



KARIM

1.LF UK A VFN V PRAZE

Testování plicní recruitability proč, kdy a jak?

ČSARIM 2023

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VŠEOBECNÁ FAKULTNÍ
NEMOCNICE V PRAZE



1. LÉKAŘSKÁ
FAKULTA
Univerzita Karlova

Recrutabilita?

- JDE to vůbec?
- JAK to udělat?
- Záleží na poloze!!!

JAK TO ZJISTÍME bedside:

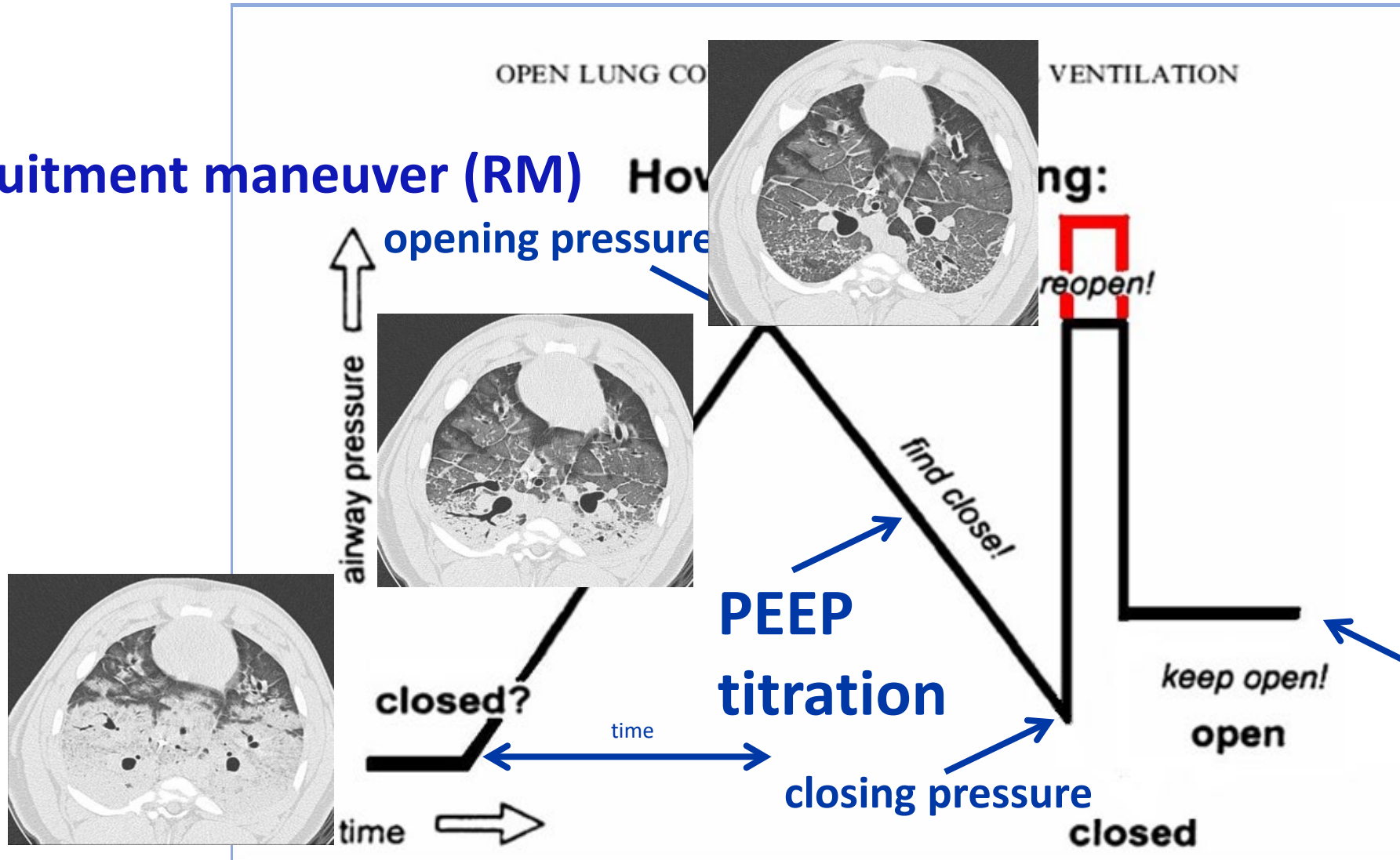
- PV tool ... Normalized Maximum
- R/I ratio
- PV tool s Insp.pauzou / SI
- EIT monitorace? SONO monitorace?



Homogenizací distribuce ventilace

Open up the lung and keep the lung open

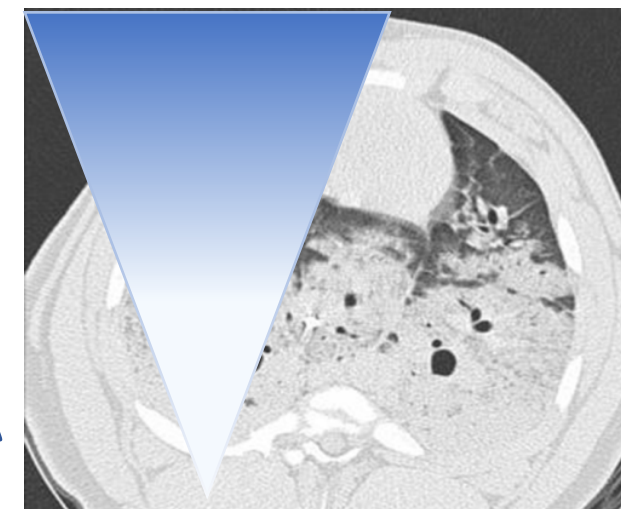
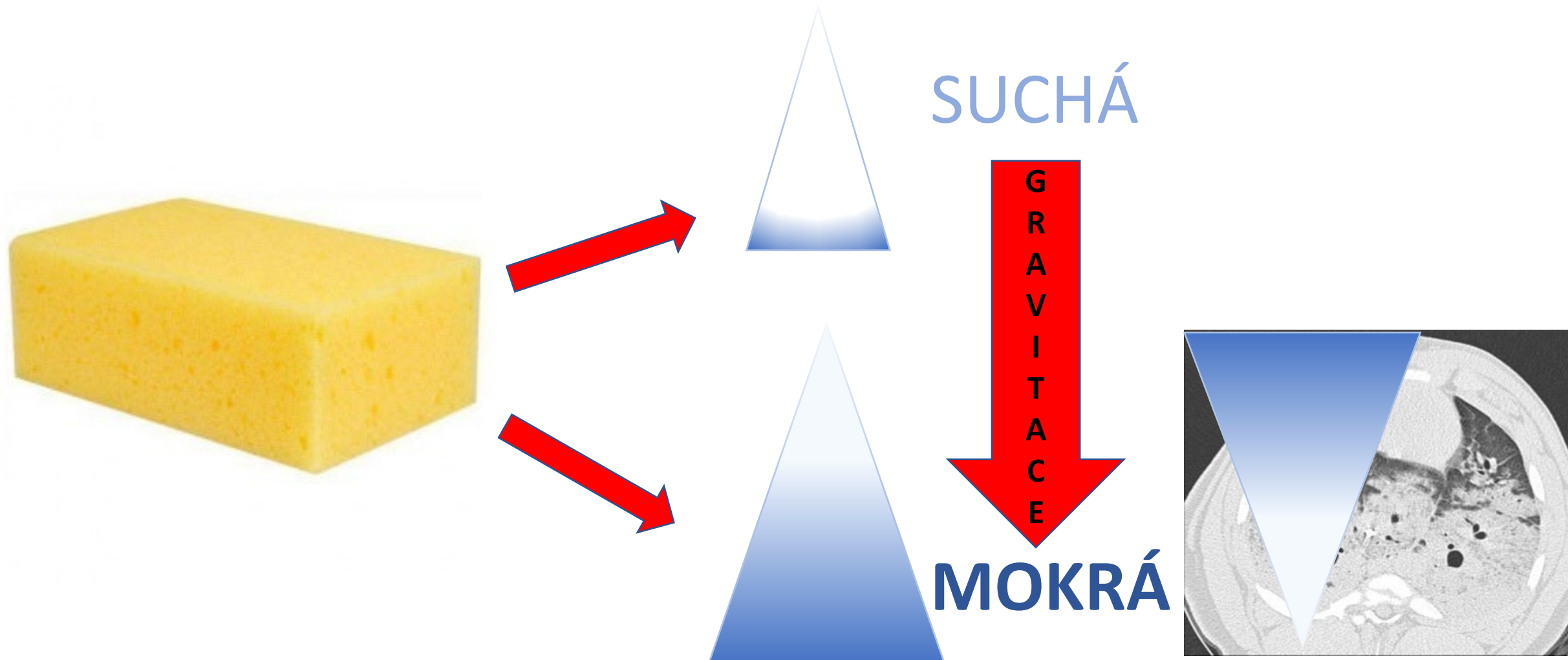
Recruitment maneuver (RM)



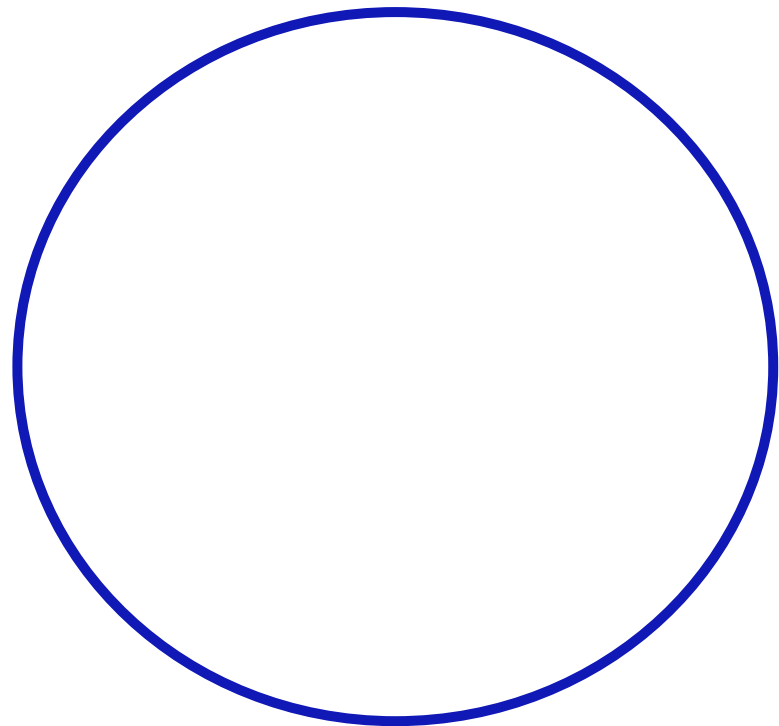
optimize
PEEP

PROČ je „SPRÁVNÁ“ poloha důležitá???

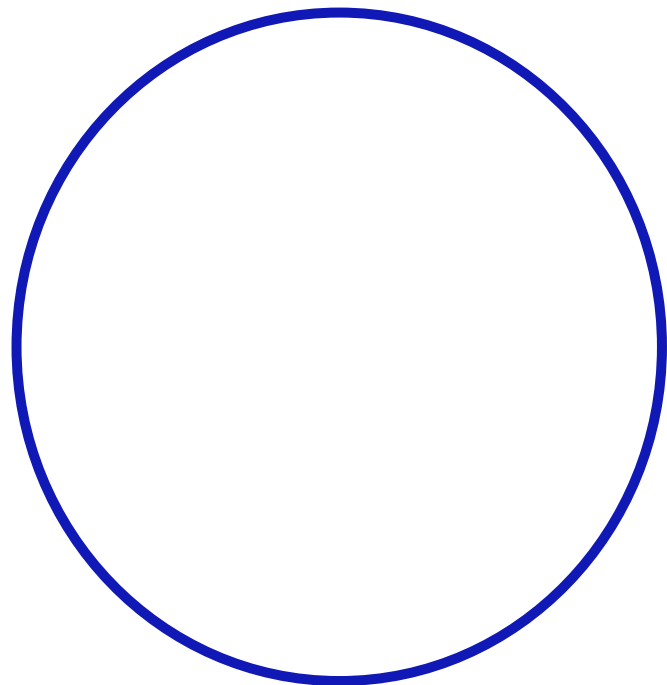
Protože GRAVITACE!!!



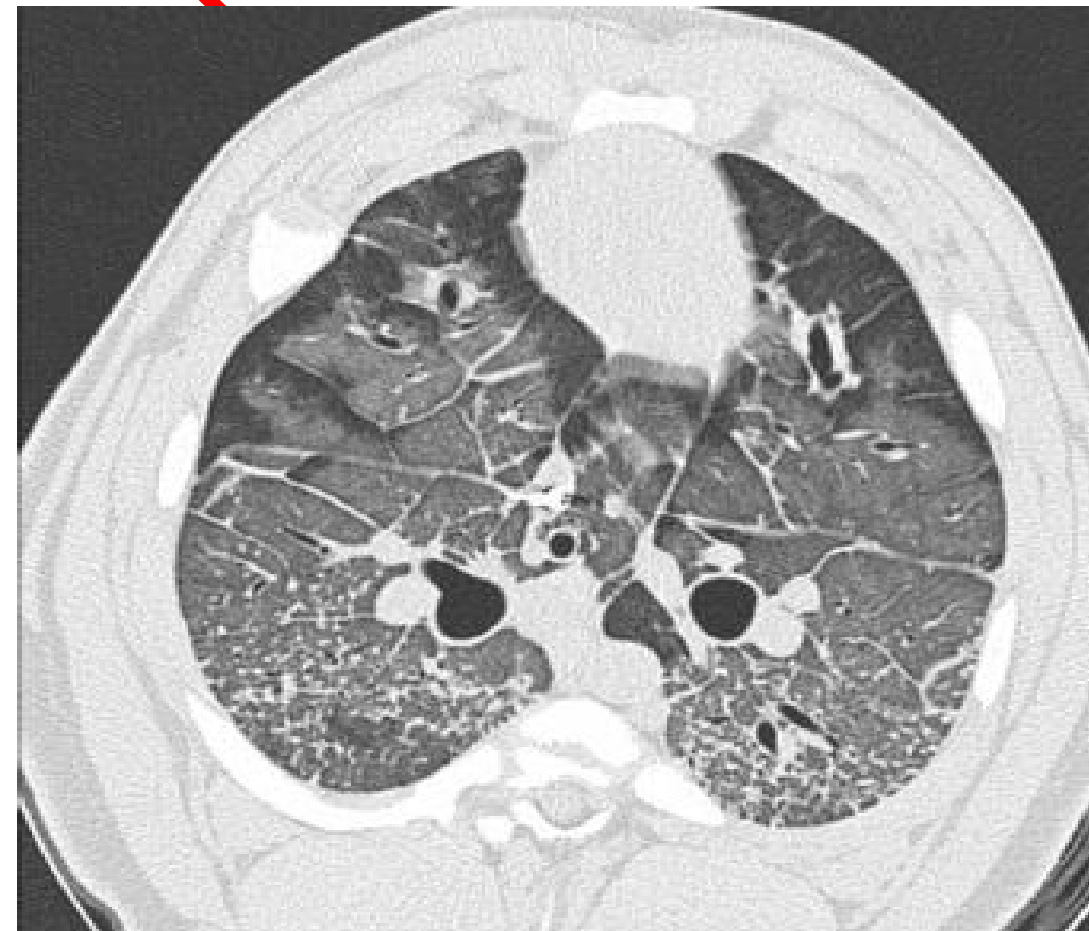
PEEP optimalizace



RM v PRONACI !!!

