Using Esophageal Balloon Manometry in the ICU

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The Clinical Problem

During mechanical ventilation, the pressure applied to the lung itself is usually not known, and is often assumed to be the approximately same as ventilator pressures.

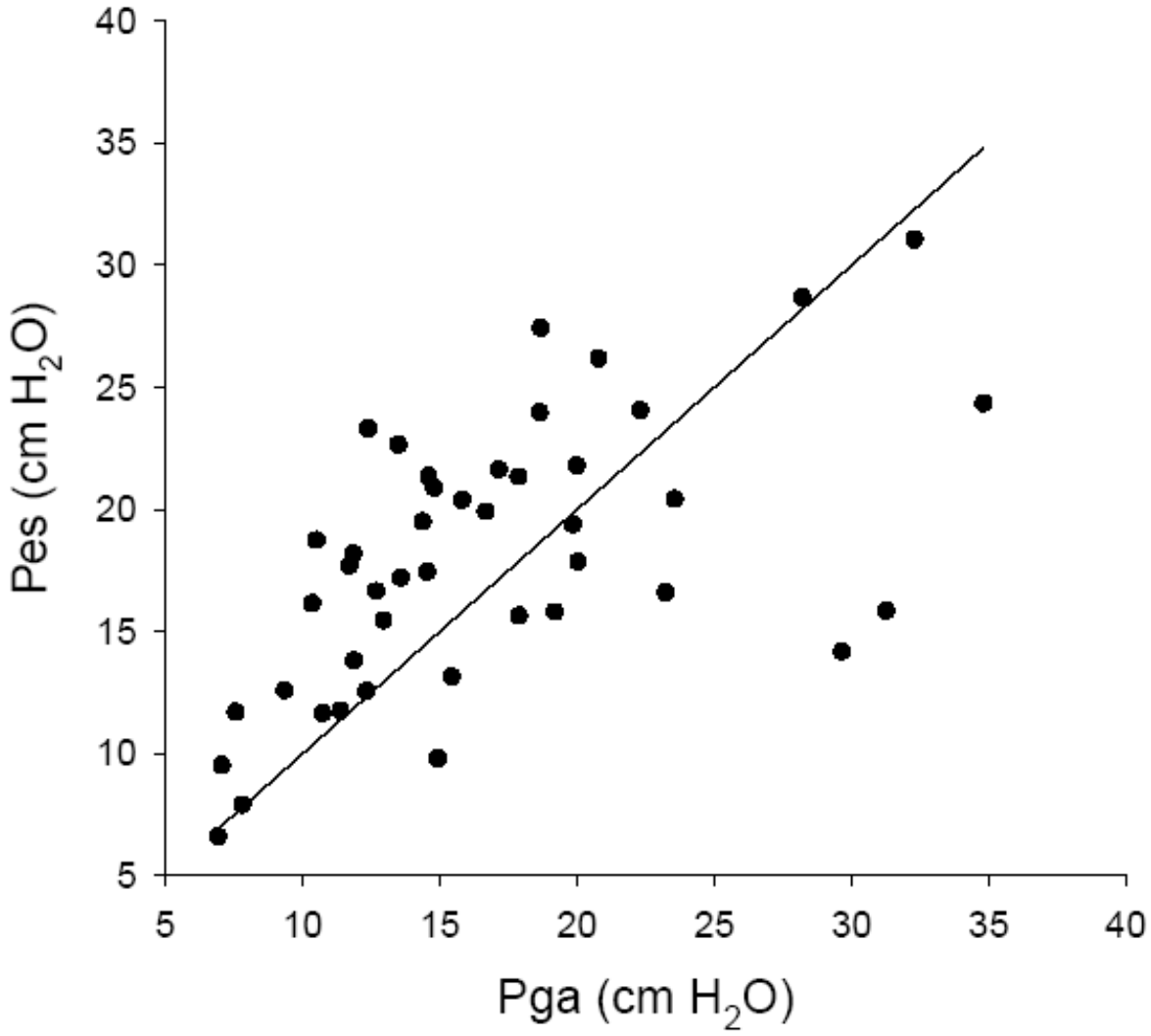
In some patients, the chest wall contributes to a large part of the trans-respiratory pressure, making the above assumption false.

Titrating ventilation based on ventilator pressures does not allow us to take this variability into account, since pleural pressure is typically unknown.

Transpulmonary Pressure

- Knowing pleural pressure could allow calculation of transpulmonary pressure to permit ventilation with pressures appropriate to the individual lungs.
- Can esophageal pressure (P_{es}) be used as an estimate of pleural pressure?
- Can these be used to individualize therapy?

Esophageal and Gastric Pressures



Trans-pulmonary Pressure (Ptp)

$$P_{tp} = P_{ao} - P_{pl}$$

- P_{tp} is the pressure actually distending the lung.
- This may be very different from the pressure measured at the airway.
- Think of this as the pressure pushing out from the lung in relation to the pressure pushing in on the lung.

Esophageal Pressure Measurements

- P_{es} as an estimate of pleural pressure is problematic in supine, mechanically ventilated patients.

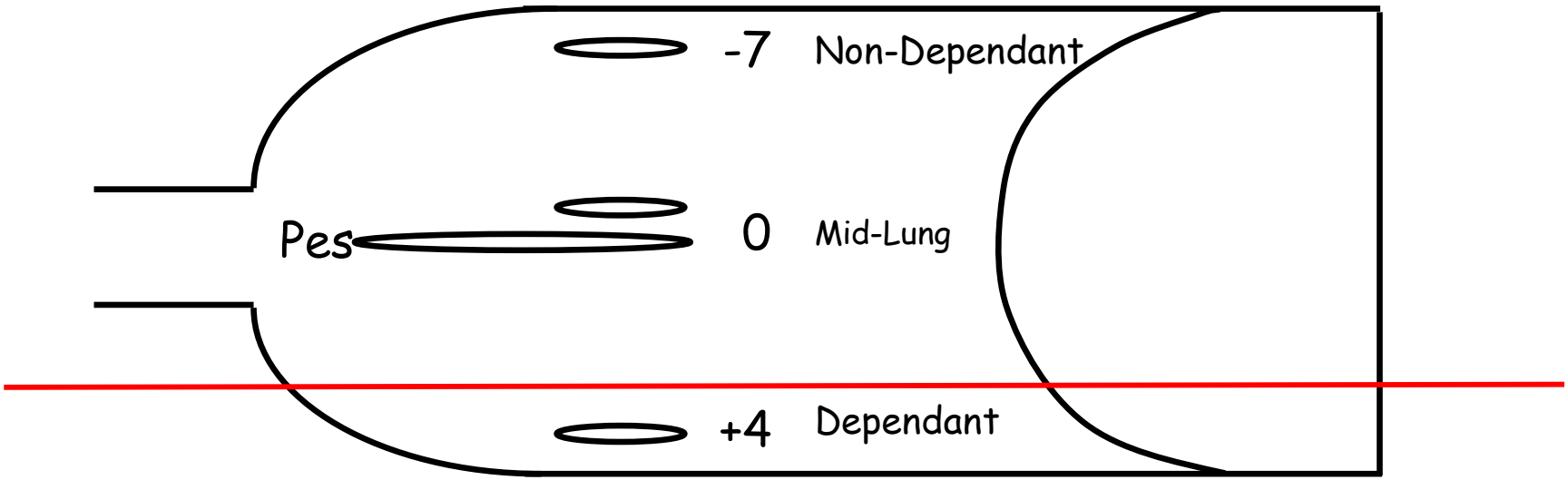
- P_{es} may be influenced by overlying cardiac weight, thus overestimating the pressure within the pleural space at low lung volumes.

- On the other hand, at high lung volumes, the baseline value of P_{es} may underestimate the actual pressure measured in the pleural space.
- We must continue to use good clinical judgement when using any tool or procedure to assess ventilatory needs.

Pleural Pressure Measurement

Gravitational Effect on Regional Pleural Pressure

Pressure transducing wafers implanted in dog lungs revealed differences in pleural pressure due to the gravitational effect of the dependent vs. non-dependent regions of the lung.



Pelosi Am J Respir Crit Care Med 2001; 164:122-130

How Can We Use This To Guide Ventilator Management?

- P_{tp} that are less than 15-20 cmH2O on inspiration are correlated with safer end inspiratory pressures and provide objective data that the V_T is in a safe, lung protective range. This can be combined with other tools like driving pressure and ARDSnet guidelines to ensure safe tidal volumes.

- Measuring the P_{tp} at end expiration allows for the determination of the best PEEP for each patient. We can see if we are over distending or collapsing at the current PEEP levels and adjust accordingly.

- In short, measuring P_{tp} allows us to personalize vent settings for each patient.

Measuring Esophageal Pressure in ARDS- Hypothesis

DEPENDING ON THE CHEST WALL CONTRIBUTION TO RESPIRATORY MECHANICS, A GIVEN PEEP LEVEL OR PLATEAU PRESSURE MAY BE ADEQUATE FOR ONE PATIENT BUT POTENTIALLY INJURIOUS FOR ANOTHER.

THIS MAY EXPLAIN VARYING RESULTS IN CLINICAL TRIALS.

What are the Barriers to Using an Esophageal Balloon?

