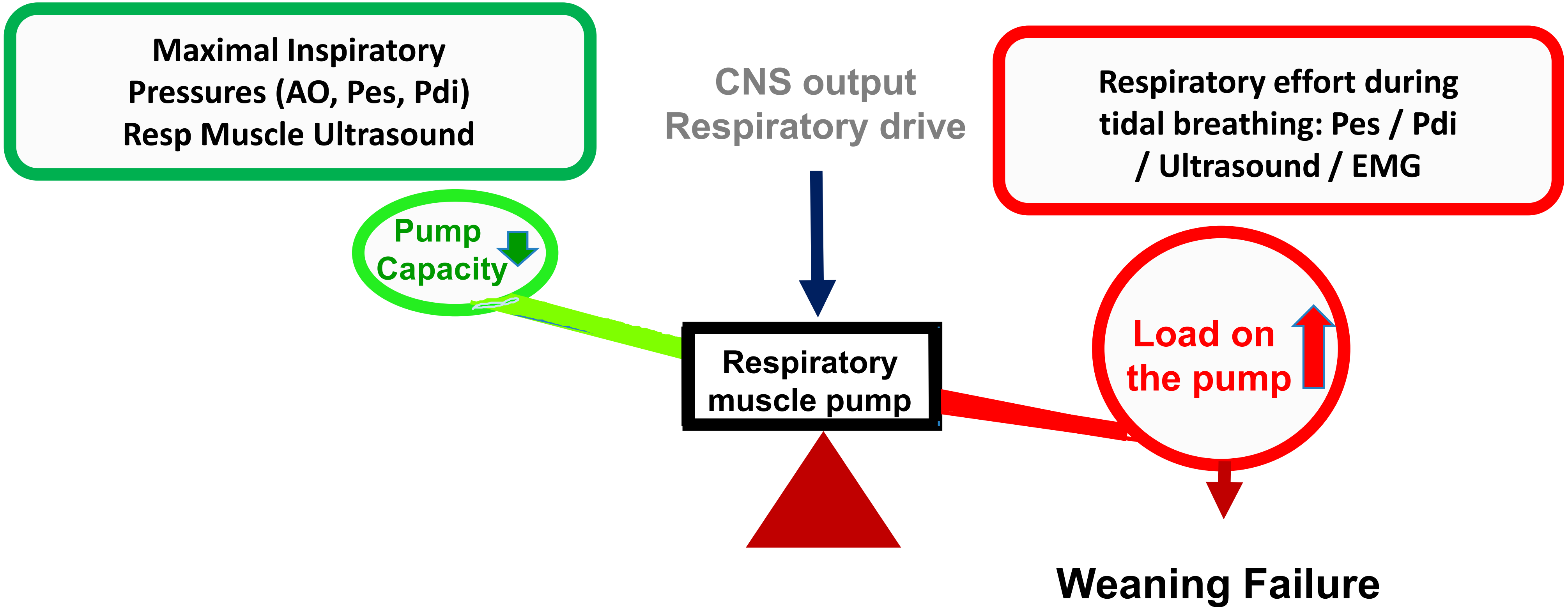


Dres et al. Am. J. Resp. Crit. Care Med. 2017

Techniques to measure respiratory muscle function



DIFFICULT WEANING



Adapted from Moxham J.

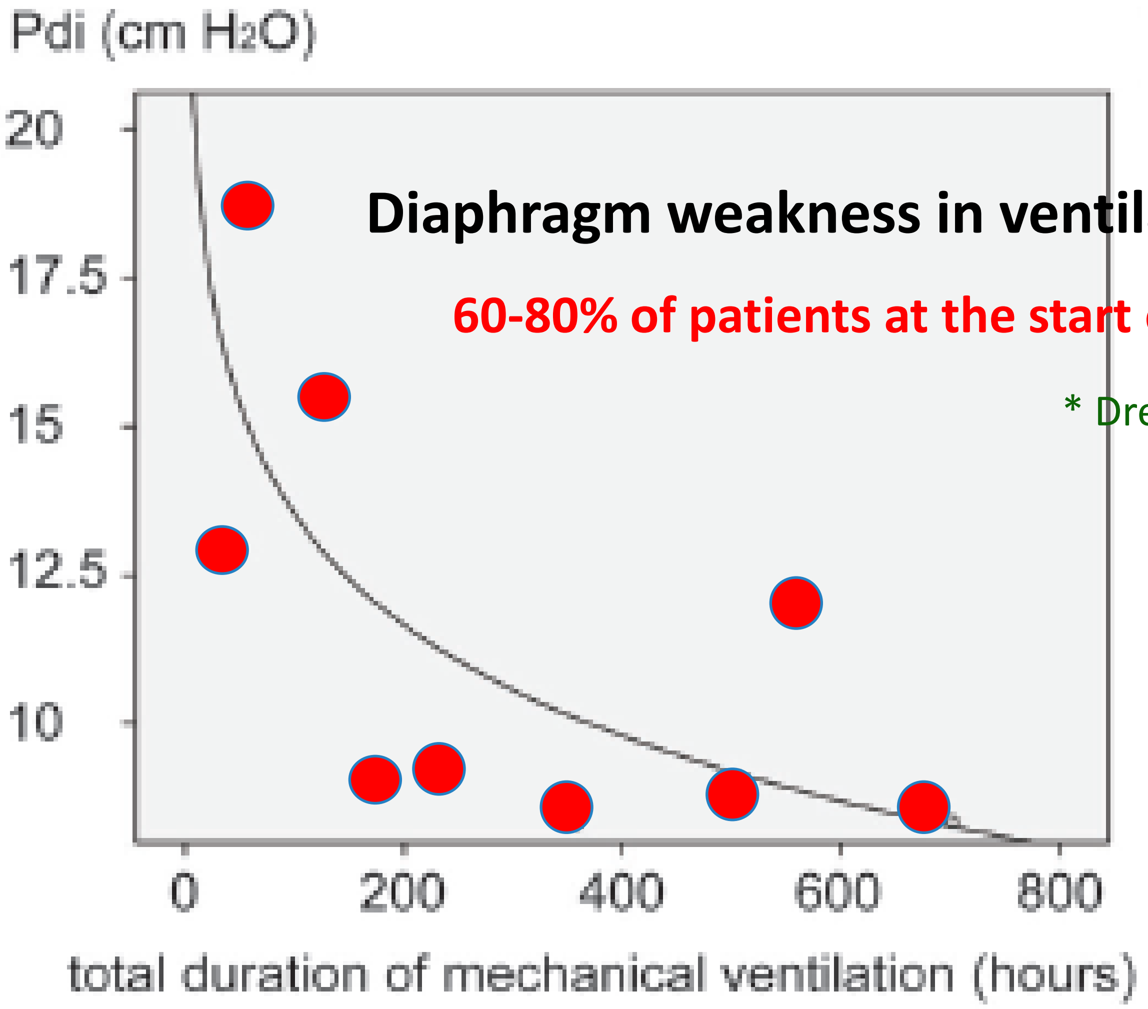
RESPIRATORY MUSCLE STRENGTH ASSESSMENT:

MAGNETIC PHRENIC NERVE STIMULATION

Polkey & Moxham.

Chest 2001; 119:926-939.

TRANSDIAPHRAGMATIC TWITCH PRESSURE IN MECHANICALLY VENTILATED PATIENTS

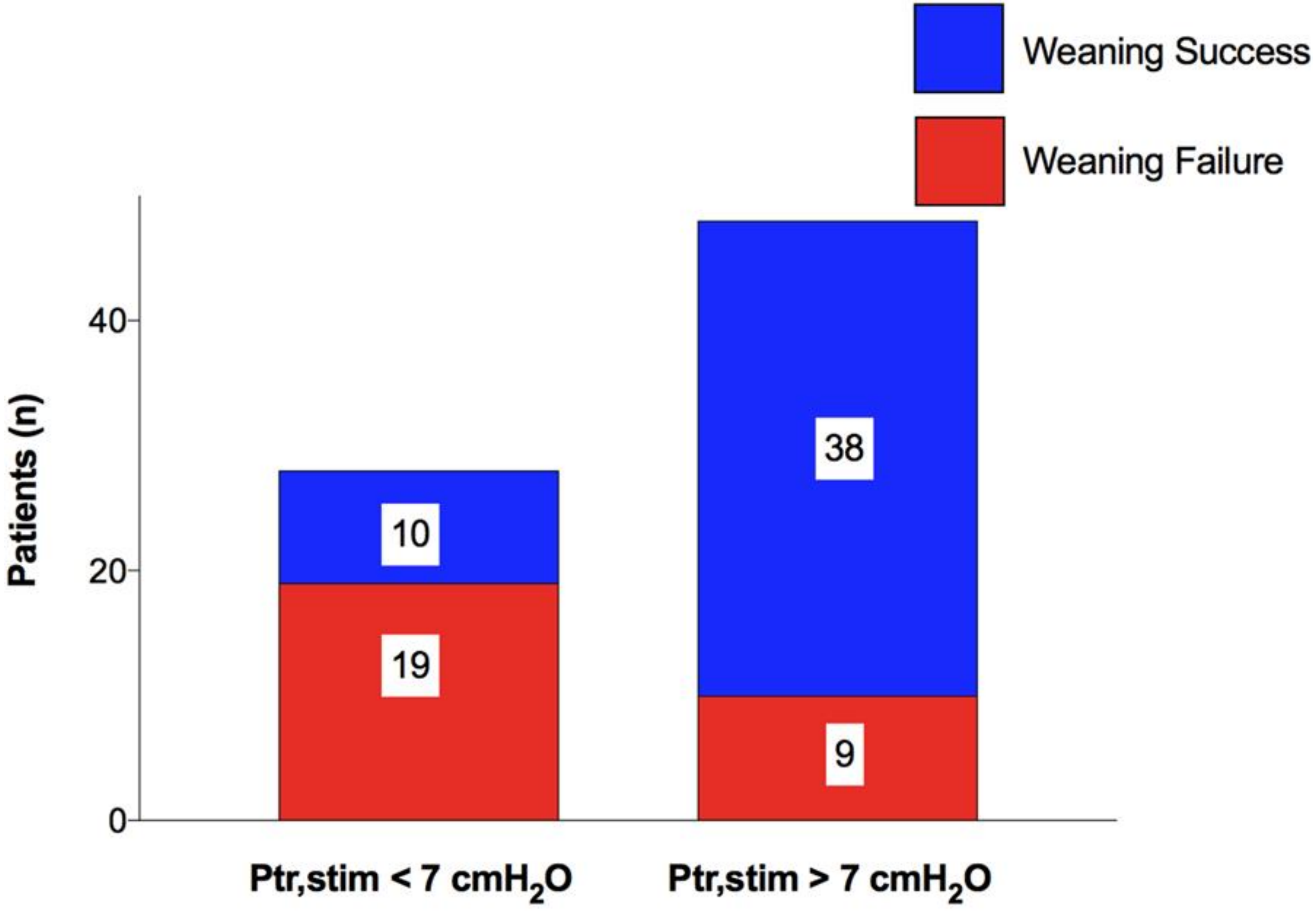


Diaphragm weakness in ventilated patients:

