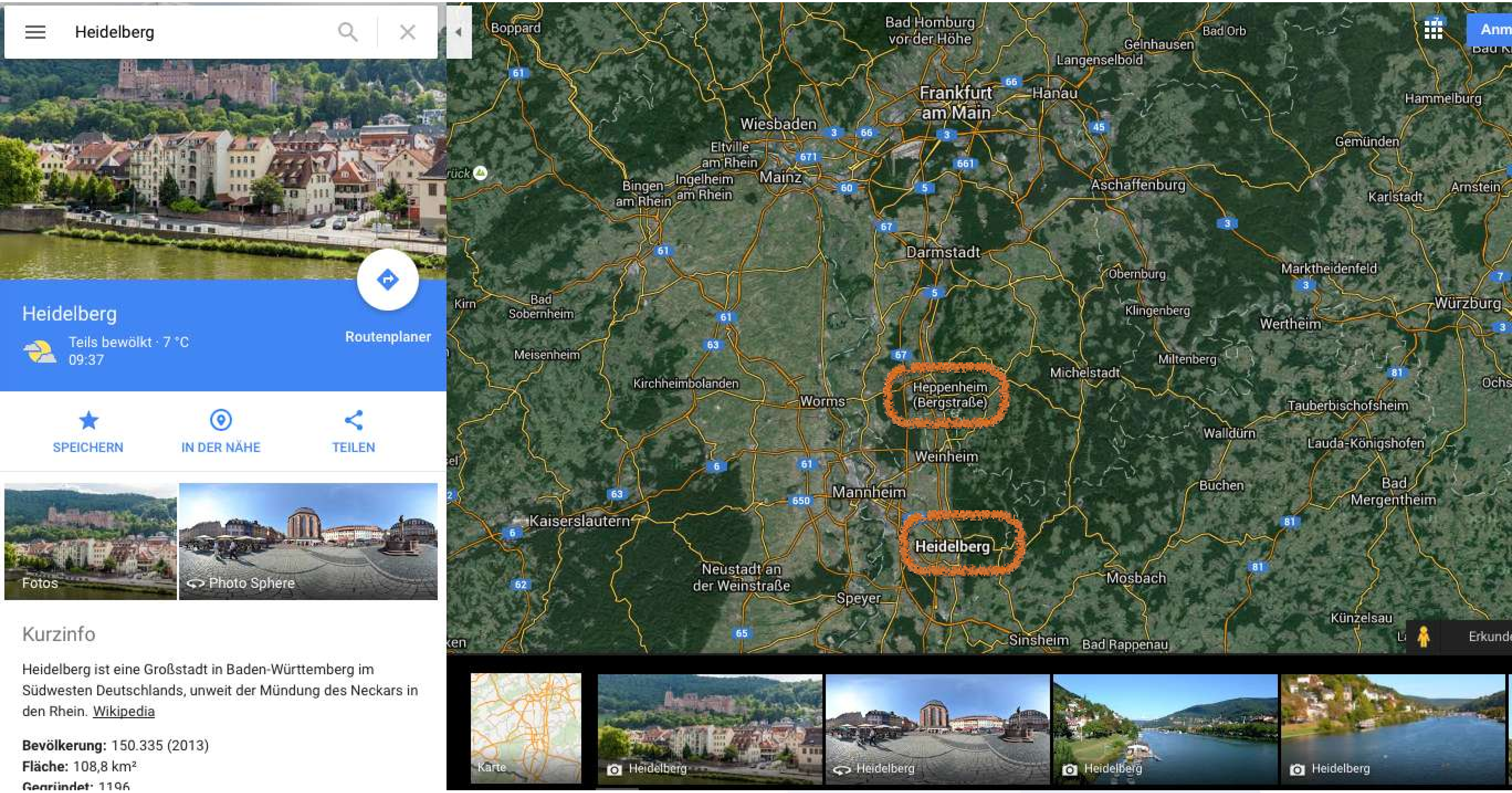
Heidelberg University Hospital
Hospital Bergstraße

mechanical ventilation in patients with sepsis

Armin Kalenka, MD, Ph.D.
head of anaesthesia/intensive care med

Heidelberg University Hospital
Hospital Bergstraße



armin.kalenka@med.uni-heidelberg.de

conflict of interest

consultant, travel expenses, lecture fees

GE Healthcare

What is your focus for a patient on the ventilator?

- Oxygenation
- CO_2 Elimination
- Lung protection

Best practice in mechanical ventilation?

- **V_T**: 6 ml/kg pbw for all patients?
    - NEJM 2000
- **PEEP**: ARDS network table based on Oxygenation?
    - NEJM 2000 or NEJM 2004
- **High PEEP**: for severe ARDS
    - JAMA 2010
- **Prone**: for severe ARDS
    - NEJM 2013
- **NMB**: for severe ARDS
    - NEJM 2010
- **No NIV** for severe ARDS
    - AJRCCM 2017

Intensive Care Med (2016) 42:787–789
DOI 10.1007/s00134-016-4309-4

WHAT'S NEW IN INTENSIVE CARE

CrossMark

What's new in mechanical ventilation in patients without ARDS: lessons from the ARDS literature

Ary Serpa Neto[1,2,3] and Samir Jaber[4*]

Intensive Care Med (2016) 42:772–774
DOI 10.1007/s00134-016-4280-0

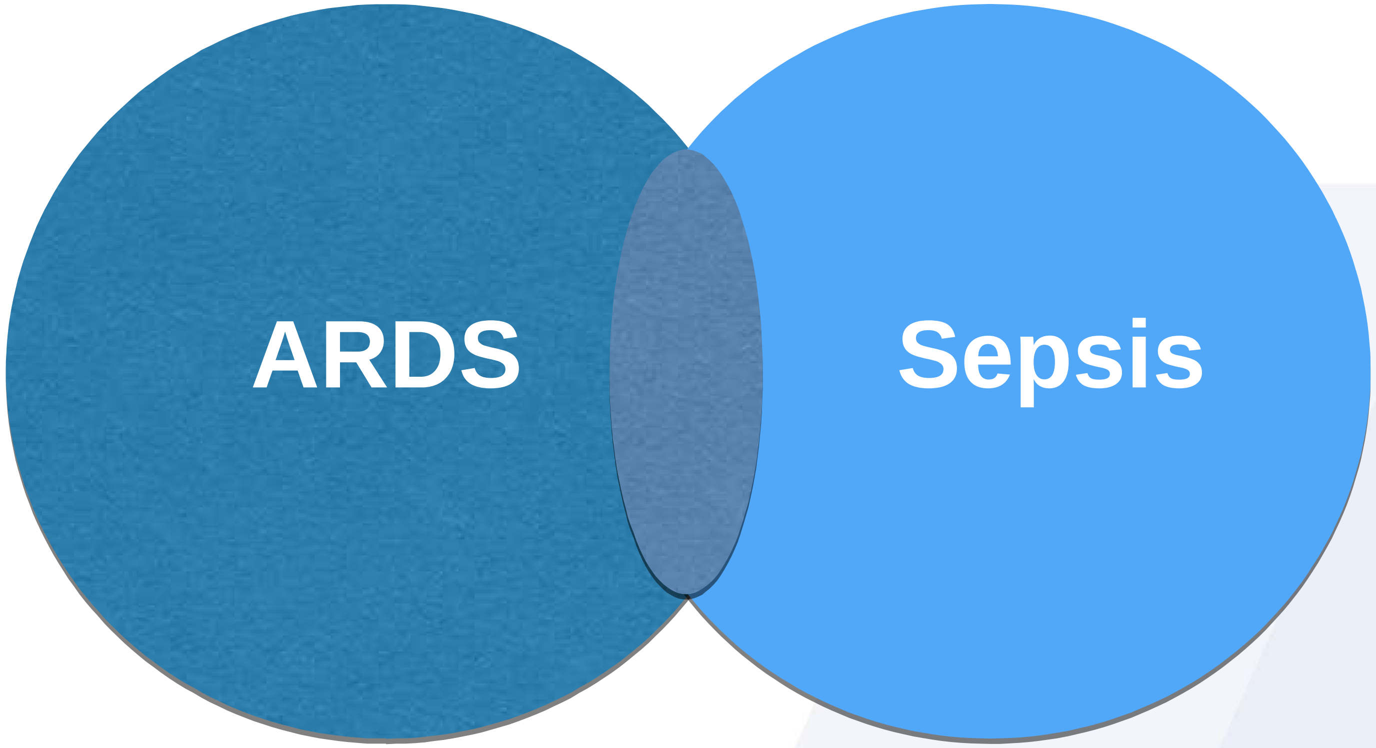
EDITORIAL

CrossMark

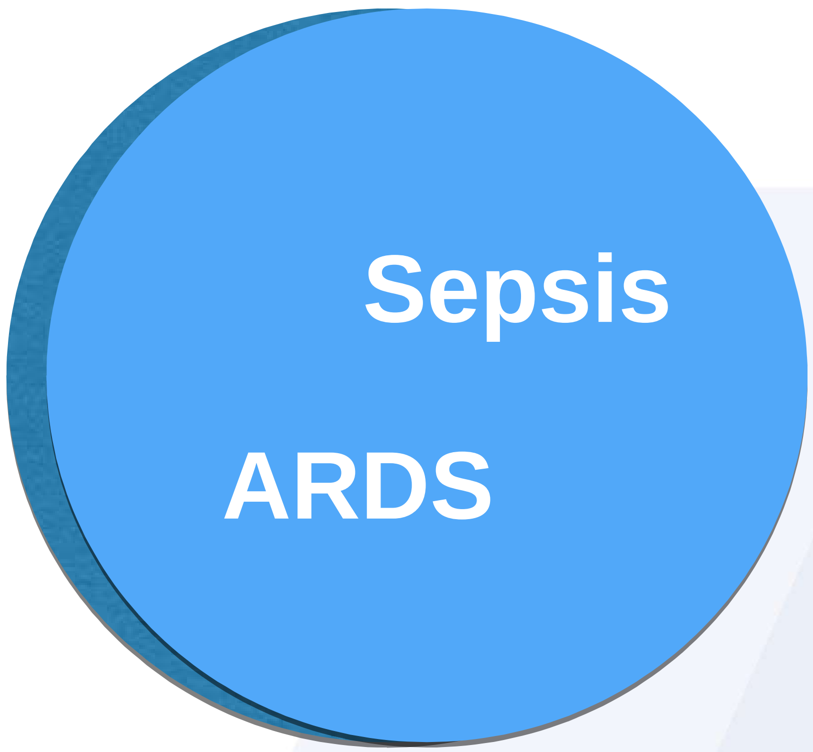
What's new in ARDS: can we prevent it?

Roy G. Brower[1] and Massimo Antonelli[2*]

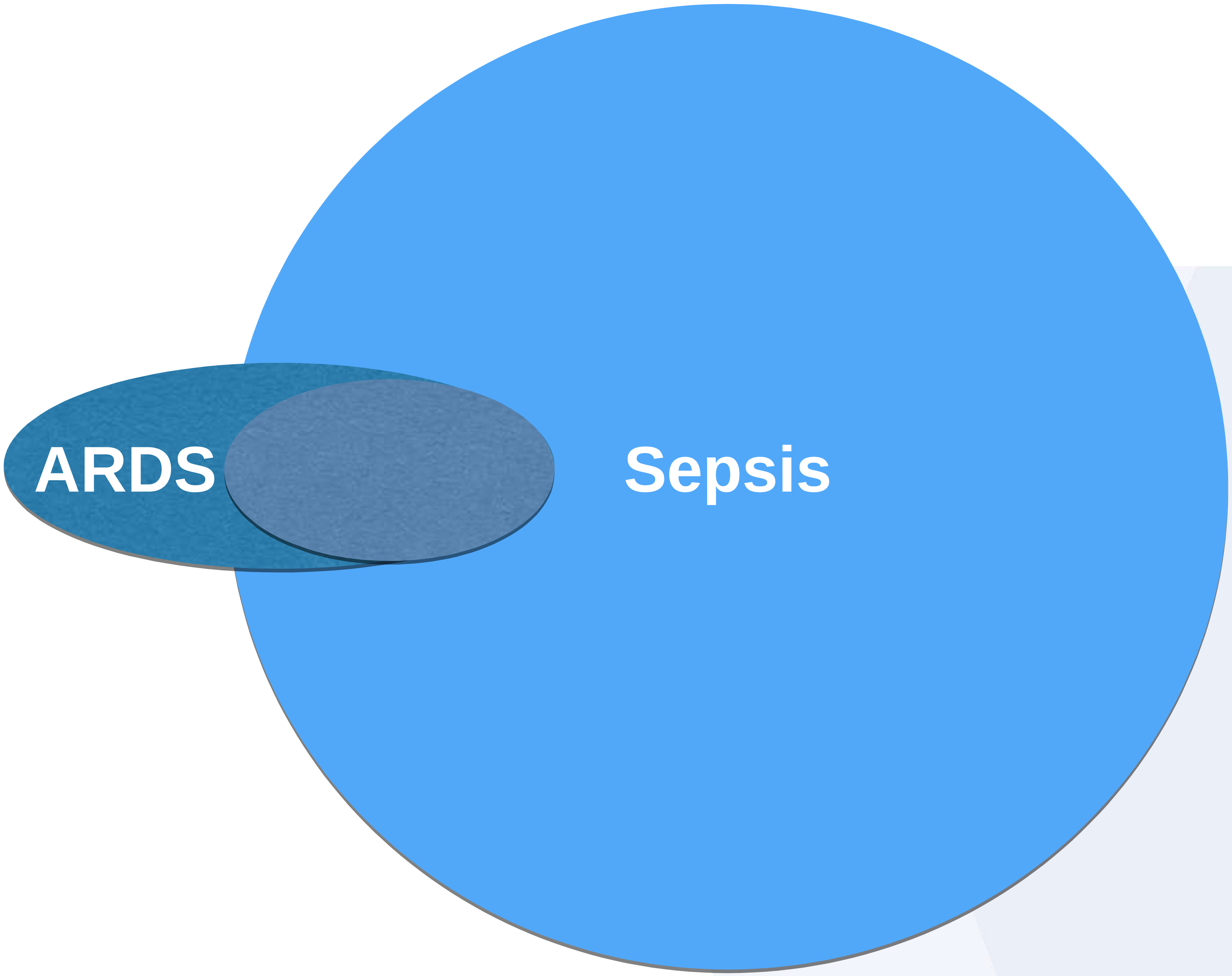
ARDS and Sepsis



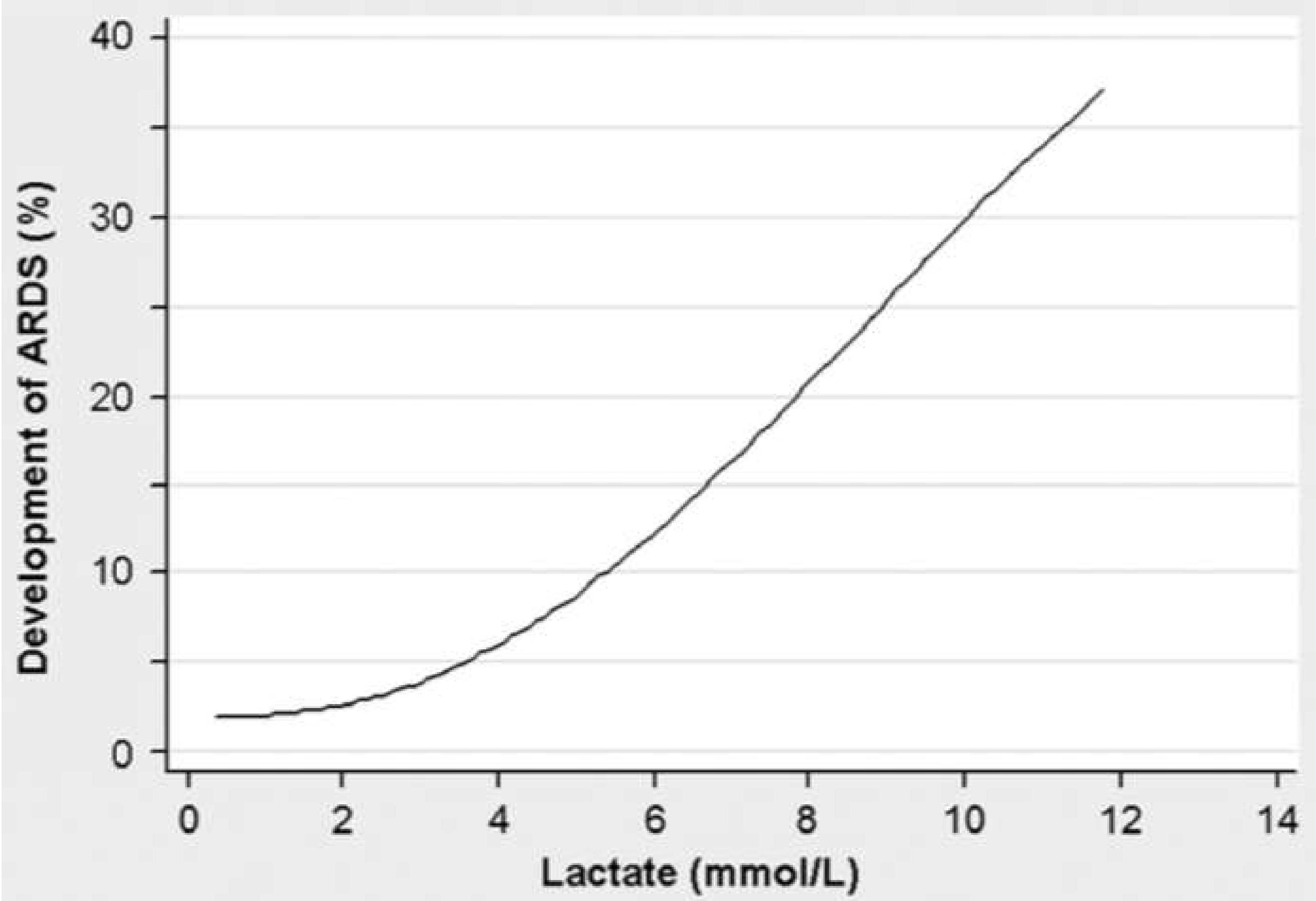
ARDS and Sepsis



ARDS and Sepsis



How often is ARDS in severe sepsis?