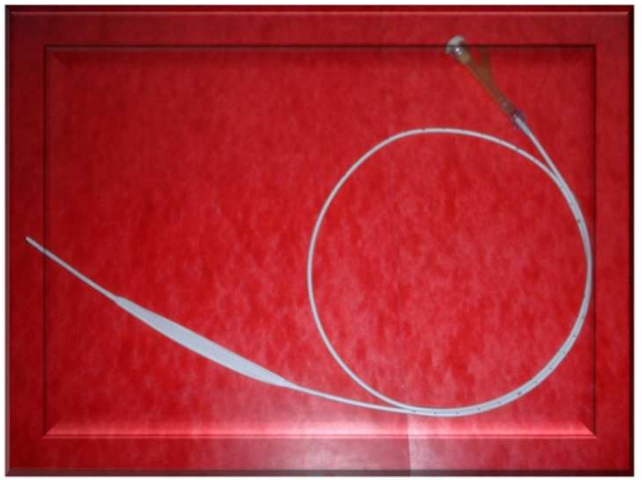
Can be complex to place and confirm

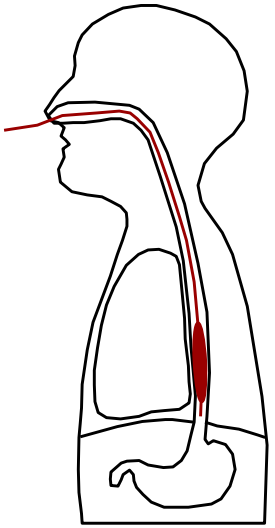
Requires significant training

Specialty equipment needed

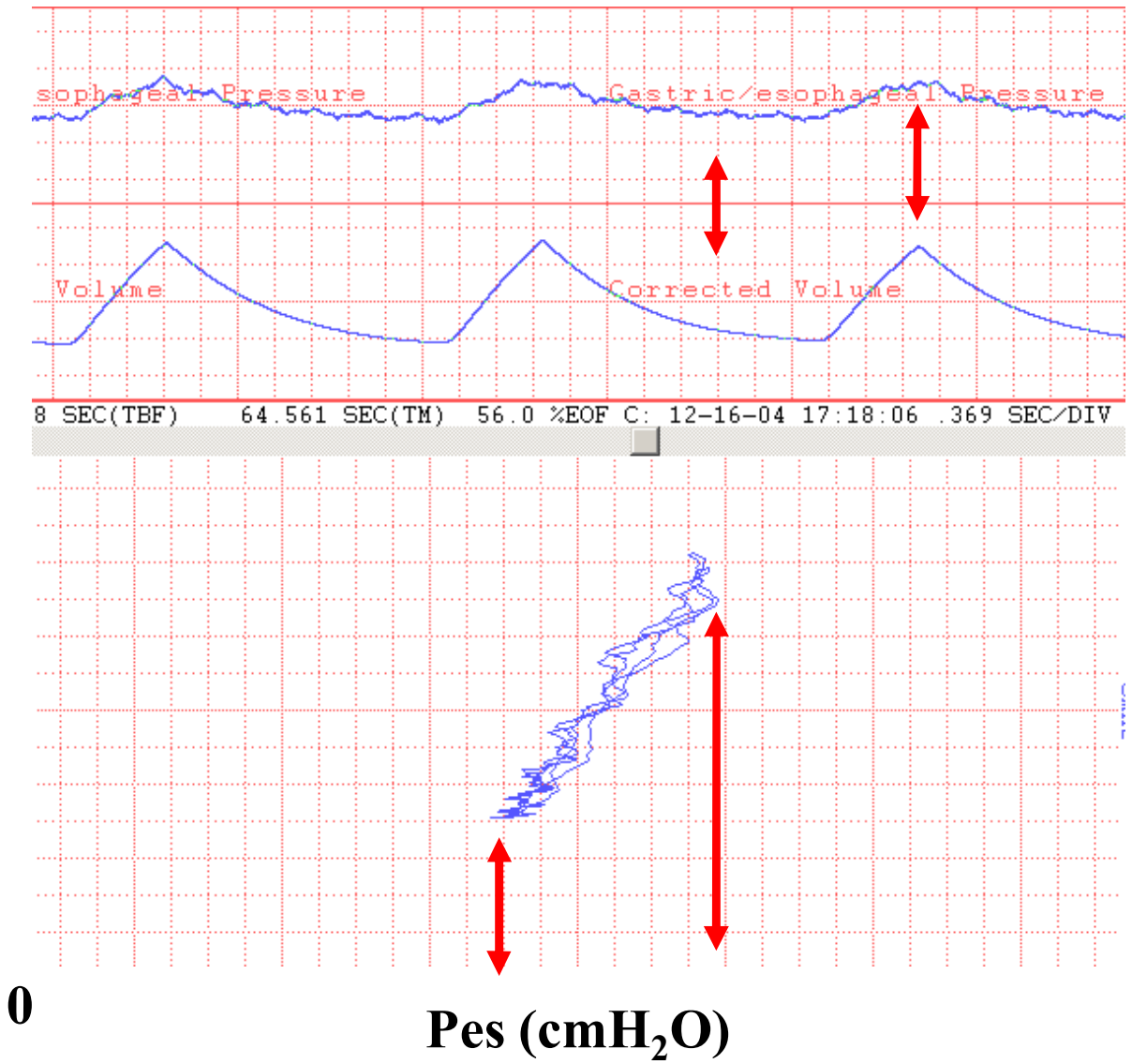
Esophageal Balloon

- Low- pressure balloon
- 9 – 10 cm long.
- Optimal fill vol. is 0.5 – 1.0 ml of air.
- Position the bottom of balloon 50 cm from incisor.

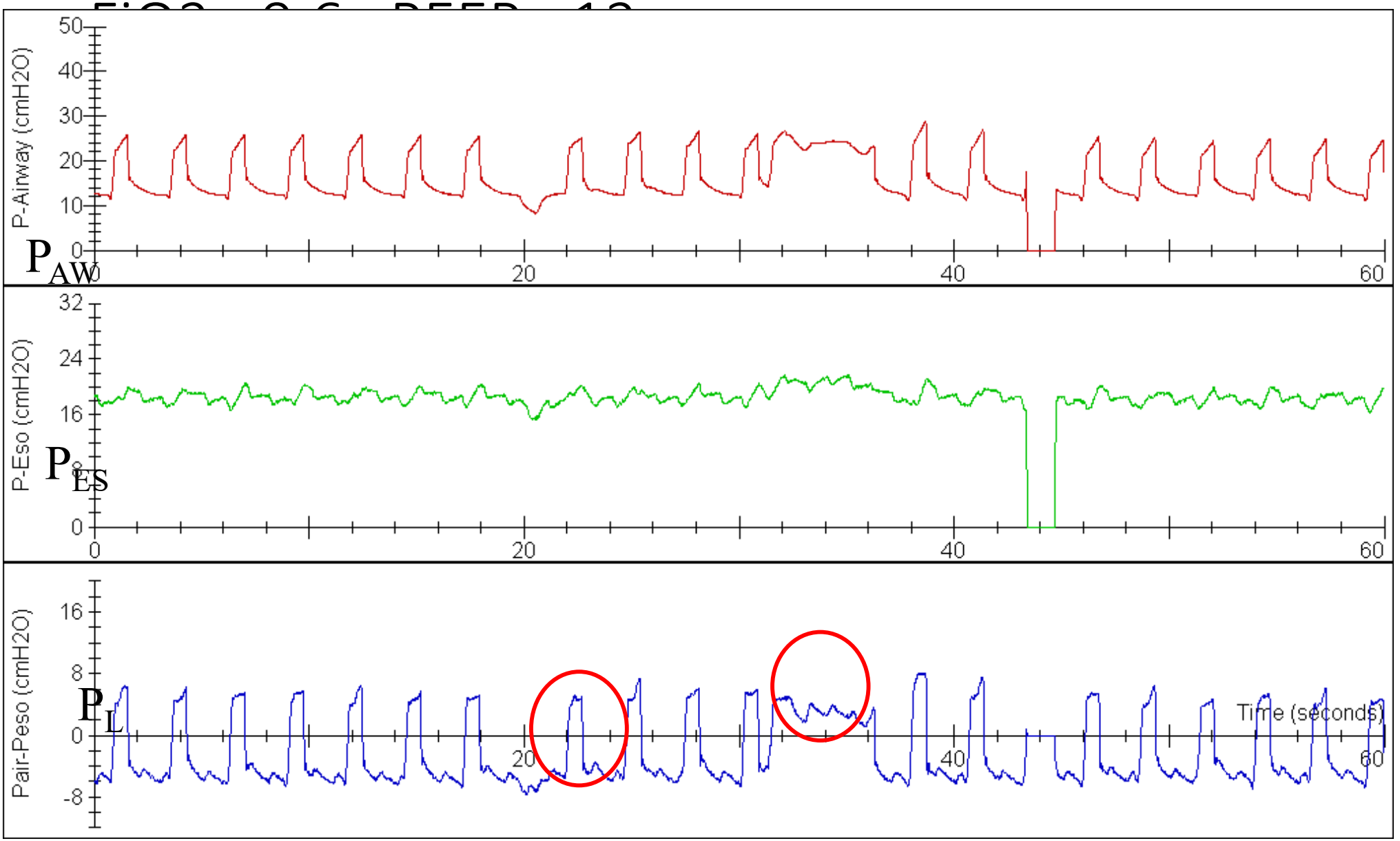




Esophageal Pressure During Passive Mechanical Ventilation.



