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JAK VENTILOVAT NEMOCNÉHO S RESTRIKTIVNÍM PLICNÍM ONEMOCNĚNÍM?

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U nemocnice 2; 128 08 Praha 2

O čem si budeme povídat

- Patofyziologie / restriktivní onemocnění
- Ventilace ARDS ….. Open lung koncept
- ARMA study
- Protektivní ventilační strategie, PEEP
- Driving pressure, Ergotrauma, Mechanical power
- Jak nastavit ventilátor?
- Mimo nastavení UPV – Pronace, Evakuace fluido

Patofyzilo

Co je restriktivi

anatomická nel
difůzní plocl

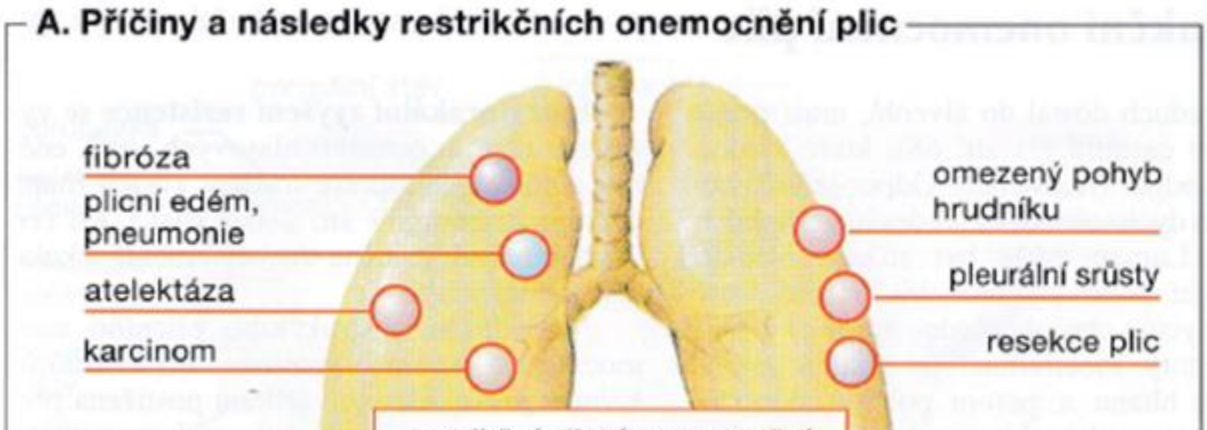
Snížení:

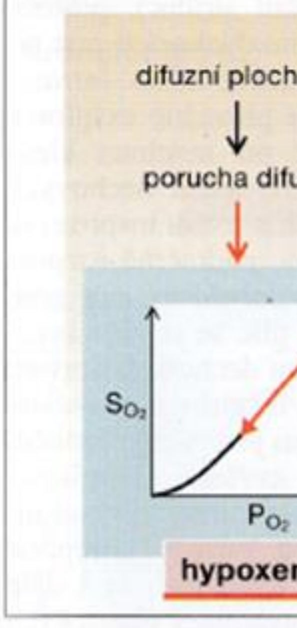
C – kompliance

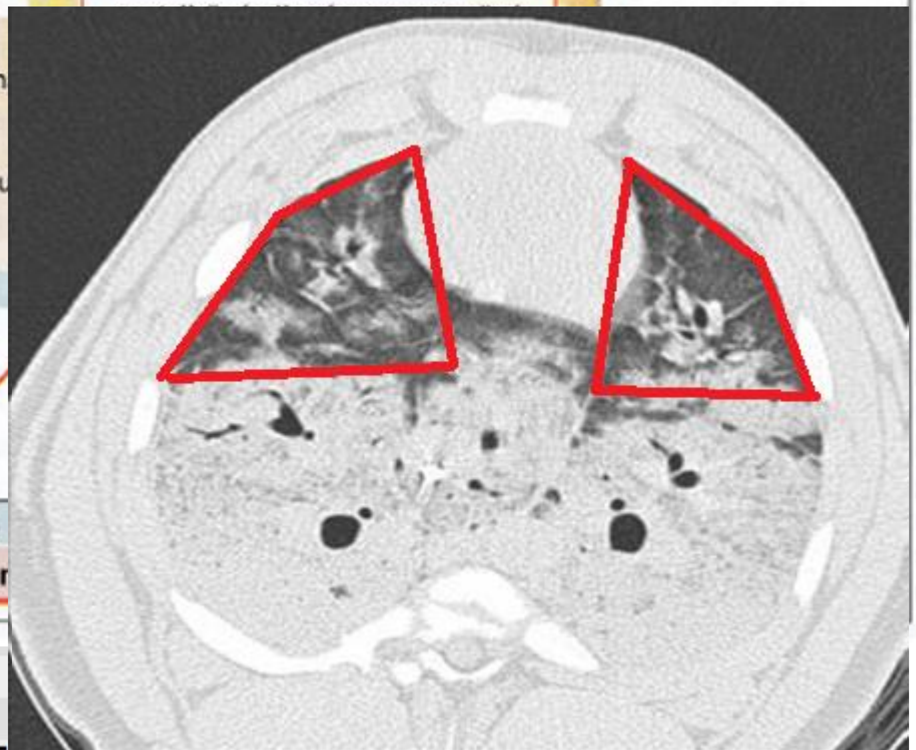
VC, FRC a difů

Manifestations of R

Decreased tidal volum
Decreased residual vo
Decreased functional
Normal residual volum
Decreased total lung c
Decreased vital capacity (VC)
Decreased inspiratory capacity (IC)
Decreased expiratory reserve volume (ERV)





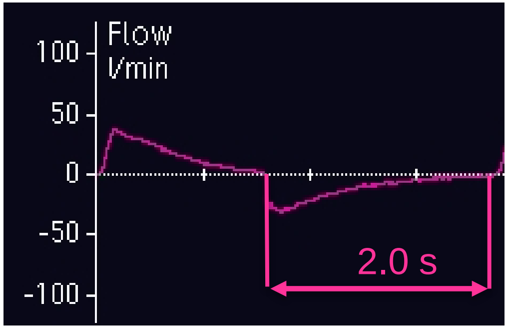


Des Jardins, T. Burton, G.C. Clinical Manifestations of Respiratory Disease 3rd Ed., ©1995

Silbernagl S., Lang F., Atlas patofyziologie člověka, 1.vydání, Grada 2001

RC_{EXP}

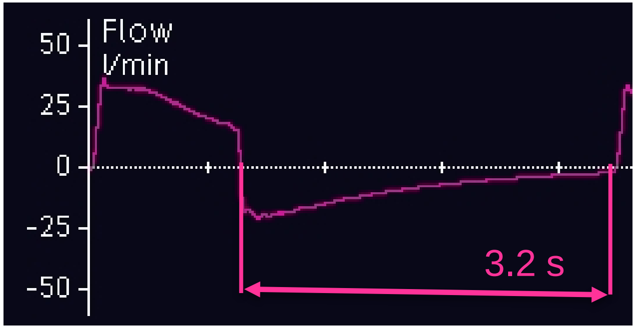
Normal: 0.6-0.9 s



$C_{STAT} = 60\ mL/cmH_20$

$R_{EXP} = 12\ cmH_2O.s/L$

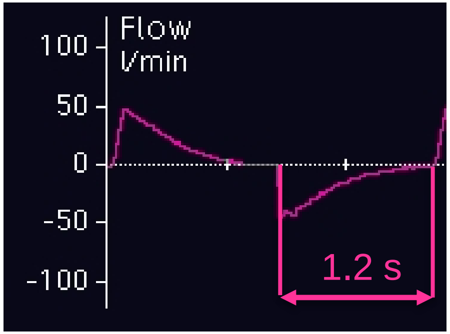
Obstructive: > 0.9s



$C_{STAT} = 60\ mL/cmH_20$

$R_{EXP} = 20\ cmH_2O.s/L$

Restrictive: < 0.6 s



$C_{STAT} = 35\ mL/cmH_20$

$R_{EXP} = 12\ cmH_2O.s/L$

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Pokud nastavíte

dechový objem

pak

vrcholový inspirační tlak / gradient

je dán rovnicí:

$$C_{RS} = \frac{Vt}{\Delta P}$$

Compliance

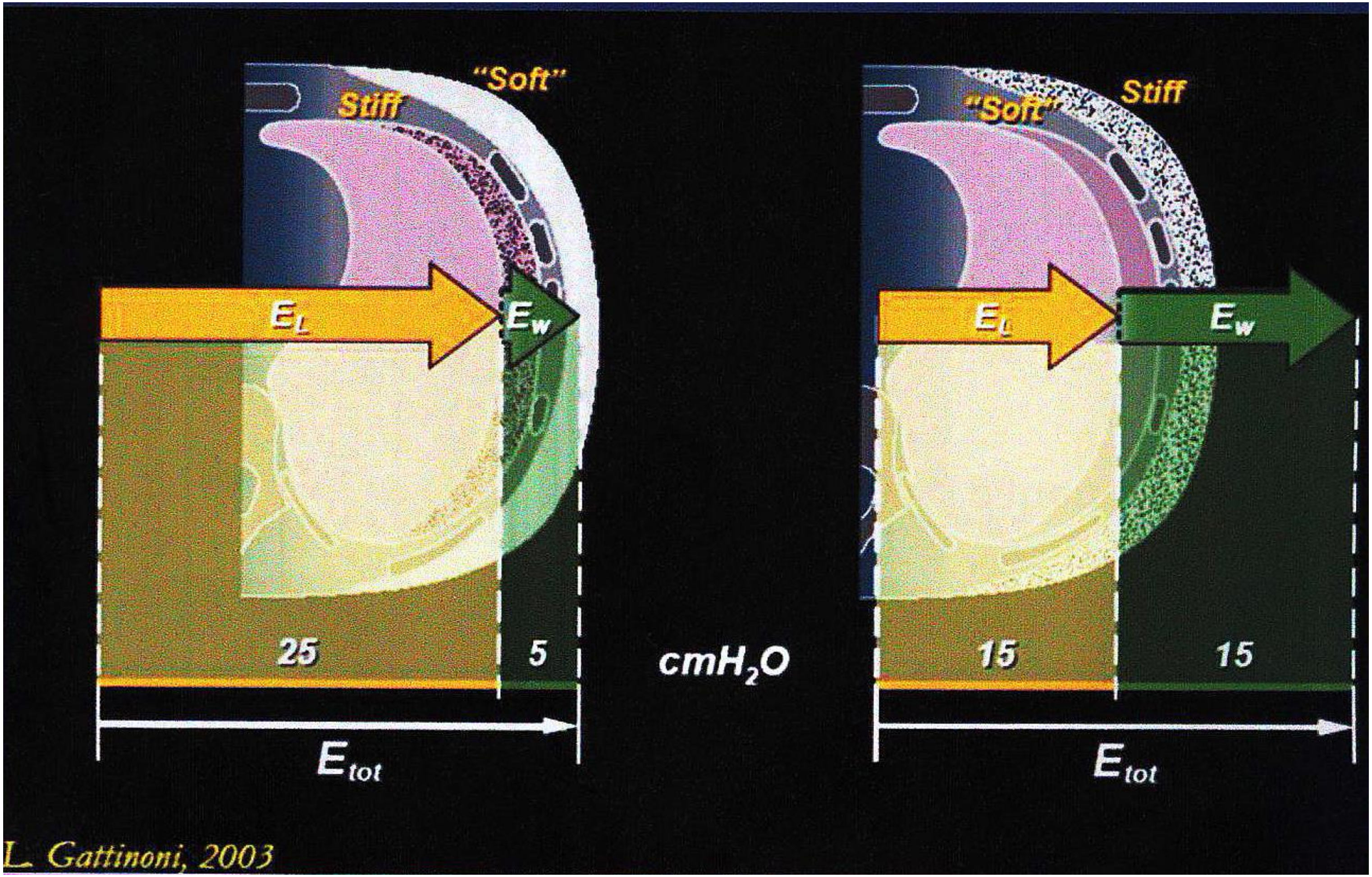
je „konstantní“

(v čase se mění)

$$\Delta P \uparrow = \frac{Vt}{C_{RS} \downarrow}$$

$$\Delta P = V_T \times E_{tot}$$

Inspirační ΔP / transpulmonální ΔP



UZ - identifikace FLUIDOTHORAXU

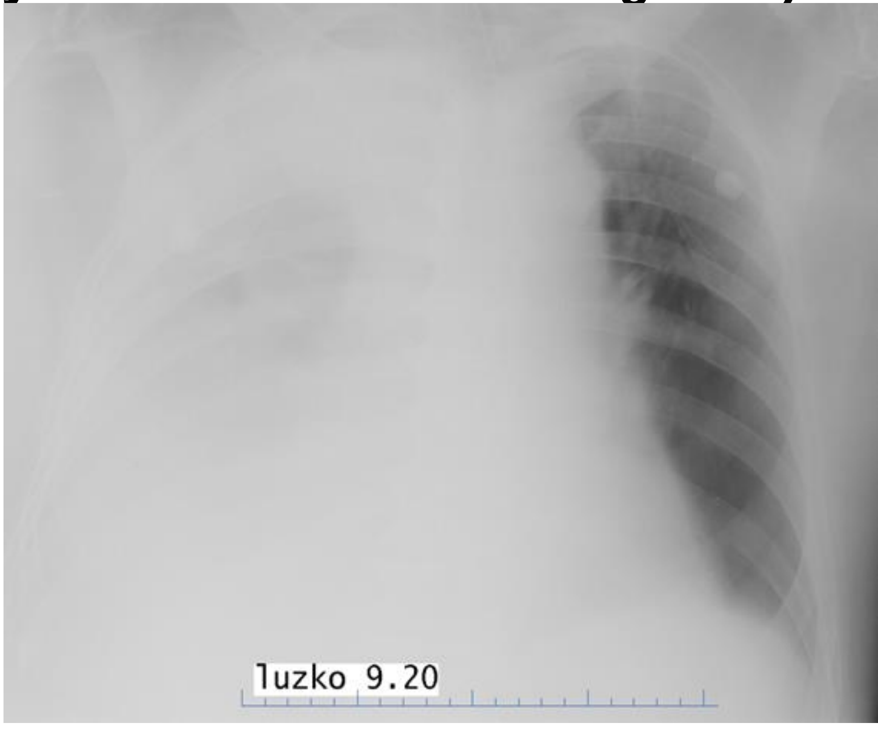
- prevalence 15-62% medical ICU (Mattison LE: Chest 1997)
- vyšší sensitivitu a specificitu než RTG (80-83%, 150-300ml)
- vylučuje bazální plicní alveolární konsolidaci / atelektázu