60-80% of patients at the start of weaning*

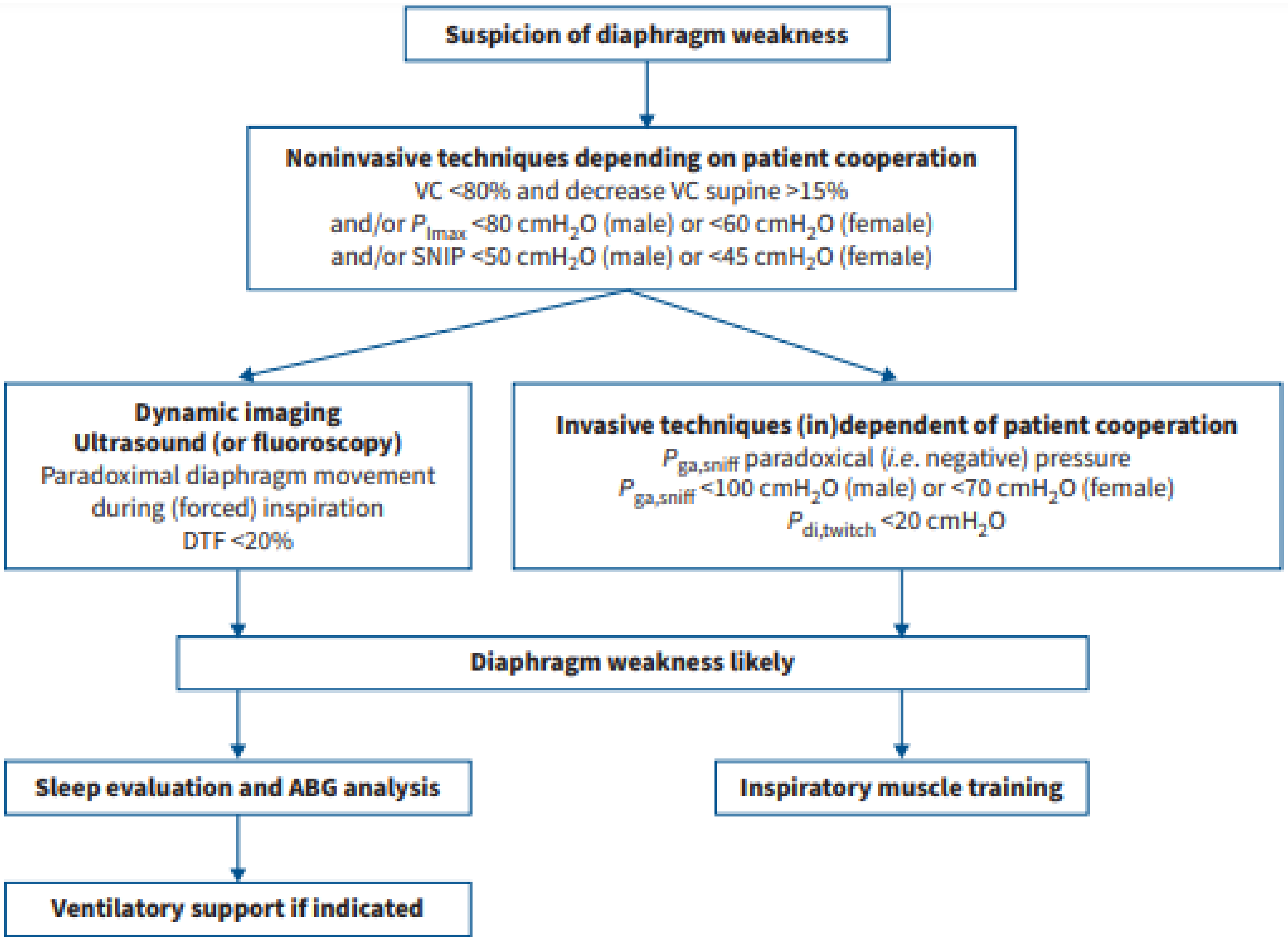
* Dres et al. AJRCCM 2017

Hermans et al. Crit. Care 2010; 14: R127

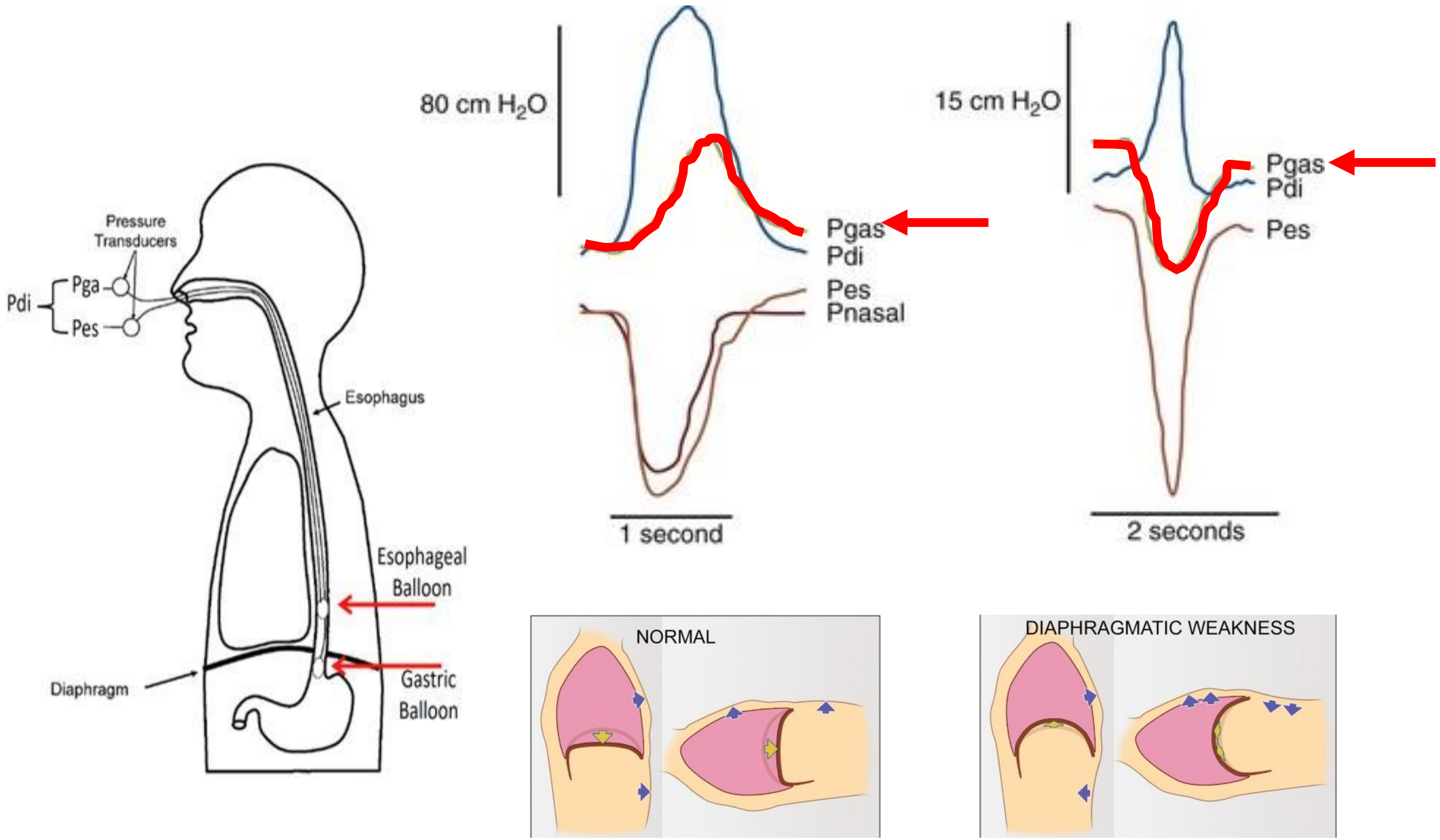


Ptr: airway (trachea) opening pressure during phrenic nerve stimulation

Dres et al. Ann. of Int. Care 2018; 8:53.



Cite this article as: Poddighe D, Van Hollebeke M, Rodrigues A, *et al*. Respiratory muscle dysfunction in acute and chronic respiratory failure: how to diagnose and how to treat? *Eur Respir Rev* 2024; 33: 240150 [DOI: 10.1183/16000617.0150-2024].



McCool et al. Disorders of the Diaphragm. Clinics in Chest Medicine 2018, 39(2):345-360

TABLE 1 Cut-off values for diagnosing weakness for each respiratory muscle test, test characteristics, practical applications and costs

Test	Cut-off values for diagnosing weakness	Respiratory muscle group assessed	Level of invasiveness and difficulty	Practical applications	Cost
P_{Imax}	M: 80 cmH_2O F: 60 cmH_2O	Diaphragm and extradiaphragmatic inspiratory muscles	Not invasive Simple	Assessment of inspiratory muscle function before and after interventions aimed at unloading or improving respiratory muscle function Determination of the external load before starting inspiratory muscle training	Low
SNIP	M: 50 cmH_2O F: 45 cmH_2O	Diaphragm and extradiaphragmatic inspiratory muscles	Not invasive Simple	Assessment of inspiratory muscle function before and after interventions aimed at unloading or improving respiratory muscle function in patients unable to perform P_{Imax} manoeuvre reliably	Low
P_{Emax}	M: 110 cmH_2O F: 80 cmH_2O	Expiratory muscles	Not invasive Simple	Assessment of expiratory muscle function before and after interventions aimed at unloading or improving respiratory muscle function	Low
PCF	M and F: 270 $L{\cdot}min^{-1}$	Expiratory muscles	Not invasive Simple	Estimation of airway clearance effectiveness in patients with NMDs Estimation of expiratory muscle function in patients with NMDs	Low
DTF	M and F: 20%	Diaphragm	Not invasive Medium	Evaluation of diaphragmatic function in the intensive care unit Confirmation or refinement of the diagnosis of (hemi-) diaphragmatic dysfunction Prediction of weaning outcomes in mechanically ventilated patients	Medium
$P_{es,sniff}$	M: 55 cmH_2O F: 50 cmH_2O	Diaphragm and extradiaphragmatic inspiratory muscles	Invasive Simple	Confirmation or refinement of the diagnosis of respiratory muscle weakness when noninvasive assessments provide equivocal results	Medium
$P_{di,sniff}$	M: 100 cmH_2O F: 70 cmH_2O	Diaphragm and extradiaphragmatic inspiratory muscles	Invasive Simple	Confirmation or refinement of the diagnosis of respiratory muscle weakness when non-invasive assessments provide equivocal results P_{ga}/P_{es} ratio can provide information about diaphragm function	Medium
$P_{di,twitch}$	M and F: 20 cmH_2O	Diaphragm	Invasive Complex	Confirmation or refinement of the diagnosis of diaphragmatic weakness Prediction of prolonged mechanical ventilation and mortality in the intensive care unit	High

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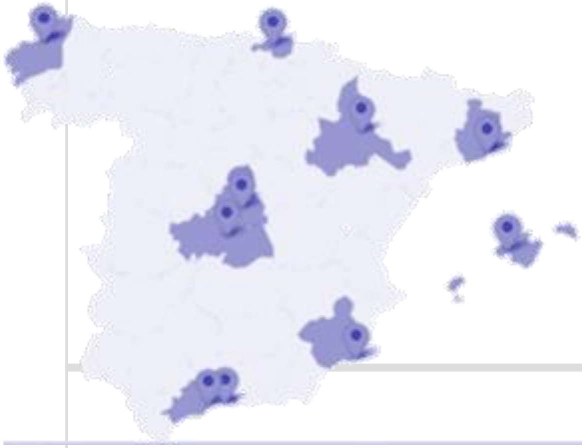
Sociedad Española de Neumología y Cirugía Torácica SEPAR

Archivos de Bronconeumología
Available online 29 September 2023
In Press, Journal Pre-proof What's this?

Maximal respiratory pressure reference equations in healthy adults and cut-off points for defining respiratory muscle weakness

Ana Lista-Paz PhD MSc PT [a 1], Daniel Langer PhD MSc PT [b c 2], Margarita Barral-Fernández MSc PT [a 3], Alejandro Quintela-del-Río PhD [d], Elena Gimeno-Santos PT MSc PhD [e f g 4], Ane Arbillaga-Etxarri PhD MSc PT [h 5], Rodrigo Torres-Castro MSc PT [i j 6], Jordi Vilaró Casamitjana PhD PT [k 7], Ana B. Varas de la Fuente PhD MSc PT [l], Cristina Serrano Veguillas MSc PT [l 8], Pilar Bravo Cortés MSc PT [m 9], Concepción Martín Cortijo PT [n ñ 10], Esther García Delgado MSc PT [n ñ], Beatriz Herrero-Cortina PhD MSc PT [o p 11], José Luis Valera RN [q], Guilherme A F Fregonezi PhD MSc PT [r], Carolina González Montañez MSc PT [s t 12], Rocío Martín-Valero PhD MSc PT [u 13], Marina Francín-Gallego MSc PT [p 14], Yolanda Sanesteban Hermida MSc PT [v a 14a] ...
Luz González-Doniz PhD MSc PT [a 18 #]



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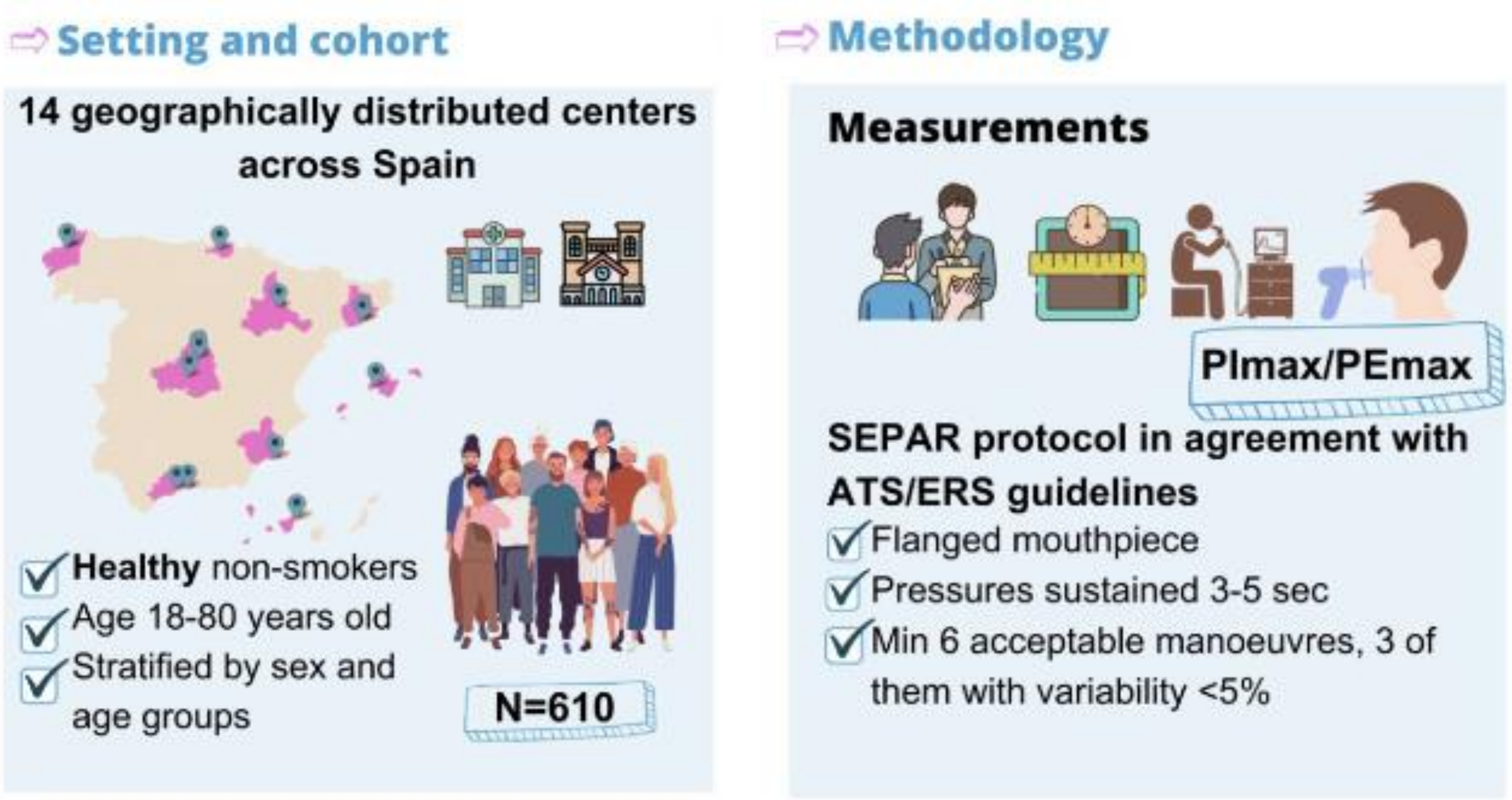
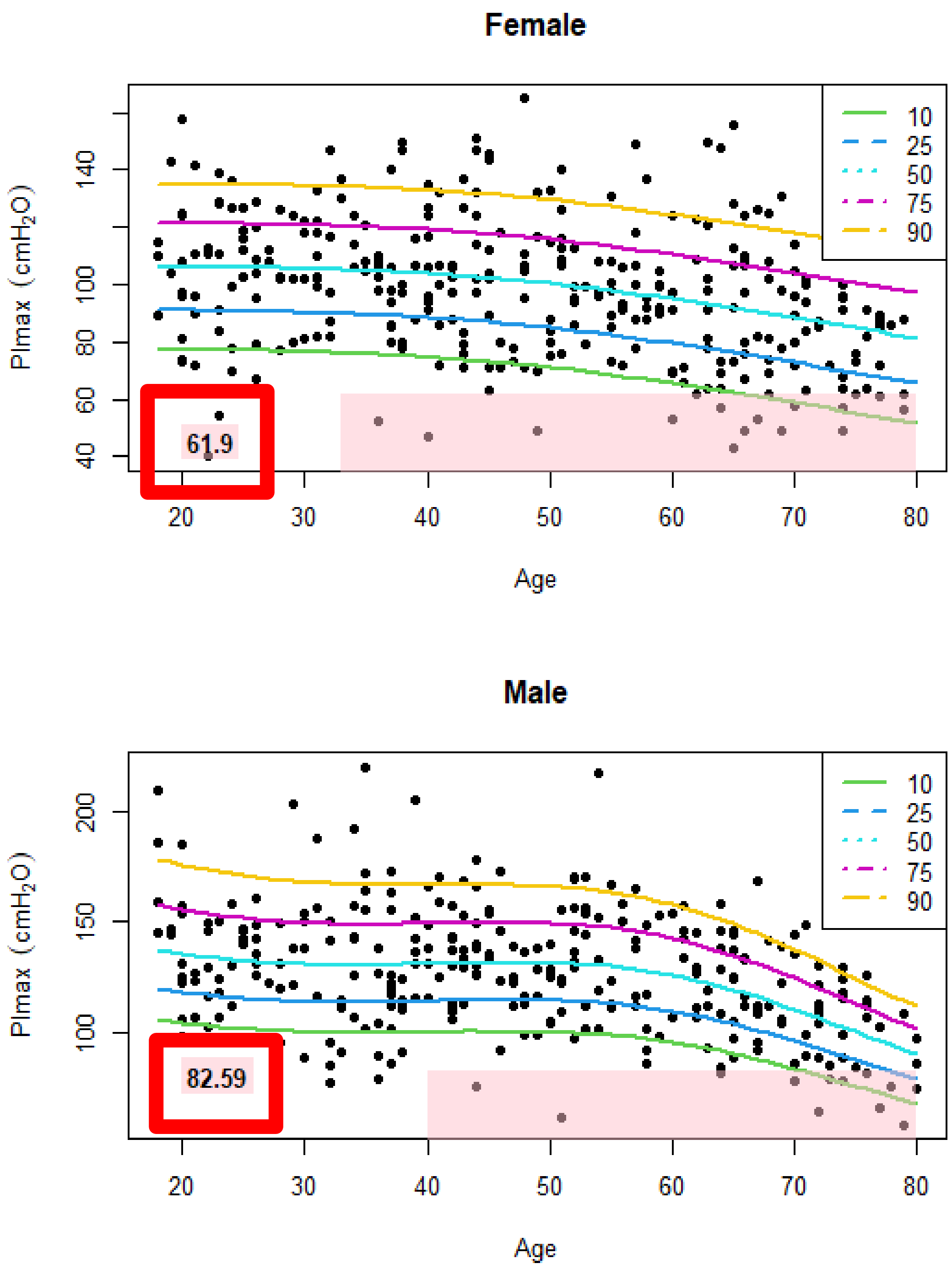
PROYECTO FINANCIADO POR Sociedad Española de Neumología y Cirugía Torácica SEPAR
Colexio Oficial de Fisioterapeutas de Galicia
UNIVERSIDADE DA CORUÑA
Facultade de Fisioterapia da Coruña