Shock; 2013:40: 375-382

Fluids, Sepsis and ARDS

LIPS:
adult patients with one or more ARDS risk factors admitted to the hospital through the Emergency Department or admitted for high-risk elective surgery.

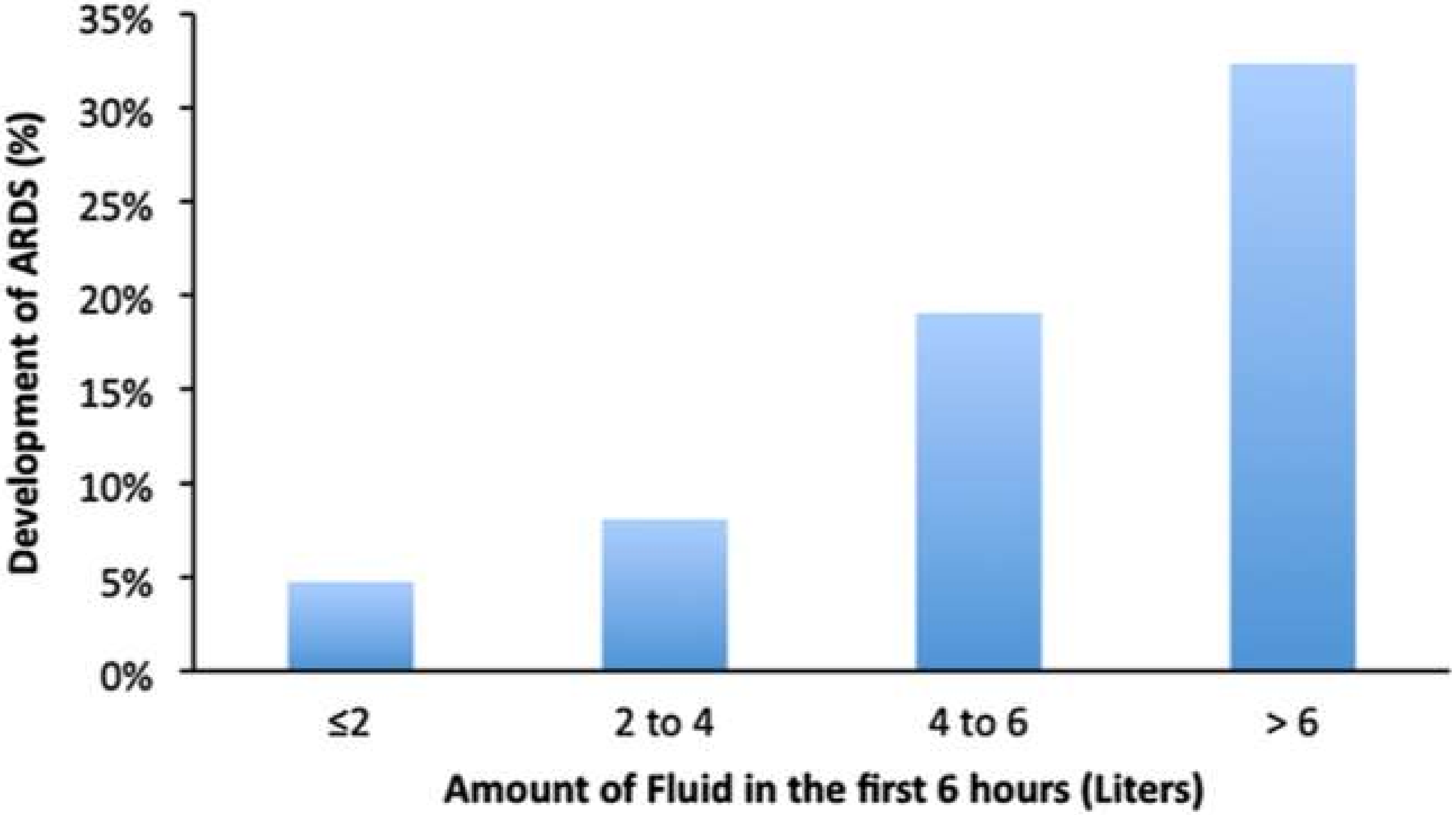


Fig. 2 Frequency of acute respiratory distress syndrome (ARDS) development according to amount of fluid administered during the first 6 h of hospital presentation

Ann Intensive Care 2017; 7: 11

Best practice in mechanical ventilation?

- **V_T**: 6 ml/kg pbw for all patients?
    - NEJM 2000
- **PEEP**: ARDS ne … on Oxygenation?
    - NEJM 2000 or N
- **High PEEP**: for severe ARDS
    - JAMA 2010
- **Prone**: for severe ARD
    - NEJM 2013
- **NMB**: for severe ARDS
    - NEJM 2010
- **No NIV** for severe A
    - AJRCCM 2017

Normalisation because of unknown size of the „baby“ lung

The NEW ENGLAND JOURNAL of MEDICINE

SPECIAL ARTICLE

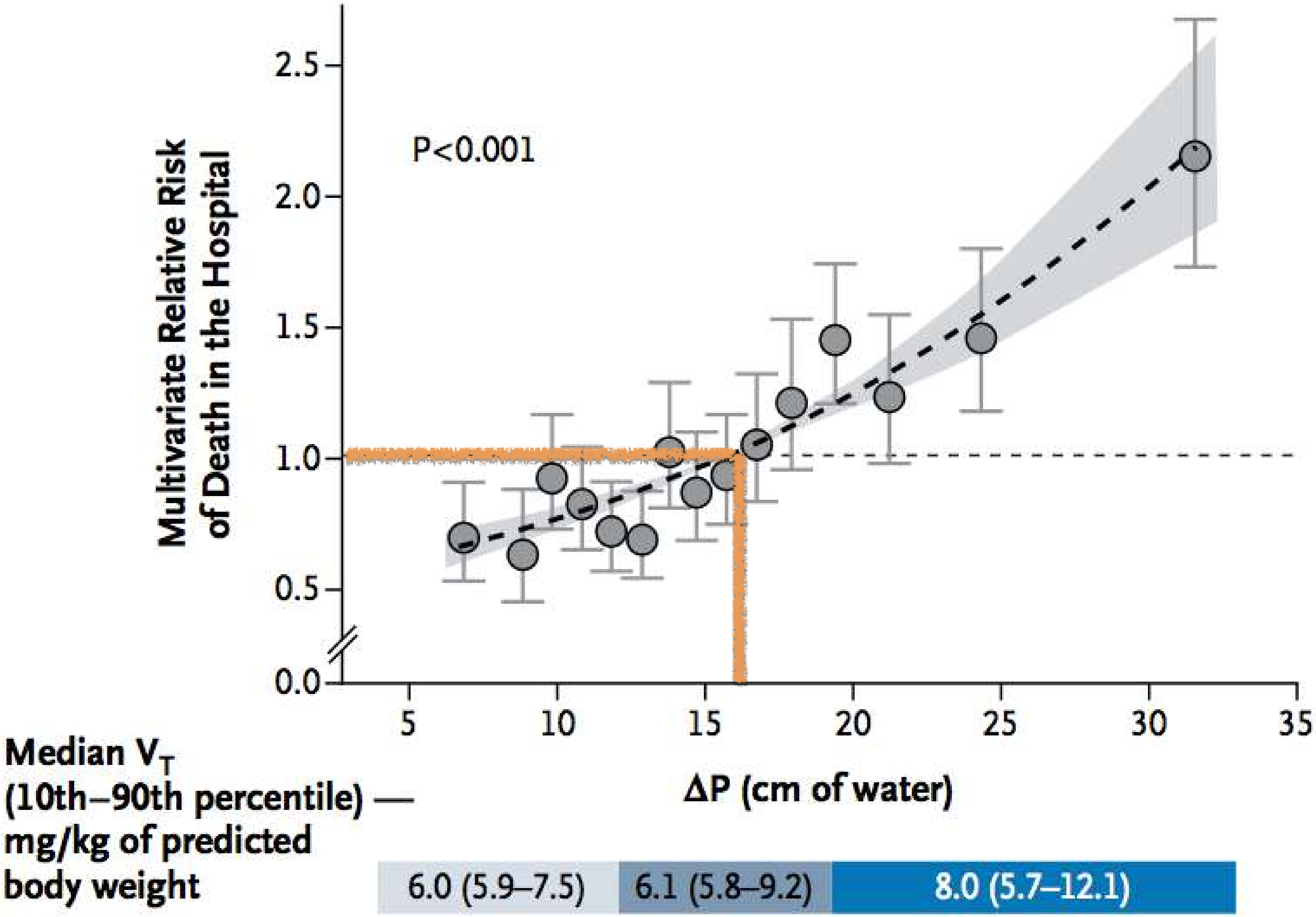
Driving Pressure and Survival in the Acute Respiratory Distress Syndrome

Marcelo B.P. Amato, M.D., Maureen O. Meade, M.D., Arthur S. Slutsky, M.D., Laurent Brochard, M.D., Eduardo L.V. Costa, M.D., David A. Schoenfeld, Ph.D., Thomas E. Stewart, M.D., Matthias Briel, M.D., Daniel Talmor, M.D., M.P.H., Alain Mercat, M.D., Jean-Christophe M. Richard, M.D., Carlos R.R. Carvalho, M.D., and Roy G. Brower, M.D.

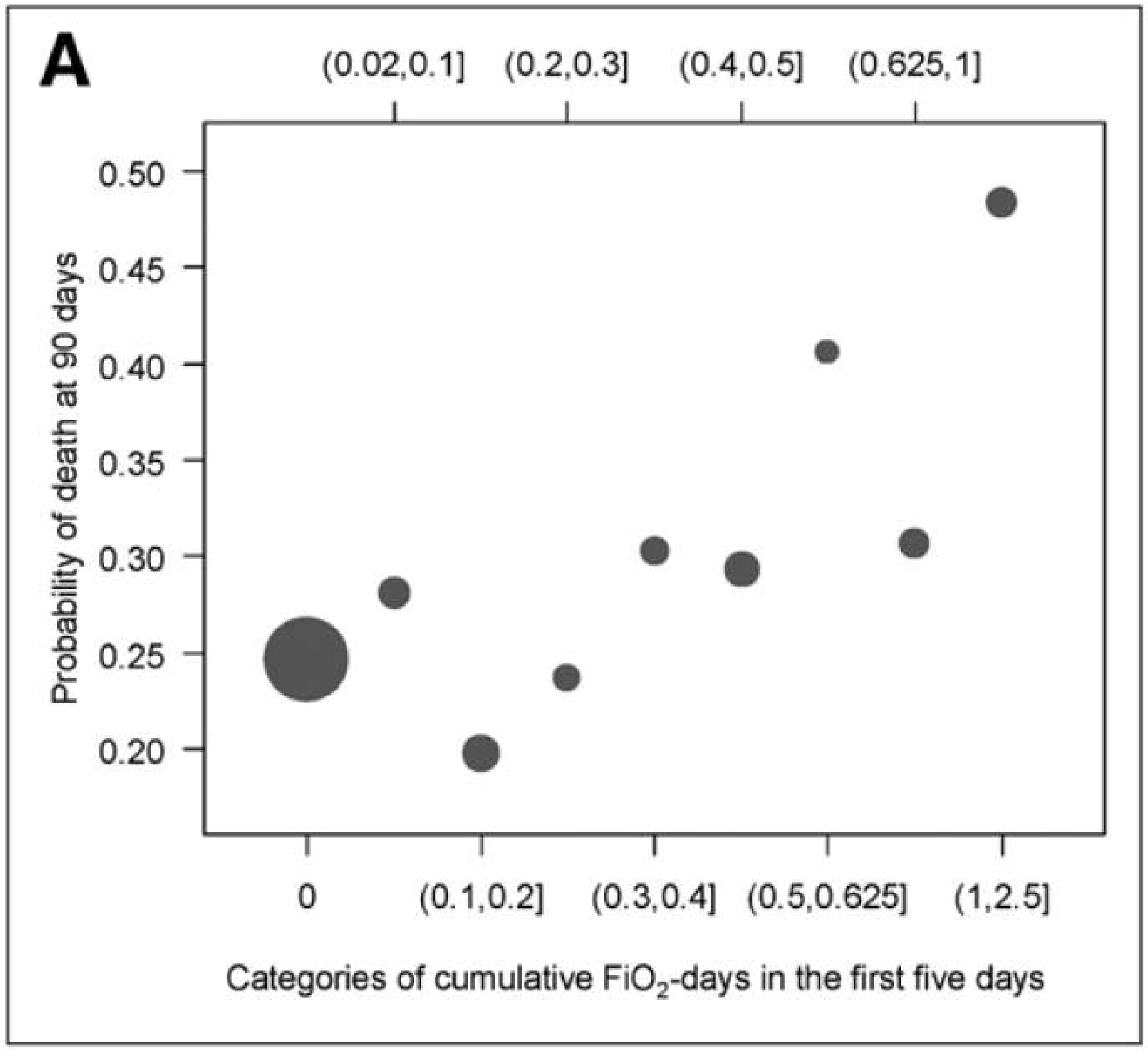
Because respiratory-system compliance (C_{RS}) is strongly related to the volume of aerated remaining functional lung during disease (termed functional lung size), we hypothesized that driving pressure ($\Delta P = V_T/C_{RS}$), in which V_T is intrinsically normalized to functional lung size (instead of predicted lung size in healthy persons),

N Engl J Med 2015;372:747-55.
DOI: 10.1056/NEJMsa1410639

tidal volume should not longer be the target!