  (hepatizace bez dynamického air bronchogramu)
- „cílená thorakocentéza“
- thorakocentéza:

  1) kratší LOS

  2) trend k nižší mortalitě

(Fartoukh,Chest 2002, Adenigbagbe,Chest 2007)



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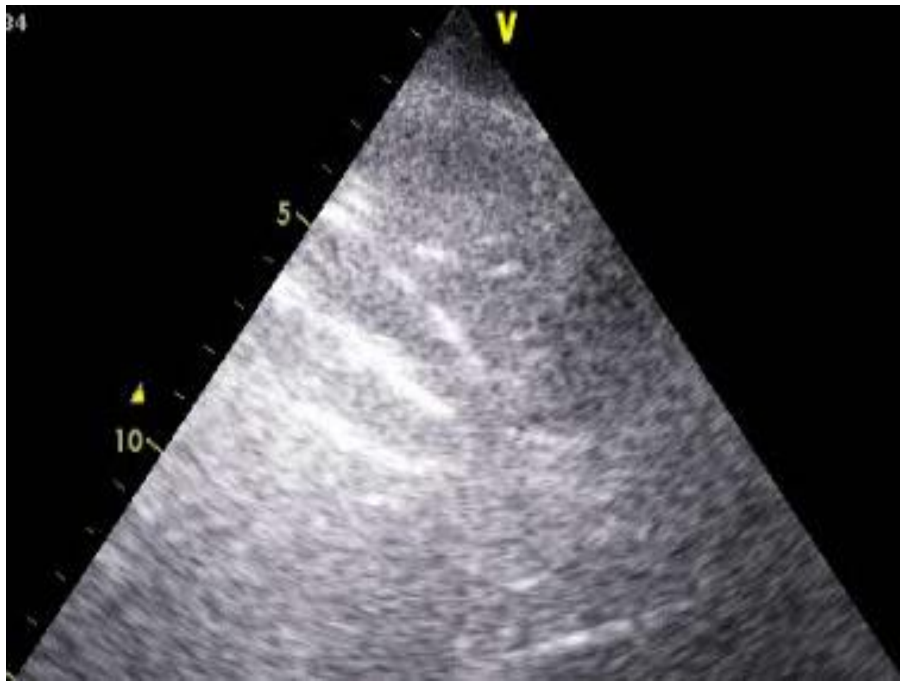
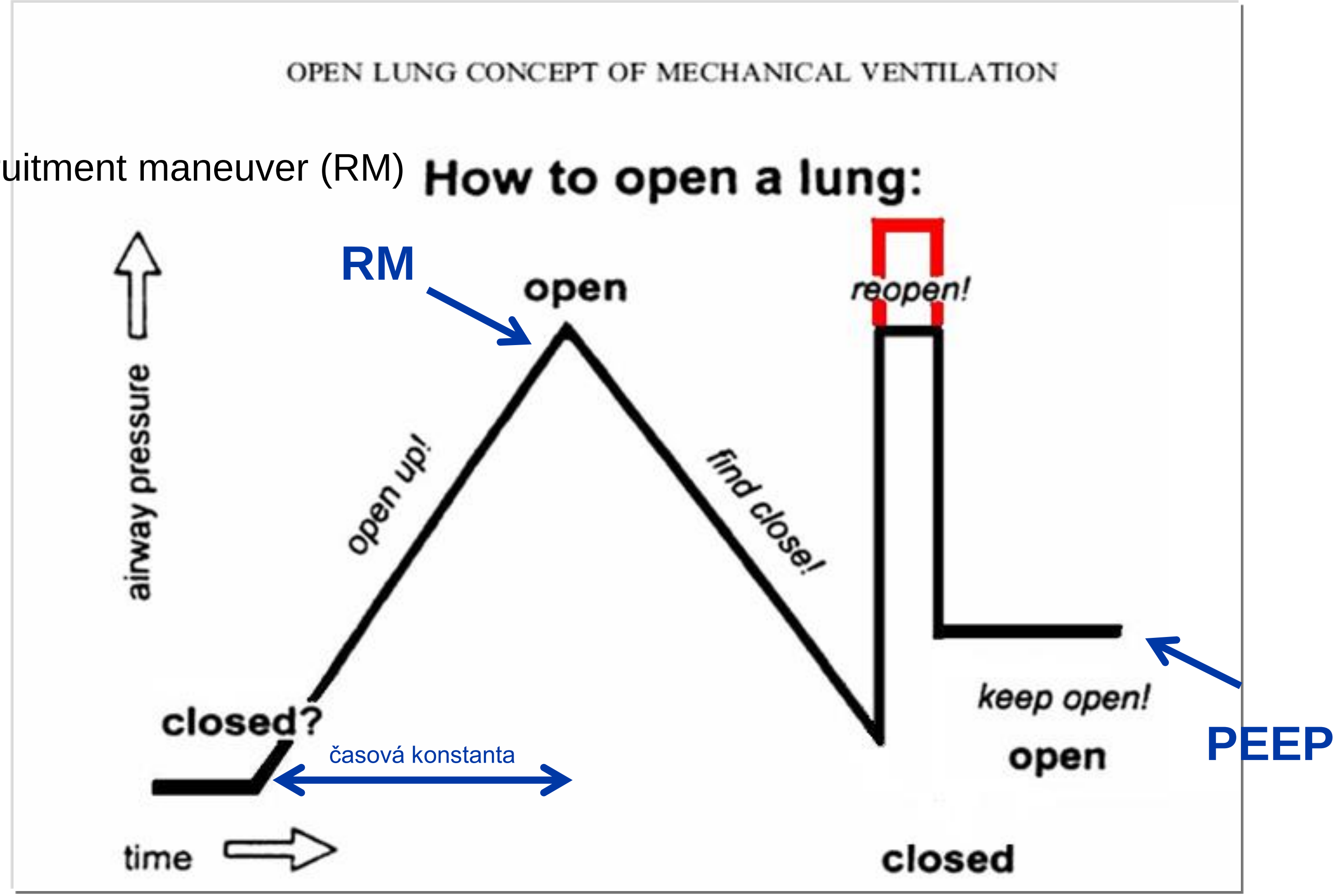
3) FOB toaleta



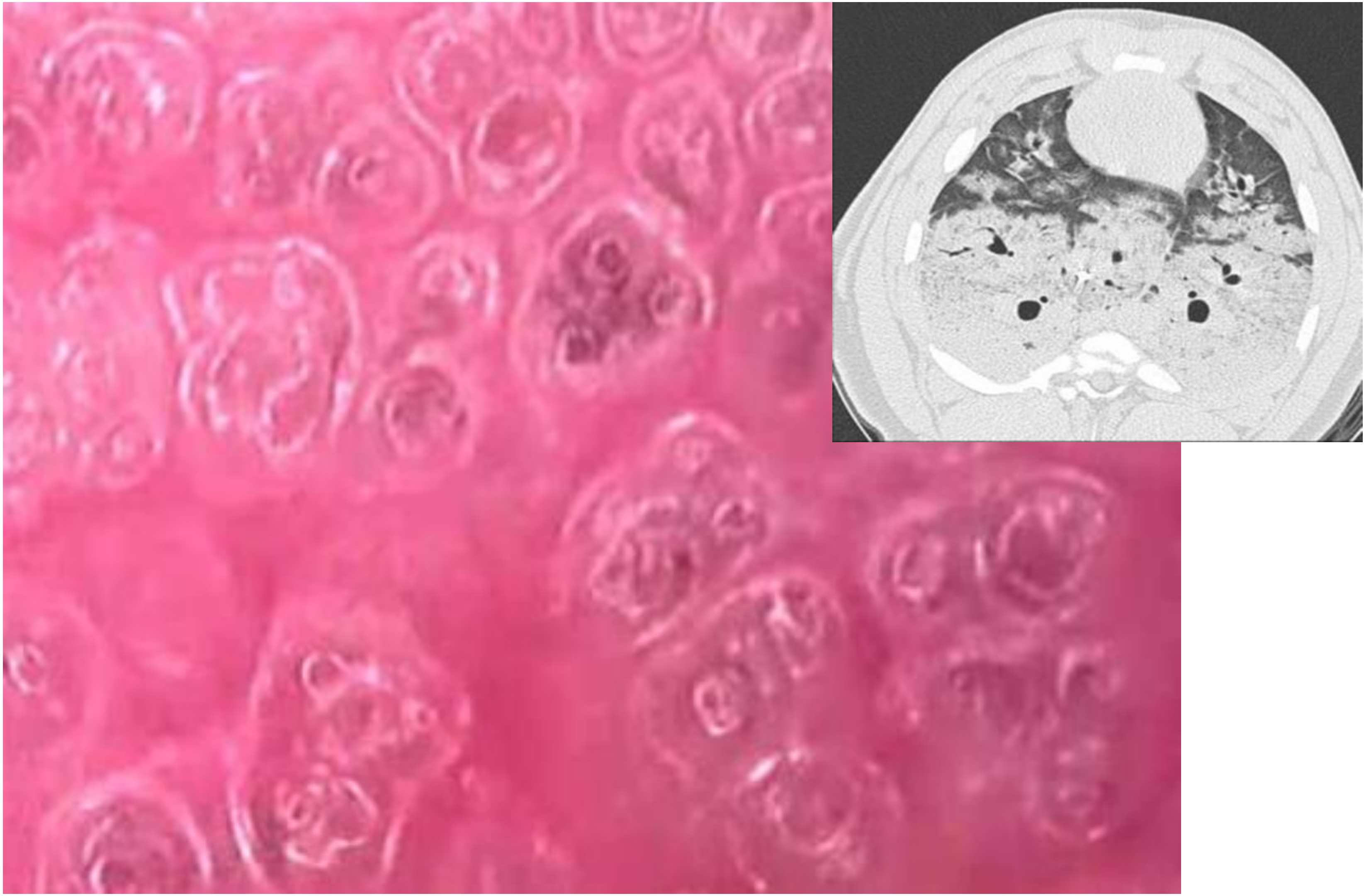
Open up the lung and keep the lung open

Recruitment maneuver (RM)

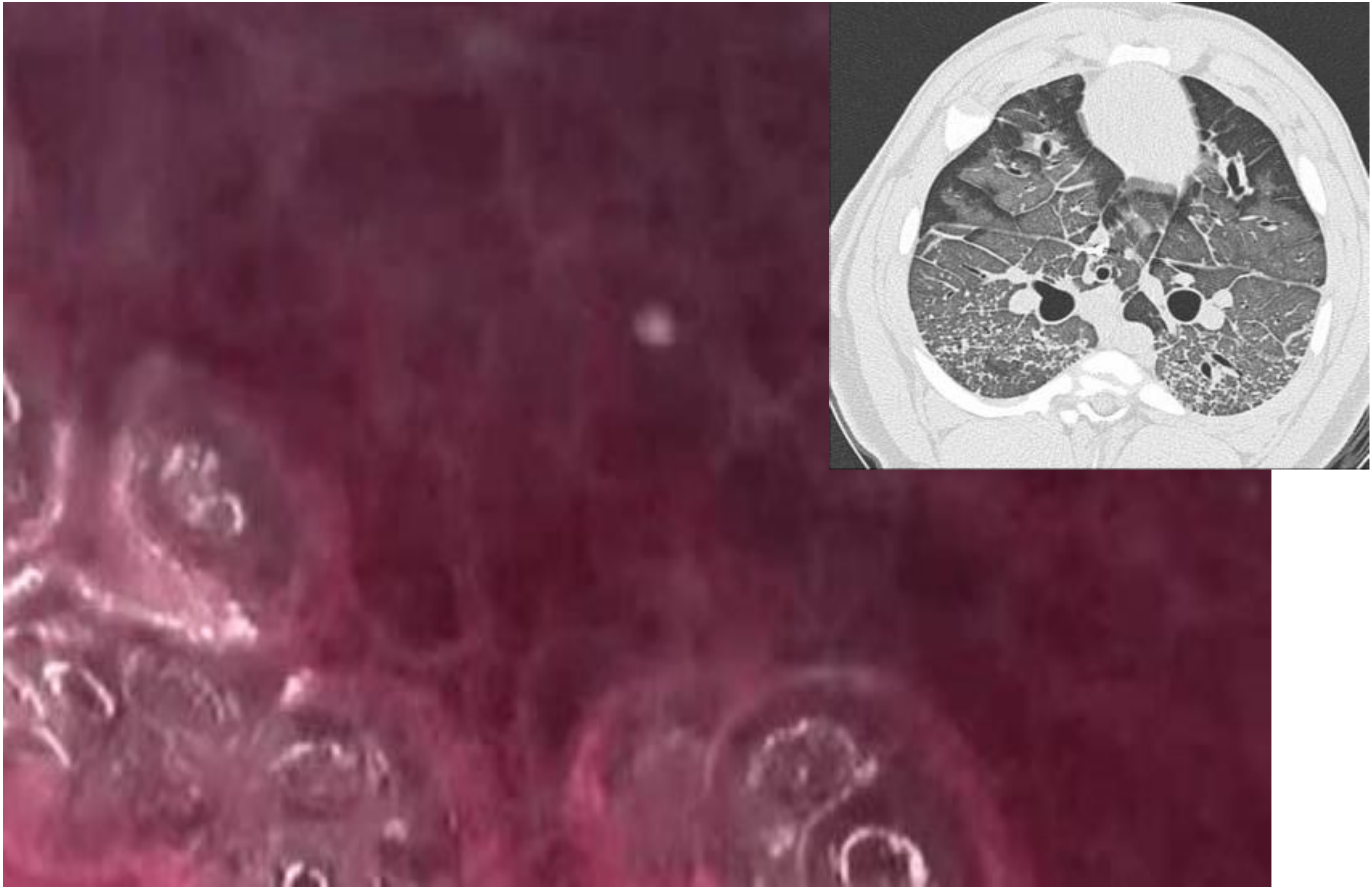


Lachmann B, ICM, 1992

Použití PEEPu



Použití PEEPu / RM



Efekt PEEPu na mortalitu ARDS?