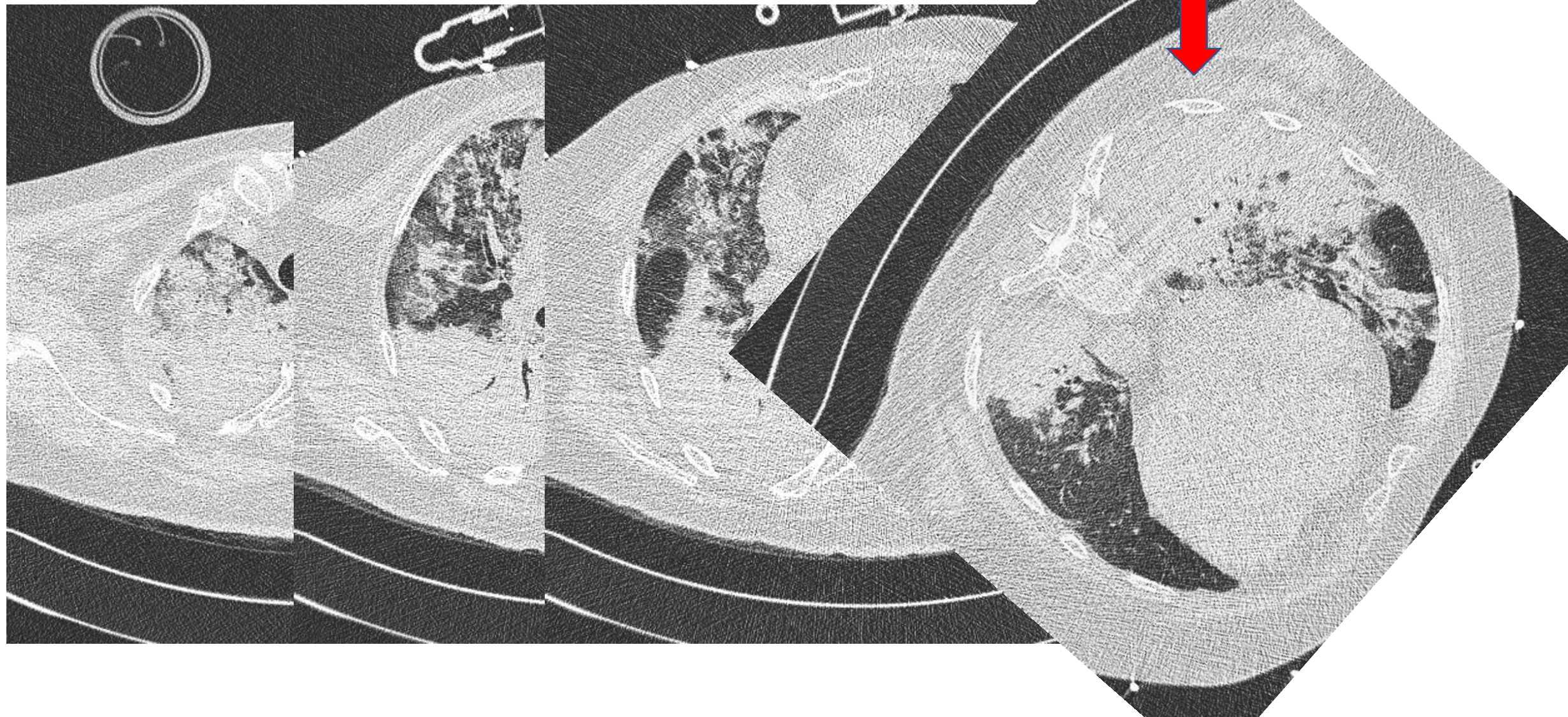


hyperdistenze = volumotrauma



**re-areace
homogenizace**

Efekt SEMI-PRONE 135° / lateral 90°

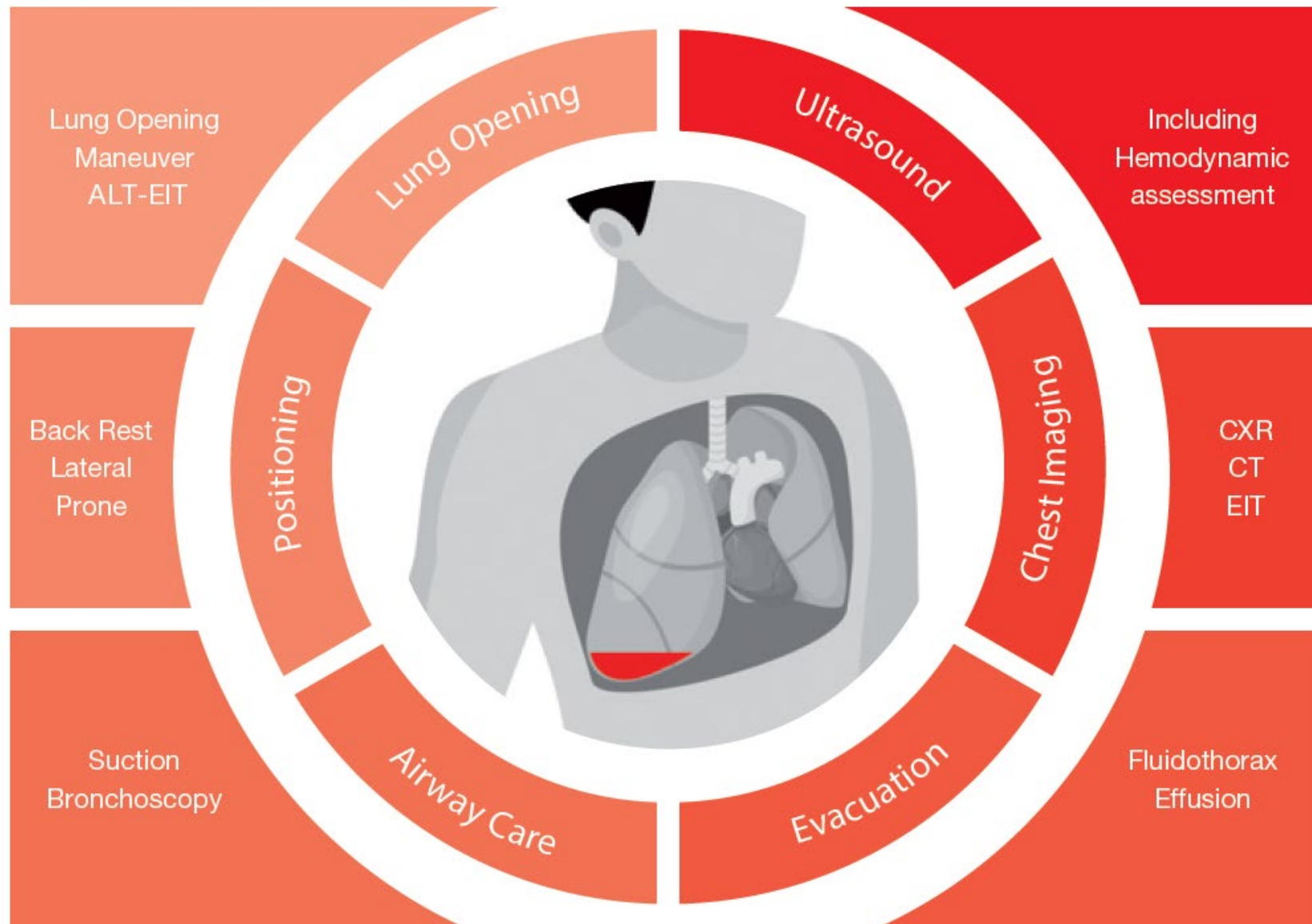


COMPLETE care ... co musíme udělat před RM?

RM

POZICE

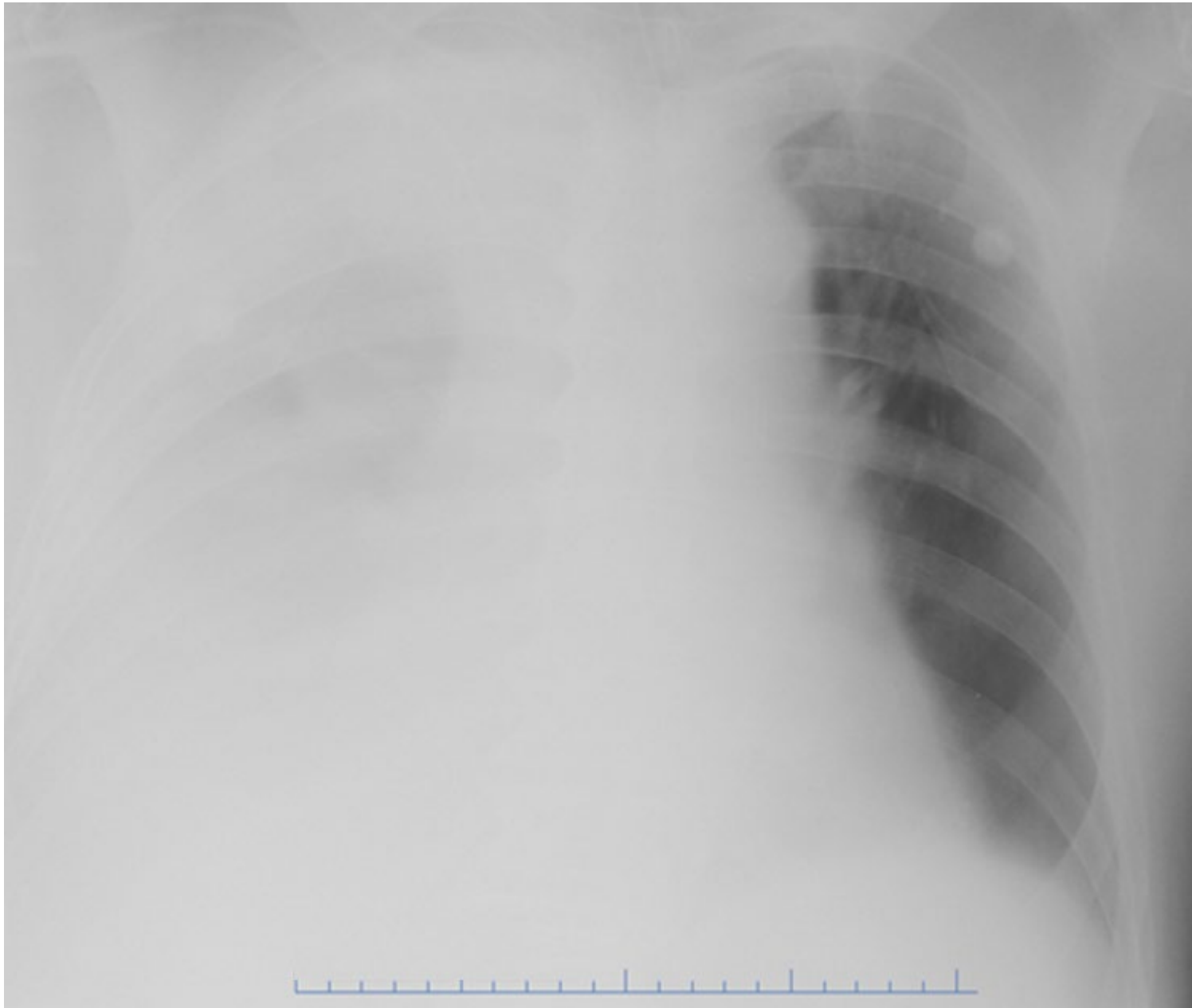
FOB



HEMO

FLUIDO

COMPLETE care ... co musíme udělat před RM?



Recruitment maneuver (RM)

- různá **tíže** plicního postižení i různá **fáze**

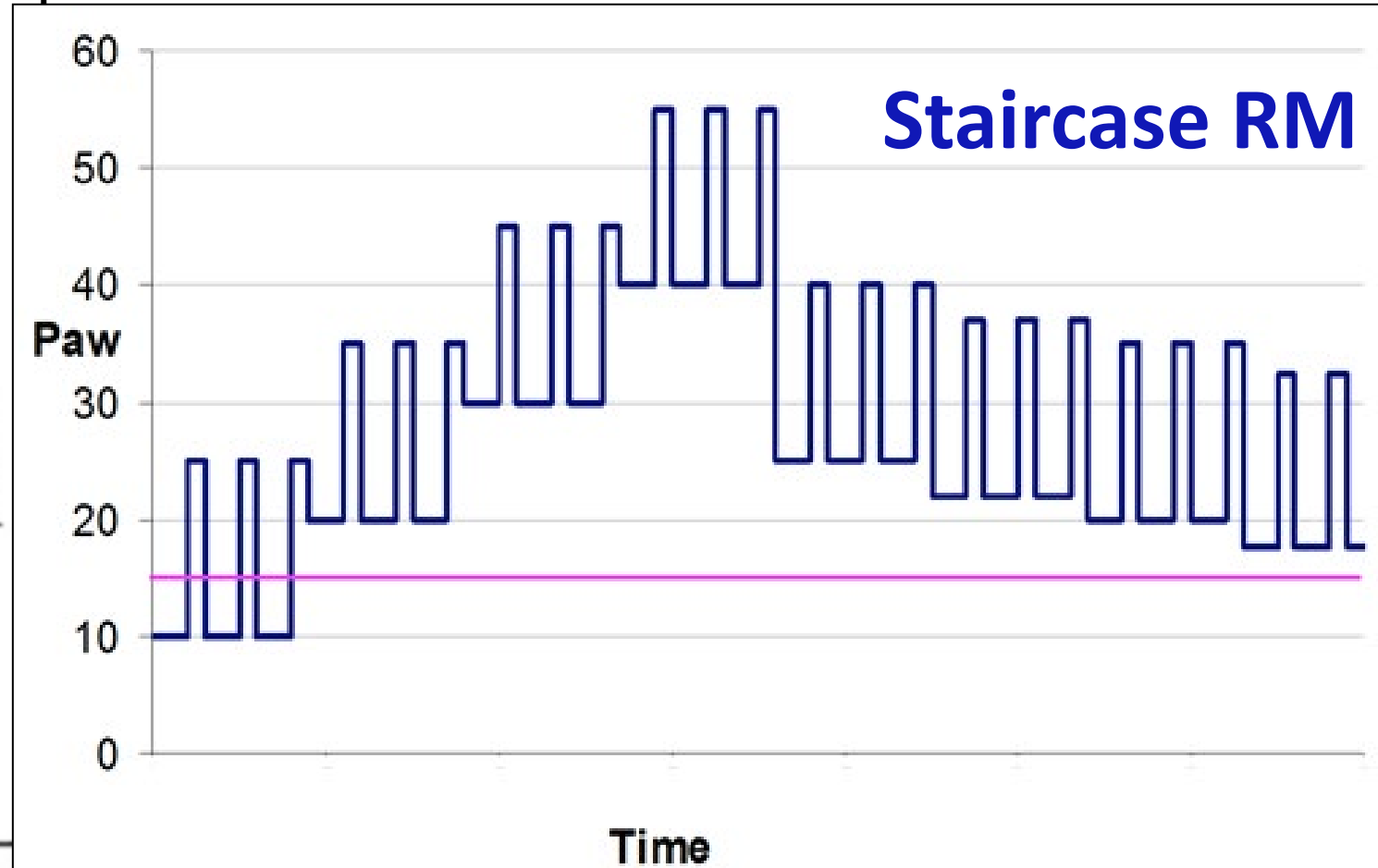
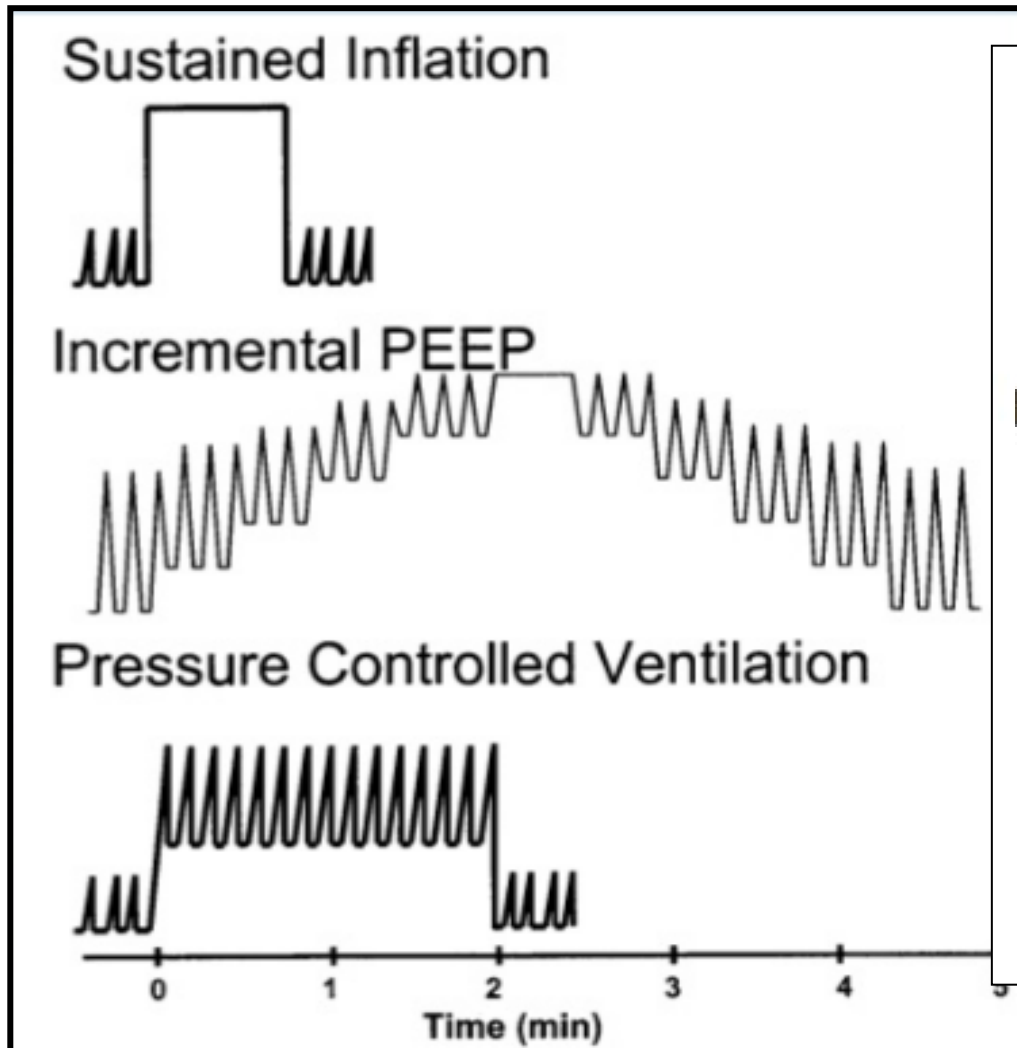
RECRUTABILITA?

- **transpulmonální tlak** dosažený během RM
- **typ recruitment manévru SI / PCV - RM**
- **diference v poloze pacienta (pronace)**
- **nastavení PEEPu po provedeném RM**

RMS – typy provedení

- **incrementally increased PEEP** limiting the **maximum inspiratory pressure**
Rzezinski, *Respir Physiol Neurobiol* 2009
- **PCV applied with escalating PEEP and constant driving pressure**
Villagrà, *Am J Respir Crit Care Med* 2002
- **SRM - staircase RM** progressive increase in PEEP (up to 40 cm H₂O / higher pr. 55 cm H₂O)
Hudgson, *CC* 2011
- **intermittent sighs** to reach a specific plateau pressure in volume or pressure control mode
Steimback, *IMC*,2009, Badet, *Respiratory Care*, 2009
- **(RAMP)** long slow increase in inspiratory pressure up to 40 cmH₂O = **PV tool**
Riva, *Crit Care Med* 2009
- **PCV RM - eSigh**: 10 cmH₂O above LIP, 15 min
Constantin, *CC* 2008
- **PCV RM - PEEP 25 / P_{high} 40**, 30 min
Borges, *AJRCCM*,2006

Recruitment maneuver (RM)



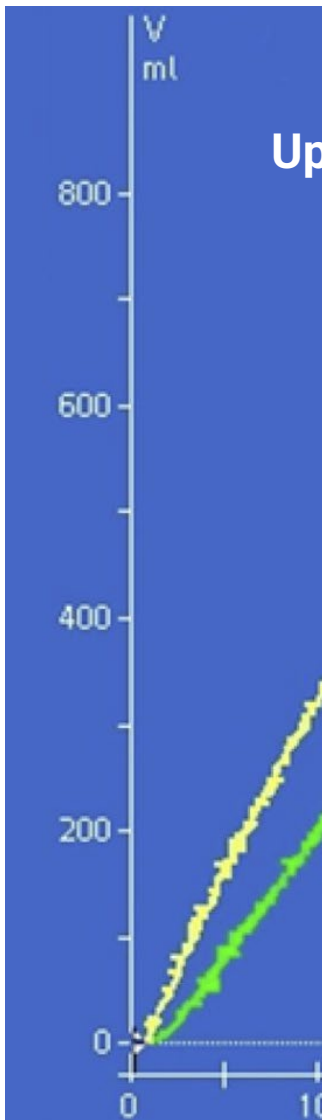
Recrutability?