Oxygen Exposure Resulting in Arterial Oxygen Tensions Above the Protocol Goal Was Associated With Worse Clinical Outcomes in Acute Respiratory Distress Syndrome



goal partial pressure of oxygen in arterial blood range of 55–80 mm Hg

f_iO_2 of 0.5 = 0

increasing deaths with higher oxygenation in all groups of ARDS severity

Crit Care Med 2017; DOI: 10.1097/CCM.0000000000002886

The New England
Journal of Medicine

VOLUME 342 | MAY 4, 2000 | NUMBER 18

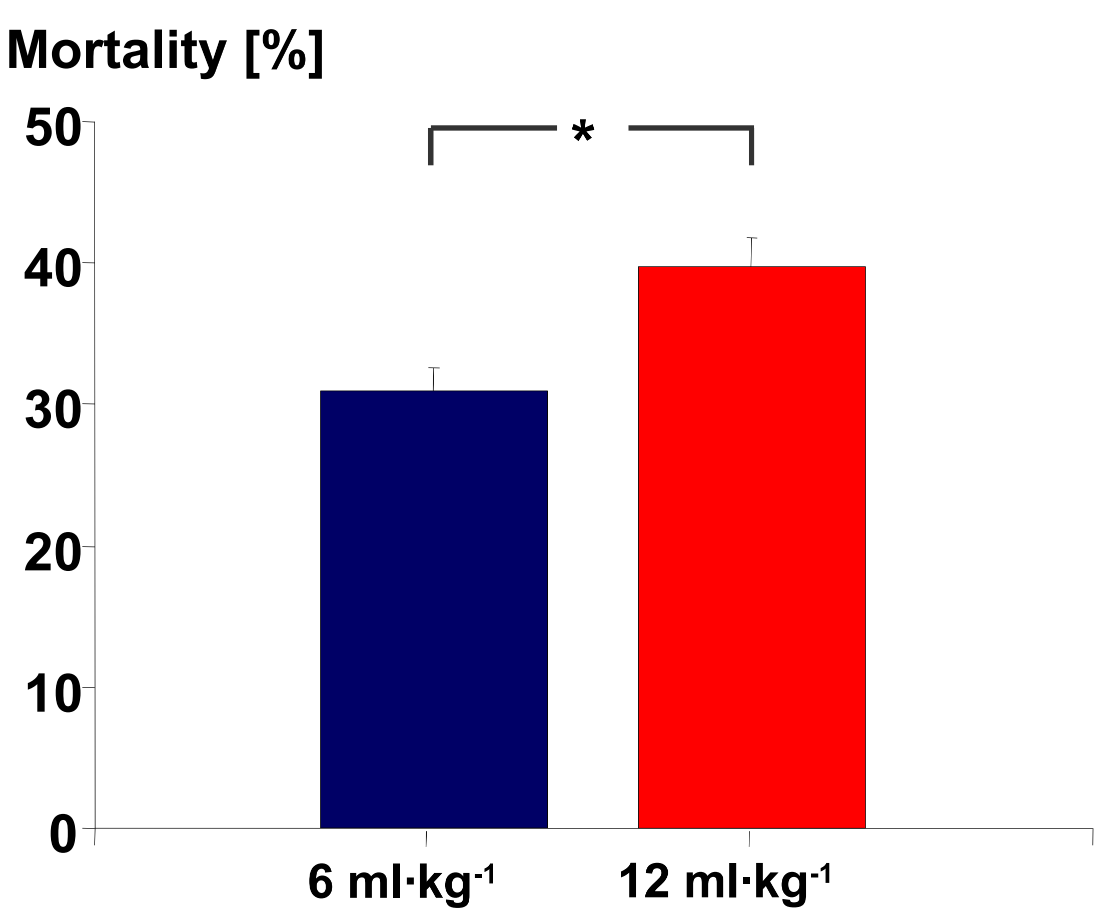
VENTILATION WITH LOWER TIDAL VOLUMES AS COMPARED WITH TRADITIONAL TIDAL VOLUMES FOR ACUTE LUNG INJURY AND THE ACUTE RESPIRATORY DISTRESS SYNDROME

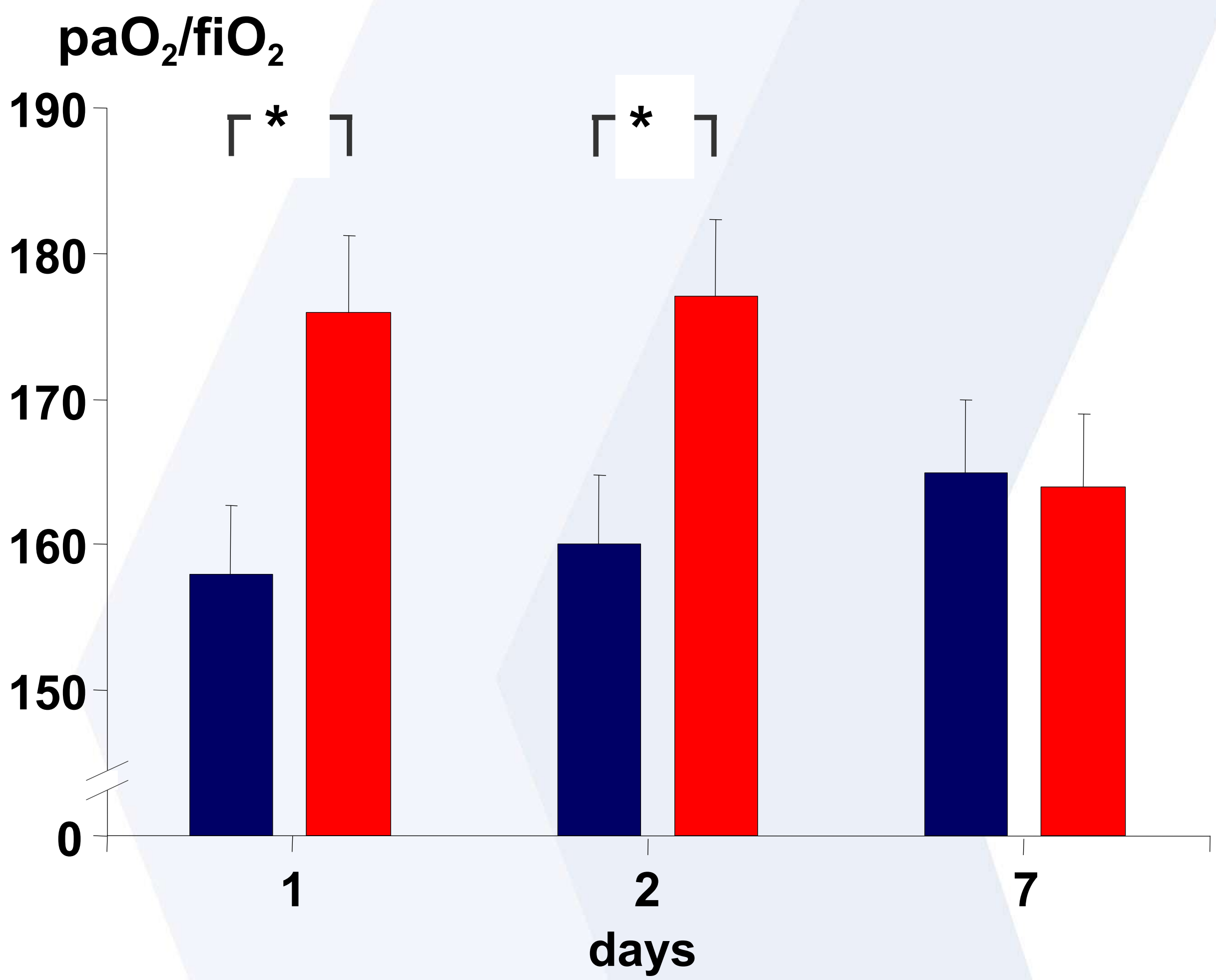
THE ACUTE RESPIRATORY DISTRESS SYNDROME NETWORK*

n = 861

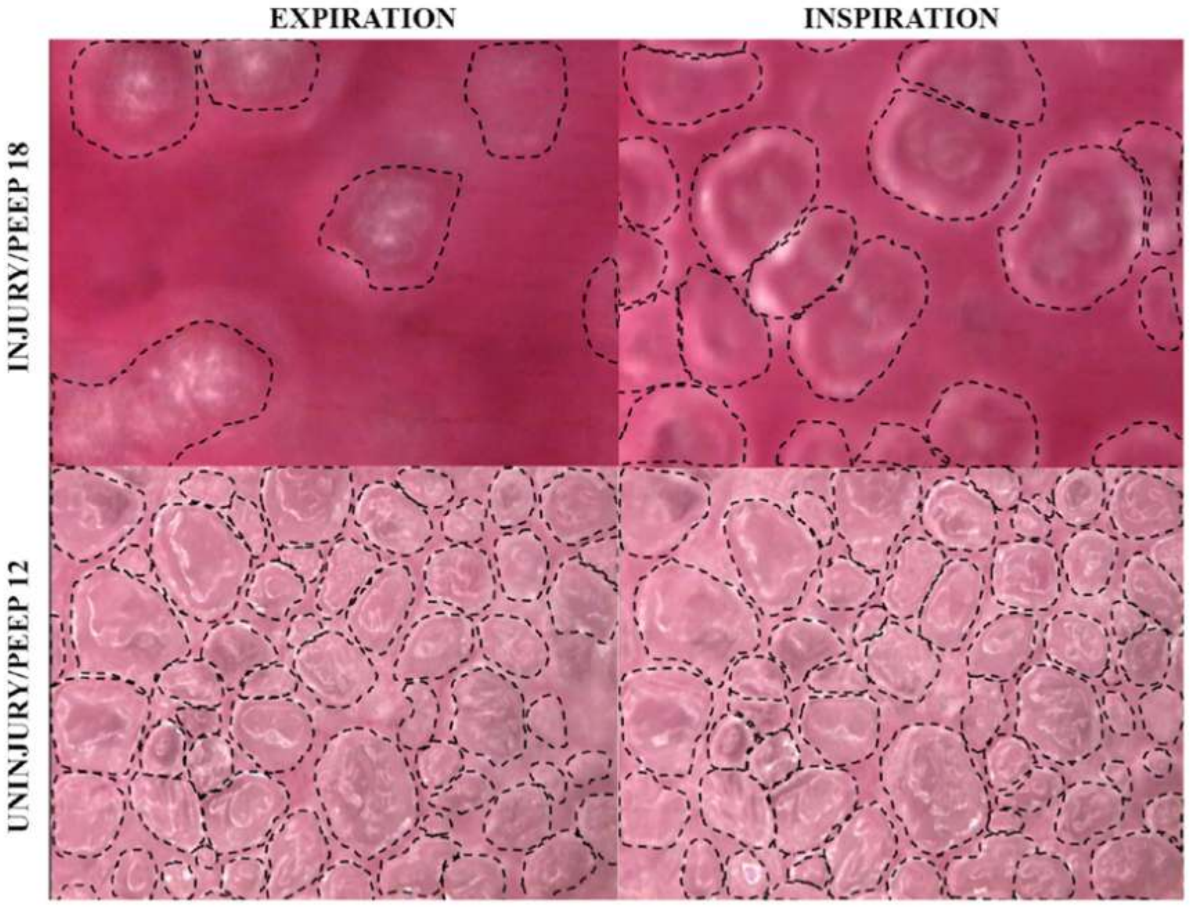
6 ml·kg^{-1}: n = 432

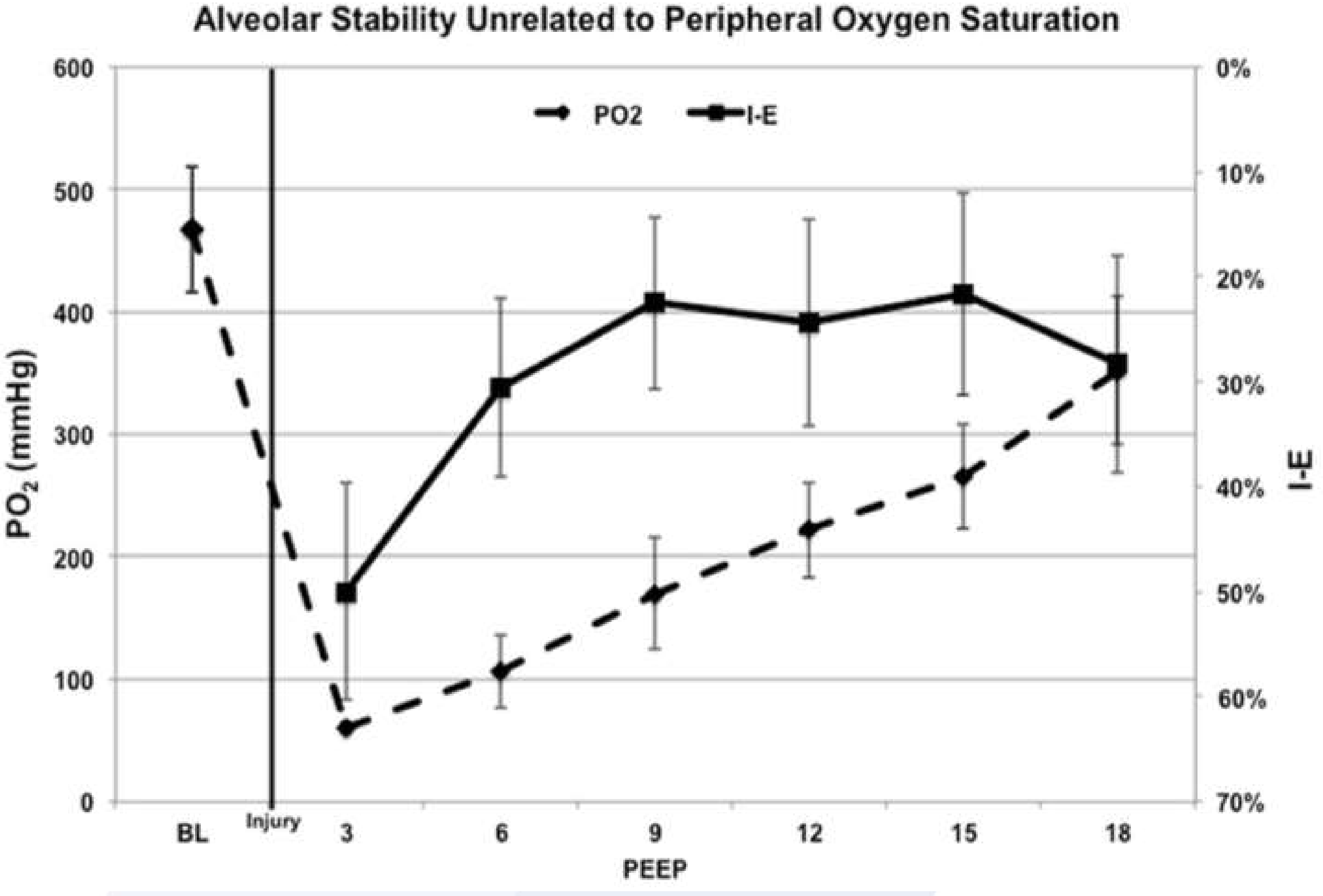
12 ml·kg^{-1}: n = 429



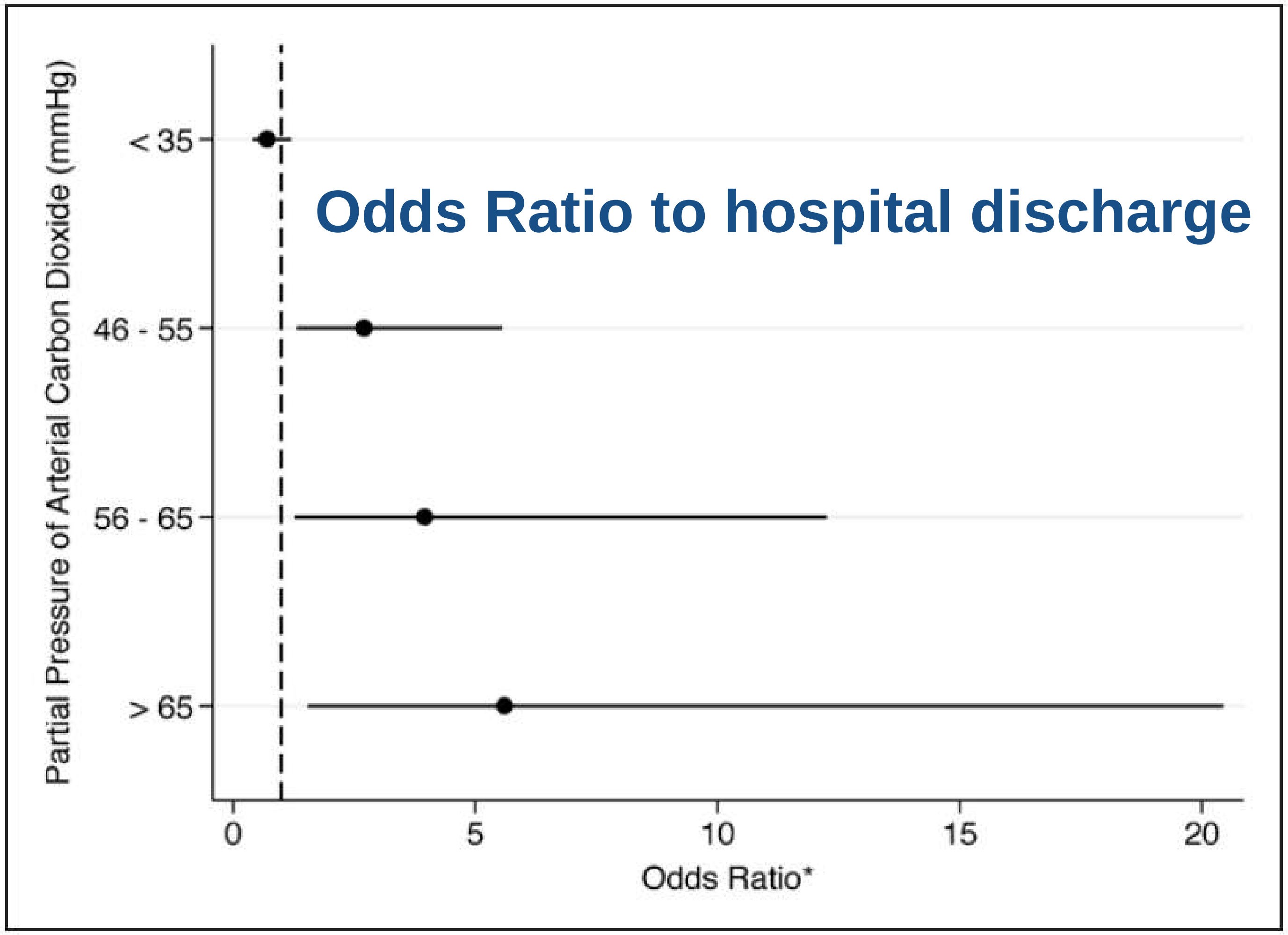


alveolar stability is unrelated to arterial oxygenation





Association Between Partial Pressure of Arterial Carbon Dioxide and Survival to Hospital Discharge Among Patients Diagnosed With Sepsis in the Emergency Department