In Practice- Pre Intervention



$P_{tpexp} = -6$ $P_{tpinsp} = 3$

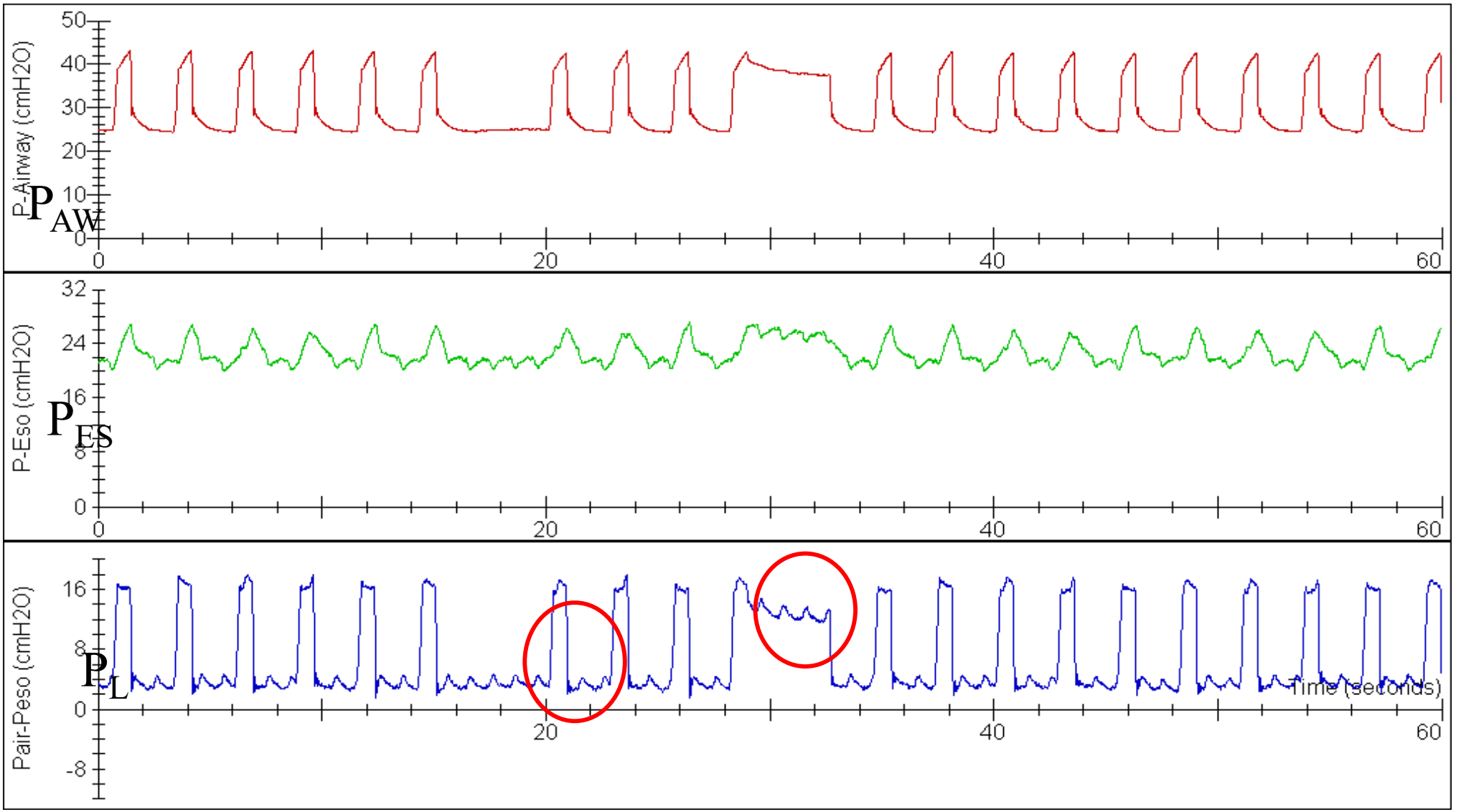
What is a Negative Transpulmonary Pressure?

This is not negative pressure in the lung.

Indicates that pleural pressure is greater than pressure at the airway opening.

This will lead to collapse or air trapping in parts of the lung.

In Practice- Post Intervention
FiO2= 0.6 PEEP= 24



$P_{lexp} = 4$ $P_{linsp} = 12$

Pt 1 Strategy: Change ventilator pressures to optimize P_{tp}

Ventilator pressures:

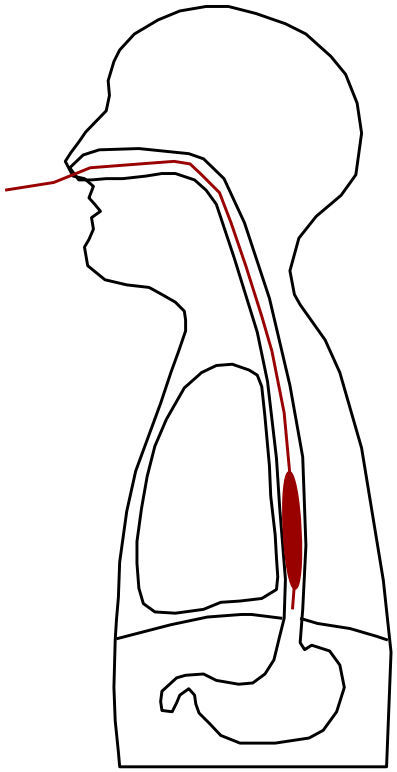
PEEP 13 → 26

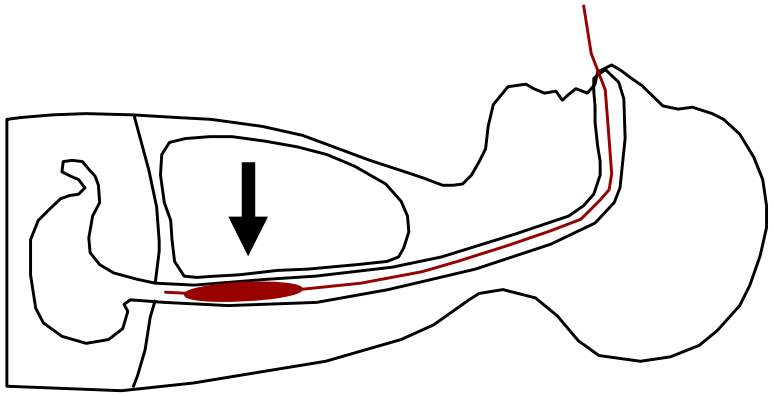
which raised

Pplateau 40 → 46

Pleural Pressure Measurement
Positional Artifact

Supine position causes approximately 3 cm H_2O (range -1 – 7) increase in the transduced Pes due to heart & lung compression of the balloon.