Higher vs Lower Positive End-Expiratory Pressure in Patients With Acute Lung Injury and Acute Respiratory Distress Syndrome
Systematic Review and Meta-analysis

	Trial		
Characteristic	ALVEOLI,[8] 2004	LOVS,[9] 2008	EXPRESS,[10] 2008
Inclusion criteria	Acute lung injury with PaO_2:FIO_2 ≤300[a]	Acute lung injury with PaO_2:FIO_2 ≤250[a]	Acute lung injury with PaO_2:FIO_2 ≤300[a]
Recruitment period	1999-2002	2000-2006	2002-2005
Recruiting hospitals (country)	23 (United States)	30 (Canada, Australia, Saudi Arabia)	37 (France)
Patients randomized to higher vs lower PEEP	276 vs 273	476 vs 509[b]	385 vs 383[c]
Validity			
Concealed allocation	Yes	Yes	Yes
Follow-up for primary outcome, %	100	100	100
Blinded data analysis	Yes	Yes	Yes
Stopped early	Stopped for perceived futility	No	Stopped for perceived futility
Experimental intervention	Higher PEEP according to FIO_2 chart, recruitment maneuvers for first 80 patients	Higher PEEP according to FIO_2 chart, required plateau pressures ≤40 cm H_2O, recruitment maneuvers	PEEP as high as possible without increasing the maximum inspiratory plateau pressure >28-30 cm H_2O
Control intervention	Conventional PEEP according to FIO_2 chart, required plateau pressures ≤30 cm H_2O, no recruitment maneuvers	Conventional PEEP according to FIO_2 chart, required plateau pressures ≤30 cm H_2O, no recruitment maneuvers	Conventional PEEP (5-9 cm H_2O) to meet oxygenation goals

Briel, JAMA, 2010

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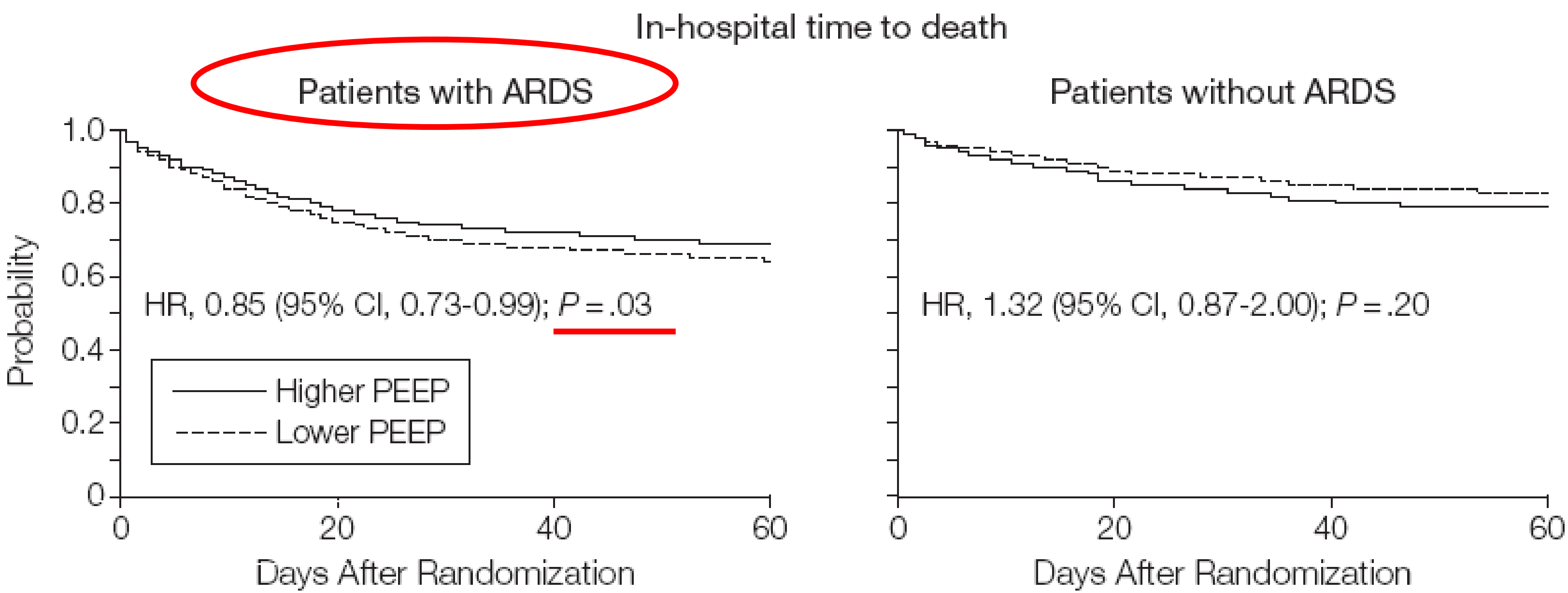


Briel, JAMA, 2010

Lower Tidal Volume Trial - ARMA study

VENTILATION WITH LOWER TIDAL VOLUMES AS COMPARED WITH TRADITIONAL TIDAL VOLUMES FOR ACUTE LUNG INJURY AND THE ACUTE RESPIRATORY DISTRESS SYNDROME

THE ACUTE RESPIRATORY DISTRESS SYNDROME NETWORK*

10 univers. centers, 1996-1999
ARDS $paO_2/FiO_2 < 300$, **432** (6ml/kg) **vs 429** (12ml/kg) pts
volume-assist–control
PBW = M 50 / F 45.5 + 0.91(centimeters of height-152.4)

12 ml/kg PBW + Pplat (0.5s) =< 50 cmH_2O
vs. 6 ml/kg PBW + Pplat (0.5s) **=< 30 cmH_2O**

- primary outcome was **death before** a patient was discharged home and was breathing without assistance.
- second primary outcome was the number of days without ventilator use from day 1 to day 28

NEJM, 2000

Lower Tidal Volume Trial - ARMA study

VENTILATION WITH LOWER TIDAL VOLUMES AS COMPARED WITH TRADITIONAL TIDAL VOLUMES FOR ACUTE LUNG INJURY AND THE ACUTE RESPIRATORY DISTRESS SYNDROME

Variable	Group Receiving Traditional Tidal Volumes	Group Receiving Lower Tidal Volumes
Ventilator mode	Volume assist–control	Volume assist–control
Initial tidal volume (ml/kg of predicted body weight)†	12	6
Plateau pressure (cm of water)	≤50	≤30
Ventilator rate setting needed to achieve a pH goal of 7.3 to 7.45 (breaths/min)	6–35	6–35
Ratio of the duration of inspiration to the duration of expiration	1:1–1:3	1:1–1:3
Oxygenation goal	PaO_2, 55–80 mm Hg, or SpO_2, 88–95%	PaO_2, 55–80 mm Hg, or SpO_2, 88–95%
Allowable combinations of FiO_2 and PEEP (cm of water)‡		
Weaning	By pressure support; required by protocol when FiO_2≤0.4	By pressure support; required by protocol when FiO_2≤0.4

PEEP (cm H_2O)	5	5	8	8	10	10	10	12	14	14	14	16	18	18-24
F_iO_2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.0

NEJM, 2000

Lower Tidal Volume Trial - ARMA study

MAIN OUTCOME VARIABLES

VARIABLE	GROUP RECEIVING LOWER TIDAL VOLUMES	GROUP RECEIVING TRADITIONAL TIDAL VOLUMES	P VALUE
Death before discharge home and breathing without assistance (%)	31.0	39.8	0.007
Breathing without assistance by day 28 (%)	65.7	55.0	<0.001
No. of ventilator-free days, days 1 to 28	12±11	10±11	0.007
Barotrauma, days 1 to 28 (%)	10	11	0.43
No. of days without failure of nonpulmonary organs or systems, days 1 to 28	15±11	12±11	0.006

NEJM, 2000

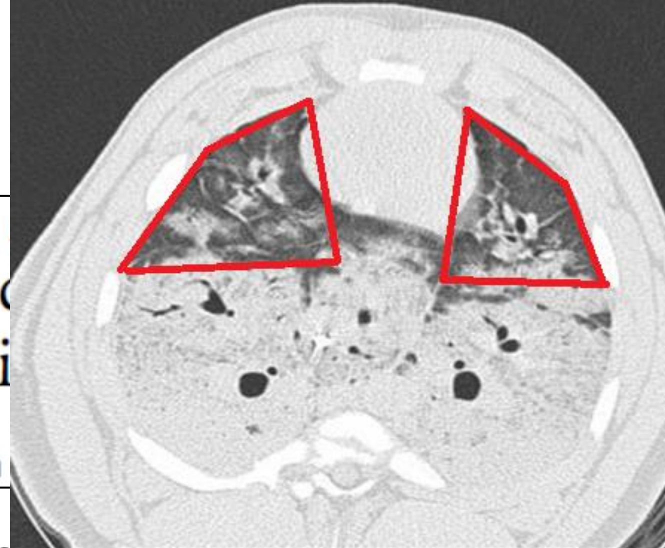
Driving pressure ΔP

The NEW ENGLAND

Driving Pressure anc

Respiratory Di

Marcelo B.P. Amato, M.D., Maureen



respiratory-system compliance C_{RS} is strongly related to the volume of **aerated remaining functional lung** during disease (termed functional lung size)

driving pressure $\Delta P = V_T / C_{RS}$, in which V_T is intrinsically normalized to **functional lung size** (instead of PBW lung size in healthy persons), more strongly associated with survival than VT or PEEP

ΔP = Pplat – PEEP

- **3562 patients with ARDS enrolled in nine previously reported randomized trials**

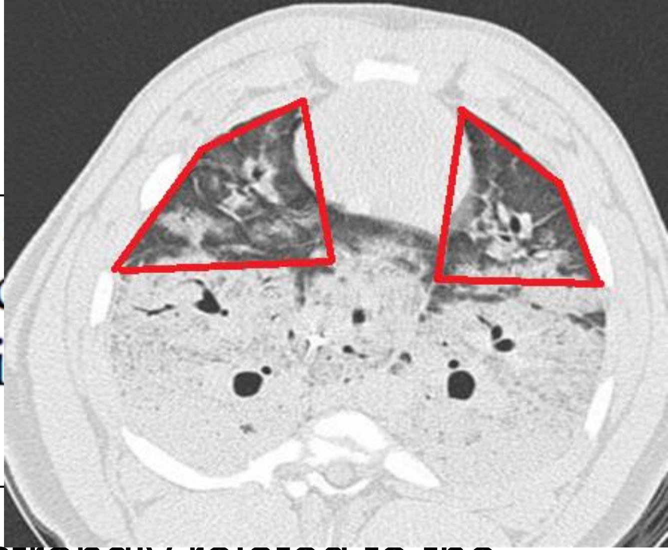
Amato, NEJM, 2015

Driving pressure ΔP

The NEW ENGLAND

Driving Pressure and
Respiratory Di

Marcelo B.P. Amato, M.D., Maureen



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Amato, NEJM, 2015

Driving pressure ΔP

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	Years of recruitment	Patients (N)	Randomization Cont. / Treat.	Age mean (SD)	Sepsis at Entry (%)	Pneumonia/ Aspiration*	MV.Days at entry‡	Interventions (within treatment-arm)
Lower vs. Higher V_T-trials ¶:								
Amato et al.[1 §]	*1991-1995*	53	24 / 29	34 (13)	83%	28%	1	$V_T \leq 6$mL/kg; $\Delta P \leq 20$cmH_2O $P_{PLAT} \leq 40$cmH_2O;
Stewart et al.[2]	*1995-1996*	118	59 / 59	59 (18)	40%	58%	0	$V_T \leq 8$mL/kg; $P_{PEAK} \leq 30$cmH_2O
Brochard et al.[3]	*1994-1996*	113	57 / 56	57 (15)	n.a.	n.a.	2	$V_T < 10$mL/kg; $P_{PLAT} \leq 25$cmH_2O
Brower et al.[4]	*1994-1996*	52	26 / 26	48 (16)	23%	54%	n.a.	$V_T \leq 8$mL/kg; $P_{PLAT} \leq 30$cmH_2O
$ARDSnet_{VT}$[5]	*1996-1999*	861	429 / 432	51 (17)	27%	49%	1	$V_T \leq 6$mL/kg; $P_{PLAT} \leq 30$cmH_2O;
Higher vs. Lower PEEP-trials ‖ :								
$ARDSnet_{PEEP}$[6]	*1999-2002*	545	271 / 274	51 (17)	38%	55%	1	Higher PEEP guided by higher PEEP/ FiO_2 table; $V_T = 6.0 \pm 0.9$ mL/kg/pbw
EXPRESS[7]	*2002-2005*	767	382 / 385	60 (15)	61%	72%	1.5	Highest PEEP keeping $P_{PLAT} < 30$cmH_2O; $V_T = 6.1 \pm 0.3$ mL/kg/pbw
LOVS[8]	*2000-2006*	983	508 / 475	56 (17)	47%	64%	2	Higher PEEP guided by higher PEEP/ FiO_2 table; $V_T = 7.0 \pm 1.5$ mL/kg/pbw
Talmor et al.[9]	*2004-2007*	61	31 / 30	53 (20)	48%	20%	n.a.	Higher PEEP guided by esophageal-pressure; $V_T = 7.6 \pm 1.5$ mL/kg/pbw