- **JDE to vůbec?**
- **JAK to udělat?**
- **Záleží na poloze!!!**

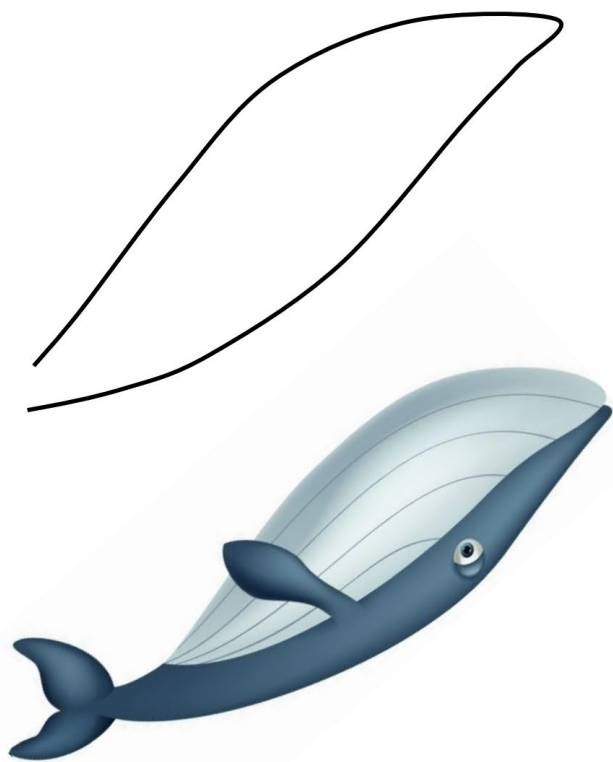
JAK TO ZJISTÍME bedside:

- **PV tool ... Normalized Maximum Distance (NMD)**
- **R/I ratio**
- **PV tool s Insp.pauzou / SI**
- **EIT monitorace? SONO monitorace?**

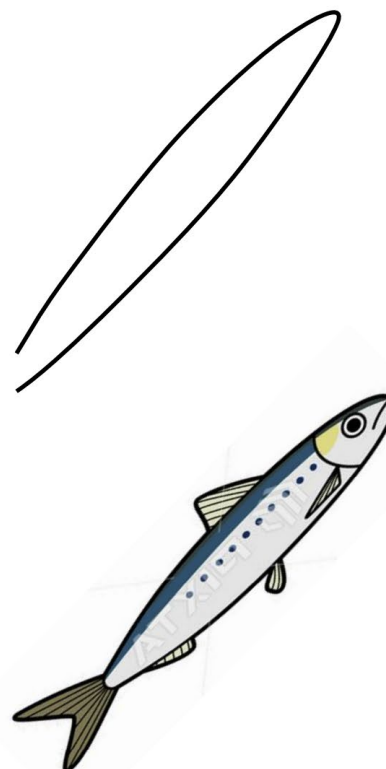
Recrutability – PV tool



high
recruitability



low
recruitability



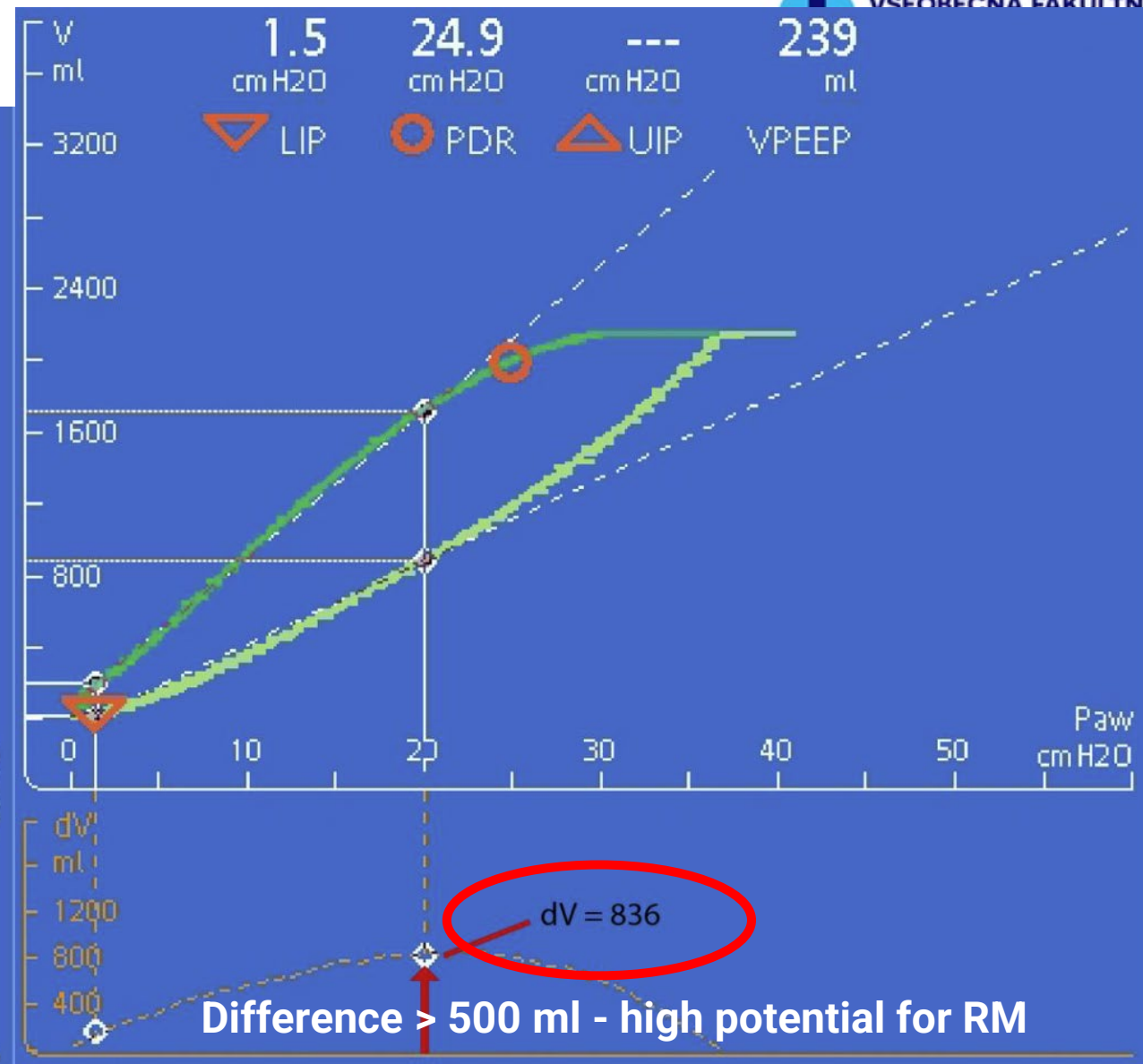
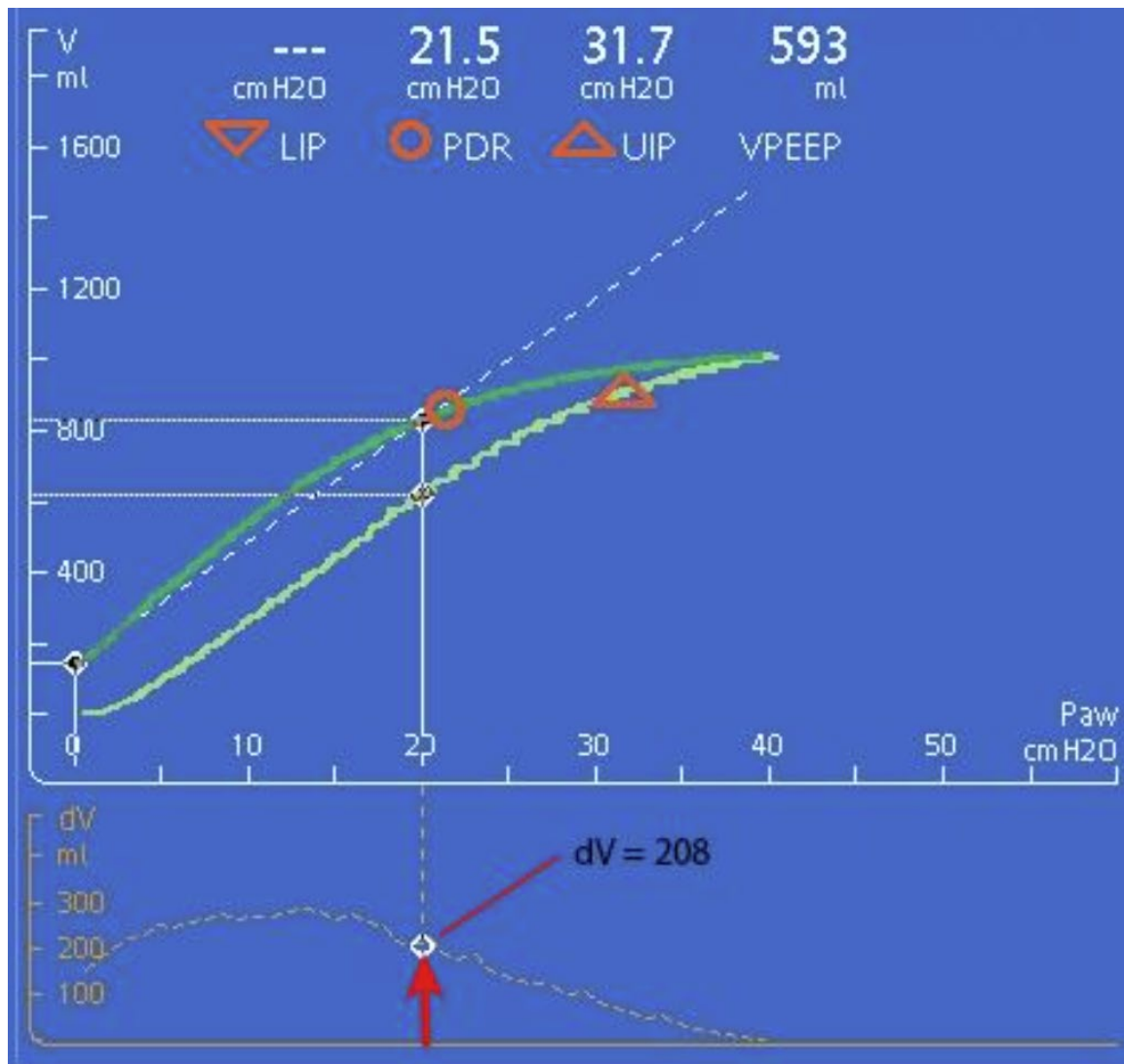
lung
overdistention



or RM

Paw
50 cm H2O

Recrutability – PV tool

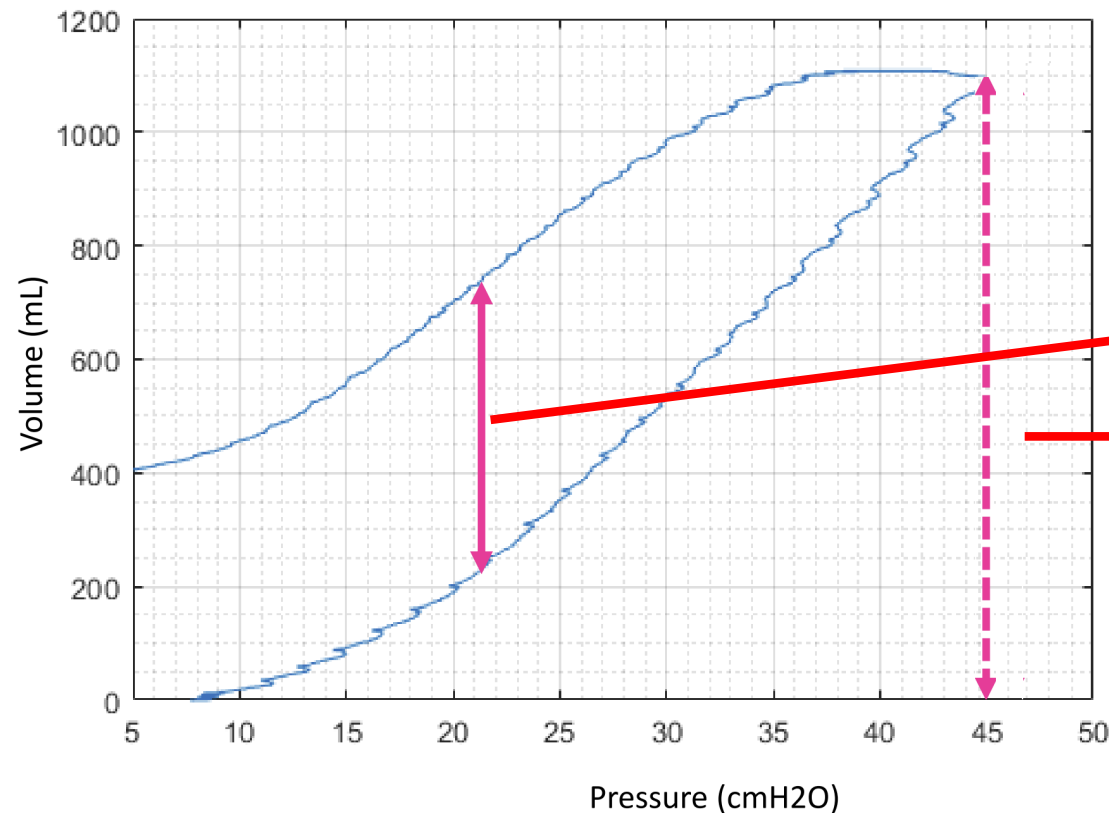


Recrutability – PV tool

NMD

Hysteresis and Lung Recruitment in Acute Respiratory Distress Syndrome Patients: A CT Scan Study*

Davide Chiumello, MD¹⁻³; Jean-Michel Arnal, MD^{4,5}; Michele Umbrello, MD¹; Antonio Cammaroto, MD²;
 Paolo Formenti, MD¹; Giovanni Mistracchi, MD^{1,6}; Luca Bolgiaghi, MD¹; Miriam Gotti, MD¹;
 Dominik Novotni, MD⁵; Sascha Reidt, PhD⁵; Sara Froio, MD¹; Silvia Coppola, MD¹



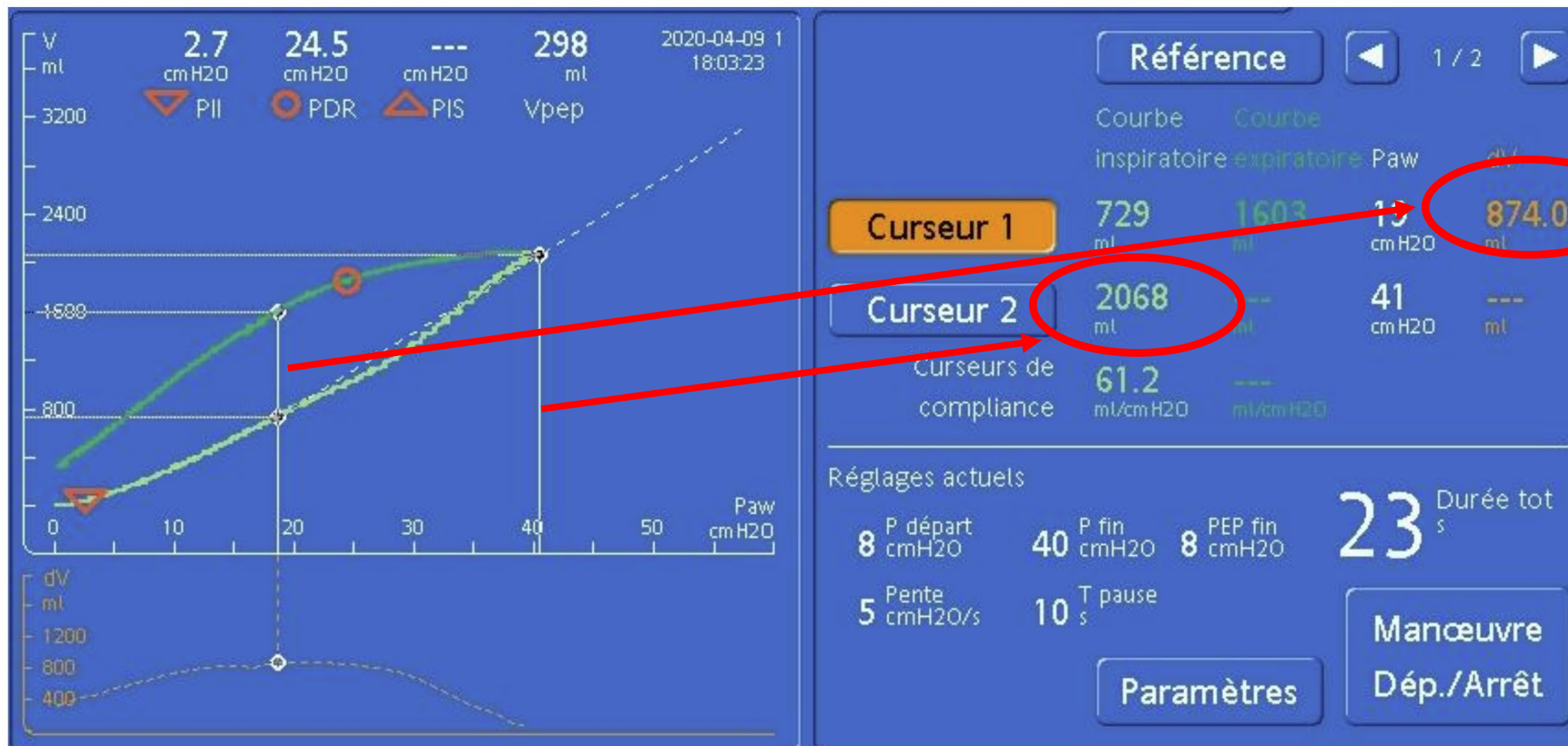
Normalized maximum distance (%) = $\frac{\text{Maximum distance between inflation and deflation (mL)}}{\text{Maximum volume (mL)}}$

If > 41%, 75% chance to recruit

Recrutability – PV tool

Normalized maximum distance

e

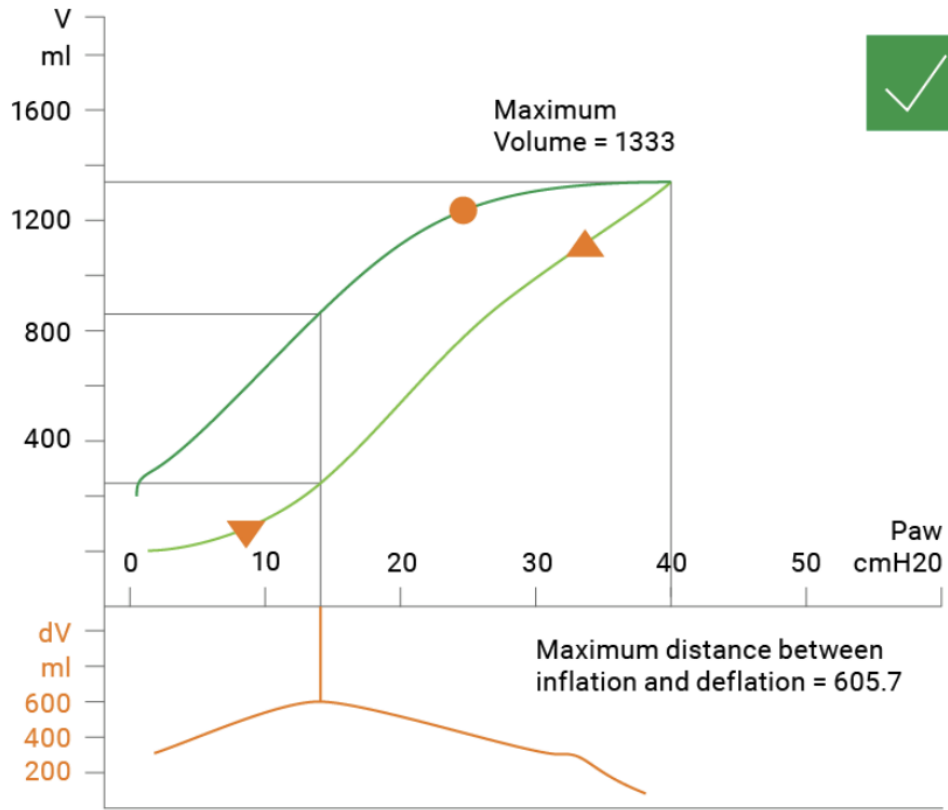


immaroto, MD²;
D¹;