Washko J Appl Physio 2006; 100:753-8

Pt 1 After Ventilator Changes to Optimize P_{tp}

P_{aw}

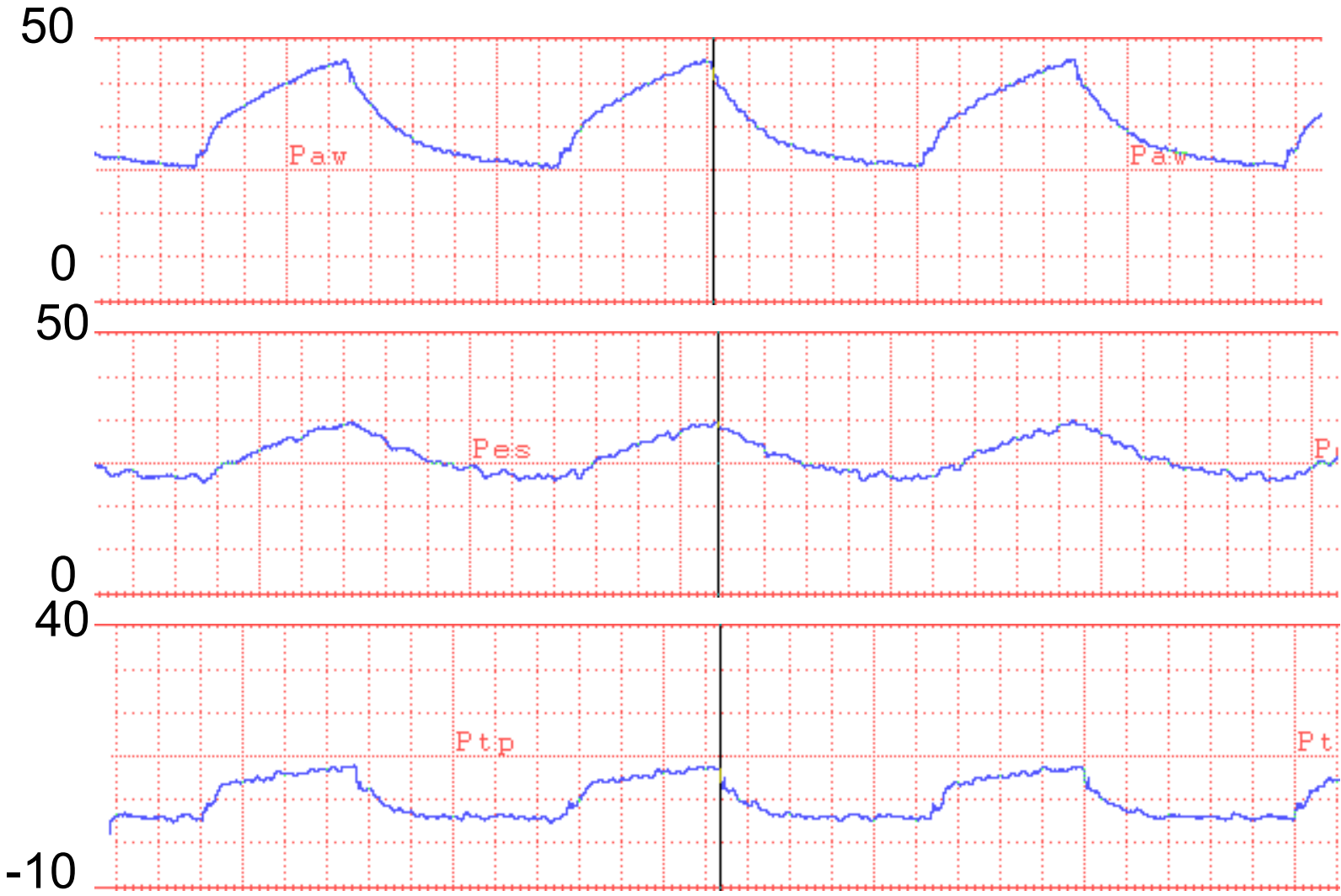
$P_{aw} = 26$ to 46

P_{es}

$P_{es} = 22$ to 33

P_{tp}

$P_{tp} = 4$ to 12



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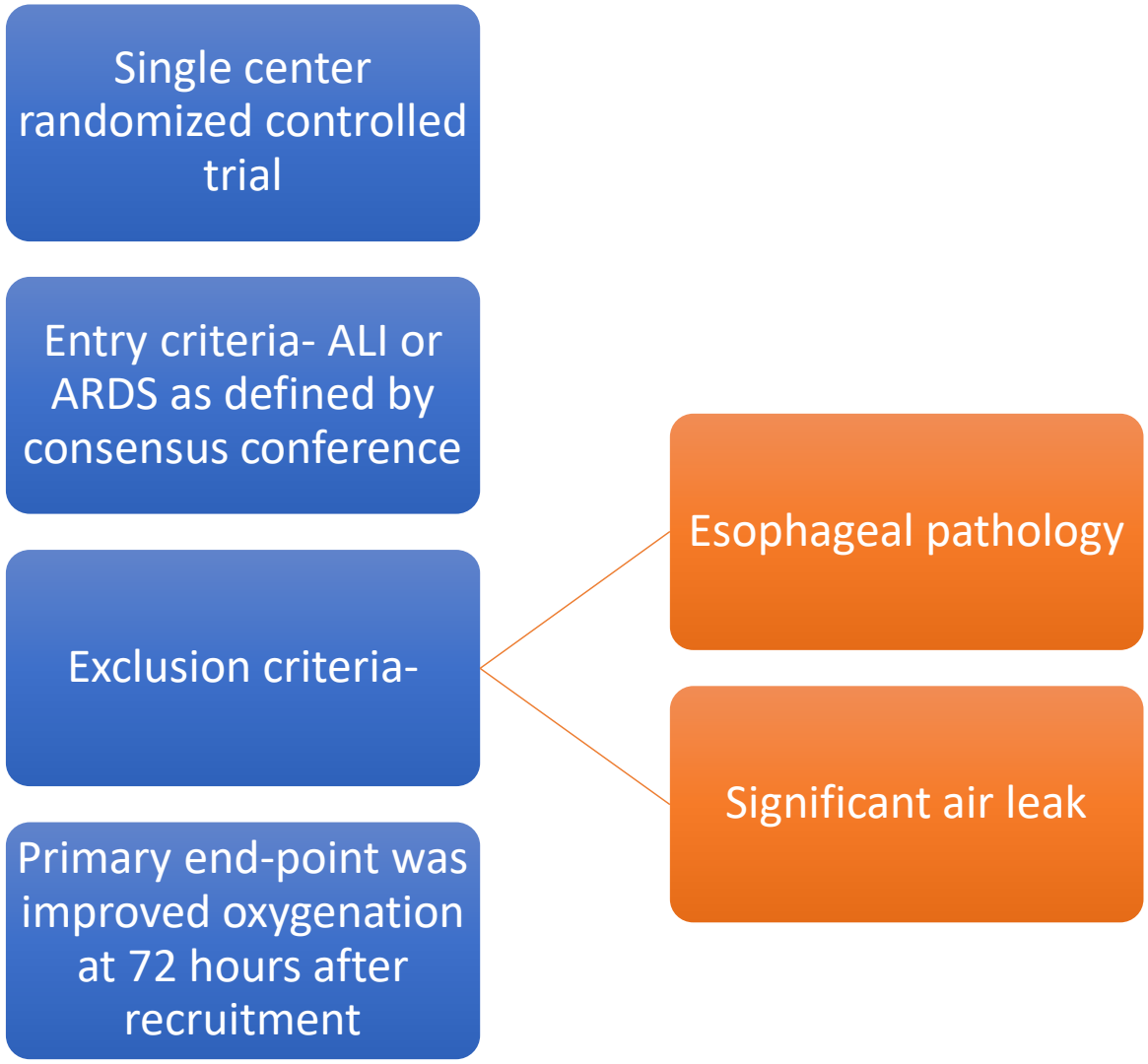
Mechanical Ventilation Guided by Esophageal Pressure in Acute Lung Injury

Daniel Talmor, M.D., M.P.H., Todd Sarge, M.D., Atul Malhotra, M.D., Carl R. O'Donnell, Sc.D., M.P.H., Ray Ritz, R.R.T., Alan Lisbon, M.D., Victor Novack, M.D., Ph.D., and Stephen H. Loring, M.D.

- NHLBI- HL 52586
- www.clinicaltrials.gov as NCT00127491

EPVent-Study Design



EPVent

- Baseline measurements performed
- Randomization
- Initial recruitment maneuver
  - 40 cmH_2O for 30 seconds
  - Limited to a transpulmonary pressure of 25
- Patients placed on study settings
- In both groups this included TV 4-8 ml/kg

EPVent Control Group

- ARDS net low tidal volume study protocol.
- Keep PaO2 between 55 and 120 mmHg.
- Set PEEP and tidal volume to keep the airway pressure during end-inspiratory hold less than 30 cmH_2O.

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
PEEP	5	5	8	8	10	10	10	12	14	14	14	16	18	20-24

EPVent Study Group

- Keep PaO2 between 55 and 120 mmHg.
- Set PEEP and tidal volume to keep
  - $\mathbf{P_{tpexp}}$ between 0 and 10 cmH_2O
- Set TV to keep
  - $\mathbf{P_{tpins}}$ less than 25 cm H2O

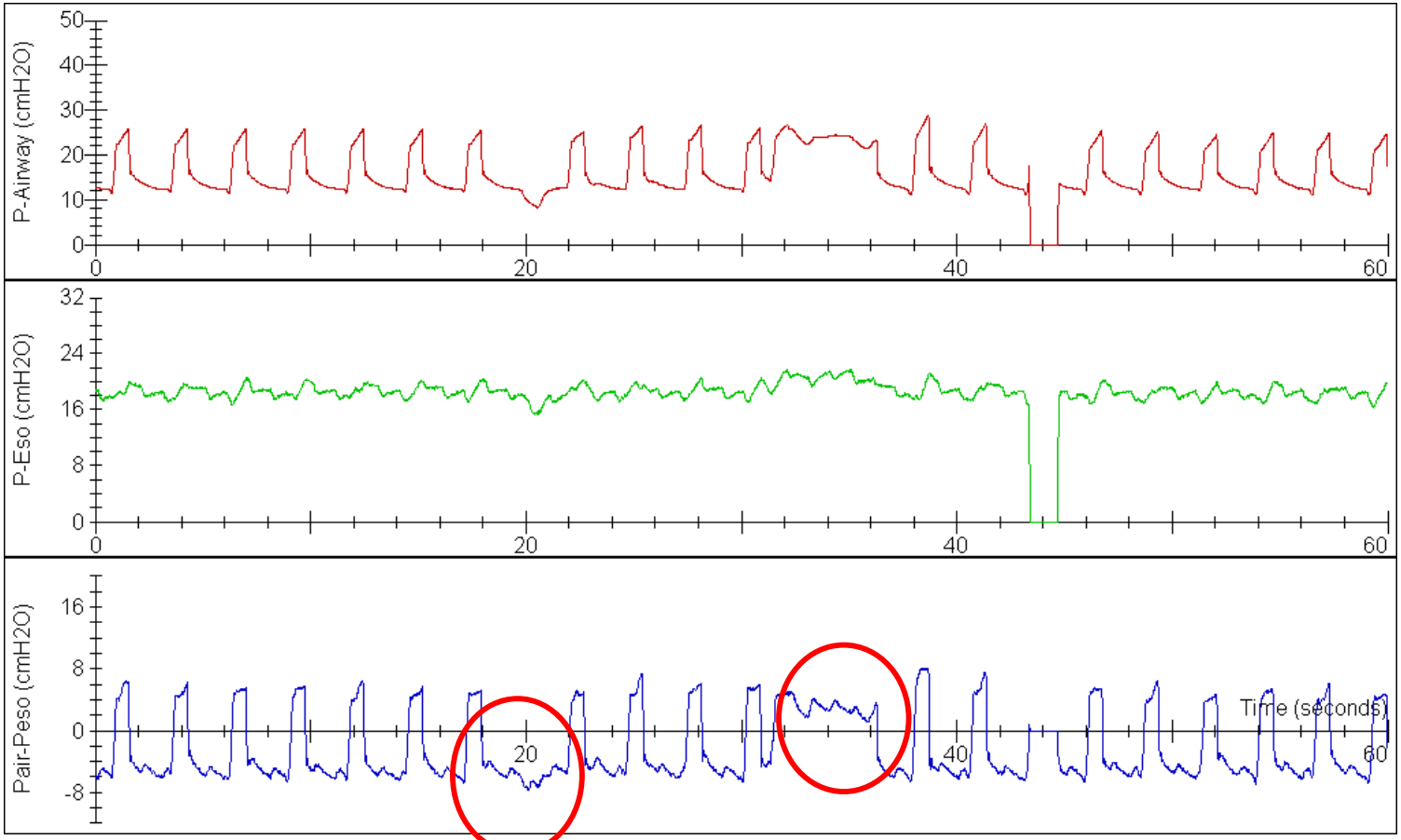
F_IO_2	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	.1.0
P_{Lexp}	0	0	2	2	4	4	6	6	8	8	10	10

