

# Turning Data Into Decisions: Case-Based Use of Electrical Impedance Tomography in Pediatric Critical Care

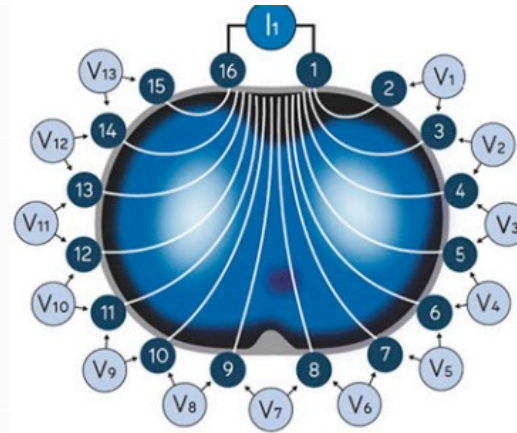
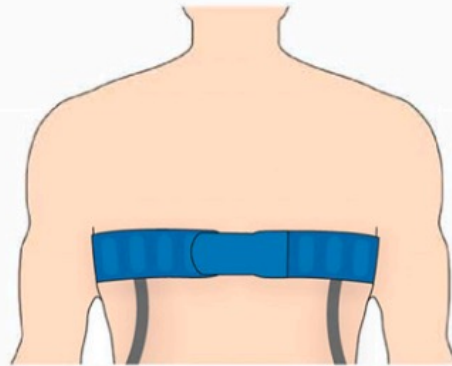
Hayden Leeds, MD

Children's Hospital Los Angeles,  
Pediatric Critical Care Medicine Fellowship Program,  
Department of Anesthesiology, Critical Care Medicine

- Equipment and supplies provided by Timpel Medical for ongoing research

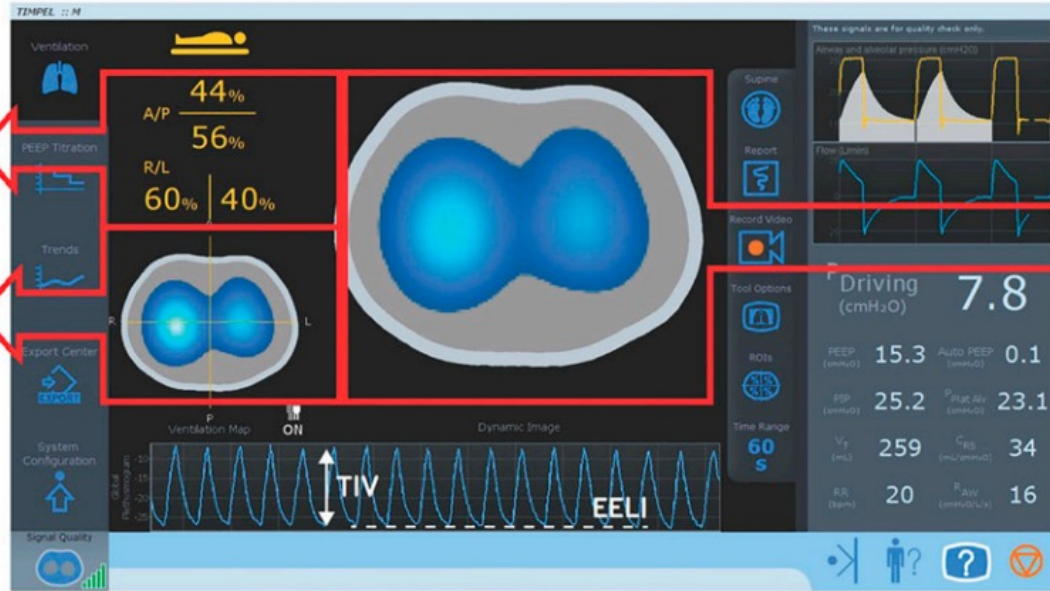
1. Review EIT's role in real-time, non-invasive lung monitoring
2. Examine a case of ventilator-induced lung injury, focusing on EIT's role in detecting ventilation/perfusion inhomogeneity
3. Understand recruitability in ARDS
4. Evaluate EIT's role in a PEEP titration trial in PARDS
5. Explore future EIT applications

# Electrical Impedance Tomography (EIT)



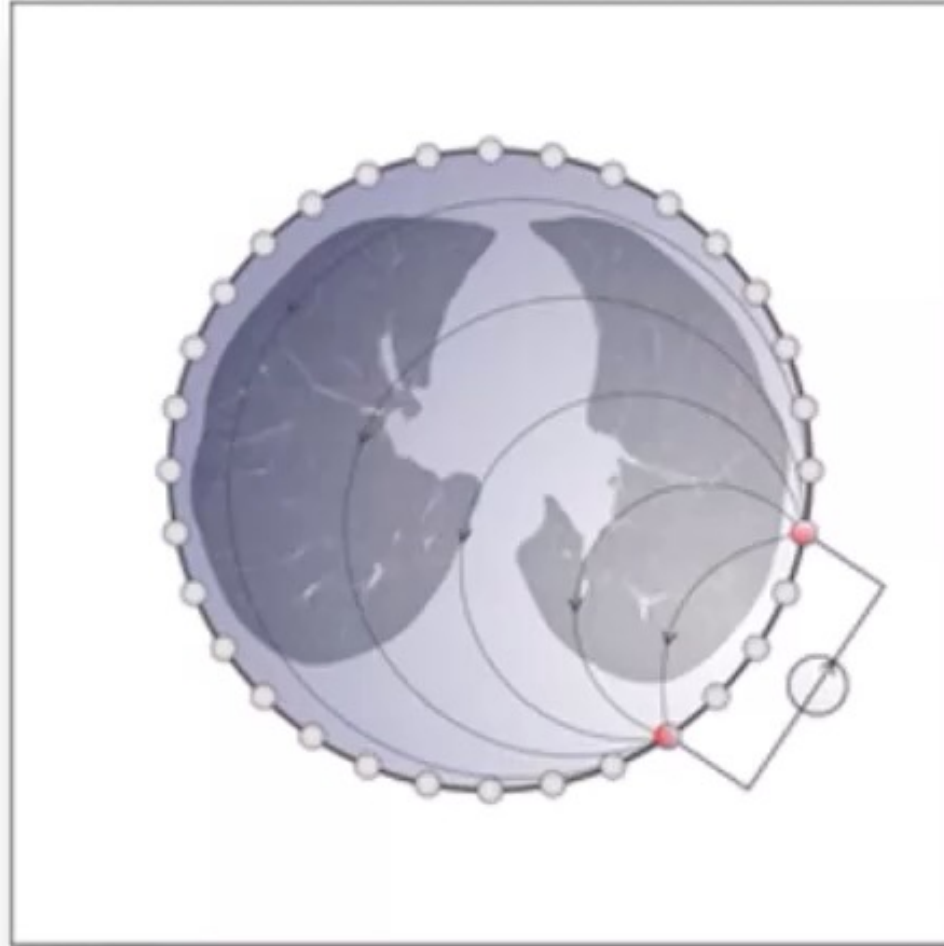
Distribution of ventilation depending on prespecified ROI

Tidal image: distribution of tidal volume over the last breath, with selected region of interest

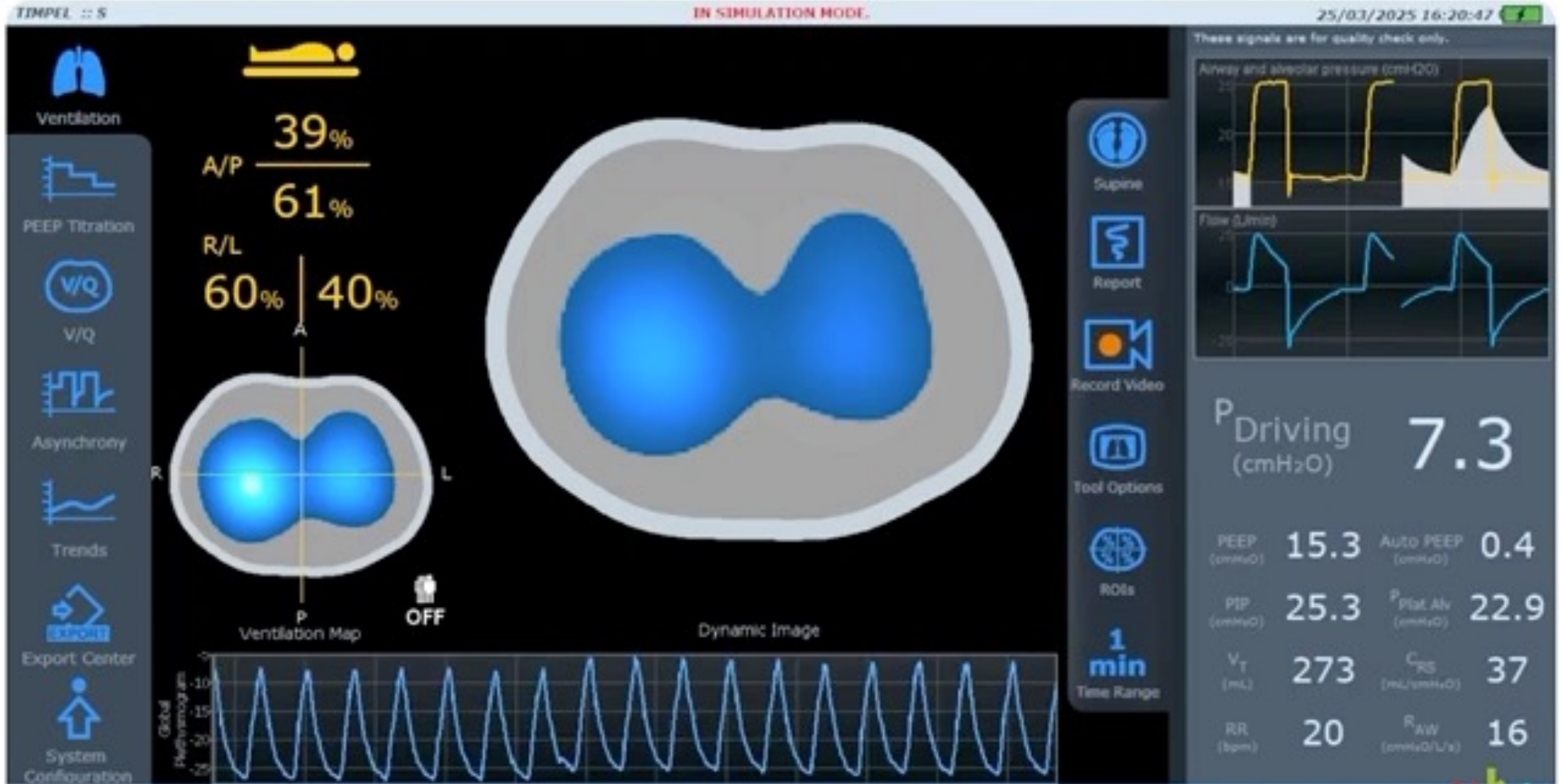


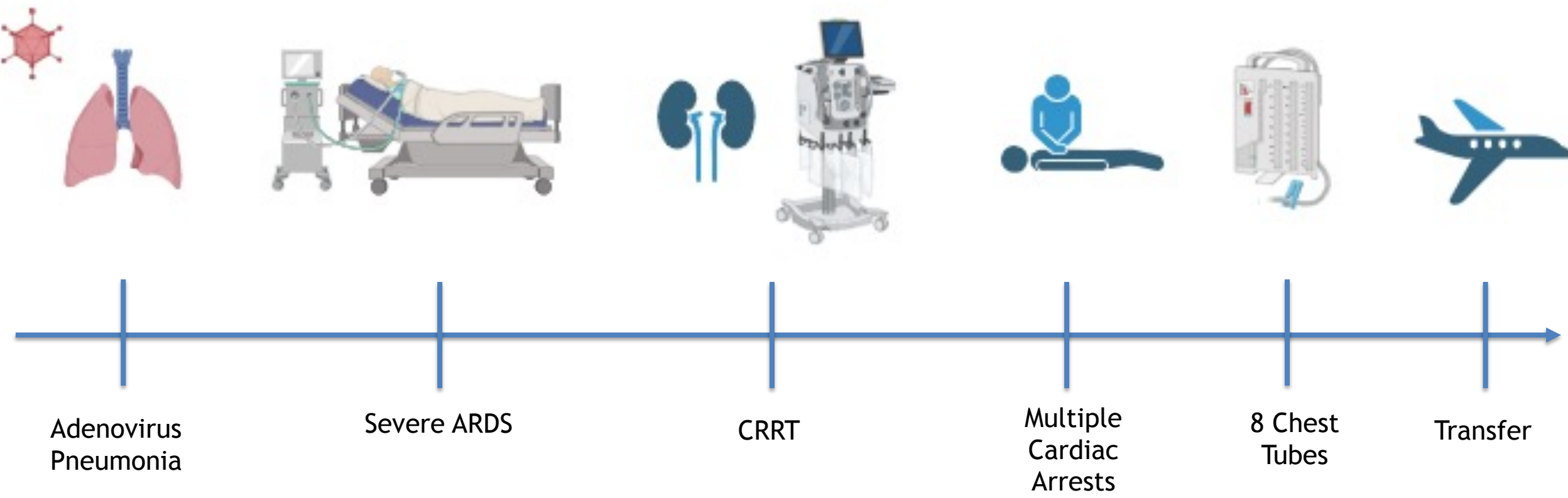
Dynamic image: real time distribution of tidal volume over time

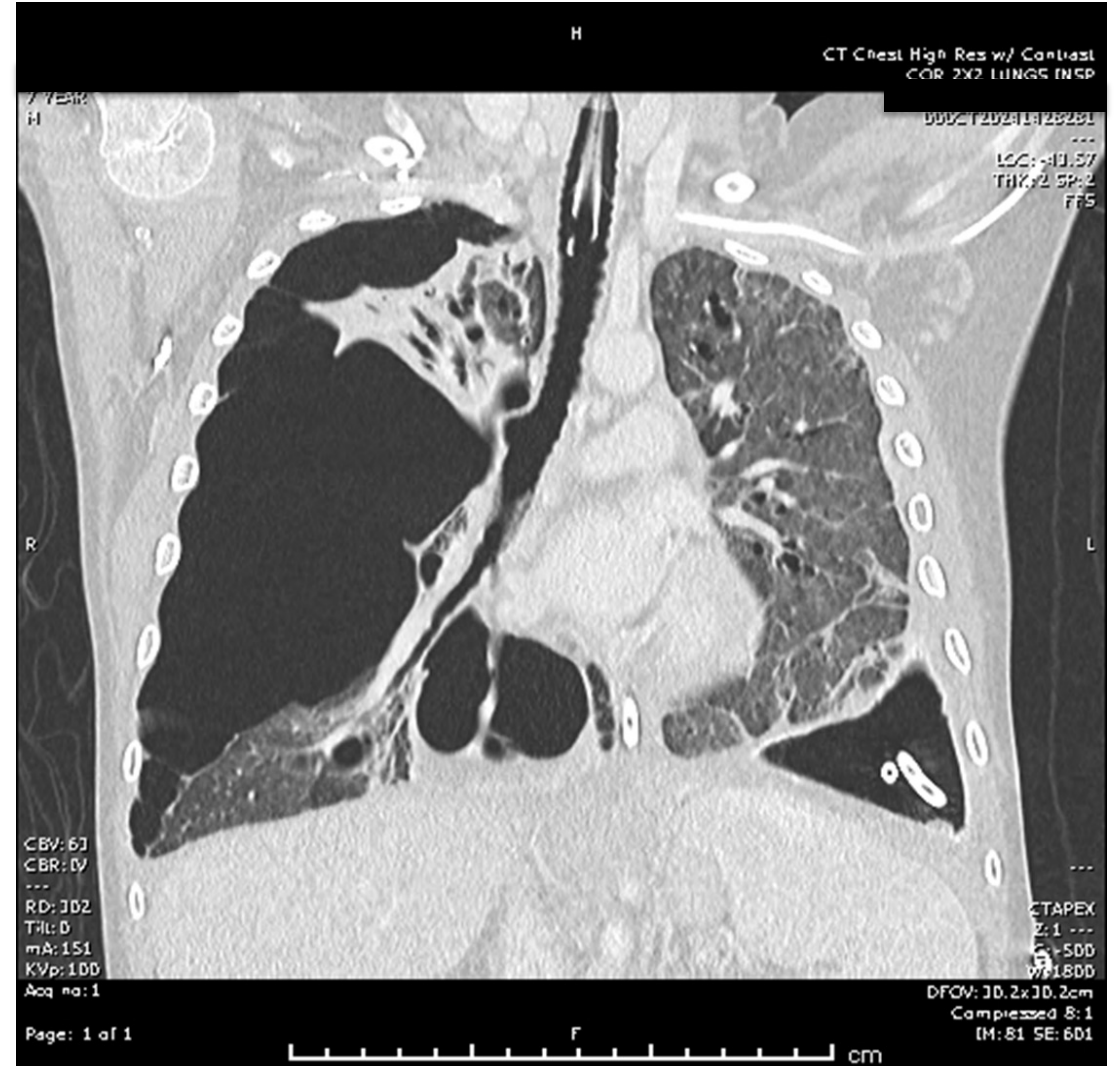
# Electrical Impedance Tomography (EIT)

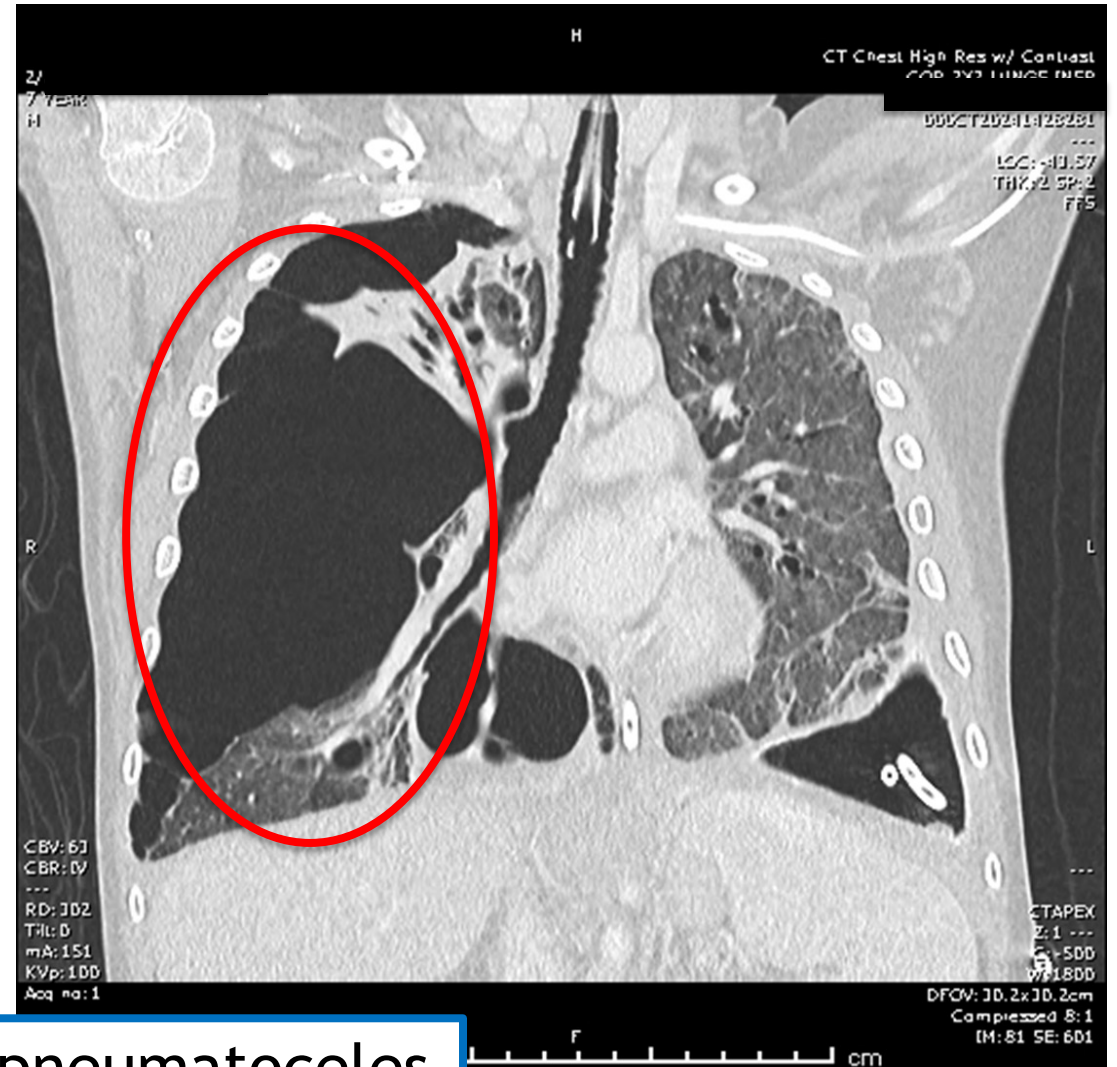
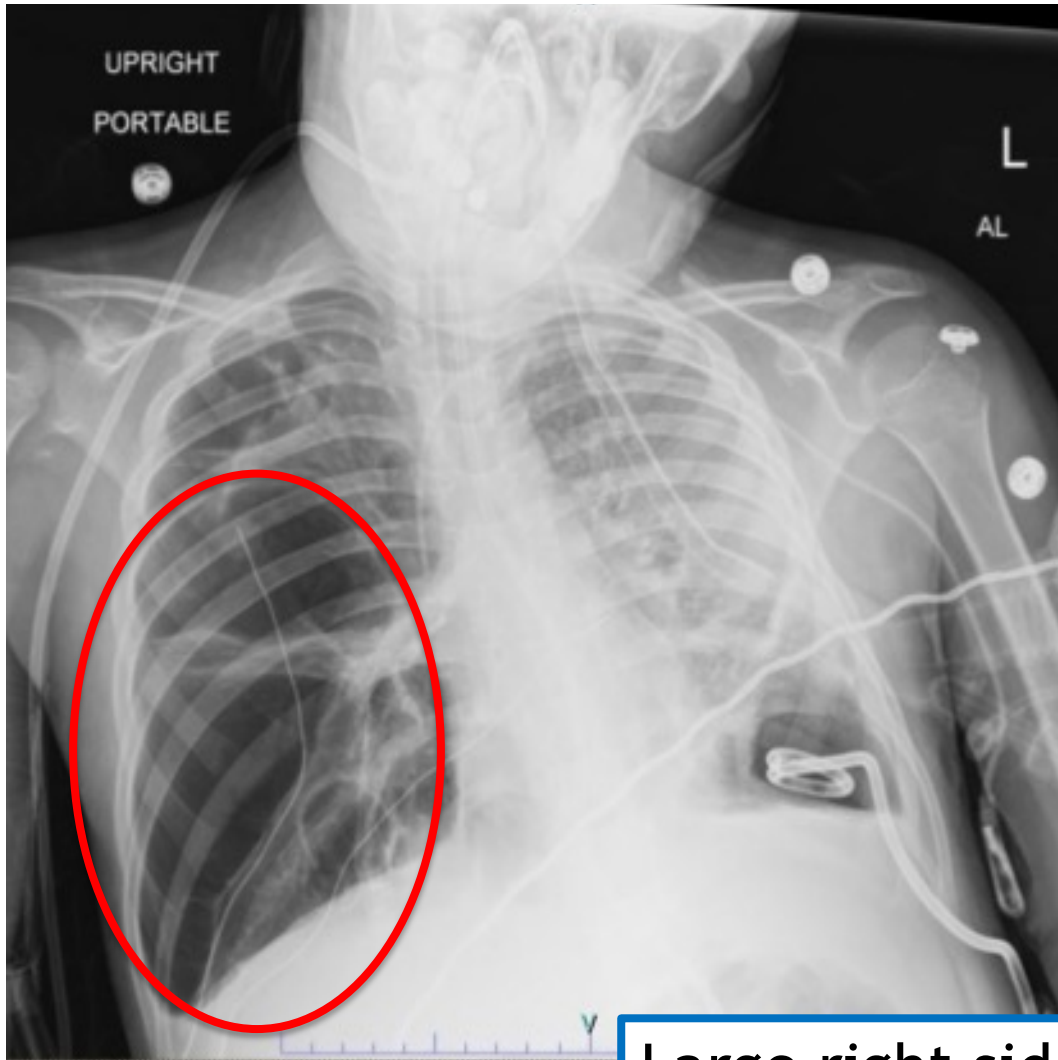