Normalized maximum distance = $874 / 2068 = 42\%$

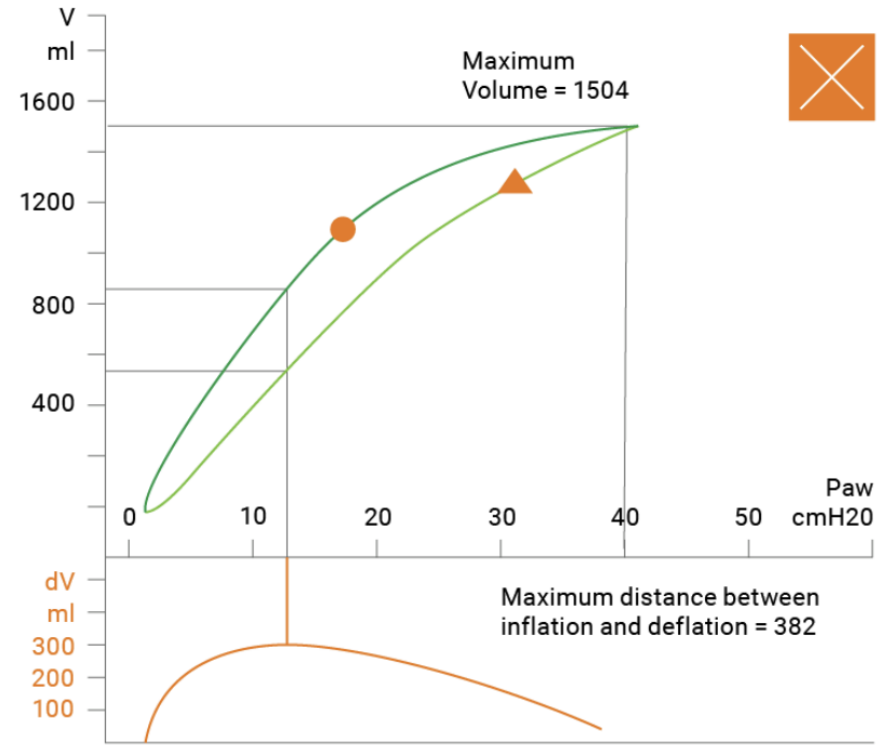
If $> 41\%$, 75% chance to recruit

Recrutability – PV too



$$\text{NMD} = \frac{\text{Maximum distance between inflation and deflation}}{\text{Maximum Volume}} = \frac{606}{1333}$$

NMD = 0.45 = High potential for recruitment



$$\text{NMD} = \frac{\text{Maximum distance between inflation and deflation}}{\text{Maximum Volume}} = \frac{328}{1504}$$

NMD = 0.22 = Low potential for recruitment

Recrutability

Recruitment to Inflation Ratio

Potential for Lung Recruitment Estimated by the Recruitment-to-Inflation Ratio in Acute Respiratory Distress Syndrome

A Clinical Trial

Lu Chen^{1,2,3}, Lorenzo Del Sorbo^{3,4}, Domenico L. Grieco⁵, Detajin Junhasavasdikul⁶, Nuttapol Rittayamai⁷, Ibrahim Soliman⁸, Michael C. Sklar³, Michela Rauseo⁹, Niall D. Ferguson^{3,4}, Eddy Fan^{3,4}, Jean-Christophe M. Richard¹⁰, and Laurent Brochard^{1,2,3*}

- Patients with ARDS were **ventilated at 15 and 5 cm H₂O of PEEP**
- Abruptly releasing PEEP (from 15 to 5 cm H₂O) increases expired volume:
- the **difference between this volume and the volume predicted by compliance at low PEEP** (or above airway opening pressure) estimated the recruited volume by PEEP.
- this recruited volume divided by the effective pressure change gave the compliance of the recruited lung; the **ratio of this compliance to the compliance at low PEEP** gave the **recruitment-to-inflation ratio**
- **recruitment-to-inflation ratio (median, 0.5; range, 0-2.0) correlated with both oxygenation at low PEEP and the oxygenation response**

(S)CMV

71
5
35
Ppeak
cmH2O

22
0.6
11.0
ExpMinVol
l/min

850
85
941
VTE
ml

42
0
22
fTotal
b/min

0.57
RCexp
s



Modes

25
b/min
Rate

420
ml
Vt

5
cmH2O
PEEP/CPAP

40
%
Oxygen

Controls

Alarms

$$R/I \text{ ratio} = \frac{V_{Te_{H \rightarrow L}} - V_{Te_H}}{V_{Ti}} \times \frac{P_{plat_L} - PEEP_L}{PEEP_H - PEEP_L} - 1$$

AJRCCM 2020;201:176-87

R/I = 0.6

Rittayamai⁷,

Recruitment to Inflation Ratio

Calculate

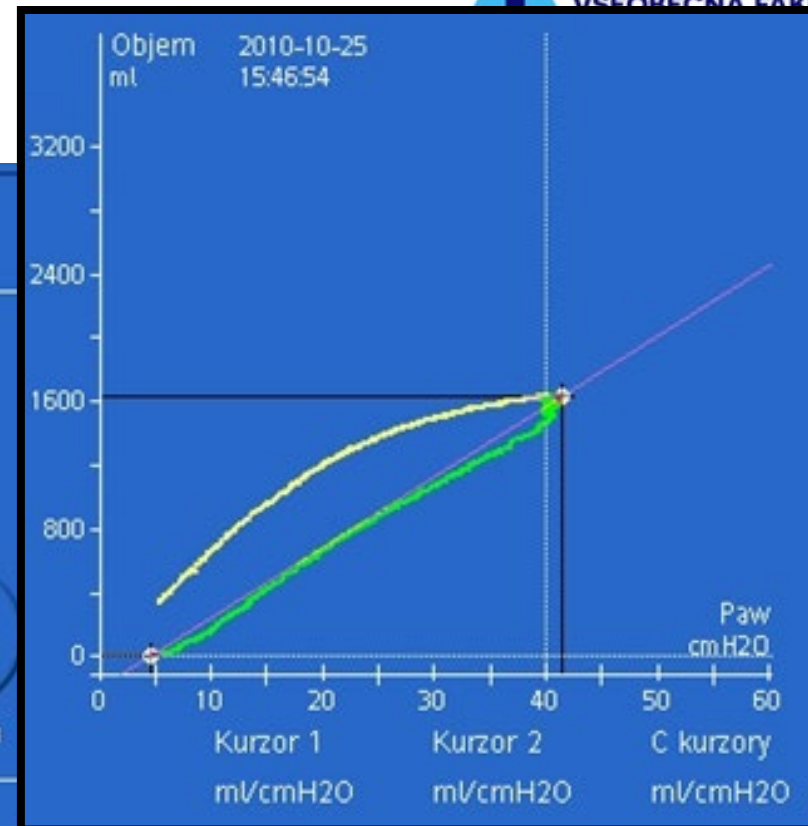
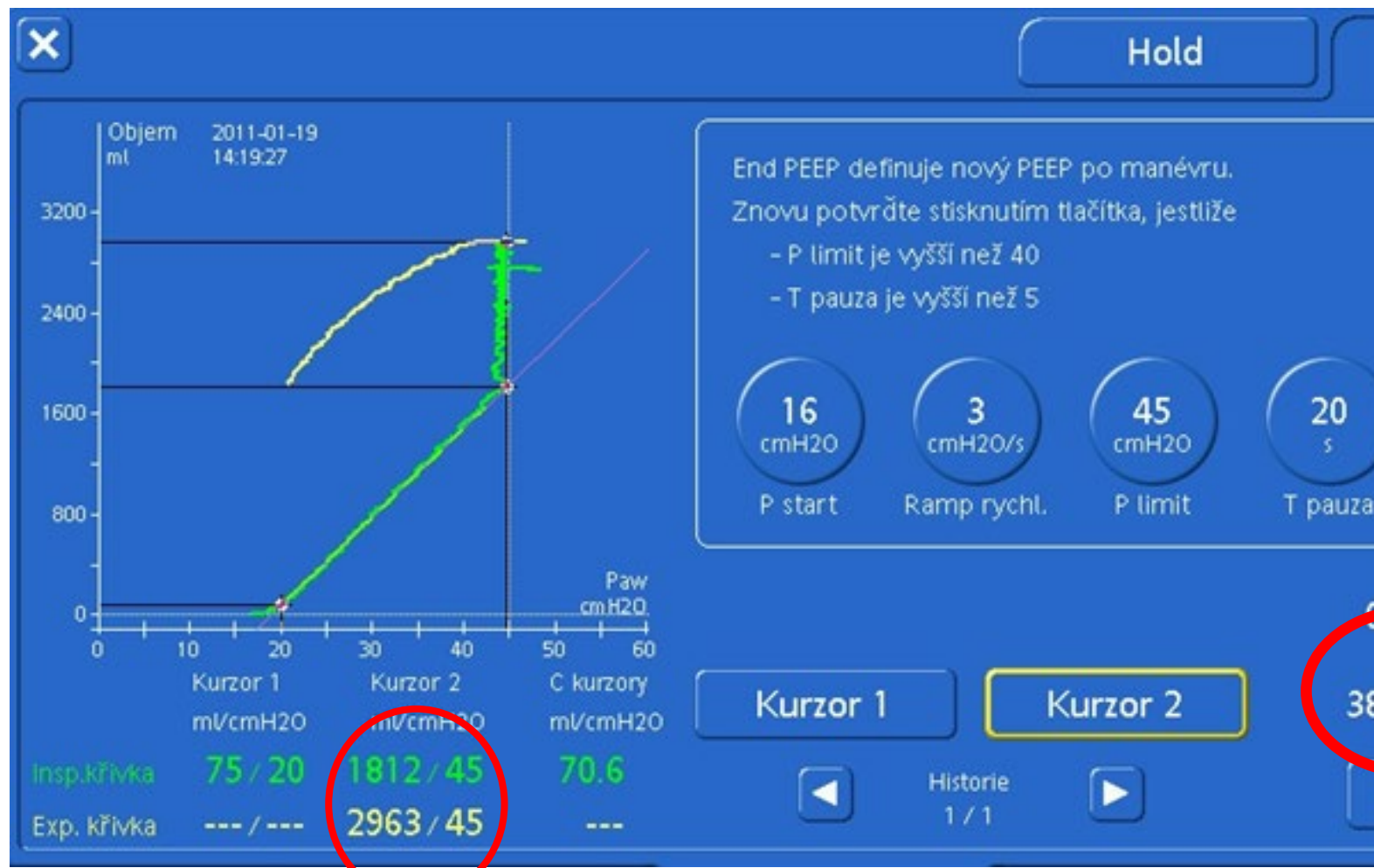
0.57

Recruitment to Inflation Ratio

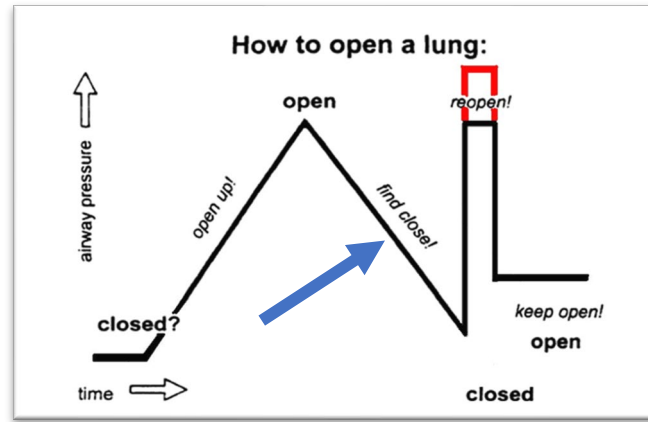
The value below is the ratio between the compliance of the recruited lung to that of the respiratory system. Values ≥ 0.5 suggest more potential for lung recruitment with respect to lung inflation.

15	400	398
cm H ₂ O	ml	ml
Low PEEP	VT exhaled from high to low PEEP	Plateau Pressure (at low PEEP)
5	818	17
cm H ₂ O	ml	cm H ₂ O

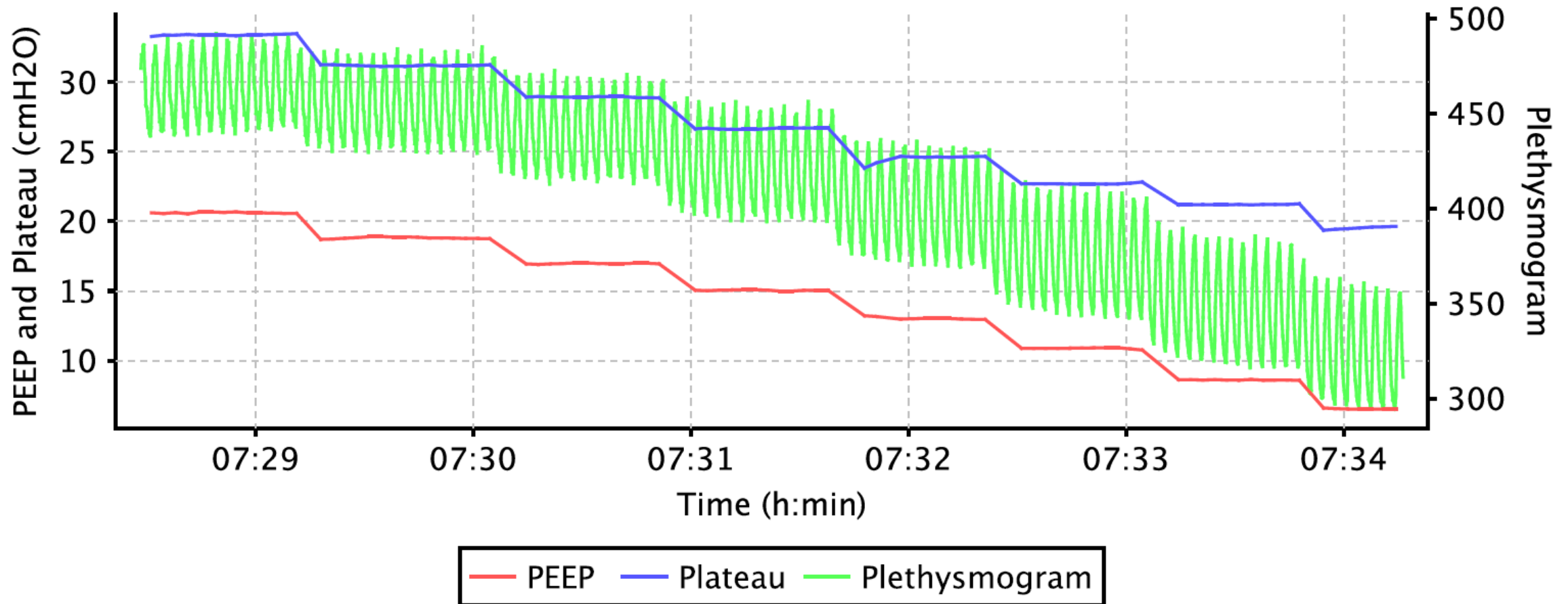
Recrutability – PV tool + pauza



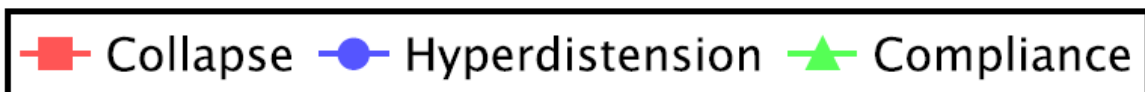
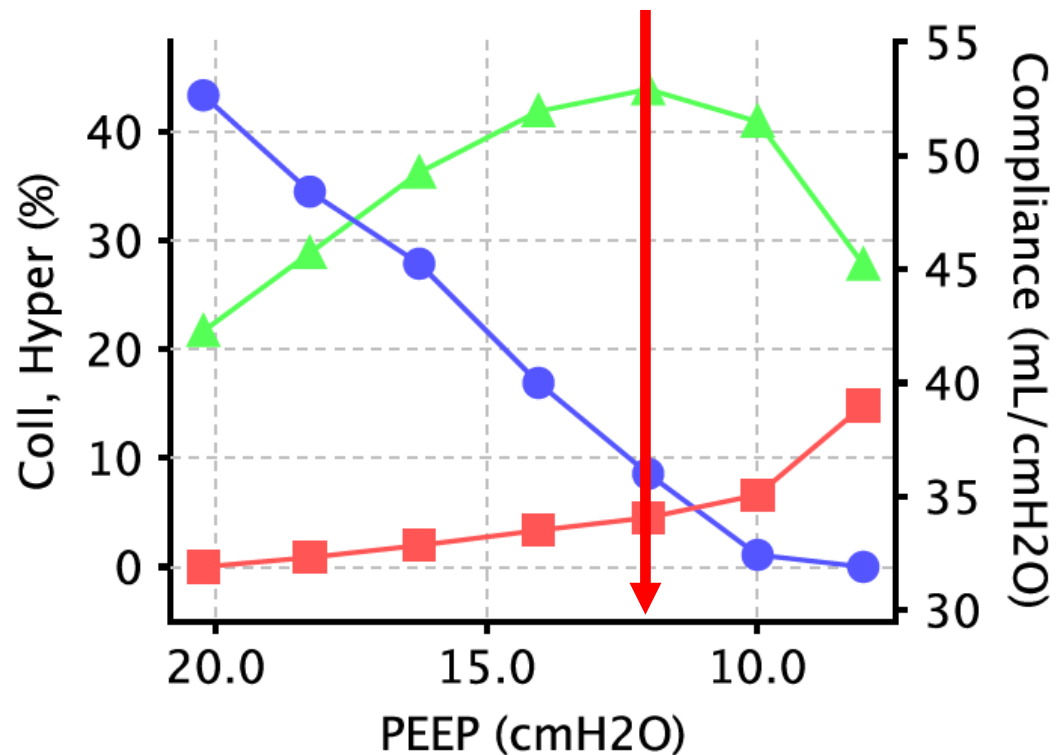
PEEP titrace