Paz et al. Arch Bronconeumol. 2023



Results

Reference equations

$PImax = 61.48 + 0.66 * age + 1.55 * BMI - 0.01 * age^2$
$PImax = 98.60 + 1.18 * age + 0.76 * BMI – 0.02 * age^2$
$PEmax = 74.75 + 1.67 * age + 1.75 * BMI – 0.02 * age^2$
$PEmax = 58.11 + 3.71 * age + 2.64 * BMI – 0.04 * age^2$

Cut-offs

Inspiratory muscle weakness

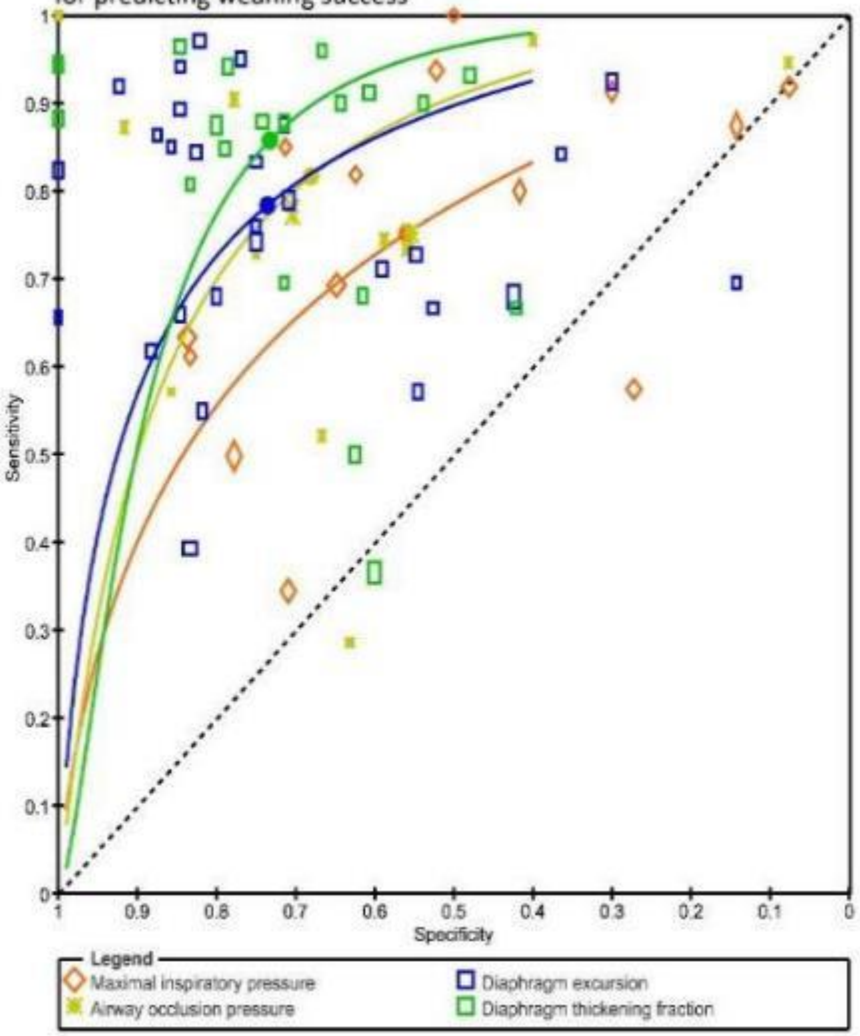
62 cmH_2O 83 cmH_2O

Expiratory muscle weakness

81 cmH_2O 109 cmH_2O

Paz et al. Arch Bronconeumol. 2023

Figure 1. Summary receiver operating characteristic (SROC) curves for predicting weaning success



Poddighe *et al. Critical Care* (2024) 28:70
https://doi.org/10.1186/s13054-024-04823-4

Critical Care

RESEARCH **Open Access**

Accuracy of respiratory muscle assessments to predict weaning outcomes: a systematic review and comparative meta-analysis

Diego Poddighe[1,2†], Marine Van Hollebeke[1,2†], Yasir Qaiser Choudhary[1], Débora Ribeiro Campos[3], Michele R. Schaeffer[1], Jan Y. Verbakel[4,5], Greet Hermans[2,6], Rik Gosselink[1,2,7] and Daniel Langer[1,2*]

Conclusions DTF and DE are superior to PImax and DTF seems to have the highest accuracy among all included respiratory muscle assessments for predicting weaning success. Further studies aiming at identifying the optimal threshold of DTF to predict weaning success are warranted.

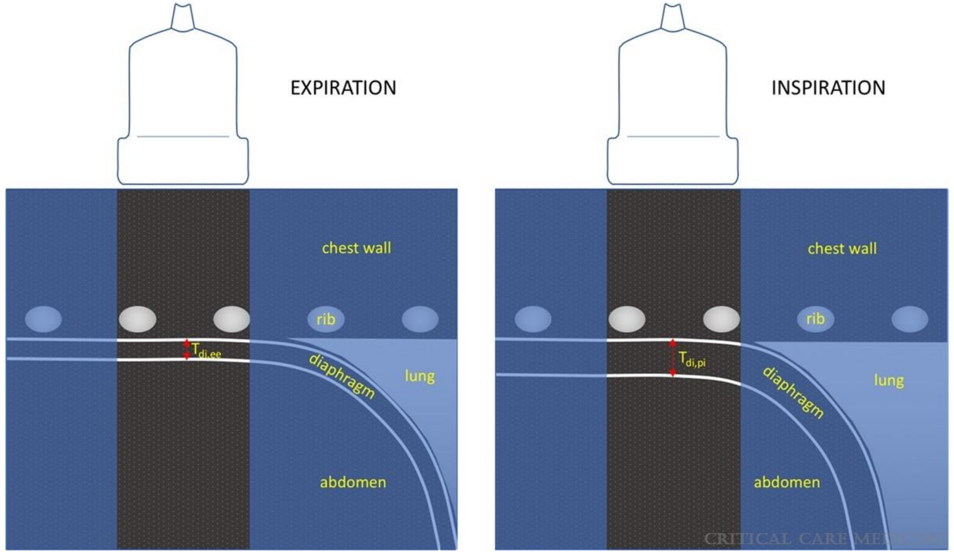
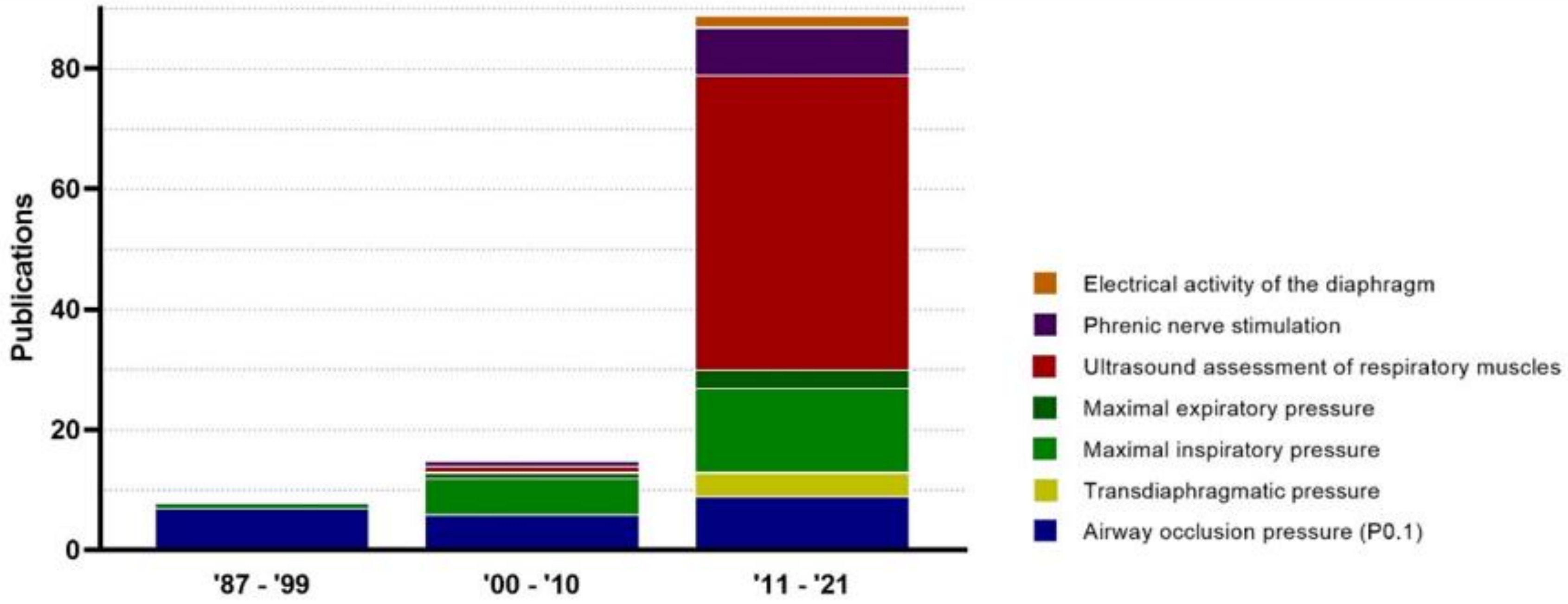


Figure 2: Published articles per assessment method over time

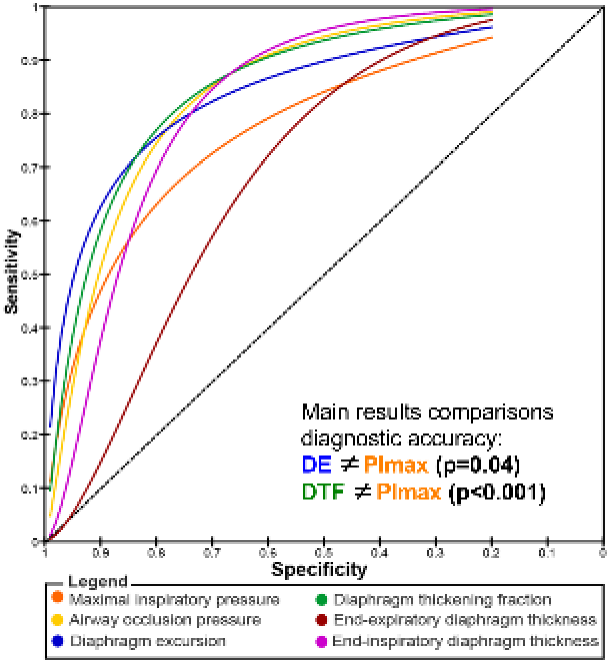


Investigated assessments of interest according to the decade of publication

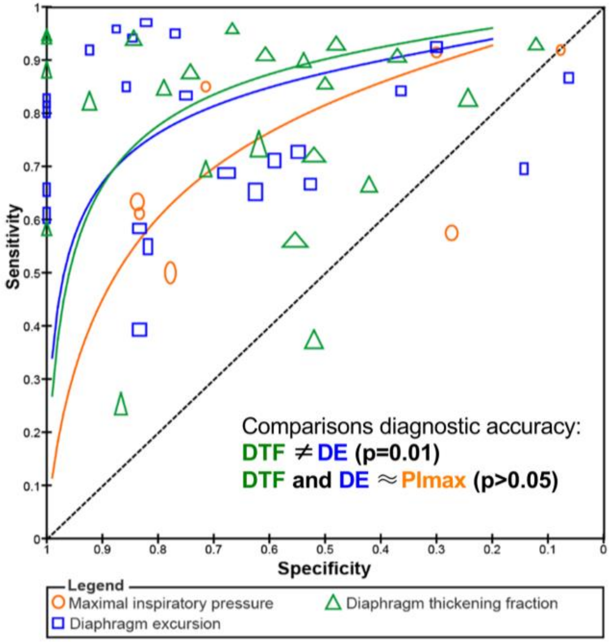

Quick ID
END EXAM
30 Hz
18.0 cm
S4-1
FAST
-0.3 dB
Fast Flow
MMode
Slow Flow
Save Loop
Depth
Gain
PHILIPS
Lumify