# Electrical Impedance Tomography (EIT)

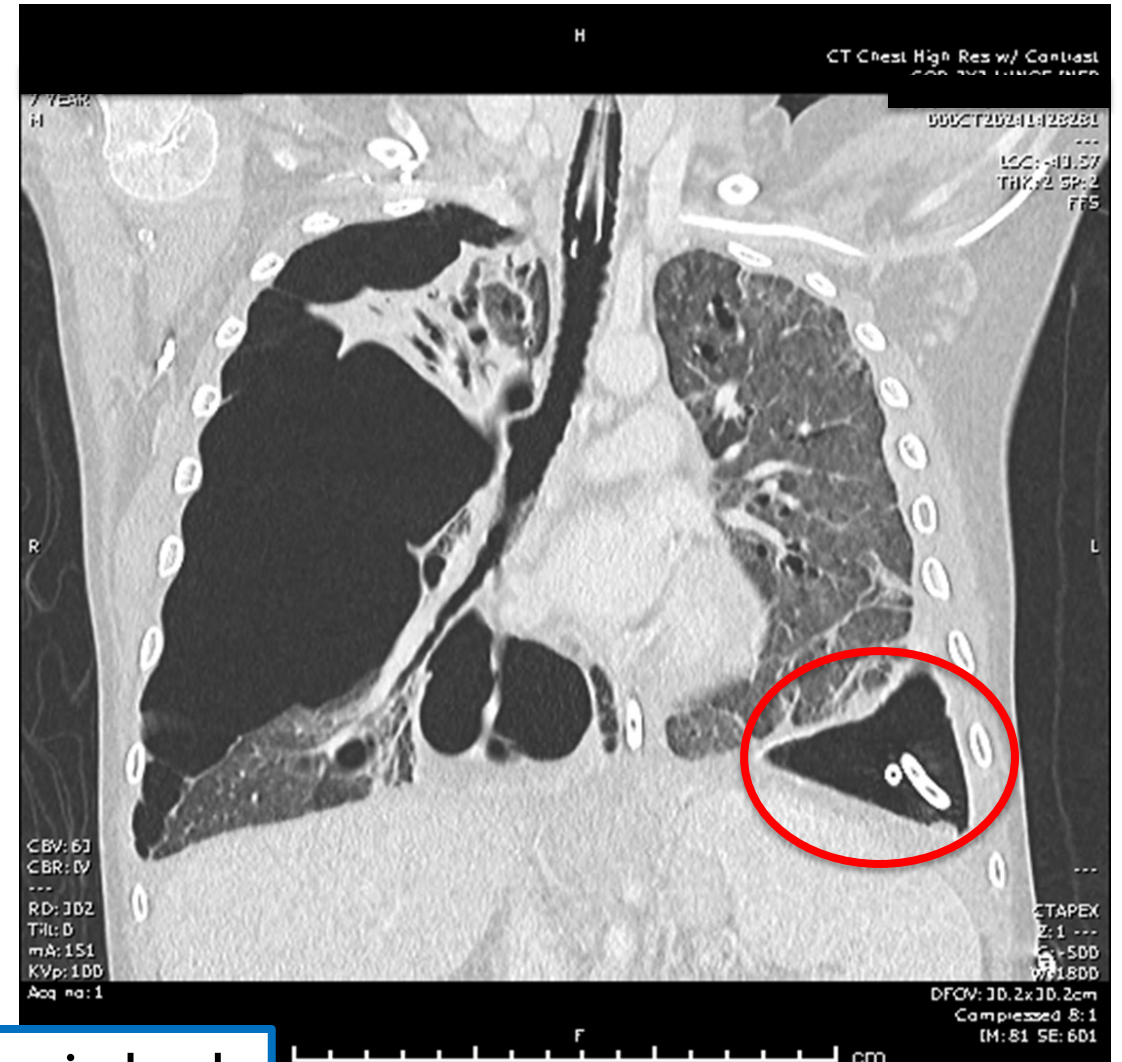
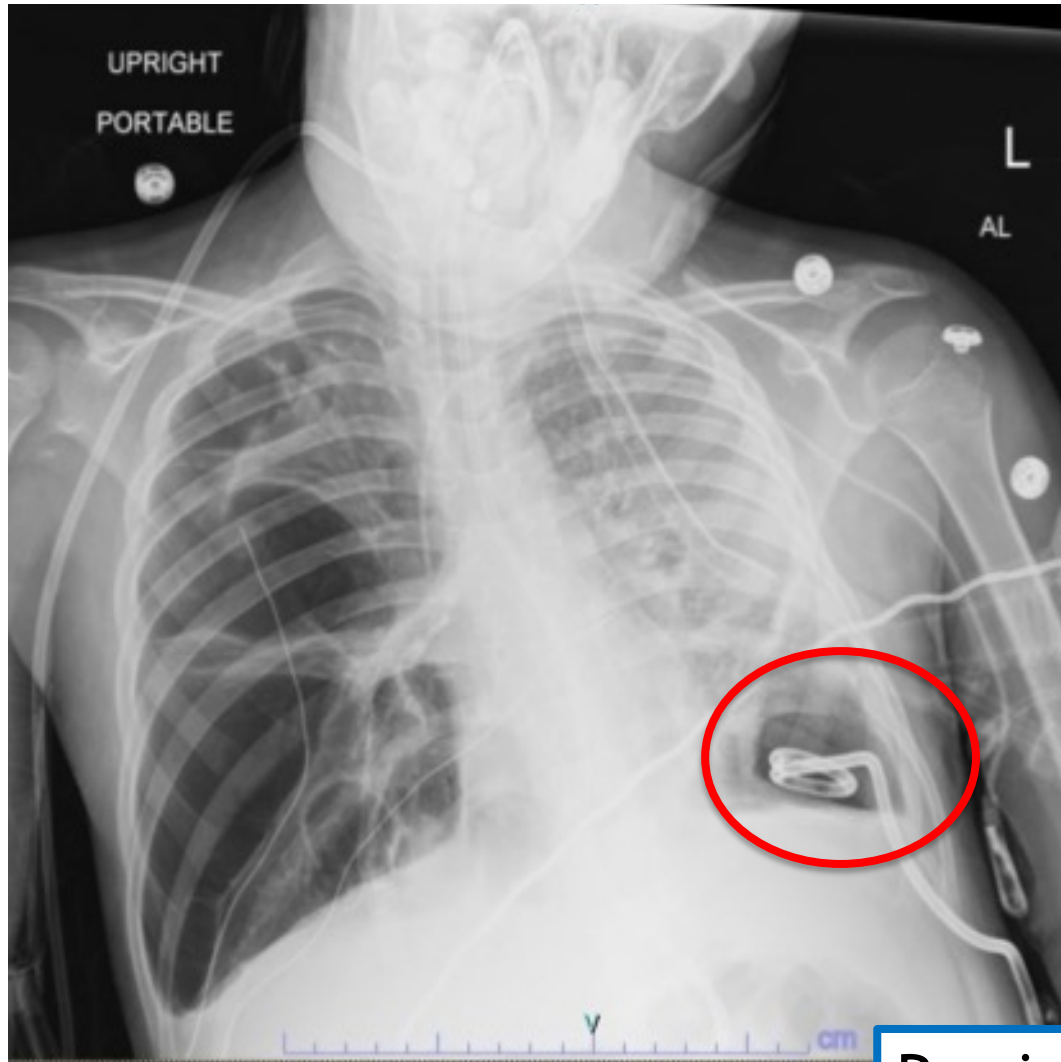






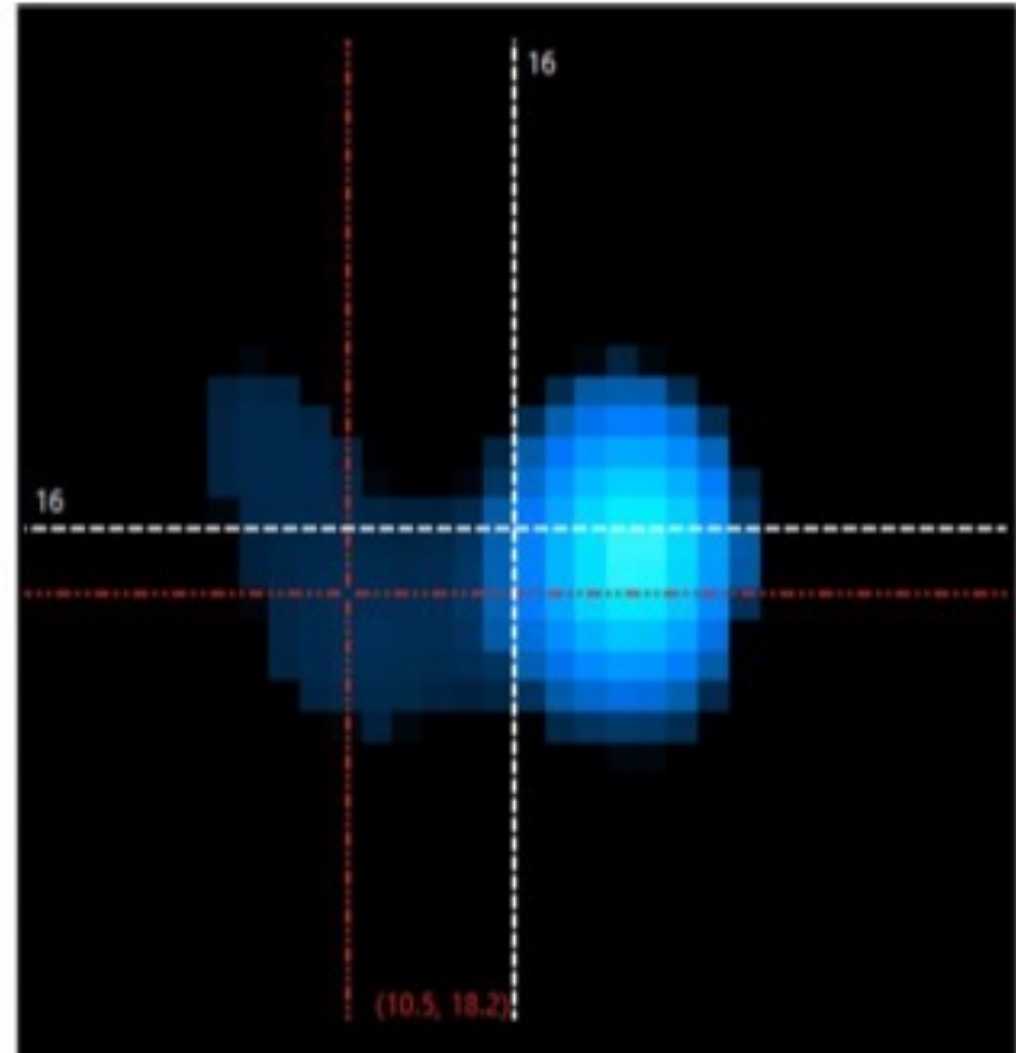


Large right sided pneumatoceles

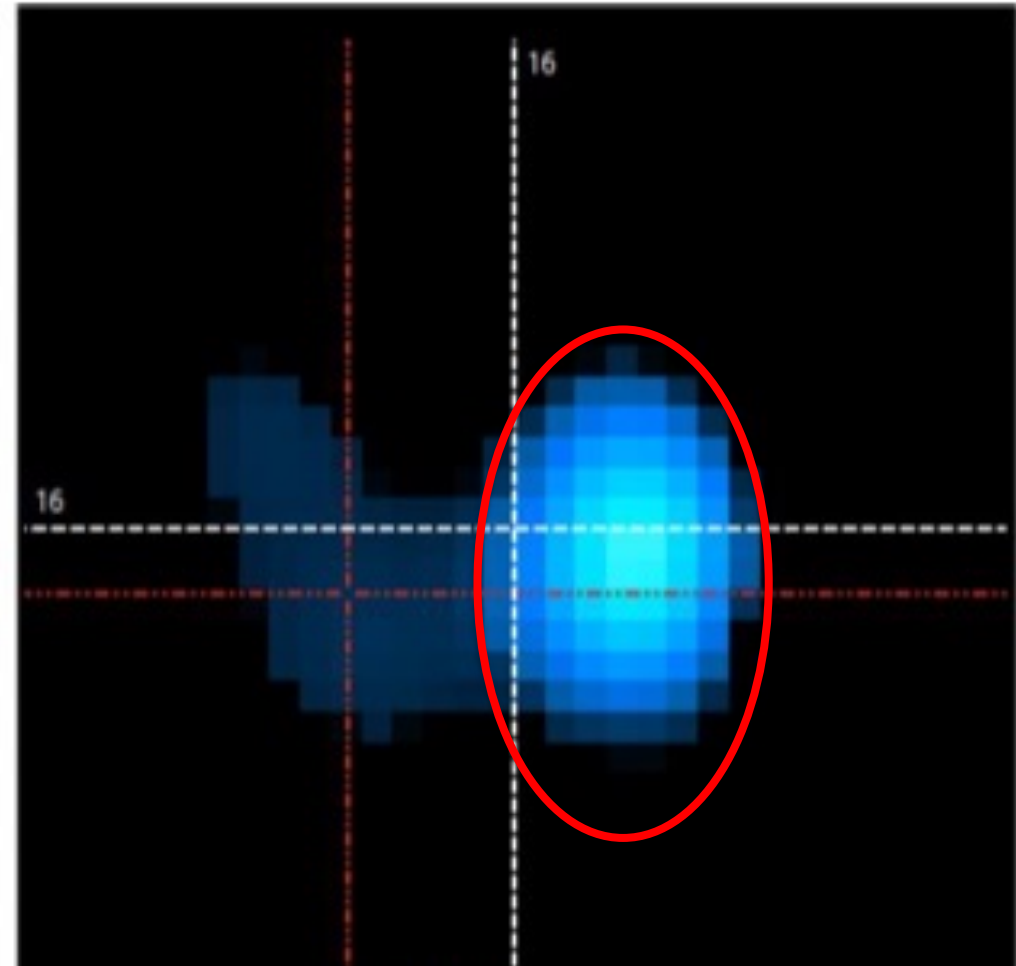


Persistent air leak

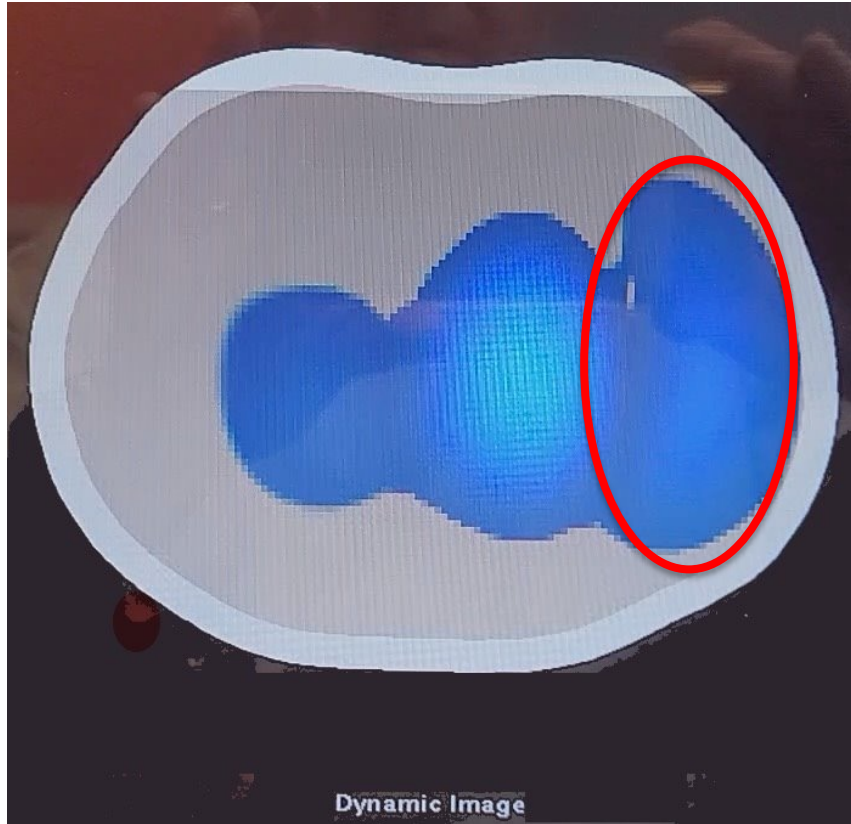
- PC-SIMV
- PIP 24 cmH<sub>2</sub>O
- PEEP 8 cmH<sub>2</sub>O
- RR 24 BPM
- $V_t \sim 10$  mL/kg
- $FiO_2$  0.4
- P 0.1 5-7 cmH<sub>2</sub>O