PEEP Titration Curves



PEEP titrace – GLOBÁLNÍ parametry

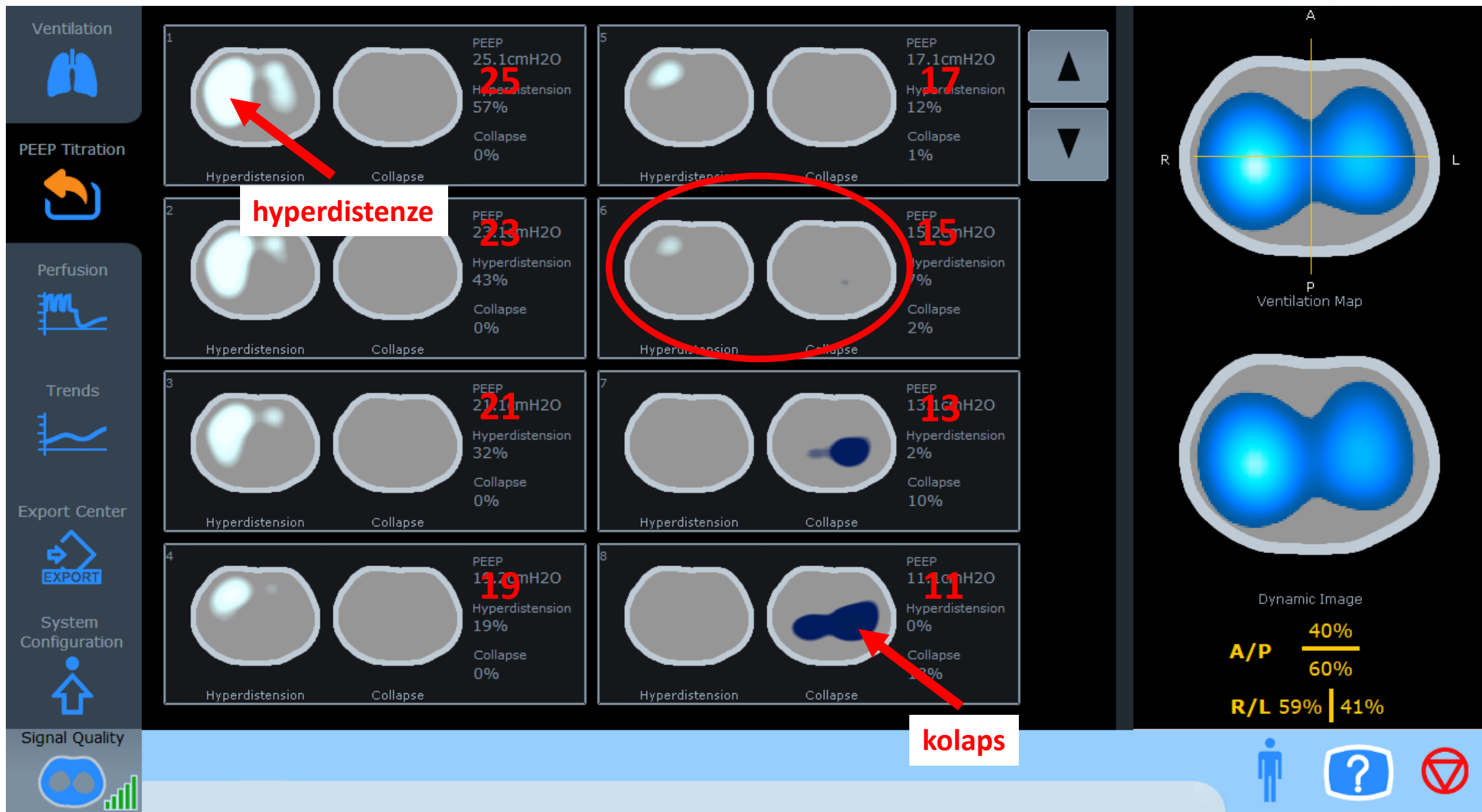


PEEP (cmH ₂ O)	Compliance (mL/cmH ₂ O)	Hyperdist. (%)	Collapse (%)
20.2	42	43.3	0.0
18.3	46	34.5	0.9
16.2	49	27.9	2.0
14.0	52	16.9	3.4
12.0	53	8.6	4.5
10.0	51	1.1	6.6
8.0	45	0.0	14.8

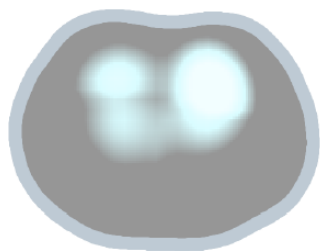
PEEP titrace

- zobrazovací metody – CT, ultrazvuk
- globalní parametry - compliance, oxygenace, P/V křivka, stress index, pomocí Volumetric CO₂
- titrace transpulmonálního tlaku měřením eosophageálního tlaku

EIT - PEEP titrace – REGIONÁLNÍ distribuce



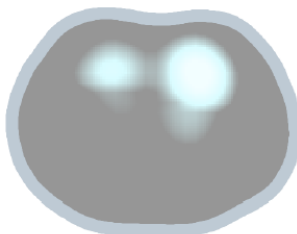
PEEP titrace pomocí EIT



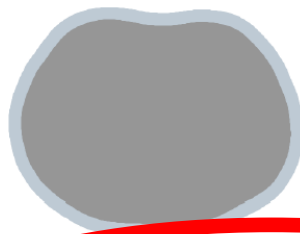
Hyperdistension



PEEP: 18.4 cmH₂O
Hyperdistension: 27.8%
Collapse: 0.1%
Compliance: 32.2 mL/cmH₂O

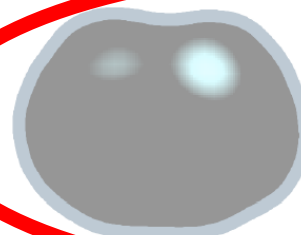


Hyperdistension



PEEP: 16.2 cmH₂O
Hyperdistension: 20.1%
Collapse: 0.1%
Compliance: 35.9 mL/cmH₂O

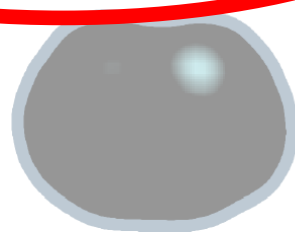
Hyperdistension



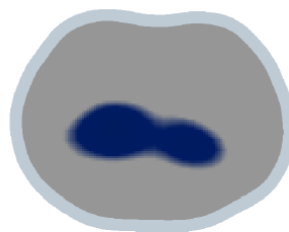
Hyperdistension



PEEP: 14.2 cmH₂O
Hyperdistension: 9.7%
Collapse: 0.3%
Compliance: 40.2 mL/cmH₂O



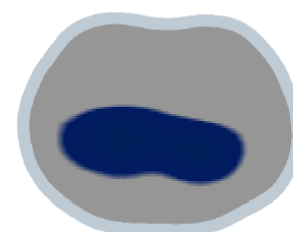
Hyperdistension



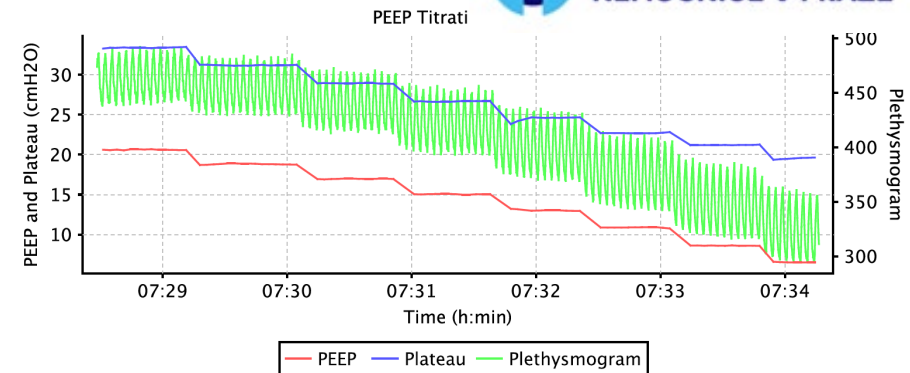
PEEP: 12.1 cmH₂O
Hyperdistension: 7.5%
Collapse: 9.6%
Compliance: 41.0 mL/cmH₂O



Hyperdistension



PEEP: 10.1 cmH₂O
Hyperdistension: 3.4%
Collapse: 17.5%
Compliance: 38.7 mL/cmH₂O



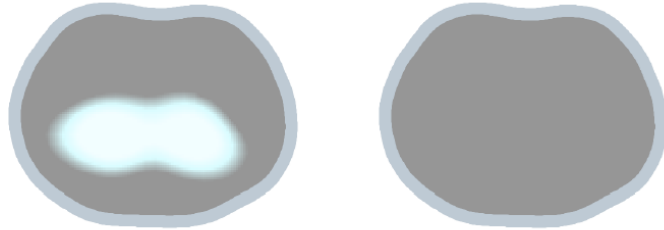
Optimal PEEP:
Minimální hyperdistenze
Minimální kolaps (do 5%)

PEEP titrace pomocí EIT – stejný pacient



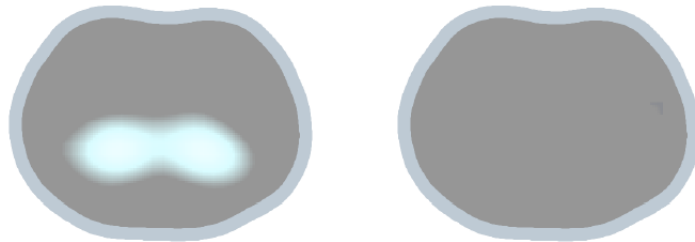
PEEP: 18.2 cmH₂O
Hyperdistension: 36.9%
Collapse: 1.0%
Compliance: 28.8 mL/cmH₂O

Hyperdistension



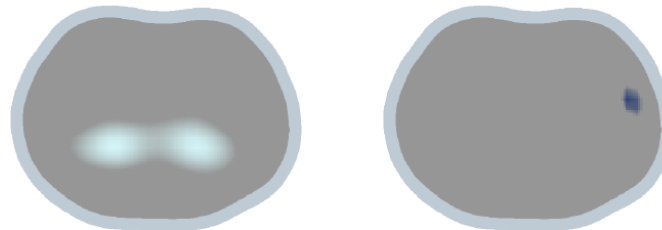
PEEP: 16.2 cmH₂O
Hyperdistension: 31.6%
Collapse: 1.5%
Compliance: 32.3 mL/cmH₂O

Hyperdistension



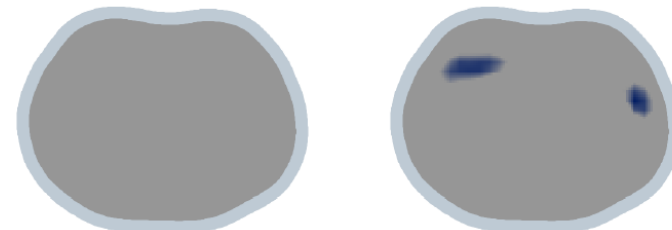
PEEP: 14.3 cmH₂O
Hyperdistension: 19.5%
Collapse: 2.3%
Compliance: 36.5 mL/cmH₂O

Hyperdistension

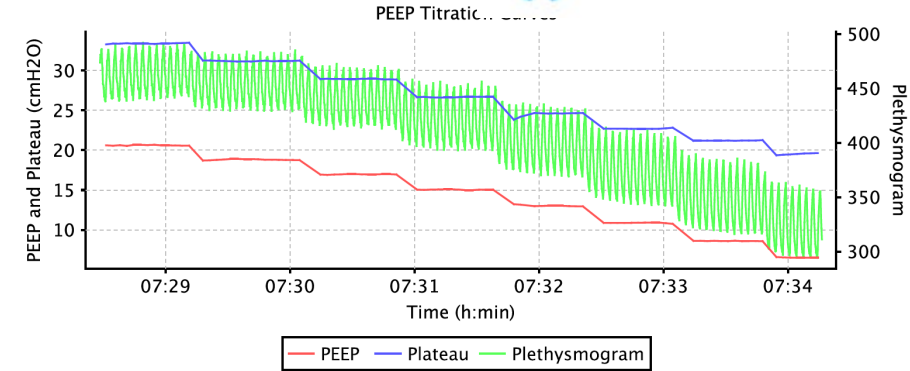


PEEP: 12.4 cmH₂O
Hyperdistension: 13.0%
Collapse: 3.7%
Compliance: 38.5 mL/cmH₂O

Hyperdistension



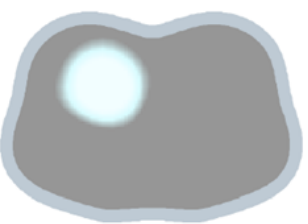
PEEP: 10.6 cmH₂O
Hyperdistension: 6.2%
Collapse: 5.7%
Compliance: 42.1 mL/cmH₂O



PRONACE

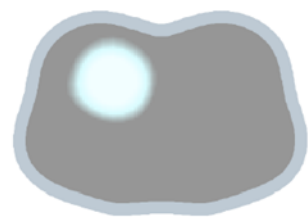
Homogenizace PRONACÍ

PEEP titrace pomocí EIT



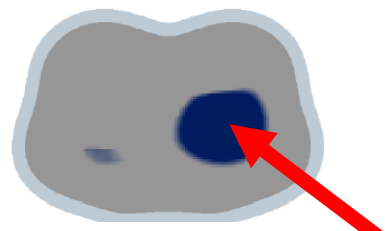
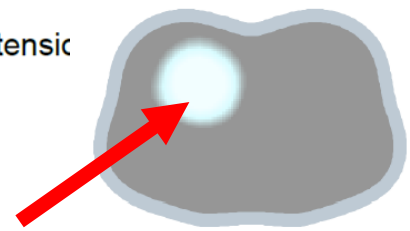
PEEP: 16.0 cmH₂O
 Hyperdistension: 15.5%
 Collapse: 0.0%
 Compliance: 42.4 mL/cmH₂O

Hyperdistension



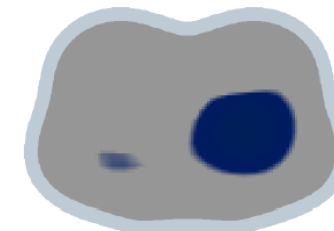
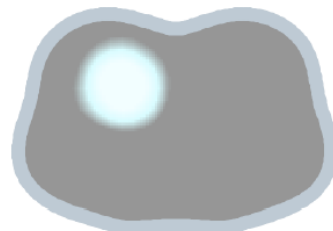
PEEP: 14.1 cmH₂O
 Hyperdistension: 14.2%
 Collapse: 1.4%
 Compliance: 41.8 mL/cmH₂O

Hyperdistensic



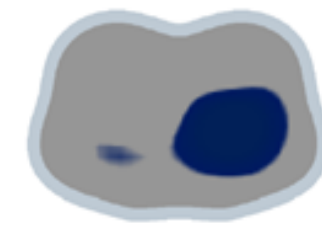
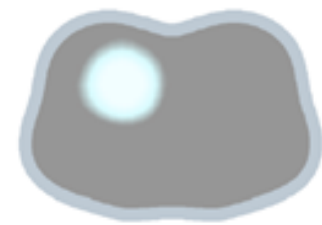
PEEP: **11.9 cmH₂O**
 Hyperdistension: 14.2%
 Collapse: 8.8%
 Compliance: 40.7 mL/cmH₂O

Hyperdistension



PEEP: 10.3 cmH₂O
 Hyperdistension: 13.2%
 Collapse: 10.7%
 Compliance: 109.7 mL/cmH₂O

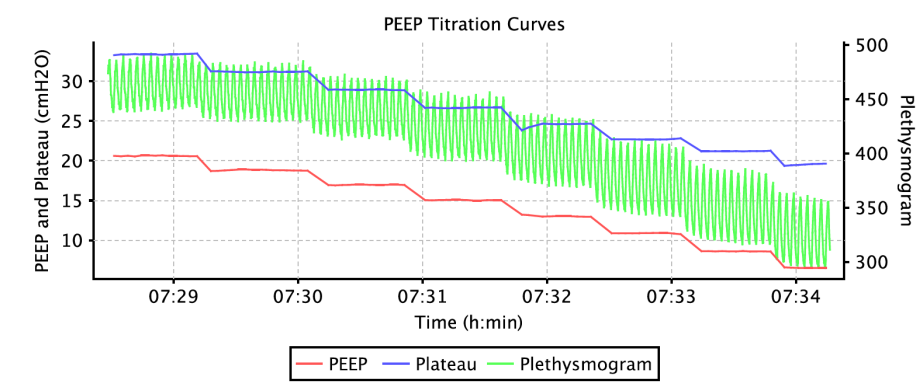
Hyperdistension



PEEP: 8.1 cmH₂O
 Hyperdistension: 12.9%
 Collapse: 17.3%
 Compliance: 37.7 mL/cmH₂O

Hyperdistension

Cumulative Collapse



**Optimal PEEP:
 Nejmíň hyperdistenze
 Nejmíň kolapsu (do 5%)**

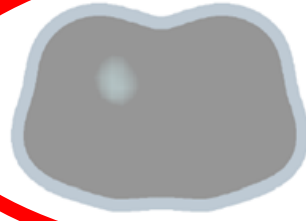
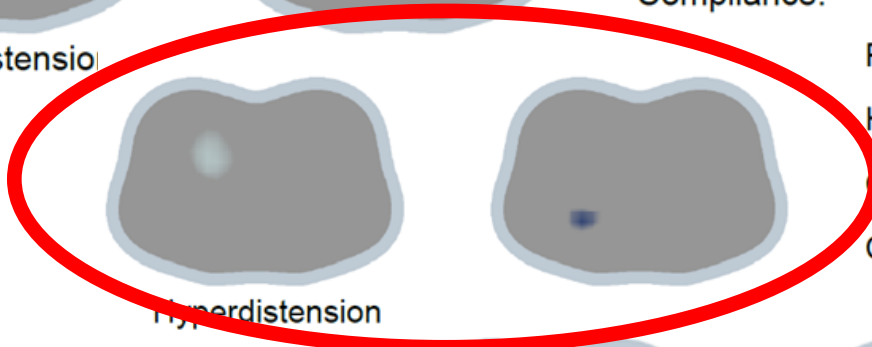
PEEP titrace pomocí EIT – stejný pacient



Hyperdistension



Hyperdistensio



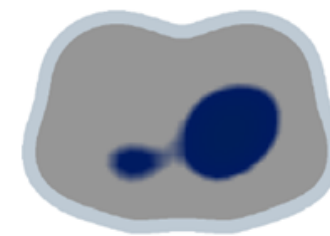
Hyperdistensio



Hyperdistension



Hyperdistension



Cumulative Collapse

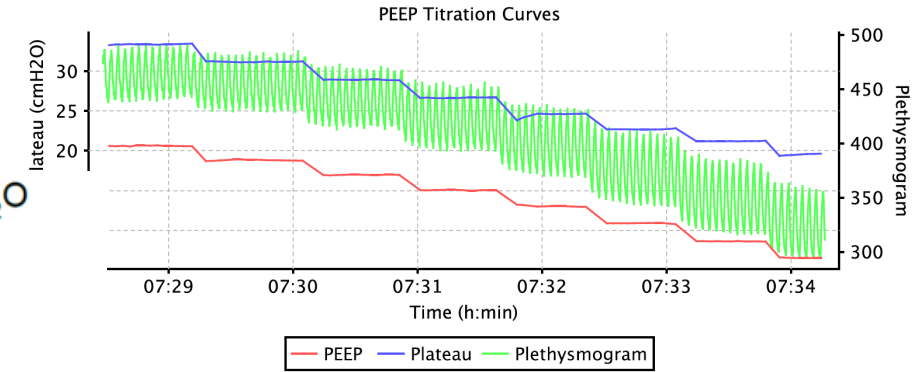
PEEP: 16.0 cmH₂O
 Hyperdistension: 12.2%
 Collapse: 0.5%
 Compliance: 42.7 mL/cmH₂O

PEEP: 14.0 cmH₂O
 Hyperdistension: 9.6%
 Collapse: 1.9%
 Compliance: 40.6 mL/cmH₂O

PEEP: 12.1 cmH₂O
 Hyperdistension: 4.4%
 Collapse: 4.3%
 Compliance: 41.4 mL/cmH₂O

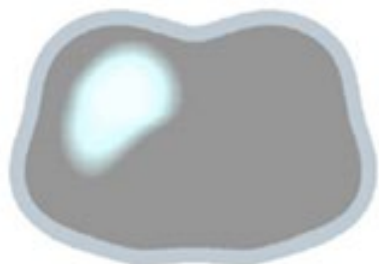
PEEP: 9.9 cmH₂O
 Hyperdistension: 4.1%
 Collapse: 6.5%
 Compliance: 40.3 mL/cmH₂O

PEEP: 8.1 cmH₂O
 Hyperdistension: 0.1%
 Collapse: 13.2%
 Compliance: 41.4 mL/cmH₂O



Homogenizace pomocí ALT

Cílená ALT jako RM???