In Practice- Pre Intervention
FiO2= 0.6 PEEP= 12

P_{AW}

P_{ES}

P_L



$P_{Lexp} = -6$

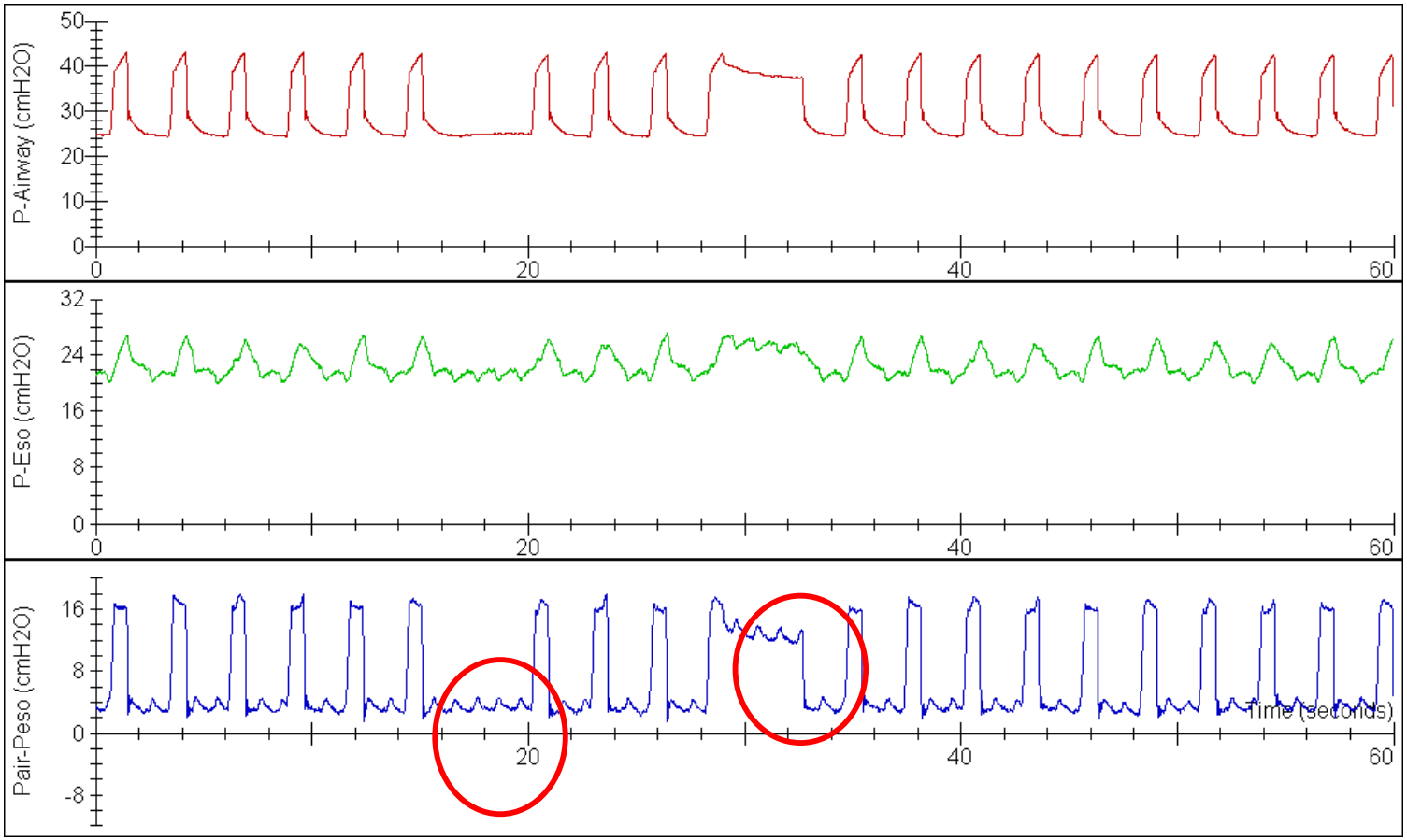
$P_{Linsp} = 3$

In Practice- Post Intervention
FiO2= 0.6 PEEP= 24

P_{AW}

P_{ES}

P_L



$P_{lexp} = 4$

$P_{linsp} = 12$

EPVent-Outcomes

- Stopped at interim analysis by DSMB for overwhelming effect.
- 61 patients enrolled
- Intention to treat analysis
  - Conventional 31 patients
  - EP group 30 patients
    - One did not receive therapy

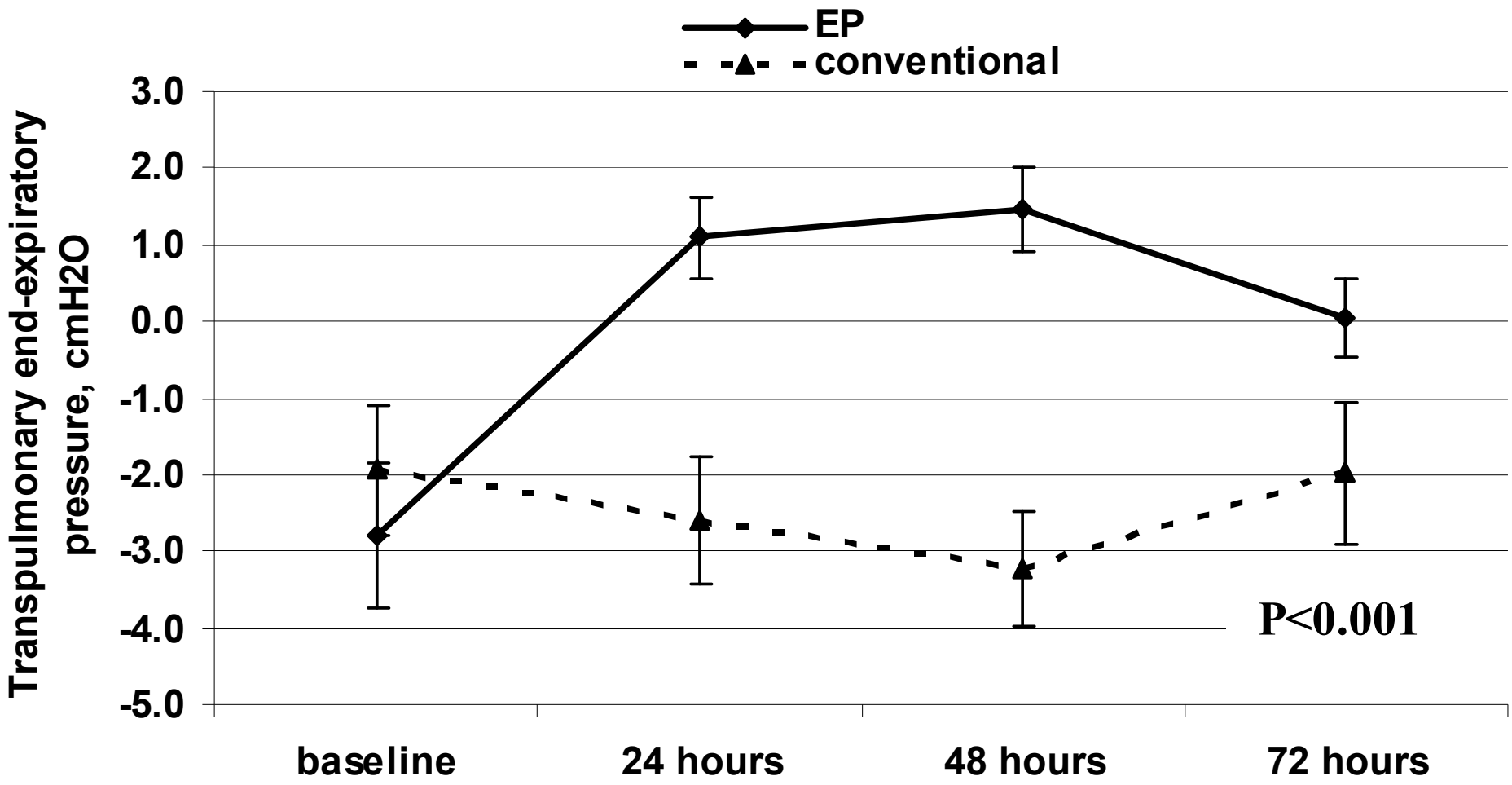
EPVent-Subjects

	EP protocol N=30	Conventional N=31	p-value
Male gender, (%)	19 (63.3)	17 (54.8)	0.44
Age, years	54.5±16.1	51.2±23.0	0.52
Caucasian, (%)	26 (86.7)	27 (87.1)	0.96
Ideal body weight, kg	67.1±8.9	63.2±11.1	0.14
APACHE II on admission, points	26.3±6.4	26.8±6.5	0.76
Primary physiological injury (%)			
Pulmonary	7 (23.3)	5 (16.1)	0.54
Abdominal	13 (43.3)	11 (35.5)	
Trauma	6 (20.0)	9 (29.0)	
Sepsis	3 (10.0)	2 (6.5)	
Other	1 (3.3)	4 (12.9)	