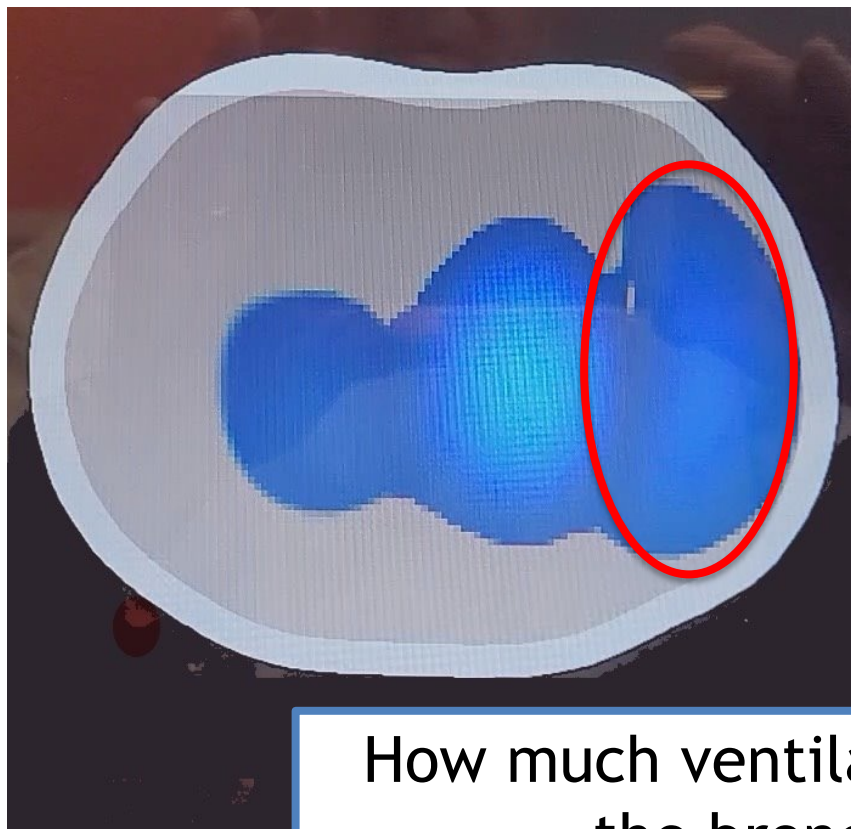


- PC-SIMV
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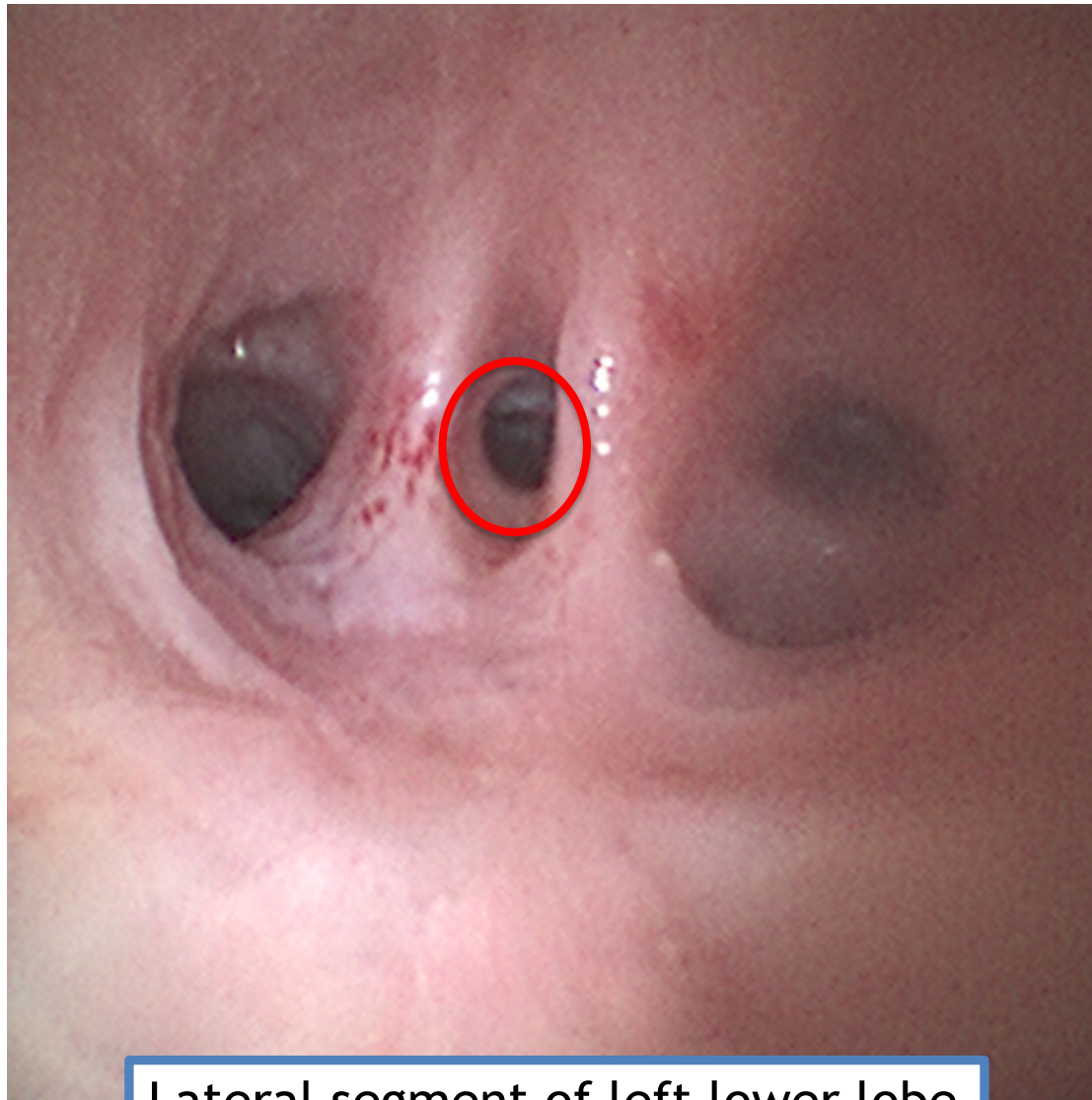


70% of the ventilation going to the left lung



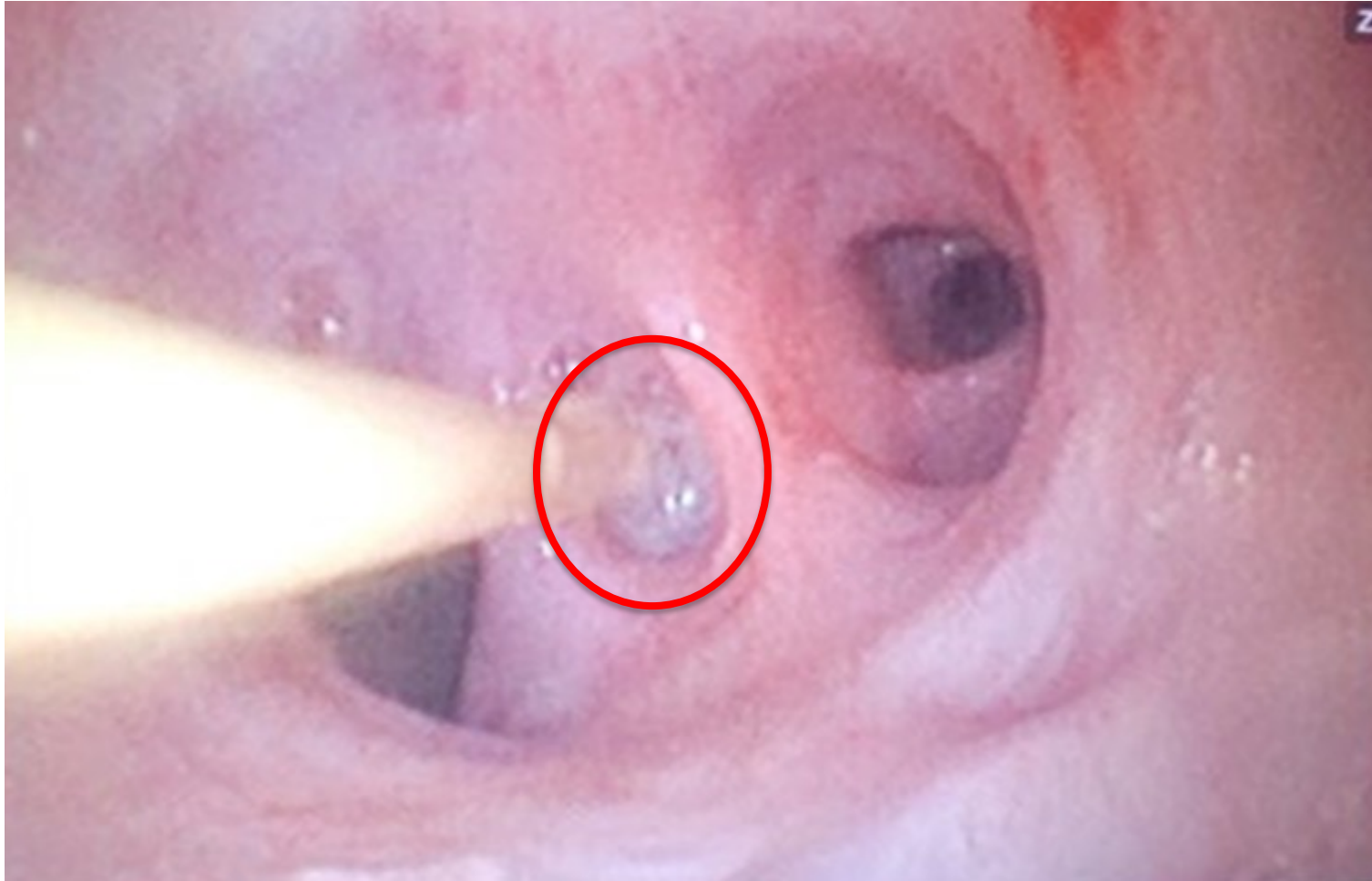


How much ventilation is being lost through the bronchopleural fistula?



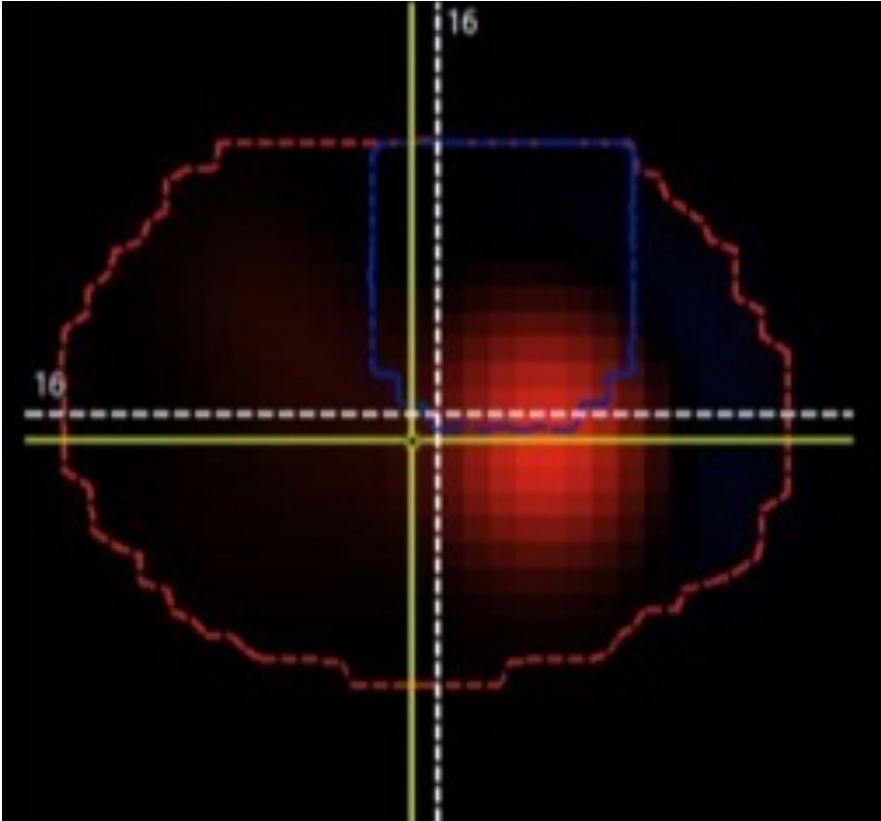
Lateral segment of left lower lobe

PC SIMV  
PIP 30 cmH<sub>2</sub>O  
PEEP 10 cmH<sub>2</sub>O  
V<sub>t</sub> ~8ml/kg  
RR 22 bpm  
FiO<sub>2</sub> 0.35  
SpO<sub>2</sub> 98%

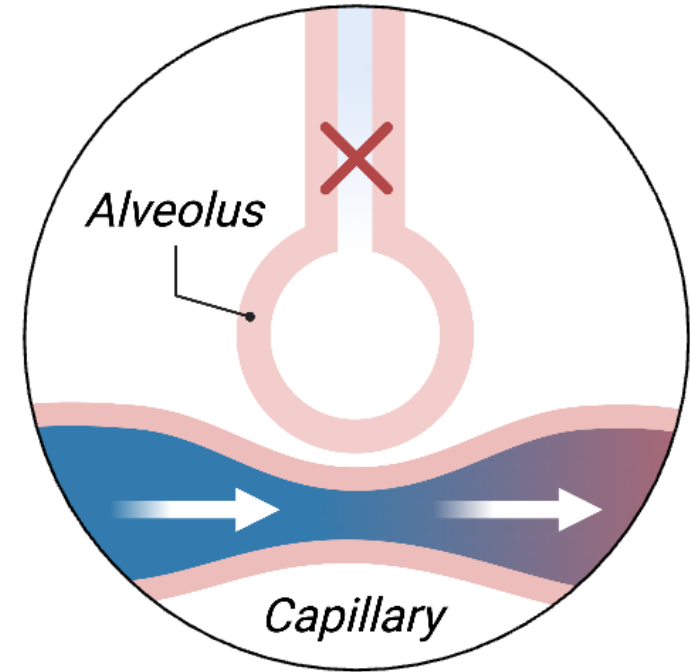


PC SIMV  
PIP 38 cmH<sub>2</sub>O  
PEEP 10 cmH<sub>2</sub>O  
RR 28 bpm  
FiO<sub>2</sub> 1.0  
SpO<sub>2</sub> 84%