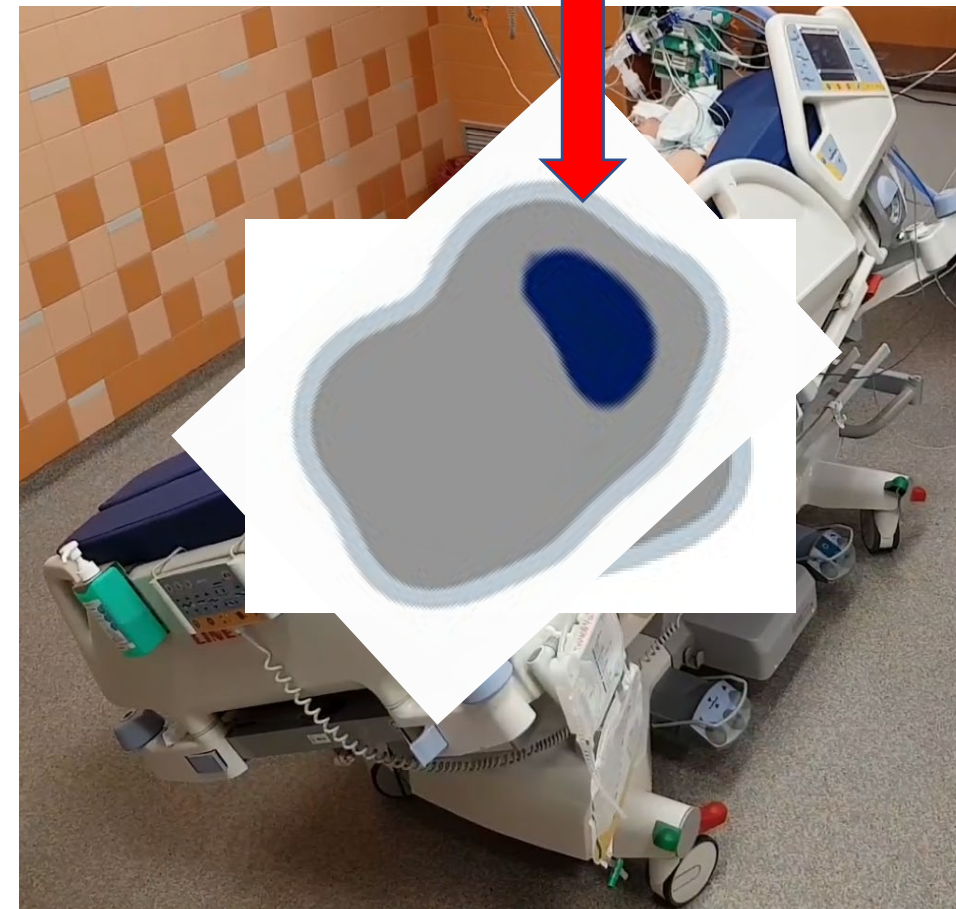


Hyperdistension

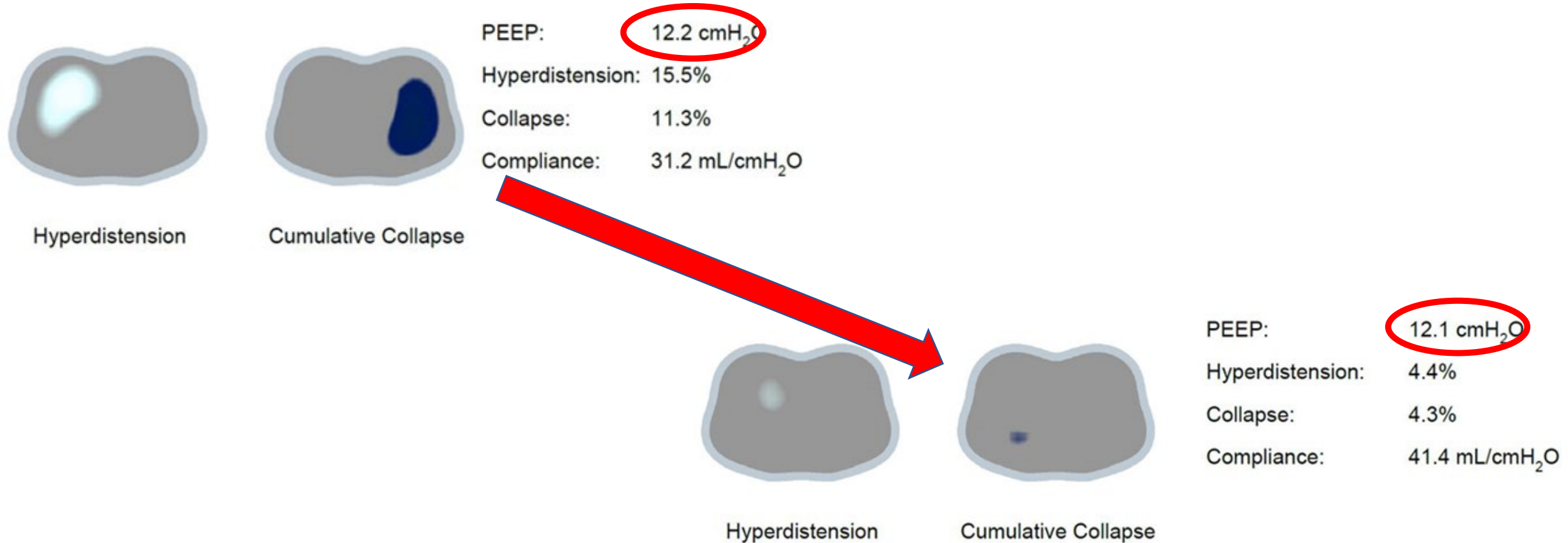


Cumulative Collapse

PEEP: 12.2 cmH₂O
Hyperdistension: 15.5%
Collapse: 11.3%
Compliance: 31.2 mL/cmH₂O

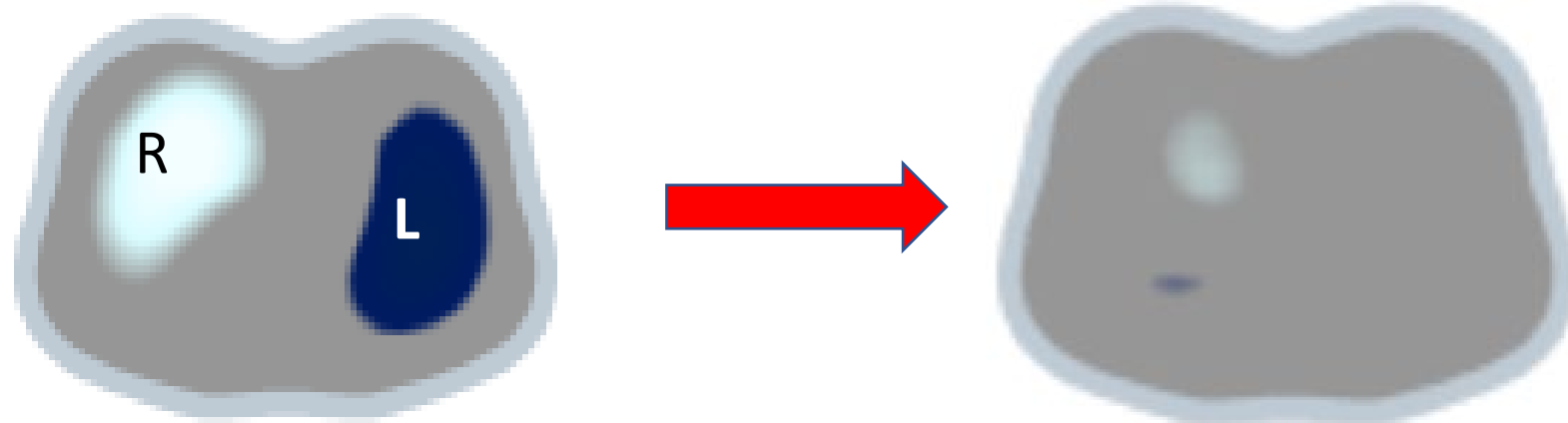


Cílená ALT jako RM???



po 15 hodinách ALT - R 30° / záda

Cílená ALT jako RM???



na stejném PEEPu:

redukce hyperdistenze

71%

redukce kolapsu

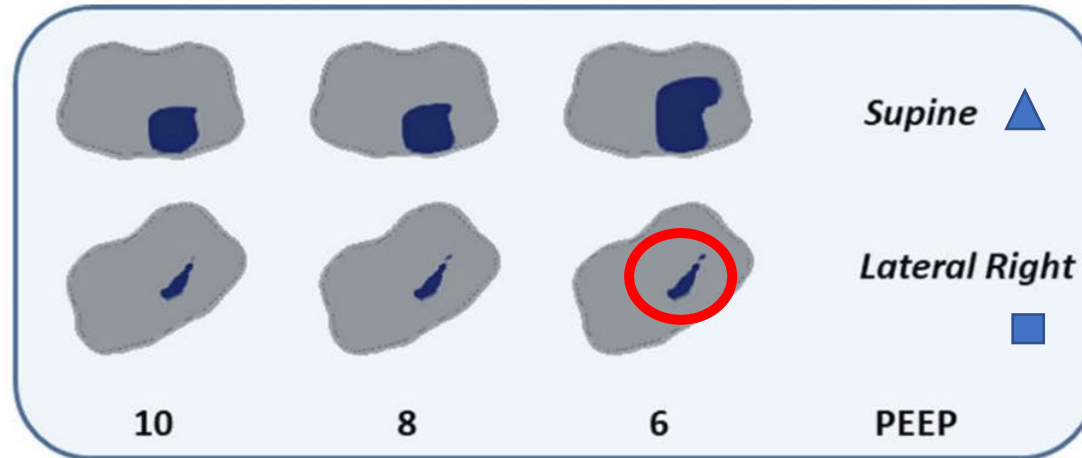
82%

zvýšení compliance

28%

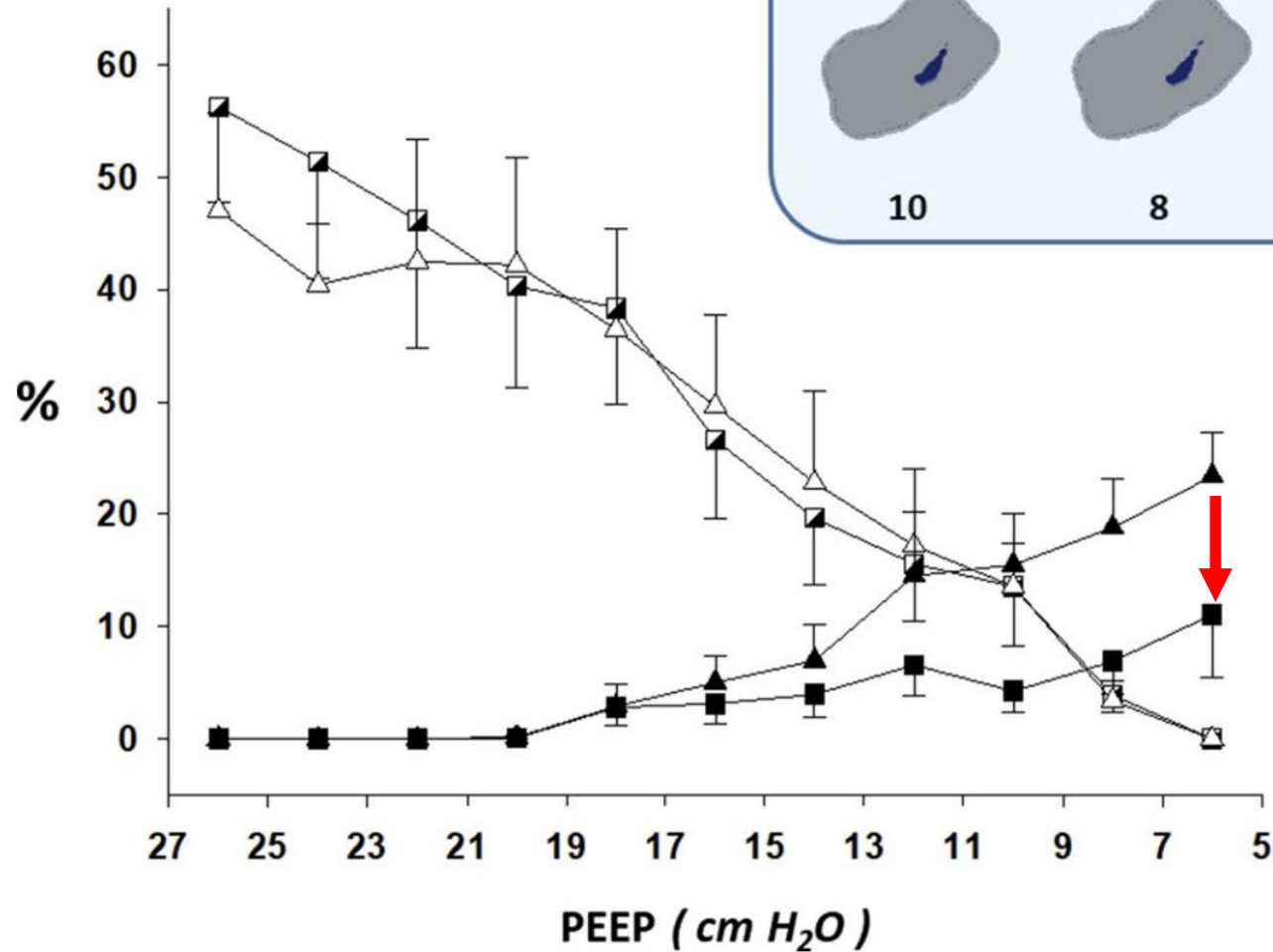
po 15 hodinách ALT - R 30° / zřada

Cílené POLOHOVÁNÍ – ALT



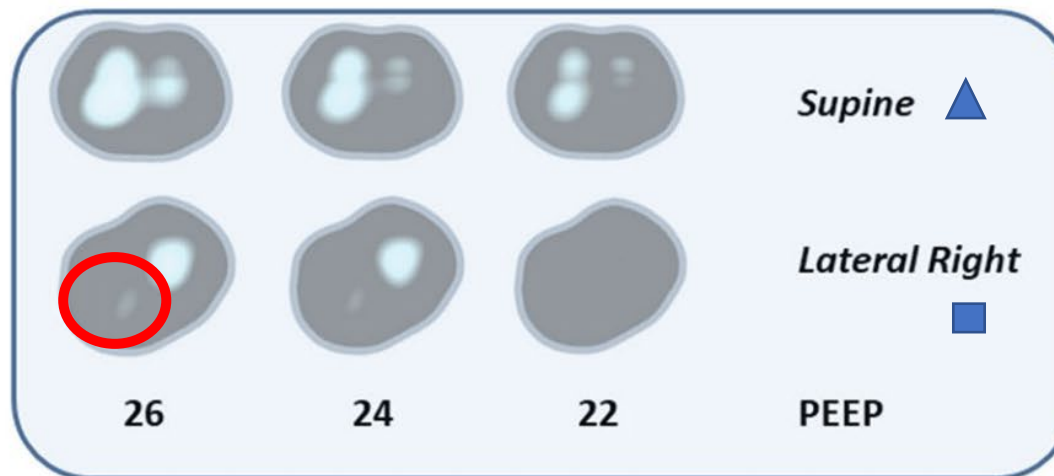
ositioning decreases
overdistension
ciated ARDS

atista Boraes^{1*}, Glasielle Cristina Alcalá³,
;Tejkl¹, Marcelo Amato³ and Otomar Kittnar¹
Mlček et al. *BMC Pulm Med* (2021) 21:133