Ventilator Settings at Baseline

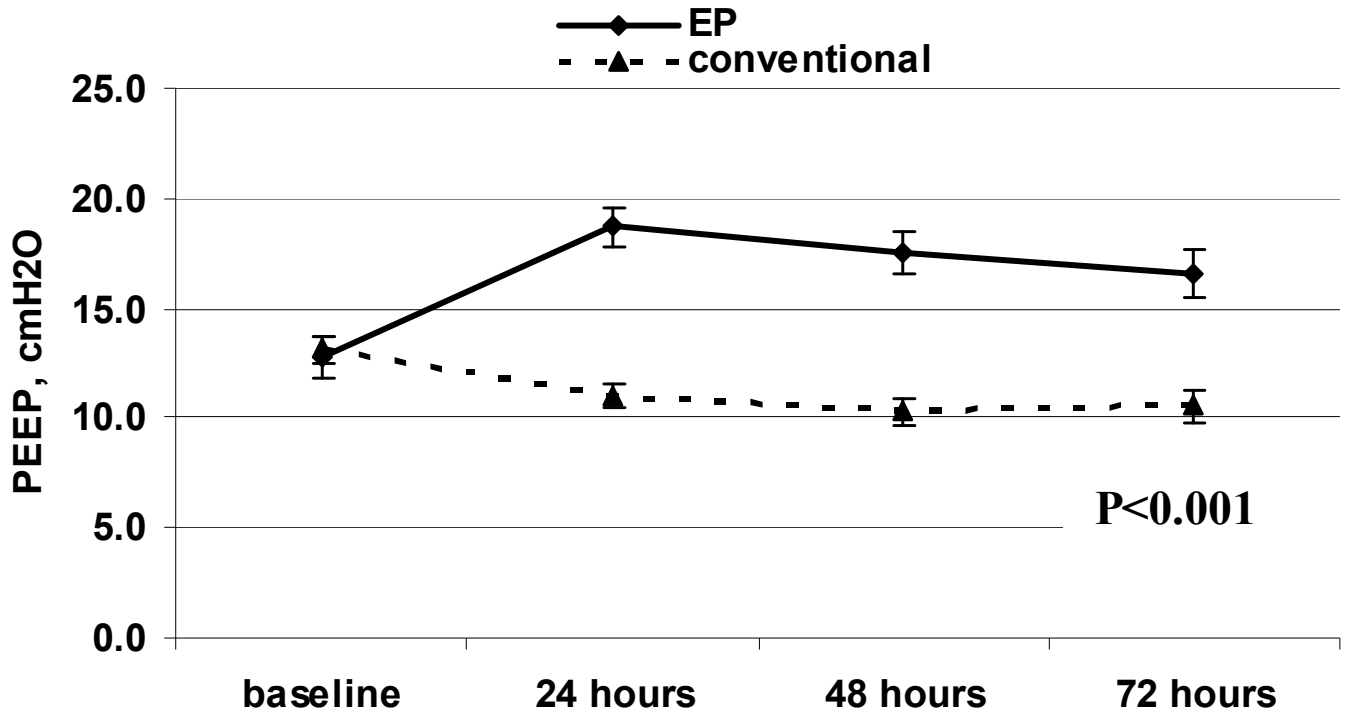
	Baseline		
	EP protocol	**Conventional**	**P-value**
	N=30	**N=31**	
PaO2 / FIO2 ratio	**147 ± 56**	**145 ± 57**	**0.89**
Respiratory Compliance, ml/cmH_2O	**36 ± 12**	**36 ± 10**	**0.94**
Dead space to tidal volume ratio, %	**67.± 11.**	**67 ± 9**	**0.95**
PaO2, mmHg	**91 ± 25**	**107 ± 44**	**0.09**
FIO_2, %	**66 ± 17**	**77 ± 18**	**0.02**
PEEP, cmH_2O	**13 ± 5**	**13 ± 3**	**0.73**
Tidal volume, cc^3	**484 ± 98**	**491 ± 105**	**0.80**
Tidal volume/ ideal body weight, cc/kg	**7.3 ± 1.3**	**7.9 ± 1.4**	**0.12**

Transpulmonary End-expiratory Pressures



The Intervention Effect on Set PEEP

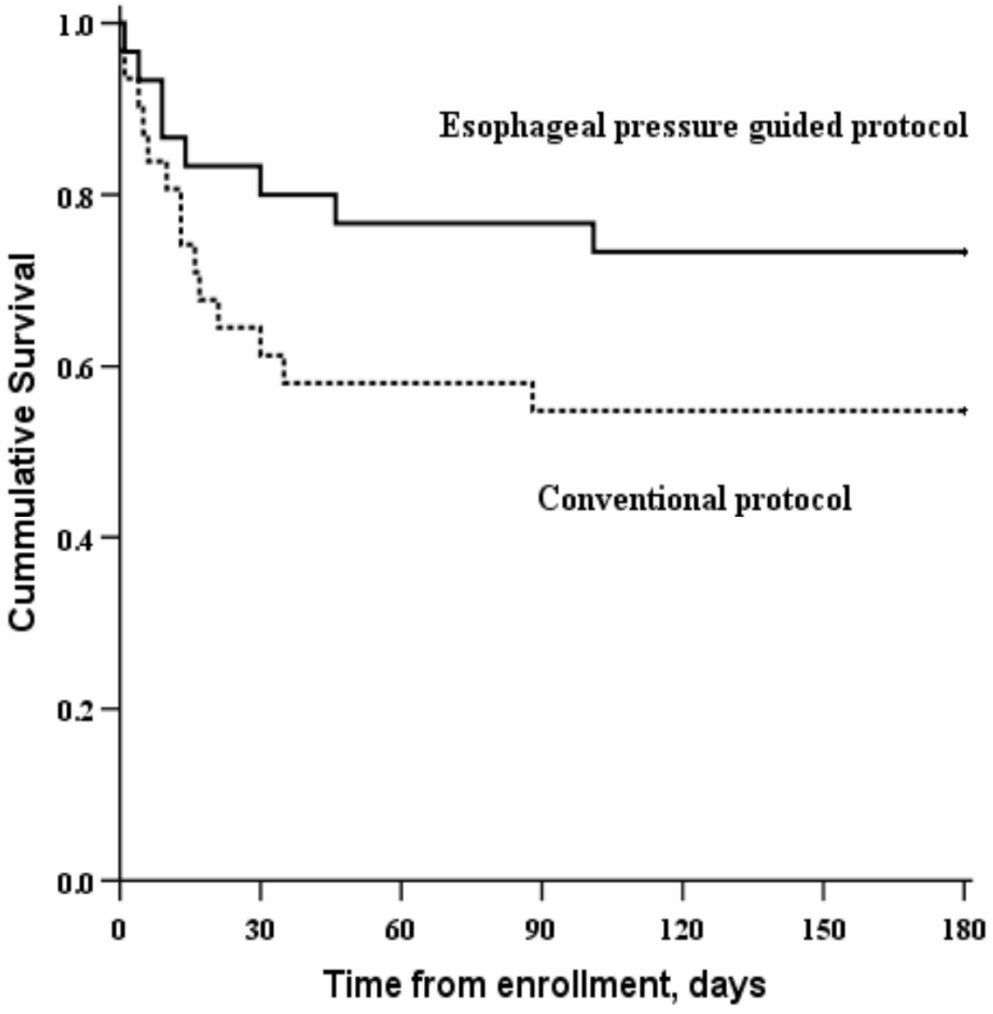
	Change in PEEP on the first therapeutic day				
	-1 to -6	0 to 5	6 to 10	11 to 15	16 to 20
EP Group	3	9	12	4	2
Control	12	18	1	0	0



PEEP Levels in Comparable Trials

	Day 1		Day 3	
	Control	Intervention	Control	Intervention
ALVEOLI	8.9	14.7	8.5	12.9
ARIES	9.0	14.1	8.7	11.2
LOVS	10.1	15.6	8.8	11.8
EXPRESS	7.1	14.6	6.7	13.4
EPVent	11.0	18.7	10.5	16.6

6- Month Survival



ARDSnet

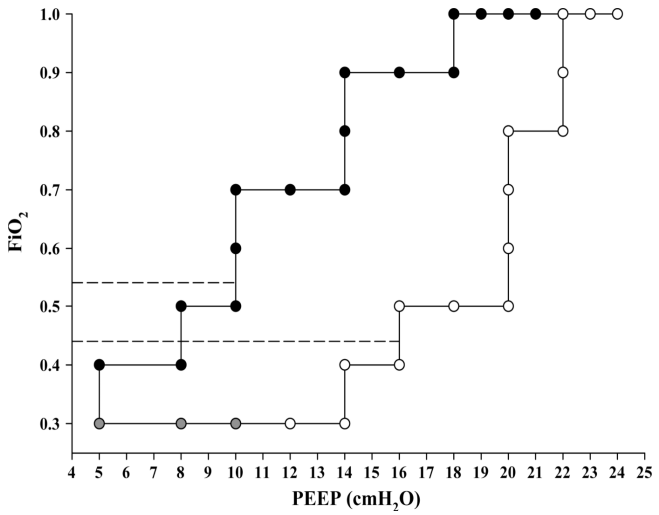
The ARDSnet low tidal volume ventilation study showed a mortality benefit using low tidal volumes. This study did not address the issues of optimal PEEP

PEEP and FiO_2 set based on sliding scales to keep PaO_2 between 55 and 120 mmHg

ALVEOLI Trial

- ALVEOLI randomized to higher vs. lower levels of PEEP based on tables- Day 1 PEEP- 8.9 vs. 14.7 cm H_2O .

- Tables of PEEP vs. F_IO_2 are based on expert opinion and not physiological measurements.



Background

Neuromuscular Blocking Agents (NMBAs) are administered to patient's with refractory hypoxemia secondary to ARDS or other acute pulmonary failure.

Historically in these patients, the use of a Train-Of-Four, or other peripheral monitoring device has been used to determine if the patient was adequately paralyzed.

Background

Often, these devices do not appropriately reflect the patients level of activity as it relates to the muscles of breathing.

The use of an esophageal balloon to measure activity in the abdomen has been shown to be a better indicator of passive breathing in these patients.