Results

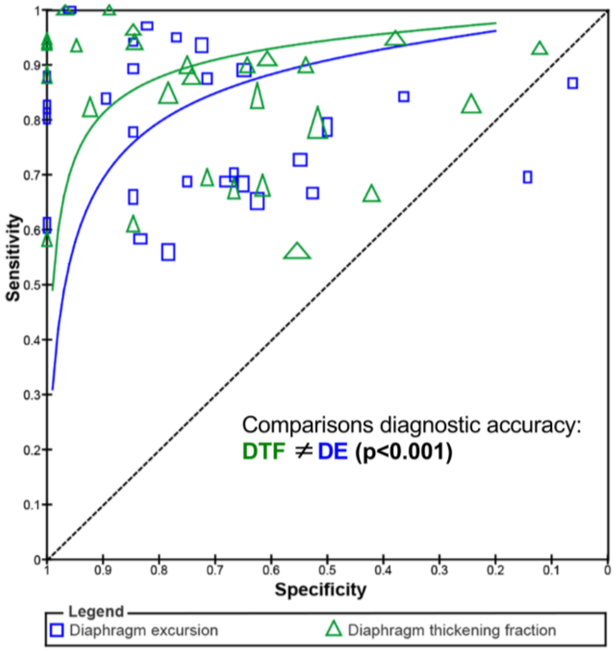
All studies considered



Only low risk of bias studies



Based on direct comparative studies

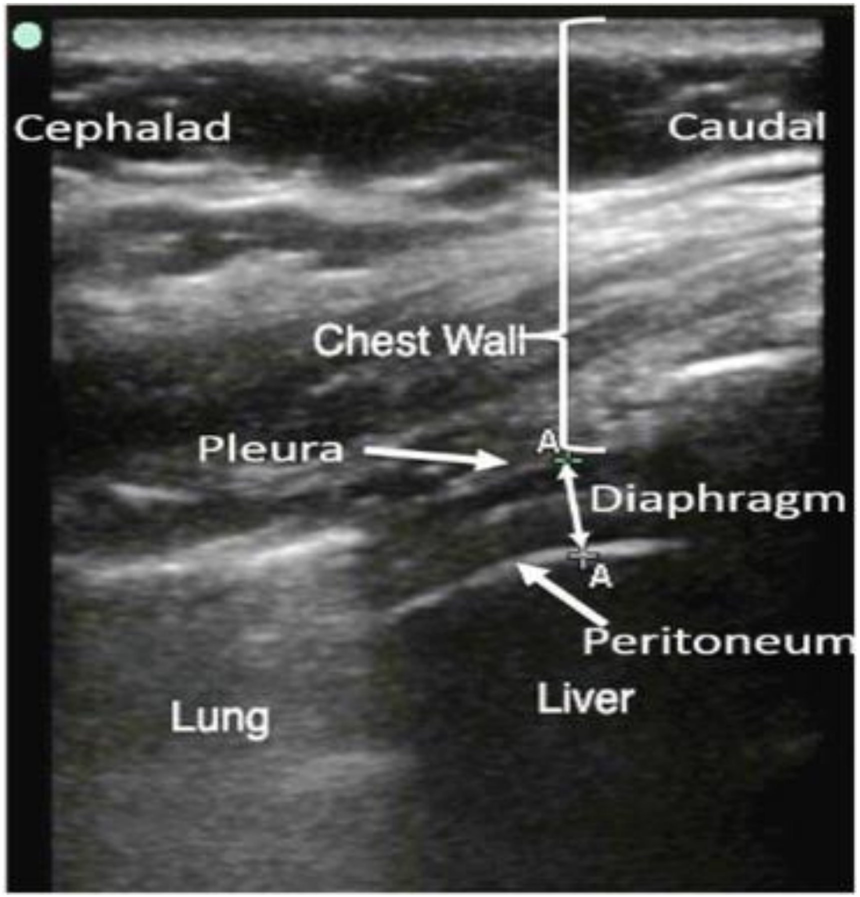


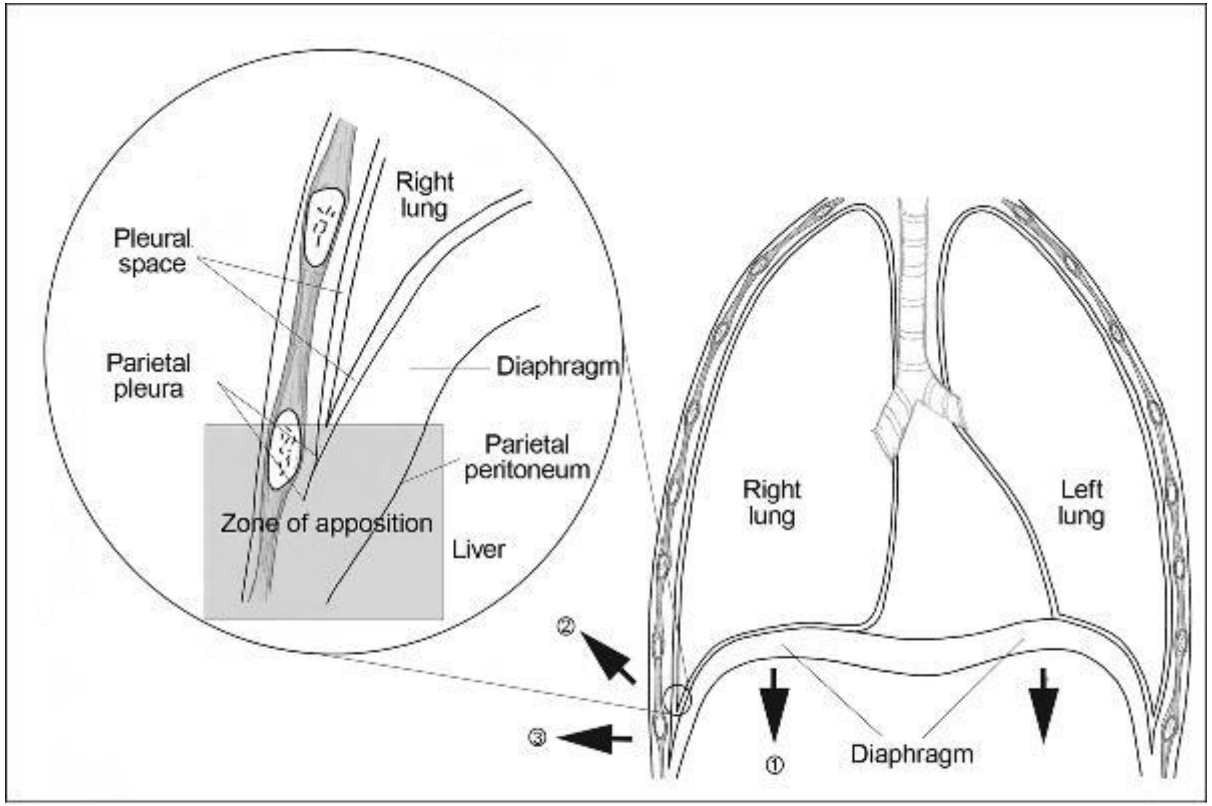
Assessment	Sensitivity at 80% specificity	95%CI
PImax	63%	47-77%
DE	75%	67-82%
DTF	77%	61-87%
P0.1	74%	40-93%
Tdi_{ei}	69%	13-97%
Tdi_{ee}	37%	13-70%

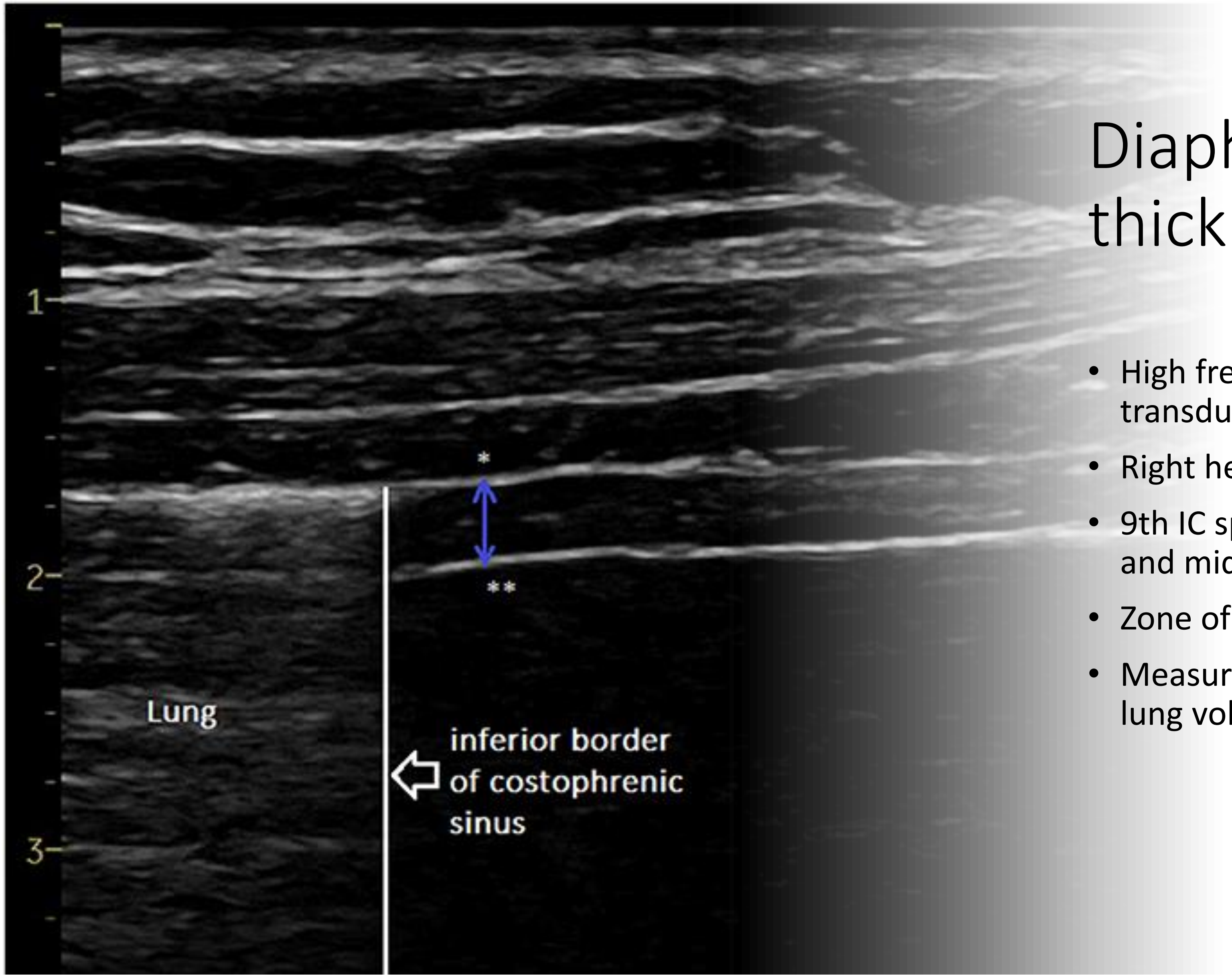
Assessment	Sensitivity at 80% specificity	95%CI
PImax	61%	44-75%
DE	76%	64-85%
DTF	78%	63-88%

Assessment	Sensitivity at 80% specificity	95%CI
DE	79%	68-87%
DTF	88%	78-93%

Poddighe D, Van Hollebeke M et al. Crit Care. 2024


Cephalad
Caudal
Chest Wall
Pleura
A
Diaphragm
A
Peritoneum
Lung
Liver


Right lung
Pleural space
Parietal pleura
Diaphragm
Parietal peritoneum
Zone of apposition
Liver
Right lung
Left lung
②
③
①
Diaphragm

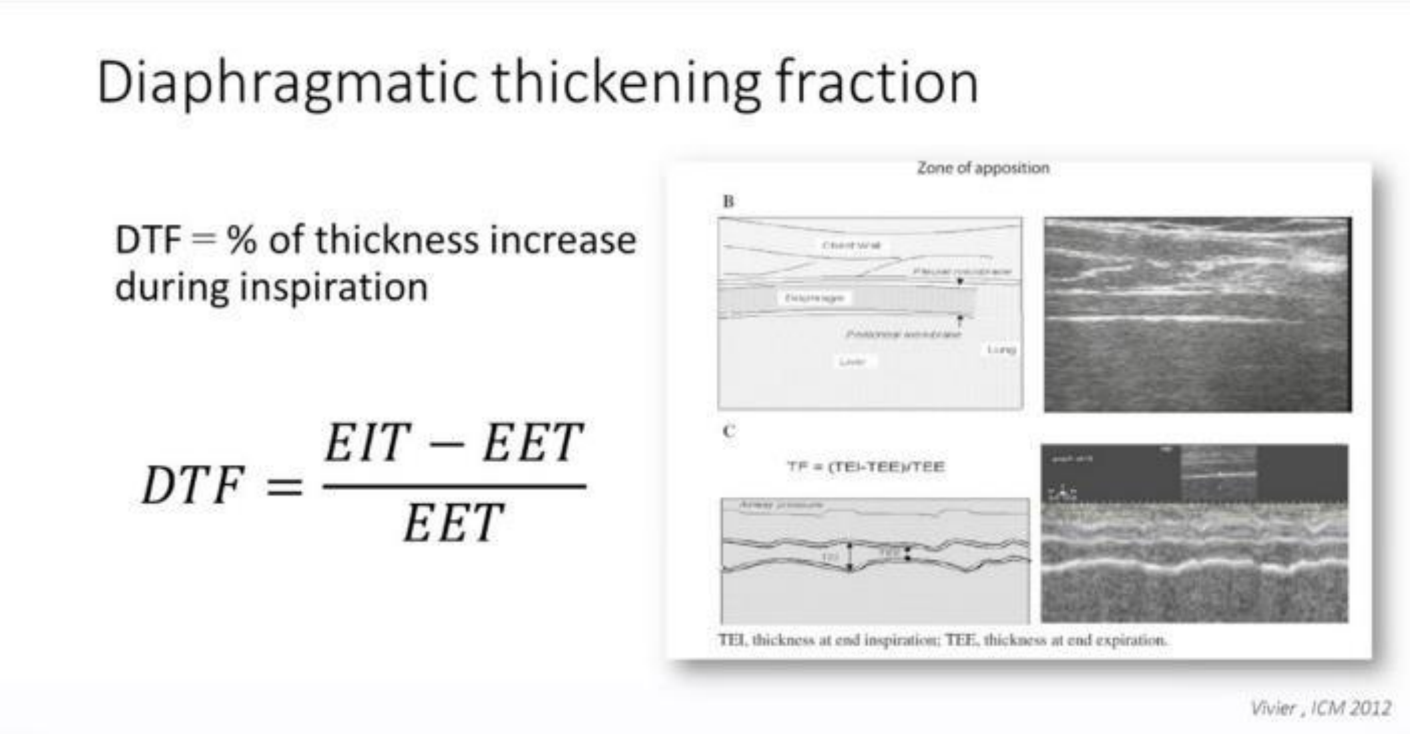


Diaphragm thickness

- High frequency linear transducer, B-mode
- Right hemidiaphragm
- 9th IC space between anterior and mid-axillary line
- Zone of apposition
- Measurement at end-expiratory lung volume

Diaphragm thickening fraction (tidal)

- High frequency linear transducer, M-mode
- Only in spontaneously breathing patients



Intensive Care Med
https://doi.org/10.1007/s00134-024-07688-x

How I perform diaphragmatic ultrasound in the intensive care unit

Editorial | Published: 29 October 2024
(2024) Cite this article

Greet Hermans, Alexandre Demoule & Leo Heunks

SUBCOSTAL APPROACH	INTERCOSTAL APPROACH

1. Baseline conditions

Patient positioning

Subcostal approach:

Place the patient in a semi-recumbent position (30-45°)

Intercostal approach:

Place the patient in a semi-recumbent position (30-45°)

Ventilator conditions[1]

Subcostal approach:

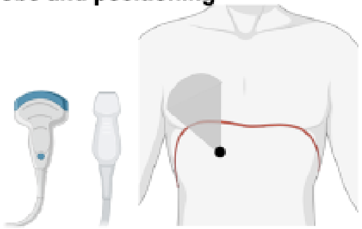
- Adequate respiratory drive (eg P0.1 >2cmH$_2$O)(no or minimal sedation)
- No (or minimal tolerable) ventilator support (intubated or extubated)

Intercostal approach:

- Adequate respiratory drive
- No (or minimal tolerable) ventilator support (intubated or extubated)

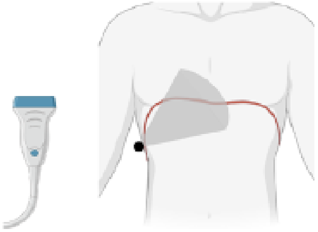
2. Probe and positioning

Subcostal approach:



- 2-5 MHz, abdominal or cardiac transducer
- The probe is positioned subcostally on the mid-clavicular line, angle directed medially, dorsally and cranially to reach the posterior third of the diaphragm
- Right side is easiest and sufficient unless unilateral involvement is suspected

Intercostal approach:

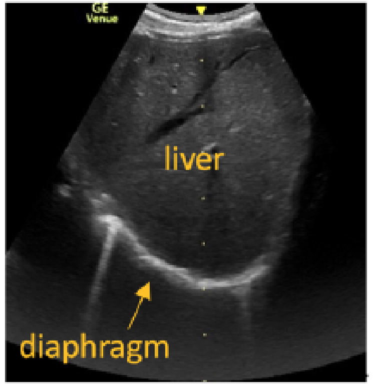


- 7-12 MHz, linear transducer
- The probe is positioned at the antero- or mid-axillary line between the 8th and 11th intercostal space, perpendicular to the chest wall at the zone of apposition, in line with the intercostal space
- Right side is easiest and sufficient unless unilateral involvement is suspected

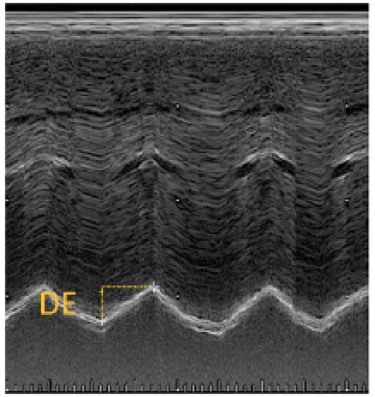
3. Image acquisition

Subcostal approach:

B mode



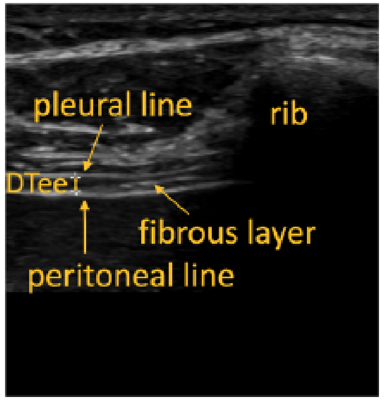
M Mode



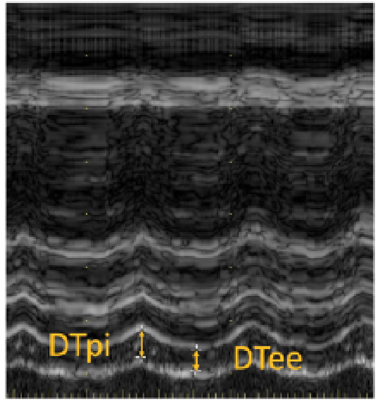
- Adjust depth to optimally capture excursion
- Adjust gain to optimize contrast with surrounding structures
- Adjust focus is used to optimize image quality
- Position the M line perpendicular to the diaphragm movement, focusing on the area with the greatest displacement
- Adjust sweep speed to obtain at least 3 respiratory cycles within 1 frame

Intercostal approach:

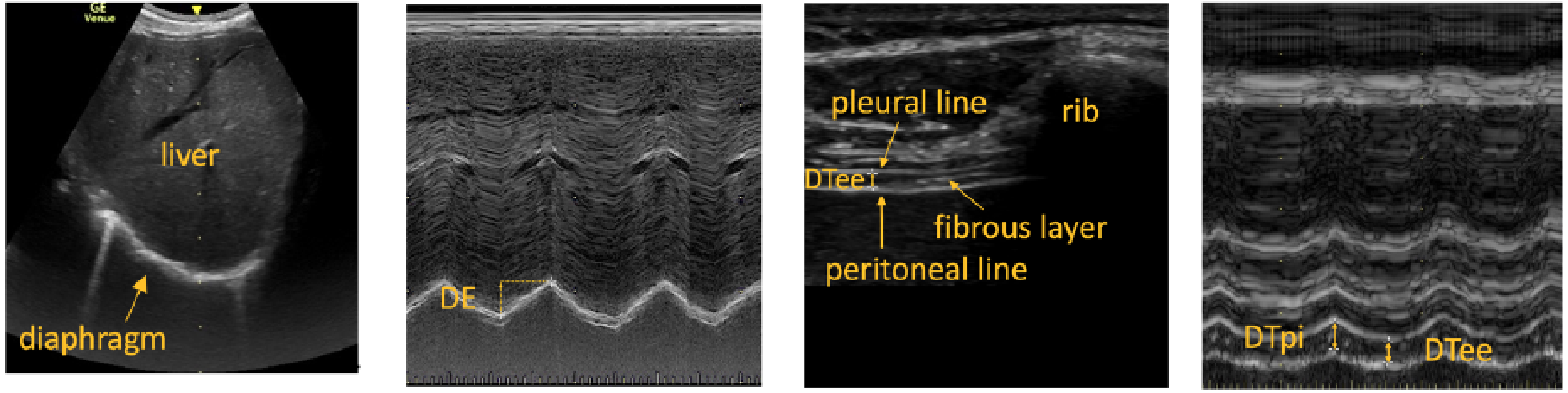
B mode



M Mode



- Adjust depth center the diaphragm
- Adjust gain to optimize contrast with surrounding structures
- Adjust focus is used to optimize image quality
- Position the M line perpendicular to the diaphragm
- Adjust sweep speed to obtain at least 3 respiratory cycles within 1 frame



- Adjust depth to optimally capture excursion
- Adjust gain to optimize contrast with surrounding structures
- Adjust focus is used to optimize image quality
- Position the M line perpendicular to the diaphragm movement, focusing on the area with the greatest displacement
- Adjust sweep speed to obtain at least 3 respiratory cycles within 1 frame

- Adjust depth center the diaphragm
- Adjust gain to optimize contrast with surrounding structures
- Adjust focus is used to optimize image quality
- Position the M line perpendicular to the diaphragm
- Adjust sweep speed to obtain at least 3 respiratory cycles within 1 frame

4. Measurements

- Measure DE during tidal breathing in M-mode
- Place the markers at the lowest (foot) and the highest point (apex) of the inspiratory slope and measure the distance between both on the vertical axis

- Measure thickness at end inspiration (DTpi) and end-expiration (DTee) of the same respiratory cycle in the B mode or M mode
- Place the calipers perpendicular to the fiber direction closest at the internal margin of the pleural and peritoneal lining without including them
- Calculate DTF as (DTpi-DTee)*100/(DTee)
- To achieve representative results, obtain at least 3 measurements with a difference of <10%

5. Normal values in healthy individuals[14]

DE: seated, tidal breathing, end-expiration (values as mean±SD)
right: male: 2.0±0.5 cm; female: 1.9±0.5 cm
left: male: 2.2±0.6 cm; female: 1.9±0.5 cm

Thickness: seated, tiddal breathing, end-expiration (values as mean±SD)
right: male: 2.1±0.4 mm; female: 1.9±0.4 mm
left: male: 2.0±0.4 mm; female: 1.7±0.3 mm

DTF: seated, tidal breathing, end-expiration (values as mean±SD)
right: male: 32±15%; female: 35±16%
left: male: 30±14%; female: 33±15%

6. Relevant thresholds/related to outcome

DE:
DE <10-15 mm during tidal breathing: diaphragm dysfunction[4]

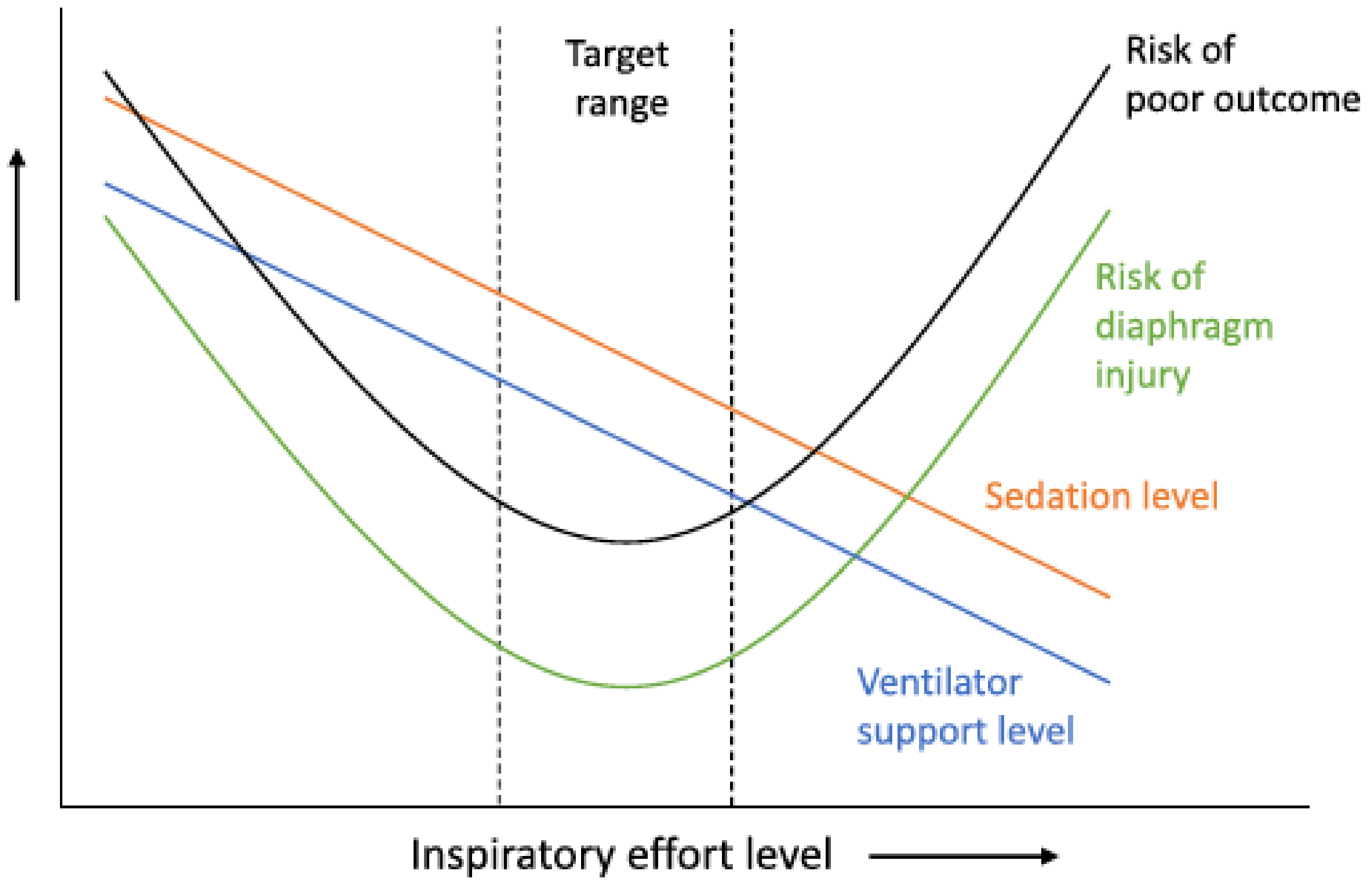
DTF:
DTF_{max} <20%: diaphragm dysfunction[4]
DTF <25-33%: predicts weaning failure[9]
DTF <20%: predicts NIV failure[10]

are not required for other situations, such as detection of asynchrony.

Abbreviations: DTpi: diaphragm thickness at peak-inspiration; DTee: diaphragm thickness at end-expiration; DTF: diaphragm thickening fractio; DTF_{max}: diaphragm thickening fraction during maximal inspiratory maneuver; DE: diaphragm excursion.

Parts of this figure were produced with Biorender

CONCEPTIONAL MODEL OF RESPIRATORY MUSCLE PROTECTIVE MECHANICAL VENTILATION

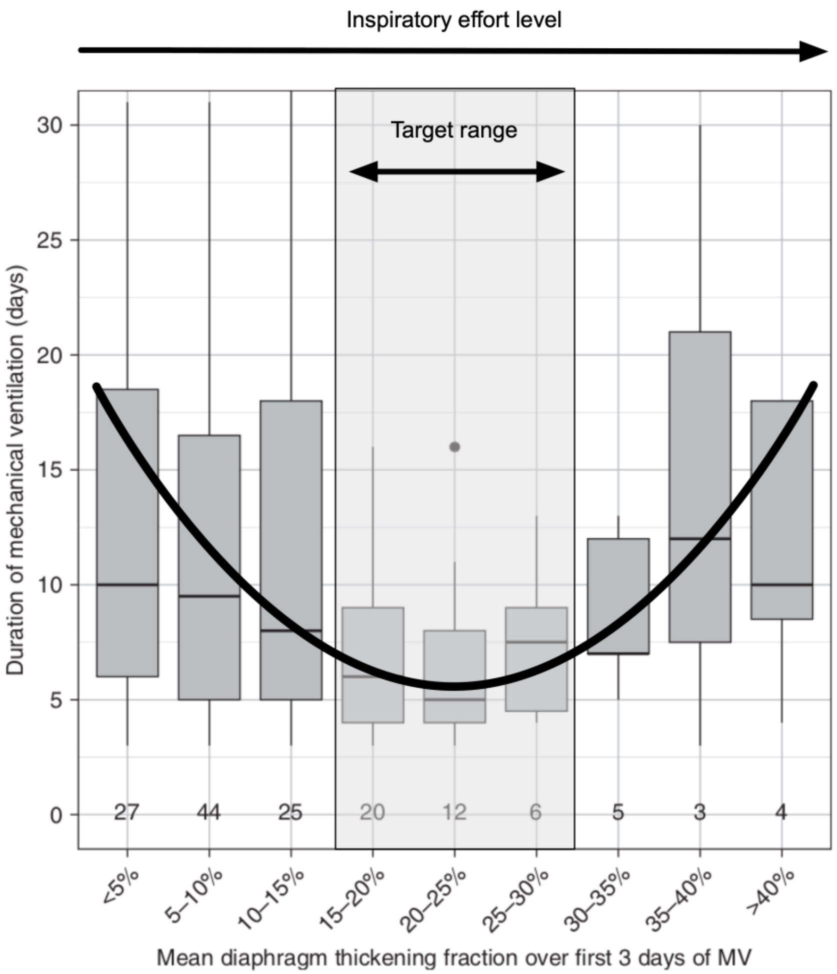


Schreiber et al. Crit. Care Clin. 2018

Thickening fraction 15-30% = shortest duration of mechanical ventilation in comparison with lower or higher thickening fraction values