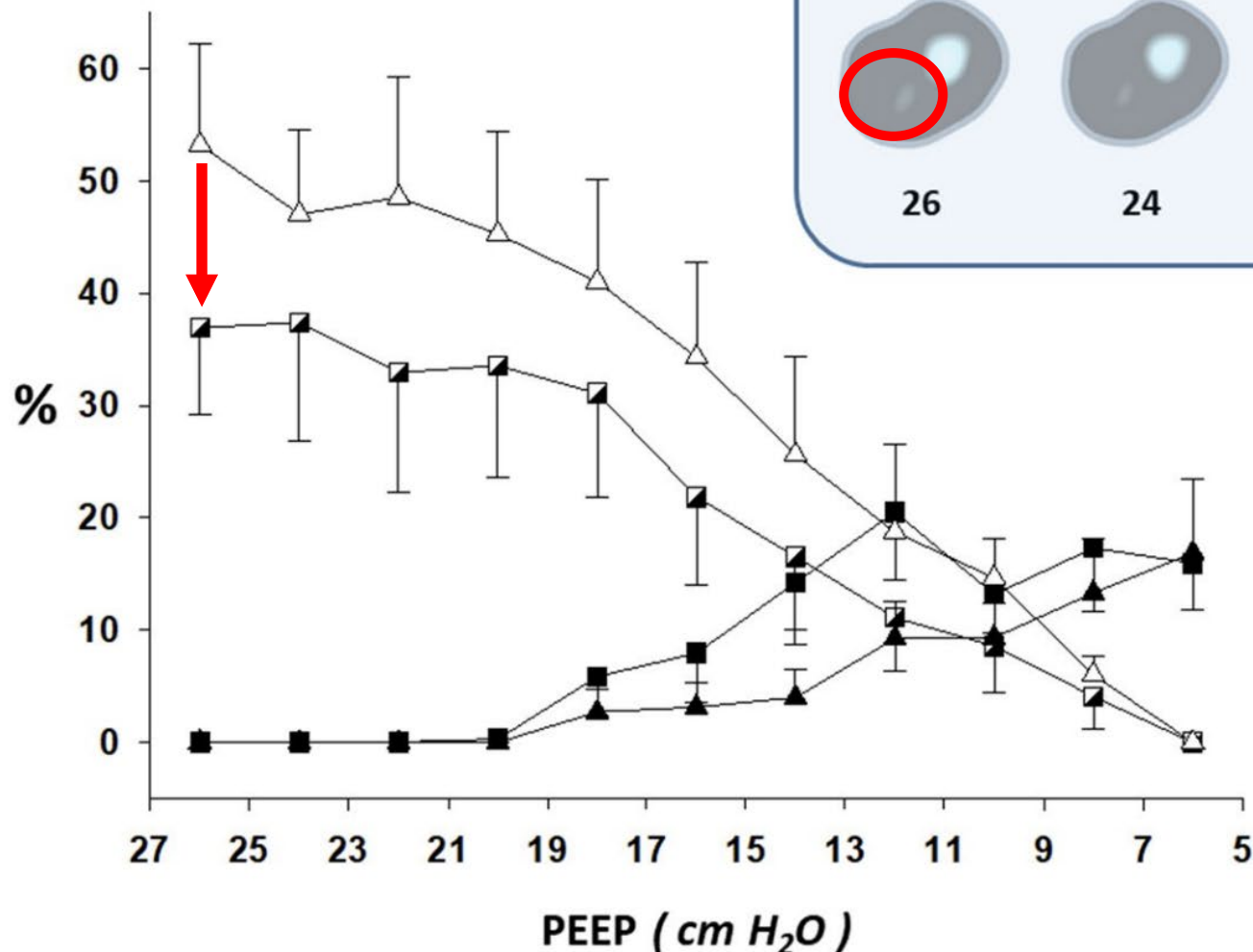
Left Lung
less collapse P=0.014

Cílené POLOHOVÁNÍ – ALT



Positioning decreases
overdistension
related ARDS

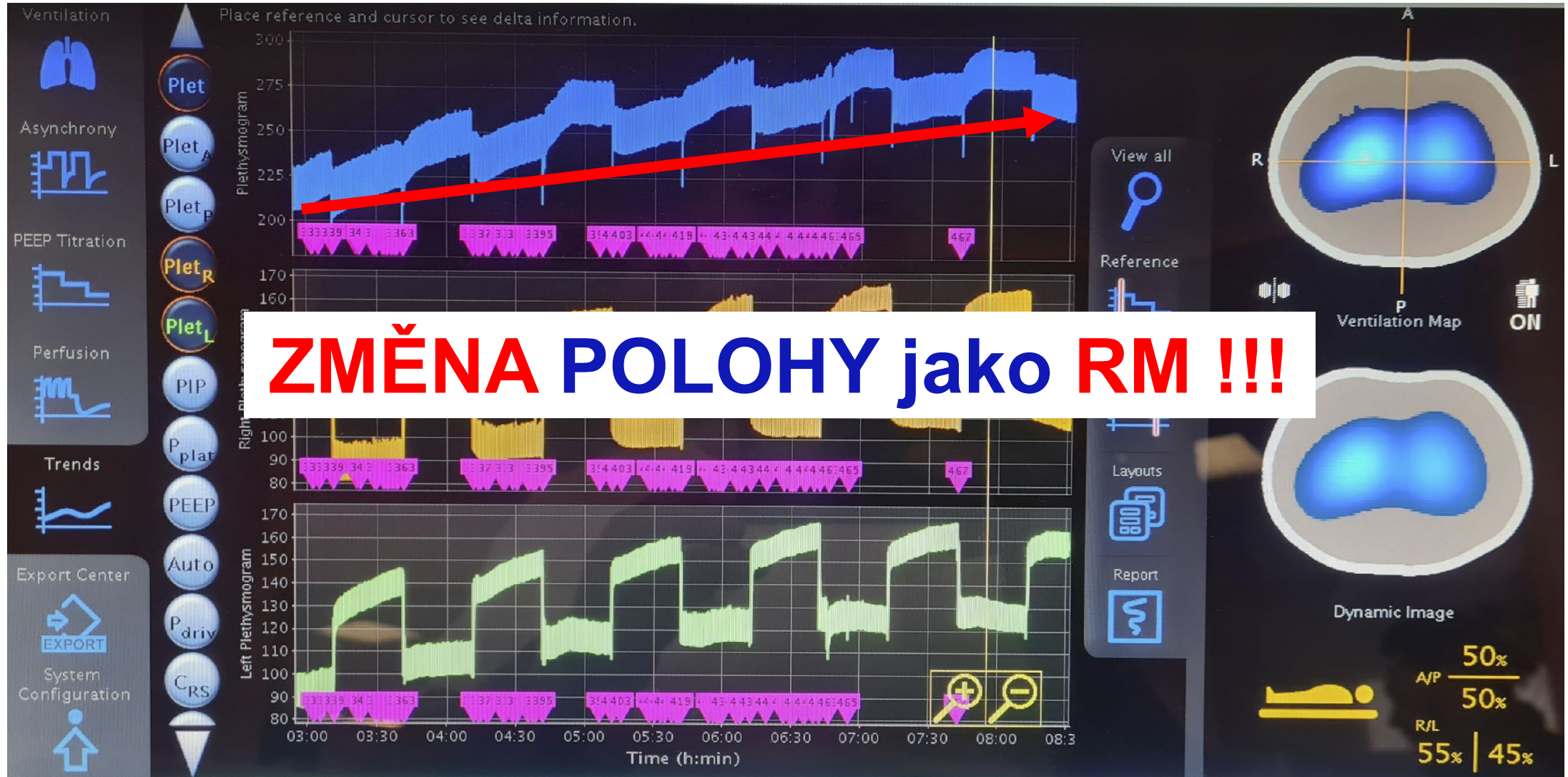
Costa Boroes^{1*}, Glasielle Cristina Alcalá³,
Krejčí¹, Marcelo Amato³ and Otomar Kittnar¹
Mlček et al. *BMC Pulm Med* (2021) 21:133



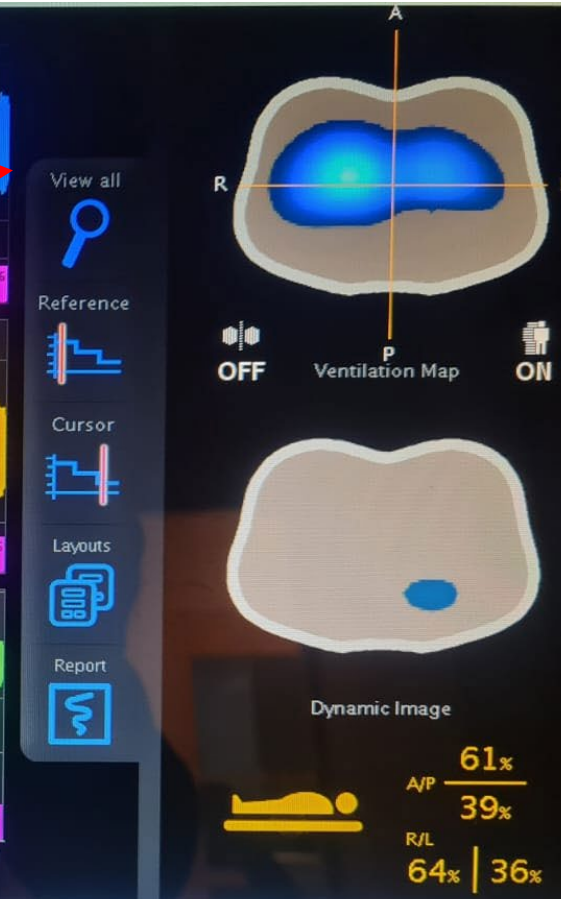
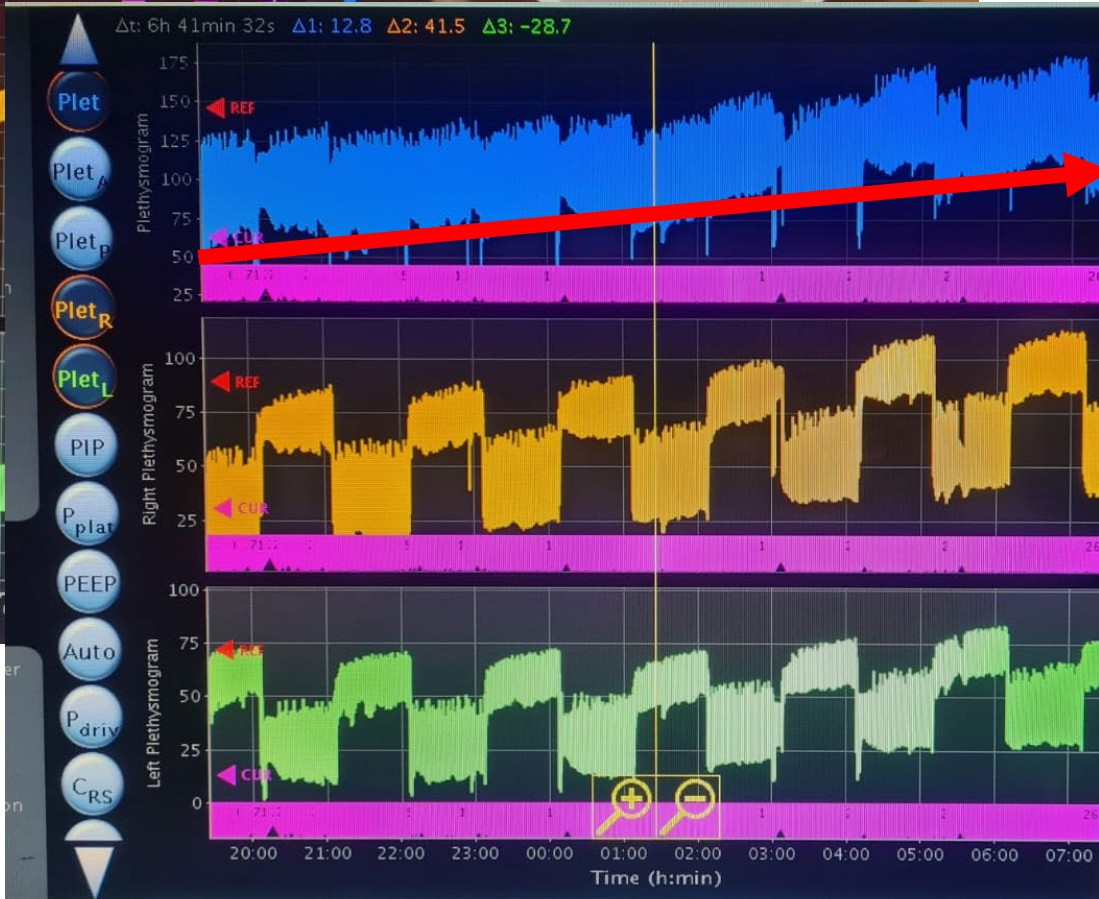
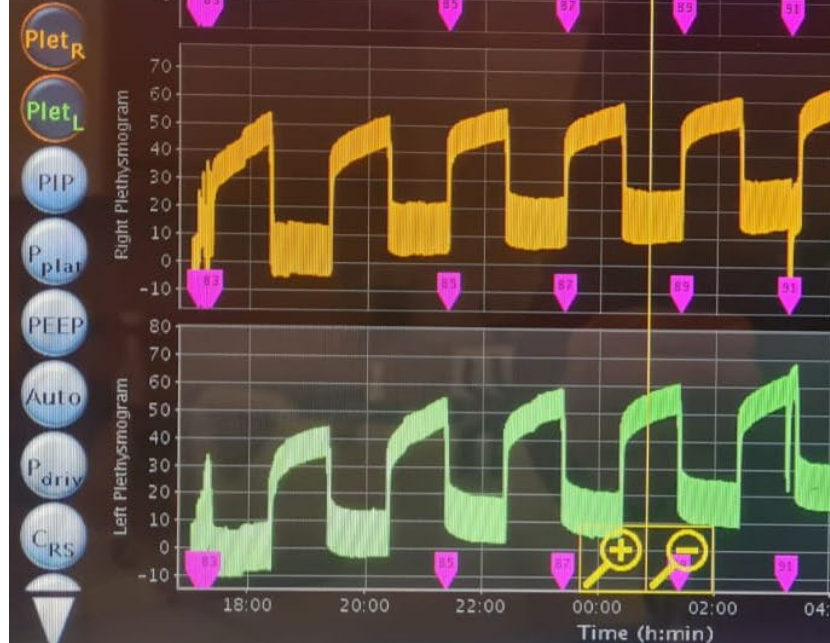
Right Lung

less overdistension P=0.005

Cílené POLOHOVÁNÍ – ALT jako RM?



Cílené POLOHOVÁNÍ – ALT jako RM?