Background

- All appropriate patients who receive NMBAs should have an esophageal balloon put in place.
- Typically, by the time NMBAs become an option, the patient already has a balloon. If they do not, one must be inserted.

Paralyzed or Not Paralyzed?

- When referring to these patients, the terminology used should be **passive breathing** or **active breathing**, instead of paralyzed or not paralyzed.

- This method does not directly measure paralysis. Instead, it measures muscle activity. A patient can be passive without NMBAs if appropriately sedated.

Background

- After confirming correct placement of the balloon, configure the screen to perform a loop analysis as follows…

Interpretation

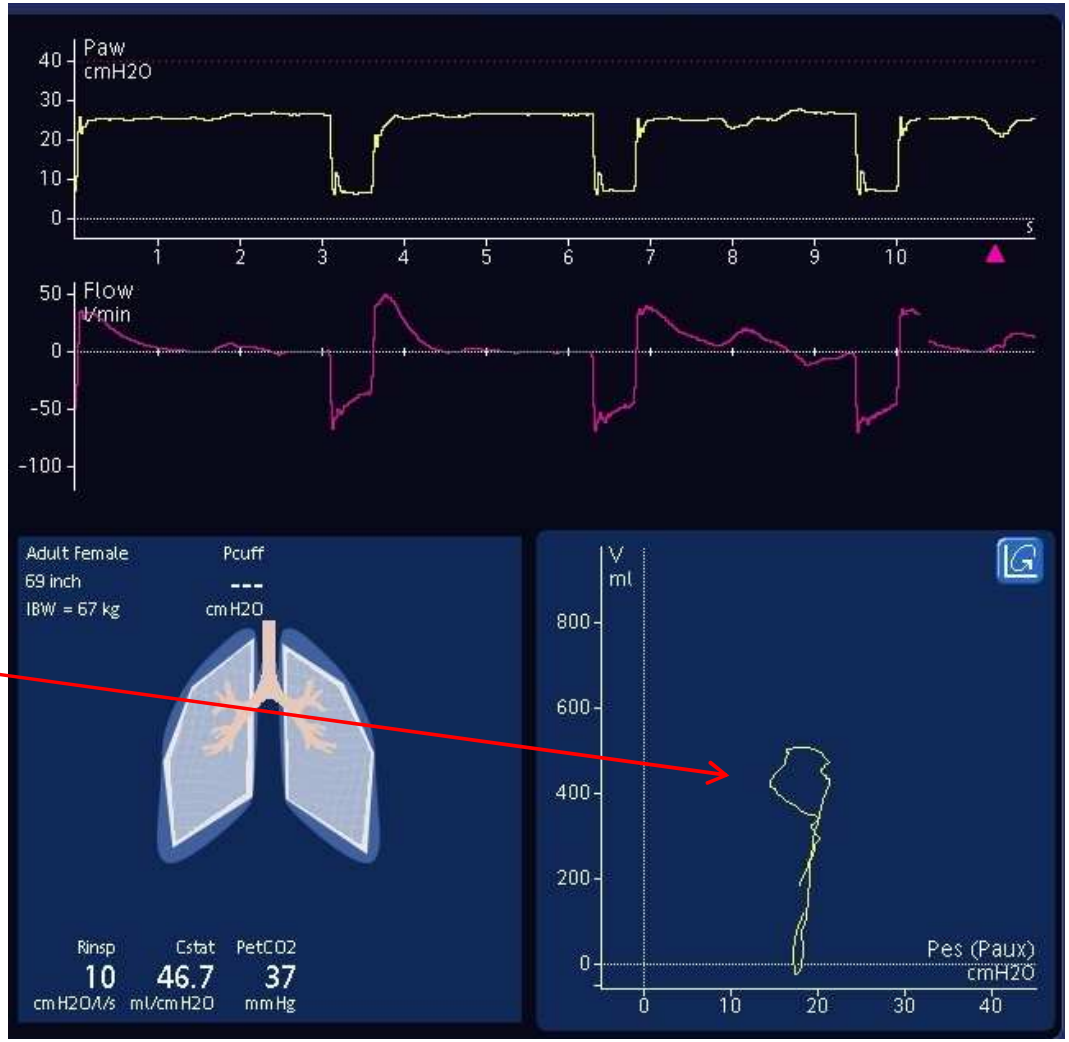
It is important to remember that when assessing patients for breathing activity, you must observe them over several breaths.

Peristalsis and esophageal spasm can produce an artifact which will dissipate over a few minutes.

Interpretation

A patient who is **actively breathing** will have a varying degree of movement in the loop.

This patient would **NOT** be considered adequately paralyzed.



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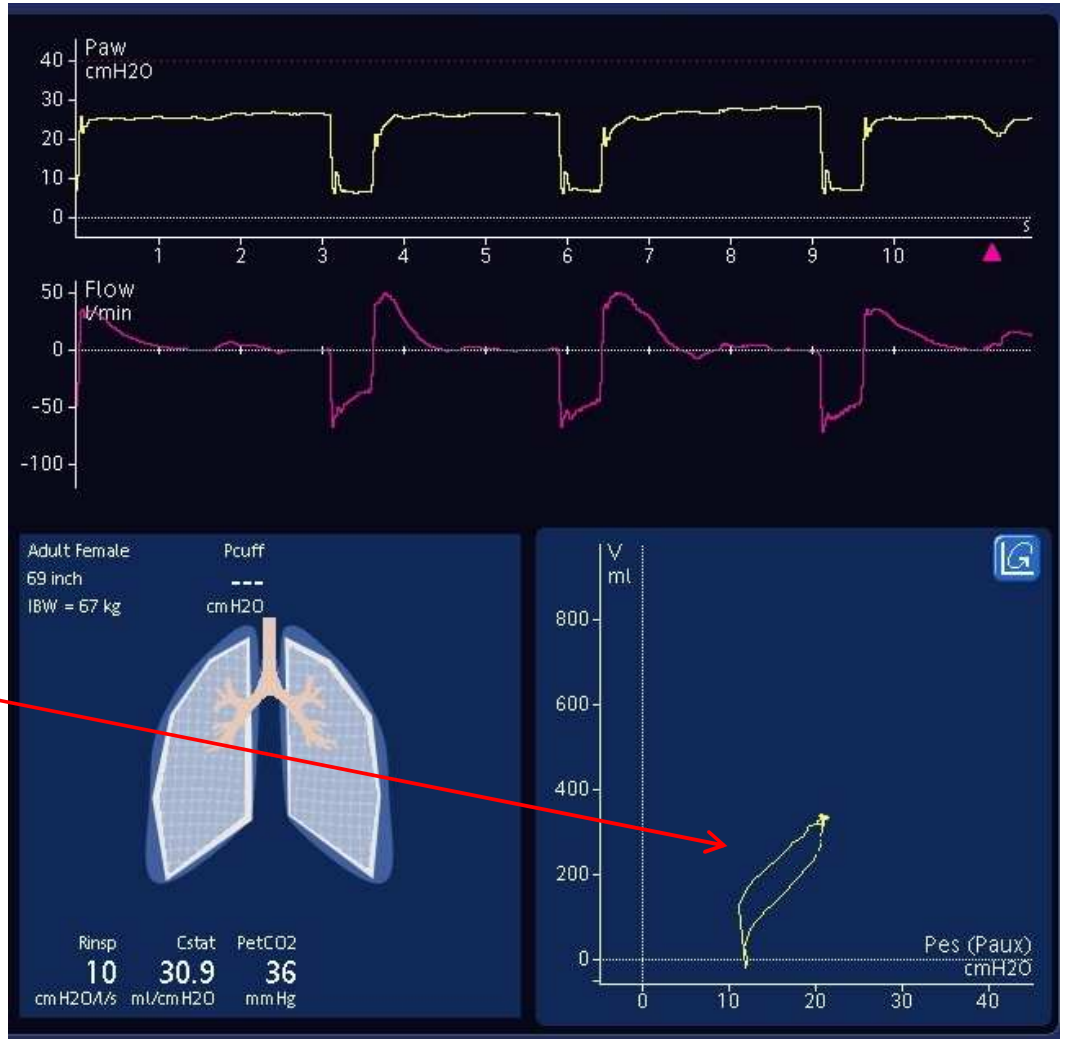
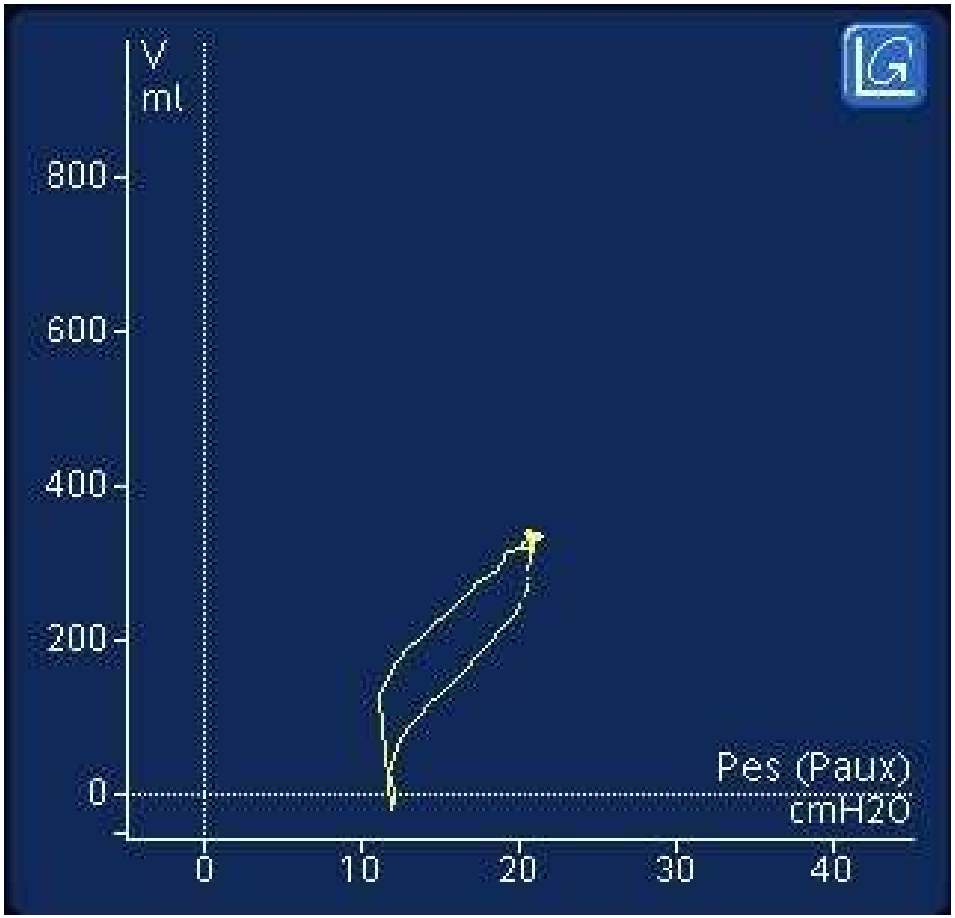