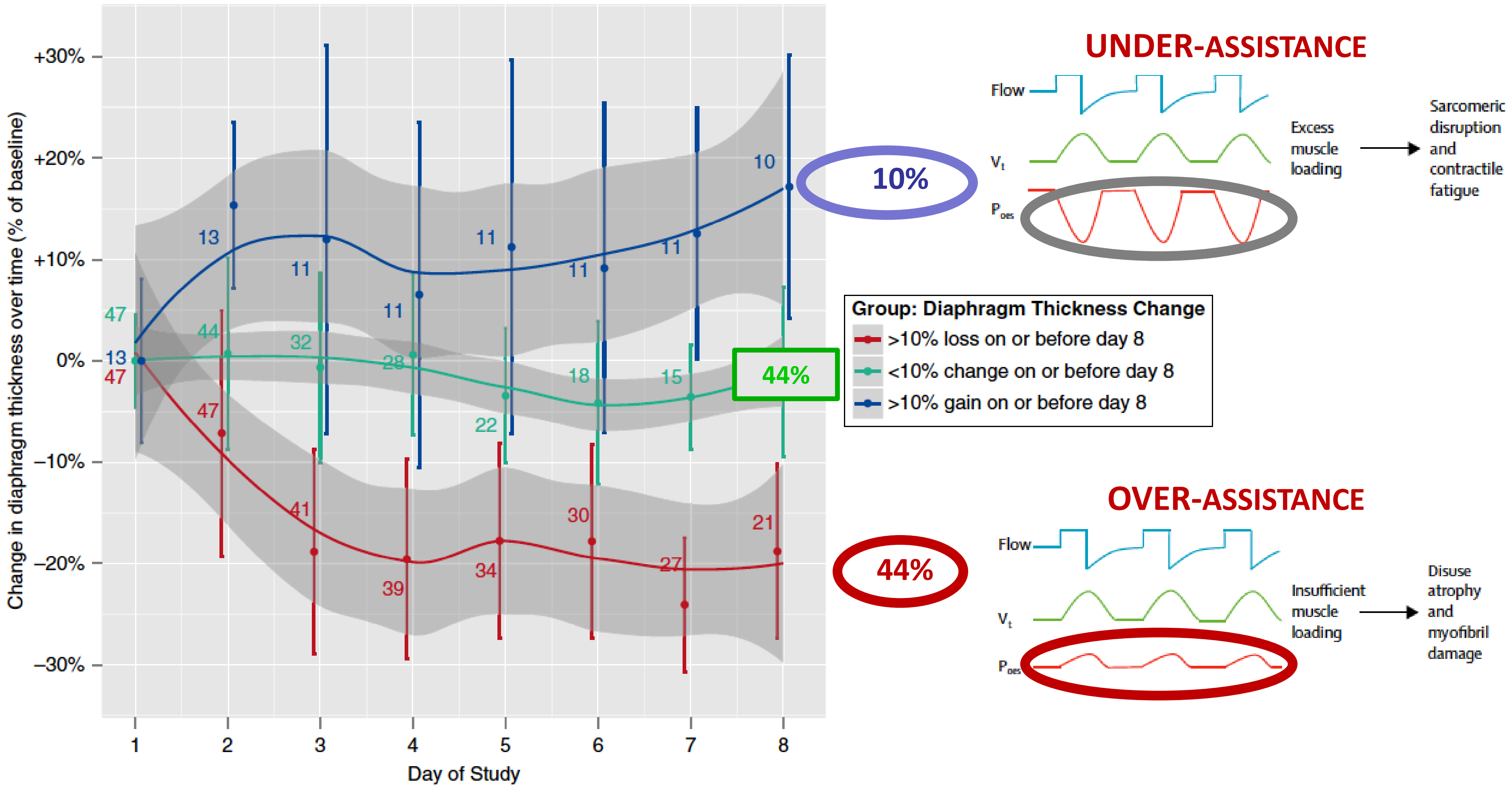
TFdi < 10% = Overassist

TFdi > 40% = Underassist



Goligher et al. AJRCCM 2018

Diaphragm thickness in mechanically ventilated patients



Goligher et al. AJRCCM 2015; 192: 1080

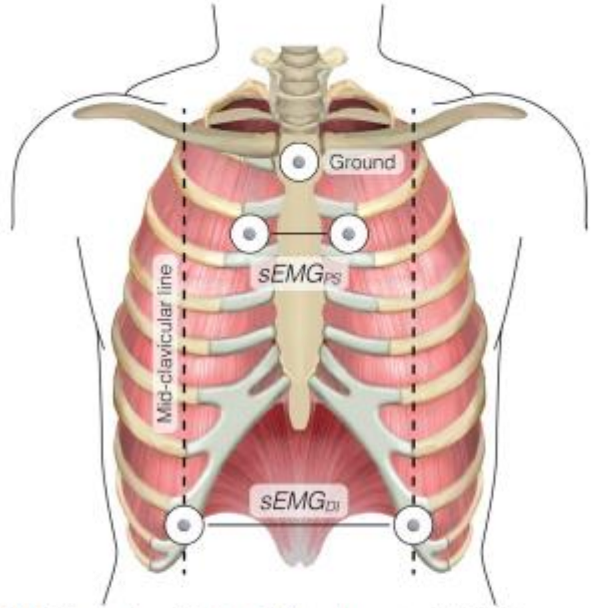


Fig. 1 Electrode positioning for bilateral parasternal ($sEMG_{PS}$) and diaphragm ($sEMG_{DI}$) configuration, redrawn from [107]

Jonkman *et al. Critical Care* (2024) 28:2
https://doi.org/10.1186/s13054-023-04779-x

Critical Care

REVIEW **Open Access**

Analysis and applications of respiratory surface EMG: report of a round table meeting

A. H. Jonkman[1], R. S. P. Warnaar[2], W. Baccinelli[3], N. M. Carbon[4], R. F. D'Cruz[5], J. Doorduin[6], J. L. M. van Doorn[6], J. Elshof[7], L. Estrada-Petrocelli[8], J. Graßhoff[9], L. M. A. Heunks[10], A. A. Koopman[11], D. Langer[12], C. M. Moore[3], J. M. Nunez Silveira[13], E. Petersen[14], D. Poddighe[12], M. Ramsay[5], A. Rodrigues[15], L. H. Roesthuis[10], A. Rossel[16], A. Torres[17], M. L. Duiverman[7] and E. Oppersma[2*]

RESEARCH **Open Access**

Recruitment pattern of the diaphragm and extradiaphragmatic inspiratory muscles in response to different levels of pressure support

L. H. Roesthuis[1], J. G. van der Hoeven[1], H. W. H. van Hees[2], W.-J. M. Schellekens[3], J. Doorduin[4] and L. M. A. Heunks[5*]

Australian Critical Care 38 (2025) 101152

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Brief research report

Inspiratory effort and respiratory muscle activation during different breathing conditions in patients with weaning difficulties: An exploratory study

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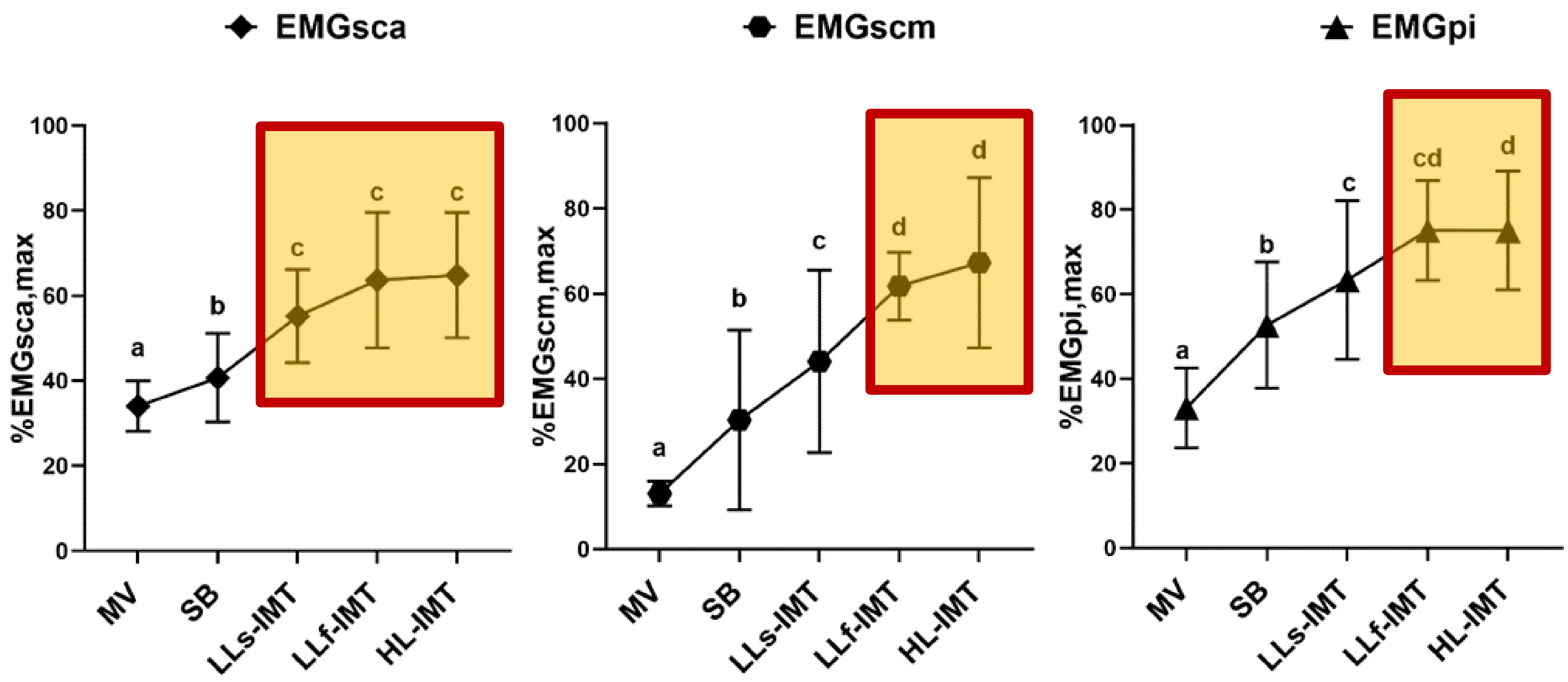
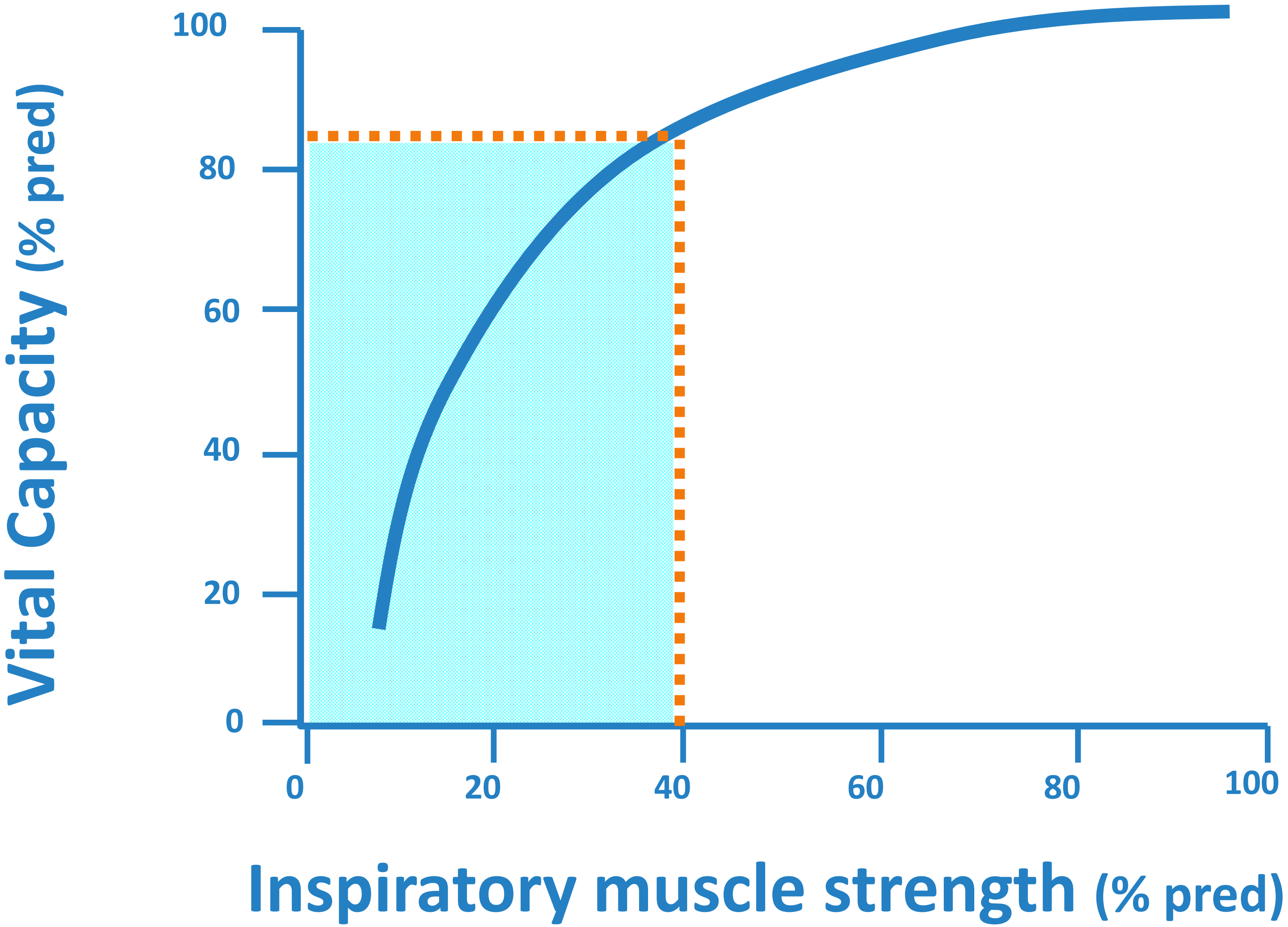
Respiratory surface EMG during respiratory muscle loading



Poddighe D et al. ACC 2025

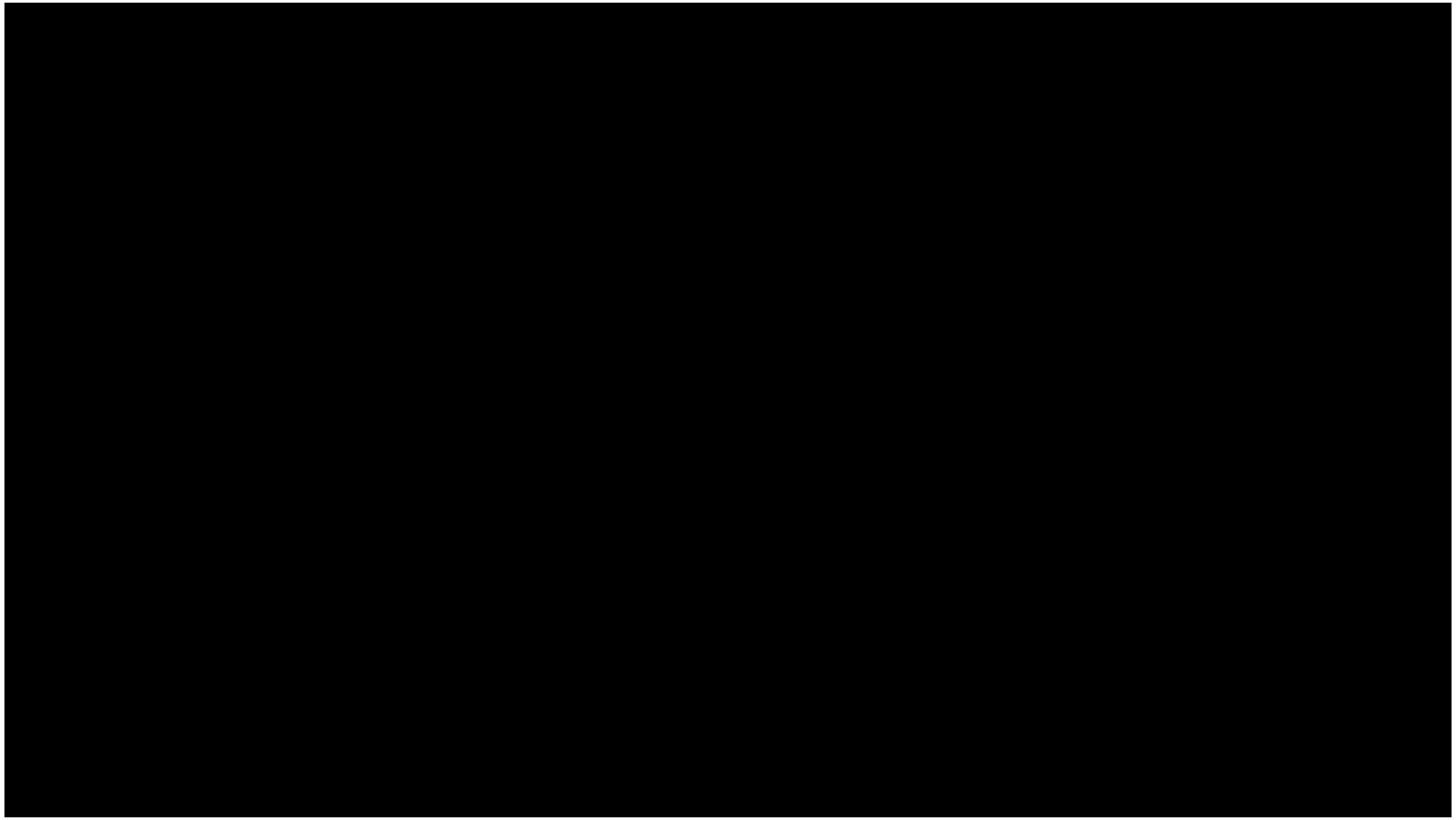
VENTILATORY PUMP CAPACITY

- PULMONARY FUNCTION (FVC)
- STRENGTH ($P_I max$, $P_E max$)