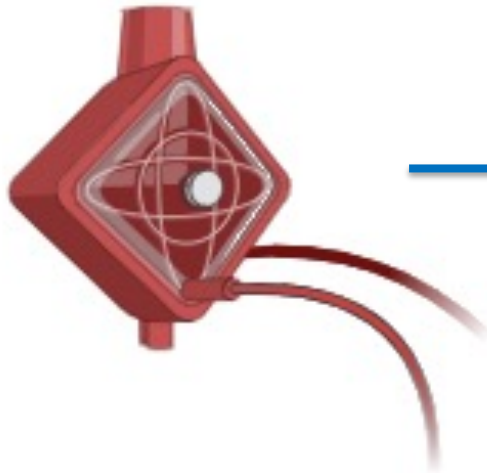
Arndt endotracheal blocker



Limited right lung perfusion



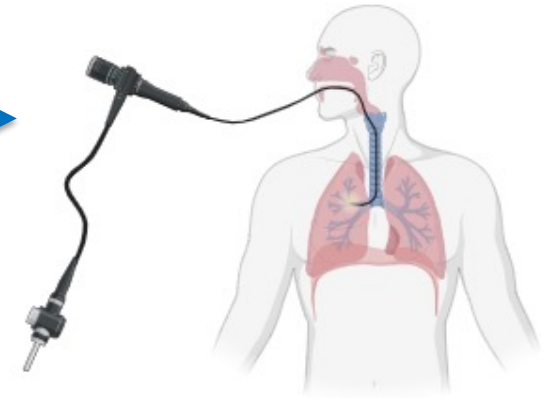
Pulmonary shunt



V-V ECMO

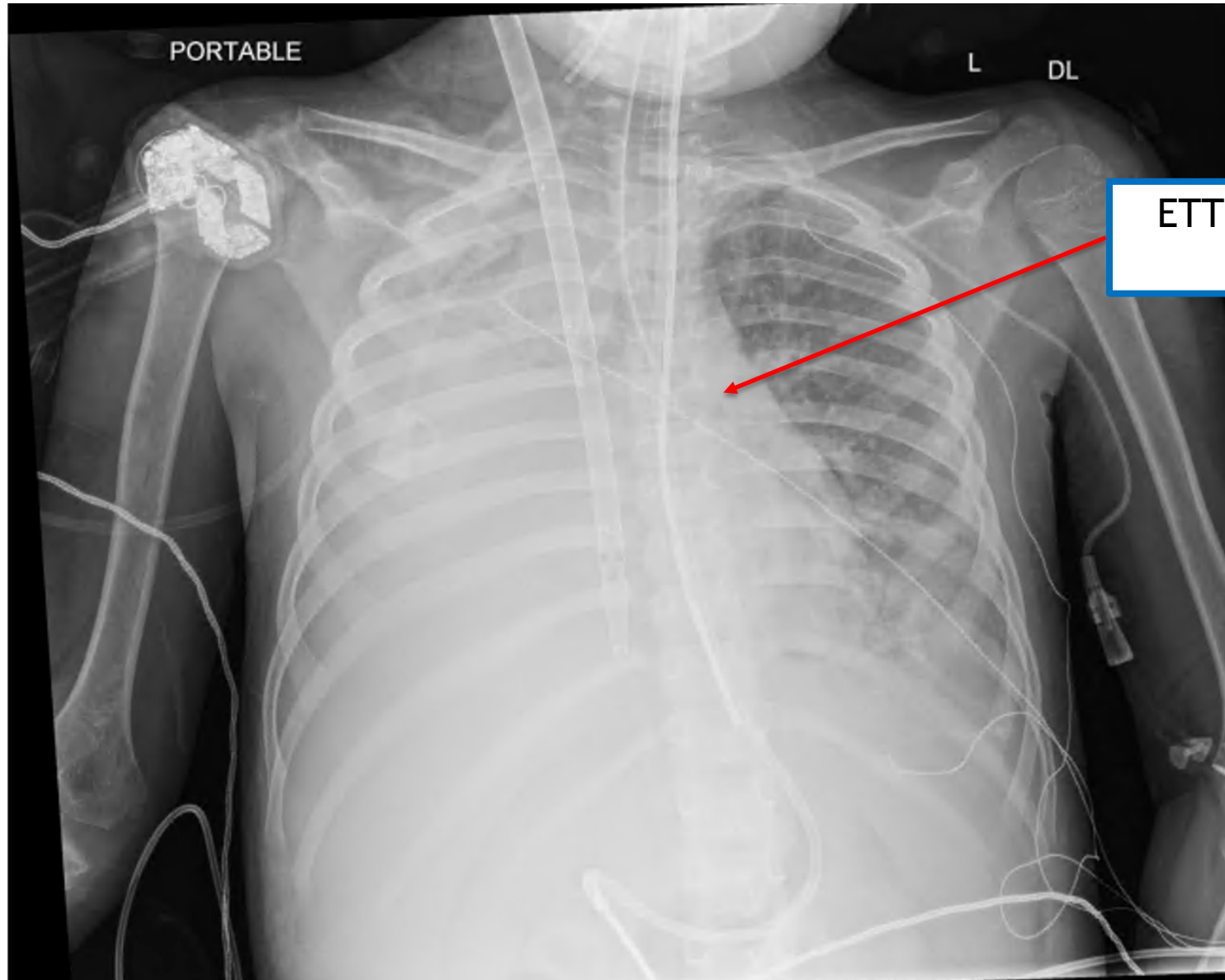


Resolution of  
Air Leak

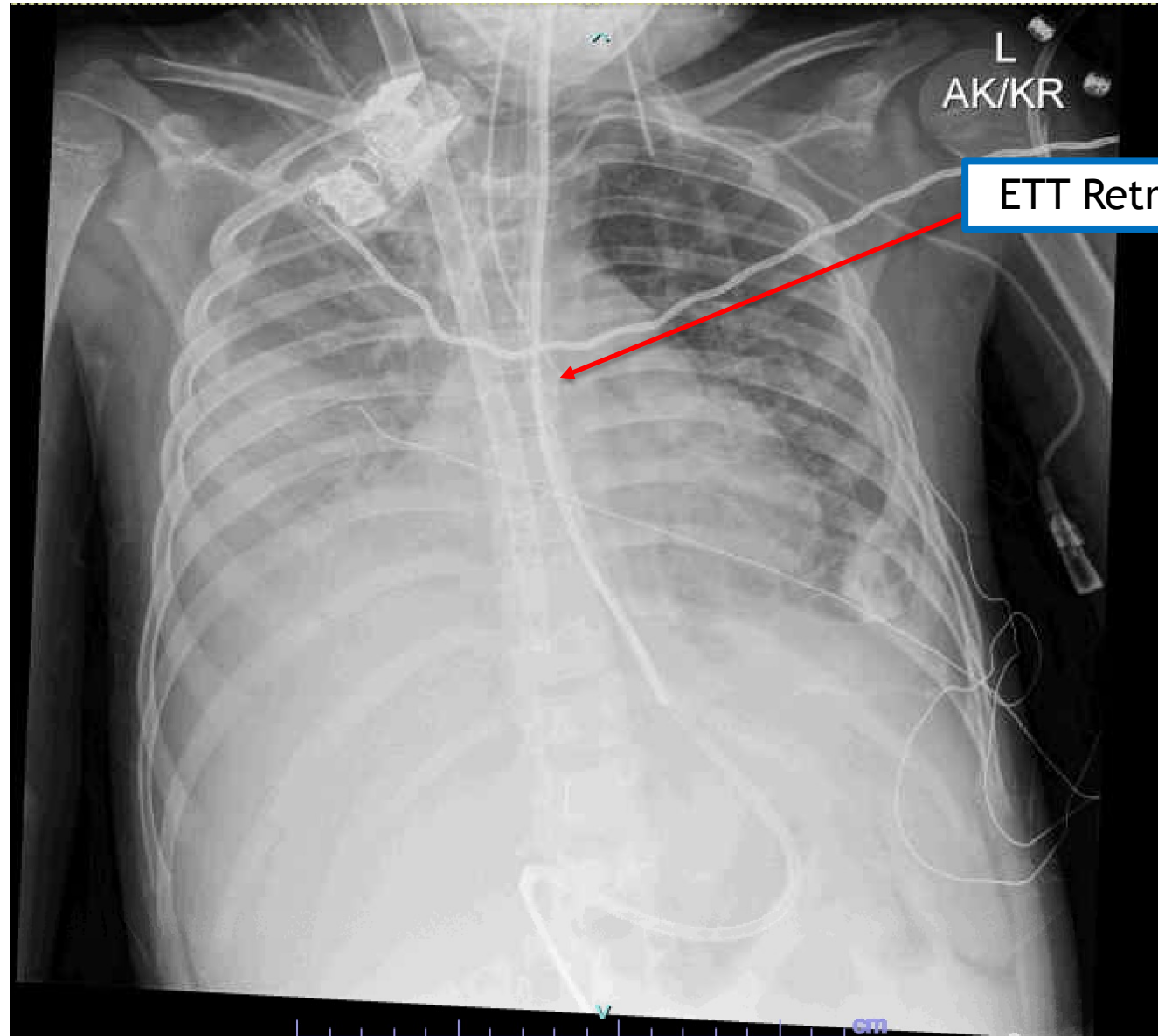


Left Mainstem  
Intubation

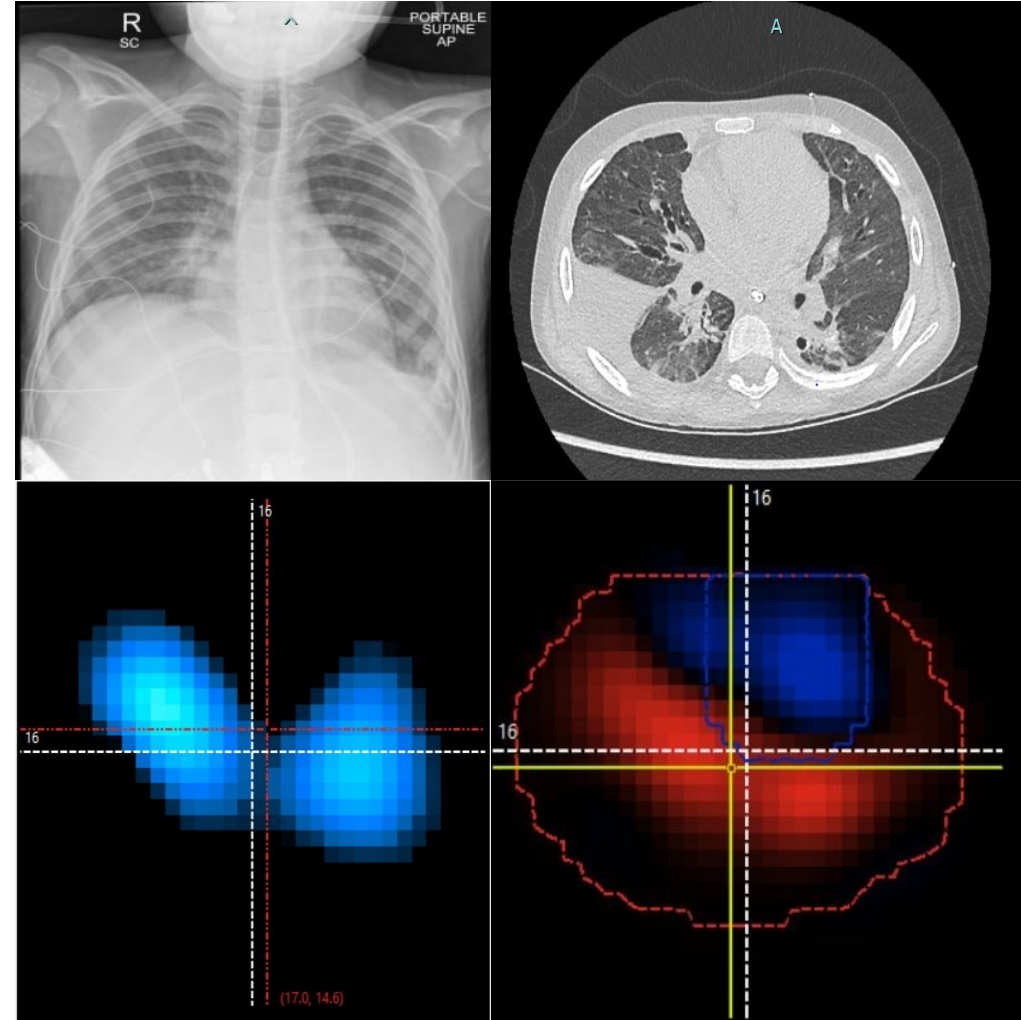




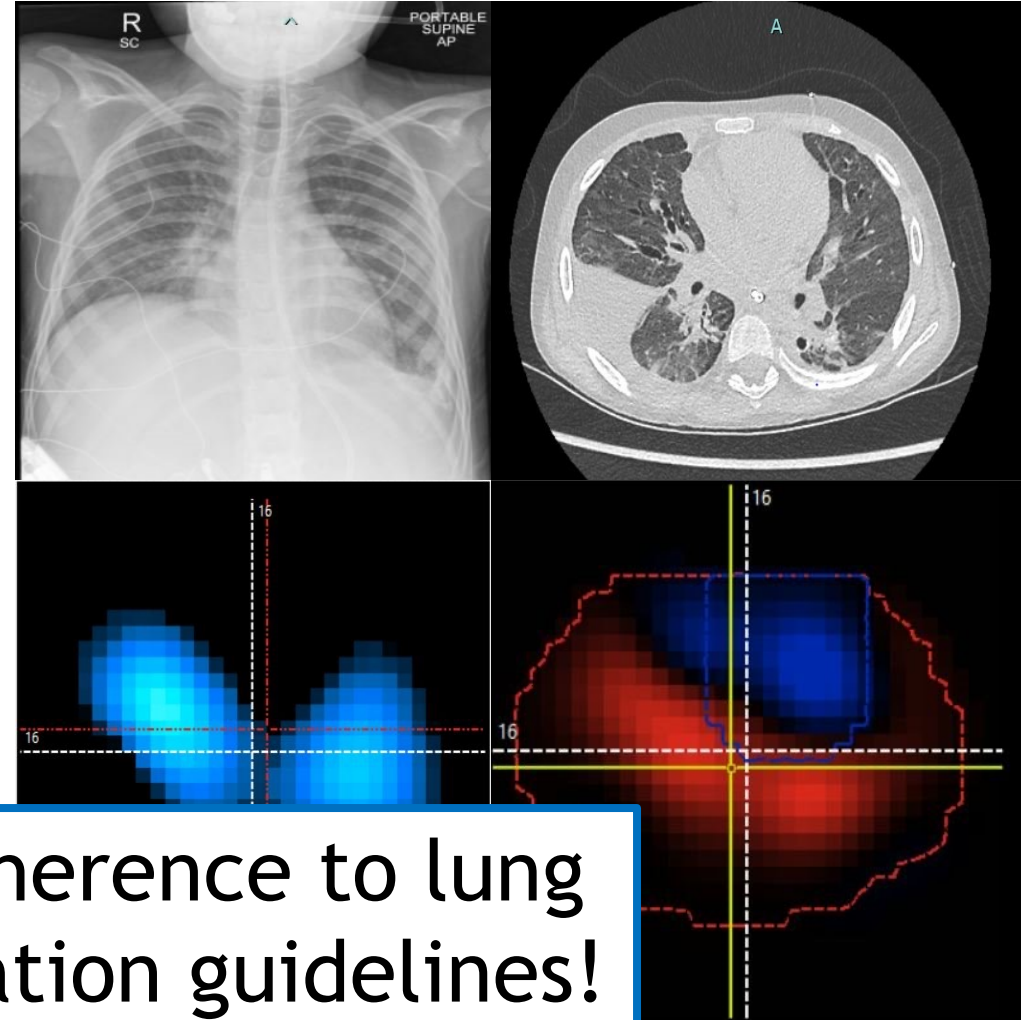
ETT in left mainstem  
bronchus



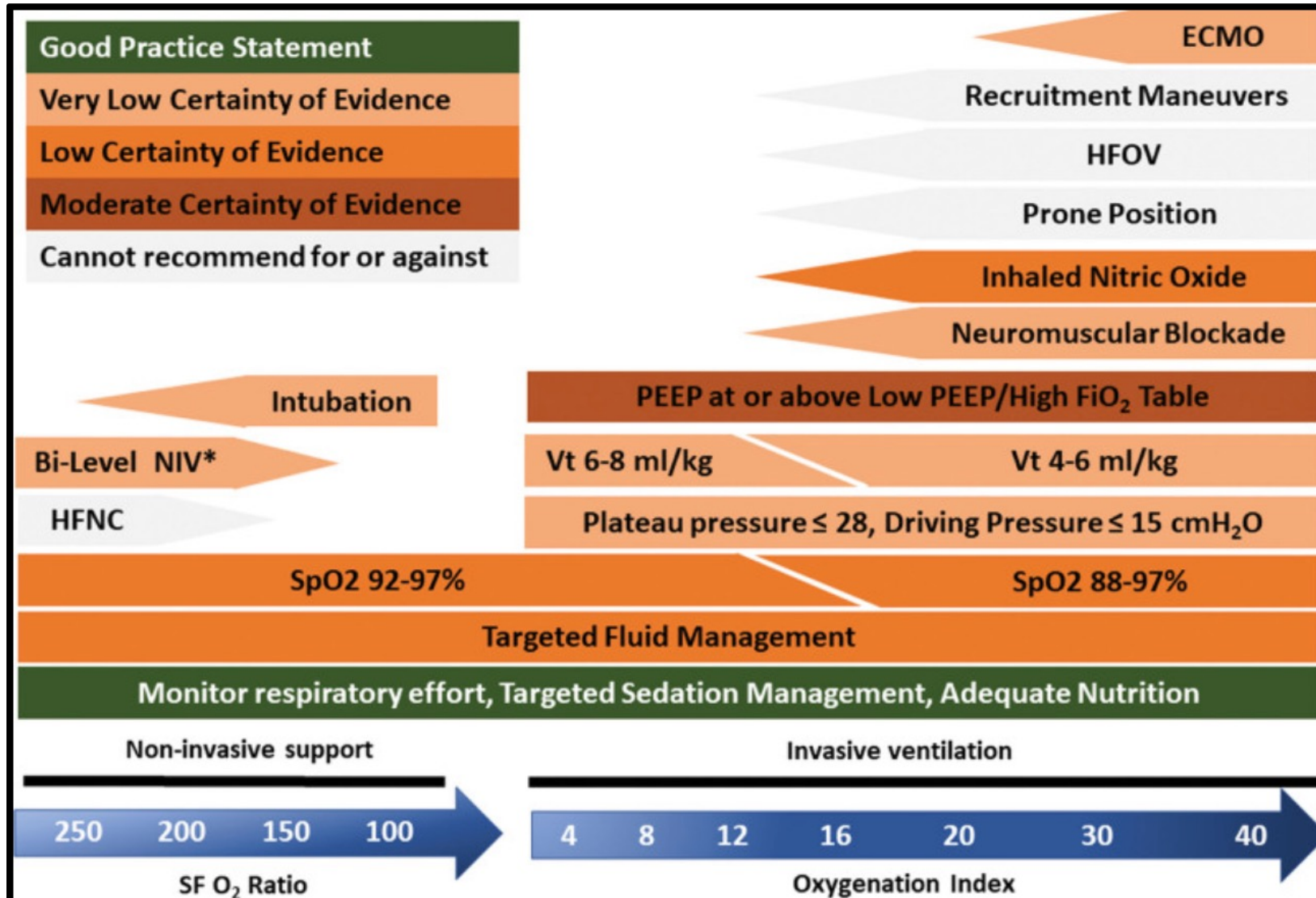
1. Re-recruitment of lung parenchyma
2. Decannulated from ECMO
3. Extubated
4. Discharged on room air

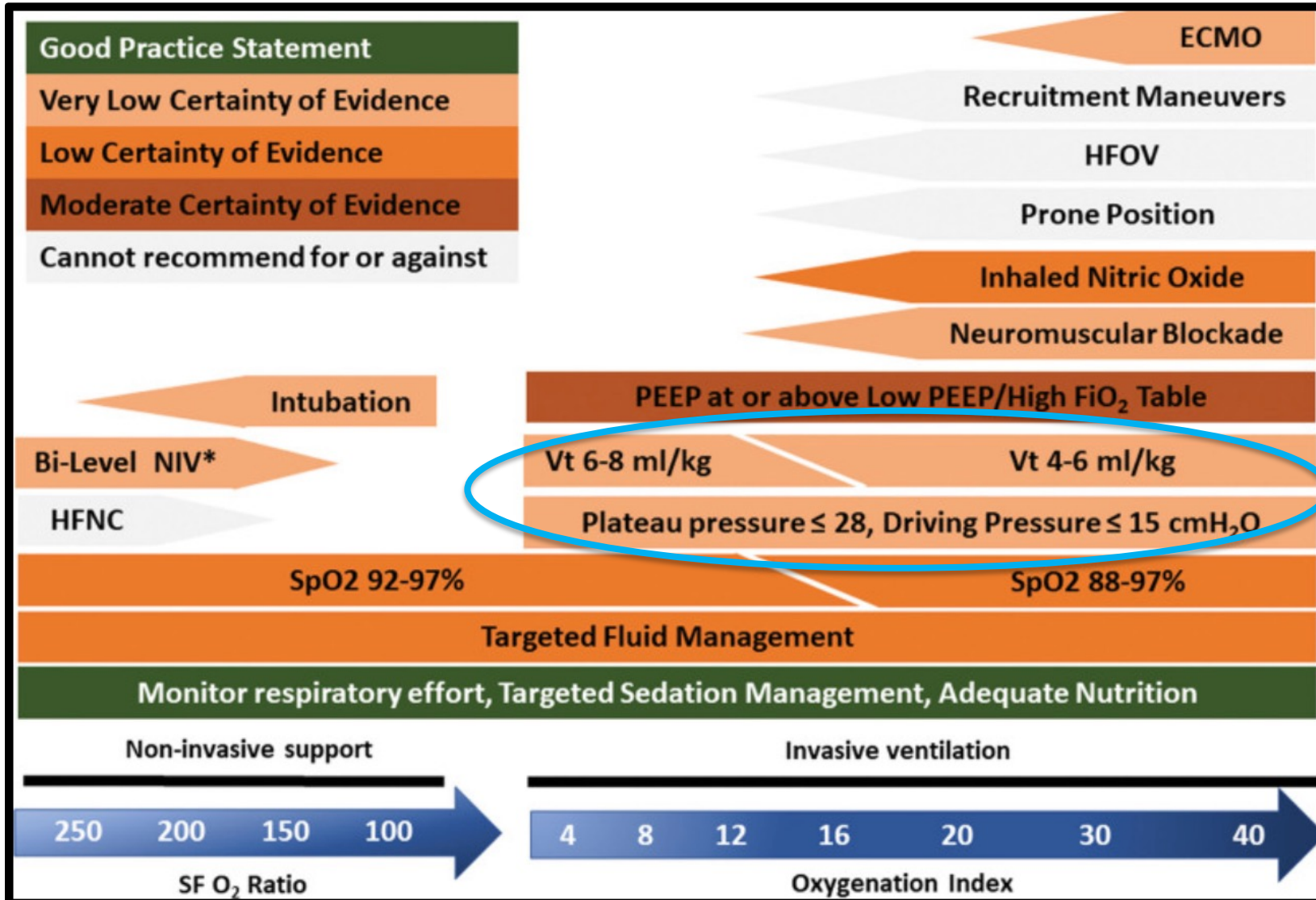


1. Re-recruitment of lung parenchyma
2. Decannulated from ECMO
3. Extubated
4. Discharged on room air



Importance of adherence to lung protective ventilation guidelines!

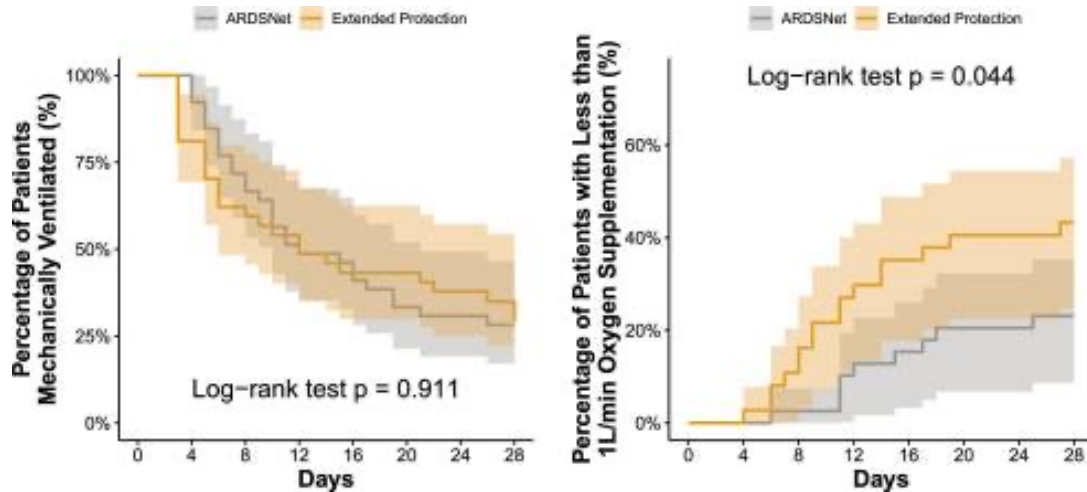
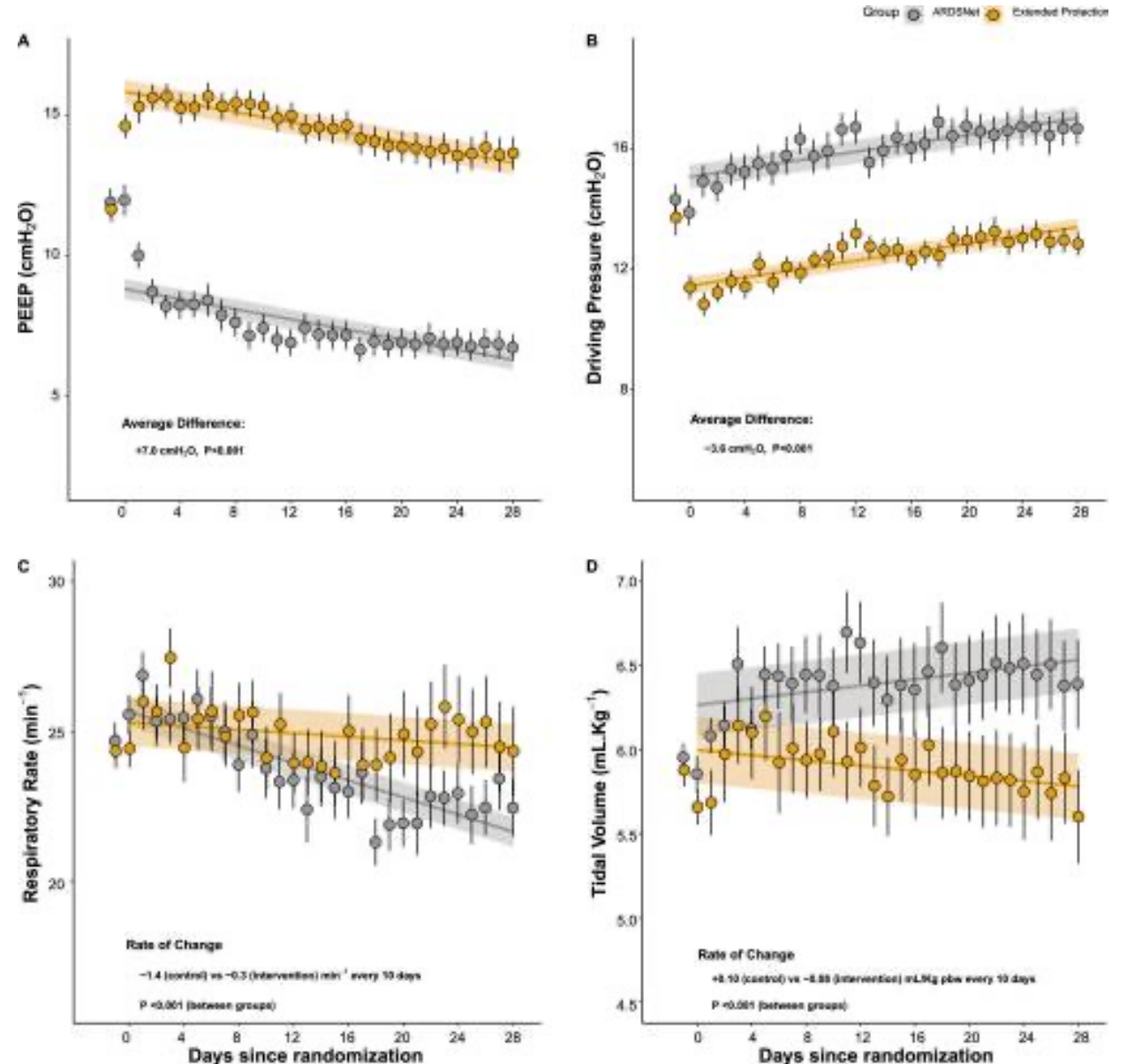




> Ann Intensive Care. 2024 Jun 8;14(1):85. doi: 10.1186/s13613-024-01297-z.