Interpretation

- Some close ups of active loops…

- This patient would **NOT** be considered adequately paralyzed. (Active)



Interpretation

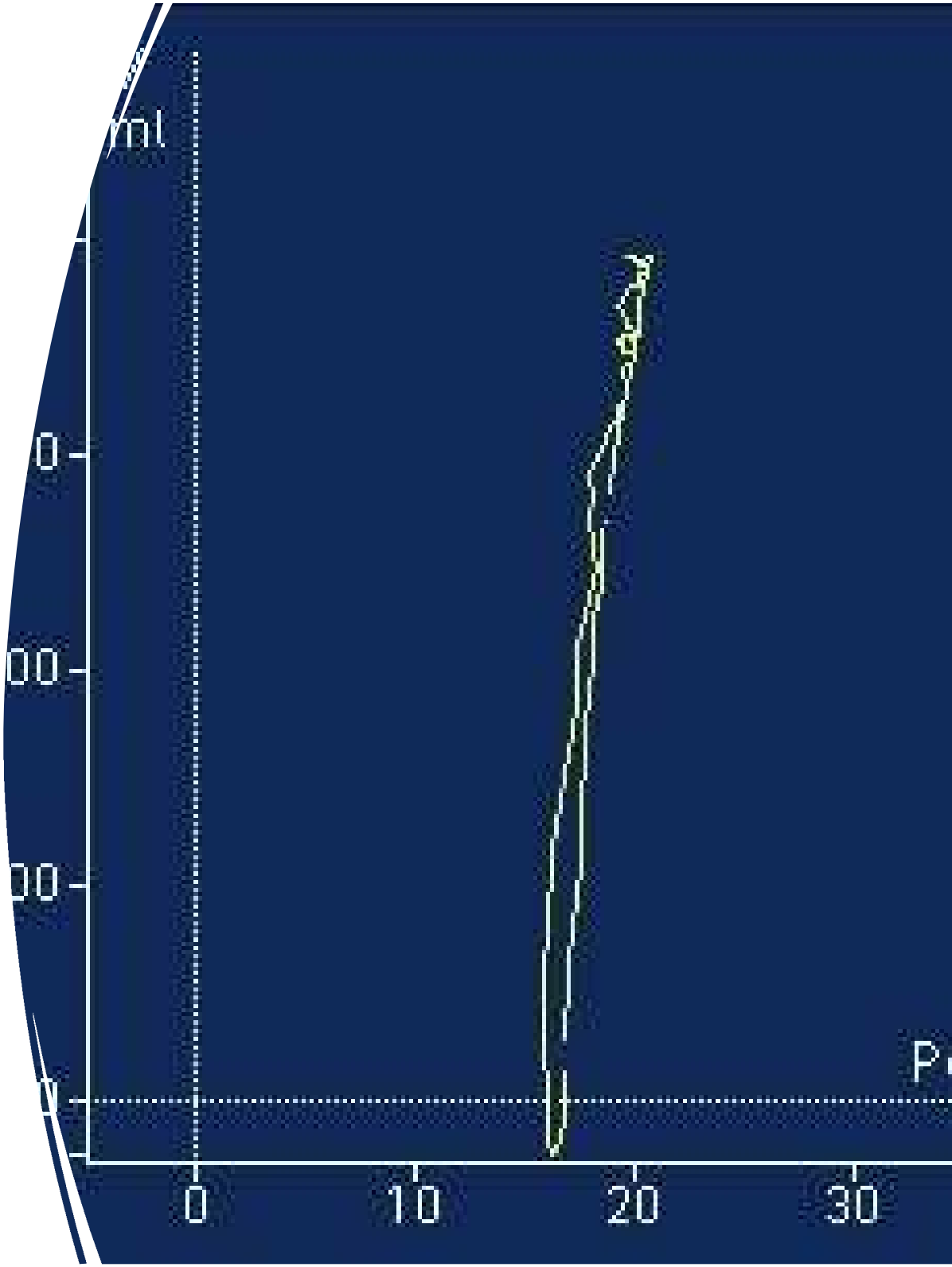
- Some close ups of active loops…

- This patient would **NOT** be considered adequately paralyzed. (Active)

Interpretation

- A patient who is **passively breathing** will have a static loop, with very little variation. A shift up and to the right is normal.

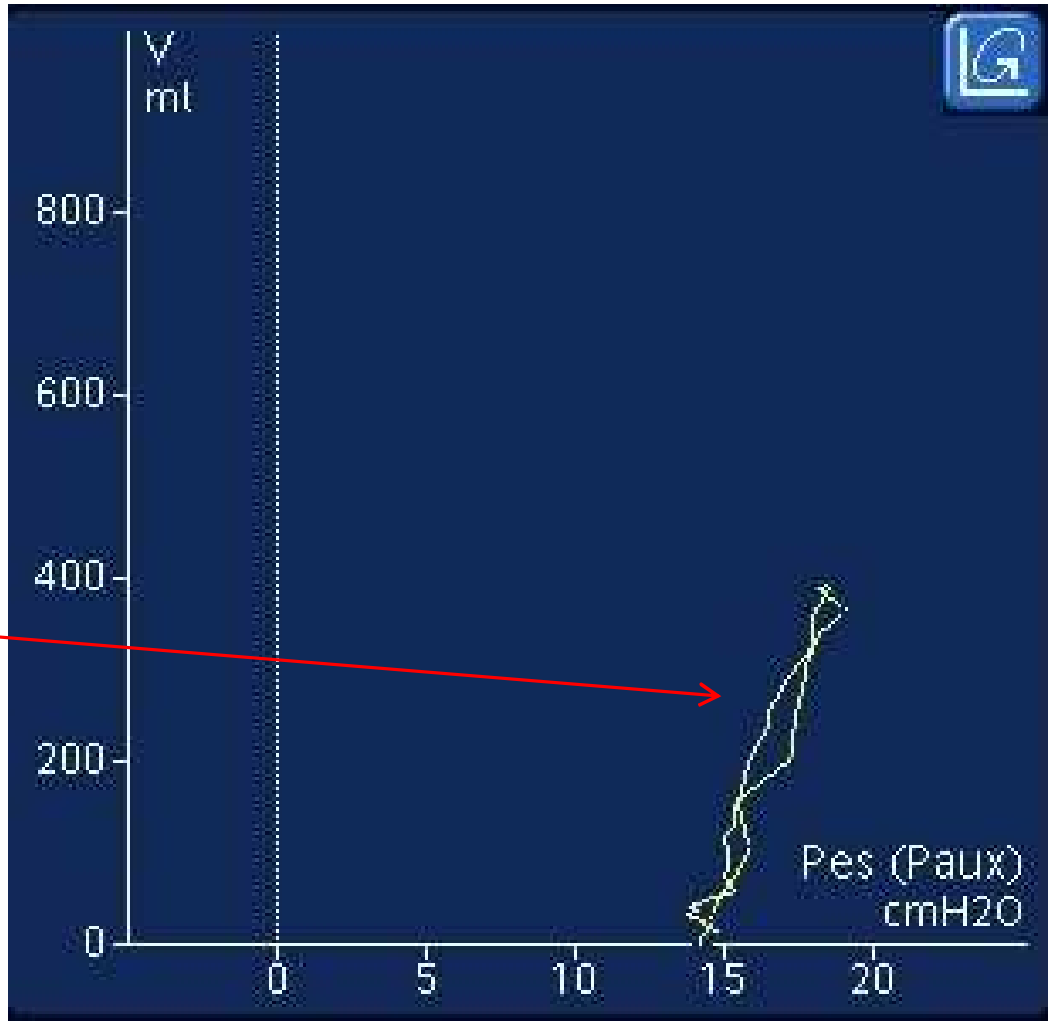
- This patient would be considered adequately paralyzed. (Passive)



Interpretation

A patient who is passively breathing will have a static loop, with very little variation.

This patient would be considered adequately paralyzed. (Passive)



Take Away-

Chest wall compliance is a major factor in pressure seen across the lung.

Higher Pplat is not always dangerous

Keep Ptp_{insp} < 20 cmH20

Indicative of safe tidal volumes

Keep Ptp_{exp} at or near zero

At higher PEEP levels, a Ptp_{exp} of zero is safe and not over extended

Balloon should rest just behind the mediastinum.