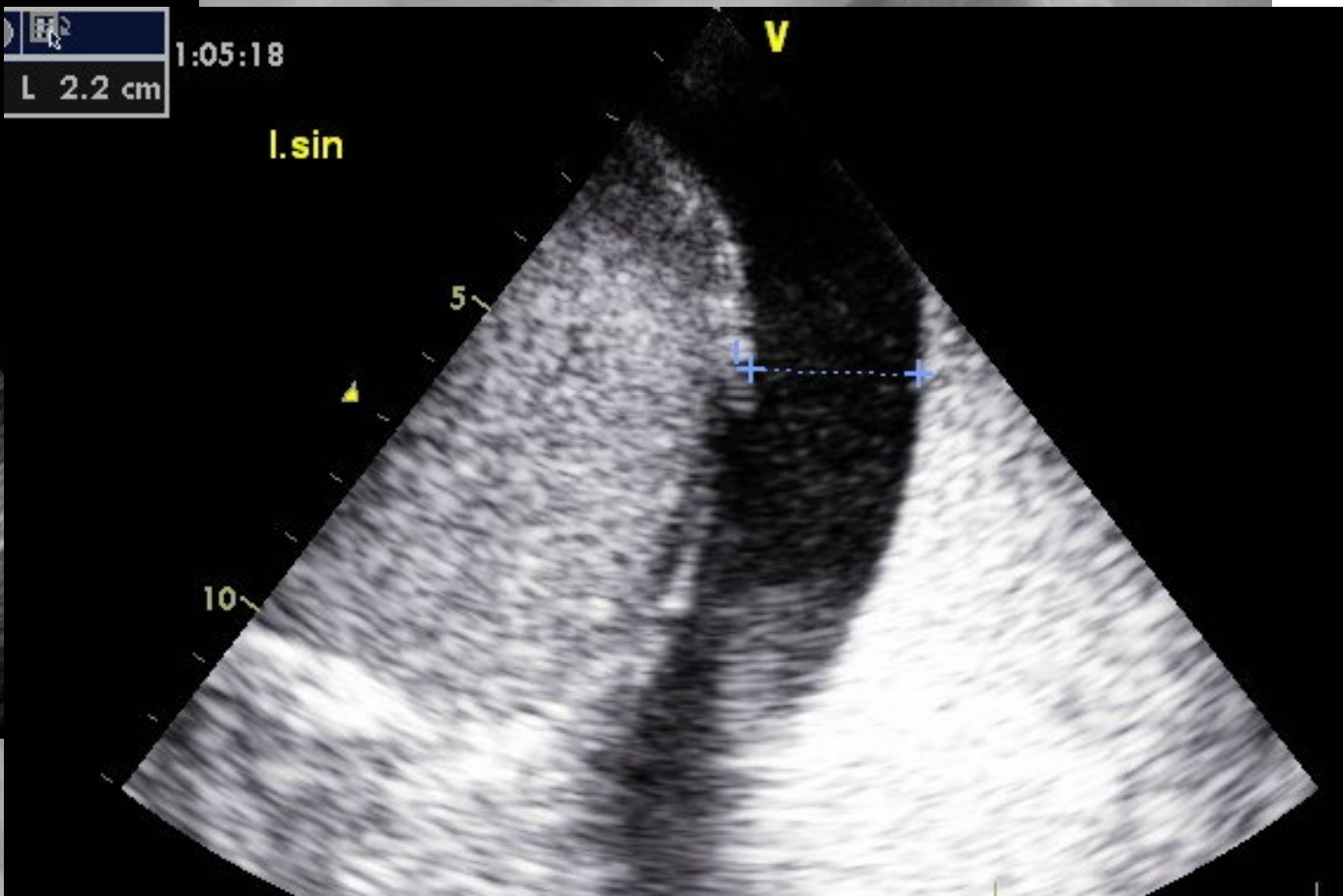
PCV RM - VIZUALIZACE monitorace UZ

20.05 na lu



PCV RM - VIZUALIZACE monitorace UZ

20.05 na lu

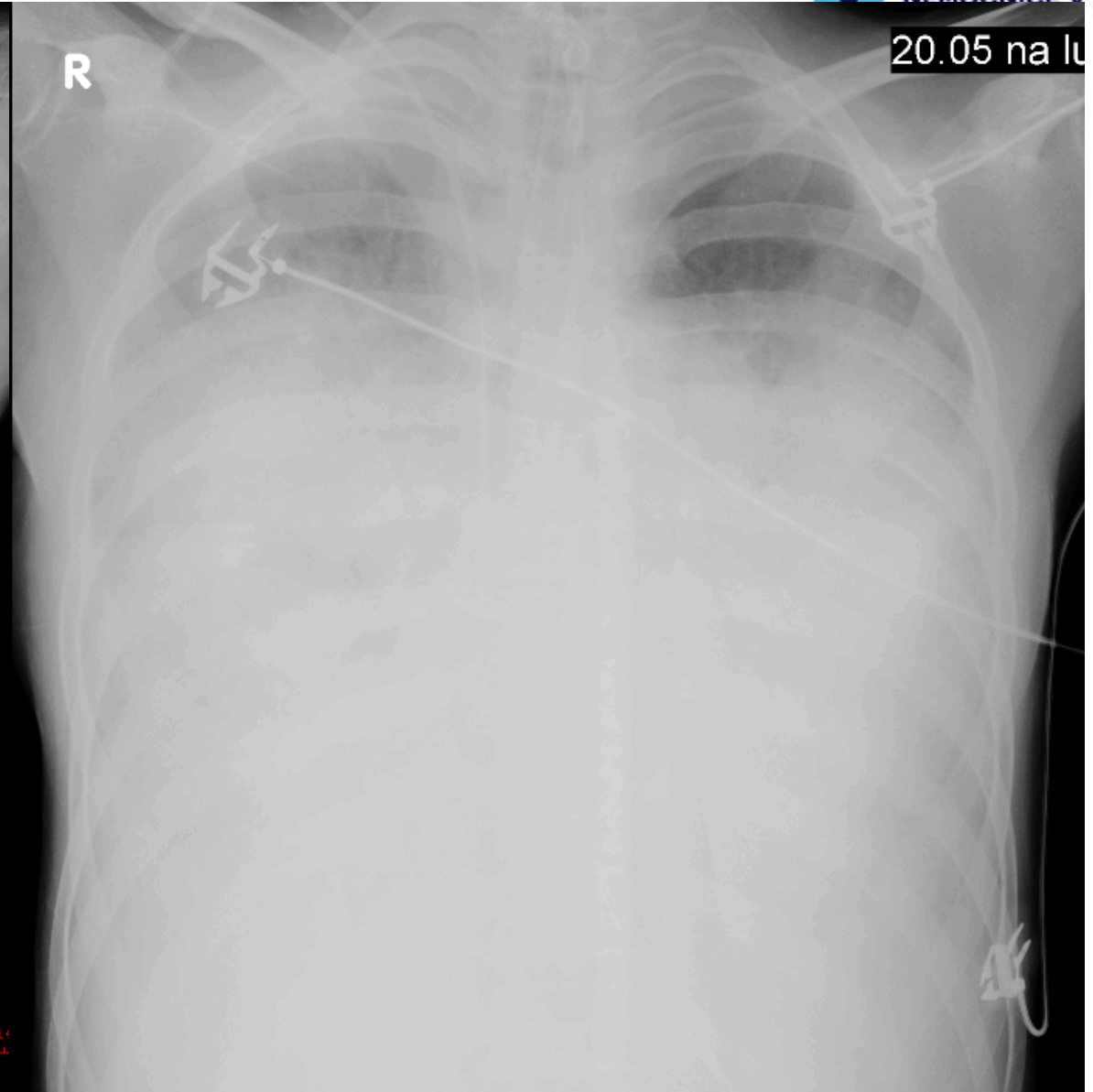


PCV RM - VIZUALIZACE monitorace UZ

20.05 na lu

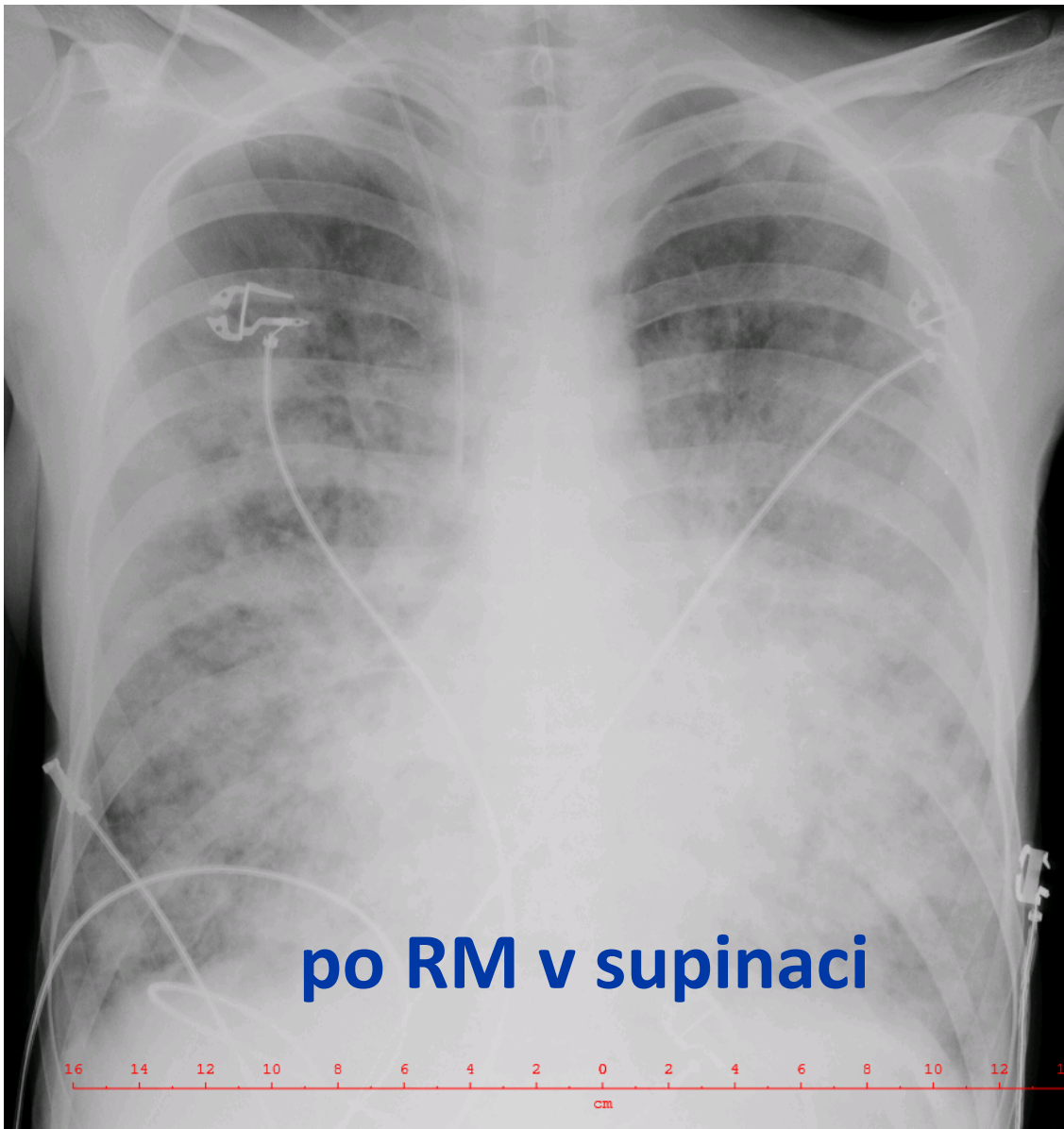


**SONO bilat. s kondenzací
FOB toaleta**

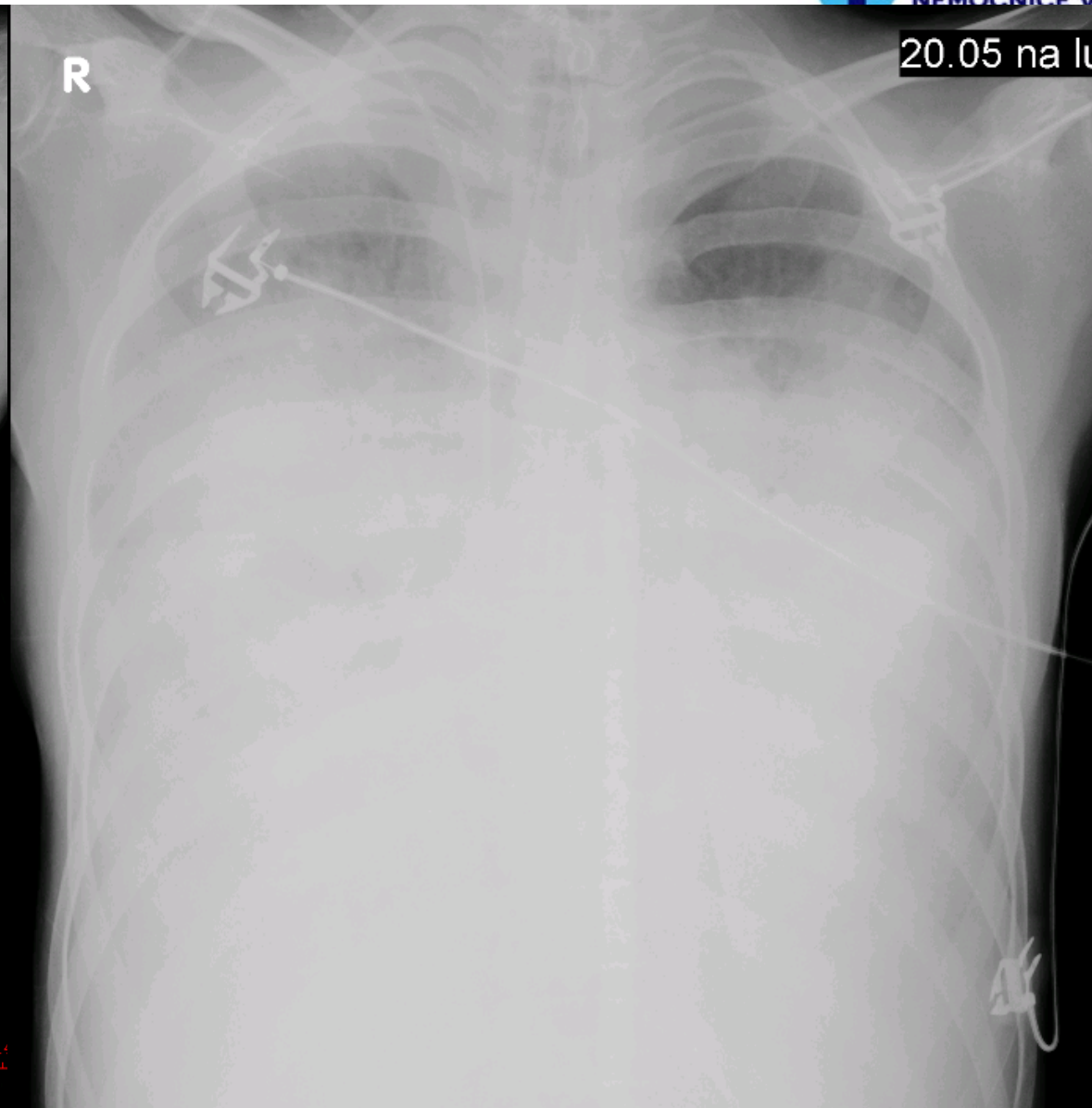


PCV RM - VIZUALIZACE monitorace UZ

20.05 na lu

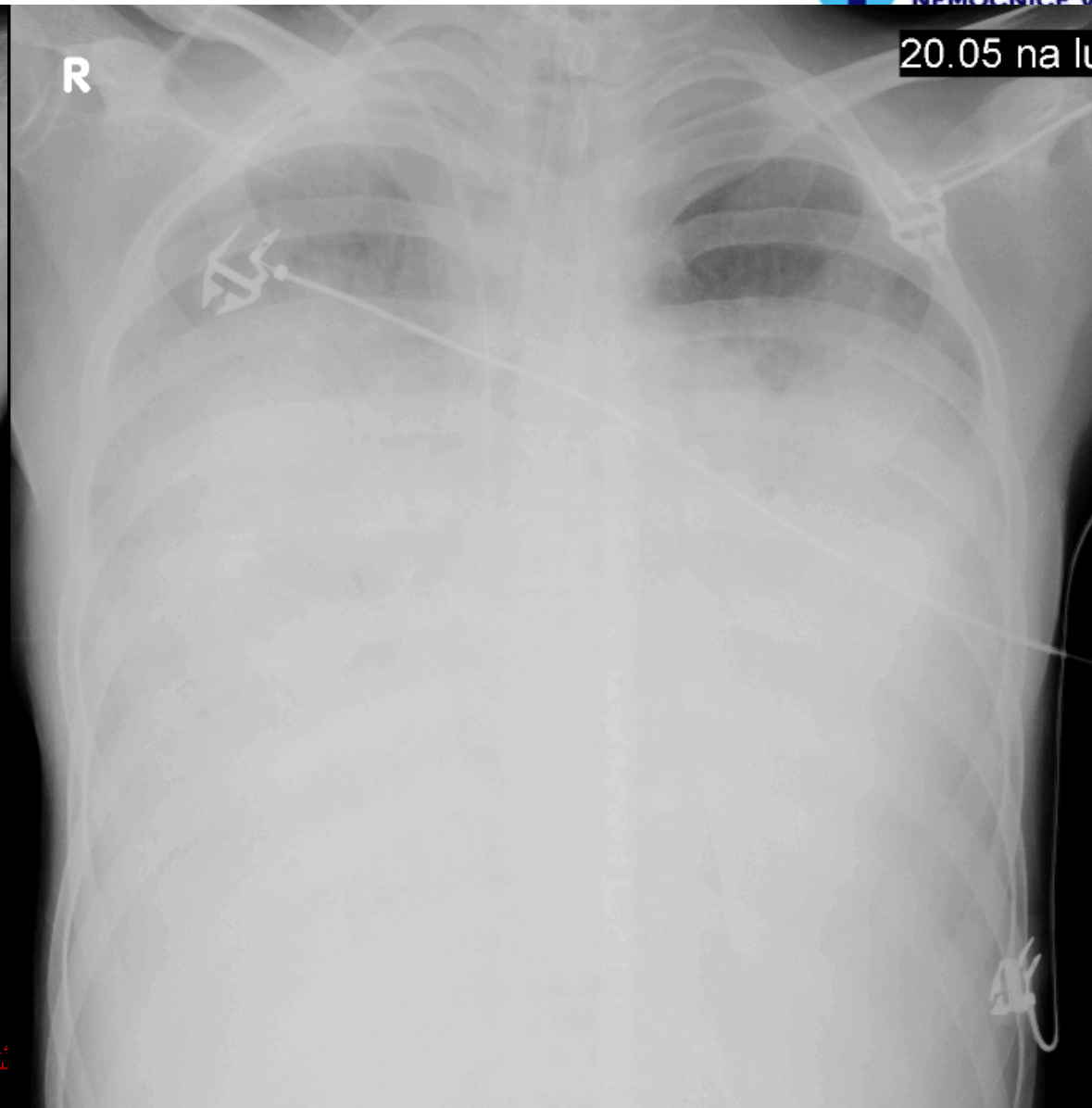
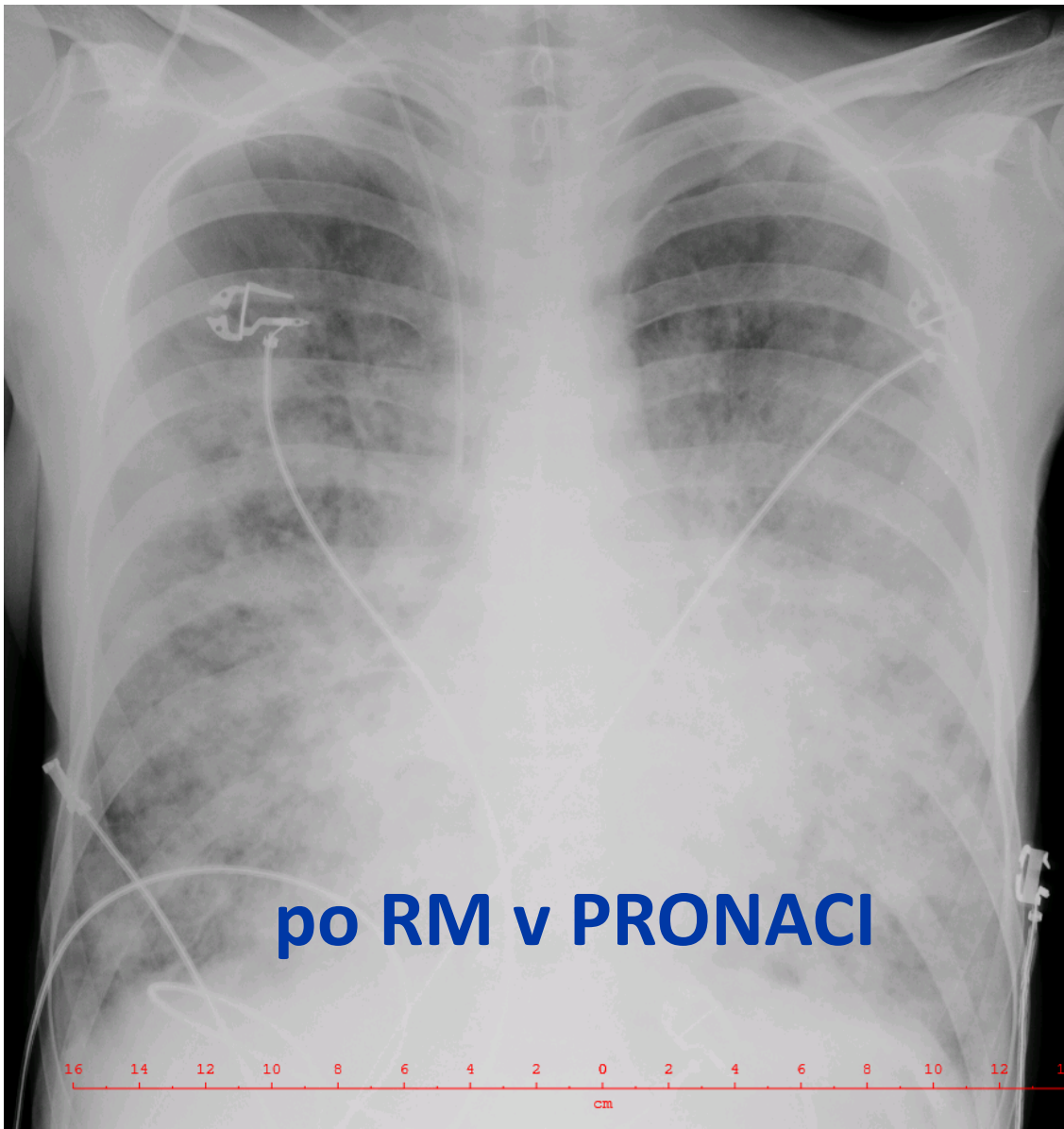


po RM v supinaci



PCV RM - VIZUALIZACE monitorace UZ

20.05 na lu





NA POLOZE ZÁLEŽÍ