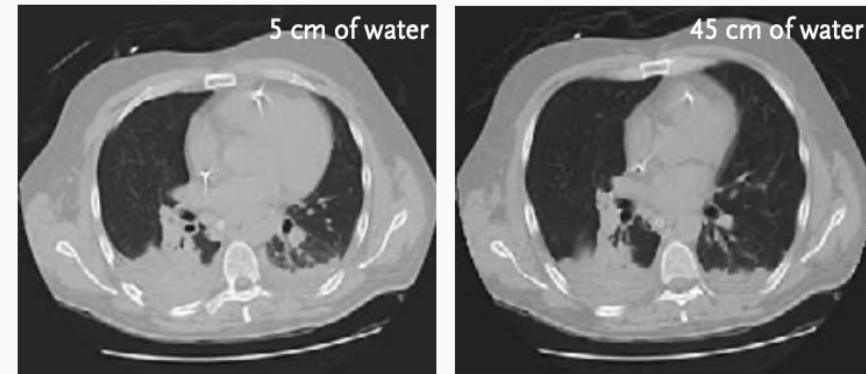
## Impact of extended lung protection during mechanical ventilation on lung recovery in patients with COVID-19 ARDS: a phase II randomized controlled trial

Eduardo L V Costa # 1 2 3, Glasielle C Alcalá # 1 3, Mauro R Tucci 3, Ewan Goligher 4 5 6, Caio C Morais 1 7, Jose Dianti 4 5 6, Miyuki A P Nakamura 1, Larissa B Oliveira 3, Sérgio M Pereira 1 4 5, Carlos Toufen Jr 3, Carmen S V Barbas 3 8, Carlos R R Carvalho 1 3, Marcelo B P Amato 9 10

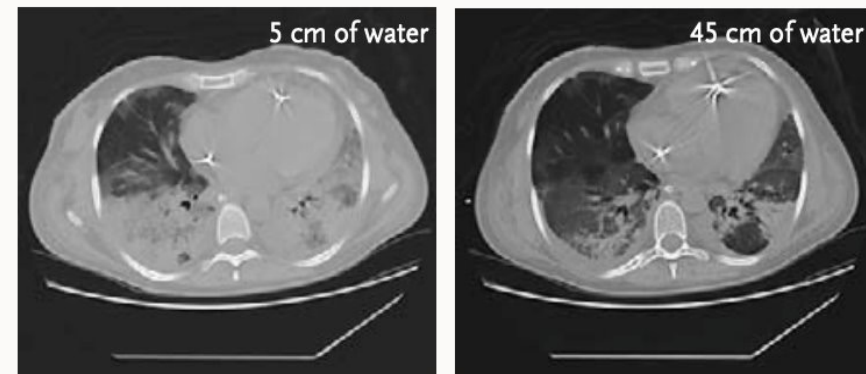


- Utilize PEEP to improve oxygenation and limit driving pressure
- Ideal PEEP
  - Recruit collapsed lung, limit overdistention
- ARDS is heterogeneous
- **Recruitability** (Gattinoni et al.) impacts ARDS morbidity and mortality

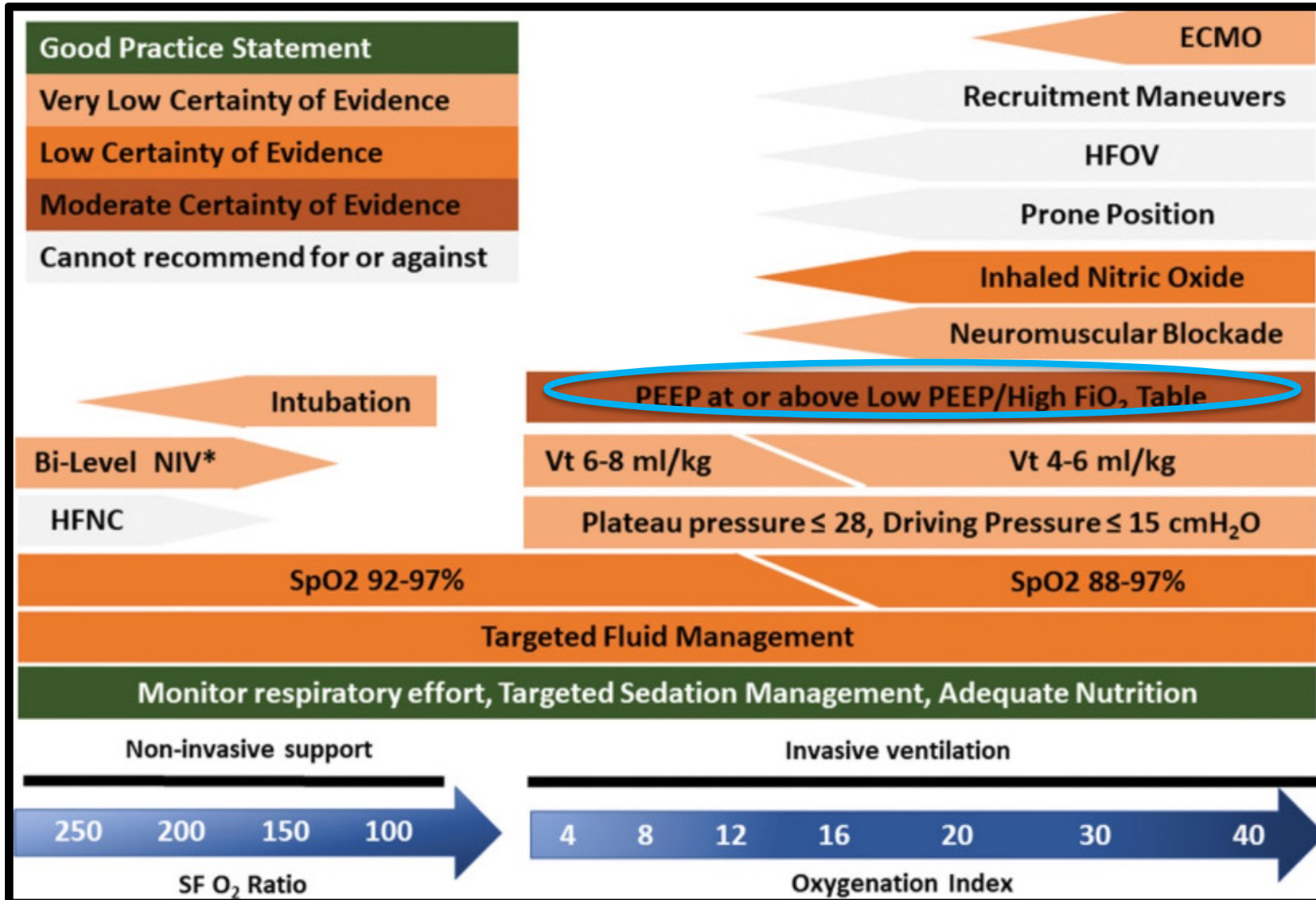
**B Lower Percentage of Potentially Recrutable Lung**



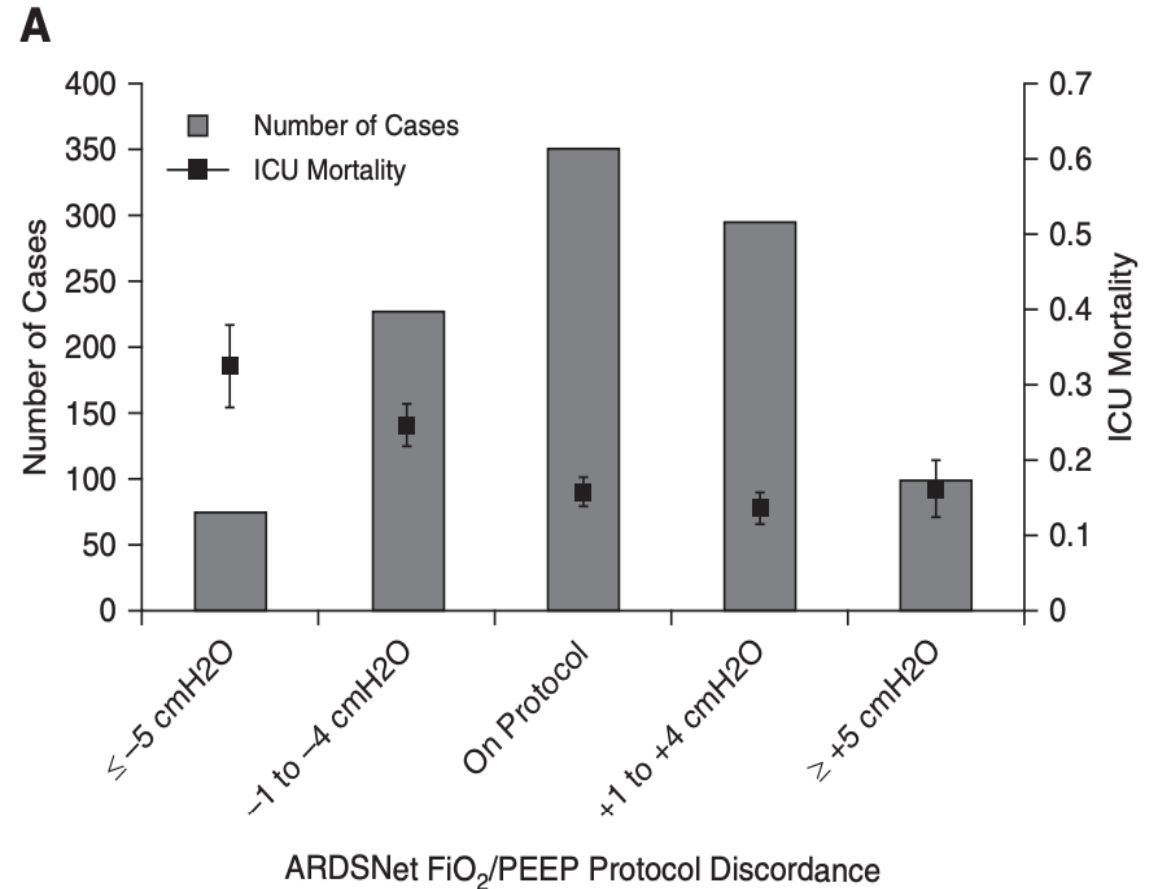
**C Higher Percentage of Potentially Recrutable Lung**



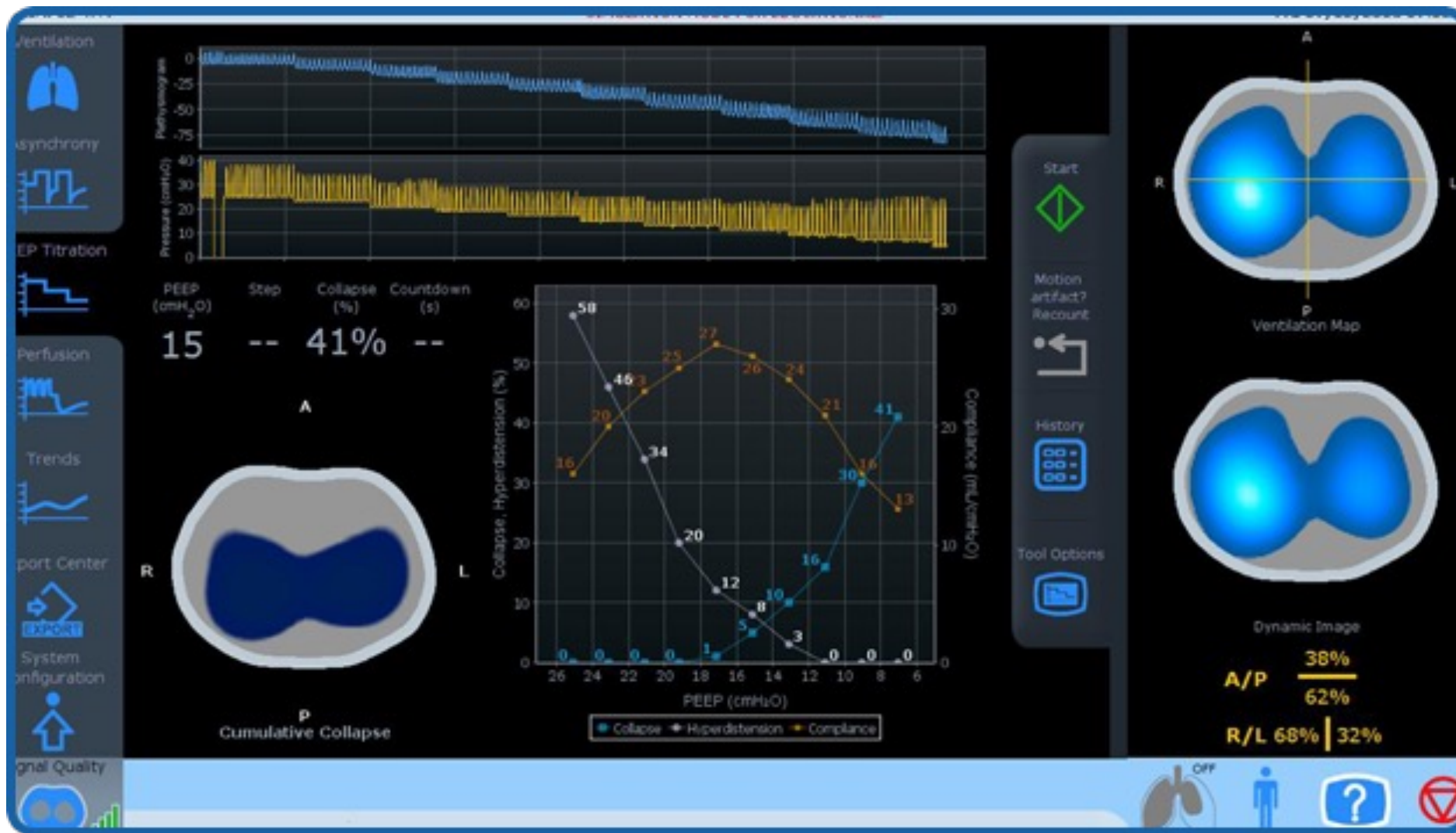
Gattinoni LC, P.; Cressoni, M.; Chiumello, D.; Ranieri, V.M.; Quintel, M.; Russo, S.; Patroniti, N.; Cornejo, R.; Bugedo, G. Lung Recruitment in Patients with the Acute Respiratory Distress Syndrome. *The New England Journal of Medicine* 2006;354(17):1775-86.



- PALICC-2
  - Maintain PEEP at or above the ARDSNet low PEEP/high FiO<sub>2</sub> table recommendation
- One-size-fits-all approach
- Not all patients may benefit from higher PEEP
- Reliable tools needed to guide bedside management



Khemani RG, Parvathaneni K, Yehya N, Bhalla AK, Thomas NJ, Newth CJL. Positive End-Expiratory Pressure Lower Than the ARDS Network Protocol Is Associated with Higher Pediatric Acute Respiratory Distress Syndrome Mortality. *Am J Respir Crit Care Med.* Jul 1 2018;198(1):77-89. doi:10.1164/rccm.201707-1404OC



**OXYGENATION GOAL: PaO<sub>2</sub> 55-80 mmHg or SpO<sub>2</sub> 88-95%**  
Use a minimum PEEP of 5 cm H<sub>2</sub>O. Consider use of incremental FiO<sub>2</sub>/PEEP combinations such as shown below (not required) to achieve goal.

**Lower PEEP/higher FiO<sub>2</sub>**

FiO <sub>2</sub>	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7
PEEP	5	5	8	8	10	10	10	12

FiO <sub>2</sub>	0.7	0.8	0.9	0.9	0.9	1.0
PEEP	14	14	14	16	18	18-24

**Higher PEEP/lower FiO<sub>2</sub>**

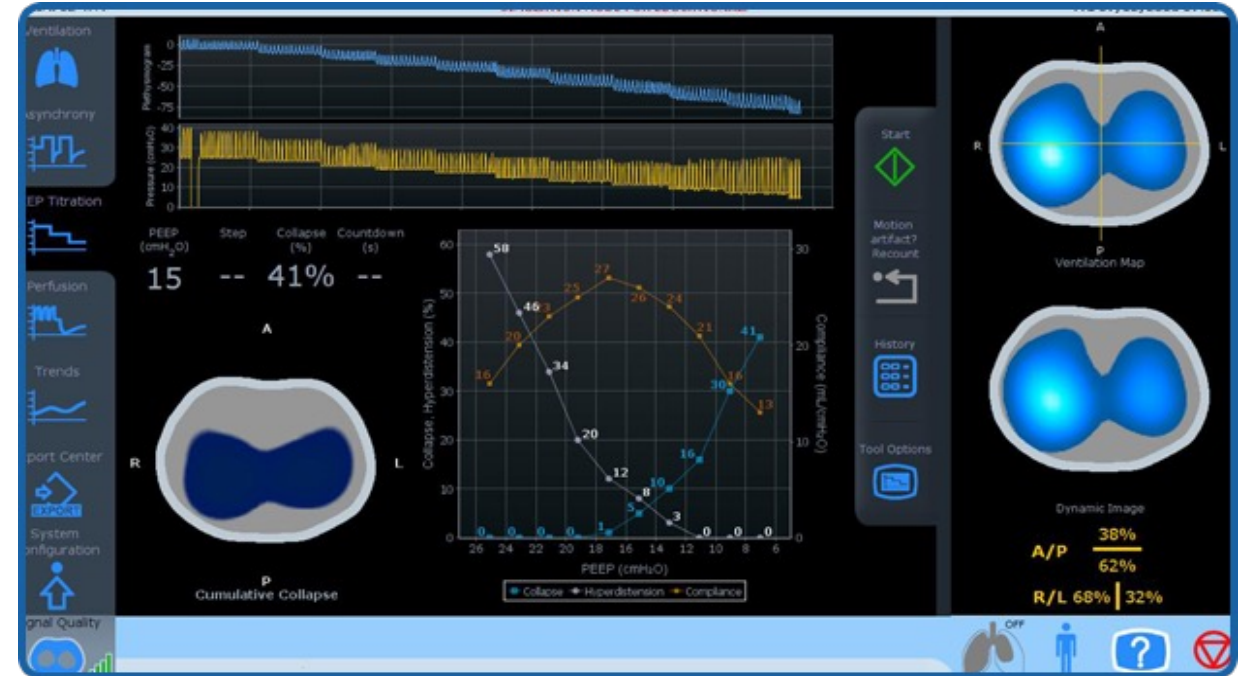
FiO <sub>2</sub>	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5
PEEP	5	8	10	12	14	14	16	16

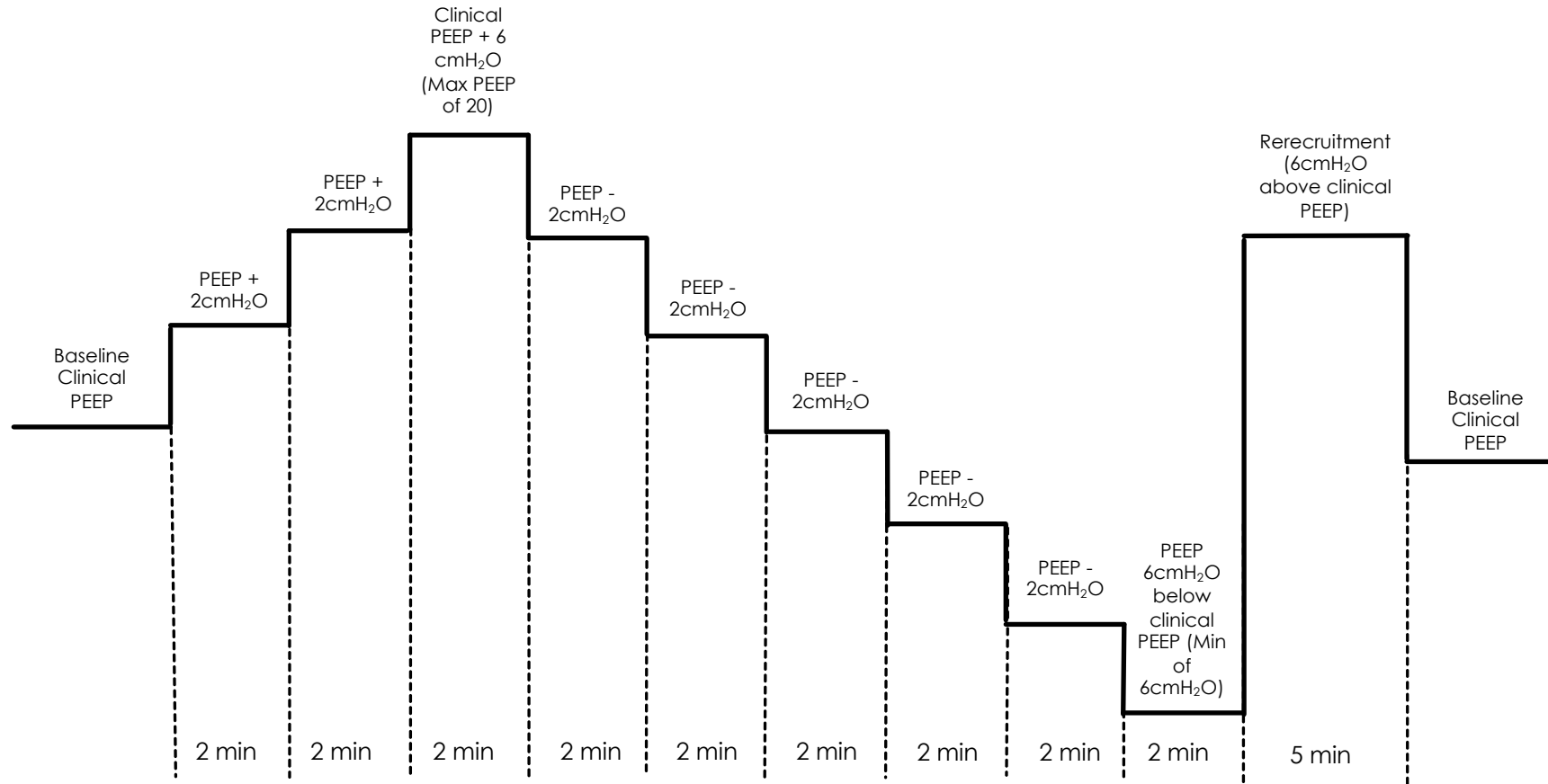
FiO <sub>2</sub>	0.5	0.5-0.8	0.8	0.9	1.0	1.0
PEEP	18	20	22	22	22	24