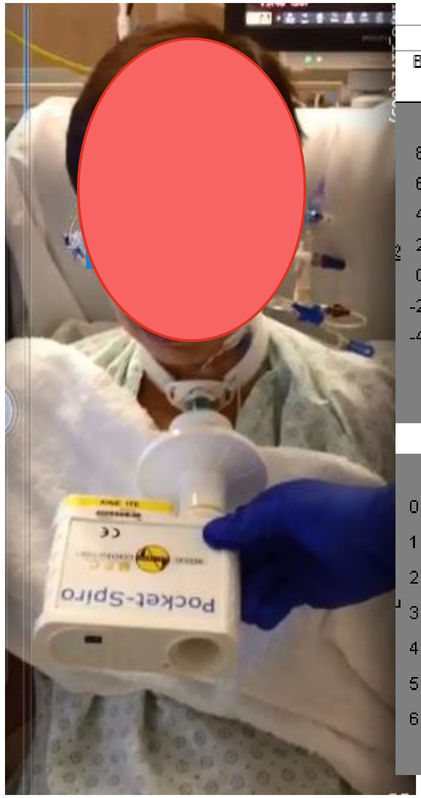


De Troyer et al. Thorax 1980, 35: 603- 610.

Assessment of pulmonary function



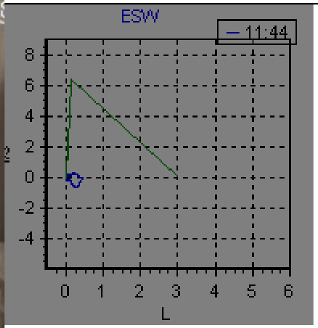
Assessment of pulmonary function

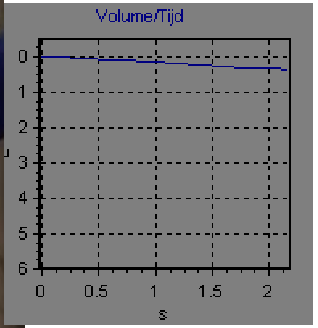


Naam :		op :	28/07/1971	Leeftijd :	44 an(s)
Vornaam :		cht:	F	Dokter:	
ID#		um:	15/10/2015	Sig:	

Lengte :	160 cm
Gewicht :	45 kg
Tech .:	

BTPS Factor: 1.07 Temp: 25.00 ° Humid : 50.00 % Pbaro: 1050.00 hPa



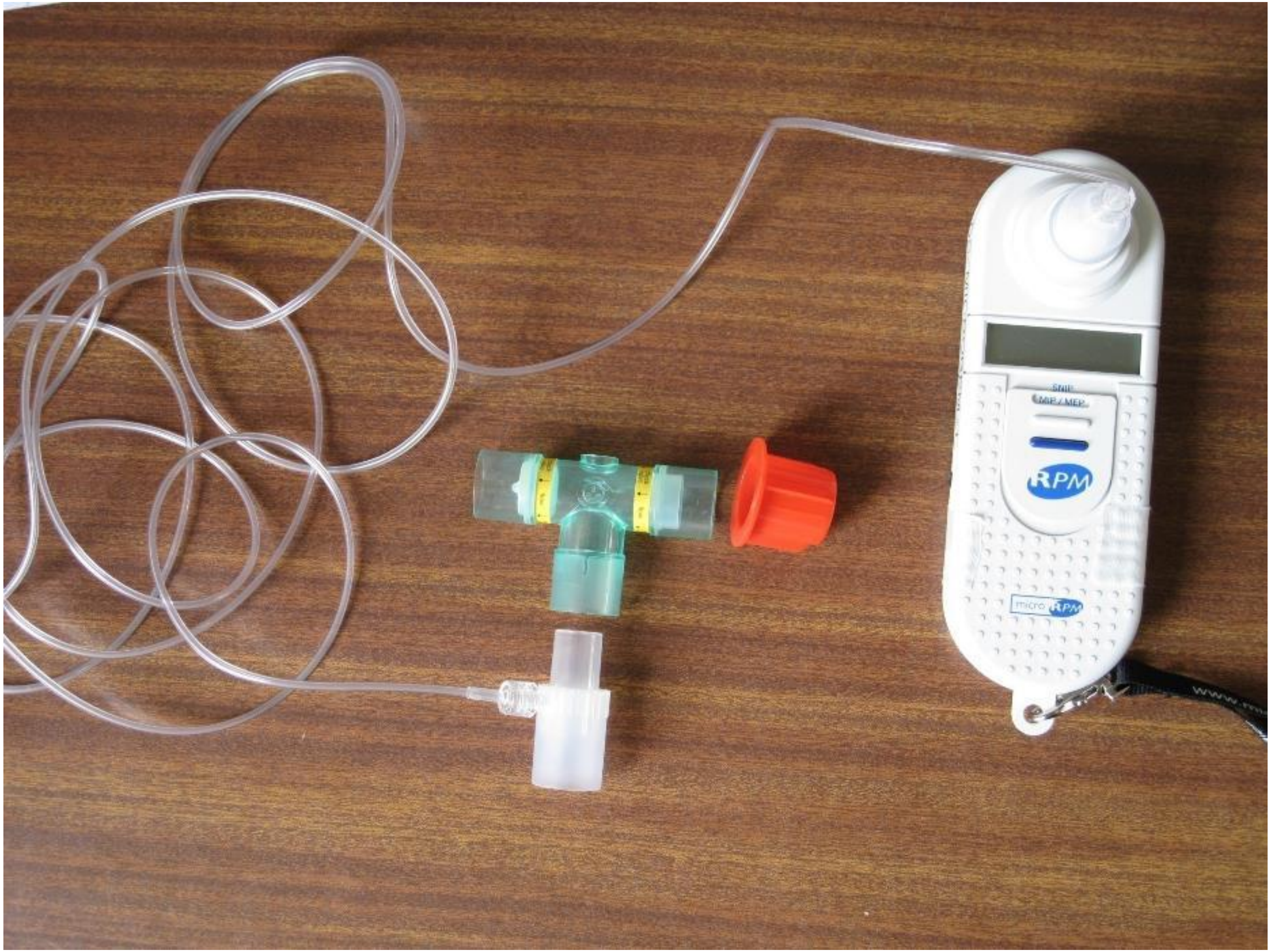


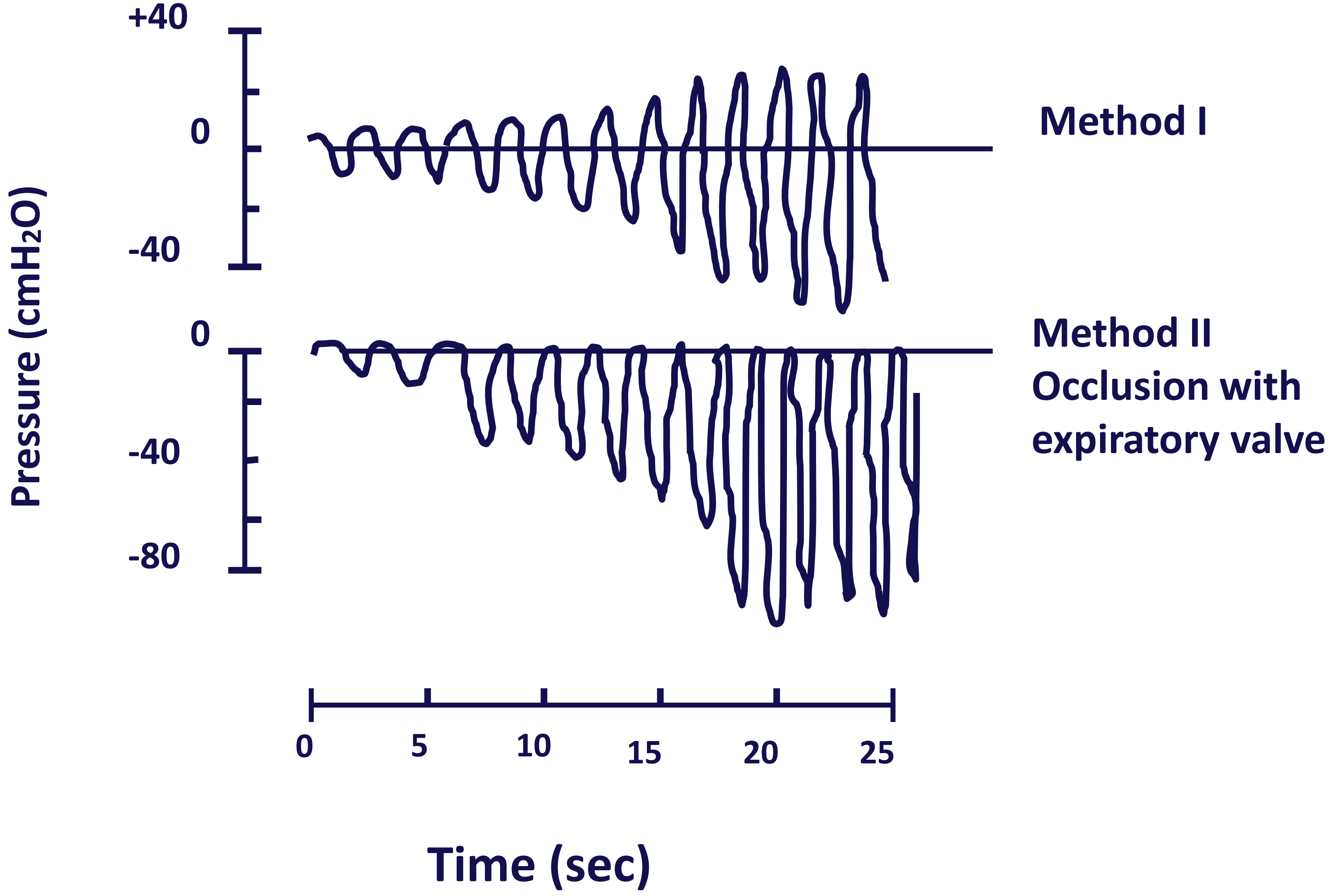
DYNAMISCHE SPIROMETRIE

Para	U.	Theo	Pre	%Theo.	SD	Post	%Theo.	% Chg
Tijd			11:52					
FEV1 best	l	2.62	0.25	10%	1.38			
FVC best	l	3.05	0.34	11%	1.82			
DEP best	l/s	6.37	0.26	4%	5.14			
FVC	l	3.05	0.34	11%	1.82			
ESW	l	2.62	0.25	10%	1.38			
FEV1/FVC	%	1	74	9161%	-0			
PEF	l/s	6.37	0.26	4%	5.14			
FEF25	l/s	5.65	0.09	2%	4.26			
FEF50	l/s	3.98	0.25	6%	2.53			
FEF75	l/s	1.69	0.21	12%	0.02			
FEF25-75	l/s	3.42	0.20	6%	2.02			
PIF	l/s		0.63					
FIF50	l/s		0.42					
PIF/PEF	%		239.31					
MEF50/MIF50	%		58					
MVV (FEV1)	l/min	91.7	8.8	10%	90.5			

ASSESSMENT OF RESPIRATORY MUSCLE STRENGTH

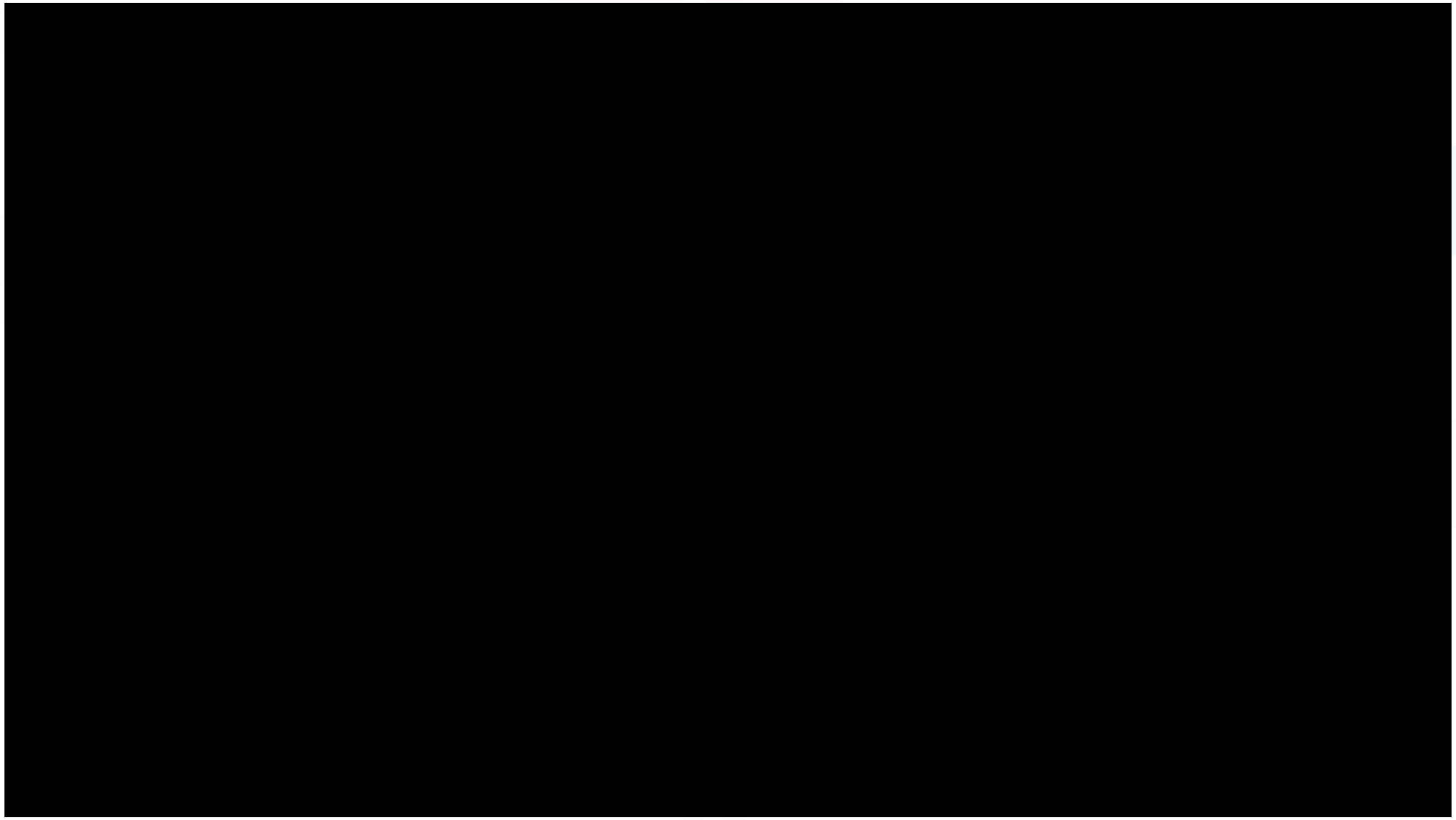
- Presence of inspiratory muscle weakness ?
- Guidance for inspiratory muscle loading !