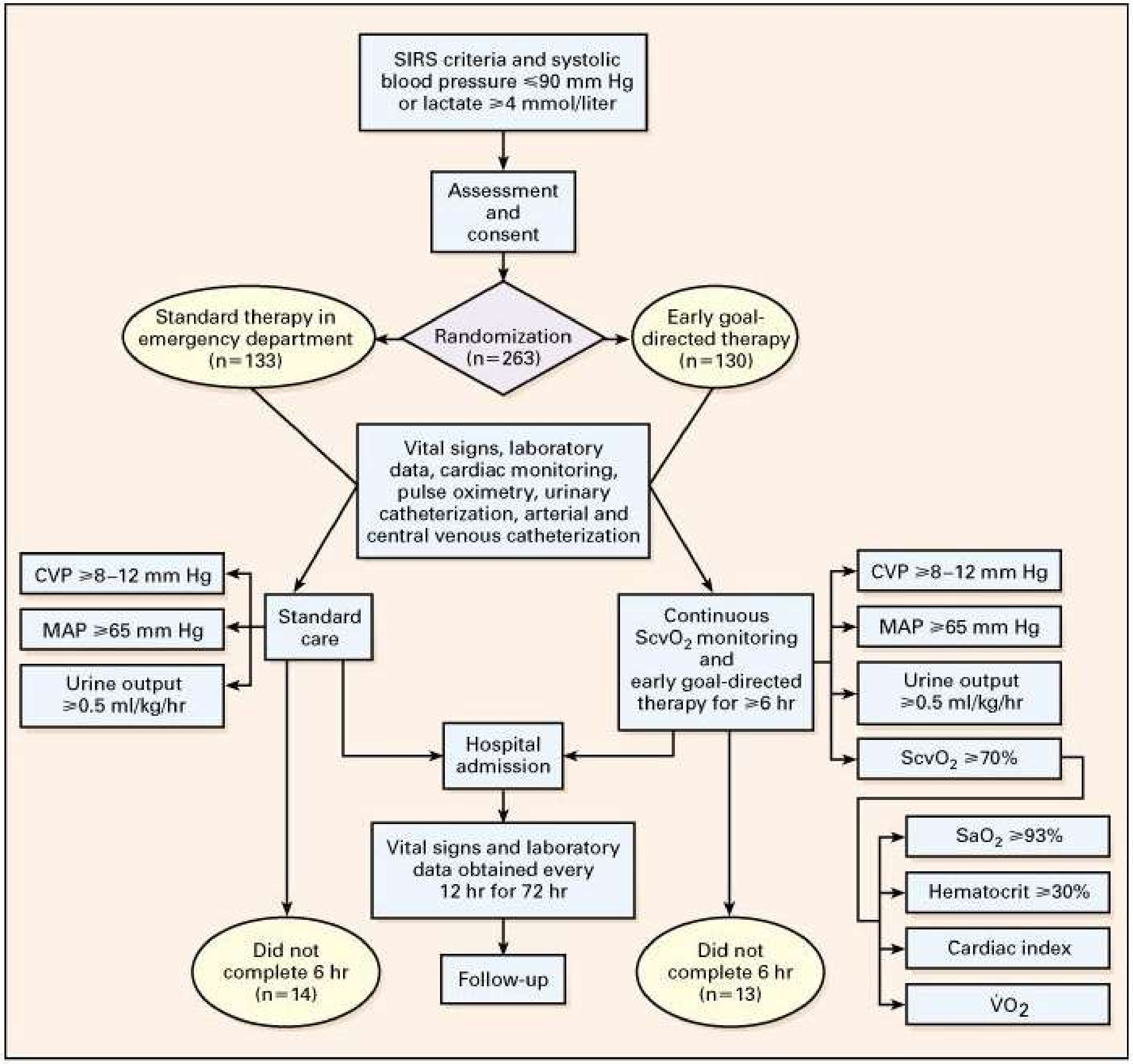
rise in CO_2 of 1 mmHg

with a 3% increase in odds of survival

Crit Care Med 2017; DOI: 10.1097/CCM.0000000000002918


LOST
CONFUSED
UNSURE
UNCLEAR
PERPLEXED
DISORIENTED
BEWILDERED

The Rivers protocol



1. stratify according to severity

2. measure relevant parameter

3. individualize therapy

Nieman *et al. Intensive Care Medicine Experimental* (2017) 5:8
DOI 10.1186/s40635-017-0121-x

Intensive Care Medicine Experimental

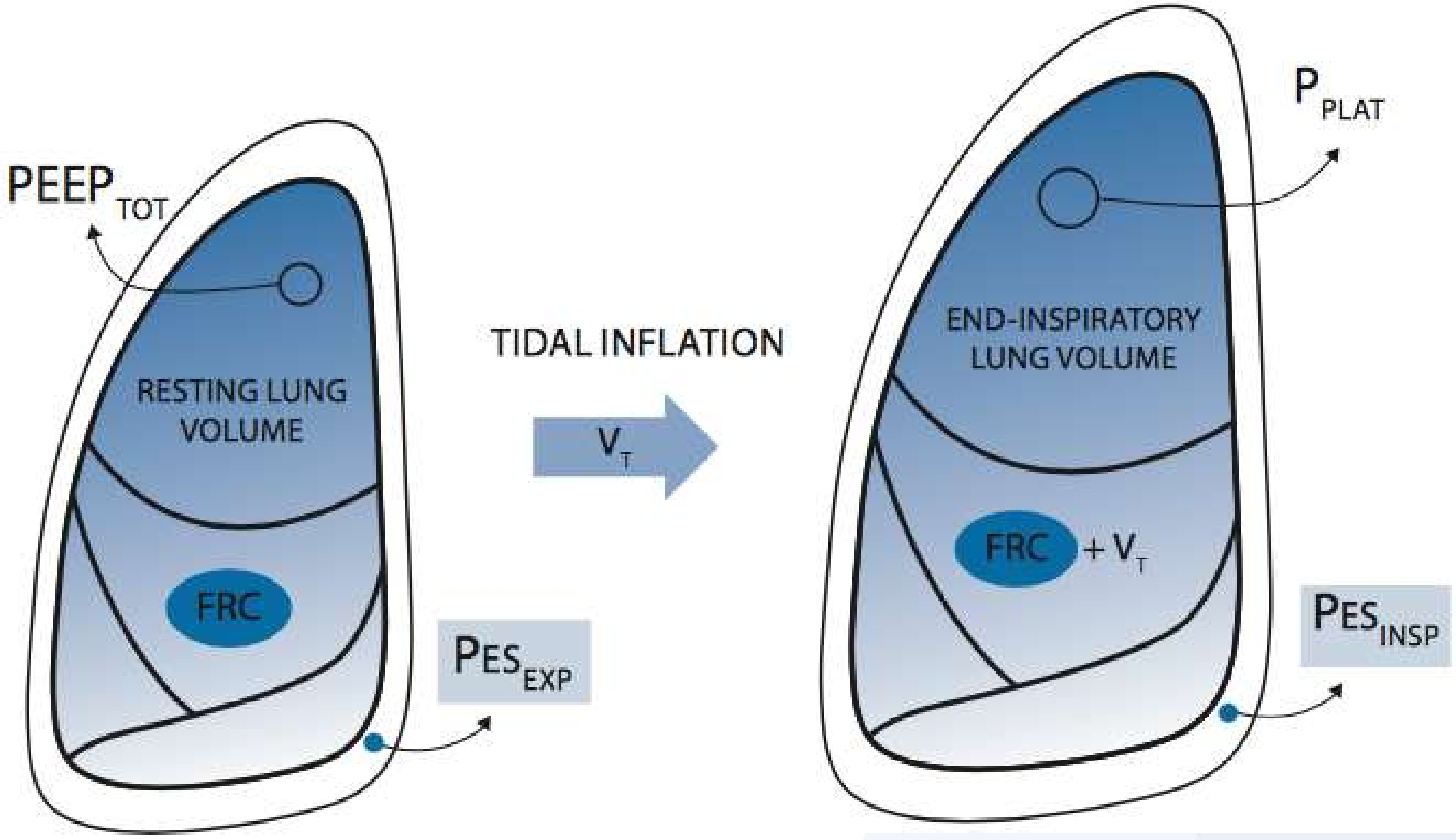
REVIEW **Open Access**

CrossMark

Personalizing mechanical ventilation according to physiologic parameters to stabilize alveoli and minimize ventilator induced lung injury (VILI)

Gary F. Nieman[1], Joshua Satalin[1,5*], Penny Andrews[2], Hani Aiash[1], Nader M. Habashi[3] and Louis A. Gatto[4]

Niemann et al Intensive Care Expr. 2017; 5:8

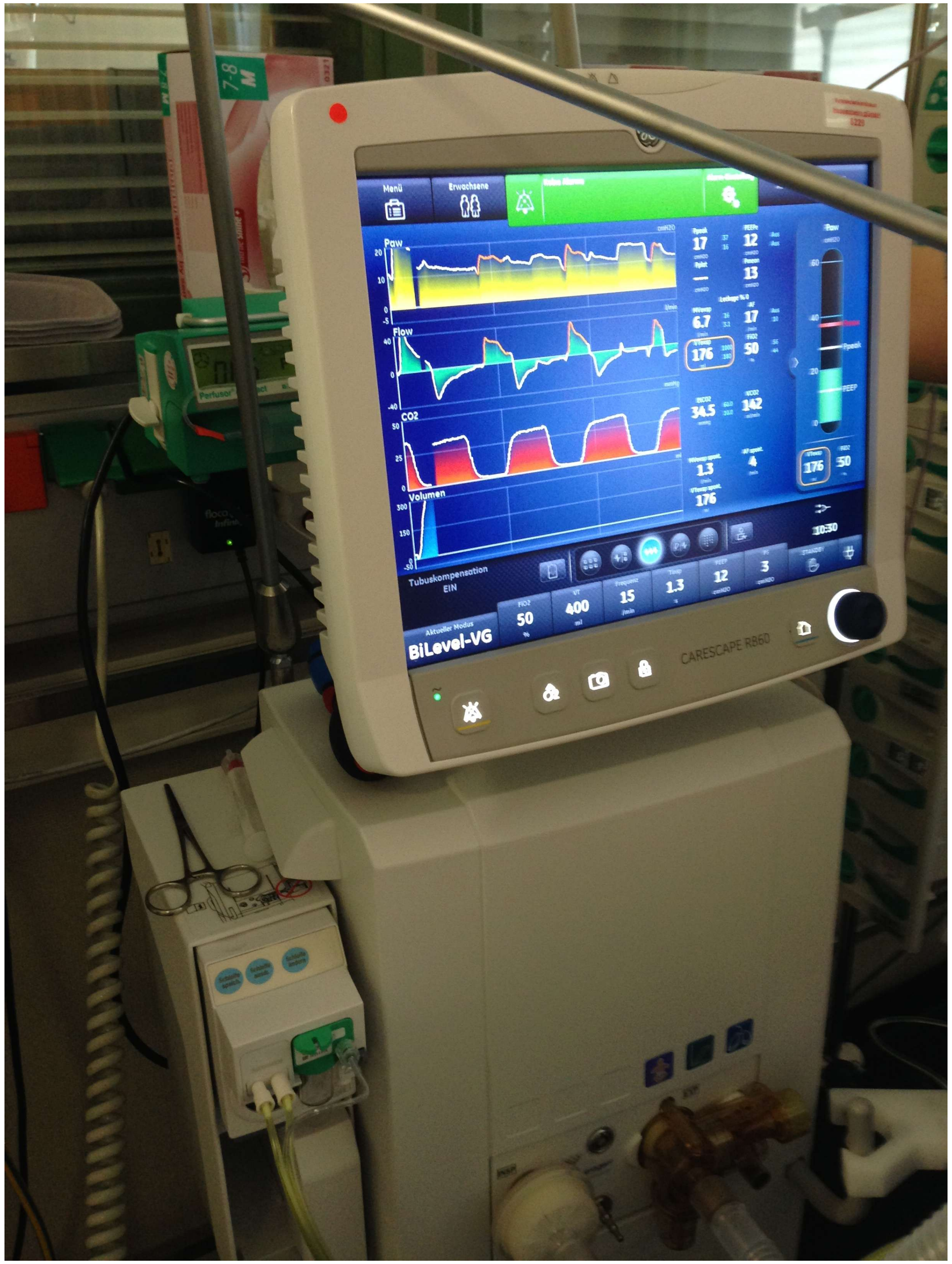


1. **End-expiratory lung volume (EELV) at a given PEEP**

2. **Transpulmonary pressure gradient**

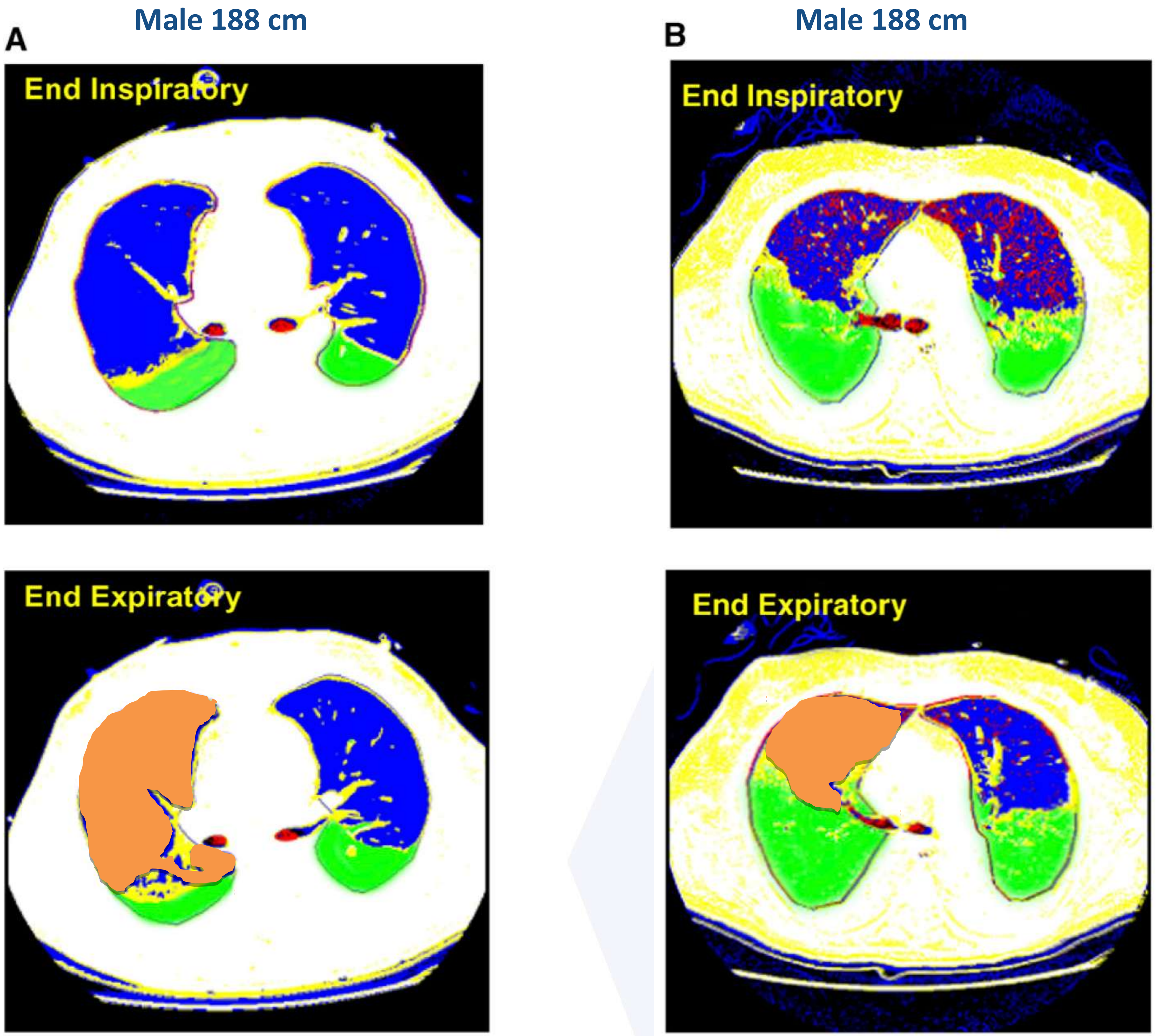
$$(P_{plat} - P_{oes/EI}) - (PEEP - P_{eos/EE})$$