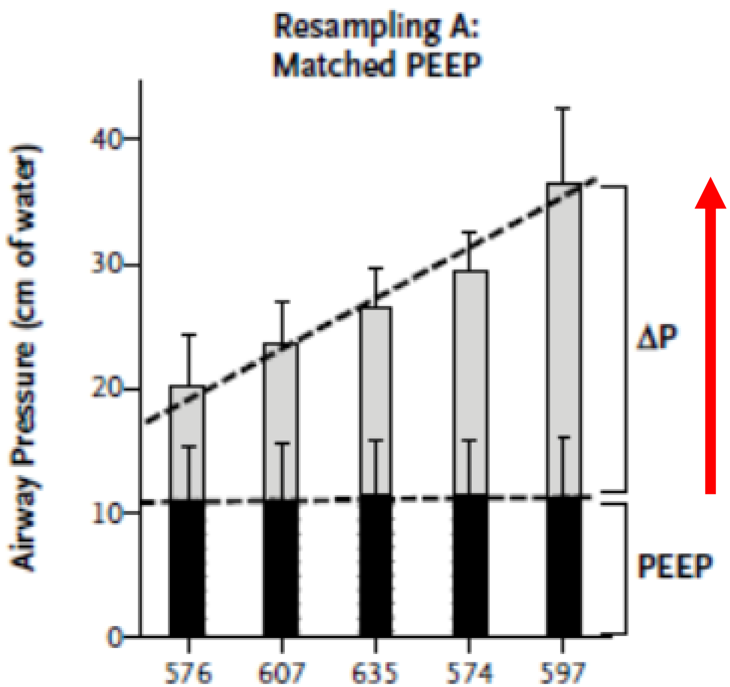
Amato, NEJM, 2015

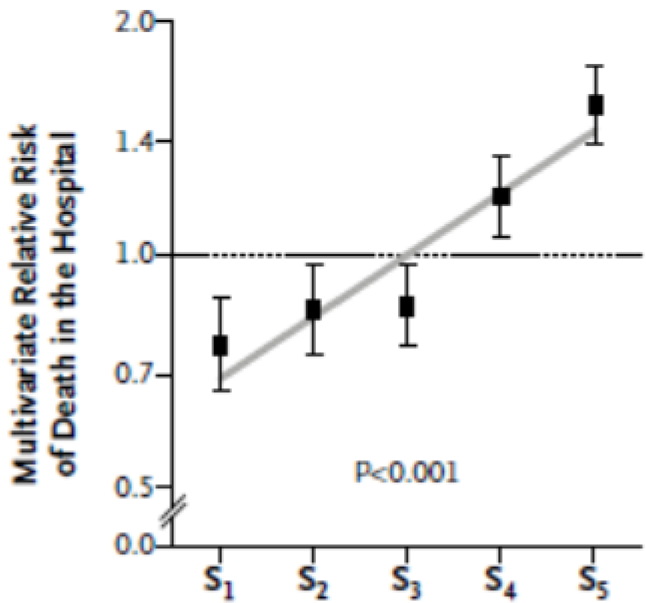
Driving pressure ΔP

The NEW ENGLAND JOURNAL of MEDICINE

Driving Pressure and Survival in the Acute Respiratory Distress Syndrome

Marcelo B.P. Amato, M.D., Maureen O. Meade, M.D., Arthur S. Slutsky, M.D.,





Amato, NEJM, 2015

Driving pressure ΔP

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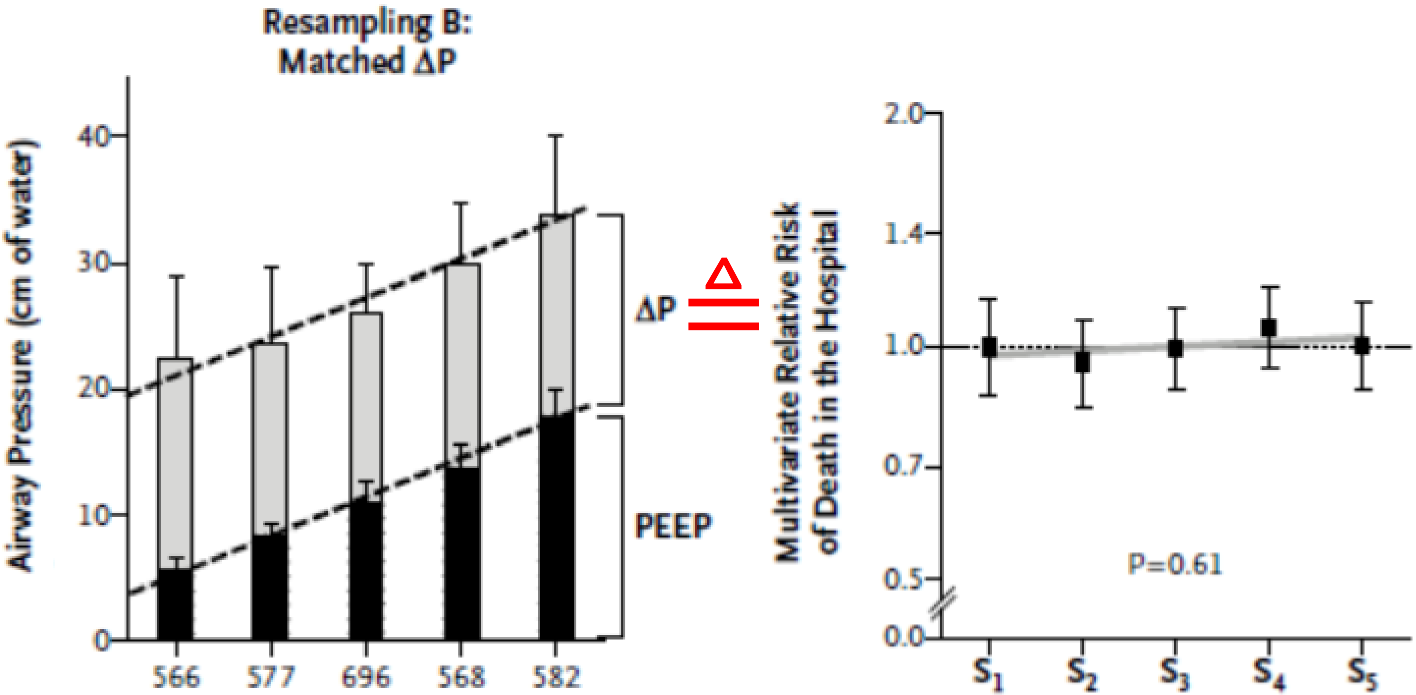
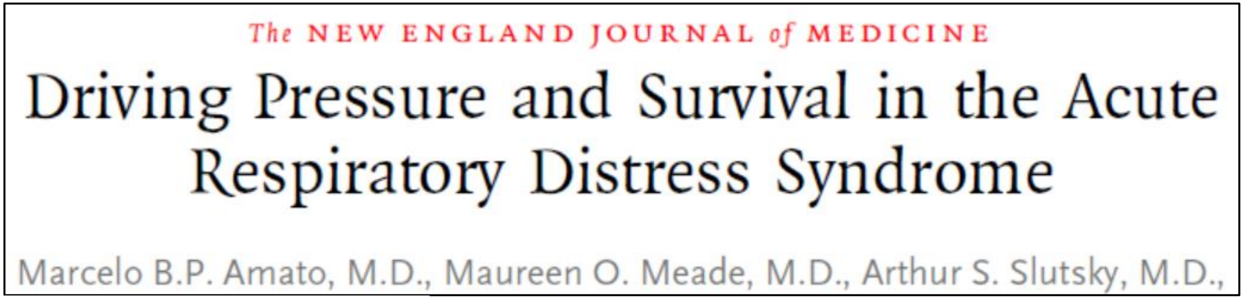
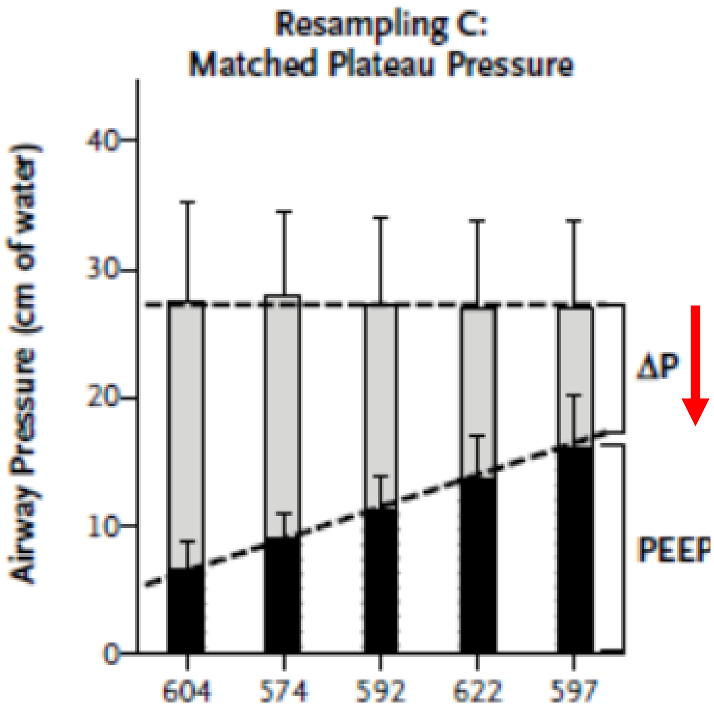
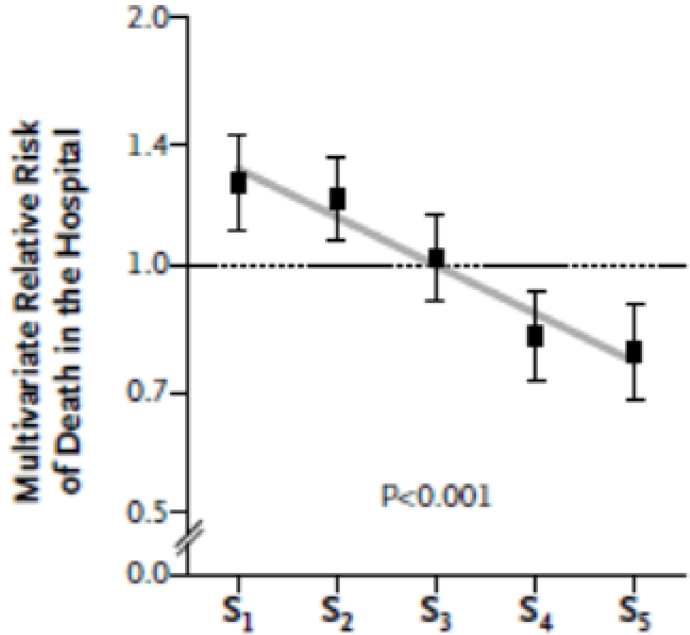


Amato, NEJM, 2015

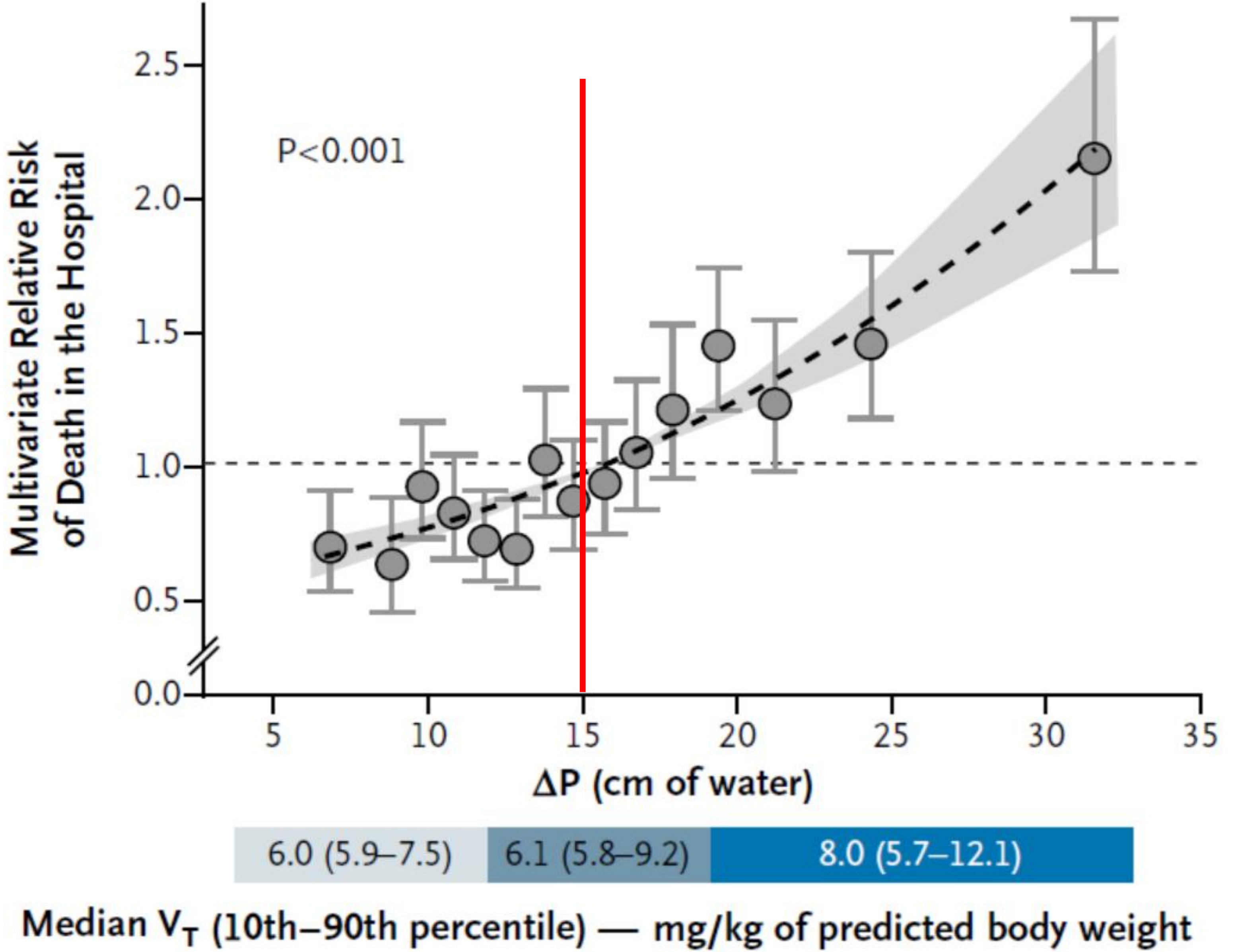
Driving pressure ΔP







Amato, NEJM, 2015



Amato, NEJM, 2015

Energytrauma / Ergotrauma
Mechanical Power

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Ventilator-related causes of lung injury: the mechanical power

L. Gattinoni[1*], T. Tonetti[1], M. Cressoni[2], P. Cadringher[3], P. Herrmann[1], O. Moerer[1], A. Protti[3], M. Gotti[2], C. Chiurazzi[2], E. Carlesso[2], D. Chiumello[4] and M. Quintel[1]

$$\mathrm{Power}_{rs} = \mathrm{RR} \cdot \left\{ \Delta V^2 \cdot \left[\frac{1}{2} \cdot \mathrm{EL}_{rs} + \mathrm{RR} \cdot \frac{(1 + I:E)}{60 \cdot I:E} \cdot R_{aw} \right] + \Delta V \cdot \mathrm{PEEP} \right\}$$

RR – dechová frekvence, Elrs – elastance resp. Systému, Raw – resistance resp. Systému,
ΔV – dechový objem, I:E – poměr inspiria a exspira, PEEP – endexspirační tlak

In 30 patients with normal lungs and in 50 ARDS patients mechanical power was computed via the power equation and **measured from the dynamic pressure–volume** curve at 5 and 15 cmH2O PEEP and 6, 8, 10, and 12 ml/kg TV