NIH NHLBI ARDS Clinical Network  
Mechanical Ventilation Protocol Summary

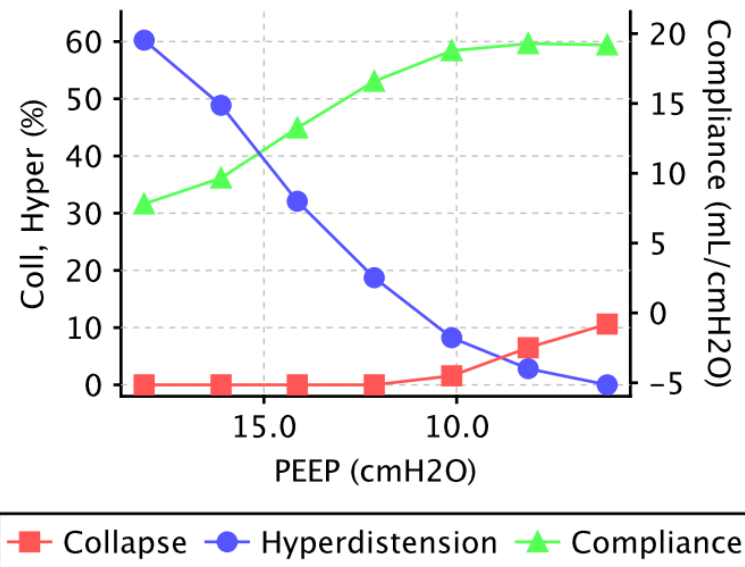
VS





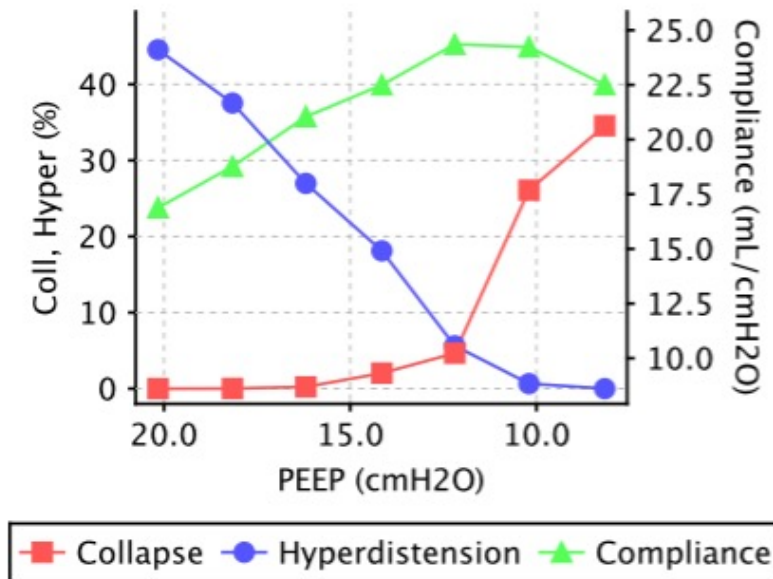
Inspiratory and Expiratory Holds at Each Step  
 Continuous Vcap\*, EIT, and oxygenation data throughout  
 \* For patients who opt-in

- FiO2 40%; SpO2 95%
- PEEP/FiO2 table recommendation: 5-8
- EIT recommendation: 9



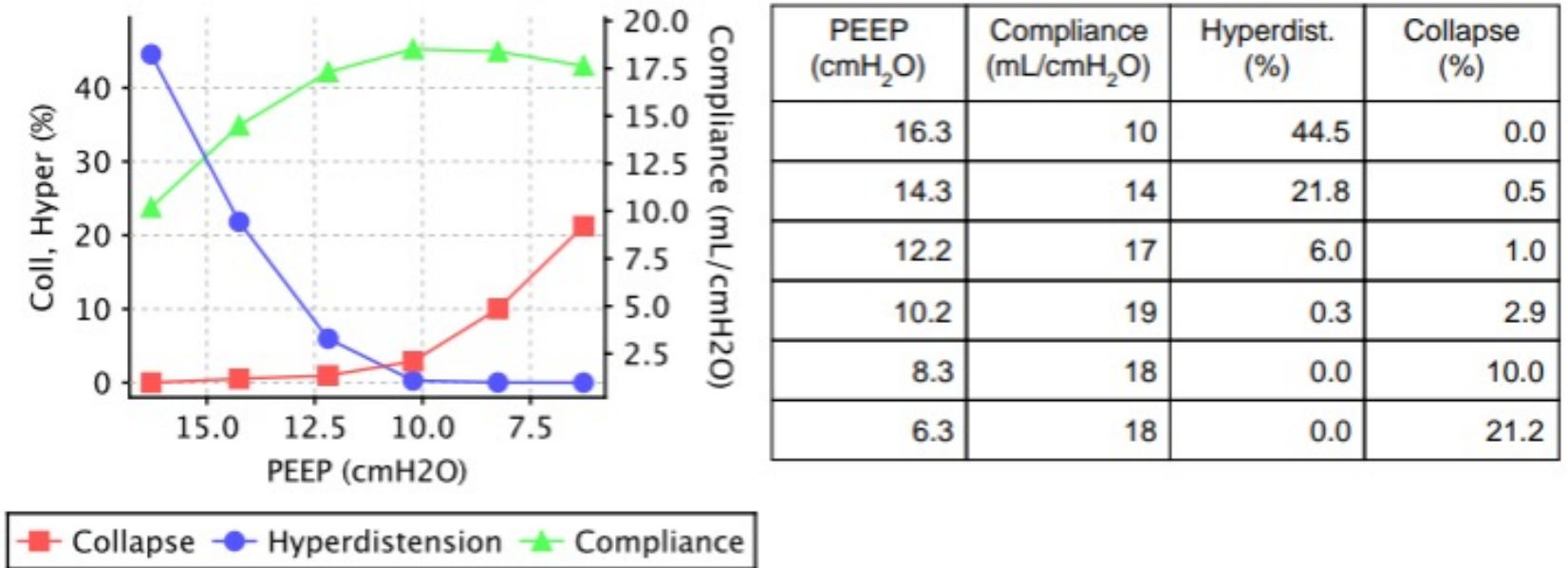
PEEP (cmH <sub>2</sub> O)	Compliance (mL/cmH <sub>2</sub> O)	Hyperdist. (%)	Collapse (%)
18.1	8	60.2	0.0
16.1	10	48.9	0.0
14.1	13	32.1	0.0
12.1	17	18.7	0.0
10.1	19	8.2	1.6
8.1	19	2.8	6.5
6.1	19	0.0	10.6

- FiO2 60%; SpO2 95%
- PEEP/FiO2 table recommendation: 10
- EIT recommendation: 12



PEEP (cmH <sub>2</sub> O)	Compliance (mL/cmH <sub>2</sub> O)	Hyperdist. (%)	Collapse (%)
20.2	17	44.6	0.0
18.2	19	37.5	0.0
16.2	21	27.0	0.2
14.2	22	18.1	2.0
12.2	24	5.6	4.7
10.2	24	0.7	26.1
8.2	23	0.0	34.6

- FiO2 100%; SpO2 92%
- PEEP/FiO2 table recommendation: 18-24
- EIT recommendation: 11



## Step Images

PEEP Step: 1



Hyperdistension



Cumulative Collapse

PEEP: 20.2 cmH<sub>2</sub>O  
Hyperdistension: 44.6%  
Collapse: 0.0%  
Compliance: 17 mL/cmH<sub>2</sub>

PEEP Step: 2



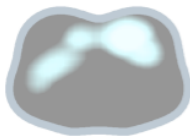
Hyperdistension



Cumulative Collapse

PEEP: 18.2 cmH<sub>2</sub>O  
Hyperdistension: 37.5%  
Collapse: 0.0%  
Compliance: 19 mL/cmH<sub>2</sub>O

PEEP Step: 3



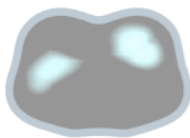
Hyperdistension



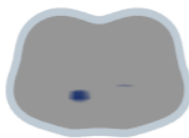
Cumulative Collapse

PEEP: 16.2 cmH<sub>2</sub>O  
Hyperdistension: 27.0%  
Collapse: 0.2%  
Compliance: 21 mL/cmH<sub>2</sub>O

PEEP Step: 4



Hyperdistension



Cumulative Collapse

PEEP: 14.2 cmH<sub>2</sub>O  
Hyperdistension: 18.1%  
Collapse: 2.0%  
Compliance: 22 mL/cmH<sub>2</sub>O

PEEP Step: 5



Hyperdistension



Cumulative Collapse

PEEP: 12.2 cmH<sub>2</sub>O  
Hyperdistension: 5.6%  
Collapse: 4.7%  
Compliance: 24 mL/cmH<sub>2</sub>O

## Step Images (cont'd)

PEEP Step: 6



Hyperdistension



Cumulative Collapse

PEEP: 10.2 cmH<sub>2</sub>O  
Hyperdistension: 0.7%  
Collapse: 26.1%  
Compliance: 24 mL/cmH<sub>2</sub>O

PEEP Step: 7



Hyperdistension



Cumulative Collapse

PEEP: 8.2 cmH<sub>2</sub>O  
Hyperdistension: 0.0%  
Collapse: 34.6%  
Compliance: 23 mL/cmH<sub>2</sub>O

## Step Images

PEEP Step: 1



Hyperdistension



Cumulative Collapse

PEEP: 16.2 cmH<sub>2</sub>O  
Hyperdistension: 55.3%  
Collapse: 0.0%  
Compliance: 14 mL/cmH<sub>2</sub>O

PEEP Step: 5



Hyperdistension



Cumulative Collapse

PEEP: 8.2 cmH<sub>2</sub>O  
Hyperdistension: 14.3%  
Collapse: 0.8%  
Compliance: 26 mL/cmH<sub>2</sub>O

PEEP Step: 2



Hyperdistension



Cumulative Collapse

PEEP: 14.2 cmH<sub>2</sub>O  
Hyperdistension: 45.8%  
Collapse: 0.3%  
Compliance: 17 mL/cmH<sub>2</sub>O

PEEP Step: 6



Hyperdistension



Cumulative Collapse

PEEP: 6.3 cmH<sub>2</sub>O  
Hyperdistension: 0.0%  
Collapse: 1.2%  
Compliance: 29 mL/cmH<sub>2</sub>O

## Step Images (cont'd)

PEEP Step: 3



Hyperdistension



Cumulative Collapse

PEEP: 12.2 cmH<sub>2</sub>O  
Hyperdistension: 30.9%  
Collapse: 0.4%  
Compliance: 21 mL/cmH<sub>2</sub>O

PEEP Step: 4



Hyperdistension



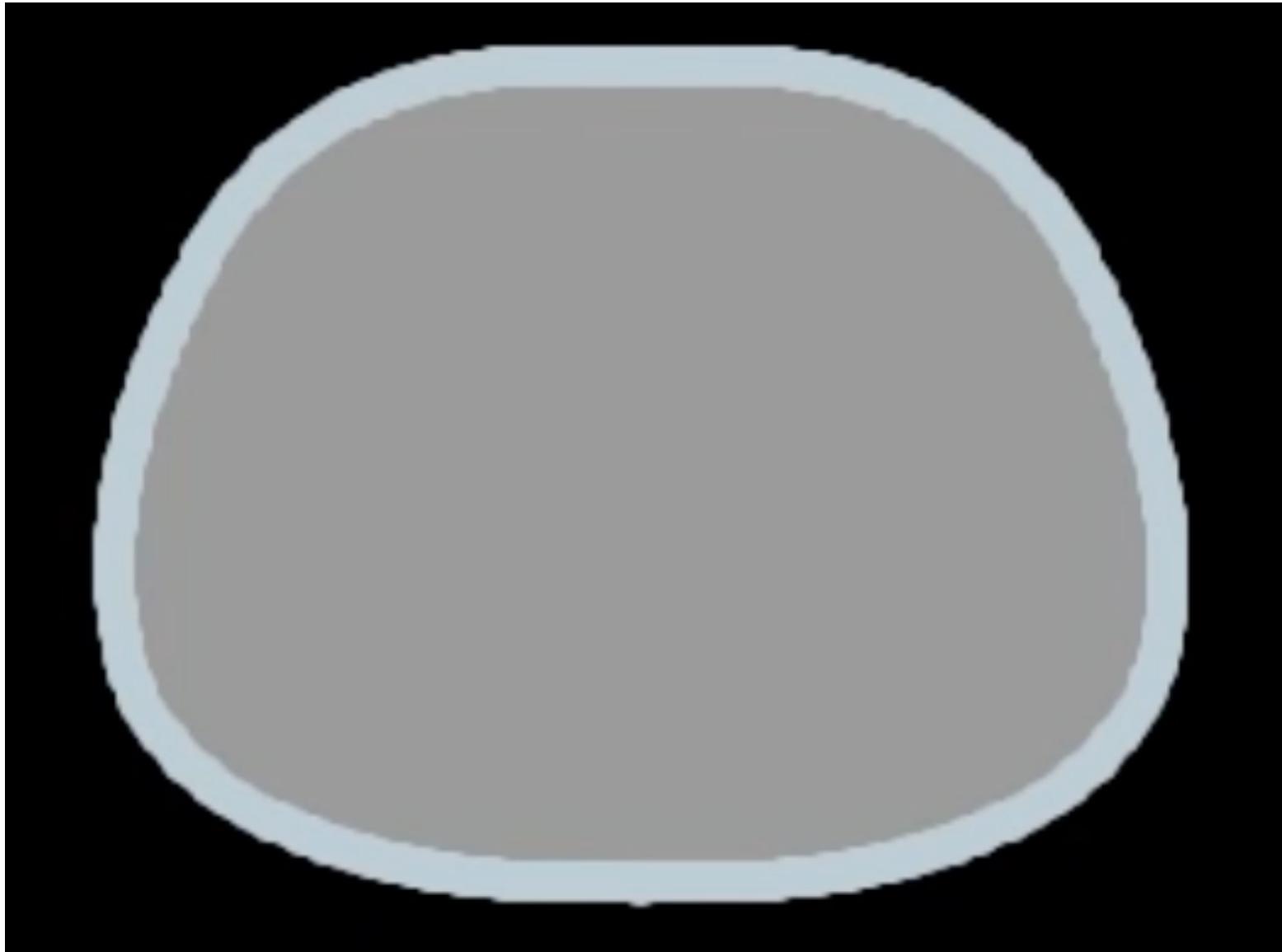
Cumulative Collapse

PEEP: 10.2 cmH<sub>2</sub>O  
Hyperdistension: 17.0%  
Collapse: 0.6%  
Compliance: 25 mL/cmH<sub>2</sub>O