Cortes and Marini Critical Care 2013, 17:219

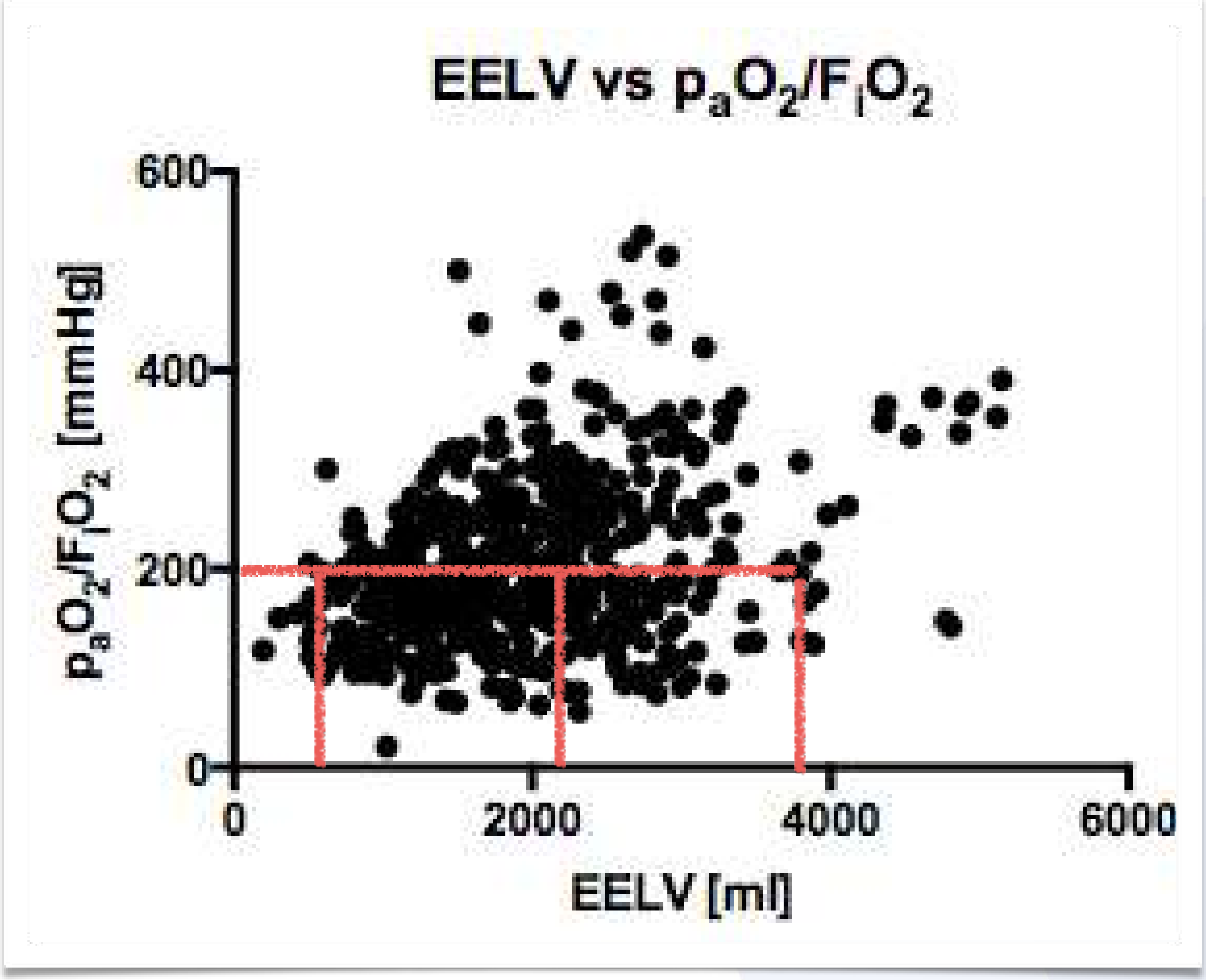

Paw
Flow
CO2
Volumen
Tubuskompensation
EIN
BiLevel-VG
CARESCAPE R860


11.07.15

baby lung size ≈ EELV



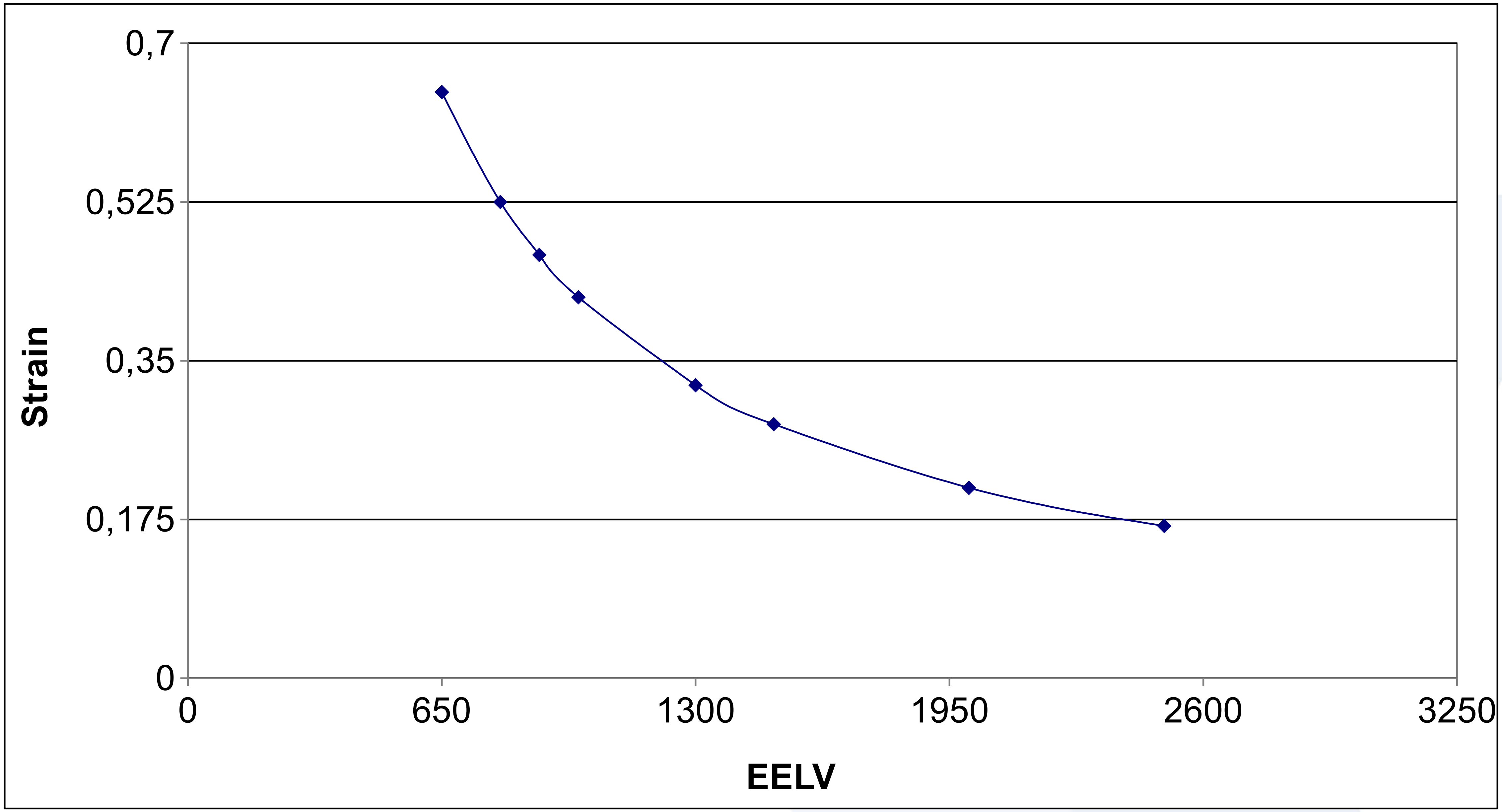
Why oxygenation is not a good target



Kalenka et al, unpublished data

Menü
Erwachsene
Alarme 3
Leckagealarm Beatmungs-schlauchsystem AUS
Alarm-Einstellung
Absaug.
Insp. Stop
Messbedingungen
FRC INview
PEEP INview
FRC O2 60 %
Intervall Einzel
EELV / FRC
09-Nov 14:34
2000 ml
1000
0
0
10
20
Atemzüge
09-Nov 14:34
FRC ml 1642
PEEPe+i cmH2O 11+1
Cstat ml/cmH2O 45
Paw cmH2O
60
40
Pmax
Ppeak
20
PEEP
0
VTexsp 452 ml
FiO2 50 %
Leckage-Kompens. EIN
SBT
FRC
14:34
Aktueller Modus BiLevel-VG
FiO2 50 %
VT 450 ml
Frequenz 21 /min
Tinsp 0.80 s
PEEP 12 cmH2O
PS 6 cmH2O
STANDBY
CARESCAPE R860

Tidal volume of 420 ml based on kg iBW at different FRC (EELV)



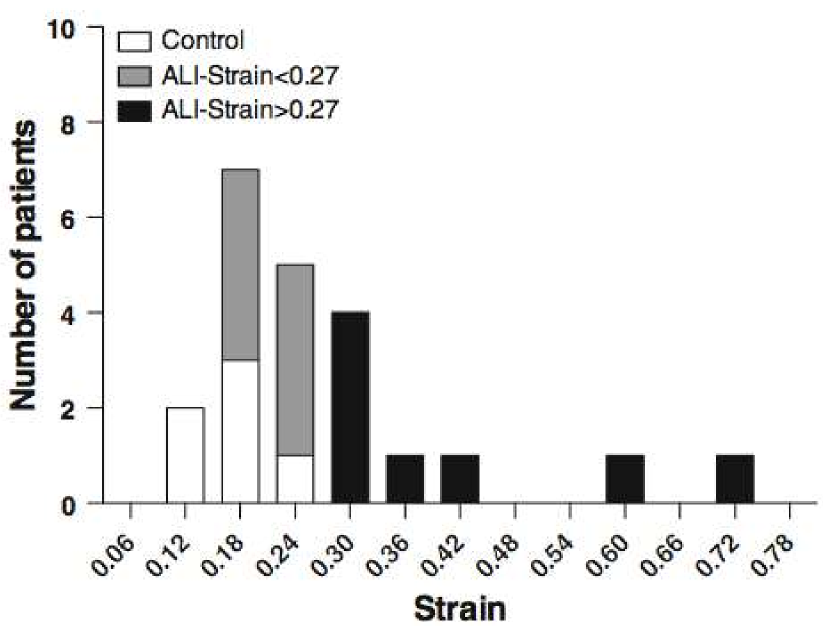
dynamic strain = V_T/EELV

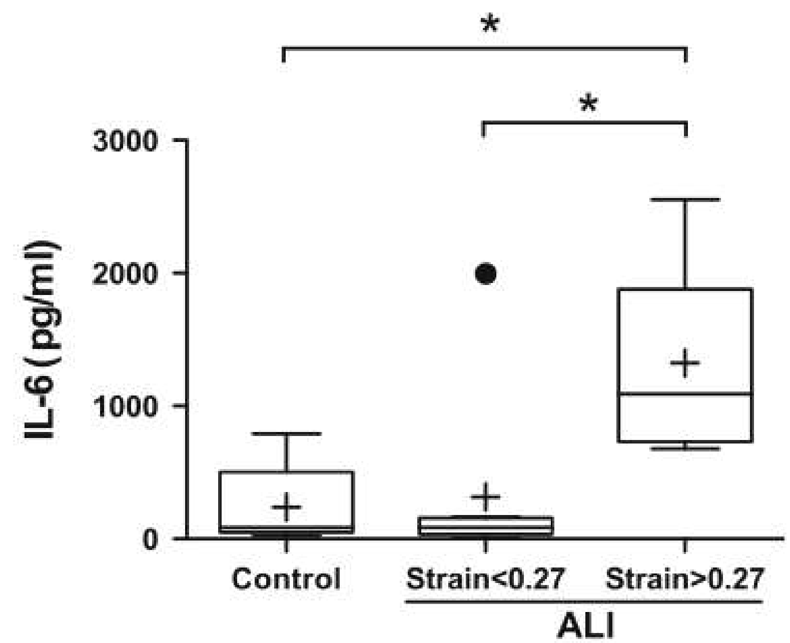
Intensive Care Med
DOI 10.1007/s00134-011-2403-1

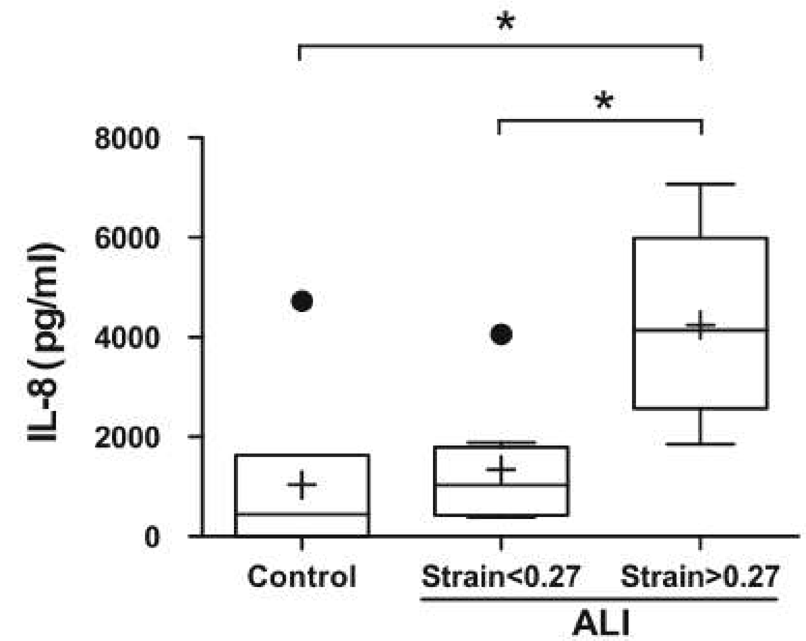
ORIGINAL

Adrián González-López
Emilio García-Prieto
Estefanía Batalla-Solís
Laura Amado-Rodríguez
Noelia Avello
Lluís Blanch
Guillermo M. Albaiceta