Gattinoni, Intensive Care Med, 2016

Energytrauma / Ergotrauma
Mechanical Power

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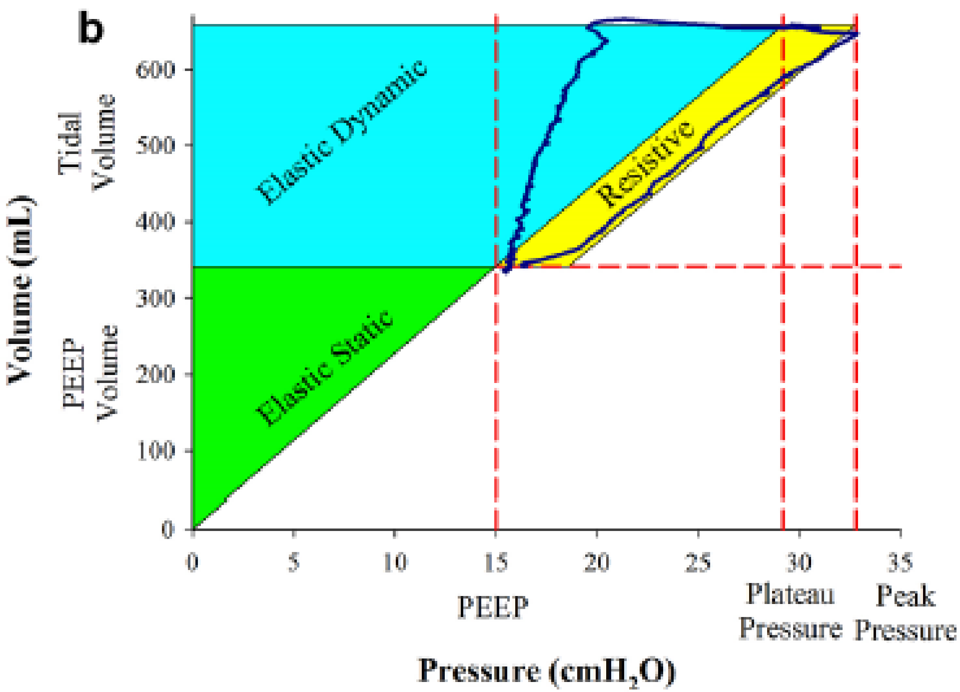


Pohlcená energie na 1 dech cca 0,7 až 0,8 J (ARDS)

Množství dodané energie koreluje s plicním postižením

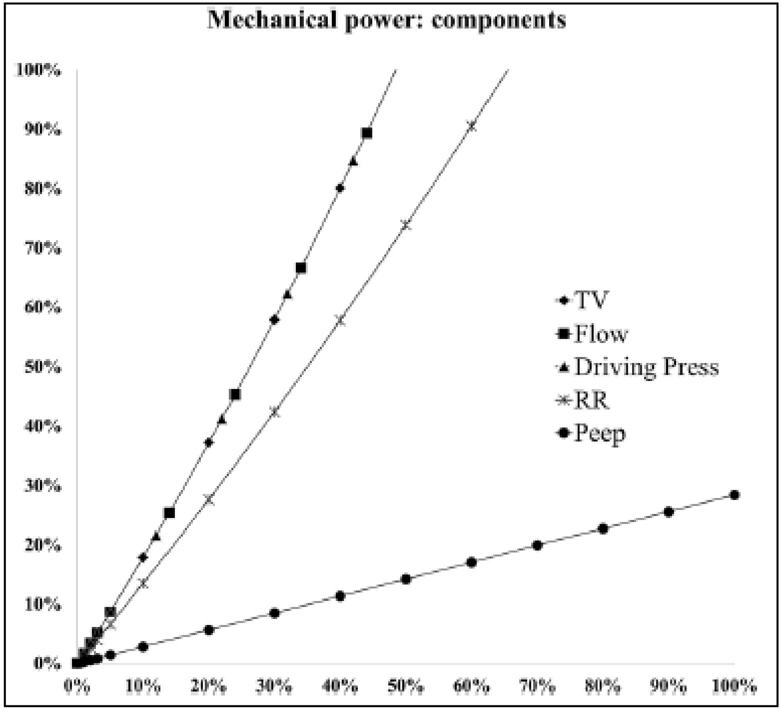
Hranice v experimentu 12j/min

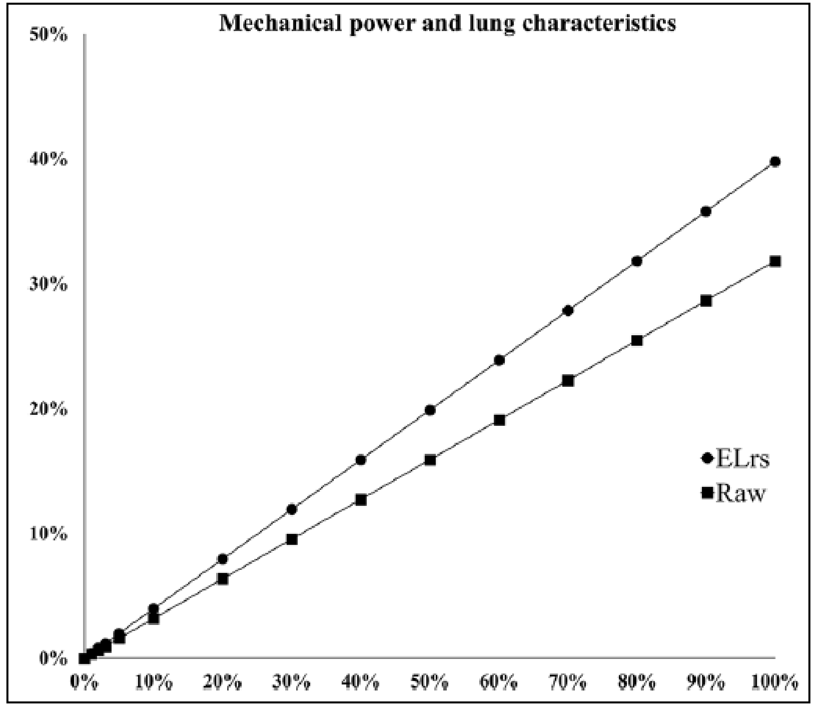
Cressoni Anesthesiology, 2016

measured energy, i.e. the area of the *trapezoid* described by the inspiratory *blue line*, Peak pressure line (major base), the PEEP line (minor base)
TV line (height) was 0.77 J, computed was 0.80 J.
With the RR = 18 bpm, the measured power was13.9 J/min and the computed was 14.4 J/min

Gattinoni, Intensive Care Med, 2016

Význam jednotlivých faktorů





Nastavení ventilátoru

Nejvýznamnější Vt, flow, driving pressure (exponent = 2)

Méně dechová frekvence (exponent = 1.4)

Nejméně PEEP (lineárně)

Plicní patologie

Více důležitá elastance

Méně významná rezistence

Gattinoni, Intensive Care Med, 2016

Mechanical Power

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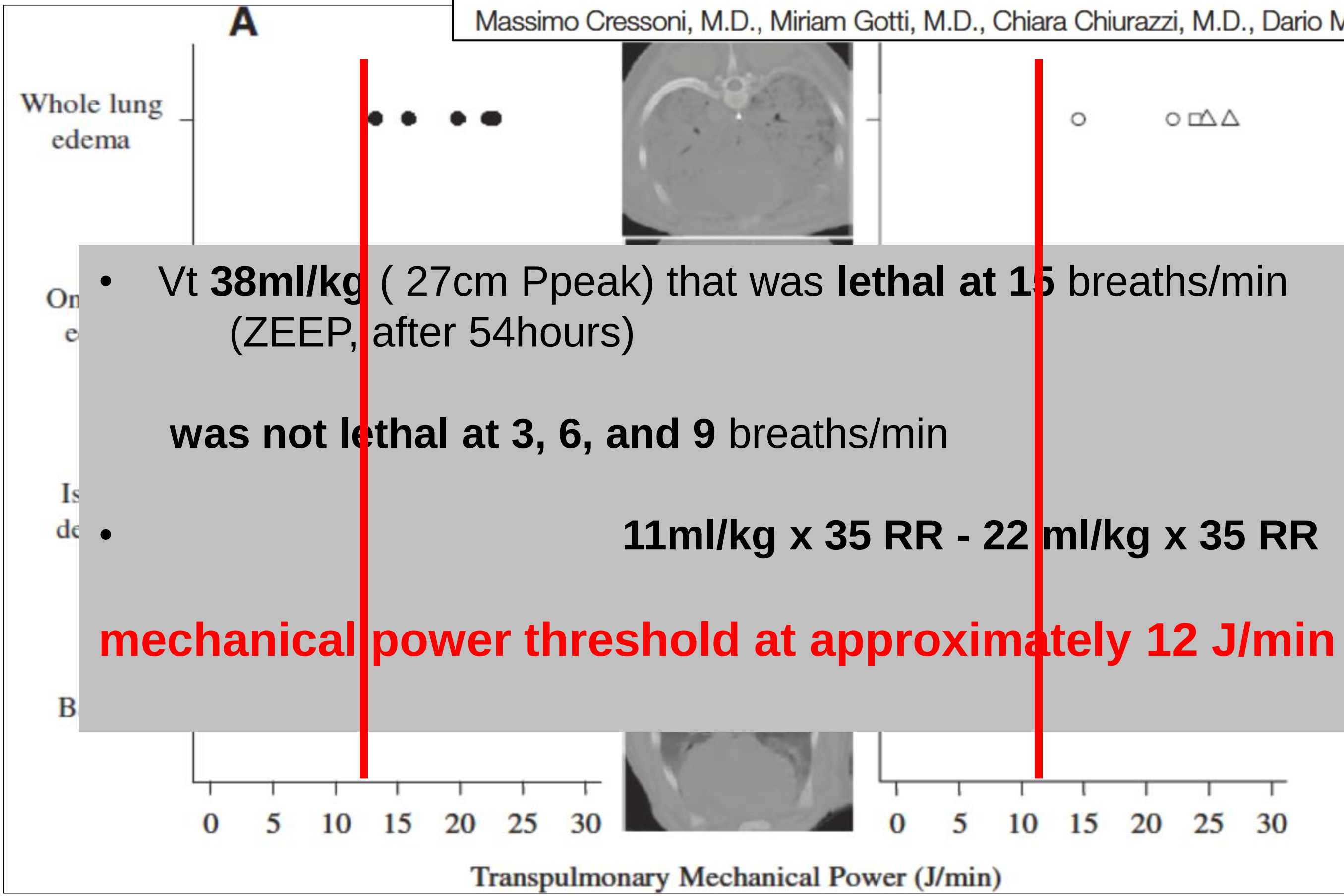
Mechanical Power and Development of Ventilator-induced Lung Injury

Massimo Cressoni, M.D., Miriam Gotti, M.D., Chiara Chiurazzi, M.D., Dario Massari, M.D.,



- Vt **38ml/kg** (27cm Ppeak) that was **lethal at 15** breaths/min (ZEEP, after 54hours)

  was not lethal at 3, 6, and 9 breaths/min

- **11ml/kg x 35 RR - 22 ml/kg x 35 RR**

mechanical power threshold at approximately 12 J/min

Cressoni, Anesthesiology 2016

Driving pressure ΔP

RESEARCH Open Access

Effect of driving pressure on mortality in ARDS patients during lung protective mechanical ventilation in two randomized controlled trials

Critical Care

Claude Guérin[1,2,3*], Laurent Papazian[4,5,6], Jean Reignier[7], Louis Ayzac[8], Anderson Loundou[5], Jean-Marie Forel[9] and on behalf of the investigators of the Acurasys and Proseva trials

805 patients of **ACURASYS** and **PROSEVA** trial 787 had day-1 data available, and 533 of these survived

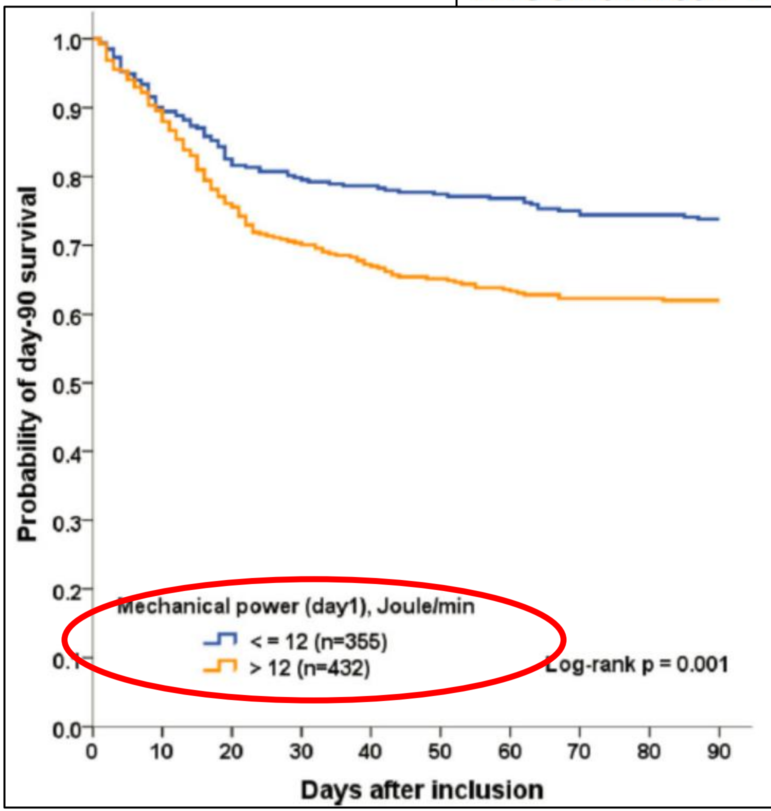
- ΔPrs averaged **13.7 ± 3.7** and **12.8 ± 3.7** cmH2O (P = 0.002) in **nonsurvivors** and **survivors**