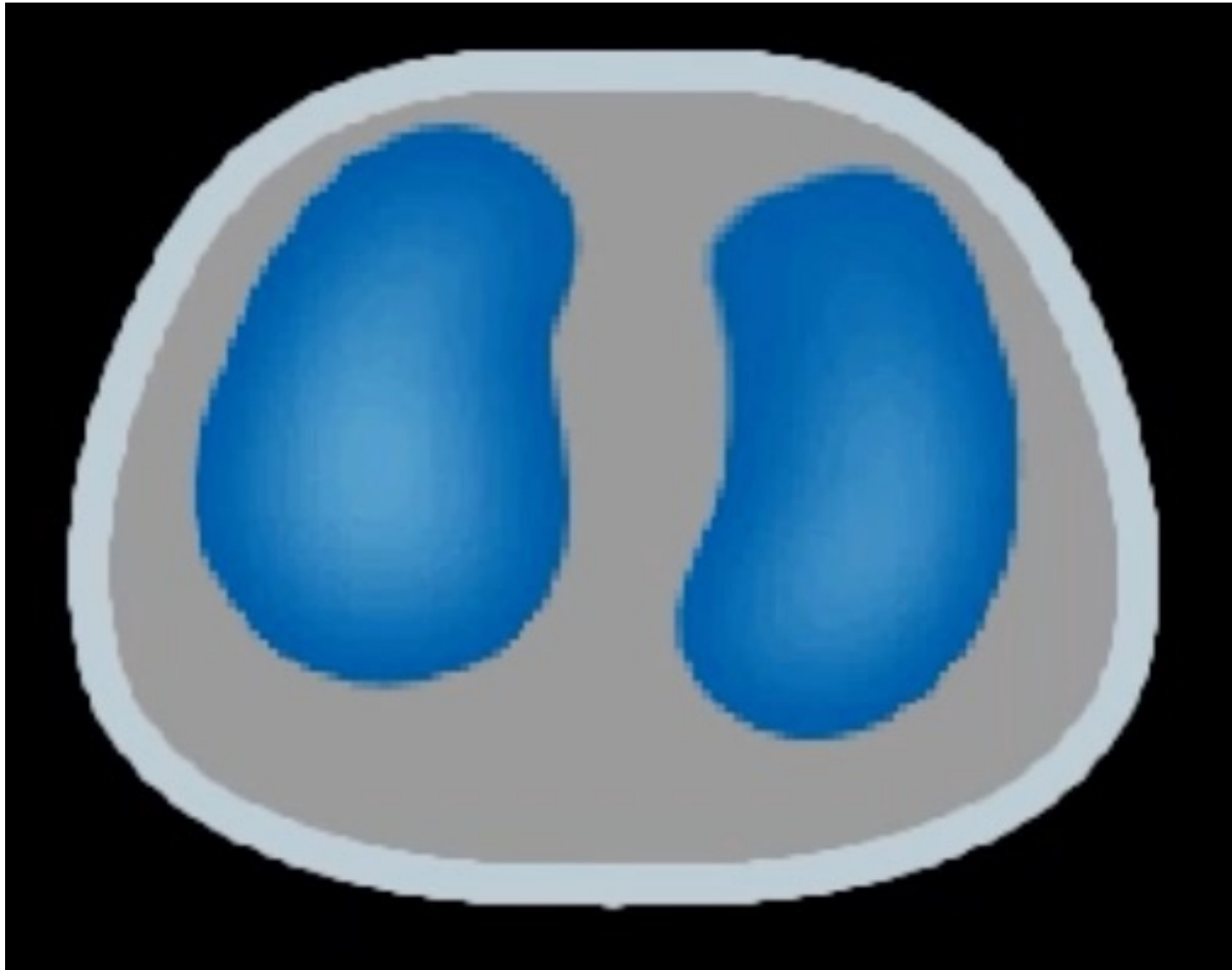
# OTHER EIT APPLICATIONS

# Mechanically Ventilated Asthmatic



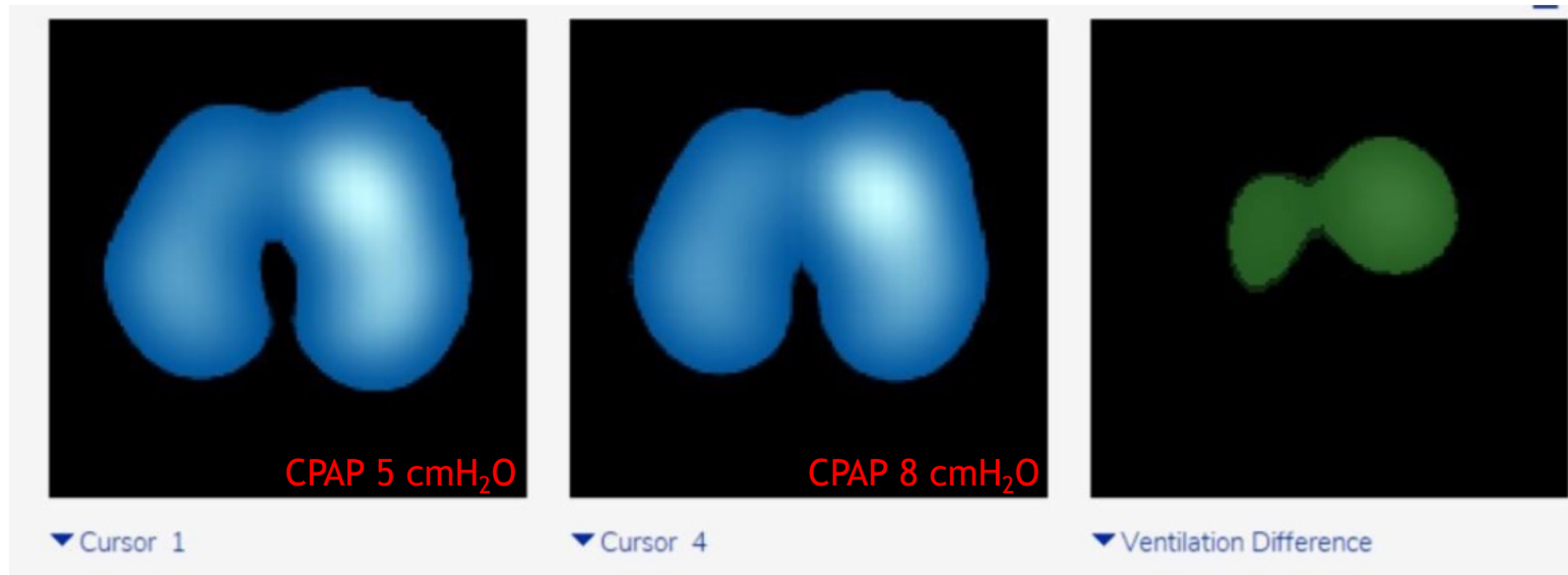
CPAP 5 cmH<sub>2</sub>O

# Mechanically Ventilated Asthmatic

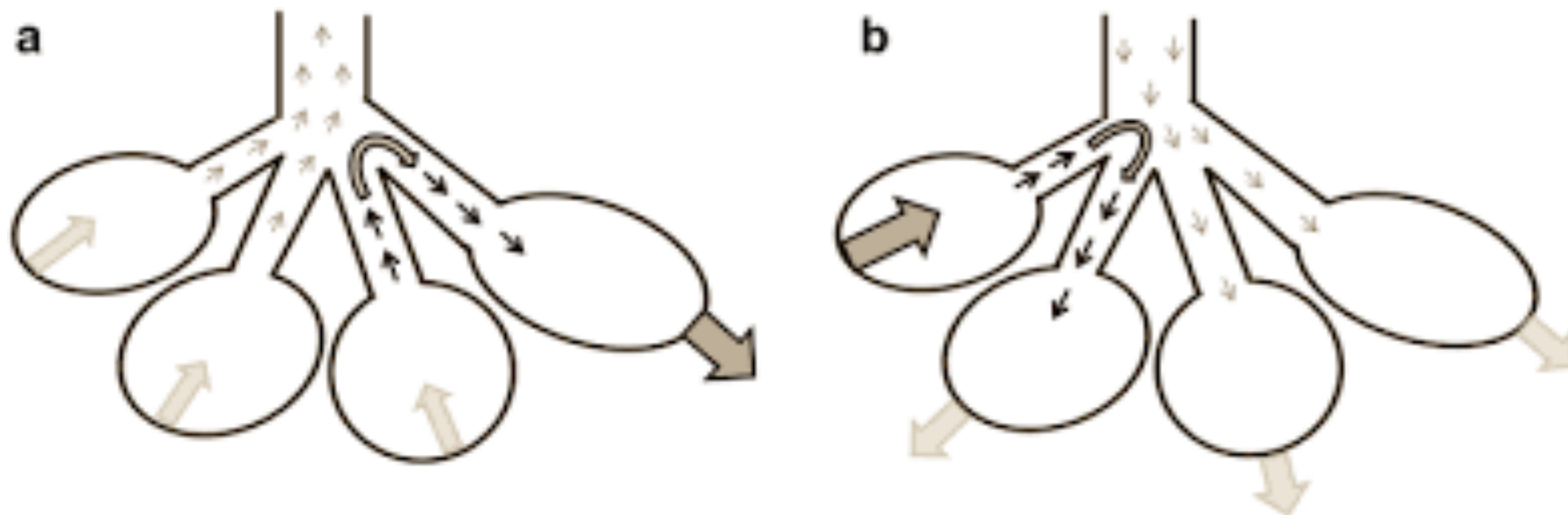


CPAP 8 cmH<sub>2</sub>O

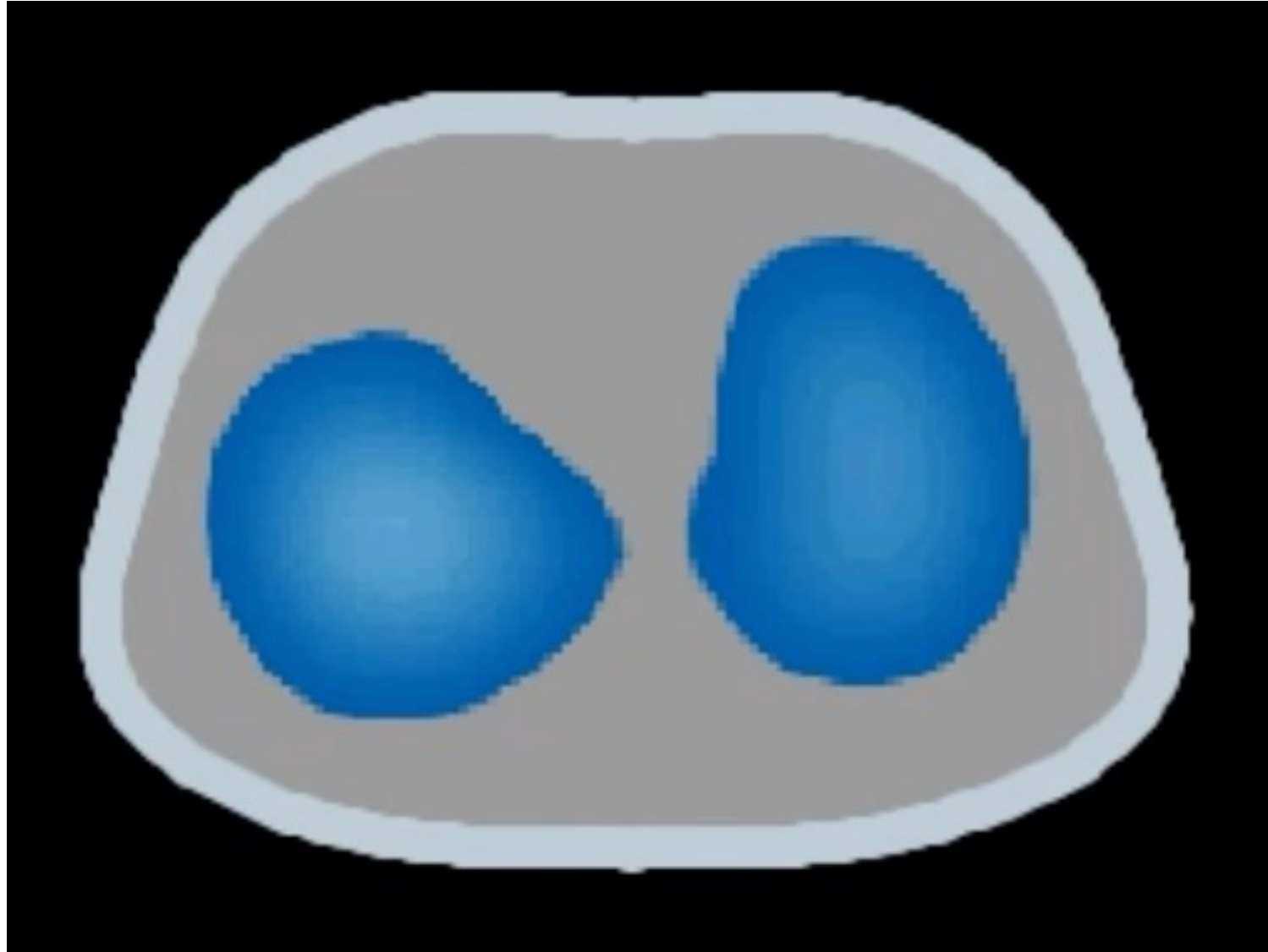
- Useful for titrating PEEP, matching intrinsic PEEP and decreasing work of breathing

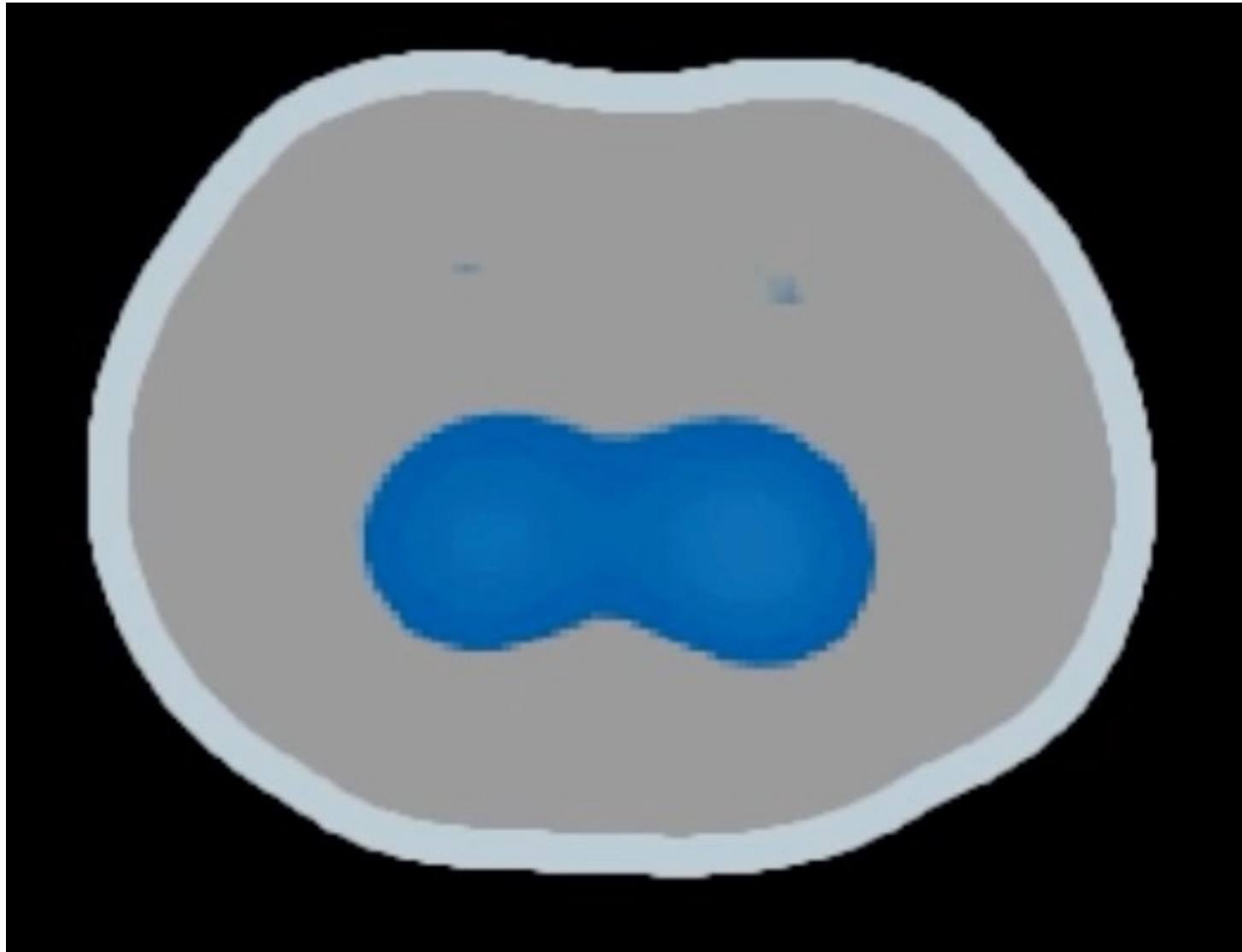


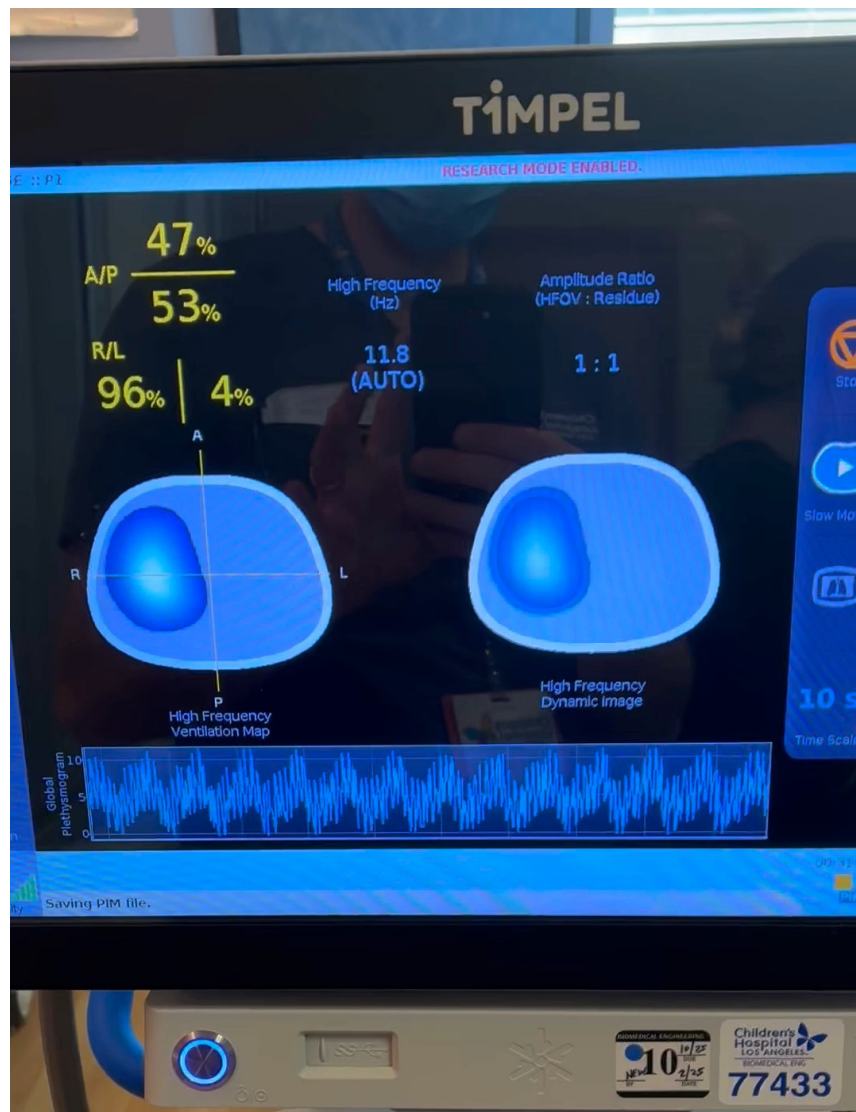
- Improved ventilation, facilitating successful extubation!



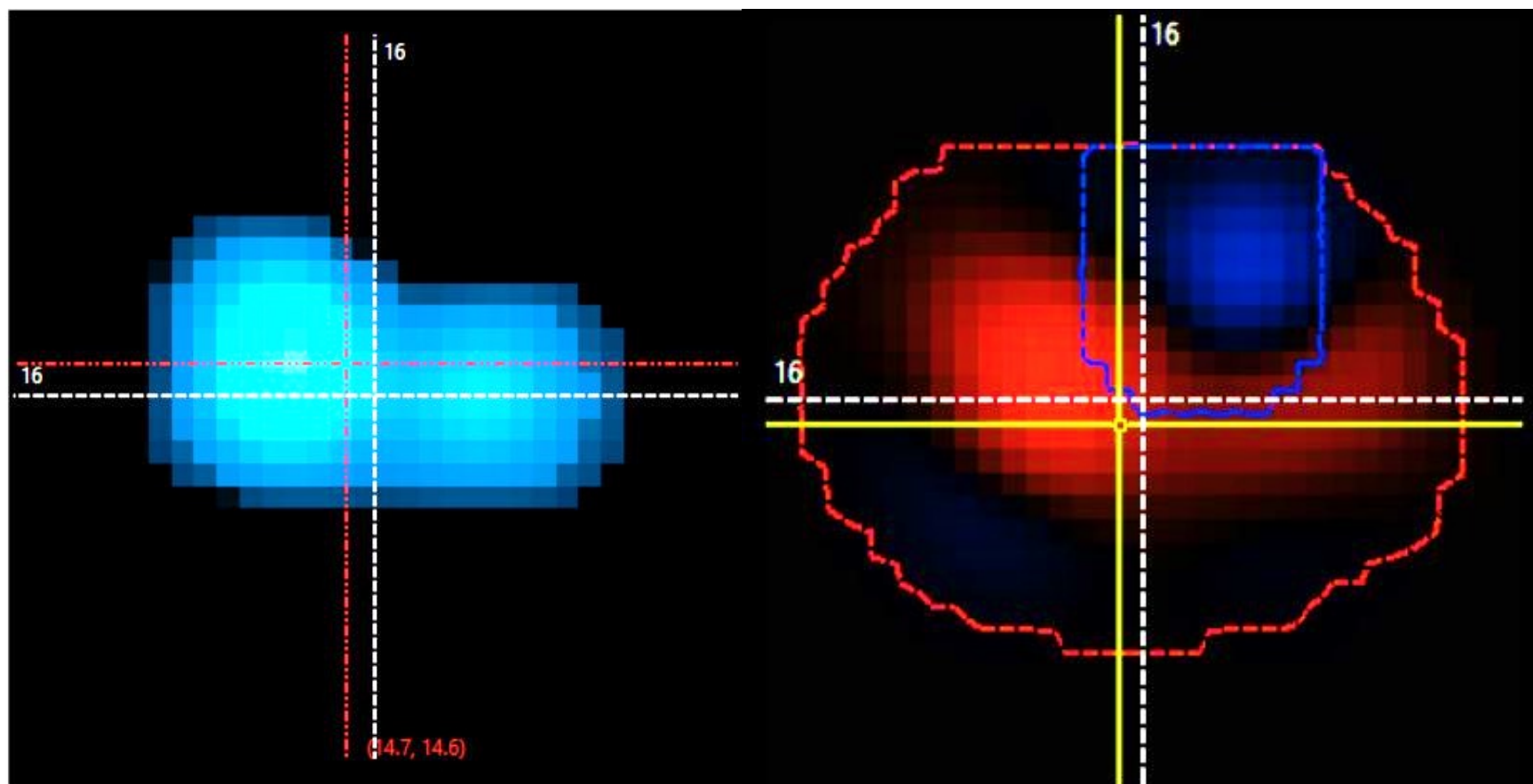
Coppadoro A, Grassi A, Giovannoni C, Rabboni F, Eronia N, Bronco A, Foti G, Fumagalli R, Bellani G. Occurrence of pendelluft under pressure support ventilation in patients who failed a spontaneous breathing trial: an observational study. *Ann Intensive Care*. 2020 Apr 7;10(1):39. doi: 10.1186/s13613-020-00654-y. PMID: 32266600; PMCID: PMC7138895