SNIP
MIP / MEP
RPM
micro RPM

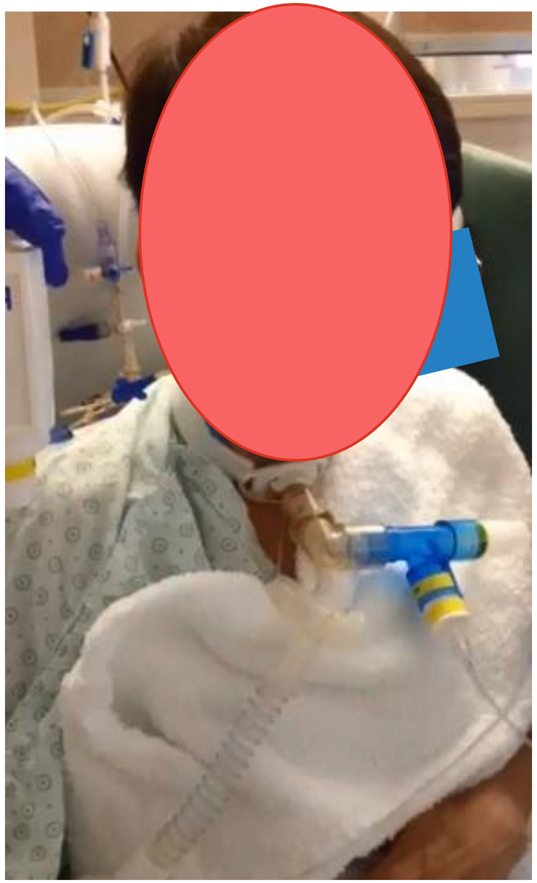


Marini et al. J. Crit. Care 1: 32-38, 1986.

Assessment of respiratory muscle strength



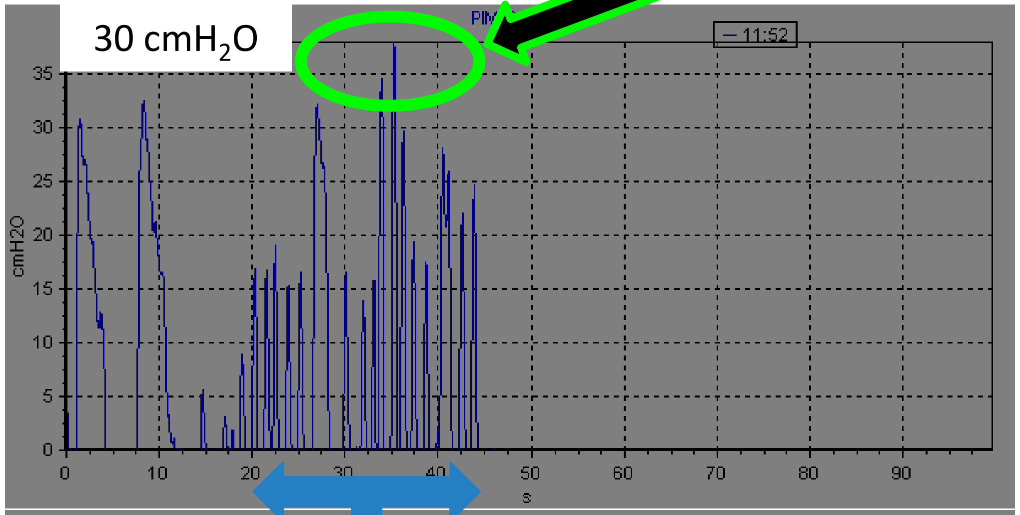
Maximal Inspiratory Pressure



Naam :	Geboren op : 1971.07.28	Leeftijd : 44	Lengte : 160
Voornaam :	Geslacht: F	Dokt er:	Gewicht 45
ID#	Test Datum : 20151015	sig/dag :	Medicatie :

MOUTH PRESSURE

Para	E.	Theo	1	%Theo.	2	%Theo.	3	%Theo.	4	%Theo.
PImax	cmH2O	86.47	30.76	36%						
PEmax	cmH2O	113.95	0.00	0%						
PImax Peak	cmH2O		39.53							



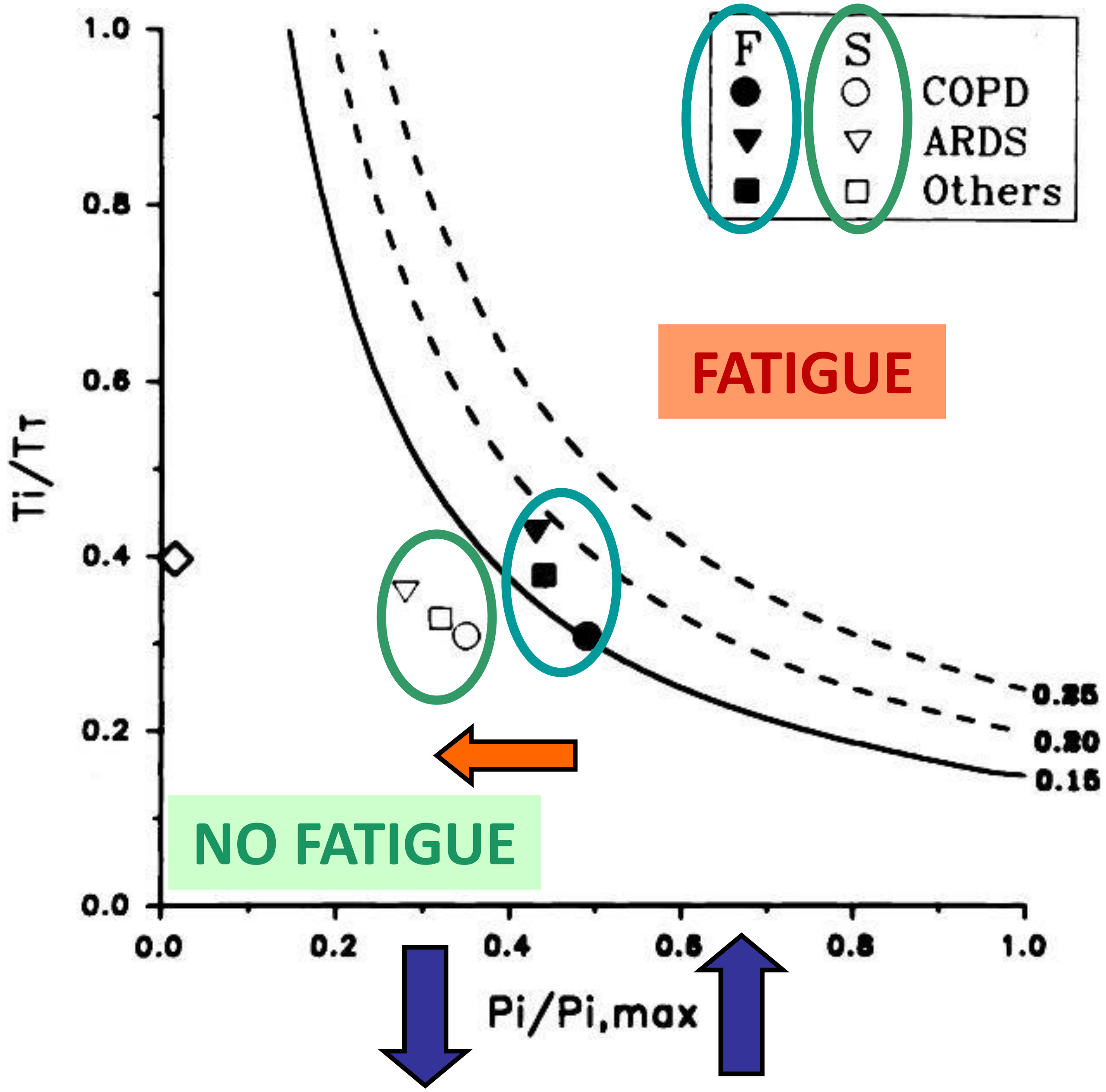
Occlusion: 25s

Peak pressure during PS

PS 24 cmH_2O
TV 350ml

Pi/Pimax:
24/30 (80%)

UNSUSTAINABLE!
Even with Ti/Ttot 0.2 TTI would be 0.16



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Respiration

Clinical Investigations

Respiration 2024;103:182–192
DOI: 10.1159/000536589

Received: July 19, 2023
Accepted: January 28, 2024
Published online: February 7, 2024

Inspiratory Muscle Dysfunction Mediates and Predicts a Disease Continuum of Hypercapnic Failure in Chronic Obstructive Pulmonary Disease

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Anja Pietzke-Calcagnile[c] Lars Hagmeyer[c, d] Binaya Regmi[a]
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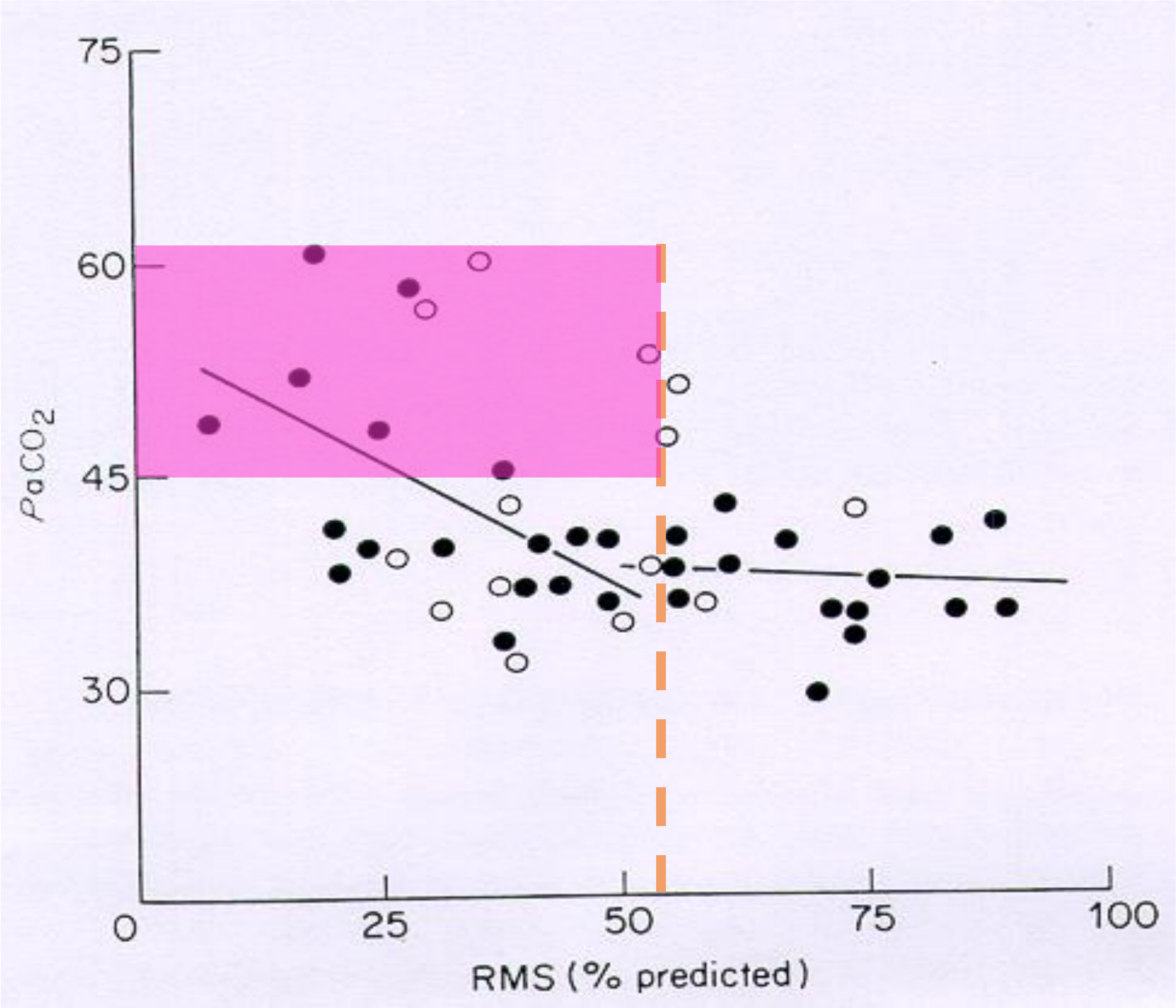
Winfried J. Randerath[c, d]

PImax: clinical relevance

- Assessment of respiratory muscle function encompassed:
  - body plethysmography
  - maximum inspiratory pressure (MIP)
  - diaphragm ultrasound
  - transdiaphragmatic pressure recordings following cervical magnetic stimulation of the phrenic nerves (twPdi) and a maximum sniff manoeuvre (Sniff Pdi).
- Only MIP reflected the extent of hypercapnia across all three stages.
- MIP values below −48 cmH2O predicted nocturnal hypercapnia (area under the curve = 0.733, p = 0.052).



Green and Laroche, Resp Med,1990, 1373 - 1387.

scientific reports

Check for updates

OPEN

Respiratory muscle strength can improve the prognostic assessment in COPD

Rebeca Nunes Silva[1], Cássia da Luz Goulart[1], Claudio R. de Oliveira[2], Renata Gonçalves Mendes[1], Ross Arena[3], Jonathan Myers[4] & Audrey Borghi-Silva[1]✉

PImax: clinical relevance

- Patients severely affected by COPD presenting MIP ≤ 55 and/or MEP ≤ 80 cmH2O are at increased risk of mortality.
- MIP and MEP substantially improve the mortality risk assessment when combined with FEV1, VO2peak and 6MWD in patients with COPD.

Take Home Messages

- Respiratory muscle dysfunction can be cause and consequence of respiratory failure.
- It is often reversible and should be diagnosed and treated.
- Evaluating respiratory muscle function is valuable for diagnosing, phenotyping, setting up and assessing treatment efficacy in patients with ARF and CRF.
- EMG and MUS play an increasingly important role alongside established invasive and noninvasive pressure assessment techniques.
- While MUS is already frequently applied in clinical practice, EMG remains currently underused.
- Both are useful tools for quantifying respiratory muscle effort and can be useful for titrating ventilatory support, optimising muscle stimulation during training interventions and guiding treatment decisions.

THANK YOU FOR YOUR ATTENTION!

If you have any questions please share your thoughts and ideas!

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