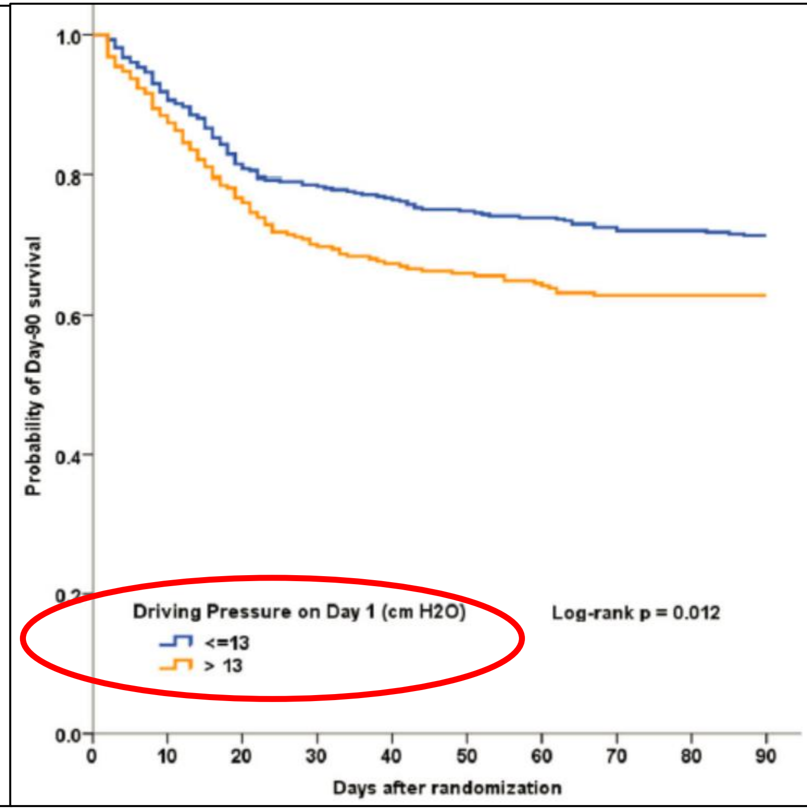
Guerin, CC, 2016

Driving pressure ΔP

RESEARCH Open Access

Effect of driving pressure on mortality in ARDS patients during lung protective mechanical ventilation in two randomized





Guerin, CC, 2016

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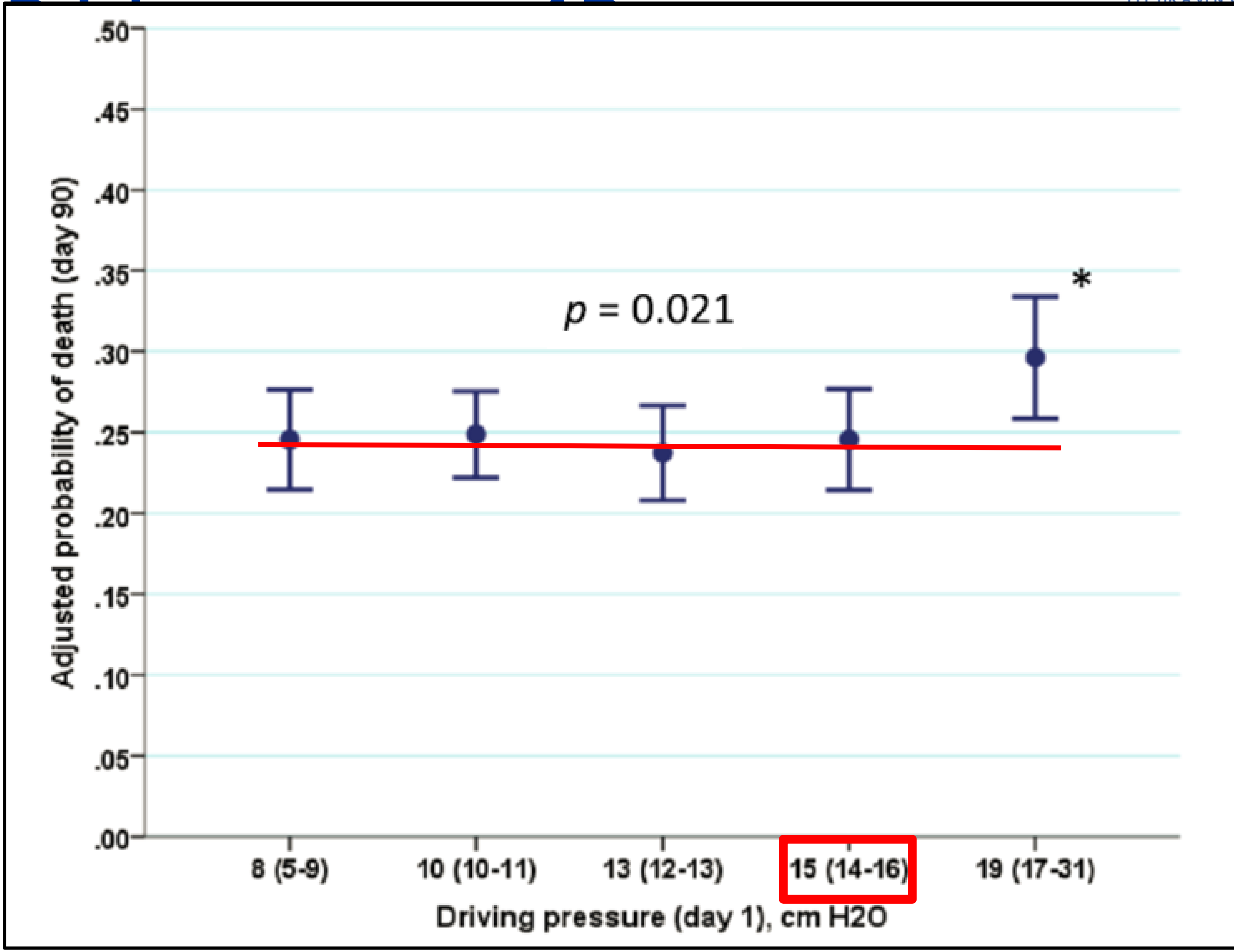

Access
CrossMark
Care

Guerin, CC, 2016

Driving pressure ΔP
cíl nastavení!!!

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VIEWPOINT Open Access

Driving pressure: a marker of severity, a safety limit, or a goal for mechanical ventilation?

Critical Care

Guillermo Bugedo*, Jaime Retamal and Alejandro Bruhn

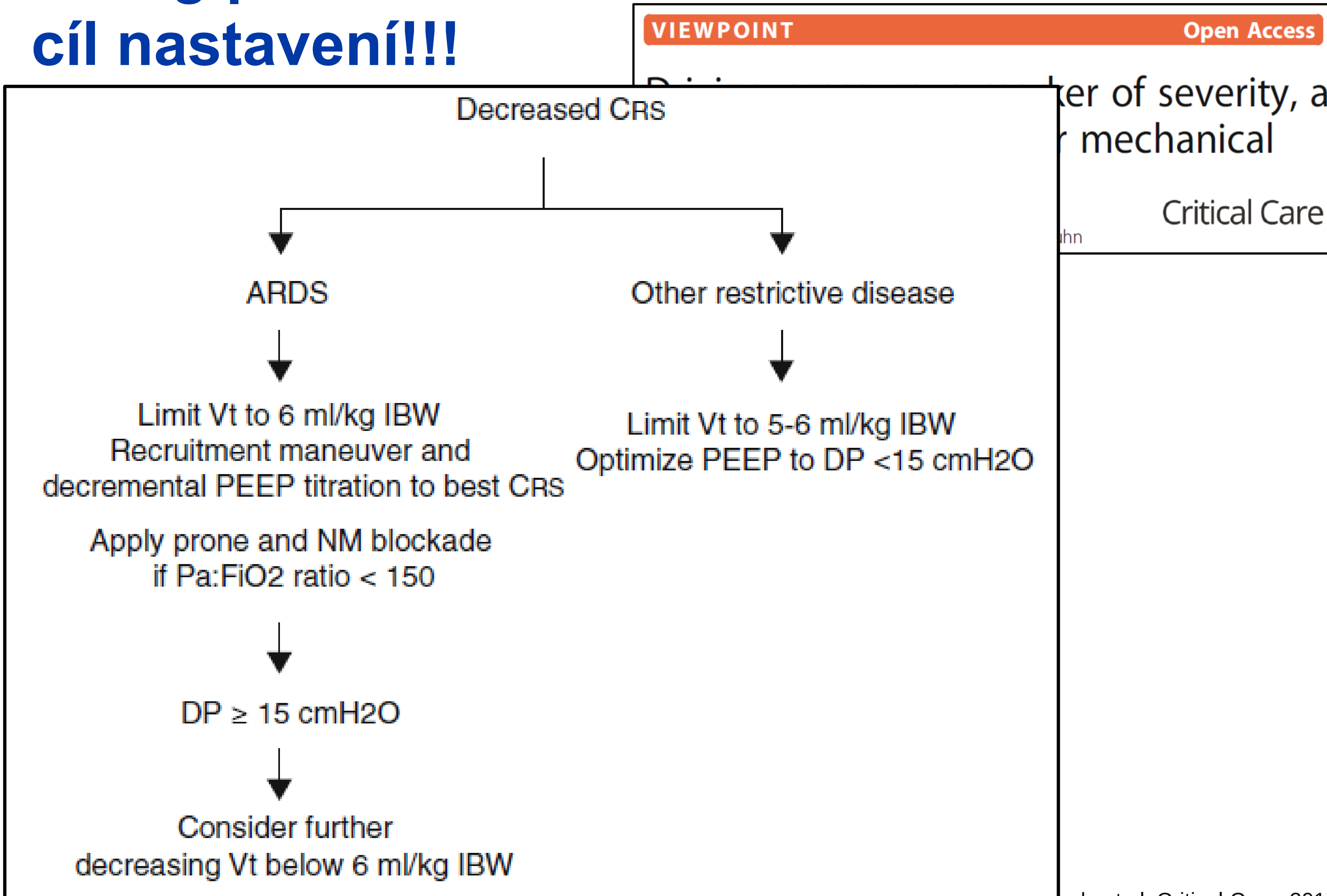
Table 1 Ventilatory parameters at 24 h and mortality in clinical studies comparing a protective strategy (Vt limitation) versus a control group (top panel), and a strategy of high PEEP versus low PEEP or minimal distension (lower panel) in patients with ARDS

Author	Year	N	Vt	P_{pl}	PEEP	DP	Mort	Vt	P_{pl}	PEEP	DP	Mort	Dif DP	p^{b}
Protective strategy								Control group						
Brochard	1998	108	7.1	25.7	10.7	15	46.6%	10.3	31.7	10.7	21	37.9%	6	NS
Stewart	1998	120	7.2	22.3	8.6	13.7	48.0%	10.8	26.8	7.2	19.6	46.0%	5.9	NS
Ranieri[a]	1999	44	7.6	24.6	14.8[a]	9.8	38.0%	11.1	31	6.5	24.5	58.0%	14.7	0.19
Brower	1999	52	7.3	27	9.3	17.7	50.0%	10.2	30	8.2	21.8	46.0%	4.1	NS
Amato[a]	1998	53	6	31.8	16.3[a]	15.5	38.0%	12	34.4	6.9	27.5	71.0%	12	<0.001
ARDSnet	2000	861	6.1	25	9.4	15.6	31.0%	11.9	33	8.6	24.4	39.8%	8.8	0.007
High PEEP								Low PEEP						
ALVEOLI	2004	549	6.1	27	14.7	12.3	27.5%	6.0	24	9.1	14.9	24.9%	2.6	NS
Mercat	2008	767	6.1	27.5	15.8	11.7	35.4%	6.1	21.1	8.4	12.7	39.0%	1.0	NS
Meade	2008	983	6.8	30.2	15.6	14.6	36.4%	6.8	24.9	10.1	14.8	40.4%	0.2	NS
Talmor[c]	2008	61	7.1	28	17	11	17%	6.8	25	10	15	39%	4.0	0.055
Kacmarek	2016	200	5.6	27.9	15.8	11.8	22%	6.2	25.2	11.6	13.8	27%	2.0	0.18

Driving pressure of the respiratory system (*DP*) is calculated as the difference between the plateau pressure (P_{pl}) and PEEP. Note that a larger difference in DP

Bugedo et al. Critical Care, 2017

Driving pressure ΔP cíl nastavení!!!



Bugedo et al. Critical Care, 2017

Možnosti mimo UPV?

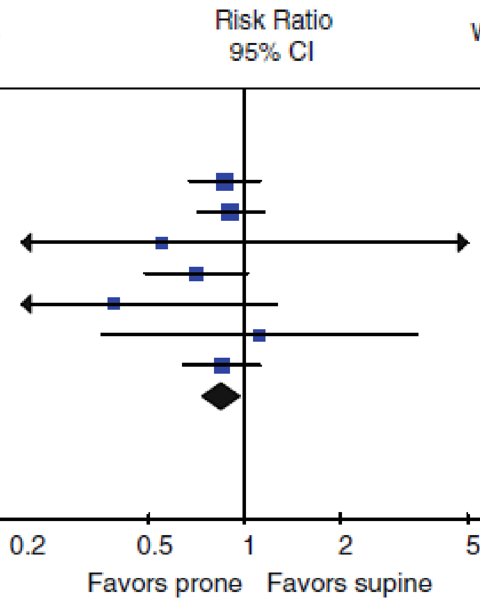
Efekt PRONACE na mortalitu ARDS?