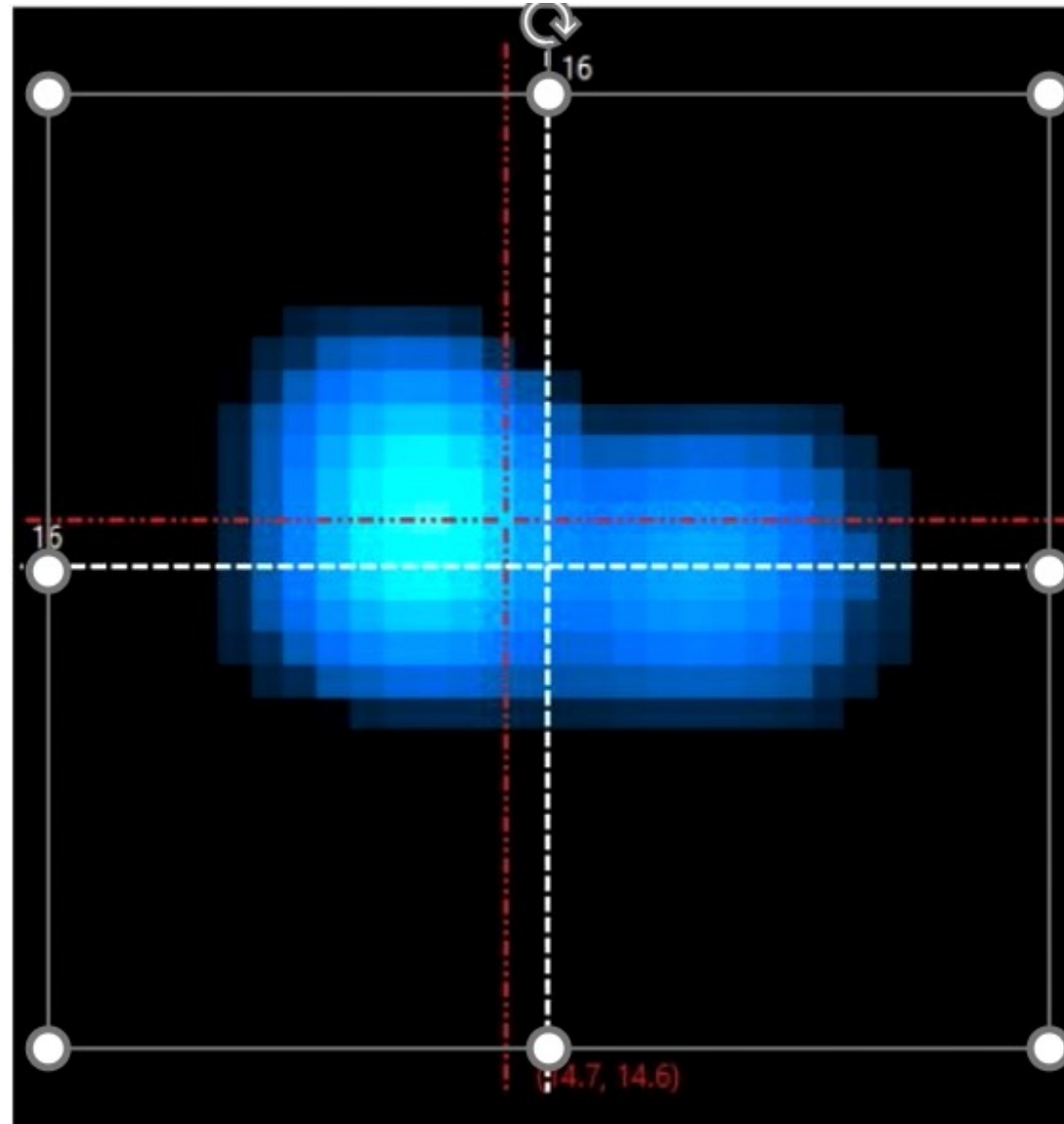
# Ventilation and Perfusion Maps

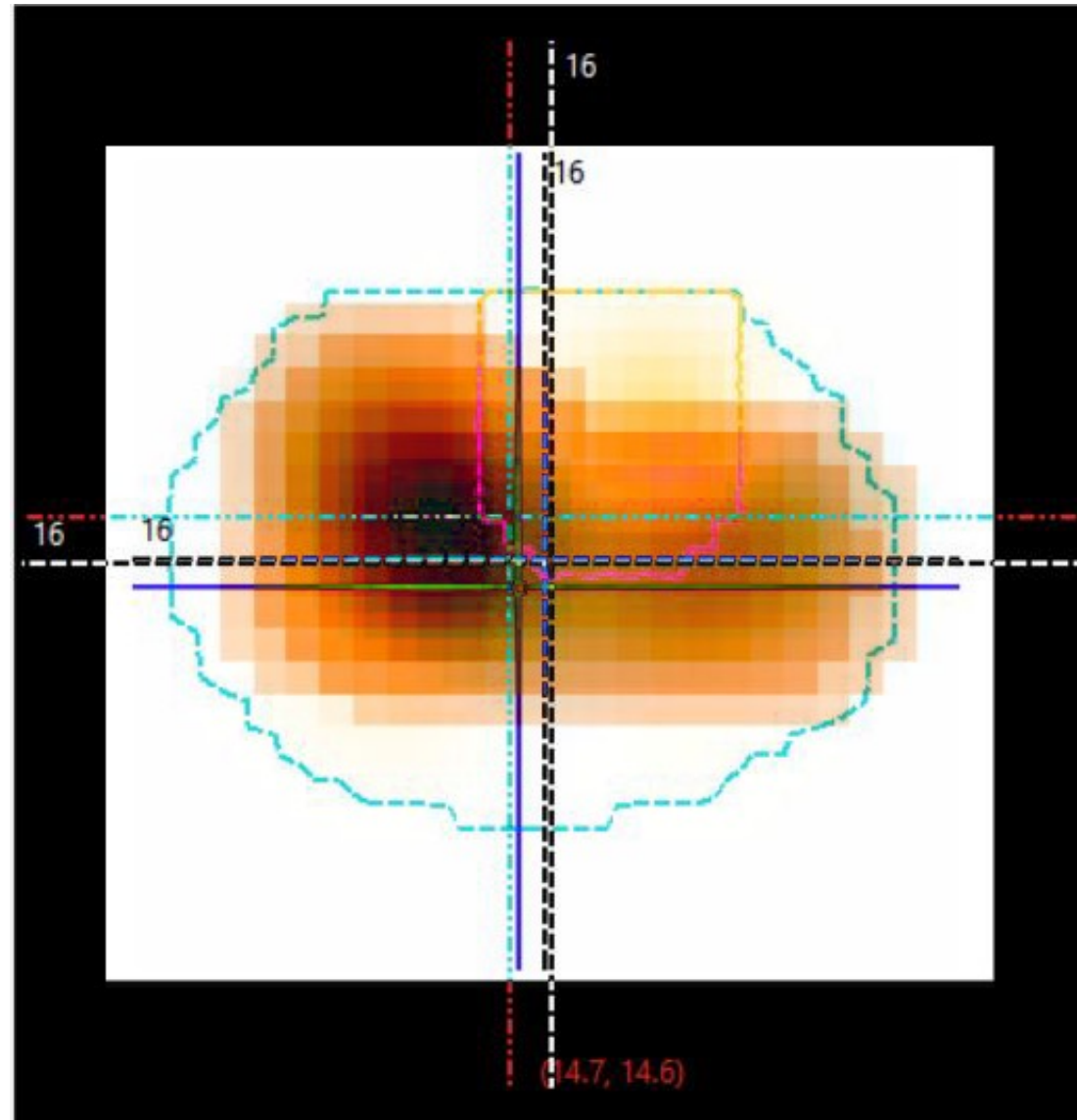


Ventilation

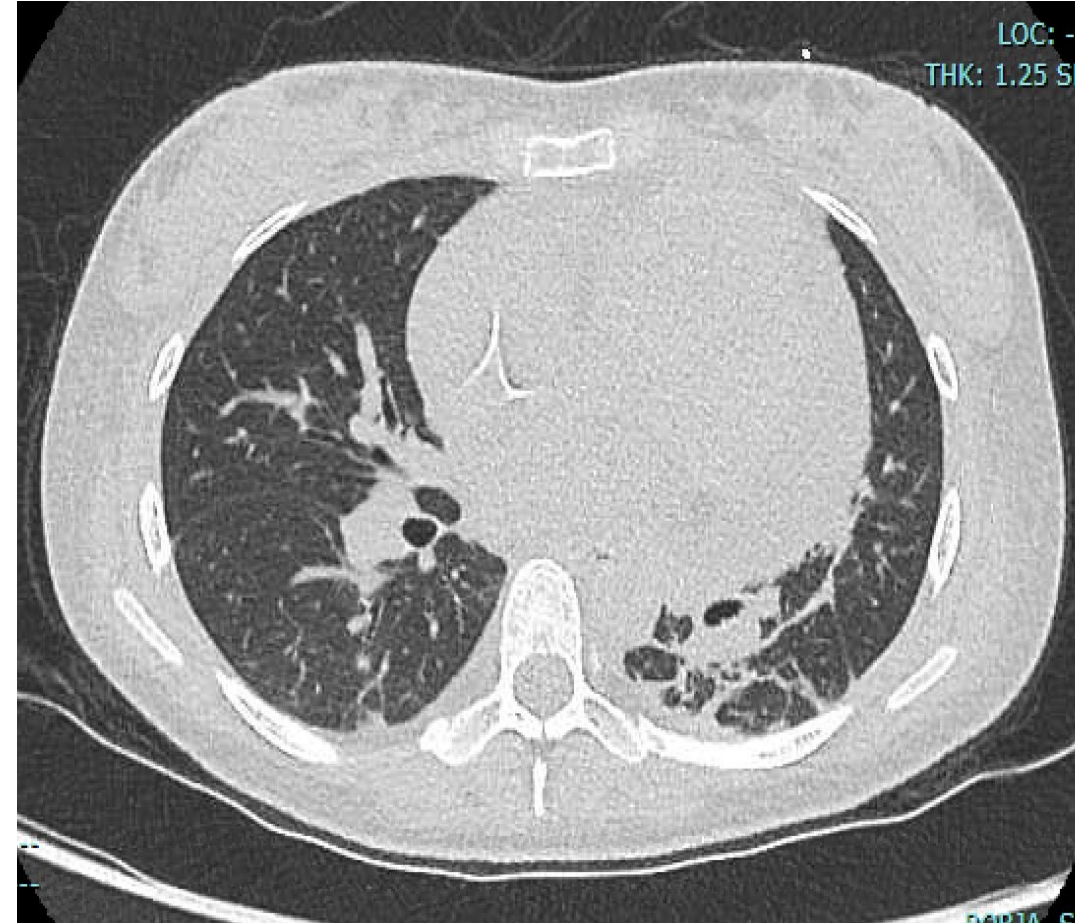
Perfusion/Pulsatility

Blue= Heart  
Red= Lung  
Perfusion

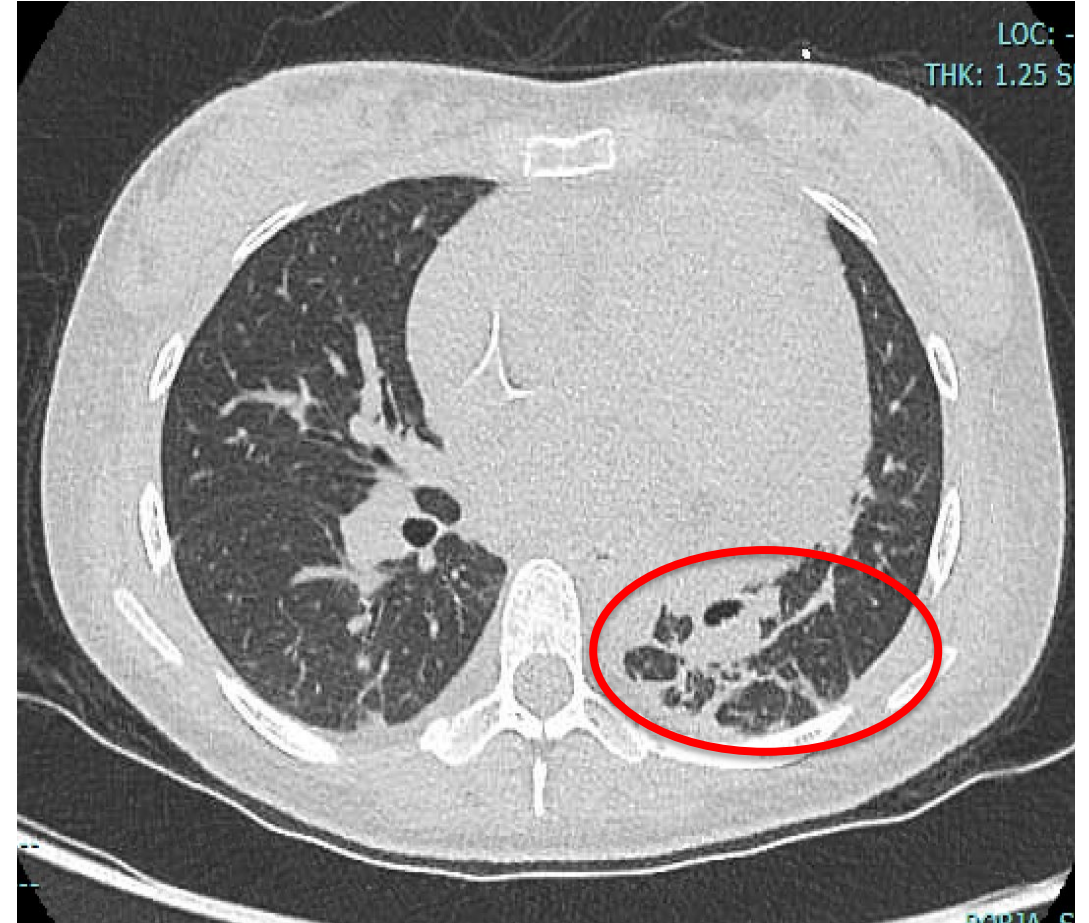




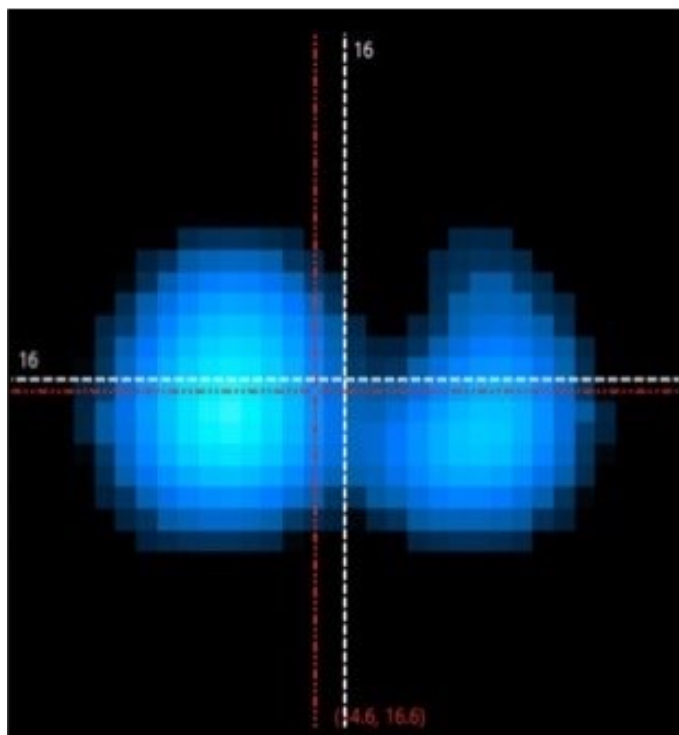
# Assessing Response to Therapy



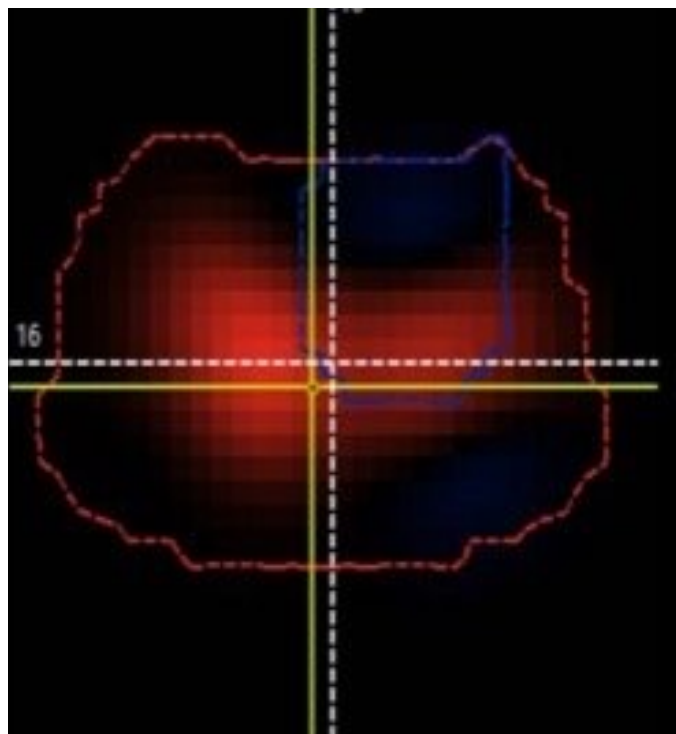
New diagnosis of lupus and severe pulmonary hypertension



New diagnosis of lupus and severe pulmonary hypertension



Ventilation Map



Perfusion Map

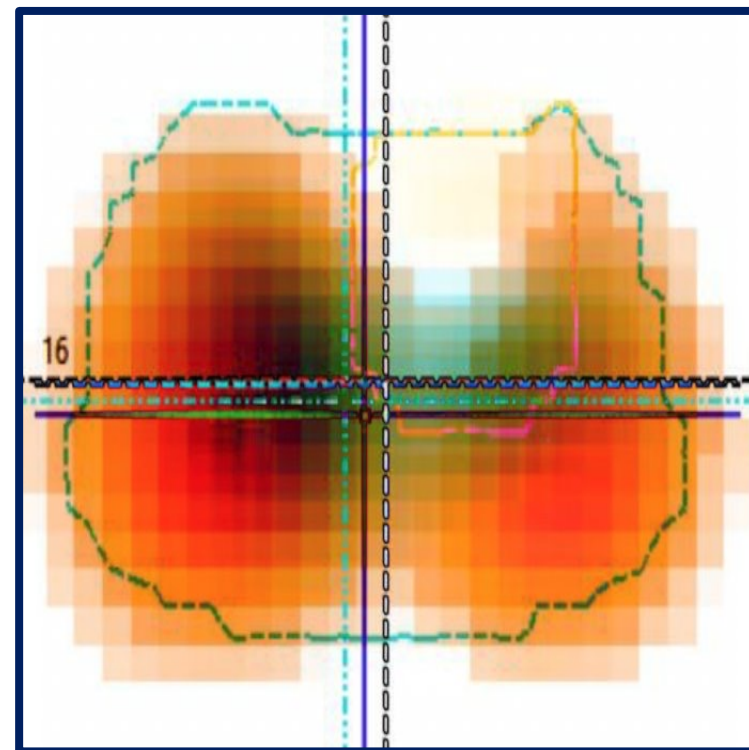
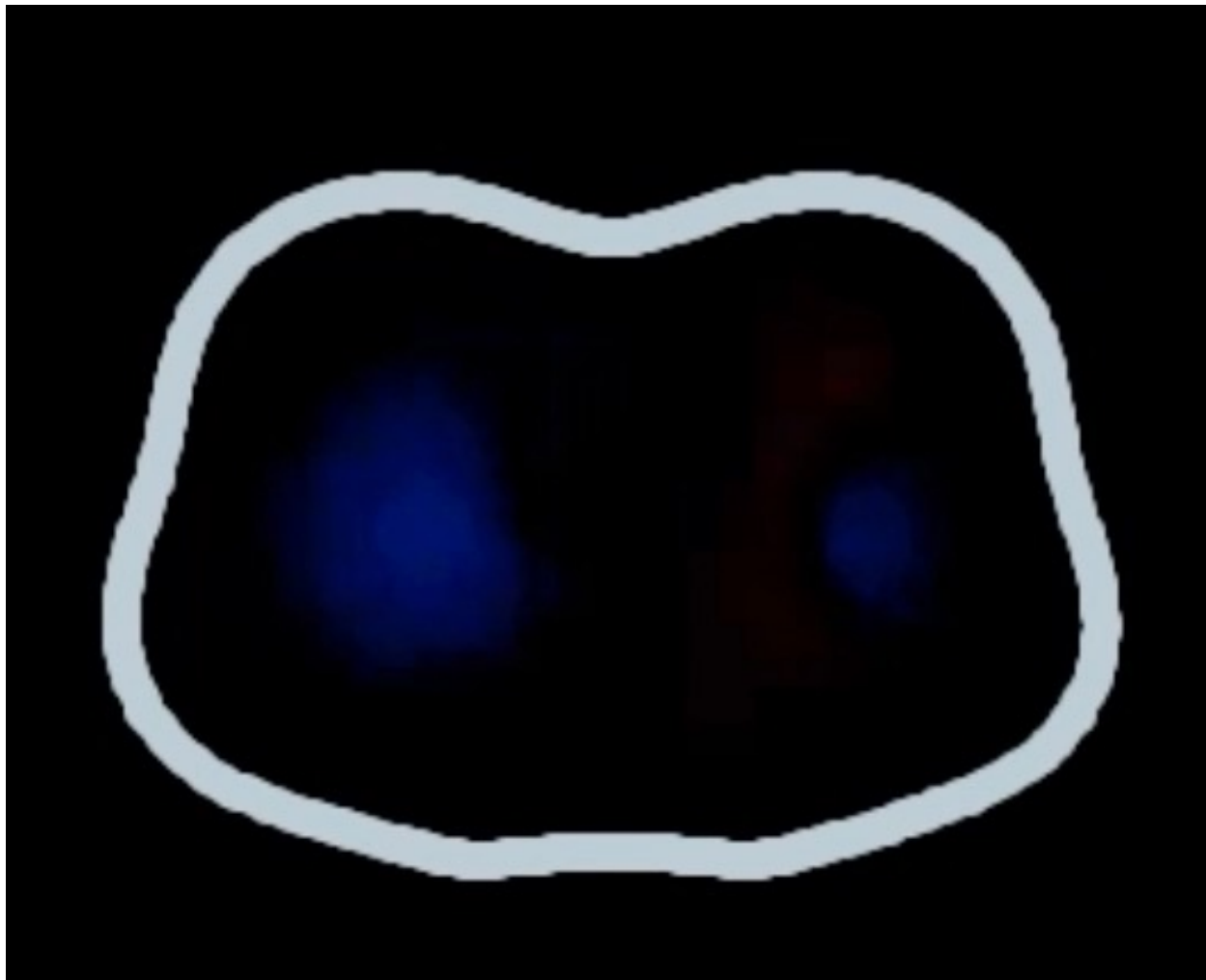
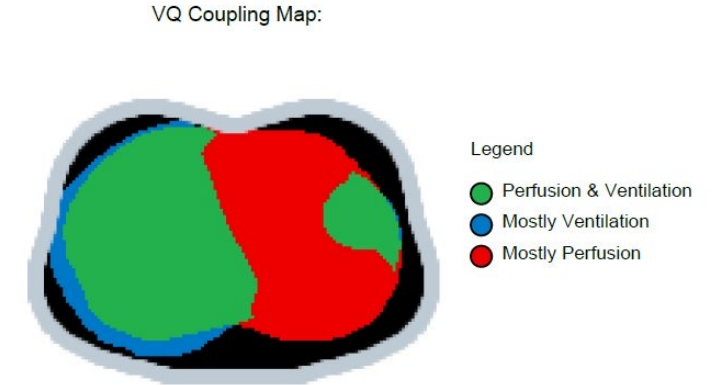
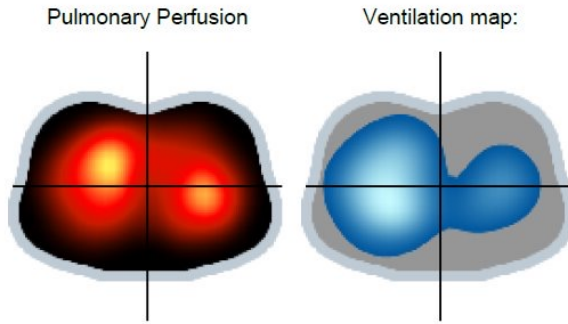
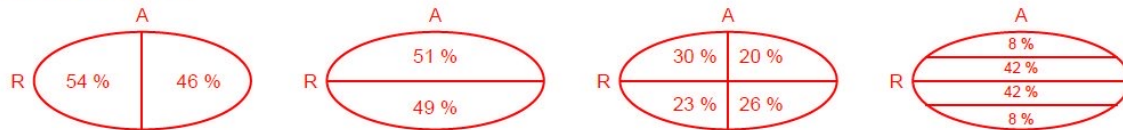


Image Overlay

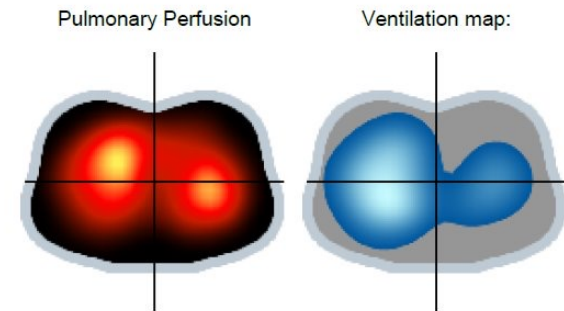
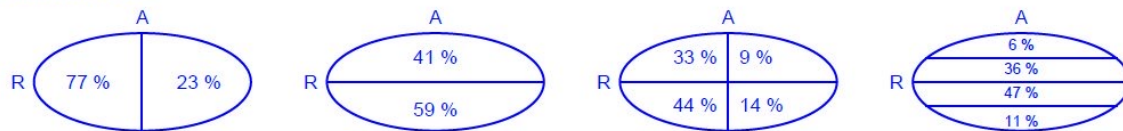




Perfusion Distribution:



Distribution Ratio:



- Enables real-time regional lung ventilation/perfusion monitoring
- Aids in lung-protective ventilation through bedside assessment
- Targeted PEEP management by distinguishing recruitable vs. non-recruitable lung disease
- Future potential: V/Q mapping and perfusion imaging

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