Lung strain and biological response in mechanically ventilated patients

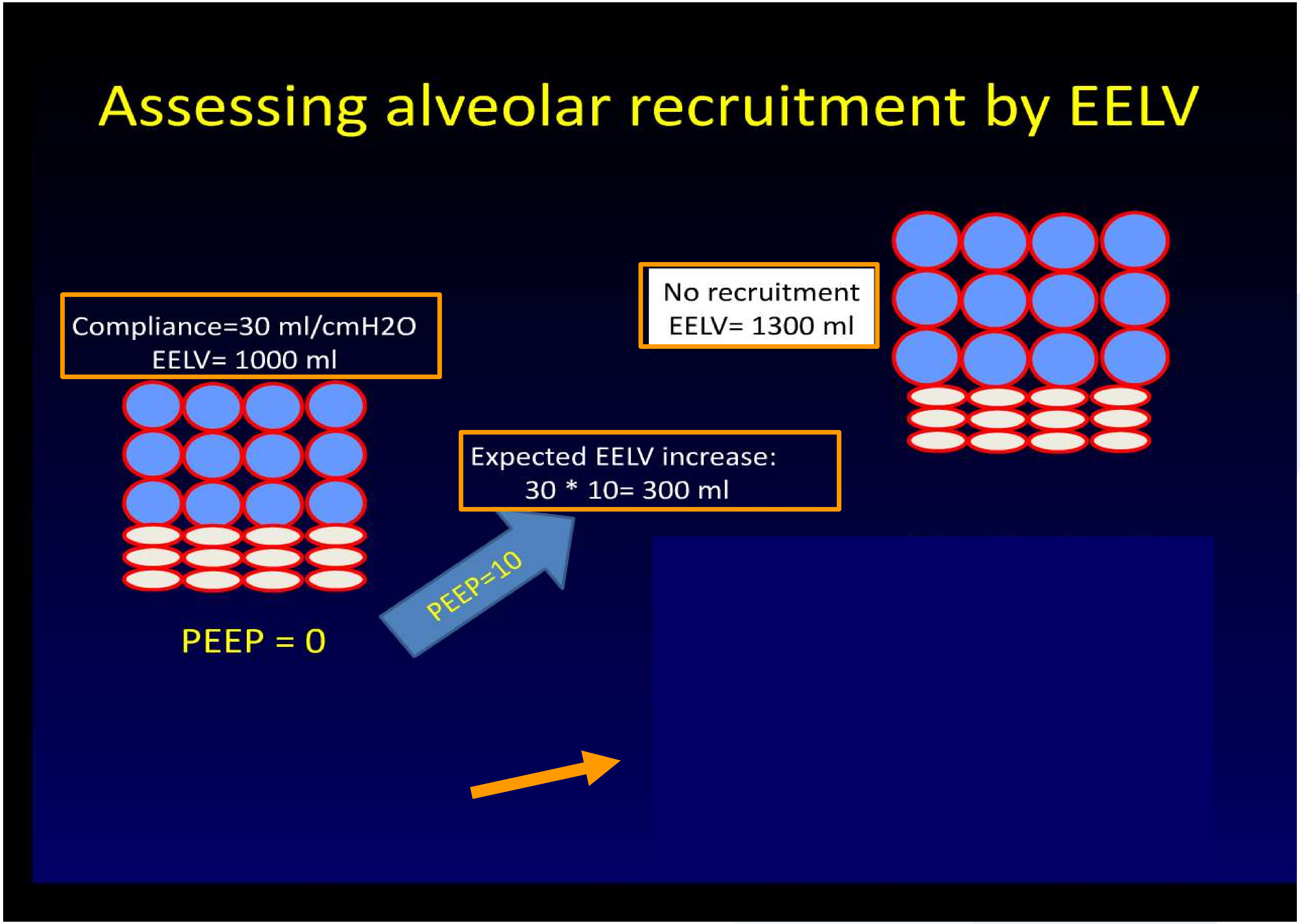




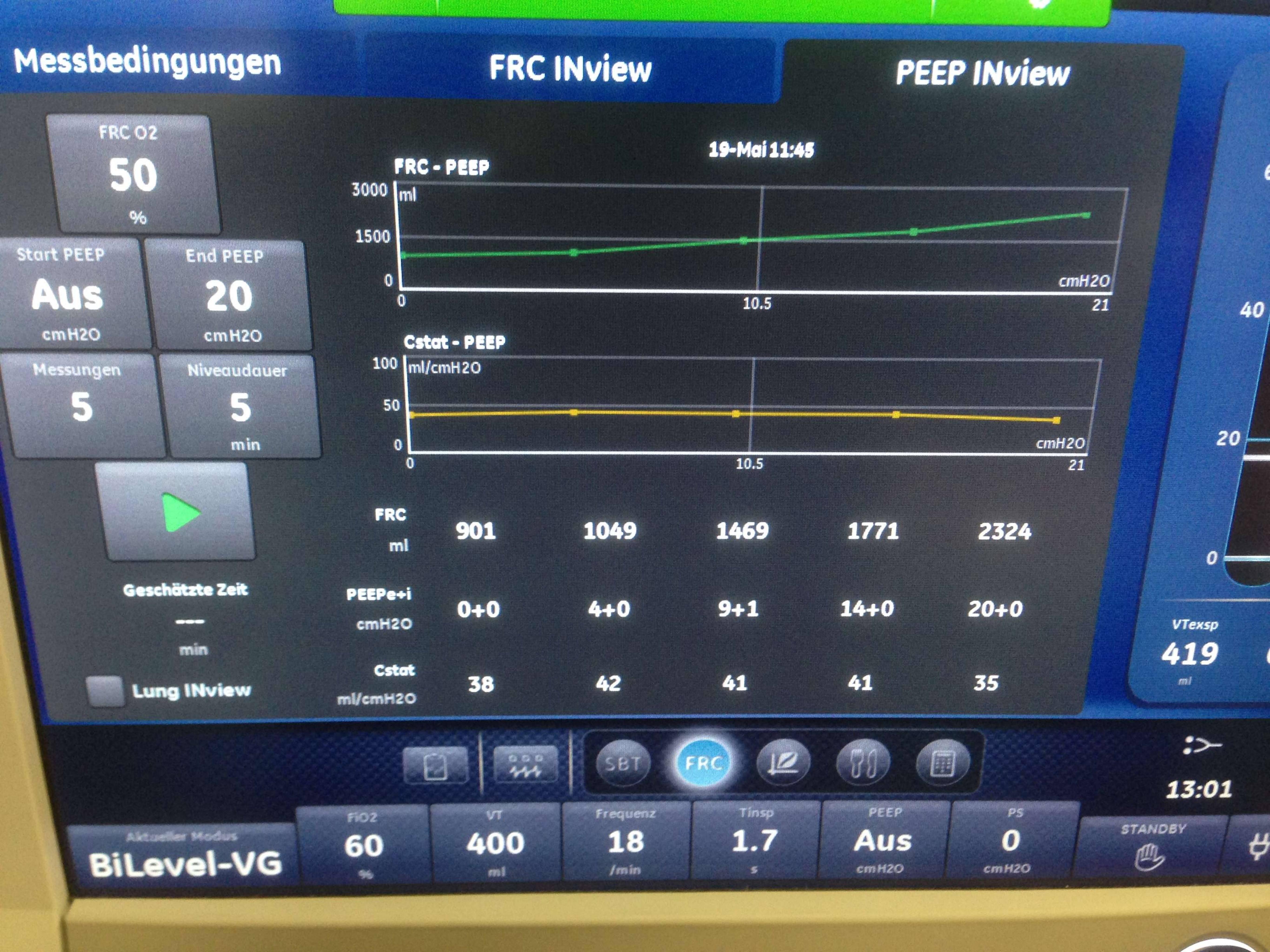


dynamic strain = V_T/EELV

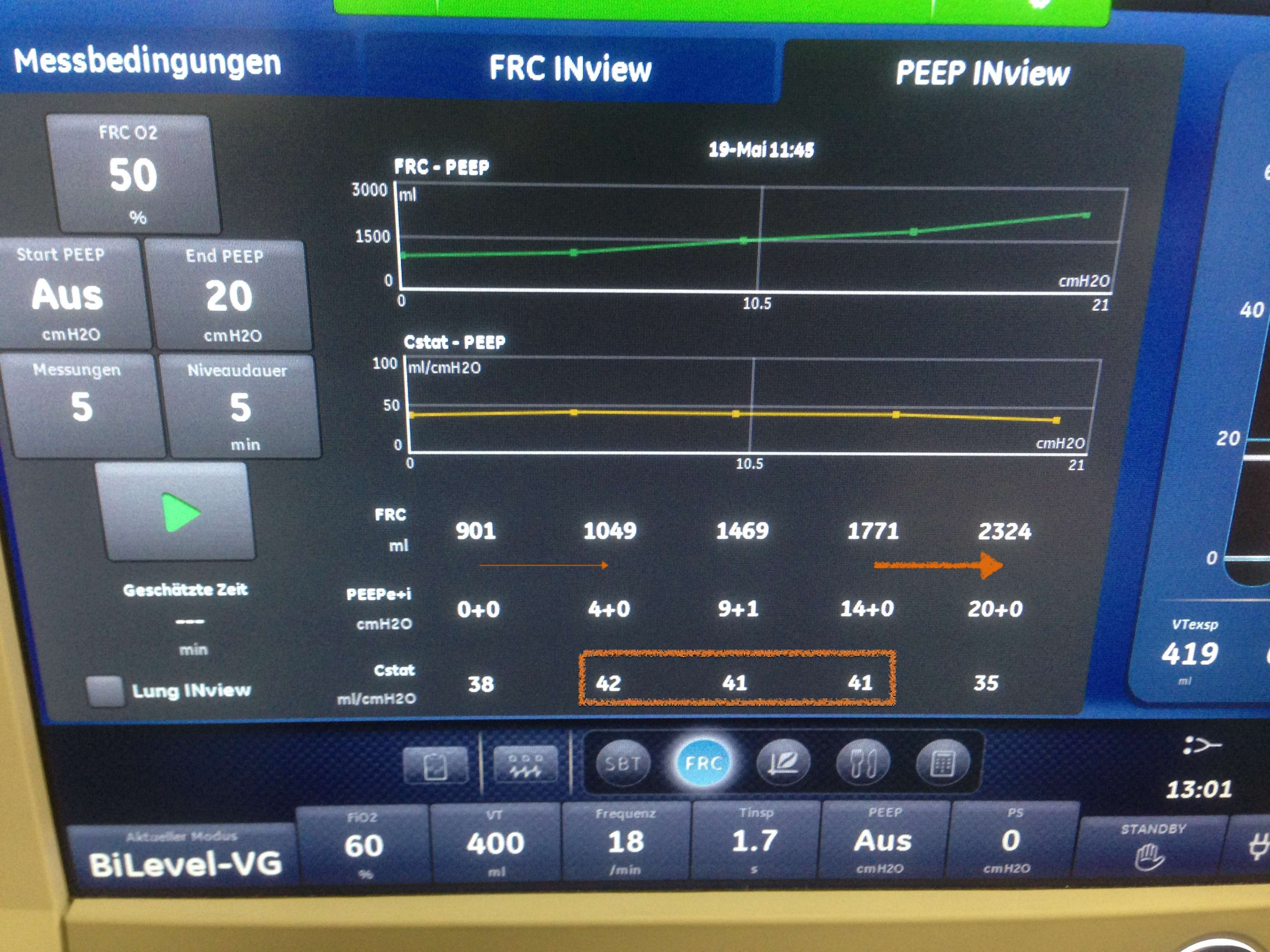
aim for dynamic strain < 0.25



Courtesy of Antonio Pesenti



Messbedingungen
FRC INview
PEEP INview
FRC O2
50
%
Start PEEP
Aus
cmH2O
End PEEP
20
cmH2O
Messungen
5
Niveaudauer
5
min
Geschätzte Zeit
---
min
Lung INview
19-Mai 11:45
FRC - PEEP
3000
ml
1500
0
cmH2O
0
10.5
21
Cstat - PEEP
100
ml/cmH2O
50
0
cmH2O
0
10.5
21
FRC
ml
901
1049
1469
1771
2324
PEEPe+i
cmH2O
0+0
4+0
9+1
14+0
20+0
Cstat
ml/cmH2O
38
42
41
41
35
40
20
0
VTexsp
419
ml
SBT
FRC
13:01
Aktueller Modus
BiLevel-VG
FiO2
60
%
VT
400
ml
Frequenz
18
/min
Tinsp
1.7
s
PEEP
Aus
cmH2O
PS
0
cmH2O
STANDBY



Messbedingungen
FRC INview
PEEP INview
FRC O2
50
%
Start PEEP
Aus
cmH2O
End PEEP
20
cmH2O
Messungen
5
Niveaudauer
5
min
Geschätzte Zeit
---
min
Lung INview
19-Mai 11:45
FRC - PEEP
3000
1500
0
ml
cmH2O
0
10.5
21
Cstat - PEEP
100
50
0
ml/cmH2O
cmH2O
0
10.5
21
FRC
ml
901
1049
1469
1771
2324
PEEPe+i
cmH2O
0+0
4+0
9+1
14+0
20+0
Cstat
ml/cmH2O
38
42
41
41
35
40
20
0
VTexsp
419
ml
SBT
FRC
13:01
Aktueller Modus
BiLevel-VG
FiO2
60
%
VT
400
ml
Frequenz
18
/min
Tinsp
1.7
s
PEEP
Aus
cmH2O
PS
0
cmH2O
STANDBY

Lung Stress and Strain during Mechanical Ventilation for Acute Respiratory Distress Syndrome

Davide Chiumello[1], Eleonora Carlesso[2], Paolo Cadringher[2], Pietro Caironi[1,2], Franco Valenza[1,2], Federico Polli[2], Federica Tallarini[2], Paola Cozzi[2], Massimo Cressoni[2], Angelo Colombo[1], John J. Marini[3], and Luciano Gattinoni[1,2]

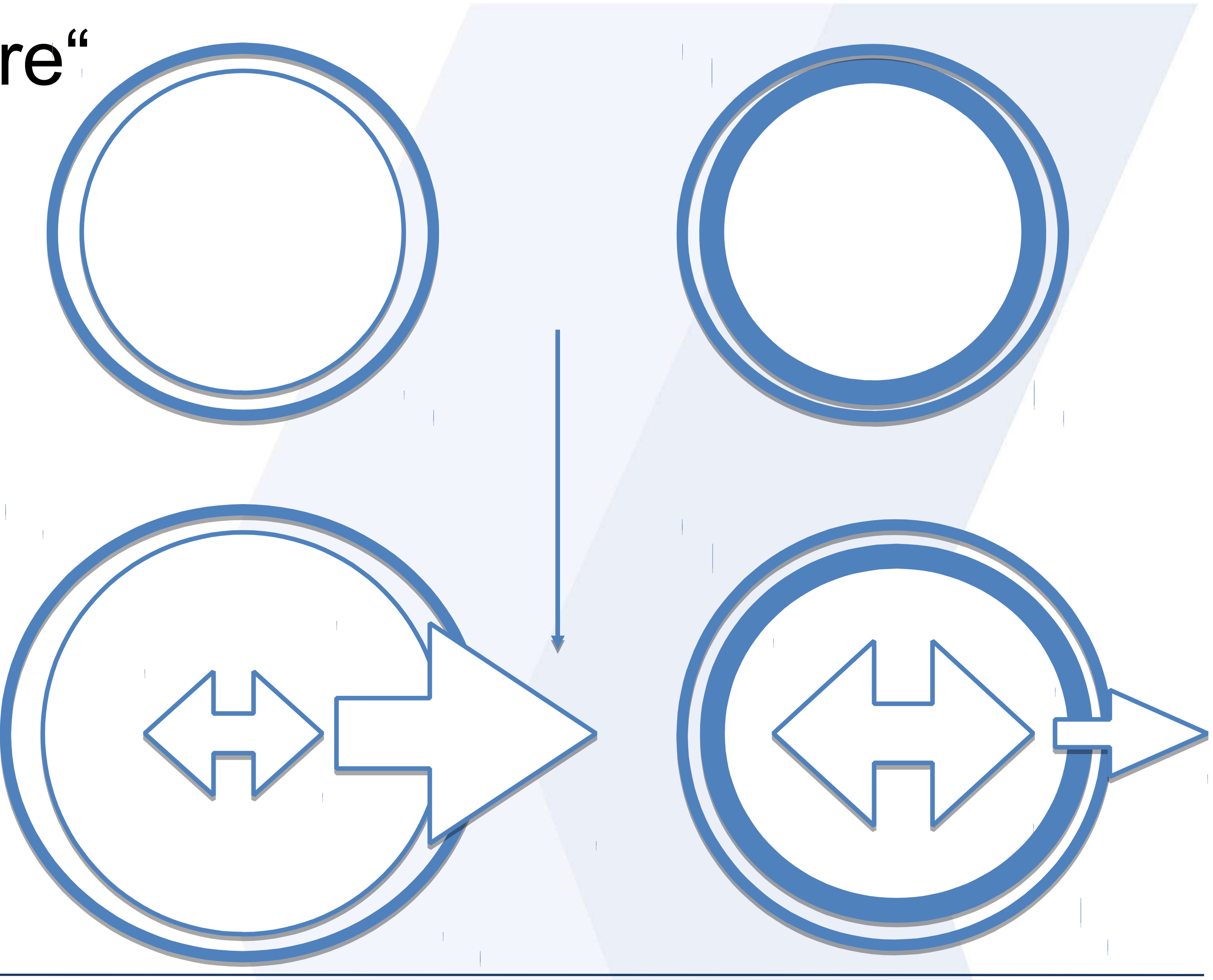
Am J Respir Crit Care Med Vol 178. pp 346–355, 2008