Prone ventilation reduces mortality in patients with acute respiratory failure and severe hypoxemia: systematic review and meta-analysis

Study or sub-category	Prone n/N	Supine n/N	Weight %	Risk Ratio 95% CI
PaO_2/FiO_2 < 100 Subgroup				
Gattinoni 2001	35/53	35/46	28.31	0.87 [0.67, 1.12]
Guerin 2004	53/90	49/75	31.56	0.90 [0.71, 1.14]
Curley 2005	1/21	2/23	0.33	0.55 [0.05, 5.61]
Mancebo 2006	22/43	21/29	13.25	0.71 [0.49, 1.02]
Chan 2007	2/6	6/7	1.31	0.39 [0.12, 1.25]
Fernandez 2008	5/9	2/4	1.38	1.11 [0.36, 3.48]
Taccone 2009	39/73	48/76	23.86	0.85 [0.64, 1.11]
Subtotal (95% CI)	157/295	163/260	100.00	0.84 [0.74, 0.96]

Test for Overall Effect: p=0.01

Heterogeneity: $I^2 = 0\%$



Sud, ICM,2010

PROSEVA trial

Prone Positioning in Severe Acute Respiratory Distress Syndrome

The NEW ENGLAND JOURNAL of MEDICINE

Claude Guérin, M.D., Ph.D., Jean Reignier, M.D., Ph.D., Jean-Christophe Richard, M.D., Ph.D.,

- multicenter, prospective, randomized, controlled trial
- 26 ICUs in France and 1 in Spain, all of which have used prone positioning in daily practice for more than 5 years
- **237 pts. prone / 229 pts. supine** group,
- **Sever ARDS paO2/FiO2 < 150, FiO2 > 0.6**
- Vt 6ml/kg, Ppeak < 30 cmH2O, pH 7.20 - 7.45

PEEP (cm H_2O)	5	5	8	8	10	10	10	12	14	14	14	16	18	18-24
F_iO_2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.0

- stopping prone: improvement in oxygenation

(Pao2:Fio2 ≥150, with a PEEP of ≤10 cm of water and an Fio2 of ≤0.6)

Guerin,NEJM,2013

PROSEVA trial

Prone Positioning in Severe Acute Respiratory Distress Syndrome

The NEW ENGLAND JOURNAL of MEDICINE

ARDS intubated for < 36 Hrs

Confirmed after 12-24 hours

Severity criteria $PaO_2/F_IO_2 < 150$mmHg + PEEP $\geq$ 5cm H2O + $F_IO_2 \geq 0.6$ + VT 6 $ml.kg^{-1}$ PBW

Inclusion and randomization

SP
24 hours

PP in the hour after randomization
At least 16 hours per day

LPV

VT 6 $ml.kg^{-1}$ PBW, $Pplat_{,RS} \leq 30$ cm H_2O, PaO2 55-80 mmHg or SpO2 88-95%, PEEP/F_IO_2 table

Sedation+analgesia+NB

$PaO_2/F_IO_2 \geq 150$ mmHg + PEEP $\leq$ 10 cmH_2O+ $F_IO_2 \leq 0.6$

Stop sedation, NB, PP

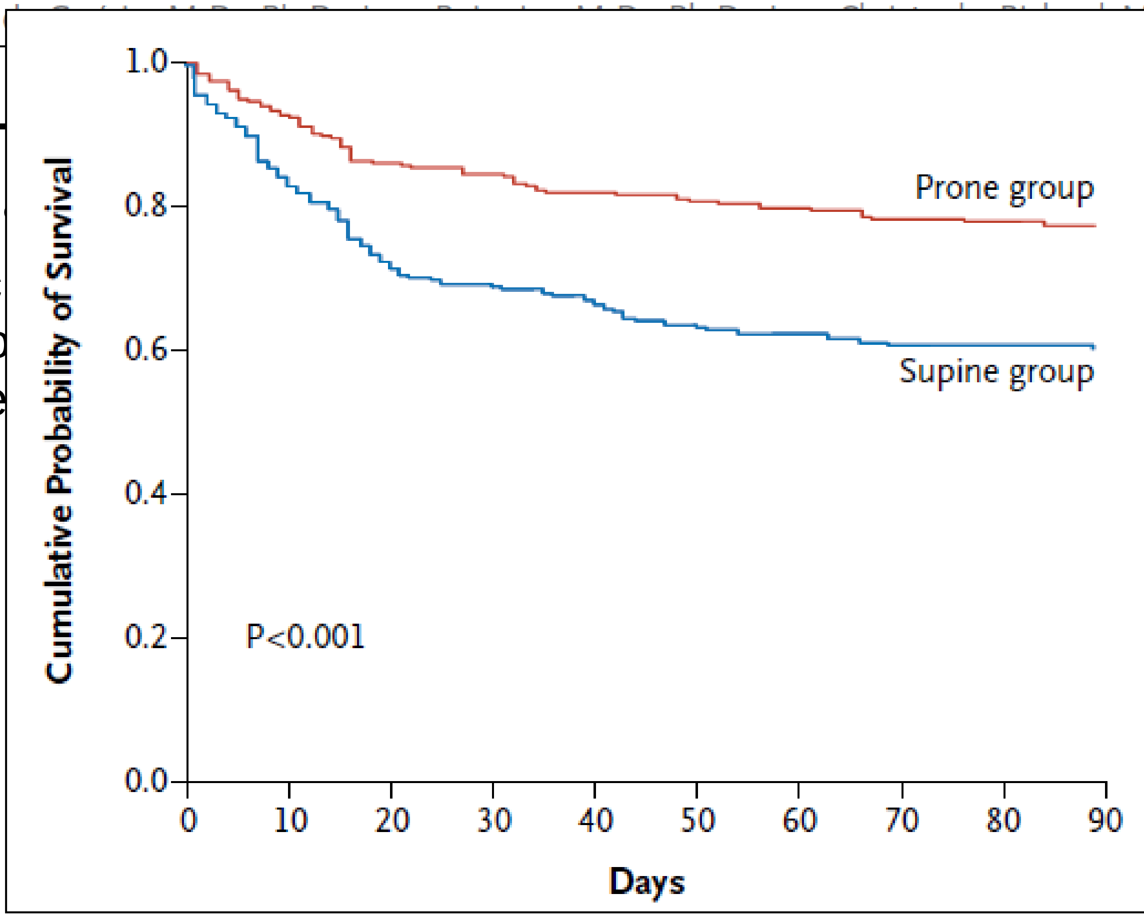
Guerin,NEJM,2013

PROSEVA trial

Prone Positioning in Severe Acute Respiratory Distress Syndrome

The NEW ENGLAND JOURNAL of MEDICINE

Clau … .D., Ph.D.,



- **28-**
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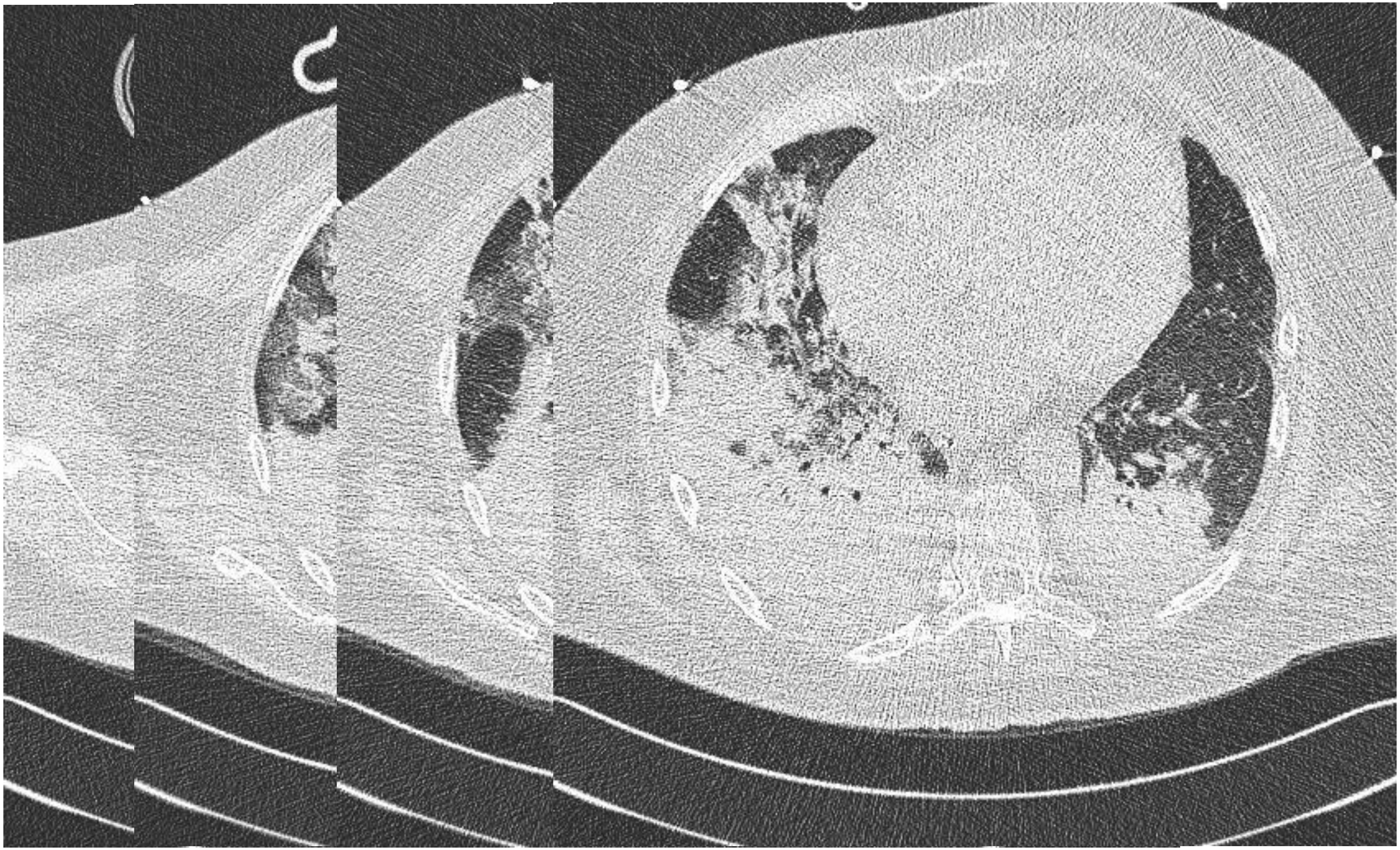
Guerin,NEJM,2013

Effect of SEMI-PRONE 135° / lateral 90°



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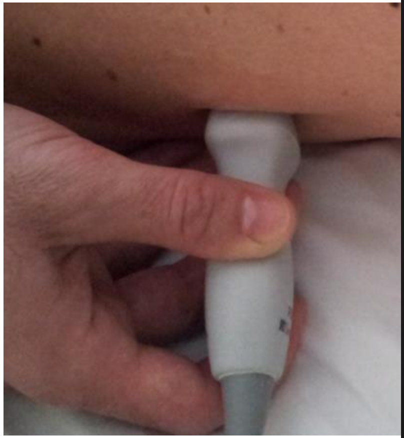
Effect of SEMI-PRONE 135° / lateral 90°

UZ cílená thorakocentéza



transversální rovina
LUQ

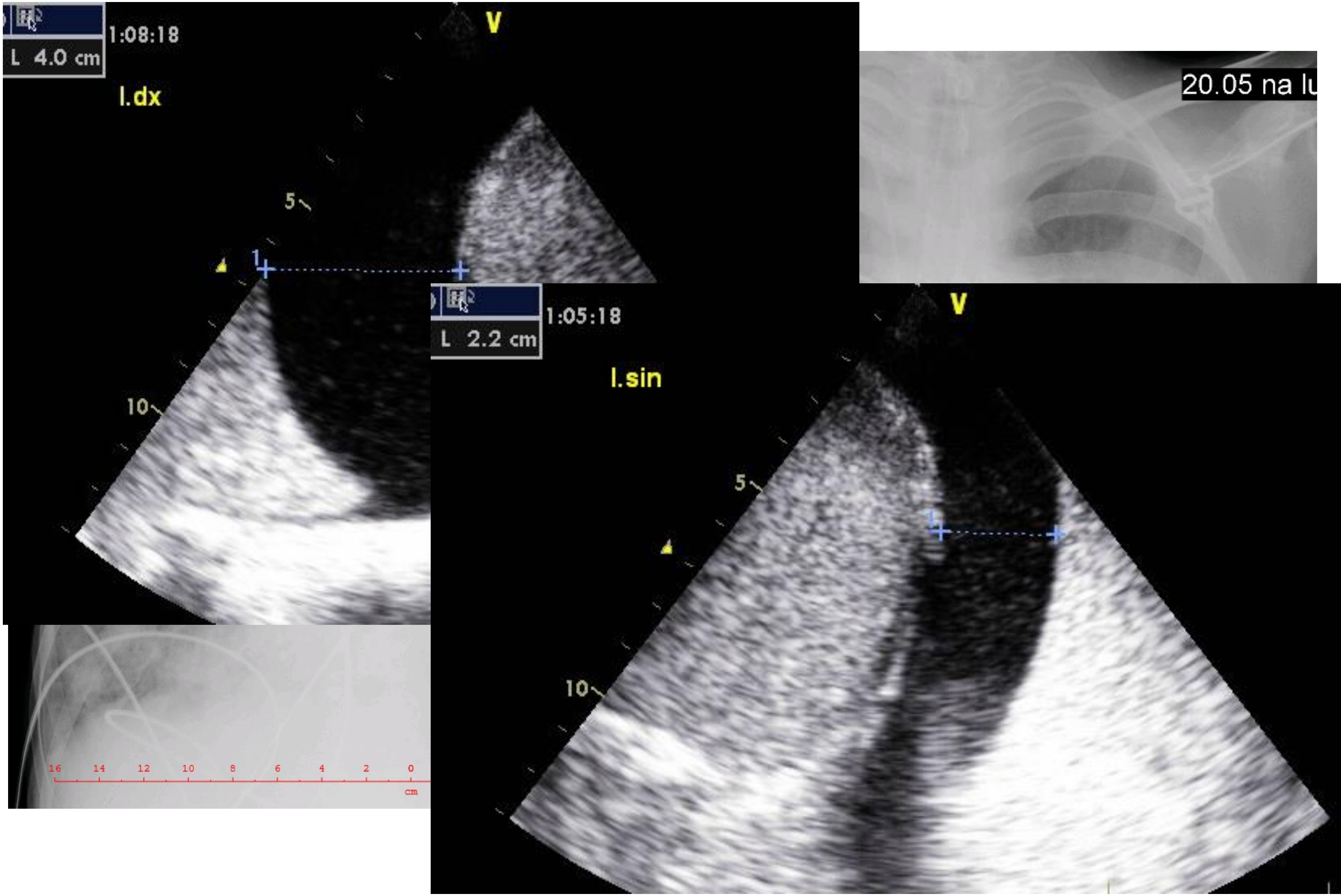
UZ kontrola po evakuaci / HD

před talc slurry pleurodézou nutná **KOMPLETNÍ** evakuace

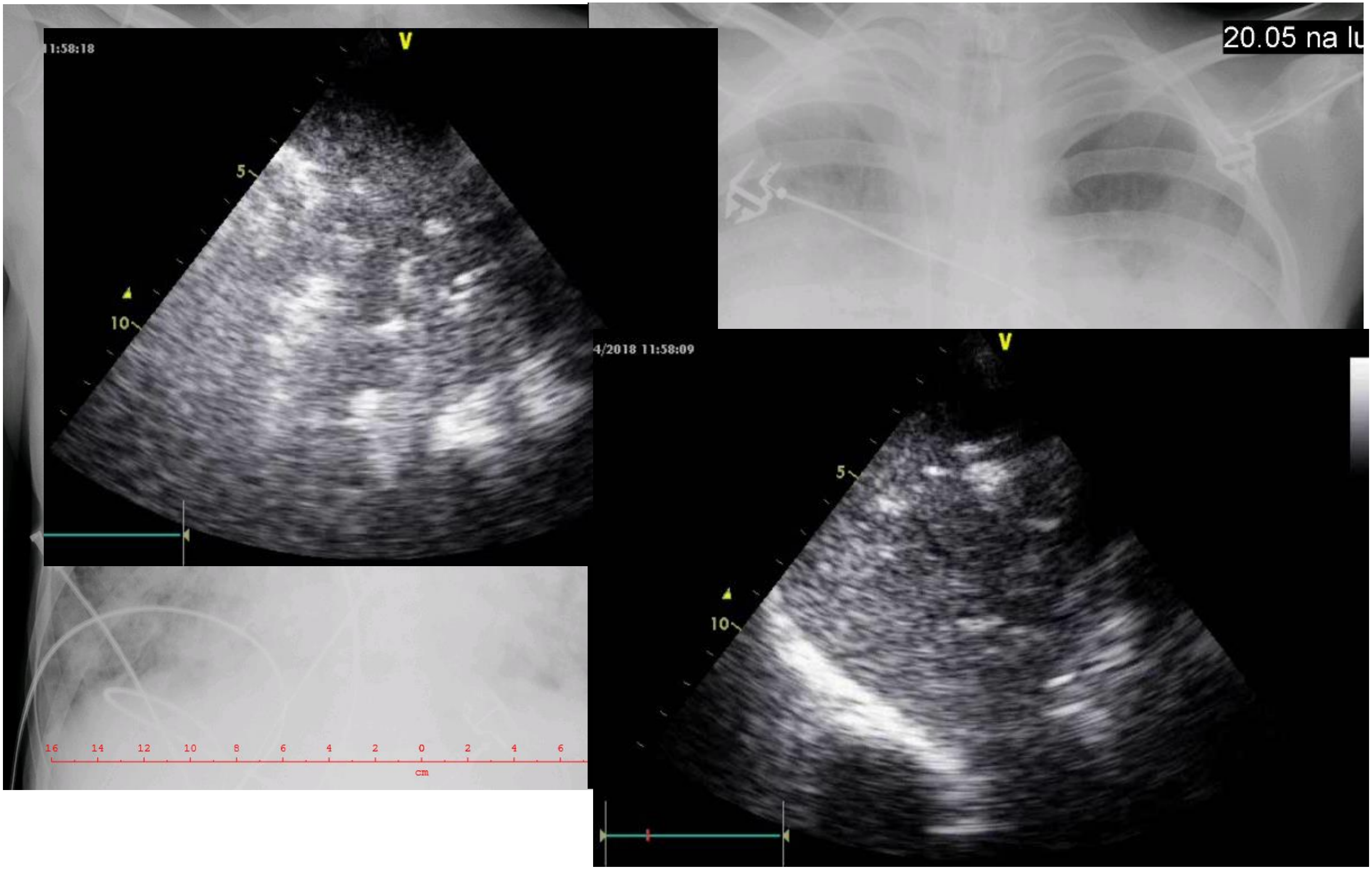
sliding vylučuje PNO

PCV RM monitorace UZ

PCV RM monitorace UZ



PCV RM monitorace UZ



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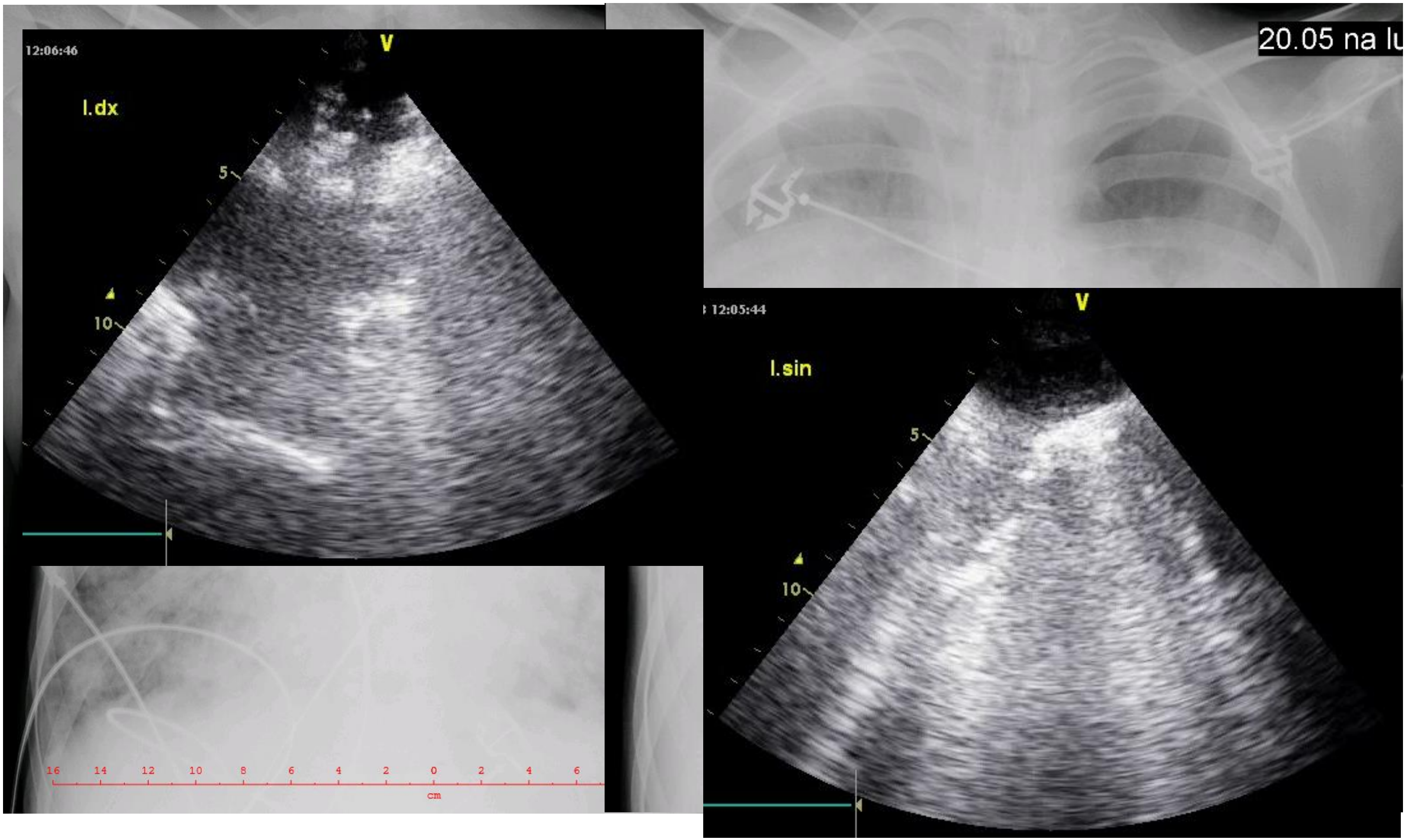
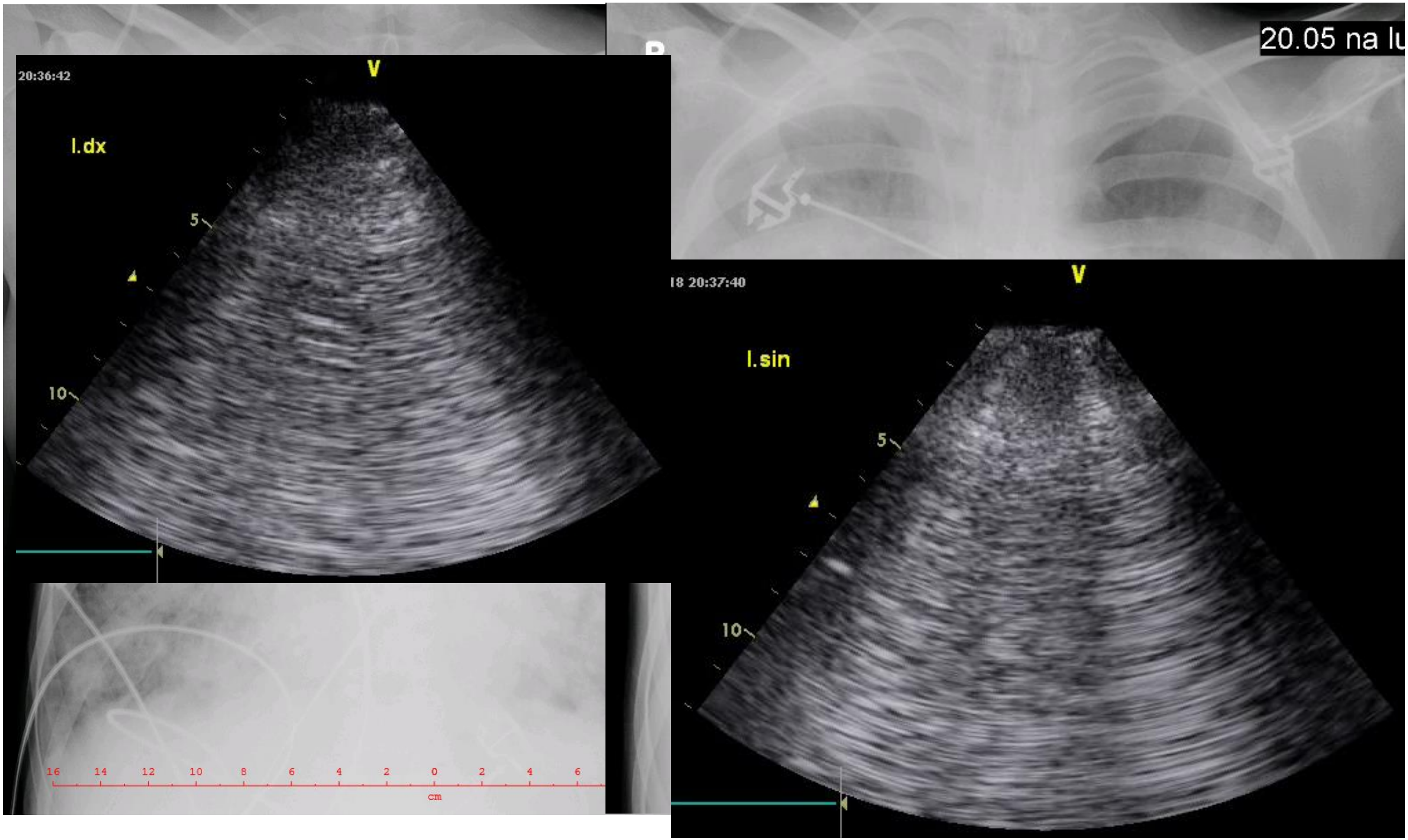
PCV RM monitorace UZ



PCV RM monitorace UZ



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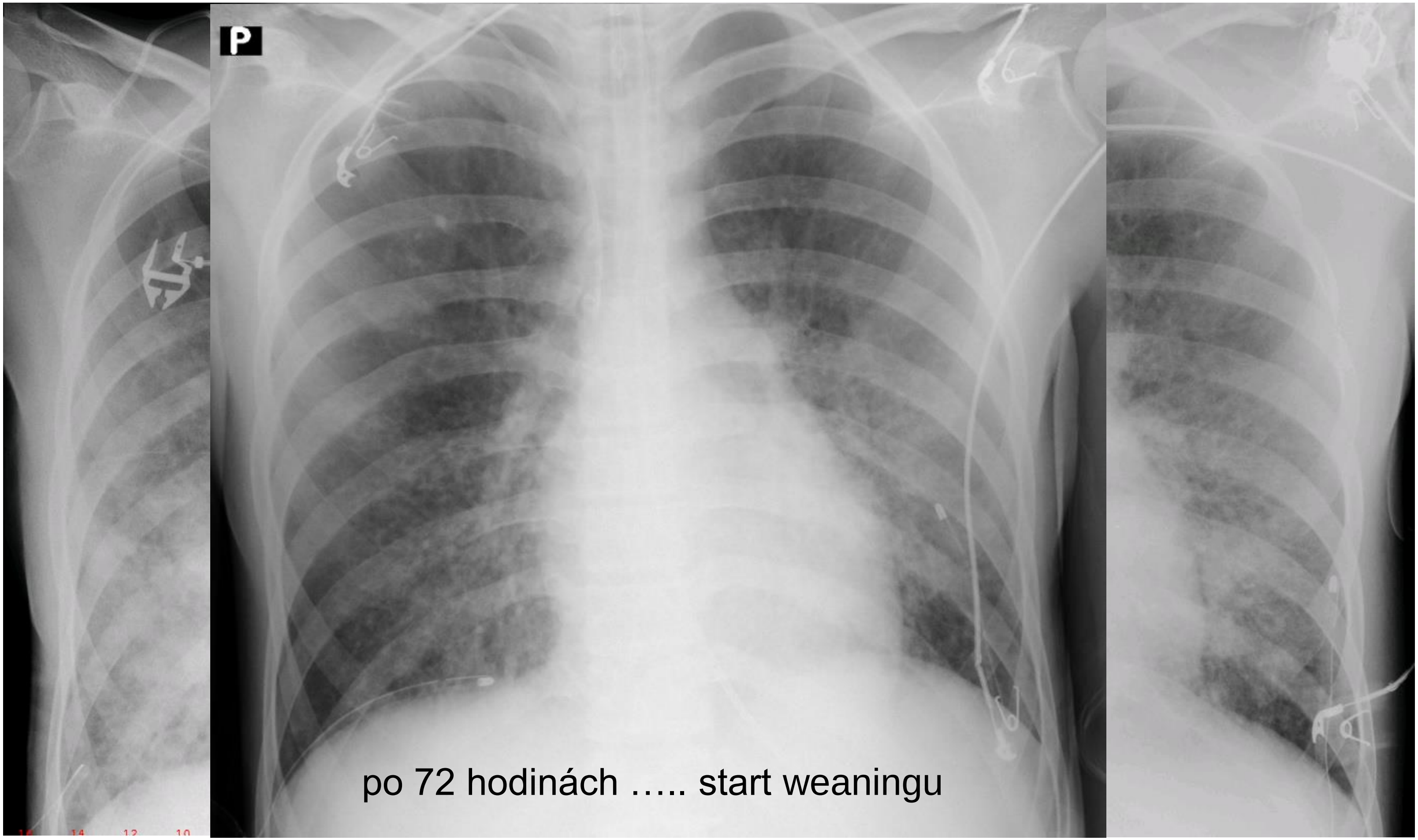
PCV RM monitorace UZ



po 18 hodinách pronace + ALT

po 48 hodinách ….. pronace + ALT

ALT – Automatic Lateral Therapy

Jak ventilovat?

- Vt 6ml/kg/ PBW? ….. ΔP<=15 (13)
- Ppeak < 30/27cm H2O
- Mechanical power < 12j/min???

  ……….. lepší zvyšovat DF
- optimalizovat PEEP
- homogenizace / RM …. reareace
- pronační poloha / polohování / ALT?
- SONO, FOB toaleta