Strain: „the driving pressure“

$V_T/EELV \neq V_T/ml/iKG$

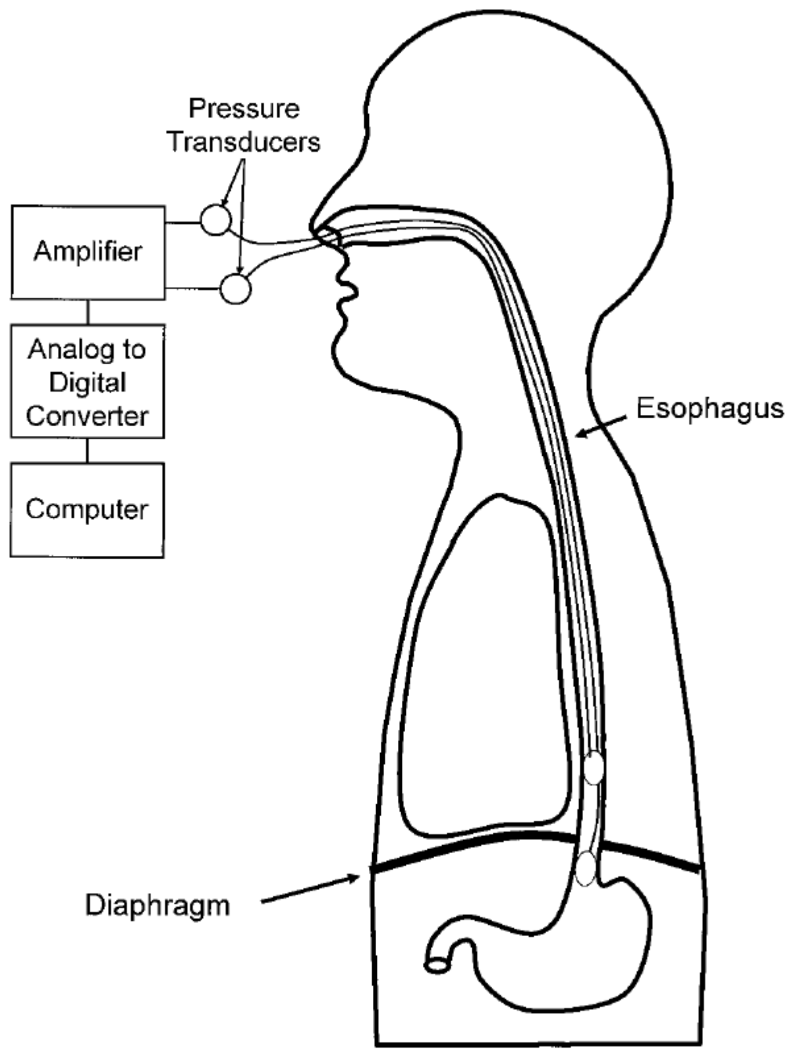
Stress:

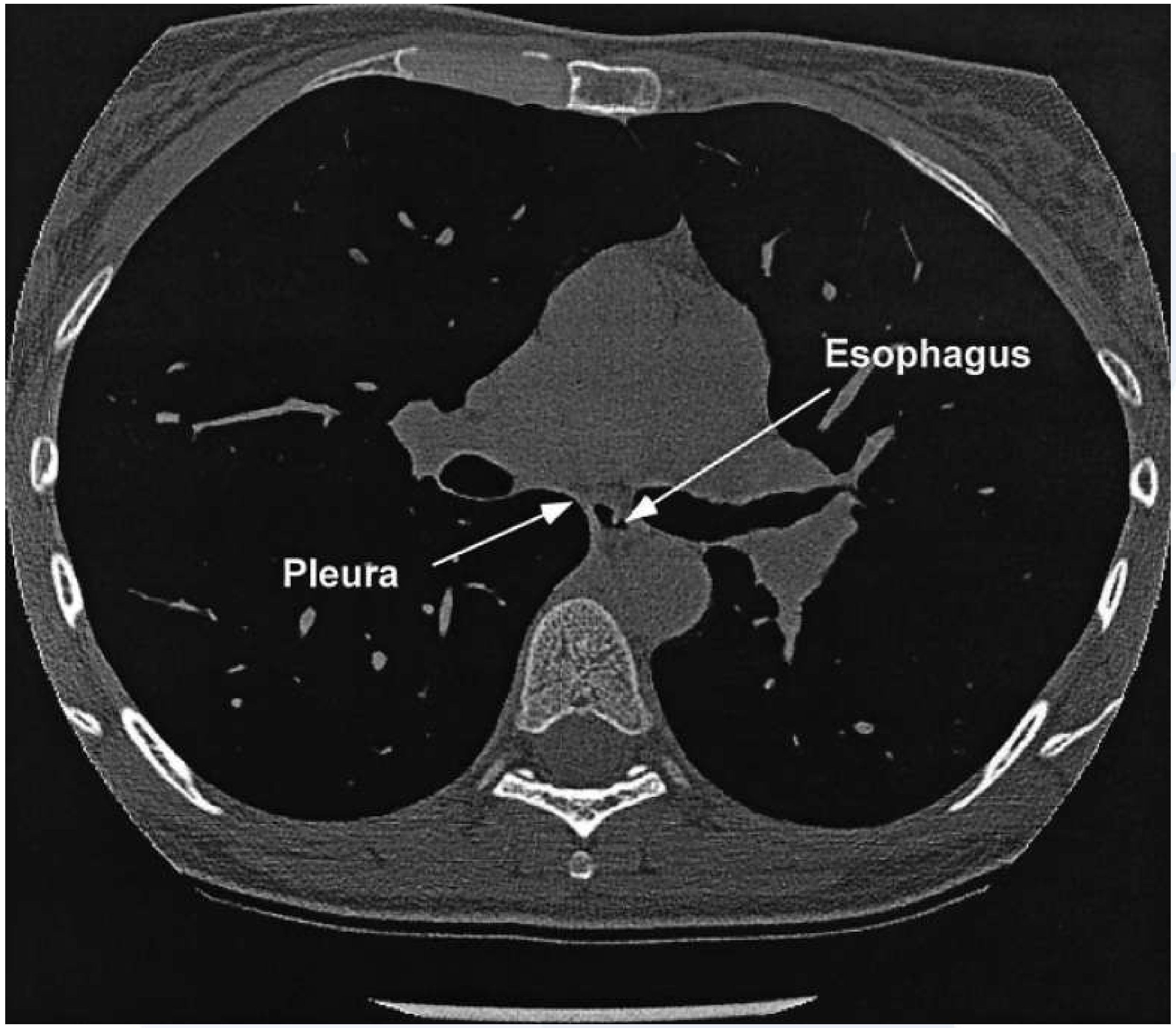
$P_{TP} \neq P_{AW}$



Stress = k * Strain
k = Specific Elastance ($E_{L,s}$) = Stress/Strain
Specific Elastance = 13 – 15 cmH_2O

Individualized titration of PEEP and V_T





Ppulm. = Palv – Ppl ~ Poes

optimize PEEP and V_T

with measurement of esophageal pressure and transpulmonary pressure gradient

1. PEEP > endexspiratory esophageal pressure

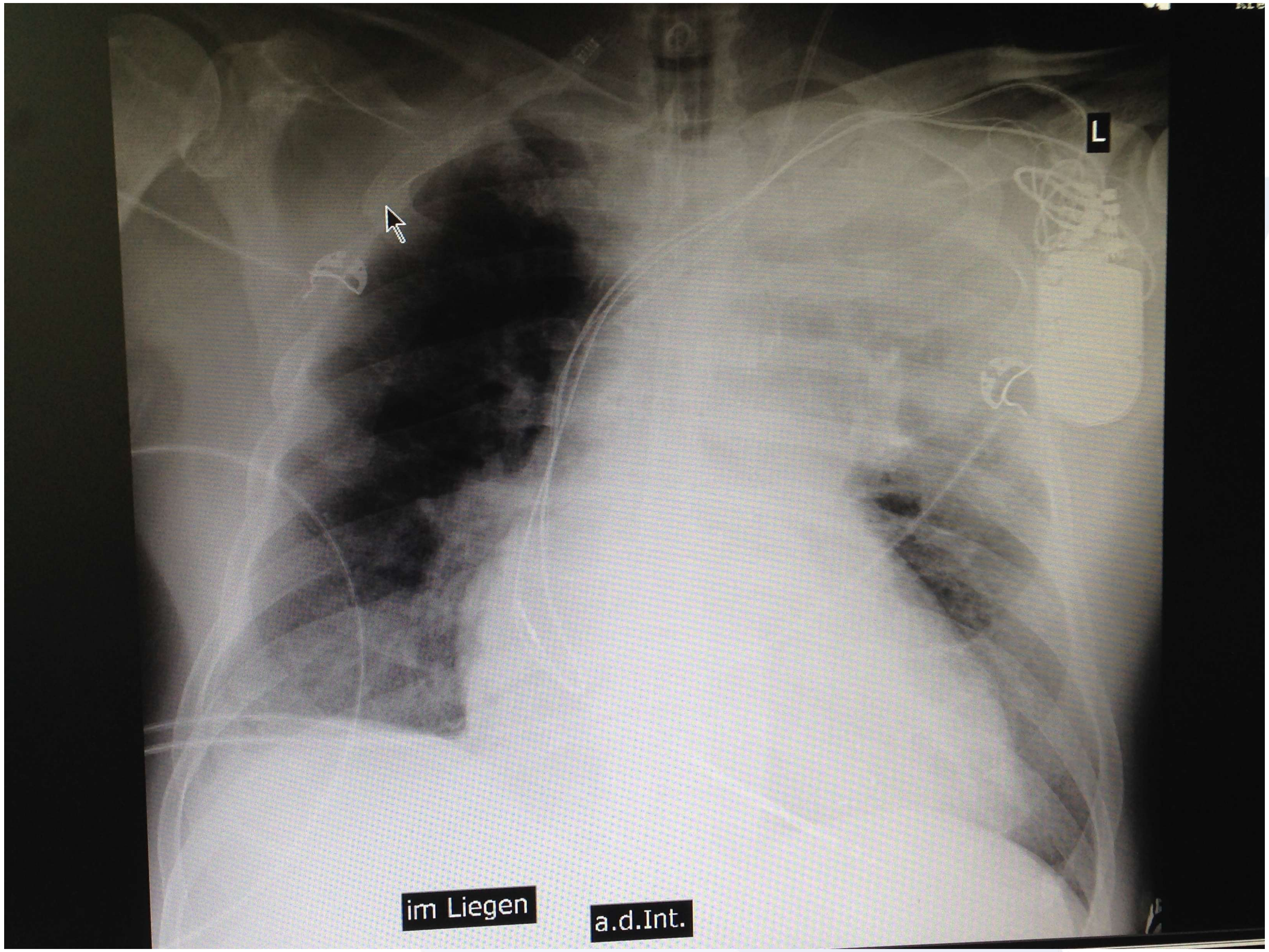
2. $V_{T\ max}$ = transpulmonary pressure gradient < 10 (20)

$$(P_{plat} - P_{oes/EI}) - (PEEP - P_{eos/EE})$$

V_T and PEEP ?

male
172 cm
86 kg
EF 20%
respiratory
distress

high dose vasopressor
f_iO_2 0.9
s_pO_2 88 %



Menü
Erwachsene
Alarme 7
EtCO2 tief
Alarm-Einstellung
Absaug.
Insp. Stop
Messbedingungen
FRC INview
PEEP INview
FRC O2
100
%
Start PEEP
20
cmH2O
End PEEP
14
cmH2O
Messungen
3
Niveaudauer
10
min
Geschätzte Zeit
---
min
Lung INview
03-Nov 11:55
FRC - PEEP
3000
1500
0
ml
cmH2O
13
17
21
Cstat - PEEP
40
20
0
ml/cmH2O
cmH2O
13
17
21
400/2000=0.2
400/1600=0.25
FRC
ml
2064
1725
1588
PEEPe+i
cmH2O
20+0
17+1
14+0
Cstat
ml/cmH2O
35
34
34
Paw
cmH2O
60
40
20
0
Pmax
Ppeak
PEEP
VTexsp
398
ml
FiO2
91
%
Leckage-Kompens.
EIN
SBT
FRC
12:34
Aktueller Modus
BiLevel-VG
FiO2
90
%
VT
400
ml
Frequenz
22
/min
Tinsp
1.0
s
PEEP
18
cmH2O
PS
8
cmH2O
STANDBY

TPP = (35-26)-(20-18) = 9-2=7
Menü
Erwachsene
Alarme 7
EtCO2 tief
Alarm-Einstellung
Absaug.
Insp. Stop
Paw
cmH2O
Flow
l/min
CO2
mmHg
Paux
Ppeak 35 cmH2O
PEEPe 20 cmH2O
Pplat --- cmH2O
Pmean 25 cmH2O
Leckage % 0
MVexsp 9.1 l/min
AF 22 /min
VTexsp 414 ml
FiO2 91 %
EtCO2 46.0 mmHg
VCO2 192 ml/min
Paux mean 21 cmH2O
Paux min 18 cmH2O
Paux peak 26 cmH2O
Pmax
Ppeak
PEEP
Leckage-Kompens. EIN
15:19
Aktueller Modus
BiLevel-VG
FiO2 90 %
VT 400 ml
Frequenz 22 /min
Tinsp 1.0 s
PEEP 20 cmH2O
PS 8 cmH2O
STANDBY
CARESCAPE R860
6230

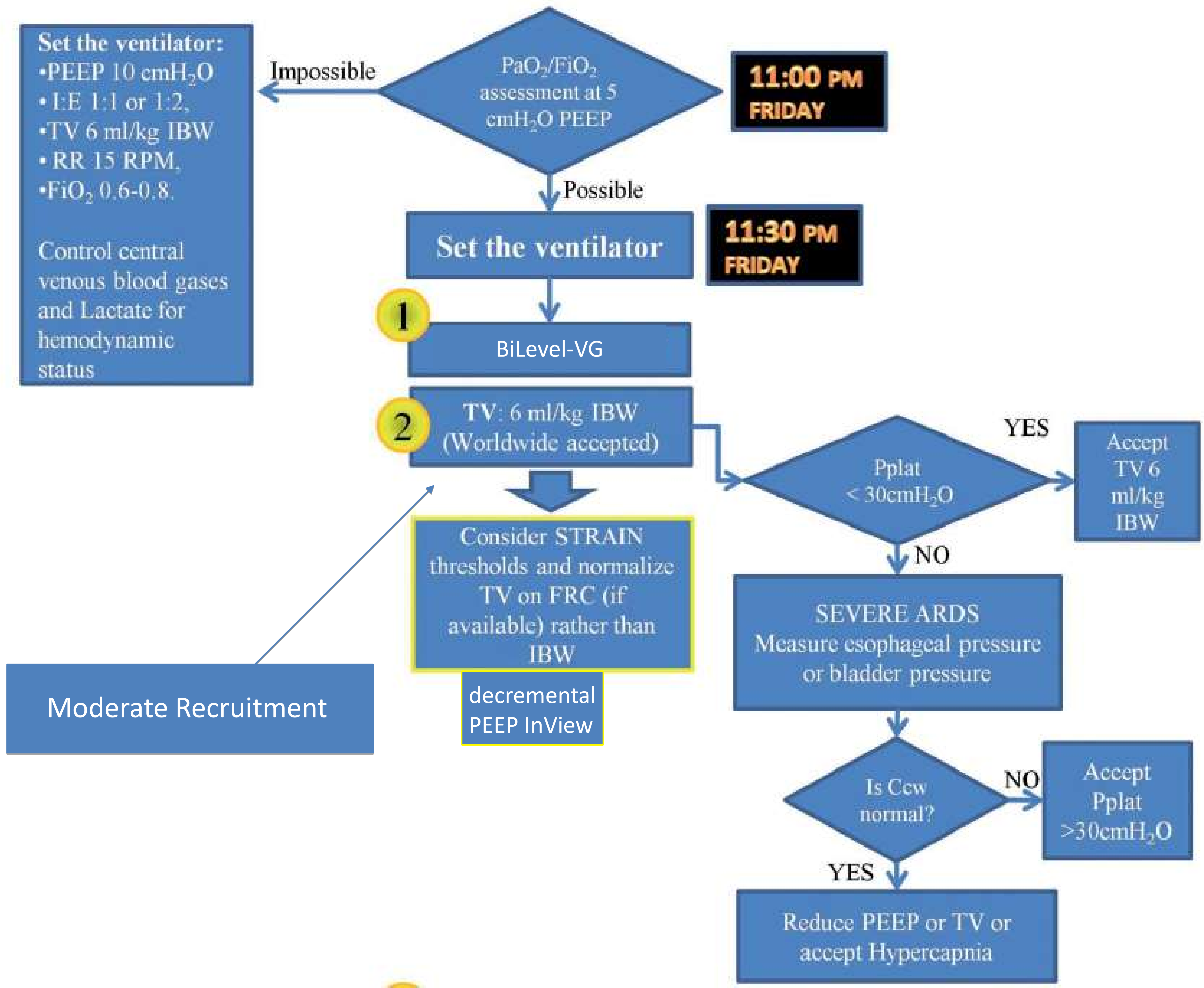
SOP

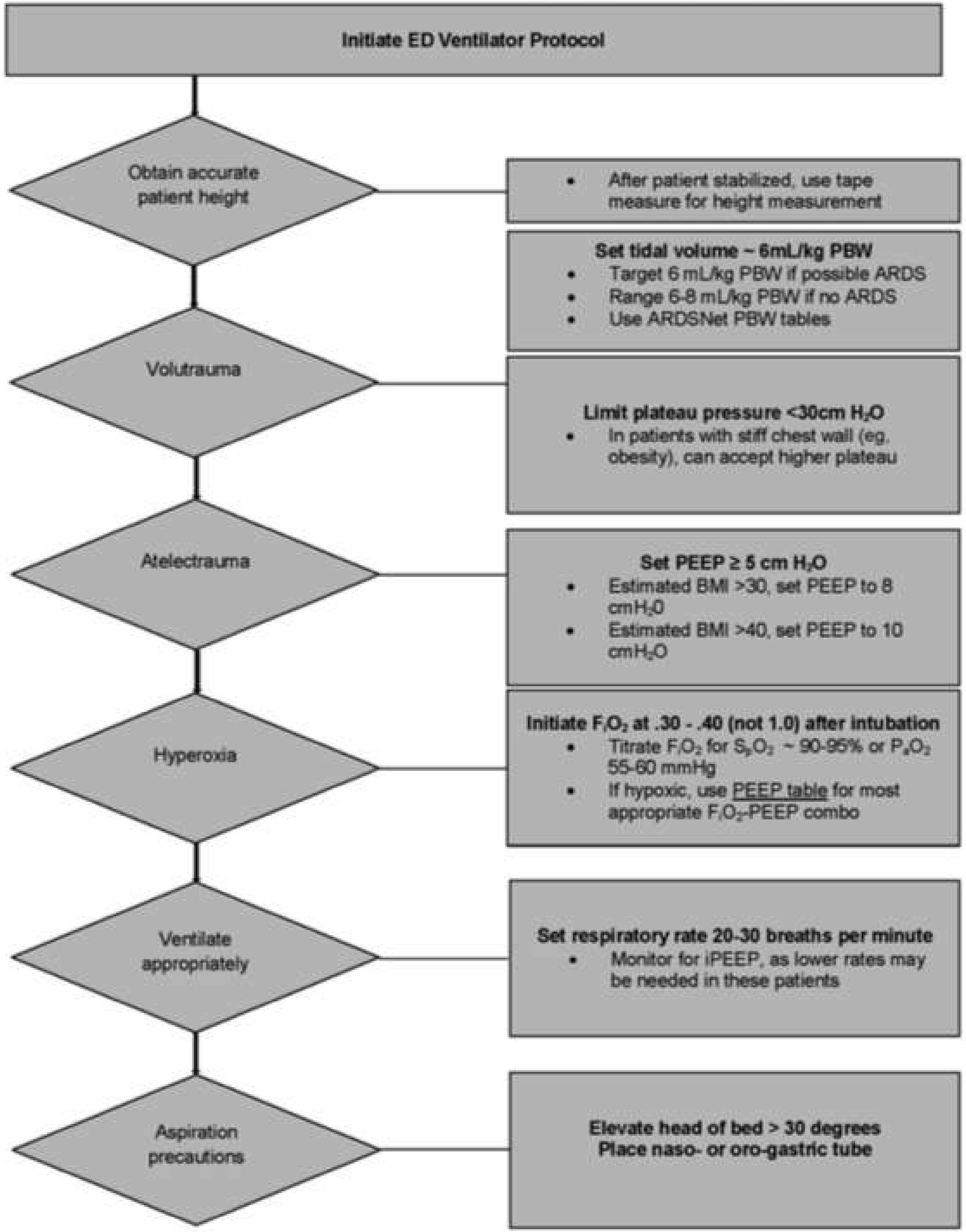
EXPERTS' OPINION

Friday night ventilation: a safety starting tool kit for mechanically ventilated patients

L. GATTINONI [1, 2], E. CARLESSO [2], L. BRAZZI [3, 4], M. CRESSONI [2]
S. ROSSEAU [5], S. KLUGE [6], A. KALENKA [7], M. BACHMANN [8], L. TOEPFER [9]
H. WRIGGE [10], F. REDAELLI [11], C. VETTER [12], M. WYSOCKI [13]

„Friday night" Minerva Anestesiologica 2014; 80: 1046

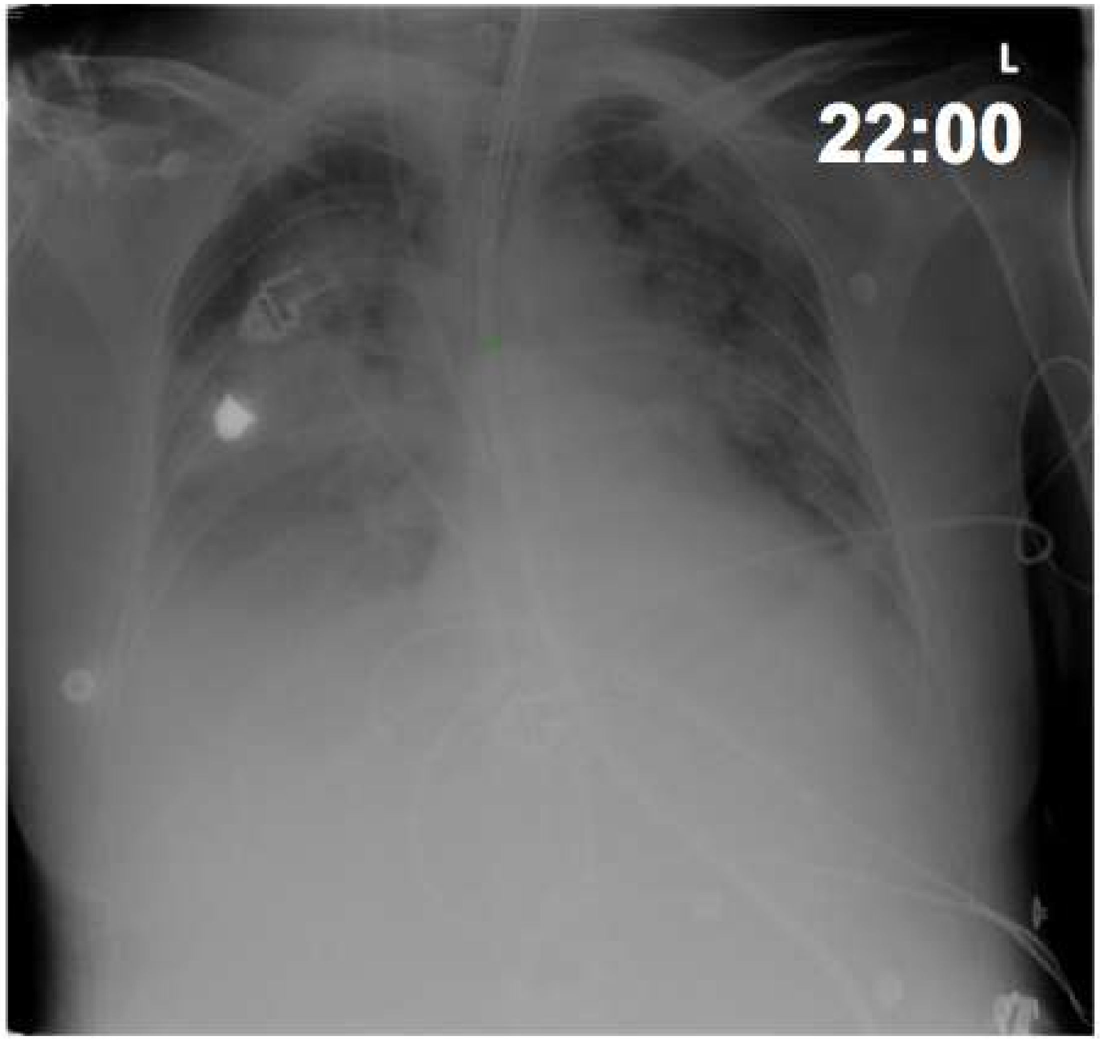

Set the ventilator:
•PEEP 10 cmH2O
• I:E 1:1 or 1:2,
•TV 6 ml/kg IBW
• RR 15 RPM,
•FiO2 0.6-0.8.
Control central venous blood gases and Lactate for hemodynamic status
Impossible
PaO2/FiO2 assessment at 5 cmH2O PEEP
11:00 PM FRIDAY
Possible
Set the ventilator
11:30 PM FRIDAY
1
BiLevel-VG
2
TV: 6 ml/kg IBW (Worldwide accepted)
Consider STRAIN thresholds and normalize TV on FRC (if available) rather than IBW
decremental PEEP InView
Moderate Recruitment
Pplat < 30cmH2O
YES
Accept TV 6 ml/kg IBW
NO
SEVERE ARDS
Measure esophageal pressure or bladder pressure
Is Ccw normal?
NO
Accept Pplat >30cmH2O
YES
Reduce PEEP or TV or accept Hypercapnia



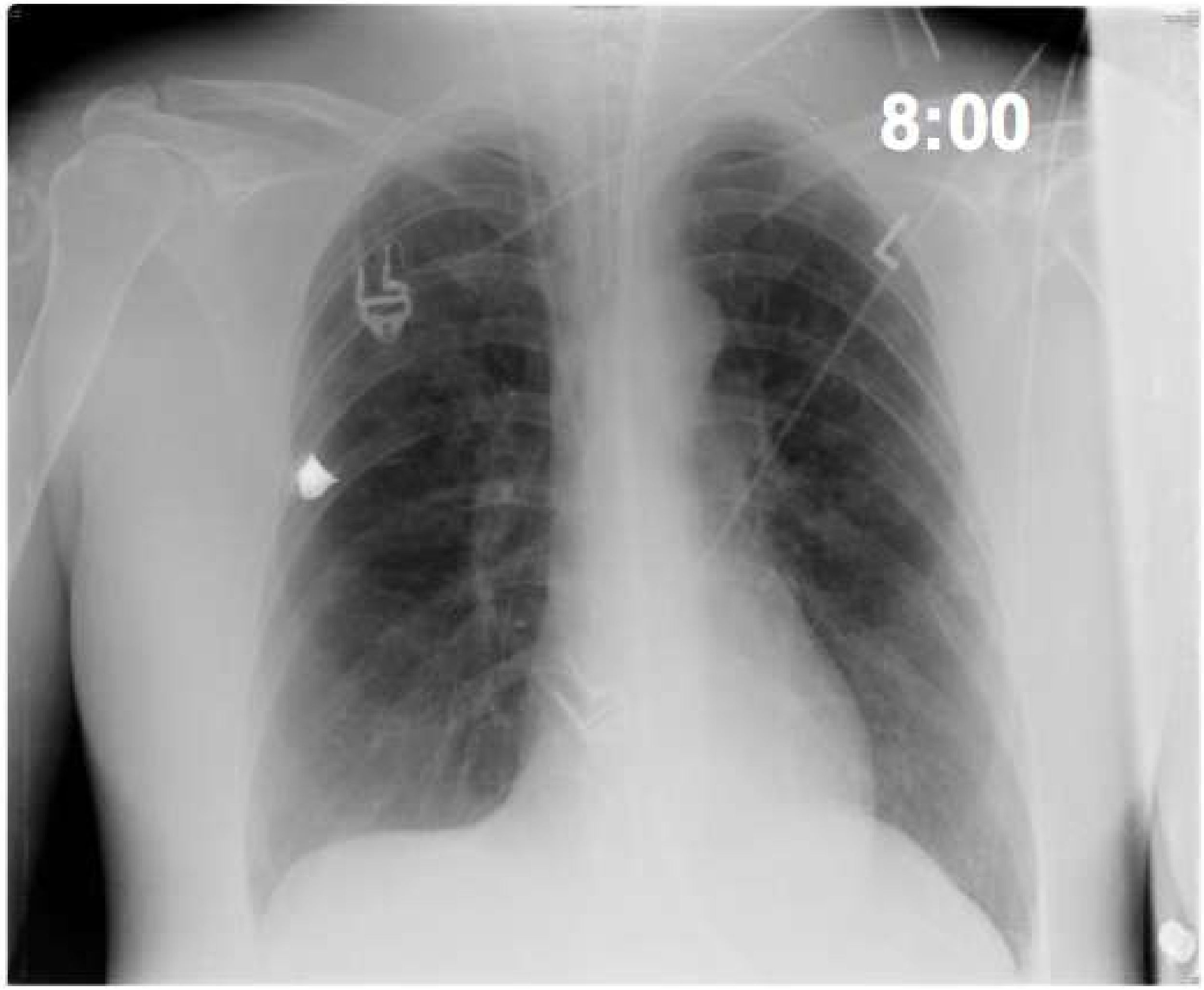
Lung-Protective Ventilation Initiated in the Emergency Department (LOV-ED): A Quasi-Experimental, Before-After Trial

	(n=490)	(n=490)
Primary composite outcome, No. (%)	71 (14.5)	36 (7.4)
ARDS	53 (10.8)	20 (4.1)
VACs	37 (7.6)	23 (4.7)
Secondary outcomes		
Ventilator-free days	14.7 (11.7)	18.4 (10.4)
Hospital-free days	9.4 (9.5)	11.7 (9.2)
ICU-free days	13.6 (11.1)	16.0 (9.9)
Mortality, No. (%)	167 (34.1)	96 (19.6)

Ann Emerg Med. 2017;70:406-418.



BILEVEL 34/18 mbar
VT 6,1 ml/kg
AF 18/min
FiO_2 1.0
P/F 67 mmHg
PCO_2 78 mmHg



BILEVEL 42/32 mbar
VT 5,7 ml/kg
AF 18/min
FiO_2 0.4
P/F 244 mmHg
PCO_2 38 mmHg

Résumé